
Evaluating Acceptance of Lateral Wedge Insoles for Knee Osteoarthritis in Saudi Arabia: A Mixed-Methods Study.

Abdullah Hamdi Al Assiri

A thesis submitted to University of Nottingham, UK, for the award of the degree of Doctor of Philosophy.

School of Medicine

Division of Injury, Recovery and Inflammation Sciences

November 2024

TABLE OF CONTENTS

TABLE OF CONTENTS	1
LIST OF APPENDICES:	5
LIST OF FIGURES:	5
LIST OF TABLES:	6
LIST OF ABBREVIATIONS:	7
Abstract	9
Acknowledgements:	12
Teamwork and Reflection in Research:	12
CHAPTER 1	13
INTRODUCTION & THESIS STRUCTURE	13
1.1 Brief review:	14
1.1.1 Knee osteoarthritis:	14
1.1.2 An overview of KOA clinical practice guidelines:	15
1.1.3 KOA Management through Gait Modification Techniques:	16
1.1.4 Biomechanical loading in KOA:	18
1.1.5 Background on Saudi Arabia:	20
1.1.6 Overview of Healthcare system in Saudi Arabia:	20
1.1.7 KOA management in Saudi Arabia:	21
1.1.8 Rehabilitation Services in Saudi Arabia:	25
1.2 Rationale:	26
1.3 UK Medical Research Council (MRC) Framework:	29
1.4 Thesis Structure: (Aims & Objectives)	31
CHAPTER 2	34
BACKGROUND	34
2.1 Background:	36
2.2 Osteoarthritis Definition:	37
2.3 Pathogenesis:	38
2.4 Understanding of OA inflammation and resolution:	40
2.5 Incidence and Prevalence:	44
2.6 Risk Factors:	45
2.7 Symptoms of KOA:	56
2.8 Impacts of KOA:	69
2.9 Diagnosis:	71
2.10 Management of KOA:	74
2.11 Biomechanics of KOA:	81
2.12 Muscle Contribution and Activation in KOA Subjects:	87
2.13 Gait Abnormalities in KOA subjects:	90
2.14 Gait modification as Intervention for KOA:	95
2.14.1 Learned Gait Modification Approaches:	96
2.14.2 Assistive Gait Modification Approaches:	101
2.15 Real-time biofeedback and gait modification:	105
2.16 Clinical obstacles & difficulties:	107
2.17 Research aims and questions:	108
CHAPTER 3	109
RESEARCH METHODOLOGY	109
3.1 Introduction:	110
3.2 Overview of the PhD Studies:	110
3.3 Mixed-methods Frameworks:	112

3.4	Exploratory sequential design used in this thesis:	115
3.5	Theoretical Framework for Qualitative Studies:	119
3.5.1	Rationale and explanation:	121
3.5.2	A mixed-methods study's applicability:	123
3.6	Philosophical basis of this thesis:	125
3.7	Summary:	127
CHAPTER 4	.....	128
SYSTEMATIC REVIEW & META-ANALYSIS	.....	128
4.1	Summary:	129
4.2	Background:	129
1.4.1	Learned gait modification approaches:	130
1.4.2	Assistive gait modification approaches:	133
1.4.2.1	Assessed various knee braces:	133
1.4.2.2	Assessed various LWI designs:	134
1.4.2.3	Combinations between KB and multi foot orthosis:	136
1.4.2.4	Combinations between LWI and footwears:	137
1.4.3	Combination between learned and assistive gait modifications:	139
4.3	Study aim:	139
4.4	Methods:	140
4.4.1	Protocol & Registration:	140
4.4.2	Eligibility Criteria:	140
4.4.3	Population:	141
4.4.4	Intervention:	141
4.4.5	Comparator/Control:	142
4.4.6	Outcomes:	142
4.4.7	Information sources:	143
4.4.8	Search Strategy:	144
4.4.9	Study selection:	144
4.4.10	Data extraction process:	145
4.4.11	Synthesis of results:	145
4.4.12	Risk of Bias Assessment:	147
4.4.13	Certainty assessment:	147
4.5	Results:	148
4.5.1	Study Selection:	148
4.5.2	Characteristics of Included Studies:	150
4.5.3	Risk of bias within studies:	151
4.5.4	Randomisation and blinding bias:	153
4.5.5	Results of individual study:	153
4.5.6	Studies Analysis:	164
4.5.6.1	KAM 1 st peak short term effect (up to 6 months):	164
4.5.6.2	KAM 1 st peak mid-term effect (6 to 12 months):	168
4.5.6.3	KAM 2 nd peak short term effect:	169
4.5.6.4	KAAI short term effect:	171
4.5.6.5	KAAI med-term effect:	173
4.5.6.6	KFM short term effect:	174
4.5.6.7	Pain level short term effect:	175
4.5.6.8	Knee ROM short term effect:	177
4.5.6.9	Gait speed short term effect:	179
4.5.6.10	Stride length short term effect:	182
4.5.6.11	Cadence short term effect:	184

4.5.6.12	Variable physical activity tests short term effect:	185
4.5.7	Certainty of evidence:	187
4.6	Discussion:	188
4.6.1	Knee loading (KAM 1 st & 2 nd peaks and KAAI):.....	188
4.6.2	Knee flexion moment (KFM):.....	192
4.6.3	Pain level:	193
4.6.4	Knee ROM:	195
4.6.5	Gait speed:	196
4.6.6	Stride length and Cadence:	197
4.6.7	Variable physical activities:.....	197
4.6.8	Strength and Limitations:	198
4.6.9	Future Recommendations:	199
4.7	Conclusion:	200
CHAPTER 5	.....	202
QUALITATIVE STUDY	.....	202
5.1	Summary:.....	203
5.2	Introduction:	203
5.3	Methods, research paradigm and approach:	204
5.3.1	Participants:	205
5.3.2	Participant information and informed consent:	207
5.3.3	Data Management and Storage:	208
5.3.4	Data Collection:	208
5.3.5	Topic Guide:	212
5.3.6	Duration & Data Management:	213
5.3.7	Data organisation:.....	215
5.5	Ethical Approval:.....	218
5.6	Data Analysis:	219
5.7	Results:	222
5.7.1	Participants:	222
5.7.2	Themes and Main findings:	225
5.7.2.1	Affective attitude:.....	225
5.7.2.2	Burden:.....	232
5.7.2.3	Ethicality:.....	236
5.7.2.4	Intervention coherence:.....	237
5.7.2.5	Opportunity costs:	240
5.7.2.6	Perceived effectiveness:	241
5.7.2.7	Self-efficacy:.....	242
5.8	Discussion:	243
5.8.1	Strength and Limitations:	265
5.9	Conclusion:	268
CHAPTER 6	.....	270
PROPOSED INTERVENTION	.....	270
6.1	Summary:.....	271
6.2	Introduction:	271
6.3	Justification for LWI Intervention:.....	271
6.4	Lateral Wedge Insole (LWI) Rationale:.....	273
6.5	Biomechanical effect of LWI:	274
6.6	The clinical effects of LWI:.....	276

6.7	Knee Function effect:	279
6.8	LWI: Effective Delivery, Consistent Use and Integration:.....	280
6.9	Influence of Designs and Inclinations:	283
6.10	Conclusion:	284
CHAPTER 7	.....	285
FEASIBILITY STUDY	.....	285
7.1	Summary:	286
7.2	Introduction:	286
7.3	Methods:	288
7.3.1	Study Design:	288
7.3.2	The research environment:.....	288
7.3.3	Participants:	288
7.3.4	Recruitment:	289
7.3.5	Blinding & Randomisation:.....	290
7.3.6	Procedure:	292
7.3.7	Intervention:	294
7.3.8	Outcomes:	295
7.3.8.1	Feasibility outcomes:.....	295
7.3.8.2	Acceptability:	296
7.3.8.3	Satisfaction rate:	297
7.3.8.4	Self-reported outcomes:.....	297
7.4	Data Management:	298
7.5	Analysis:	298
7.5.1	Sample size:	298
7.5.2	Data Analysis:.....	299
7.5.3	Analysis of Missing data:	300
7.6	Feasibility study criteria:	300
7.7	Ethical Approval:	301
7.8	Results:	302
7.8.1	Participants Flow:	302
7.8.2	Participants Recruitment:.....	304
7.8.3	Baseline Data:	304
7.8.4	Feasibility Outcomes and Estimation:	305
7.8.4.1	Retention and Attrition rates:.....	305
7.8.4.2	Intervention compliance and adherence:	306
7.8.4.3	Likert scale satisfaction rates:	306
7.8.5	Patients Self-reported Outcomes:	314
7.8.6	Adverse Event:	317
7.9	Discussion:	317
7.10	Conclusion:	328
CHAPTER 8	.....	330
THESIS DISCUSSION, STRENGTHS, LIMITATIONS, FUTURE DIRECTIONS AND CONCLUSION.	.....	330
8.1	Summary:	331
8.2	Findings from main chapters of the thesis:	331
8.3	Discussion Aligned with Research Questions:	336
8.4	Synthesis of the Qualitative and Feasibility Findings:	341
8.5	Contribution to the Existing Knowledge:	344
8.6	Strengths and limitations of the thesis:	346

8.7	Initial recommendations and future research:.....	349
8.8	Conclusion:	353
REFERENCES:		355
APPENDEIXES:		425

LIST OF APPENDICES:

APPENDIX 1: DATABASES SEARCH STRATEGY	425
APPENDIX 2: GRADE EVIDENCE PROFILE	431
APPENDIX 3: TOPIC GUIDE FOR KOA PARTICIPANTS	433
APPENDIX 4: TOPIC GUID FOR THE THERAPISTS' PARTICIPATION	434
APPENDIX 5: ETHICAL APPROVAL FROM UNIVERSITY OF NOTTINGHAM	435
APPENDIX 6: ETHICAL APPROVAL FROM ASEER CENTRAL HOSPITAL	436
APPENDIX 7 PARTICIPANTS INFORMATION SHEETS:	437
APPENDIX 8 CASE REPORT FORMS:	439
APPENDIX 9 PARTICIPANTS CONSENT FORM.....	440
APPENDIX 10 WITHDRAWAL STUDY FORM:	441
APPENDIX 11 NUMERIC RATING PAIN SCALE (NRPS) FORM:.....	442
APPENDIX 12 WESTERN ONTARIO AND McMASTER UNIVERSITIES OSTEOARTHRITIS (WOMAC)	443
APPENDIX 13 LIKERT SCALE FORMS FOR BOTH KOA AND THERAPISTS' PARTICIPANTS:	444
APPENDIX 14 PATIENTS' DAILY RECORD FORM:.....	445
APPENDIX 15 KOA PATIENT'S FOLLOW-UP SHEET:	446
APPENDIX 16 ARABIC VERSION OF WOAMC INDEX:	447
APPENDIX 17 KING FAISAL SPECIALIST HOSPITAL ETHICAL APPROVAL FORM:.....	448
APPENDIX 18 THE CALCULATION OF MCIDS FOR THE WOMAC AND NRPS SCORES:.....	449
APPENDIX 19 COPY FROM PATIENT'S ADVERSE EVENT:	450

LIST OF FIGURES:

FIGURE 1: KEY ELEMENTS OF THE DEVELOPMENT AND EVALUATION PROCESS	29
FIGURE 2: DEVELOPING AND EVALUATING COMPLEX INTERVENTIONS.....	30
FIGURE 3: KNEE OSTEOARTHRITIS-COMPLIANT PATHOGENIC FEATURES	40
FIGURE 4: (A) ANTEROLATERAL X-RAY VIEW FOR BILATERAL MEDIAL JOINT SPACE NARROWING. ...	72
FIGURE 5: (B) MRI (PROTON DENSITY, FAT SATURATED) OF RIGHT KNEE.....	73
FIGURE 6: KELLGREN-LAWRENCE OA GRADING.	73
FIGURE 7: GAIT PHASE VISUAL REPRESENTATION & TERMINOLOGY.....	82
FIGURE 8: (A) IN A NEUTRALLY ALIGNED LOWER LIMB.....	84
FIGURE 9: THE KAM DURING THE STANCE PROCESS OF GAIT.....	85

FIGURE 10: A WEAKENING HIP ABDUCTOR MECHANISM IN THE STANCE PAHSE.....	95
FIGURE 11: KAM DETERMINED BY THE FRONTAL PLANE GRF.	100
FIGURE 12: AN UPPER AND LOWER CUFF SUPPORT AND A DYNAMIC FORCE STRAP.....	102
FIGURE 13: APOS THERAPY.....	105
FIGURE 14: TYPES OF MIXED-METHODS RESEARCH DESIGNS.....	114
FIGURE 15: A SEQUENTIAL EXPLORATORY DESIGN ADAPTED FROM AND MRC GUIDELINES.	116
FIGURE 16: THE FUNDAMENTAL STEPS OF EXPLORATORY SEQUENTIAL DESIGN.....	118
FIGURE 17: ACCEPTABILITY FRAMEWORK CONSTRUCTS..	121
FIGURE 18: PRISMA FLOW CHART FOR STUDIES SELECTION.	149
FIGURE 19: SUMMARY OF RISK OF BIAS.	152
FIGURE 20: INDIVIDUAL STUDY'S QUALITY ASSESSMENT	152
FIGURE 21: KAM 1ST PEAK SHORT TERM EFFECT FOREST PLOT.	166
FIGURE 22: KAM 1ST PEAK MID-TERM EFFECT FOREST PLOT	168
FIGURE 23: KAM 2ND PEAK SHORT TERM EFFECT FOREST PLOT	169
FIGURE 24: KAAI SHORT TERM EFFECT FOREST PLOT.....	171
FIGURE 25: KFM SHORT TERM EFFECT FOREST PLOT.....	174
FIGURE 26: KNEE PAIN SHORT TERM EFFECT FOREST PLOT	176
FIGURE 27: KNEE ROM SHORT TERM EFFECT FOREST PLOTS.....	178
FIGURE 28: GAIT SPEED SHORT TERM EFFECT FOREST PLOT	181
FIGURE 29: STRIDE LENGTH SHORT TERM EFFECT FOREST PLOT.....	183
FIGURE 30: CADENCE SHORT TERM EFFECT FOREST PLOT.....	185
FIGURE 31: AN ILLUSTRATION OF THE TRANSCRIPT AND TRANSLATION PROCESSES.....	214
FIGURE 32: SUMMARY OF THE STUDY PROCESSES	217
FIGURE 33: POSTERIOR VIEW OF A LWI AND ANTERIOR VIEW OF LWI'S EFFECTS ON GRF.	274
FIGURE 34: DIAGRAM OF THE STUDY PROTOCOL.	291
FIGURE 35: SALFORD LATERAL WEDGE INSOLE.	294
FIGURE 36: PARTICIPANTS' FLOW DIAGRAM DURING FEASIBILITY STUDY.....	303
FIGURE 37: LIKERT SCALE-BASED CLUSTERED BAR CHART OF KOA PATIENT SATISFACTION	310
FIGURE 38: LIKERT SCALE-BASED CLUSTERED BAR CHART OF KOA PATIENT SATISFACTION.....	313
FIGURE 39: BAR PLOT OF PRE- AND POST-INTERVENTION MEANS WITH SD FOR NRPS	316
FIGURE 40: BAR PLOT OF PRE- AND POST-INTERVENTION MEANS WITH SD FOR WOMAC	316

LIST OF TABLES:

TABLE 1: MRC (2013) CRITERIA TO EVALUATE THE GAIT MODIFICATION TRAINING PROGRAM	33
TABLE 2: SUMMARY TABLE OF KOA RISK FACTORS:.....	46
TABLE 3: THE GOALS OF MIXED METHODS RESEARCH	122
TABLE 4: BASED ON GREENE, CARACELLI AND GRAHAM (1989), THE PURPOSES OF DESIGN.	124
TABLE 5: MATRIX OF WORLDVIEW DRAWN FROM CHRIST (2013).	126
TABLE 6: META-ANALYSIS & SYSTEMATIC REVIEW INCLUSION & EXCLUSION CRITERIA:.....	141

TABLE 7: OUTCOMES AND TIME POINTS.....	143
TABLE 8: SEARCH RESOURCE DETAILS AND NUMBER OF RESULTS AFTER APPLYING LIMITERS	149
TABLE 9: CHARACTERISTICS OF INCLUDED STUDIES:	159
TABLE 10: THE THEORETICAL FRAMEWORK FOR ACCEPTABILITY TERMS (SEKHON <i>ET AL.</i> , 2017):	220
TABLE 11: THEMATIC ANALYSIS IN SIX STAGES (BASED ON BRAUN AND CLARKE, 2006):	221
TABLE 12: AN OVERVIEW OF PARTICIPANT CHARACTERISTICS:	224
TABLE 13: INTERVIEWS AND FOCUS GROUPS IDENTIFIED THEMES AND SUB-THEMES:	225
TABLE 14: FEASIBILITY STUDY ELIGIBILITY CRITERIA:	289
TABLE 15: FEASIBILITY STUDY'S OUTCOMES:.....	296
TABLE 16: FEASIBILITY STUDY SUCCESS CRITERIA:.....	301
TABLE 17: PARTICIPANTS' BASELINE CHARACTERISTICS.....	305
TABLE 18: FEASIBILITY PARAMETERS RESULTS.....	308
TABLE 19: KOA PARTICIPANTS' DESCRIPTIVE STATISTICS OF THE 8 LIKERT SCALE OUTCOMES:...	309
TABLE 20: DESCRIPTION OF THE LIKERT SCALE SATISFACTION FOR PHYSIOTHERAPISTS:	312
TABLE 21: THE BASELINE AND 6-WEEK OUTCOMES OF THE LWI INTERVENTION:.....	315

LIST OF ABBREVIATIONS:

- Case Report Form (CRF).
- External Adduction Moment (EAM).
- European Alliance of Associations for Rheumatology (EULAR).
- Foot Progression Angle (FPA).
- Global Burden of Disease (GBD).
- Ground Reaction Force (GRF).
- Knee Angular Abduction Impulse (KAAI).
- Knee Adduction Moment (KAM).
- Knee Bracing (KB).
- Knee Contact Force (KCF).
- Knee Osteoarthritis (KOA).
- Knee Injury and Osteoarthritis Outcome Score (KOOS).
- Lateral Wedge Insole (LWI).
- Magnetic Resonance Imaging (MRI).
- Meta-Analysis (MA).
- Minimum Clinical Importance Difference (MCID).
- Musculoskeletal (MSK).
- The Medical Research Council (MRC).
- National Institute for Health and Clinical Excellence (NICE).
- Numerical Rating Pain Scale (NRPS).

- International Society for Osteo-Arthritis Research (OARSI).
- Participants' Information Sheet (PIS).
- Preferred Reporting Items for Systematic Reviews & Meta-Analyses (PRISMA).
- Quantitative Sensory Testing (QST).
- Randomised Clinical Trials (RCTs).
- Cochrane Risk of Bias Tool (RoB).
- Range of Motion (ROM).
- Standard Deviation (SD).
- Star Excursion Balancing Test (SEBT).
- Standardised Mean Differences (SMDs).
- Systematic Review (SR).
- Total Joint Replacement (TKR).
- Timed Up and Go Test (TUGT).
- Visual Analogue Scale (VAS).
- World Health Organization (WHO).
- Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) .
- Years of Living with Disability (YLD).

Abstract

Background: Knee osteoarthritis (KOA) is a degenerative cartilage condition marked by inflammation and mechanical processes. In Saudi Arabia (SA), one in ten older individuals suffer from it. KOA often leads to pain, functional limitations, reduced daily activities, and diminished quality of life. For those with medial knee osteoarthritis, lateral wedge insoles (LWI) can alleviate knee pain and enhance function. While LWI offers biomechanical and symptomatic benefits, the perspectives of Saudi KOA patients and physiotherapists on its clinical use are not well-understood. In addition, there is limited research on gait modification treatment for other types of KOA, especially regarding facilitators and barriers in the Saudi context.

Aims: This study aims to identify the suitability and acceptable use of the gait modification approach for reducing knee pain and enhancing functional ability among KOA patients in Saudi Arabia using a mixed methods approach.

Methods & Findings: A sequential exploratory mixed-methods approach was employed for this evidence-based study, following the Medical Research Council's (MRC) Framework for Developing Complex Interventions. The research consisted of a systematic review and qualitative investigations, along with the development and testing of a feasibility study.

The first component (Background, chapter 2) assesses the efficacy of various gait modification approaches on knee loading, pain, and function with KOA patients, with evidence from the Saudi healthcare system highlighted. Research goals and questions were set.

The second component (Systematic reviews and meta-analyses, chapter 4) identifies the most effective gait modification approaches and their primary clinical outcomes during walking. The analysis revealed that most gait modification methods did not significantly reduce the KAM 1st peak in the short and mid-terms. However, the systematic review indicated that lateral stiffener shoes could reduce the KAM 1st peak in the short term, and re-gait training with toe-out positioning might significantly improve the KAM 2nd peak. Furthermore, in the short term, LWI significantly impacted both the KAM 2nd peak and the knee adduction angular impulse (KAAI). Despite these specific

benefits, the overall effectiveness of gait modification in reducing knee loading was limited.

Subsequently, the third section (Qualitative – chapter 5) utilised semi-structured interviews and focus group discussions to grasp KOA patients' and physiotherapists' views on various gait modification techniques before adapting the LWI approach to the Saudi healthcare setting. This approach aimed to identify key features of gait modification and further understanding of stakeholders' knowledge, attitudes, and challenges in its application for KOA patients. The research indicated that implementing knee braces, canes, footwear and insoles was straightforward for patients and therapists, providing notable benefits and improving daily activities.

Drawing from prior research, a feasibility study was designed, outlining the suggested LWI as a gait modification, implementation duration, outcomes, and satisfaction survey.

The fourth component (Feasibility - chapter 7) evaluated the acceptability, tolerability, and feasibility of personalised LWI for KOA patients at a Saudi centre. This section implemented LWI as a gait modification, measuring recruitment, retention, adherence rates, the Numerical Rating Pain Scale (NRPS), the Osteoarthritis Index (WOAMC), and conducting satisfaction surveys for both patients and therapists.

In the initial session, KOA patients were assigned LWI with baseline records, followed by self-reported outcomes. Then, at the 6th week, clinical outcomes (NRPS & WOAMC) were reassessed, and a survey was collected. Of the 21 KOA participants who consented for the quantitative analysis, 17 completed the final evaluation. The study achieved an 87.5% recruitment rate and an 81% retention rate after six weeks. However, it is important to note that comfort was an issue for some participants, as two withdrew citing insole discomfort. The compliance rate assisting at 5.47 hours/day, indicating a 71% adherence, which was below the targeted value.

After six weeks, KOA participants showed significant improvements in the NRPS. A t-test revealed that these improvements were statistically significant ($p = 0.007$) with a large effect size (Cohen's $d = 0.98$). Similarly, the

WOMAC results also demonstrated statistically significant improvements ($p < 0.001$) and large effect size (Cohen's $d = 1.56$).

Seventeen KOA patients, who completed a survey, approved the LWI and expressed their satisfaction. They rated their satisfaction with the LWI application's clarity at 5 (extremely satisfied) and their symptoms improved satisfaction with the LWI at (64.7% - very satisfied). In the survey, KOA patients rated LWI as straightforward, well-tolerated and adverse-effect-free.

The overall therapists' satisfaction median was "Very satisfied," highlighting a positive response towards the practical skills enhancement provided by the insole, while the overall median for agreement items was "Agree," indicating a consensus among therapists on the insole's beneficial impact on their treatment routine. Given these results, the suitability of LWI in KOA recovery remains debatable.

Conclusion: The LWI was viewed as a viable treatment option for KOA in the Saudi context. Both patients and physiotherapists had shown significant interest in this approach. The results of a six-week intervention highlighted its practical benefits, such as reduced knee pain and improved walking capability. Continuous support and guidance from physiotherapists contributed to high levels of adherence, contributing to maintaining activity levels. While LWI offered a promising option in KOA rehabilitation, its full potential remained unexplored. Factors like the current SA KOA clinical protocol, infrastructure difficulties, therapist expertise and LWI availability needed consideration. In the Saudi context, a follow-up trial was essential after this initial intervention to assess the programme's long-term viability and cost-effectiveness. Furthermore, Although the physiotherapists' satisfaction survey indicated that the LWI programme was debatable, the physiotherapy educators needed to integrate knowledge about assistive gait modification (LWI) into their academic and clinical programmes to enhance evidence-based practice.

Keywords: *Gait modification, Insole, Knee, Mixed methods, Osteoarthritis, Prescriptions, Saudi Arabia*

Acknowledgements:

My sincere appreciation extends to my supervising team professors, Pip Logan, Ana Valdes, and Dr. Benjamin Smith. I appreciate their continuous support, helpful advice, and assurance at all times. Also, I would like to thank Professor Michelle Hall, my internal assessor, for her guidance and support. The study could not have been conducted without the assistance of Saudi Arabia's King Khalid University Medical City, the Physiotherapy Department at Aseer Central Hospital in Abha, and the King Faisal Specialist & Research Centre in Jeddah. It is with great gratitude that I extend my thanks to the members of my family who have supported and believed in me throughout my journey.

Teamwork and Reflection in Research:

During my research, I recognised potential biases stemming from my background and experience, notably as an Arabic-speaking physiotherapist with expertise in the musculoskeletal physiotherapy field. This could influence participants' interactions and data interpretation. However, academic training and regular feedback sessions with my thesis supervisors helped mitigate these biases.

During my PhD journey, focused on gait modification within Saudi's healthcare system, I observed the short-lived effects of current KOA treatments. As a physiotherapist, I noticed a lack of rehabilitation options for chronic conditions like KOA. My research explored how gait modification and tools like LWIs, footwear, and specific walking techniques toe-in or toe-out could offer enduring therapeutic strategies.

Ultimately, this research underscored the potential to enhance KOA treatment by bridging knowledge gaps and tackling logistical challenges. This could lead to improved patient outcomes, aligned with Saudi's 2030 healthcare vision. The study not only revealed challenges within the Saudi healthcare system but also underscored the significance of innovation and persistence in advancing KOA management for the betterment of both local and international patients.

CHAPTER 1

INTRODUCTION & THESIS STRUCTURE

Chapter overview:

1.1 Brief overview:

This chapter offers a very brief overview of knee osteoarthritis (KOA) healthcare system and rehabilitation services of the Kingdom of Saudi Arabia (SA). Furthermore, this chapter presents the rationale for this research and gives an overview of The Medical Research Council's (MRC) guidelines for complex interventions (2021), upon which the research in this thesis is based. The chapter concludes with a description of the thesis structure. A full review of KOA is in chapter 2 with a review of the biomechanics.

1.1.1 Knee osteoarthritis:

Knee osteoarthritis (KOA) is identified as a degenerative joint disease in the knee, typically caused by articular cartilage wear and tear and progressive cartilage loss (Hsu & Siwiec, 2018). KOA becoming more common due to aging, obesity, poor diet, lack of physical activity and stress (Dobson et al., 2018). Moreover, this condition progressively impairs joint function due to various factors such as excessive body weight, age, joint surgical treatments, repeated joint injuries, and genetics (Martel-Pelletier et al., 2016; He et al., 2020).

Furthermore, recent imaging advances have assisted in understanding KOA, revealing the deterioration of cartilage and structural changes throughout the joint (Hunter and Bierma-Zeinstra, 2019; Jang, Lee and Ju, 2021). Notably, it has been found that subchondral bone lesions occur before cartilage deterioration, highlighting their significant role in the disease's development and progression (Donell, 2019; Cai et al., 2021; Hu et al., 2021). In addition, recent insights have emphasised the importance of subchondral bone lesions in both the onset and progression of KOA, indicating a pivotal understanding of the disease (Coaccioli et al., 2022).

The aetiology of KOA remains elusive, despite the identification of multiple risk factors such as: age, obesity, strenuous occupations, high levels of sports participation, and misaligned knees (Visser *et al.*, 2015). In

addition, biomechanical factors, notably excessive loading, have been crucial in precipitating the onset and progression of KOA (Andriacchi, Koo and Scanlan, 2009; Duffell *et al.*, 2014).

1.1.2 An overview of KOA clinical practice guidelines:

Several evidence-based guidelines, including those from the American Academy of Orthopaedic Surgeons (AAOS) (Brophy and Fillingham, 2022), the American College of Rheumatology (ACR) (Kolasinski *et al.*, 2020), the National Institute for Health and Care Excellence (NICE, 2022), the European Alliance of Associations for Rheumatology (EULAR) (Moseng *et al.*, 2024) and the Osteoarthritis Research Society International (OARSI) (Bannuru *et al.*, 2019), have issued recommendations for effectively managing this condition.

These guidelines emphasise a combination of non-pharmacological and pharmacological approaches tailored to the individual needs of KOA patients before considering surgical options.

Both self-management (e.g., medication compliance, pain management, and pain coping strategies, joint protection strategies during exercises, exercise advice, problem-solving approaches, and stress management) (AAOS, 2022) and patient education (e.g., KOA progression and self-care techniques and a positive expectation of benefit from treatment), (OARSI, 2019) that make KOA understandable for the patients shows benefits and adverse effects, joints protection and realistic exercise and fitness objectives (ACR, 2020).

Exercise and physical activity are fundamental principles of KOA management and are generally advocated in all guidelines. NICE (2022) recommends prioritising overall aerobic fitness to enhance joint health and alleviate pain. The ACR (2020) promotes using strength training exercises to improve knee joint muscles. The AAOS (2022) recommends using neuromuscular training, which involves engaging in balance and coordination exercises to alleviate pain and enhance physical performance. In addition, EULAR (2024) also recommended including exercises that focus on strength, aerobics, flexibility, or neuromotor activities. All

guidelines emphasise that for overweight or obese individuals, weight loss is essential to lessen the load on knee joints, ease discomfort, and increase mobility.

Moreover, pharmacological therapies encompass a range of options, including topical and oral versions of non-steroidal anti-inflammatory medications (NSAIDs). NICE (2022) and the OARSI (2019) advise topical NSAIDs because of their fewer systemic adverse effects. When topical treatments are unsuccessful, oral NSAIDs are recommended but should be used with caution due to possible hazards (NICE, 2022; OARSI, 2019). In contrast, the AAOS (2022) advised acetaminophen and oral NSAIDs for the treatment of pain. Furthermore, as advised by (ACR, 2020), NSAIDs are taken into consideration when needed to reduce symptoms.

Further, when alternative therapies prove to be inappropriate or unsuccessful, intra-articular corticosteroid injections (IACS) are advised for short-term pain relief. When alternative pharmacological therapies are inadequate or inappropriate, the majority of guidelines (AAOS, 2022; ACR, 2020; NICE, 2022 and OARSI, 2019) advise IACS for short-term pain management. This kind of treatment is usually considered when supporting therapeutic exercise, which requires instant pain alleviation (NICE, 2019).

In Chapter 2, guidelines for conservative management of KOA were presented, including details and a summary of recommendations.

1.1.3 KOA Management through Gait Modification Techniques:

Clinical practice guidelines for KOA strongly support conservative, non-pharmacological therapies, highlighting the importance of gait modification techniques. Demonstrated gait retraining and assistive devices like (foot insoles and knee braces) can improve knee loading and pain and enhance function, which could manage KOA (Fregly et al., 2007; Simic et al., 2011, 2012; Wheeler, Shull and Besier, 2011; Fregly, 2012; Uhlich et al., 2019).

Further studies suggest that conservative gait modification approaches can be efficient by reducing the knee adduction moment (KAM) through alterations in the foot progression angle, thereby decreasing pain and improving function (Rokhmanova et al., 2022). Additionally, it has been

shown that knee loading can be significantly reduced by employing active feedback during gait retraining, underscoring the necessity for customised therapies (Erhart - Hledik et al., 2017; Hunt et al., 2018).

Gait retraining, specifically through toe-in or toe-out walking, aims to minimise peak KAM, which has proven to alleviate pain more effectively than control therapies in the short term (Uhlirch et al., 2019). As a non-invasive early treatment option for KOA, this approach includes various techniques such as medial-lateral trunk lean, toeing-in, toeing-out, walking with a decreased stride length, and medial thrust gait (Fregly et al., 2007; Barrios, Crossley and Davis, 2010; Hunt et al., 2011; Shull et al., 2011; Wheeler, Shull and Besier, 2011; Simic et al., 2012).

The biomechanical effectiveness of orthotic interventions, such as lateral wedged insoles (LWI), has been evaluated in terms of knee loading. Both a standard LWI (unsupported) and a combined insole with LWI and off-the-shelf anti-pronatory device in shoes while walking (supported insole) have been shown to reduce eversion at the ankle/subtalar joint complex and increase comfort, thereby decreasing knee loading (Jones et al., 2013). In addition, it examined the effects on knee pain, function and knee loading between LWI with a subtalar strap (combined insole) versus barefoot and LWI placed within a sandal. Both devices exhibited similar outcomes after a month, including improved performance and reduced knee pain (Falahatgar et al., 2022).

Practically, investigations of the effects of LWI on gait variability (swing duration, stride length and stance phase) within KOA patients have shown that LWI can enhance these gait variability according to acceleration monitoring using a wearable sensor and reduce dynamic knee instability as well (Ishii et al., 2023). Moreover, biomechanical non-invasive therapies such as AposTherapy have demonstrated significant pain relief and improved function for individuals with medial knee osteoarthritis by modifying the centre of pressure and continually altering the gait, greatly enhancing subjective results and functional capacities (Haim et al., 2012).

Furthermore, knee braces (that provide direct abduction moment) have effectively reduced medial tibiofemoral loads (Brandon et al., 2019). The combination of LWI and knee brace has improved knee kinematics (velocity, stride length, cadence) features, range of motion (ROM) and KOA patient satisfaction (Kohsravi et al., 2021).

Thus, these gait modification techniques' efficacy as non-pharmacological and non-surgical treatments of KOA has been emphasised by their alignment with clinical practice guidelines and the assurance of their benefits to KOA subjects. While these conservative measures can alleviate pain and impairment, they do not affect the underlying disease process, making surgery a more definitive solution (Aweid et al., 2018; Collins et al., 2019; Martel- Pelletier et al., 2019).

The different gait modification approaches will be further explored in Chapter 2.

1.1.4 Biomechanical loading in KOA:

Knee osteoarthritis (KOA) is considered a mechanical condition (Brandt et al., 2006). To assess KOA's progression through biomechanical variables, the knee joint's dynamic load during walking is crucial (Walter et al., 2015), and overload force can intensify KOA progression (Andriacchi & Mündermann, 2006). Additionally, altered biomechanics and cumulative load effects could cause tissue damage, structural changes, joint pain, and restricted knee movement (Van Tunen et al., 2016).

For individuals with KOA, excessive knee loading can unbalance joint tissue breakdown and repair, leading to progressive degeneration of articular cartilage. This indicates a significant disruption in the equilibrium of chondrocyte metabolic activities (Miyazaki et al., 2002; Felson, 2013). Additionally, this altered joint loading causes changes in the structure, metabolism, and mechanical characteristics of articular cartilage and other joint tissues (Guilak, 2011).

The knee adduction moment (KAM), a fundamental biomechanical parameter calculated during gait, accurately assessed the dynamic load on

knee cartilage (Jones, Nester, *et al.*, 2013). KAM was commonly used to estimate loading on the medial part of the knee joint and was associated with pain, intensity, extent of cartilage contact and disease progression in medial KOA patients (Hurwitz *et al.*, 2002; Miyazaki *et al.*, 2002; Dong Zhao *et al.*, 2007; Thorp *et al.*, 2007). Reducing KAM through biomechanical methods was a primary research focus in KOA management (Paterson *et al.*, 2017).

Such therapies could alleviate knee pain, improve physical function, and potentially slow disease progression (McAlindon *et al.*, 2014). Interestingly, despite potential shortcomings in care, such as non-strengthening exercise prescriptions and inadequate weight management within educational settings, integrating these aspects into care protocols could significantly improve patient outcomes. Nonetheless, patients with KOA often reported satisfaction with their treatment. However, research indicated that treatment outcomes could be further optimised. This optimisation could be achieved by implementing a therapy approach firmly based on guidelines emphasising patient education and attitude transformation towards the condition and its management (Thom *et al.*, 2023).

Numerous guidelines highlight the benefits of non-surgical KOA treatments delivered through research-based interdisciplinary programmes (R. R. R. Bannuru *et al.*, 2019; Hinman *et al.*, 2023). Various aspects of KOA care such as education, land-based exercises, and weight management are predominantly provided by physiotherapists (Skou and Roos, 2017; Barton *et al.*, 2021; Zeng *et al.*, 2021).

Furthermore, there is evidence that a physiotherapist's interpersonal skills significantly contribute to KOA patient satisfaction (Hush *et al.*, 2012). By adopting such early conservative approaches, the societal burden decreases (Ommen *et al.*, 2008; Lowe *et al.*, 2015), patients' quality of life improves (Street *et al.*, 2009), and healthcare expenses are decreased (Pinto *et al.*, 2012). However, incorporating high-quality, evidence-based care into standard practice remains a difficult task (Abaraogu *et al.*, 2019).

It is crucial to gain a comprehensive understanding of the current healthcare system in order to align KOA treatments with clinical guidelines (Hartvigsen, Kamper and French, 2022). Thus, in the SA healthcare context, it was vital to comprehend the perspectives of both KOA patients and therapists regarding gait modification. Moreover, a thorough consideration of acceptance, clinical protocols, and effectiveness are necessary to implement gait modification.

1.1.5 Background on Saudi Arabia:

Saudi Arabia occupies approximately 2,217,949 square kilometres (856,356 square miles) (Zuhur, 2011) and is a prominent Middle Eastern nation (Luz, 2020). The country's population comprises an estimated 19.4 million men (56.8%) and 14 million women (43.2%). According to the latest census data, 32% of the population is under 20 years of age, 36% are between 20 and 39 years, and 32% are aged 40 and above (*General Authority for Statistics*, 2022).

Saudi Arabia is divided into 13 regions, with the largest urban centres being Riyadh, Jeddah, Makkah, Madinah, and Dammam (Central Intelligence Agency, 2022). The country's transportation relies mainly on private automobiles, aeroplanes, and an expanding railroad system. Vision 2030, a comprehensive socio-economic reform introduced by SA, seeks to diversify its economy, diminish its oil dependency, and enhance public services including education, health, infrastructure, leisure, and tourism (Chowdhury, Mok and Leenen, 2021). This vision is being realised through various governmental initiatives and societal changes.

1.1.6 Overview of Healthcare system in Saudi Arabia:

In SA, the general population has access to free healthcare services primarily provided by the Ministry of Health (MOH). This ministry oversees 20 health directorates, encompassing over 284 healthcare hospitals. (Almalki, FitzGerald and Clark, 2011). Furthermore, the MOH operates more than 3,300 primary healthcare facilities throughout the nation, acting as primary entry points to its hospitals (Walston, Al-Harbi and Al-Omar,

2008). The MOH ensures healthcare provision at primary, secondary, and tertiary levels (Almalki, FitzGerald and Clark, 2011).

Primary care clinics serve as the initial contact within the healthcare system, offering both preventative and curative care. Patients needing more specialized treatment are typically referred to the nation's public hospitals, known as "secondary care" (Asmri *et al.*, 2020). When more specialized care is required, referrals are made to tertiary care facilities, such as specialized hospitals (Almalki *et al.*, 2011; Almalki, FitzGerald and Clark, 2011).

Primary care facilities offer a range of medical services to the public, including immunisations, child and maternal health, chronic disease management, dental care, health education, and the provision of essential medications (Asmri *et al.*, 2020). However, this approach has led to growing hospital waiting lists, overcrowded emergency rooms, and heightened strain on private healthcare providers (Walston *et al.*, 2008; Asmri *et al.*, 2020).

Moreover, several hospitals, not under the MOH umbrella, receive government funding. These include Defence Medical Services, Interior Medical Services, Aviation Medical Services, University Hospitals, and National Guard Medical Affairs (Walston *et al.*, 2008; Almalki *et al.*, 2011). Around 51 of these hospitals account for 15% of nationwide healthcare visits, primarily serving their specific demographics, typically employees and their families (Ministry of Health, 2021). Additionally, the private sector plays a substantial role in healthcare provision. It operates 163 hospitals across the country, accommodating 43% of all patient visits (Ministry of Health, 2021).

1.1.7 KOA management in Saudi Arabia:

In SA, the management of KOA incorporates both non-pharmacological, pharmacological and surgical strategies to relieve symptoms and enhance the well-being of those suffering from KOA.

- **Awareness of KOA:**

Variable degrees of knowledge regarding KOA were noted, with some sufficient public awareness about this condition. This variation in knowledge level calls for increasing public awareness of KOA, the importance of early diagnosis, and the benefits of sufficient treatment methods (Mukharrib *et al.*, 2018; Alyami *et al.*, 2020; Alkalash *et al.*, 2023). Thus, the importance of enhancing KOA understating and awareness of KOA among the public can not be ignored (Albaker *et al.*, 2024).

In addition, the KOA subjects usually seek self-medication for pain management, such as paracetamol (Karami *et al.*, 2018), and also use some drugs, such as oral non-steroidal anti-inflammatory drugs (NSAIDs), without being aware of the adverse effects of these medications (Almohammed, 2023; Alshammari, 2023). Therefore, this strategy may delay necessary treatments and provide insufficient treatment outcomes (Al-Ghamdi *et al.*, 2020).

- **Non-pharmacological interventions:**

In SA, physiotherapy approaches such as therapeutic exercises and aquatic therapy have been utilised people with knee OA to enhance symptoms and quality of life (Alanazi *et al.*, 2023). However, only physicians decisions are available, and there is no coordinated organised system or multidisciplinary team for the KOA management.

Also, limited physiotherapy clinics, delayed referrals, and a lack of awareness among physiotherapists about their role in managing KOA contribute to a negative view of non-pharmacological treatments. This is further worsened by physiotherapists' inconsistent use of treatment guidelines, particularly in promoting physical activity and exercise in SA (Subahi *et al.*, 2020). Therefore, improving communications with other healthcare professionals (physicians, trained nurses, dietitians and specialised physiotherapists) will be central to providing optimal non-pharmacological KOA care in SA (Al-Ahmadi and Al-mohandis, 2018).

- **Weight management:**

Managing weight loss is a critical part of treating KOA in SA, particularly given the high incidence of obesity among KOA patients. Over the past few years, the prevalence of overweight and obesity has been increasing in SA. (Almubark and Alqahtani, 2023). The relationship between excess weight and higher BMI in SA underscores the importance of obesity as a significant risk factor for KOA (Althomali *et al.*, 2023; Altowijri *et al.*, 2023).

As highlighted by evidence study, intentional weight loss reduced the risk of developing OA and its symptoms (Bliddal, Leeds and Christensen, 2014). Thus, according to the MOH's Saudi Center for Evidence-Based Health Care (EBHC), for the non-pharmacological treatment of overweight and obese adults, it is recommended to provide lifestyle interventions (such as promoting healthy habits, dietary counselling with interventions, physical exercise training and psychological and behavioural interventions), rather than just usual care. Also, it was suggested that individualised counselling interventions be provided rather than generic educational pamphlets. Physical activity is recommended instead of no physical activity, and engaging in physical activity is recommended in addition to diet, rather than relying only on diet for weight loss (Alfadda *et al.*, 2016).

However, challenges are encountered in implementing weight loss management strategies in SA. Cultural norms influence dietary habits and physical activity levels, making it difficult to achieve desired outcomes. Thus, there is a need for tailored approaches that account for these cultural factors to enhance the effectiveness of weight loss programs in the region (Mashrai *et al.*, 2022).

Additionally, obesity is widely recognised as a risk factor, and this recognition emphasises the need for health education interventions tailored to specific demographics. Addressing disparities related to gender, age, and education is essential to promote effective community-wide initiatives to prevent and manage knee osteoarthritis (KOA) (Elmisbah *et al.*, 2024).

There seems to be a lack of consistent implementation of weight loss non-pharmacological treatments, such as structured exercise programs and

comprehensive weight management. These treatments are frequently highlighted in international CPG.

- ***Pharmacological interventions:***

Pharmacological treatments for KOA in SA include paracetamol (McAlindon *et al.*, 2014; Bannuru *et al.*, 2019), non-steroidal anti-inflammatory drugs (NSAIDs) and intra-articular injections (corticosteroids and hyaluronic acid) (Al-Ahmadi and Al-mohandis, 2018; Alshahrani *et al.*, 2023). However, a study on societal misconceptions about intra-articular injections in SA reveals a significant gap in patient understanding and acceptance of these treatments, indicating better patient education and communication (Alshahrani *et al.*, 2023).

The use of NSAIDs is highly prevalent in SA, and therefore, awareness programs are necessary to familiarise the public with the side effects of short and long-term adverse events that result from using NSAIDs (Bahdailah, 2019).

This gap underscores the importance of healthcare providers providing clearer explanations and evidence-based reassurances about the safety and efficacy of pharmacological interventions, as recommended by international CPG.

- ***Surgery intervention:***

In situations where non-pharmacological and pharmacological treatments are ineffective in relieving advanced KOA, surgical interventions like total knee replacement (TKR) are considered a viable option in SA (Batarfi *et al.*, 2018; Almaawi *et al.*, 2022; Albaker *et al.*, 2024). This is in line with the majority of clinical practice guidelines, which suggest that surgery should be considered for patients who experience severe symptoms that are not relieved by conservative treatments. As a result, the acceptance and awareness of surgical interventions like TKR are widespread in KOA management in SA (Al-Otaibi, 2021; Almaawi *et al.*, 2022).

In summary, the management of KOA in SA includes different treatment methods consistent with some clinical practice guidelines such as NICE, EULAR, and ACR. However, more attention still needs to be placed on

addressing patient education, providing detailed recommendations for exercise and weight loss strategies, addressing misconceptions of pharmacological treatments and standardising treatment protocols or guidelines, which indicate areas for improvement in SA. These changes and improvements are necessary to bring the management of KOA in SA closer to the detailed recommendations of other clinical practice guidelines, ensuring comprehensive and effective management of KOA.

1.1.8 Rehabilitation Services in Saudi Arabia:

Rehabilitation involves interventions designed to help individuals recover functionality lost due to physical, psychological, social, or vocational injury or disease (Larsen, 2021). This broad category encompasses various therapies such as physical therapy, occupational therapy, orthotics and prosthetics, psychiatry, speech therapy, and rehabilitation medicine clinics (Aleisa *et al.*, 2014). Physiotherapists, who are central to this study, work within the rehabilitation team to help those injured or disabled regain mobility and function. They also assist in injury prevention and pain reduction. In 2018, over 1.6 million individuals accessed rehabilitation services in Ministry of Health facilities, with a significant majority (76%) undergoing physiotherapy.

In SA, physiotherapy services are not offered in primary healthcare facilities; they are available in secondary healthcare settings (Al-Abbad and Madi, 2020). Therefore, patients require a physician's referral to access these services. An alternative for patients is to seek treatment from private practices (Al-Abbad and Al-Haidary, 2016). As a result, the availability of physiotherapy services may be affected (Al-Abbad & Madi, 2020). Additionally, physiotherapists are not engaged in screening patients or making referral choices despite being required to treat and assess (Al-Sobayel *et al.*, 2014).

Consequently, doctors are the principal decision-makers and gatekeepers for physiotherapy in Saudi Arabia; the patient's treatment is influenced by their opinions about physiotherapy (Alshehri *et al.*, 2018; Al-Abbad and Madi, 2020). Furthermore, in SA it is considered that

physiotherapists are crucial in KOA management, underscoring the need for research on their adherence to evidence-based therapies and their attitudes and experiences in healthcare (Teo *et al.*, 2020).

Approximately 3493 physiotherapists are registered to practise, according to reports from the Ministry of Health (2018). In addition, all physiotherapists must register with the Saudi Commission for Health Specialties (SCHS) (Alghadir *et al.*, 2015). Although there is a shortage of published data, more postgraduate programmes are anticipated to open. Currently, 16 Saudi Arabian universities offer undergraduate physiotherapy programmes; only four offer postgraduate master's degree studies in the field, and one doctorate-level programme at a university in the eastern region (Alghadir *et al.*, 2015; Alshehri *et al.*, 2017). This might highlight how few postgraduate courses are available for professional advancement.

Physiotherapists, in many healthcare systems, are the primary professionals responsible for delivering various treatments to KOA patients, including electrotherapy, therapeutic exercises, and hydrotherapy. Their interventions aim to improve community participation, enhance gait behaviour, and reduce pain and swelling. Given their role in providing most conservative therapies, physiotherapists hold a pivotal position in the healthcare management of KOA.

1.2 Rationale:

Despite advances in pain and injury management, KOA continues to pose a socio-economic challenge. Various treatment methods, including pharmacology, rehabilitation, and surgery, have been employed for people with KOA. However, these have often resulted in increased medication use and expanded surgical options (Anandacoomarasamy and March, 2010; Uivaraseanu *et al.*, 2022).

Studies in SA have highlighted the extent of the issue: Al-Modeer *et al.*, (2013) reported a 29.5% prevalence of KOA, while AlKuwaity *et al.*, (2018) found that 24.5% of the elderly population suffered from KOA, with rates of 26.8% in women and 26.1% in men. Interestingly, the BMI findings showed

that, among a total of 65 participants with knee OA, 21.2% were overweight, 25.0% were obese, and 38.3% had a normal BMI. As a result, the Alkuwaity *et al.* (2018) study underlined the links between obesity and KOA prevalence.

Another Saudi prevalence study of KOA and related obesity was conducted in Al-Ahsa, in the eastern province (Ismail, Al-Abdulwahab and Al-Mulhim, 2006). The research included 243 individuals (171 female and 72 male, ages 20 to 80) who had been diagnosed with KOA based on radiographic results and clinical symptoms. According to the reported data, 90.53% of the subjects were overweight or obese. This connection was discovered in females more than males (73% and 41.65%, respectively).

Another (2002) study showed a prevalence of 30.8% in those 46-55 years of age and 60.6% in those 66-75 years of age (Al-Arfaj and Al-Boukai, 2002). A recent study in the Arar region, a city in Saudi Arabia's northern region, found that out of 410 participants, 39.75% had MRI-diagnosed KOA. Among this group, 25.6% were under the age of 40, and the prevalence was higher in females than in males (75.6% vs 27.7%, respectively) (Alrowaili, 2019).

Nevertheless, research on the prevalence of KOA in SA showed different findings, which can be attributed to the sample's location (geographically), which might differ in its environment and culture, or due to studies' methodology techniques (self-reported or versus radiograph KOA).

Thus, the data suggests that KOA affects both genders, almost equally, and is more prevalent among the elderly and obese populations. Policymakers should prioritize raising awareness and developing strategies to prevent and manage this condition effectively (Alkuwaity *et al.*, 2018).

Health guidelines generally recommend that KOA should initially be addressed with a conservative approach (Nelson *et al.*, 2014), reserving other interventions like surgery for more severe cases. Within this conservative framework, gait modification is often recommended for managing KOA. (Fregly, 2012; He, Liu and Yi, 2019; Uhlich *et al.*, 2019; S. Wang, Chan, *et al.*, 2021). However, given the diversity of gait modification

methods available, determining the most effective strategy remains challenging.

The current background highlights concern regarding the long-term use of certain learned/assistive gait modifications. While several studies indicated dissatisfaction with the gait modification approach without specifying reasons (Kerrigan *et al.*, 2002; Pollo *et al.*, 2002; Butler *et al.*, 2007; Singer and Lamontagne, 2008; Kutzner *et al.*, 2011; Pagani *et al.*, 2012; Jones *et al.*, 2013; Moyer *et al.*, 2013). As most research focuses on short-term outcomes, introducing pre-training assessments of acceptability and commitment could address these gaps.

After recognising the importance of gait modification, the question was which suitable approach should be integrated into the therapy strategy to enhance the clinical management of KOA in SA through an evidence-based approach to gait modification. This study begins with a systematic review to assess the effectiveness of various gait modifications, ensuring the approach is grounded in scientific evidence. This review will consolidate existing knowledge and highlight validated practices to make clinical decisions and well-informed about synthesis of the evidence (Morton *et al.*, 2011).

Subsequently, a qualitative study will be conducted to understand KOA patients' and professionals' perceptions, attitudes, and preferences (Wallis *et al.*, 2019) about gait modifications in the SA and how they dealing with it. This step will help identify practical challenges and acceptance issues when implementing gait modification in real-world scenarios. Insights gained will guide the development of patient-centred and clinically feasible gait modification strategies.

This research evaluates specific gait modifications' feasibility and clinical outcomes for patients with KOA in SA. The findings will inform patient and clinician preferences, leading to broader adoption of effective conservative interventions. Additionally, it will establish the foundation for future studies, such as Randomised Controlled Trials (RCTs) (Pearson *et al.*, 2020). In conclusion, this study will improve the understanding and implementation of gait modification, align it with scientific standards, and meet patient and

clinician needs. The anticipated impact is to improve patients' quality of life and advance healthcare practices in managing KOA in SA.

1.3 UK Medical Research Council (MRC) Framework:

The MRC Framework (2000) outlines four systematic steps for healthcare researchers to aid the development, evaluation, and implementation of complex interventions for health improvement (Craig *et al.*, 2013). Phase one, the development phase, encompasses three tasks: identifying the evidence base, formulating a theory, and modelling outcomes. The aim is to identify the intervention components, comprehend potential impacts, and determine opportunities for enhancement. The second phase, feasibility or piloting, tests methods, determines recruitment and retention, and sets the sample size. During this phase, both qualitative and quantitative methods evaluate the intervention's acceptability. After refining based on these findings, the next phase, evaluation, assesses the intervention on a broader scale. This phase evaluates intervention effectiveness, changing process, and cost-efficiency. Lastly, there is the implementation phase, which involves dissemination, surveillance, and extended follow-up. Its objective is to disseminate knowledge in order to apply the intervention in practice (Figure 1).

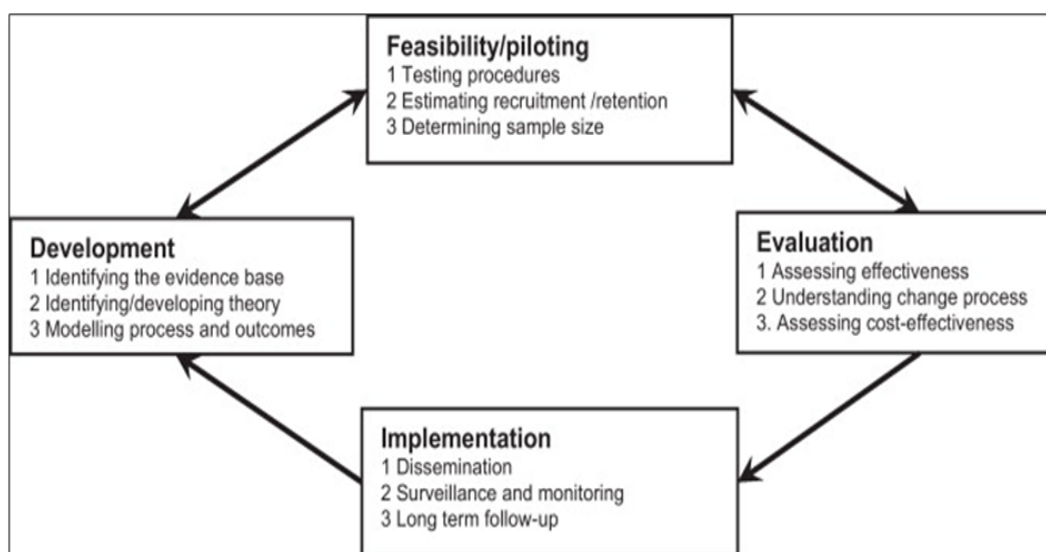


Figure 1: Key elements of the development and evaluation process (Craig *et al.*, 2013).

Compared to the MRC Framework (2000), the 2013 update introduced an iterative and cyclical approach, necessitating potential returns to previous phases in certain circumstances (Craig *et al.*, 2013). Skivington *et al.*, (2021) expanded upon this, outlining four main research phases: intervention identification, feasibility, evaluation, and implementation. They recommended considering six core elements in each phase: the intervention's interaction with its context, the underlying programme theory, diverse stakeholder perspectives, main uncertainties, intervention refinement, and cost-justification of effects. These elements guide whether to continue, return to, repeat, or stop the research. This thesis used Skivington *et al.*, (2021) as the last MRC framework, figure (2).

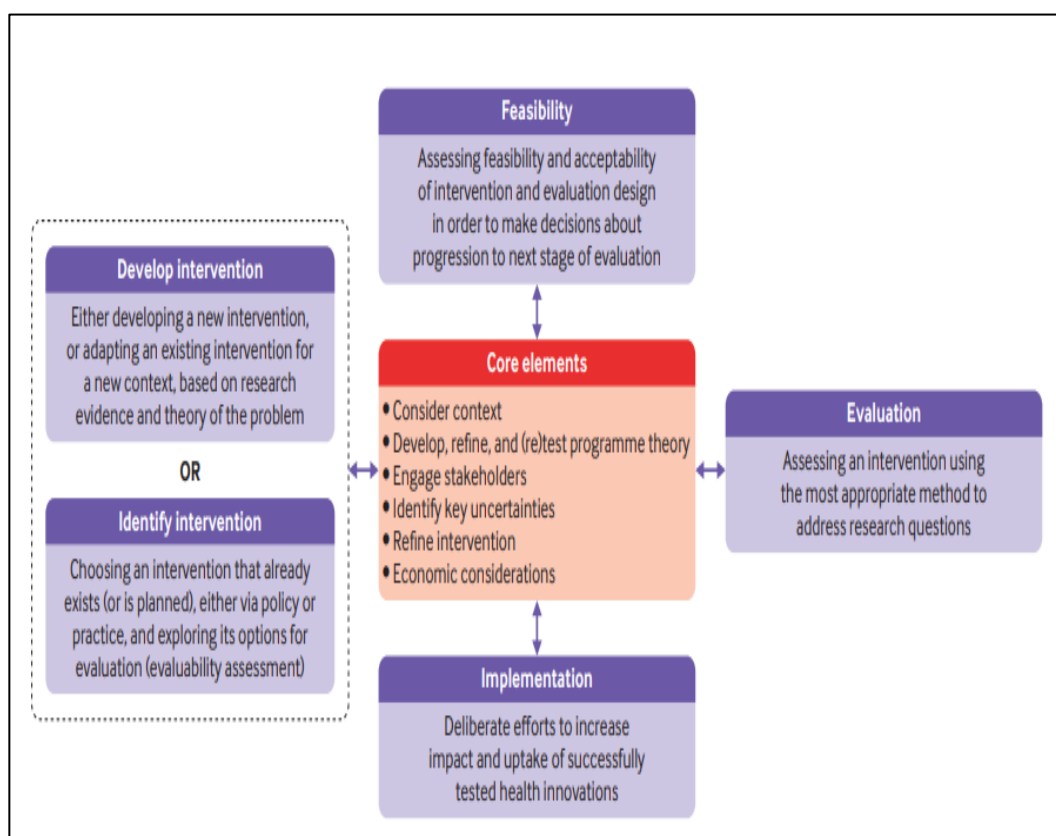


Figure 2: Developing and evaluating complex interventions: a new update Skivington *et al.*, (2021).

1.4 Thesis Structure: (Aims & Objectives)

This thesis aims to enhance KOA treatment in the Saudi medical environment by designing and evaluating a gait modification intervention. This study follows the MRC Framework (Craig et al., 2013), focusing on the first two phases, development and feasibility, due to time and resource constraints. The following are the specific goals and objectives that are closely related to each of these phases:

1- Development phase:

Systematic review: A systematic review was conducted to establish a theoretical foundation as part of a thesis focused on developing patient-specific gait modification therapies for individuals with knee osteoarthritis (KOA). The primary goal of this review was to identify the effectiveness of multiple modifying gaits (Chapter 4). This step aligns with the 'development' phase of the MRC Framework, emphasising the importance of evidence-based techniques in designing interventions (Craig et al., 2013).

Qualitative study: Following the systematic review, a qualitative study was conducted to gain deeper insights into the experiences of physiotherapists and patients with knee osteoarthritis (KOA), how they deal with it, what are the facilitators and obstacles there and who underwent gait modification programmes (Chapter 5). The study aimed to customise the intervention according to the patient's needs and preferences by identifying the most beneficial changes. This aligns with the development stage, where it is crucial to understand the intervention's acceptability and feasibility.

Identified intervention: The gait modification intervention Lateral wedge insole (LWI) described in Chapter 6 was selected based on the conclusions drawn from Chapter 4, the findings of Chapter 5, and other detailed justifications described in Chapter 6 at 6.3.

2- Feasibility phase:

Feasibility study: In Chapter 7, a study was conducted to assess the feasibility and acceptance of the LWI as a gait modification intervention. The study was conducted in an outpatient physiotherapy clinic in SA and evaluated the acceptability, tolerability, and feasibility of LWI. This step is crucial in the

MRC Framework's feasibility phase as it ensures that the intervention can be implemented successfully in practice and helps to improve the intervention and trial design in light of empirical data.

Table 1 below provides a visual view of the thesis.

Table 1: Using MRC (2013) criteria to evaluate the gait modification training program for KOA individuals.

MRC Framework	Development phase					Feasibility and Piloting Intervention Phase		
	Identify Knowledge & gaps	Identify theory	Identify evidence base	Modelling process and outcomes		Testing study intervention	Recruitment & Gather data	Intervention acceptability
Thesis Chapters	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7		Chapter 8
	Background	Methodology	Systematic review	Qualitative study	Identified interventional study	Feasibility study		Discussion
Taken steps	Saudi Arabia KOA current intervention and what is next	Identifying the most relevant current theory	Finding the most effective interventions	Patients' & professionals' perspectives	Design and selection of intervention programmes	Assessing feasibility, adherence, determining outcome measures & challenges.		Recommendation of a broader trial

CHAPTER 2

BACKGROUND

Chapter overview:

This section begins with a comprehensive overview of osteoarthritis, elaborating on its definition and various aspects. The aetiology of KOA is detailed, highlighting the knee's typical structure and function, the destruction of cartilage due to KOA, and the biomechanical factors influencing cartilage homeostasis. The ensuing sections provide in-depth information on the incidence, prevalence, and risk factors associated with KOA. They emphasize key symptoms such as knee discomfort, physical limitations, balance issues, and other related symptoms.

The chapter reviews the multifaceted impacts of KOA, encompassing economic, biopsychosocial, quality of life, and physical effects. Upon introducing diagnostic techniques for KOA, the discussion shifts to various management strategies, including: education, self-management, physiotherapy, pharmaceutical interventions, and surgical options. The biomechanics of KOA are examined, with specific attention given to the measurement of knee joint forces. The role of muscles in KOA is further explored, focusing on muscle co-contraction and its influence on knee loading.

The narrative transitions to unloading strategies, emphasizing gait modification to address gait abnormalities inherent in KOA patients. The effectiveness of different gait modification strategies is evaluated based on their ability to reduce knee loads, alleviate pain, and enhance function in KOA patients. This evaluation considers biomechanical techniques, identified gaps, and proposes future solutions.

In conclusion, there was an exploration of the clinical challenges and difficulties faced in managing and treating KOA. The objectives and research questions of the PhD study are subsequently outlined.

2.1 Background:

Knee osteoarthritis (KOA) is one of the most common musculoskeletal diseases worldwide, with a prevalence rate of 16% and an incidence rate of 203 cases per 10,000 person-years (Cui *et al.*, 2020a). KOA was once believed to be primarily a cartilage disease, but increasing evidence suggests it affects other structures, such as bone marrow, muscles, ligaments, menisci, and neural tissues (Brandt *et al.*, 2006). In the elderly, it accounts for 13% of knee pain and disability (Scott and Kowalczyk, 2008), carrying substantial social and economic implications (Guccione *et al.*, 1994; Badley, 2005; Lawrence *et al.*, 2008).

Treatment options for KOA range from conservative measures like patient education, physiotherapy, weight management, knee bracing, and various medications such as; nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, glucosamine and chondroitin sulphate, hyaluronic acid (HA) and corticosteroid injections to surgical interventions (Afzali *et al.*, 2018). Surgical procedures become the preferred choice when conservative approaches, which address symptoms but not the underlying disease process, prove inadequate (Aweid *et al.*, 2018; Collins *et al.*, 2019; Martel-Pelletier *et al.*, 2019).

Despite identifying several risk factors age, obesity, heavy manual work, sports participation level, and knee misalignment the precise aetiology of KOA remains elusive (Visser *et al.*, 2015). Biomechanical factors, such as excessive loading, play a crucial role in initiating and progressing KOA (Andriacchi, Koo and Scanlan, 2009; Duffell *et al.*, 2014). With the combined impacts of global ageing, increasing obesity, and joint injuries, the situation has become more pressing, as evident from the 250 million already afflicted globally (Vos *et al.*, 2012).

The dynamic load on the knee joint is best measured during walking to examine the impact of biomechanical variables on the advancement of KOA (Walter *et al.*, 2015) as the overload force of the joint can aggravate the

progression of KOA (Andriacchi & Mündermann, 2006). Moreover, The altered biomechanics and cumulative load impact may lead to tissue damage, resulting in structural changes, including joint pain and restricted movement (Van Tunen *et al.*, 2016).

External knee adduction moment (KAM), calculated during gait, can accurately estimate the dynamic load on knee cartilage (Jones, Nester, *et al.*, 2013). KAM is a significant indicator of loading in the medial part of the knee joint (Dong Zhao *et al.*, 2007). It is associated with pain (Thorp *et al.*, 2007), intensity (Sharma *et al.*, 1998), cartilage contact (Hurwitz *et al.*, 2002), and disease progression in medial KOA patients (Miyazaki *et al.*, 2002). Reducing KAM through biomechanical approaches has become a major research priority in KOA management (Paterson *et al.*, 2017). Such biomechanical therapies can alleviate discomfort, improve physical function, and potentially hinder the disease's development (McAlindon *et al.*, 2014).

2.2 Osteoarthritis Definition:

Despite its unique nature, defining osteoarthritis precisely for more than 100 years has remained challenging. In a recent report published by the European League Against Rheumatism (EULAR) (Weibo Zhang *et al.*, 2010), KOA is defined as follows:

“Knee osteoarthritis is characterised clinically by usage-related pain and/or functional limitation. It is a common complex joint disorder showing focal cartilage loss, new bone formation and involvement of all joint tissues. Structural tissue changes are mirrored in classical radiographic features”.

The main advantage of the EULAR definition is that it emphasizes patient subjective experience (the 'bottom line') over the pathological entity or radiological results. Many studies (Kornaat *et al.*, 2006; Bedson and Croft, 2008; Link, 2009; Neogi *et al.*, 2009; Hofmann *et al.*, 2010) have shown that radiographic, magnetic resonance imaging (MRI) and arthroscopic results do not always correlate with patient symptoms, pain or physical function. However, there are drawbacks to using pain as the primary indicator of physical disease

since pain perception is influenced not only by the condition of the joint but also by environmental and psychosocial factors (McAlindon *et al.*, 1992; Creamer, Lethbridge-Cejku and Hochberg, 1999; Dieppe and Lohmander, 2005). Due to this, it is essential to define OA precisely and categorize it appropriately for each research project.

2.3 Pathogenesis:

Diarthrodial joints exhibit an intricate design made up of various connective tissues such as subchondral bone, articular cartilage, and at times, components like menisci, ligaments, and the synovial membrane. Working in harmony, these tissues allow for the smooth function of the joint (Clouet *et al.*, 2009). Nested just beneath the articular cartilage, the subchondral bone encompasses both the subchondral plate and trabecular bone, with the subchondral bone plate, characterized by calcification cartilage and a thin layer of cortical bone, residing deep within the cartilage (Burr, 2004).

Predominantly formed of an extracellular matrix, articular cartilage is unique, devoid of blood vessels, lymph vessels, and nerves, and possesses a scant cell population (Bullough, 2007). These cells, chondrocytes, although constituting only about 1% of adult human articular cartilage (Buckwalter *et al.*, 2006), play a central role in the synthesis and degradation of the cartilage (Loeser, 2009). The exact mechanisms maintaining a balance between production and degradation are yet to be fully understood, but cytokines, both anabolic and catabolic, are believed to be instrumental (Buckwalter *et al.*, 2005; Goldring *et al.*, 2007).

Loss of articular cartilage and fibrillations are the most common pathologic changes seen in OA, then the subchondral bone is thickened, reshaped and finally the whole thickness space is lost. It is unknown whether cartilage and bone alterations exist simultaneously or if one tissue is affected before the other (Huber *et al.*, 2000). Early KOA, fibrillation and abnormalities of the articular cartilage's superficial zone occur and progress toward the transition region (Guilak *et al.*, 2004). Following this, specific areas of cartilage

loss accompany cavities and fissures as well as alterations in the cartilage's deepest layer, the calcified cartilage layer (Figure 3). Late-stage KOA may see a complete loss of articular cartilage, and the bone may become visible (Guilak *et al.*, 2004). Additional new bone formation on the trabeculae in the subchondral bone indicates pathological bony involvement.

Degradation of the articular cartilage is followed by changes of the subchondral bone, such as subchondral sclerosis, cyst-like bone cavity formation and osteophyte development (Lajeunesse and Reboul, 2003). Osteophyte growth is accompanied by alterations in the articular and subchondral cartilage of most of the synovial joints.

Beyond basic structural concerns, biomechanical factors heavily influence the health of the articular cartilage. The articular surface's important role in joint load distribution is underscored by observations that alterations in this distribution or enhanced loading can precipitate and aggravate KOA (Andriacchi *et al.*, 2004). The progressive degradation of cartilage is a testament to the disturbance in chondrocytes' natural metabolic balance, where the mechanical stress environment potentially regulates chondrocyte activity (Guilak, 2011).

Both acute and chronic stresses impact chondrocytes and subchondral bone cells (Buckwalter, Martin and Brown, 2006), underlining the necessity of biomechanical stress for cartilage homeostasis (Guilak *et al.*, 2004, 2011). However, abnormal, unpleasant, or increasing loading is associated with inflammatory and metabolic abnormalities that might later develop into osteoarthritis (Andriacchi *et al.*, 2004; Griffin and Guilak, 2005). Furthermore, balance is delicate: while stress is essential for homeostasis, in KOA, the homeostatic and repair mechanisms are outpaced by destructive forces, culminating in structural damage and clinical symptoms (Hunter and Felson, 2006).

In vivo studies indicate that "abnormal" joint loading impacts the structure, metabolism, and mechanical properties of articular cartilage and other joint tissues (Guilak, 2011). Excessive mechanical contact stress can

damage articular cartilage and subchondral bone, adversely affecting chondrocyte function (Buckwalter, Martin and Brown, 2006). High loading levels, both in magnitude and duration, cause swelling, cell death, and tissue disruption (Torzilli *et al.*, 1999; Milentijevic *et al.*, 2003). Compression injuries, characterized by high loading rates, can lead to a breakdown of the collagen fibril network and increased tissue swelling (Loening *et al.*, 2000). Furthermore, joint apposition and engagement significantly influence the severity of cartilage injury post-impact (Heijink *et al.*, 2016).

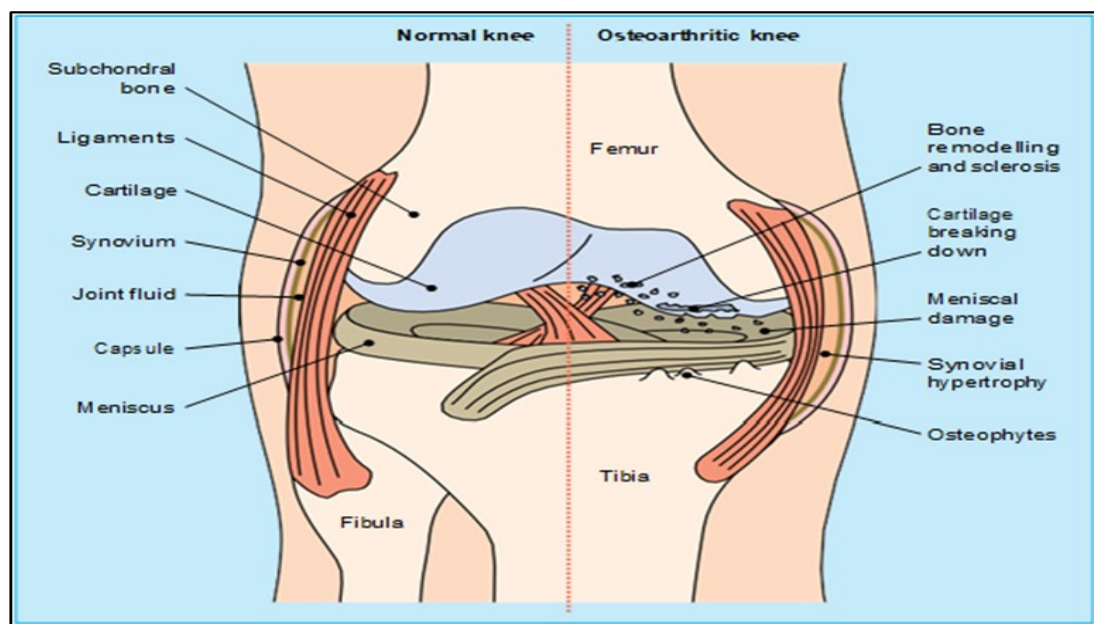


Figure 3: Knee osteoarthritis-compliant pathogenic features (joint failure), from (Hunter and Felson, 2006) with permission.

2.4 Understanding of OA inflammation and resolution:

Osteoarthritis (OA) is no longer understood solely as a degenerative joint disease characterised by cartilage wear and tear. Recent advances highlight OA as an active disease involving complex inflammatory processes and metabolic dysfunctions, which are integral to the disease's progression.

- Inflammatory processes in OA:

The role of inflammation in OA was pivotal. Inflammatory cytokines, such as interleukin-1 (IL-1) and tumour necrosis factor-alpha (TNF- α), were key mediators that exacerbated joint degradation. These cytokines stimulated the production of matrix metalloproteinases (MMPs), enzymes that degraded

extracellular matrix components, leading to cartilage breakdown (Chow and Chin, 2020). Additionally, inflammation in OA involved the infiltration of immune cells into the joint, which further perpetuated the inflammatory environment (Wang and He, 2018).

The development of OA was primarily influenced by an imbalance between proinflammatory and anti-inflammatory mediators, causing low-grade inflammation. This inflammation led to cartilage degradation, bone remodelling, and synovial proliferation. Various cytokines activated multiple signalling pathways, increasing cyclooxygenase-2 (COX-2) expression and, consequently, prostaglandin E2 (PGE-2). This process affected osteophyte formation and synovial inflammation, correlating with the severity of symptoms in OA. Targeting inflammatory pathways could have been beneficial in managing the disease (Molnar *et al.*, 2021). Nevertheless, lifestyle modifications such as diet, supplementation, and physical activity could improve OA symptoms even before drug treatments. Further research on how lifestyle changes affected cytokine modulation and slowed OA progression could yield valuable insights (Messina, Vidal Wilman and Vidal Neira, 2019; Malorgio *et al.*, 2021).

Moreover, elevated levels of pro-inflammatory mediators in synovial fluid were closely linked to increased pain and joint dysfunction in OA. As previously mentioned, key cytokines like interleukin-1 beta (IL-1 β) and (TNF- α) stimulated the production of matrix metalloproteinases (MMPs), which degraded cartilage and exacerbated joint destruction. Other mediators, such as nitric oxide (NO), prostaglandin E2 (PGE2), and adipokines like visfatin and leptin, contributed to the inflammatory environment and pain sensitisation.

The presence of these mediators in the synovium led to heightened pain perception, joint swelling, and restricted movement. Non-invasive imaging techniques like MRI and ultrasonography could detect synovitis by visualising increased synovial fluid and thickened synovial membranes, correlating with OA severity.

Understanding the role of these mediators was crucial for developing targeted therapies to reduce inflammation and improve joint health. Targeting

pro-inflammatory cytokines and other mediators through anti-inflammatory drugs and cytokine inhibitors held potential for alleviating pain and slowing joint degeneration in OA patients (Sellam and Berenbaum, 2010).

- **Metabolic Dysfunction in OA:**

Chondrocyte metabolism plays a significant role in the pathogenesis of OA. Under inflammatory conditions, chondrocytes shift from oxidative phosphorylation to glycolysis, a metabolic reprogramming known as the Warburg effect, similar to changes observed in cancer cells. This shift is regulated by key pathways such as AMP-activated protein kinase (AMPK) and mechanistic target of rapamycin (mTOR) (Zheng *et al.*, 2021). Mitochondrial dysfunction in chondrocytes leads to increased production of reactive oxygen species (ROS), contributing to oxidative stress and further cartilage degradation. This metabolic reprogramming is implicated in various OA phenotypes, including those associated with metabolic syndrome (Zheng *et al.*, 2021).

A comprehensive review by Adam *et al.* (2024) explores the metabolic characteristics and changes of chondrocytes both in vivo and in vitro in OA. The study highlights the critical role of metabolic pathways such as glycolysis, oxidative phosphorylation, and lipid metabolism in maintaining cartilage function. Miradj *et al.* discuss how chondrocytes in OA exhibit increased glycolytic activity, leading to elevated lactate production and decreased cartilage matrix synthesis. Alterations in mitochondrial activity, such as decreased “adenosine triphosphate” (carry energy molecule) generation and increased oxidative stress, contribute to cartilage deterioration. The review underscores the importance of targeting chondrocyte metabolism as a therapeutic approach for OA, suggesting that modulating these metabolic pathways could improve cartilage health and slow disease progression (Adam *et al.*, 2024).

- **Resolution Mechanisms:**

The resolution of inflammation was as critical as the inflammatory response itself. The body's inability to effectively resolve inflammation contributed to the chronic nature of OA. Pro-resolving mediators, such as

resolvins, protectins, and maresins, played essential roles in terminating inflammatory responses and promoting tissue repair (Schwab and Serhan, 2006). These mediators were derived from omega-3 polyunsaturated fatty acids and possessed potent anti-inflammatory and pro-resolving properties. Lipoxins, another class of pro-resolving mediators, were generated from arachidonic acid and also aided in resolving inflammation by inhibiting the recruitment of neutrophils and promoting the clearance of apoptotic cells.

Sokolove and Lepus (2013) highlighted that chronic inflammation in OA was characterised by the persistent activation of inflammatory pathways and an inadequate resolution response. This led to continuous tissue damage and the progression of OA. The failure to resolve inflammation was partly due to the insufficient production of pro-resolving mediators, which were crucial for restoring tissue homeostasis (Sokolove and Lepus, 2013).

Enhancing the activity of pro-resolving mediators could offer a novel therapeutic approach to OA. For instance, resolvin D1 (docosahexaenoic acid (DHA), which is one of the primary omega-3 fatty acids) was shown to reduce joint inflammation and pain in animal models of arthritis, highlighting its potential in human OA treatment (Terkawi *et al.*, 2022). Resolvins, protectins, and maresins modulated the immune response, reduced the infiltration of inflammatory cells, and promoted the clearance of debris and apoptotic cells from the site of inflammation (Schwab and Serhan, 2006).

Lastly, viewing OA through the lens of both inflammation and resolution provides a comprehensive understanding of its pathogenesis. This perspective recognises OA as a balance between destructive inflammatory processes and the body's efforts to repair and resolve these processes. The dynamic interplay between these factors determines the progression and severity of OA (Hunter and Bierma-Zeinstra, 2019).

Moreover, the necessity of addressing inflammation while simultaneously promoting resolution pathways to create effective therapies for OA. By influencing these mechanisms, it is feasible to not only reduce symptoms but also decelerate disease progression and enhance joint function (Adam *et al.*, 2024).

The contemporary understanding of OA as an active disease model incorporating inflammation and resolution mechanisms offers a more complete view of its pathogenesis. This perspective is crucial for developing innovative therapeutic strategies aimed at modulating these processes to prevent or slow the progression of OA.

2.5 Incidence and Prevalence:

The KOA prevalence varies based on the KOA definition, specific joints examined, and study population characteristics (Zhang and Jordan, 2010). In individuals ≥ 45 years, radiographic diagnostics KOA occurrence was 19.2% in Framingham participants and 27.8% in the Johnston County Osteoarthritis Project. Meanwhile, the 3rd National Health and Nutrition Examination Survey (NHANES III) reported that roughly 37% of individuals ≥ 60 had radiographic KOA (Lawrence *et al.*, 2008).

In the Johnston County Project, symptomatic KOA prevalence was 16.7% for participants < 45 , a figure higher than Framingham's, attributed to pain and radiological findings even in asymptomatic OA joints. Many surveys require recent joint pain for symptomatic joint diagnosis, even if unrelated to arthritis (Lawrence *et al.*, 2008).

A Massachusetts health maintenance study by Oliveria *et al.*, (1995) found age and gender rates for symptomatic OA of hip, knee, and hand joints at 88, 240, and 100/100,000-person years, respectively. Symptomatic OA incidence increased at age 50 but decreased after age 70 (Oliveria *et al.*, 1995). Furthermore, Murphy *et al.*, (2008) reported a 40% lifetime risk for men and 47% for women for symptomatic KOA, with higher risks linked to BMI (30 or above face a 60% chance of developing KOA).

Women's knee anatomy is distinct from men's; they have a narrower femur, larger angles of quadriceps, shorter patellae and tibial condyle size differences, resulting in different kinematic features that create a higher incidence of KOA in women (Hame and Alexander, 2013; Long *et al.*, 2020).

In 2015, KOA accounted for nearly 85% of the global osteoarthritis burden (*Disease and Injury Incidence and Prevalence Collaborators, 2016*), with a 32.7% increase from 2005–2015. It became a primary factor for years of living with disability (YLD) (Vos *et al.*, 2016). The World Health Organisation (WHO) ranked KOA eleventh for YLD in 2010 (Salmon *et al.*, 2016), and its global prevalence surged from 2000–2020, pressuring healthcare systems (Cui *et al.*, 2020b).

By 2016, OA was significant, as noted by the International Society for Osteo-Arthritis Research (OARSI) report. KOA was linked to increased mortality and cardiac diseases (McAlindon *et al.*, 2014), with disability and inactivity raising cardiovascular risk for KOA patients (Hall *et al.*, 2016; Wang *et al.*, 2016).

2.6 Risk Factors:

Risk factors that may increase the chances of developing KOA fall into two categories: non-modifiable and modifiable factors (Georgiev and Angelov, 2019). See table (2).

Table 2: Summary Table of KOA Risk Factors:

Factor	Modifiable/ Non-Modifiable	Summary
Age	Non-Modifiable	The prevalence of KOA increases with age due to accumulated risks and age-associated changes.
Gender	Non-Modifiable	Women are more likely to develop KOA, with increased rates post-menopause potentially due to hormonal changes.
Ethnicity	Non-Modifiable	KOA rates differ among ethnic groups, with certain populations showing higher or lower prevalence.
Genetics	Non-Modifiable	Genetic factors contribute significantly to the risk of OA, particularly in hand and hip joints.
Knee Injuries	Non-Modifiable	Injuries to the knee, such as fractures and ligament tears, significantly increase KOA risk.
Knee Alignment	Non-Modifiable	Misalignment of the knee can affect load distribution, influencing KOA progression.
Nutrition	Modifiable	Lower intake of vitamin D is linked with increased KOA progression, though its preventive benefits are debated.
Obesity	Modifiable	Obesity is a major risk factor for KOA; losing weight can reduce the risk and alleviate symptoms.
Occupational	Modifiable	Jobs involving heavy lifting, kneeling and squatting are associated with higher KOA risk.
Physical Activity	Modifiable	Injuries from sports, particularly ACL and meniscal injuries, greatly increase KOA risk.
Muscle Weakness impact	Modifiable	Linked to KOA development and progression, impairing joint motion regulation.

Regarding non-modifiable factors, **age** is a primary risk factor for all OA joints (Felson *et al.*, 2000; Lawrence *et al.*, 2008). KOA's prevalence rises with age, attributed to cumulative risks and age-related changes (Zhang and Jordan, 2010). The US and Europe see similar KOA rates, especially in older demographics. Specifically, the Dutch Institute reported KOA in 15.6% of males and 30.5% of females over 55 (Bijlsma and Knahr, 2007). Age-related factors, such as oxidative damage, cartilage thinning, and muscle weakness, decrease joint tissue upkeep.

Moving from age, **gender** also plays a role. Women are more likely to develop KOA. A compilation of 12 studies demonstrated a lower risk in males, female=12,261 (55% of total participants) (Srikanth *et al.*, 2005). Post-menopausal women exhibit an increased KOA rate, indicating hormones' potential role. However, research on oestrogen's impact is still inconclusive. Some data suggest oestrogen therapy lessens risk (15% lower KOA than those who did not receive such therapy), (Cirillo *et al.*, 2006).

Beyond age and gender, **ethnicity affects** OA rates. Chinese studies report lower rate of hip and hand OA than Whites in the Framingham Study (Nevitt *et al.*, 2001; Zhang *et al.*, 2001), but a higher KOA rate among Chinese women (Zhang *et al.*, 2001). The Johnston County Project found similar hip OA rates for African American (23%) and White females (22%), but African American males (21%) showed elevated rates (Nelson *et al.*, 2010).

Genetics is another influential factor. It contributes 40–80% of OA, especially in hand and hip joints (Van Meurs, 2017). Moreover, the heritable component of OA has estimates from 50–65% in twin and family studies, with higher genetic effects on both hand and hip joints than for KOA (Felson *et al.*, 1998; Kerkhof *et al.*, 2010). A genome-wide study linked a chromosome to 1.14 times increased knee/hand OA occurrence and 30% KOA progression (Dolan *et al.*, 2003; Chen *et al.*, 2008).

Injury's Influence on KOA: Knee injuries significantly elevate KOA risk, with fractures, meniscectomy tears, and ligament injuries particularly detrimental (Roos *et al.*, 2001; Lohmander *et al.*, 2004). Meniscal damage, prevalent in radiographic KOA patients, is considerably greater (82%) than those without KOA (25%) (Felson *et al.*, 1992), especially in severe cases, 95% of meniscal lesions were found in moderate (K/L = 3) and severe (K/L = 4) radiographic KOA (Englund *et al.*, 2008). Post-traumatic osteoarthritis (PTOA) arises from knee injuries, accounting for about 13% of all KOA cases (Rhon *et al.*, 2019). Those injured were 3–6 times more likely to develop KOA (Muthuri *et al.*, 2011; Silverwood *et al.*, 2015) and were diagnosed 10 years earlier than in people who had never had a knee injury (Brown *et al.*, 2006).

Despite KOA's typical slow progression (Within 4 years, 5% to 17% of knees develop structural damage), some show rapid deterioration post-injury (Bartlett *et al.*, 2011; Neogi *et al.*, 2012). Furthermore, within 5 years following an injury, the knee exhibits structural alterations that represent changed joint health (e.g., change in cartilage composition and bone structure) (Li *et al.*, 2011; Frobell *et al.*, 2011; 2015).

Lastly, **Knee alignment**, an essential determinant of load distribution, was viewed as a significant risk factor for KOA. Misalignment impacted load distribution across the knee: Varus alignment increased forces across the medial compartment, while valgus alignment did so across the lateral compartment (Ingham *et al.*, 2010). The role of misalignment as a risk factor for developing or progressing KOA remained uncertain (Brouwer *et al.*, 2007; Runhaar *et al.*, 2014). Brouwer *et al.*, (2007) demonstrated that in overweight and particularly obese individuals, malalignment significantly heightened KOA development risk, especially with specific BMI values (*varus alignment in subjects with a BMI ≥ 25 and < 30 kg/m² and for valgus and varus alignment in subjects with a BMI ≥ 30 kg/m²*). However, no correlation was found between malalignment and KOA onset in individuals with standard weight.

Furthermore, varus and valgus alignment might either cause or result from KOA (Vincent, 2004). Their findings suggested that pre-existing varus or valgus alignment could be due to genetic, developmental, or post-traumatic factors. Additionally, animal studies supported a connection between pre-existing alignment issues and the development of KOA (Vincent, 2004).

The association of osteophytes with malalignment and the progression of KOA was discussed by Felson *et al.* (2005). They found that osteophytes were strongly correlated with malalignment, with medial osteophytes linked to varus alignment and lateral osteophytes to valgus alignment. Their study concluded that the relationship between osteophytes and disease progression was partly mediated by malalignment (Felson *et al.*, 2005).

Studies on the relation between malalignment and the incidence of radiographic KOA in healthy subjects produced mixed results. Tanamas *et al.*, (2009) identified knee misalignment as an apparent risk factor for radiographic

KOA. Two MRI cohort studies also noted a connection between varus and valgus alignment and KOA structural progression. However, Hunter *et al.*, (2007) found no relationship between KOA onset and knee anatomical alignment.

Sharma *et al.*, (2010) suggested malalignment was more an indicator of KOA severity or development rather than a primary risk factor for its onset. Their study linked varus alignment with increased medial KOA progression risk and decreased lateral risk. Conversely, valgus alignment was associated with heightened lateral progression risk and diminished medial risk. They concluded that the tibiofemoral osteoarthritis progression likelihood was impacted by both varus and valgus alignment through knee biomechanics stress.

Furthermore, MRI studies presented inconsistent data on malalignment and KOA traits. For example, misalignment was associated with bone marrow abnormalities (Hayashi *et al.*, 2012) and cartilage defects (Sharma *et al.*, 2013) but was not linked to cartilage volume reduction or chondral defect onset (Zhai *et al.*, 2007). These studies predominantly involved healthy adults with average weight. However, Brouwer *et al.*, (2007) emphasized that in overweight and significantly obese individuals, malalignment considerably increased the likelihood of KOA development.

Conversely, when it comes to modifiable factors, **nutrition**, particularly vitamin D, is vital in the KOA context. Reduced vitamin D intake correlates with heightened KOA progression, though its preventive impact is debated (McAlindon *et al.*, 1996; Felson *et al.*, 2007). The Framingham Study linked low vitamin C intake to increased KOA (McAlindon, Jacques, *et al.*, 1996). In contrast, the Johnston County Project found that a specific tocopherol ratio reduced 50% KOA risk (Jordan *et al.*, 2004). However, vitamin E did not influence KOA symptoms in trials (Wluka *et al.*, 2002).

Obesity, Weight Loss, and KOA: According to the World Health Organization, obesity rates tripled between 1975 and 2016. Recognized as a major modifiable risk factor for OA (Szoek *et al.*, 2006), recent evidence supports that obesity often precedes OA (Manninen *et al.*, 1996; Felson *et al.*,

1997) and intensifies radiological progression risks in KOA patients (Dougados *et al.*, 1992; Schouten *et al.*, 1992).

Nevertheless, weight loss reduces radiographic KOA risk. A study found that 64% of obese (30 kg/m^2) KOA patients showed significant clinical improvement after a 16-week diet ($>10\%$) of their weight (Gudbergson *et al.*, 2012). Also, weight loss alleviates pain and dysfunction in advanced KOA stages (Messier *et al.*, 2004; Christensen *et al.*, 2007), with even a 5% weight decrease boosting physical activity (Christensen *et al.*, 2007).

- Obesity as an inflammatory mediator and mechanical loading effects:

The relationship between obesity and KOA encompassed both systemic inflammatory mechanisms and local biomechanical effects, each contributing significantly to the pathogenesis and progression of the disease.

Obesity was associated with chronic low-grade inflammation, characterised by elevated levels of pro-inflammatory cytokines and adipokines. Adipose tissue, particularly visceral fat, secreted various inflammatory mediators such as tumour necrosis factor-alpha (TNF- α), interleukin-6 (IL-6), and leptin. These cytokines played crucial roles in the systemic inflammatory environment observed in obese individuals and were implicated in the development of KOA.

Leptin, an adipokine produced by adipocytes (fat cells), is noteworthy due to its dual role in metabolism and inflammation. It not only regulates energy balance but also promotes the production of other cytokines and enhances the expression of cartilage-degrading enzymes like matrix metalloproteinases (MMPs). Elevated leptin levels were linked to increased cartilage degradation and inflammation in knee OA (Issa and Griffin, 2012; Berenbaum, Eymard and Houard, 2013).

Additionally, IL-6 and TNF- α , secreted by adipose tissue and injecting macrophages, contributed to the inflammatory state in obese individuals. These cytokines triggered synovial inflammation, leading to the production of degradative enzymes and further cartilage destruction. Studies showed that higher systemic levels of IL-6 and TNF- α correlated with OA severity,

highlighting their significant role in the disease's pathophysiology (Wang and He, 2018; Runhaar *et al.*, 2019).

The recruitment of various inflammatory cells into the synovial membrane was a critical aspect of this systemic influence. Obesity caused a chronic state of inflammation within the synovium, worsening joint damage and OA progression. This inflammation was characterised by an infiltration of macrophages, T cells, and B cells, contributing to the local inflammatory environment (Nedunchezhiyan *et al.*, 2022).

Biomechanical stress physically damaged joint structures and triggered local inflammatory responses. Chondrocytes, the primary cells in cartilage, respond to mechanical stress by producing inflammatory mediators and catabolic enzymes, perpetuating a cycle of cartilage degradation and inflammation. Studies highlighted the role of mechanoreceptors on chondrocytes, which when activated by excessive mechanical load, initiated intracellular signalling pathways leading to increased production of inflammatory cytokines and MMPs (Sowers and Karvonen-Gutierrez, 2010; Wang *et al.*, 2015).

Moreover, the infrapatellar fat pad (IFP), an intra-articular adipose depot, emerged as a significant local source of inflammatory mediators in the knee joint. The IFP secreted adipokines and cytokines that contributed to local inflammation and cartilage degradation. Research indicated that the IFP in obese individuals exhibited a pro-inflammatory phenotype, with increased secretion of mediators such as IL-6 and leptin, further exacerbating local joint inflammation and OA progression (Klein-Wieringa *et al.*, 2011; Warmink *et al.*, 2020).

The anatomical configuration of the knee, relying heavily on the surrounding capsule, ligaments and tissues for stability, meant that any damage to these structures due to obesity-induced mechanical stress could lead to abnormal joint loading and further KOA progression (Shumnalieva, Kotov and Monov, 2023). Furthermore, obesity was associated with changes in gait and increased thigh circumference, which altered knee joint mechanics

and exacerbated medial compartment loading, leading to more severe KOA symptoms (Chen *et al.*, 2020).

Integrated Perspective: The interplay between systemic and local factors in obesity-related KOA underscored the complexity of the disease. Systemic inflammation driven by adipose tissue-derived cytokines created a pro-inflammatory environment that predisposed joints to OA. Concurrently, local mechanical loading and inflammation within the knee joint directly contributed to cartilage degradation. This dual pathway highlighted the need for comprehensive management strategies addressing weight reduction to decrease mechanical load and targeted therapies to mitigate systemic and local inflammation.

The chronic inflammatory condition caused by adipokines and cytokines from adipose tissue, combined with the increased mechanical load on the knee joint, created a harmful cycle of cartilage destruction and inflammation. Understanding these pathways provided insight into potential therapeutic targets and underscored the importance of integrated treatment approaches for obese individuals with KOA.

Occupational Factors and KOA Development: Physically demanding jobs, particularly those necessitating kneeling, such as squatting, climbing, and lifting, contributed to KOA onset (Yucesoy *et al.*, 2015; Vignon *et al.*, 2006; Palmer, 2012). Subjects whose jobs involved these activities faced almost double the risk of KOA compared to those without such demands. This risk was further heightened in overweight individuals whose employment involved both lifting and these activities (Parsons *et al.*, 2020).

Occupations that placed undue stress on knees, such as floor layers (e.g., asphalt, sheet metal, rock), plumbers, and bricklayers, had increased chances of KOA surgery by almost five times (Jensen, 2005; Järvholm *et al.*, 2008). Military roles, with their rigorous physical demands, also heightened OA susceptibility resulting in a notably higher KOA prevalence among military personnel compared to the general population (Larcom *et al.*, 2015). In the Williams study, from 2016 to 2020, (38.8%) of all incident KOA diagnoses, and in the Showery study, from 2005 to 2014, primary KOA adjusted IR increased

by 45%, and secondary KOA adjusted IR increased by 100% (Showery *et al.*, 2016; Williams, Clark & Oh, 2016).

Several studies have investigated the link between occupational heavy lifting and KOA progression. Cumulative exposure to lifting and carrying had been identified as a significant KOA risk (Canetti *et al.*, 2020). Nonetheless, Jensen (2008) reported lift loads ranging from >10 kg to >50 kg, with evidence suggesting a link between heavy lifting and KOA progression (OR heavy lift/no heavy lift, 1.9-7.31). This elevated risk was evident in 9 of 17 trials. Fransen *et al.* (2011) built on Jensen's (2008) analysis, incorporating eight more studies that showed a relationship between heavy carrying and KOA progression (OR heavy lift/no heavy lift, 1.4-5.0), though the details of lift frequency and duration weren't specified.

Furthermore, Palmer, (2012) indicated that occupational lifting was a potential KOA factor, with eight out of 14 studies showing risk ratios exceeding 1.5 when comparing exposed to non-exposed workers. Also, McMillan and Nichols (2005) determined that the combination of heavy lifting and activities like continuous knee bending and squatting increased KOA risk more than knee bending alone. Supporting this, Palmer *et al.*, (2012) highlighted that the risk of KOA increased three to eight fold when lifting was combined with activities like kneeling or squatting.

In terms of activity, research has indicated climbing stairs as a KOA risk factor, with a notable risk when walking constituted a significant portion of one's job or exceeded 3 kms daily (Canetti *et al.*, 2020). Though Jensen's 2008 review had offered limited evidence linking stair climbing at work with KOA, subsequent reviews had similarly pinpointed the minimal risk association between stair climbing and KOA progression (Jensen, 2008; Fransen *et al.*, 2011; Ezzat and Li 2014).

In conclusion, mitigation of occupational risks, such as reducing kneeling or squatting exposure, could have prevented half of severe KOA instances (Järvholm *et al.*, 2008). Given these findings, there has been an emerging consensus on the need for occupation-specific research and the development of preventive measures (Kim *et al.*, 2010; Showery *et al.*, 2016).

Physical Activity and post injury: post-trauma OA was often associated with anterior cruciate ligament (ACL) injuries (Luc *et al.*, 2014), and traumatic degenerative meniscal lesions elevated the risk of KOA (Englund *et al.*, 2003). Those with either ACL or meniscal injuries faced heightened KOA risks (Oiestad *et al.*, 2013; van Meer *et al.*, 2015).

Recent years saw increased examine of ACL and meniscal injuries, major sports-related culprits, and their connection to KOA. A systematic review by Poulsen *et al.*, (2019) evaluated 53 studies encompassing ACL injury, meniscal damage, and a combination of both. A knee with combined ACL and meniscal damage was 6.4 times more likely to develop KOA. The findings emphasized that an ACL injury by itself quadrupled the KOA risk relative to a healthy knee, and this risk jumped six-fold when a meniscus was damaged, either stand-alone or alongside an ACL injury.

While many therapeutic methods prioritized athletes' return to sports, they often overlooked long-term joint health and KOA mitigation (Pietrosimone, 2020). Knee joint health was adversely affected by ACL injuries. Roughly a third of those with ACL lesions manifested radiographic PTOA within ten years, regardless of undergoing ACL reconstruction. Moreover, post-reconstruction, PTOA affected around 50% of patients (Luc *et al.*, 2014).

A study by Foreman *et al.*, (2019) tracking accelerated KOA across 162 knees from 149 individuals noted that, initially, 25% had notable meniscal injuries. This proportion rose to 64% in two years and reached 93% by the fourth year. Meniscal extrusion incidences evolved from 18% initially to 45% in two years and a stark 94% by the fourth year, affirming the influential role of meniscal lesions in KOA's progression.

Prior injuries significantly impacted KOA. Therefore, understanding KOA treatment post-ACL injury or meniscal damage/surgery was essential. A study by Pietrosimone *et al.*, (2017) surveyed 437 athletes: 84.7% accurately defined KOA, and 60.3% recognized post-traumatic osteoarthritis. Most athletes identified complete meniscectomy (98.9%) and meniscal tear (95.4%) as conditions increasing KOA risk, followed by ACL lesion (90.2%) and partial

meniscectomy (90.1%). Despite 84.7% accurately defining KOA, only 60.3% were familiar with PTOA.

Moreover, **muscle weakness** was linked to OA development and progression, impairing the ability to regulate joint motions (Segal *et al.*, 2010; Mikesky *et al.*, 2000). It emerged as an early symptom in OA individuals and predicted impairment more than joint narrowing or pain (McAlindon *et al.*, 1993; Palmieri-Smith *et al.*, 2010). In a study by Hootman *et al.*, (2004) women with stronger quadriceps experienced a significantly lower incidence (50% to 64%) of KOA. Another study found a functional quadriceps test (quadriceps functional test) predicted radiographic KOA development after a five-year follow-up (Thorstensson *et al.*, 2004).

However, after adjusting for various variables (age, bone mineral density, BMI, physical activity, injuries and surgery), research showed no advantage to quadriceps strength in individuals with KOA risk factors (Segal *et al.*, 2009). A systematic review by Oiestad *et al.*, (2013) found that knee extensor muscle weakness increased the risk of symptomatic KOA. Additionally, knee laxity, a potential KOA risk factor, that is, the loss of cartilage and/or bone erosion, which may present as pseudo-laxity, decreasing the space between ligament attachment sites (Rudolph, Schmitt and Lewek, 2007), chronic capsuloligamentous tension, or a combination of muscular, ligamentous, meniscal, and capsular pathologies. Thus, KOA patients have higher varus-valgus knee laxity than healthy individuals (Sharma *et al.*, 1999).

- *Muscles impact on KOA progression:*

The relationship between quadriceps strength in KOA patients and structural progression remained uncertain. Comprehensive studies did not find protection against KOA progression from stronger quadriceps after adjusting for various factors (age, BMI, sex, physical activity, and KOA severity) (Sharma *et al.*, 2003; Amin *et al.*, 2009). In a randomised controlled study, a 12-week quadriceps strengthening regimen did not change the knee loading (KAM) during walking (Lim *et al.*, 2008). Only a few trials explored the effect of leg strengthening on radiographic KOA progression (Mikesky *et al.*, 2000; Messier

et al., 2005). However, one study noted a potential positive effect (Mikesky *et al.*, 2006).

- *Muscle strength impact with other categories:*

Y. Kim *et al.*, (2018) studied 40 females to understand the link between quadriceps weakness and balance in painful KOA patients. The findings showed that weaker quadriceps were connected to reduced balance in those with more painful KOA. On the other hand, a study indicated that quadriceps strength had a complex relationship with vitamin D and KOA pain. Research on 92 patients found a positive correlation between quadriceps and vitamin D levels and a negative association with knee pain, suggesting that vitamin D might alleviate KOA pain by enhancing quadriceps strength (Javadian *et al.*, 2017).

2.7 Symptoms of KOA:

- **Pain:**

Pain often leads to medical consultations (McAlindon *et al.*, 1993; Dominick *et al.*, 2004; Ayis and Dieppe, 2009). The International Association for the Study of Pain defines it as an unpleasant experience linked to tissue damage (Merskey, 2014). This definition highlights pain's complexity, which is not merely a direct stimulus-response but involves sensory, behavioural, and emotional components (Hudspith, 2019).

The central nervous system's (CNS) primary role is to convey threat information using nociceptors. Nociceptors relay pain perceptions from harmful stimuli to the brain (McMahon *et al.*, 2013). The nociceptive fibres are believed to respond to noxious stimuli in response to acute pain, which is generally characterized by sudden and severe pain perception. During acute pain, potentiation would encourage rest, avoiding further tissue damage (Woolf, 2010). Conversely, chronic pain often lingers after an injury has healed (Ready and Edwards, 1992; Woolf, 2011).

Moreover, as described by Woolf (2010), acute pain requires strategies to minimise tissue damage, while chronic pain, as noted by Woolf, (2011),

necessitates approaches targeting central sensitisation. Both studies suggested therapeutic interventions but did not extensively discuss the practical challenges in clinical implementation.

For instance, the lack of a standardised methodology for assessing and classifying OA pain complicated the establishment of universally applicable treatment guidelines. Factors contributing to this complexity included individual variability in pain experience, influenced by physiological elements such as inflammation and central sensitisation, psychological factors such as depression and anxiety, and demographic factors including age, sex, and comorbidities. Additionally, subjective assessment and the placebo effect contributed to observed heterogeneity in clinical study outcomes, posing a challenge for healthcare practitioners in assessing and classifying OA pain (Sethi, Anand and Della Pasqua, 2024).

A holistic assessment of demographic, psychological, and physiological factors was needed. Future research should highlight the need for personalised patient categorisation and refined methodologies in clinical studies to address the observed heterogeneity in outcomes.

Genetic factors influence the central nervous system's (CNS) transmission and interpretation of pain signals. These factors either enhance or diminish pain sensitivity signals. Genetic factors impacting the body's ability to produce hormones like adrenaline affected neuron survival and the potency of nociceptive responses (Institute of Medicine, 2011).

Although there was evidence that genetic influences on hormones like adrenaline impacted neuron survival and nociceptive responses, there was growing evidence for genetic contributions to pain sensitivity, the relationships were complex and not yet fully elucidated (Dydyk and Givler, 2020).

The response to different types of pain, be it emotional, physical, or cognitive, are typically developed during childhood. Hence, an adult's pain management largely stems from these early experiences. Research has indicated that children with unhealthy responses to chronic pain are more inclined to require chronic pain treatment as adults (Walker *et al.*, 1995; Macfarlane, 2010). These observations have suggested that prolonged

adjustments to stress could harm various body tissues and systems (Institute of Medicine, 2011).

Contemporary biopsychosocial models emphasise that pain arises from dynamic interactions between biological, psychological and social factors across the lifespan (Tidmarsh *et al.*, 2022). Childhood adversity was a significant risk factor for chronic pain in adulthood, but it did not predetermine an unavoidable outcome. Many individuals with adverse childhood experiences did not develop chronic pain, while some without significant early life stressors did.

The statement that prolonged adjustments to stress could harm various body tissues and systems was vague and lacked nuance. While chronic stress could have detrimental health impacts, the body's stress response evolved to promote survival and could have protective effects in specific contexts (Victoria *et al.*, 2016). Stress was not universally harmful; the duration, timing, and type of stressor all influenced whether its effects were harmful or beneficial.

This underscored the need for a comprehensive approach to treatment that considered genetic, psychosocial, and social-environmental factors shaping pain responses. Integrating genetic and psychosocial research offered a promising avenue for advancing the understanding of pain management. This integration was crucial for ensuring that pain management strategies were effective and accessible.

- KOA Pain Origin:

According to Hunter *et al.*, (2013) and NICE (2014), the mechanism underlying KOA pain remains unclear. The cartilage in the knee lacks blood supply and nerves, preventing pain production. However, synovium, subchondral bone, joint capsules, and ligaments, rich in pain receptors, are primary pain sources (Dieppe and Lohmander, 2005; Felson, 2005).

Despite research efforts, the understanding of OA pain mechanisms remained incomplete. Also, the lack of innervation in articular cartilage and the potential role of surrounding joint tissues in pain generation failed to capture the complex interplay between peripheral and central mechanisms that

contributed to the OA pain experience (Robbins and McDougall, 2018; Hu *et al.*, 2021).

MRI studies (Hill *et al.*, 2001; Torres *et al.*, 2006; Roemer *et al.*, 2009) have linked KOA pain to subchondral bone changes and synovitis. While MRI studies had associated KOA pain with subchondral bone changes and synovitis, the causal relationship between these structural abnormalities and pain remained unclear (Vincent, 2020). Acknowledging the limitations of current imaging techniques in capturing the complex pathophysiology of KOA pain benefited the study.

Future research should aim to explain the relative contributions of peripheral and central mechanisms in OA pain and investigate the relationship between structural joint changes and pain onset. A better understanding of these mechanisms would lead to more targeted and effective pain management strategies for individuals with KOA.

Moreover, mechanical components are major pain sources in KOA patients (Trouvin and Perrot, 2018). Knee pain correlates modestly with KOA radiological severity (Dieppe and Lohmander, 2005; Schiphof *et al.*, 2014). Influences on this correlation include therapies, expectations, moods, and coping (Villemure, Slotnick and Bushnell, 2003; Wager, 2005; Colloca and Benedetti, 2006).

The relationship between KOA pain and radiological severity remained complex and multifaceted. While mechanical factors undoubtedly contributed to pain in knee OA patients, the modest correlation between pain and radiographic findings suggested a more nuanced interplay of patients' variable (age, sex, weight, height, and BMI), functional (stiffness and limitations) scores and KOA severity (Heidari, 2011; Steenkamp *et al.*, 2022).

While mechanical factors influenced KOA pain, the modest correlation with radiological severity highlighted the varied nature of the pain experience. Recognising this complexity was vital in creating more effective, patient-centred strategies to manage this common and devastating condition.

Also, reduced joint proprioception contributes to pain and functional restrictions (Felson *et al.*, 2009). As a result of the release of inflammatory

substances, the area surrounding the affected tissue becomes more sensitive, a condition known as hyperalgesia (primary sensitisation). As a result of repeated depolarisation of the primary afferent, neurotransmitters are released persistently, effectively resulting in central sensitisation (Merskey and Bogduk, 1994; Sowers *et al.*, 2003).

Felson *et al.* (2009) found that reduced joint proprioception in OA patients led to pain and functional problems. This, along with the release of inflammatory chemicals, caused sensitisation and increased pain sensitivity in the affected tissue. Continuous nociceptive signals from the sensitised joint cause central sensitisation, a process where pain processing in the central nervous system is heightened (Arendt-Nielsen *et al.*, 2018).

The complex relationship between local inflammation and central sensitisation questioned the idea that addressing local inflammation alone could effectively manage KOA pain. Future research and treatment strategies should focus on both peripheral pain sources and central sensitisation processes.

Moreover, knee pain and joint pathology are misaligned due to central sensitisation. Akin-Akinyosoye *et al.*, (2021) derived a Central Pain mechanism feature from eight distinct factors: neuropathic-like pain, fatigue, cognitive impact, catastrophizing, anxiety, sleep disturbance, depression and pain distribution. They validated the Central Aspects of Pain in the Knee (CAP-Knee), in an 8-item questionnaire. This tool served as a concise and accurate self-report method and corresponded with sensory and affective facets of knee pain severity. The CAP-Knee precisely gauged a singular 'Central Mechanisms' trait, aiming to pinpoint and apply centrally directed treatments for knee pain relief.

However, the relative contributions and interactions among these factors remained unclear. Although this approach improved the understanding of central sensitisation in KOA, applying it to targeted therapies presented challenges. The widespread and systemic nature of central sensitisation made the development of precise treatments complex (Ohashi *et al.*, 2023).

Comprehensive, multimodal interventions addressing both neurobiological and biopsychosocial aspects were likely necessary.

Future research is needed to clarify the mechanisms by which the various features of central sensitisation developed and interacted. Longitudinal studies exploring causal relationships could help with early identification and prevention strategies.

- **KOA Pain Measurement:**

Pain in KOA studies are typically assessed using the numeric rating scale (NRPS), visual analogue scale (VAS), or subscales like the Knee Injury and Osteoarthritis Outcome Score (KOOS) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC). These methods gauge pain over a set period of time or during specific activities such as walking or using stairs (Neogi, 2013). Quantitative sensory testing (QST) has recently been employed (Trouvin and Perrot, 2018).

Several QST studies have identified neurogenic responses in osteoarthritis pain (Kosek and Ordeberg, 2000; Imamura *et al.*, 2008; Arendt-Nielsen *et al.*, 2010). People with OA often show altered pain modulation (Lundblad *et al.*, 2012). QST evaluates the nervous system's response to stimuli, pinpointing somatosensory impairments on both the afflicted and distal side (Arendt-Nielsen and Yarnitsky, 2009). Graven-Nielsen and Arendt-Nielsen, (2002) described pain on the affected side indicates local sensitisation, while pain in the distant area suggests a combination of central and local sensitisation.

However, the extent to which central versus peripheral mechanisms drive osteoarthritis pain remains unclear. Graven-Nielsen and Arendt-Nielsen, (2002) suggested that pain localised to the affected joint indicates local sensitisation, while distant pain reflects central sensitisation. Although this idea is helpful, it may need to be more balanced with the complex interplay between peripheral and central factors (Izumi *et al.*, 2022).

Moreover, the diagnostic utility of QST was limited by its reliance on subjective responses and the lack of standardised protocols. Objective biomarkers were needed to distinguish between peripheral and central

contributions to an individual's pain experience. Longitudinal studies examining QST with neurogenic responses could reveal how these mechanisms evolved during KOA.

- **Limited physical function:**

Physical impairments linked to KOA represent a significant concern, influencing a spectrum of activities ranging from basic, such as getting up from a chair, to more complex ones, such as ascending stairs or maintaining balance (Nelson and Jordan, 2017; McAlindon *et al.*, (2014). The progression of KOA often amplifies these difficulties, reflecting a diminished physical function (Pisters *et al.*, 2012). Key institutions, including OARSI (Osteo-Arthritis Research Society International), OMERACT (Outcome Measures in Rheumatology Group) and GREES (Group for the Respect of Ethics and Excellence in Science), emphasize evaluating functional impairment to assessing OA's symptomatic severity (Colbert *et al.*, 2012).

Generally, the first physical limitations indicated are a reduced capacity to fulfil personal, social, or professional obligations. Recognising factors linked to the decline in physical function helped in devising strategies to halt, and reverse, such impairments (Colbert *et al.*, 2012). Research demonstrated that elements such as: age, gender, knee pain, BMI, varus-valgus laxity, malalignment, comorbid medical conditions, depressive symptoms and proprioceptive accuracy were all correlated with a pronounced decrease in functionality among those with KOA (Rejeski *et al.*, 2001; Sharma *et al.*, 2001, 2003; Dunlop *et al.*, 2005, 2011; van Dijk *et al.*, 2010).

While these correlations were well-known, more detailed research was needed to grasp the causal relationships and interplay between these factors. For example, although age and BMI were consistently linked with functional decline, their interactions with psychological factors such as depression and anxiety needed further investigation.

- ***Assessing Physical Function:***

The literature highlights the WOMAC score (Bellamy *et al.*, 1988) as a primary subjective KOA measure. Developed for knee or hip osteoarthritis patients, WOMAC's ties to general health are well-documented (Bombardier

et al., 1995; Escobar *et al.*, 2007a; Xie *et al.*, 2010). Despite variations in WOMAC's editions, it remains a credible, consistent scale (Bellamy *et al.*, 1988; Jinks, Jordan and Croft, 2002; Chesworth *et al.*, 2008). Further, using the Likert scale, the WOMAC scores consist of 17 function-related questions, two on stiffness and five on pain. Despite critics, its pain subscale is among the most employed in OA assessments (Creamer, Lethbridge-Cejku and Hochberg, 1999; Jinks, Jordan and Croft, 2002; Stratford *et al.*, 2007).

The reliance on self-reported data introduced variability and potential bias, limiting the score's objectivity. Furthermore, variations in WOMAC editions and translations affected consistency across different populations and studies (Escobar *et al.*, 2007b). These issues highlighted the need for ongoing refinement to improve the precision and cross-cultural applicability of the WOMAC index.

The future of KOA outcome measures should focus on combining patient-reported outcomes with objective clinical data. This combination could have provided a more complete and accurate understanding of patient experiences, ultimately guiding better clinical interventions and personalised treatment plans.

The Oxford knee score (OKs), formulated in the early 1990s, evaluates knee arthroplasty pre- and post-surgery. Widely used in countries like the UK, New Zealand, and Australia, its 12 questions prioritise physical function (Dawson *et al.*, 1998). Notably, the score cannot be separated into the pain and physical function domains, validated tool (Dawson *et al.*, 1998; Garratt, Brealey and Gillespie, 2004; Whitehouse *et al.*, 2005; Conaghan, Emerton and Tennant, 2007). Furthermore, it is a popular tool that is relatively easy to use.

However, its psychometric properties and clinical usefulness required examination. While the OKS showed good reliability and validity, its ability to detect changes was questioned, particularly in identifying subtle differences after surgery (Luger *et al.*, 2023). Additionally, the OKs focus on physical function and its inability to separate pain and function subscales reduced its effectiveness in capturing the multifaceted impact of knee osteoarthritis. The

Oks lacked the range and detail necessary to address many musculoskeletal disorders' complex and interconnected nature (Whitehouse *et al.*, 2005).

Therefore, this indicated a need for developing more thorough assessment tools to clearly define various outcome domains and cover broader aspects of patient well-being.

Additionally, KOOS scores, which expand on the WOMAC approach, (Bellamy *et al.*, 1988; Roos, Roos and Lohmander, 1999) are prevalent for evaluating knee injury osteoarthritis effects. It covers the broad spectrum of primary OA impact and possible secondary OA damage (Roos and Lohmander, 2003). The KOOS evaluates pain, symptoms, ADL function, sports function, and knee-related quality of life (Roos *et al.*, 1998).

KOOS showed ceiling effects in the sport and recreation subscale for older patients with advanced osteoarthritis who were less active. This limited its sensitivity in detecting treatment effects within this group. Additionally, the extensive 42-item format of the KOOS created a burden for respondents, mainly when used with other outcome measures. Streamlined versions, such as the KOOS-PS, were developed to enhance efficiency, although they needed further validation (Roos and Lohmander, 2003).

Despite these issues, the KOOS remained a widely used and validated knee-specific outcome measure. Its various subscales provided a thorough assessment of patient-relevant areas.

Regarding physical performance, several tests measure function severity. The OARSI recommends the 30-second Chair Stand Test (30s-CST), the Stair Climb Test (SCT), and the 40-metre Fast Paced Walk Test (FPWT) (Dobson *et al.*, 2013). The 30s-CST, assessing the challenge of transitioning from sitting to standing, particularly reveals OA patient performance (Nakatani *et al.*, 2002). Research has also shown a correlation between the 30s-CST and reduced knee extensor energy (Anan *et al.*, 2015).

However, reliance on these tests may have underestimated the nature of OA, potentially overlooking other critical aspects such as pain level, joint

stability, biomechanical factors and patient-reported outcomes. Future research should prioritise validating physical performance tests across all OA severities, exploring their biomechanical basis and expecting value. To enhance the comprehensiveness of KOA assessment, integrating these physical performance tests with subjective measures and biomechanical analyses could offer a better understanding.

- **Poor Balance:**

Sturnieks, (2021) defines balance as the capability to manage one's centre of gravity within one's support base. It involves processing sensory inputs from the vestibular, visual and proprioceptive systems via the cerebellum (Neptune and Vistamehr, 2019). Reduced balance is linked to limited mobility and higher fall risk among elderly (Muir *et al.*, 2010; Dionyssiotis, 2012) and younger populations (Verma *et al.*, 2016). Even although there was no correlation between poor balance and KOA (Jadelis *et al.*, 2001), it is essential to evaluate for balance impairment whenever a new intervention is introduced due to the increased risk of falls and disability in older people (Dionyssiotis, 2012; Kramarow, 2015).

- **Assessing Balance with KOA subjects:**

Balance can be statically or dynamically evaluated. A static balance refers to the position of the body about a fixed support base, while a dynamic balance refers to the position of the body about an unstable support base (Wegener, Kisner and Nichols, 1997; Huxham, Goldie and Patla, 2001; Hinman *et al.*, 2002; Shumway-Cook and Woollacott, 2007). However, dynamic evaluations, more reflective of physical activity demands, are more valuable than static ones (Gribble, Hertel and Plisky, 2012).

This highlighted the importance of incorporating dynamic balance assessments and targeted interventions in managing KOA. Despite this, there was still a reliance on static balance evaluations within clinical settings, partly due to the simplicity and ease of administering static balance tests (Hinman *et al.*, 2002; Karlinsky *et al.*, 2022). However, this approach provided an incomplete picture of a patient's functional status and potential fall risk.

Dynamic balance evaluations, provided greater insight into the proprioceptive and neuromuscular challenges faced by KOA patients (Gauchard *et al.*, 2010; Al-Khlaifat *et al.*, 2016). These evaluations were crucial for developing specific rehabilitation strategies that addressed stability and mobility, aiming to reduce fall risk and enhance overall quality of life. Further research was needed to determine the optimal balance type, frequency, and duration of balance training for KOA patients across different stages of the disease.

Factors like proprioceptive dysfunction, muscular weakness and ageing may contribute to balance issues (Stevens *et al.*, 2008; Tucker *et al.*, 2008; Lin *et al.*, 2009; Muir *et al.*, 2010; Kim *et al.*, 2018). Regarding KOA subjects, the balance has been gauged using complex (force platforms) and simple (step test) means (Hinman *et al.*, 2002; B. Lim *et al.*, 2008). The step test involves an individual quickly stepping on a 15 cm height for 15 seconds. KOA patients typically take fewer steps than healthy individuals (Hinman *et al.*, 2002). However, this test is limited in examining dynamic balance. Firstly, it examines dynamic balance in only one direction (anterior); secondly, it ignores the standing base-to-step distance, which may influence balance. Therefore, it is recommended to use different methods for measuring dynamic balance.

In addition, the Star Excursion Balancing Test (SEBT) is another affordable balance assessment method. In the SEBT, an individual reaches out with one leg in eight directions while standing on the other (Gribble, Hertel and Plisky, 2012). The test's conclusion is based on the distance reached (Olmsted *et al.*, 2002). The SEBT might be challenging for KOA patients due to age and balance issues. It provides a more comprehensive neuromuscular assessment than the step test. However, its exhaustive nature can be a limitation (Robinson and Gribble, 2008; Munro and Herrington, 2010). Therefore, selecting specific directions for evaluation, like medial, posteromedial, and anteromedial, can be effective for KOA patients (Hertel *et al.*, 2006).

Another tool is the Timed Up and Go test (TUGT), a functional assessment where a person stands, walks three metres, and returns to sit (Alghadir, Anwer and Brismée, 2015; Chan *et al.*, 2017). A shorter time

indicates better functionality, with a score under 13.5 seconds suggesting a fall risk (Khalaj, Noor Azuan Abu Osman, *et al.*, 2014).

TUGT offered a quick and practical measure of physical function. However, its reliability and sensitivity in detecting significant changes in the KOA population remained uncertain (Alghadir, Anwer and Brismée, 2015; Marconcin *et al.*, 2015). The straightforward nature of the TUGT did not capture the complex and varied nature of functional impairments associated with KOA (Svinøy *et al.*, 2020). Moreover, the single cut-off score of 13.5 seconds for fall risk was not universally applicable, as factors like age and disease severity affected performance (J. Wang, Chen, Sun, *et al.*, 2021).

Future research needed to take a more integrated approach, combining the TUGT with additional biomechanical assessments to better understand balance issues in KOA patients. This combination could have improved predictive accuracy and personalised care strategies.

- Other Symptoms:

Several symptoms are commonly associated with KOA. Patients often report stiffness, as EULAR studies indicate (Weibo Zhang *et al.*, 2010; Reichenbach *et al.*, 2011).

Stiffness was a key symptom of OA, but the duration and timing of stiffness helped distinguish OA from other conditions like inflammatory arthritis. In inflammatory arthritis, morning stiffness often lasted over 30 minutes, while in OA, stiffness usually eased within a few minutes (Bijlsma, Berenbaum and Lafeber, 2011). However, OA stiffness might recur during the day after periods of inactivity. Some people noted that their symptoms fluctuated with weather changes, reporting increased joint pain and stiffness in cold, humid or low-pressure conditions (Dorleijn *et al.*, 2014).

Understanding how weather affects symptoms led to better treatment strategies. Additionally, looking into tailored treatment plans based on personal symptoms and environmental factors enhanced patient outcomes and quality of life.

Additional symptoms may include localised inflammation, effusion and crepitus in the knee joint, particularly in the elderly (Neogi *et al.*, 2016; Pazzinatto *et al.*, 2019). Localised inflammation and effusion were common in various knee disorders. However, their presence alone did not confirm KOA, nor did the severity of effusion always match the radiographic severity of KOA.

Synovial fluid effusion and synovitis indicated partial inflammation within the knee joint and were often found in patients with symptomatic and radiographic KOA. However, synovial inflammation was not limited to KOA and could be present in other joint diseases (Cao, Tang and Ding, 2021). While effusion and synovitis were frequent signs in symptomatic KOA, they could also occur in other knee joint disorders (e.g. rheumatoid). Therefore, their presence was not a definitive indicator of KOA, and the severity of effusion did not always align with the severity of KOA changes seen on imaging, such as X-rays.

Additionally, the assessment of synovitis and effusion using non-enhanced and enhanced MRI sequences showed that both methods correlated well with joint volume measurements but might not fully capture the extent of inflammation (Loeuille *et al.*, 2011). Thus, advancements in biomarkers and imaging techniques were needed to improve the accuracy and consistency of inflammation assessment in KOA.

Crepitus, a crackling or grinding sensation in the knee, was often found in KOA and was helpful in diagnosis when linked with pain. Research showed that crepitus, pain and other symptoms improved diagnostic accuracy for KOA. It matched with structural knee issues seen in MRI, especially in the patellofemoral joint (Crema *et al.*, 2011). Although crepitus was linked with the progression of KOA and structural damage, it remained unclear whether it reflected an overall poor clinical condition, including lower function, decreased strength, reduced quality of life, and higher levels of pain (Briani *et al.*, 2017). Therefore, crepitus, persistent pain and limited movement greatly increased the chances of diagnosing radiographic KOA (Zhang *et al.*, 2010).

Future research should clarify the relationship between knee crepitus and the overall clinical presentation of knee OA, particularly regarding pain and

function. Furthermore, developing more precise diagnostic criteria and imaging techniques that included crepitus and other clinical signs could enhance KOA's early detection and management.

Joint dysfunction, swelling, muscular issues, and fatigue often manifest alongside pain (Hunter *et al.*, 2009). The clinical assessment of knee swelling in OA diagnostics often proved imprecise. Physical examinations such as the bulge sign and patellar tap were used, but their accuracy varied, especially in the early stages of OA (Berlinberg *et al.*, 2019). As a result, imaging techniques were often relied upon despite not always being easily accessible or cost-effective.

Moreover, muscular dysfunction is a significant symptom of KOA that is frequently overlooked in diagnosis. Research showed that muscular atrophy, particularly in the quadriceps, was common among KOA patients and contributed to functional decline (Fink *et al.*, 2007). However, routine clinical assessments usually concentrate on joint-specific symptoms without considering muscle health and strength.

Fatigue is another often reported yet underdiagnosed symptom of KOA that greatly affects patients' quality of life. Its fluctuating nature made it difficult to measure and effectively include in a diagnostic framework (Heijman *et al.*, 2022). Traditional diagnostic tools often miss the variability and intensity of fatigue, underscoring the need for more comprehensive patient-reported outcome measures.

2.8 Impacts of KOA:

- Economic Impact:

Knee osteoarthritis (KOA) inflicts substantial economic burdens in high-income nations. KOA's expenses, primarily from knee and hip joint replacements, surpass USD 89.1 billion/year (Vos *et al.*, 2016; Carlson *et al.*, 2019). Europe's annual costs fluctuate between EUR 408–817 billion for total costs, with direct costs ranging from EUR 350–700 billion (Salmon *et al.*, 2016). To manage this economic strain, it is imperative to identify at risk individuals,

thereby ensuring efficient healthcare resource allocation and offering focused public health interventions (Hunter *et al.*, 2014).

- Biopsychosocial Impact:

The pain from KOA manifests primarily in two forms: severe, intermittent pain and a more consistent aching (Hawker *et al.*, 2008). This pain is best understood through a biopsychosocial lens, highlighting the interplay between biological factors, psychological states and social contexts (Dieppe and Lohmander, 2005; Hunter *et al.*, 2009). Factors like self-efficacy, pain perception and social support can affect an individual's experience of pain and resulting functional limitations. Over time, constant KOA discomfort can severely limit mobility and activity (Wilkie *et al.*, 2007), as well as impacting on overall well-being, mood, tiredness and sleep (Hawker, 2009).

- Quality of Life Impact:

Understanding OA's influence on quality of life is pivotal. Losina *et al.*, (2011) found that those aged 50–84 with KOA encountered notable losses in quality-adjusted life years, on a par with other severe ailments like cardiovascular diseases and cancers. In 2010, musculoskeletal diseases ranked second globally in years lived with disabilities (YLDs), with KOA featuring prominently (Murray *et al.*, 2012).

- Physical Impacts:

Osteoarthritis is a leading global disability cause (Vos *et al.*, 2012). Between 1990 and 2019, the global population affected by osteoarthritis rose by 48%, and it was identified as the 15th leading YLDs cause, representing 2% of all YLDs based on Global Burden of Disease (GBD) data (GBD 2015 Disease and Injury Incidence and Prevalence Collaborators, 2016).

The majority of those with KOA experience disability because of its high prevalence and the associated impairment it brings (CDC, 2007). The GBD study states that KOA represents 83% of all OA cases (Murray *et al.*, 2012; Vos *et al.*, 2012). Regarding functional ability, 25% are entirely restricted, 11% require personal care assistance and 14% need help with routine activities (Guccione *et al.*, 1994). In middle-aged arthritis patients, Covinsky *et al.*,

(2008) observed a greater likelihood of difficulty with mobility and activities of daily living (ADL) (34% with significant arthritis versus 18% without significant arthritis).

Furthermore, Fautrel *et al.*, (2005) indicated that over 80% of KOA patients faced daily life activity challenges, and another study stated that 20% felt incapacitated due to their KOA (Gooberman-Hill *et al.*, 2009). Nearly 50% of symptomatic KOA patients rely on walking aids like canes, walking frames and orthopaedic footwear. However, less than half of these aids were prescribed, leading to potential misuse and associated risks (Van *et al.*, 2003). Given the significant accident risk linked to walking aids and impaired gait, those using these aids must receive appropriate guidance from professionals like physiotherapists (Deandrea *et al.*, 2010).

2.9 Diagnosis:

Diagnosis was made subjectively based on clinical symptoms like pain, morning stiffening [<30 minutes], age [>40 years], joint enlargement and crepitus (Zhang and Jordan, 2010) or objectively via radiological findings such as cartilage erosion, osteophytes and joint narrowing (Figure 4 & 5). The American College of Rheumatology's (ACR) standards were frequently applied for diagnosis, factoring in osteophyte presence, knee pain severity, age (> 50 years) and morning stiffness (<30 minutes) (Altman *et al.*, 1986).

Furthermore, recognising and diagnosing KOA early was crucial for effective management and improved patient outcomes. Early diagnosis could be facilitated by following the European League against Rheumatism (EULAR) recommendations and utilising clinical signs (e.g., persistent knee pain, morning stiffness, crepitus, joint enlargement), physical activity tests (e.g., range of motion test, gait analysis, functional tests like the timed up-and-go test, and strength tests), biochemical results (e.g., synovial fluid analysis, biomarkers) and MRI biomarkers (Zhang *et al.*, 2010).

While early diagnosis was advocated for better outcomes, there was still a lack of consensus on the specific criteria for what constituted "early" KOA. Variability in clinical signs and the reliance on advanced imaging techniques,

which might not be readily available in all clinical settings, posed significant challenges (Madry *et al.*, 2016). Moreover, further evaluation was necessary to ensure the accessibility and practicality of these early diagnostic measures for overall use (Mahmoudian *et al.*, 2021).

Radiographically, the KOA severity criteria by Kellgren and Lawrence, (1957), were extensively used (Figure 6). Adhering to recognised diagnostic criteria, as proposed by the ACR and the EULAR, ensured a standardised and accurate approach to diagnosing KOA (Altman *et al.*, 1986; Zhang *et al.*, 2010). Lastly, symptoms, physical tests like joint effusion, motion range assessment, surrounding joint tissue evaluation and laboratory tests determined KOA diagnosis. More observed characteristics increased diagnostic likelihood (Lespasio *et al.*, 2017).

Despite the ACR and EULAR criteria being mainly based on clinical and radiographic findings, they might not have captured early structural changes detectable by MRI or ultrasound (Favero *et al.*, 2015). This highlighted a gap in the diagnostic approach, where advancements in imaging techniques were not fully integrated into standard diagnostic criteria. This potential oversight could lead to underdiagnosis or delayed treatment of early-stage KOA (Wang *et al.*, 2021).

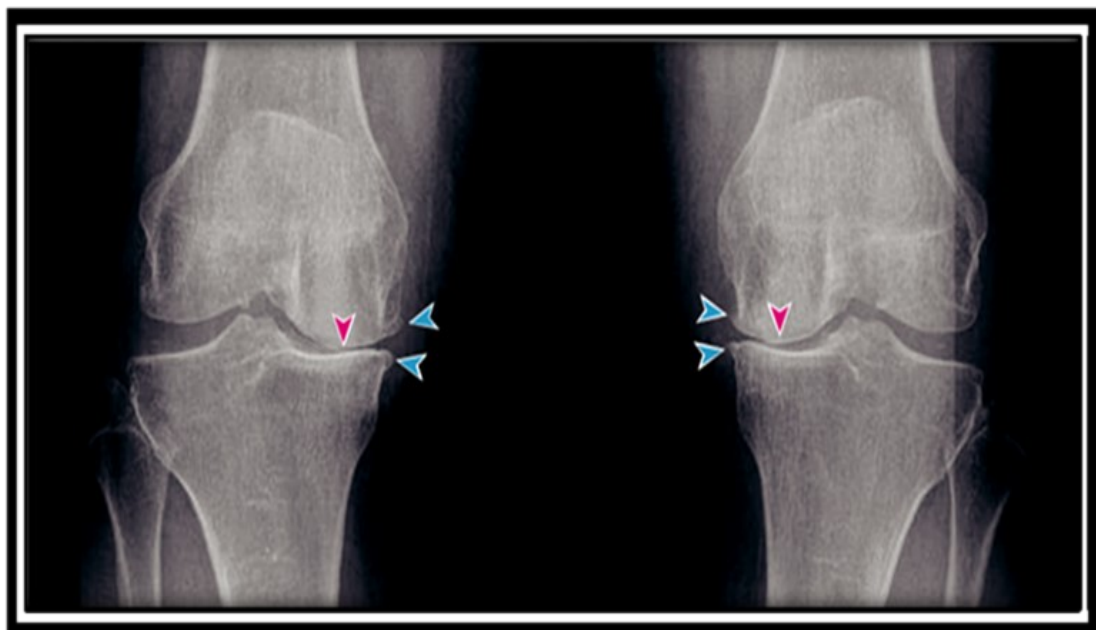


Figure 4: (a) Anterolateral X-ray view for bilateral medial joint space narrowing and osteophyte and varus deformity formation.

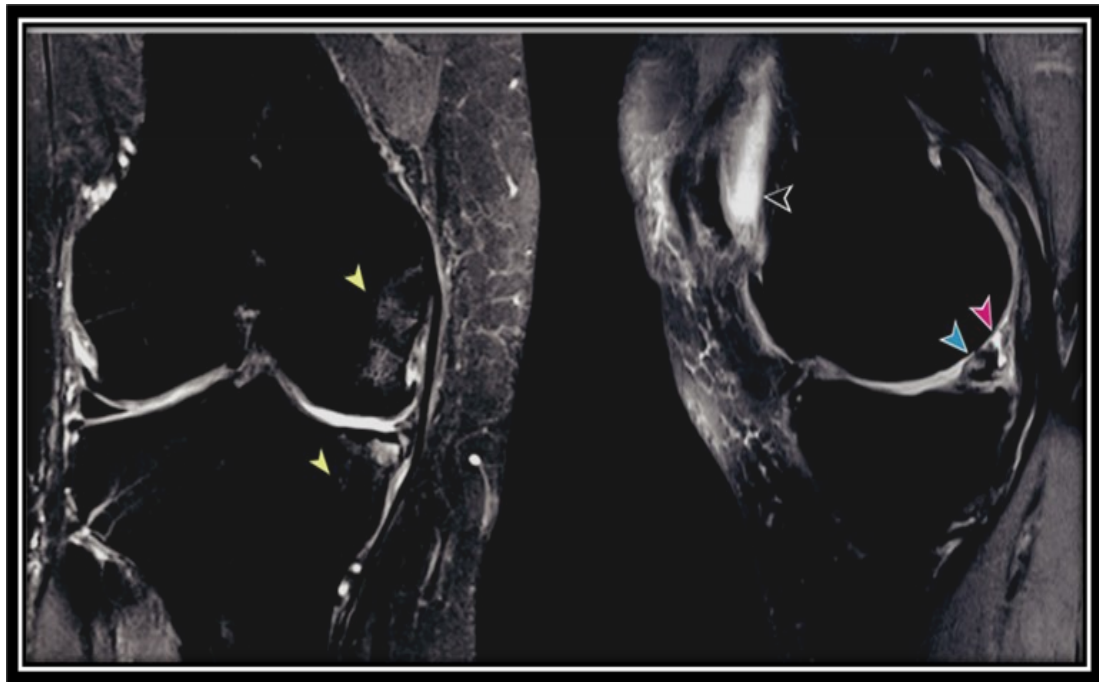


Figure 5: (b) MRI (proton density, fat saturated) of right knee. Magenta arrowheads indicate narrowing joint space; cyan arrowheads indicate medial marginal osteophytes. (Coronal view), yellow arrowheads indicate bone marrow lesions; magenta arrowheads indicate.

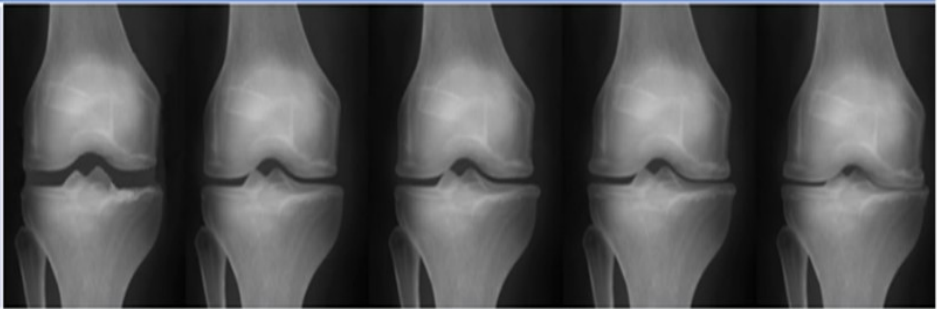
Kellgren–Lawrence grading scale					
X-Ray					
OA Grade	Grade 0 (Normal)	Grade 1 (Doubtful)	Grade 2 (Mild)	Grade 3 (Moderate)	Grade 4 (Severe)
JSN	No radiographic features of OA are present	Doubtful	Possible	Definite	Marked
Osteophytes		Possible	Definite	Multiple	Large

Figure 6: Kellgren-Lawrence OA grading, (JSN)= joint space narrowing, 0 (Normal)= No indications of OA features, 1 (Doubtful)= Reducing joint space is questionable and likely astrophysical lipping, 2 (Mild)= Certain osteophytes and likely reduction of joint space, 3 (Moderate)= Certain joint space narrowing and mild osteophytes, 4 (Severe)= sclerosis and likely deformity of the bone. From (Bany Muhammad and Yeasin, 2021) with permission.

2.10 Management of KOA:

The management of KOA involves a multifaceted approach adhering to recognised clinical practice guidelines. This includes weight management, exercise, pharmacologic treatments and gait modification techniques. Each strategy is critical for optimising patient outcomes and improving quality of life.

- **Education and Self-management:**

Educating patients about KOA and its management is crucial. NICE guidelines emphasise the importance of providing tailored information and support to help patients understand the disease, manage symptoms and adhere to treatment plans effectively (NICE, 2022). The AAOS and ACR both highlight the role of self-management programs, which include medication compliance, pain management strategies and exercise advice, as essential components of KOA management (Kolasinski *et al.*, 2020; Brophy and Fillingham, 2022). Patients should be informed about the benefits of exercise, weight management and available support resources to empower them in their self-care (Brophy and Fillingham, 2022; NICE, 2022; Moseng *et al.*, 2024).

Effective patient education and self-management strategies were crucial for the long-term management of KOA. Studies, such as those by (Hurley *et al.*, 2007), demonstrated that patient education programmes improved knowledge, self-efficacy, and adherence to treatment plans. The main challenge was ensuring that education was personalised and culturally sensitive, addressing the specific needs and preferences of individual patients.

- **Therapeutic exercises:**

Therapeutic exercise is a cornerstone in managing KOA. Exercise programs should focus on knee local muscle strengthening and general aerobic fitness, whether supervised or unsupervised. Supervised sessions have shown greater adherence and effectiveness in improving pain and function. The NICE guidelines recommend combining exercise with educational programs or behaviour-change approaches for enhanced outcomes (NICE, 2022). Similarly, the AAOS supports including neuromuscular training to improve performance-based function and walking

speed (Brophy and Fillingham, 2022). It is essential to inform patients that initial joint pain may increase when starting an exercise regimen, but regular exercise will ultimately reduce pain and improve function (Brophy and Fillingham, 2022; NICE, 2022; Moseng *et al.*, 2024).

Moreover, a systematic review explored the effects of exercise and physical activity on pain, function, and quality of life in KOA (Zhang and Jordan, 2010; Smink *et al.*, 2011; Smith, Kirby and Davies, 2014; Fransen *et al.*, 2015). Results were mixed; some studies found exercise beneficial (Corrêa *et al.*, 2003; Thorstensson *et al.*, 2005), while others did not (Lund *et al.*, 2008). More extensive trials demonstrated therapeutic exercise's efficacy in improving pain and functionality but did not indicate joint damage prevention (Fransen and McConnell, 2009). In addition to this, adherence and effectiveness of different exercise programmes varied. Supervised exercise sessions appeared more beneficial than unsupervised ones, highlighting the need for personalised and monitored exercise plans (Fransen *et al.*, 2015).

- **Biomechanically:**

Gait modification, including the use of appropriate footwear, insoles, canes, and knee braces, plays a significant role in KOA management. NICE guidelines suggest the use of walking aids (e.g. cane) for lower limb osteoarthritis and recommend against the routine use of insoles, braces, tape, splints, or supports unless specific biomechanical issues are present (NICE, 2022). Moreover, the use of canes can help improve pain and mobility. They offer additional support, reducing the load on the affected knee and aiding in stability (Brophy and Fillingham, 2022; NICE, 2022).

Knee braces can significantly enhance function, relieve pain and improve the quality of life for KOA patients. They are particularly useful in cases of joint instability, providing external support and improving alignment during movement (Brophy and Fillingham, 2022; NICE, 2022). Also, using suitable footwear can help reduce pain and improve functional outcomes for KOA patients. It's essential to select shoes that provide adequate support and cushioning to minimize joint stress (Brophy and Fillingham, 2022; NICE, 2022). While insoles such as lateral wedge insoles are generally not recommended,

specific insoles can be beneficial for patients with joint instability or abnormal biomechanical loading, provided they are used in conjunction with other treatments.

Multiple gait modifications such as FPA (toe-out and toe-in), gait speed, step width, stride length, various gait aids (including ipsilateral and contralateral cane), medial knee thrust (knee medialising) and lateral trunk lean sway were examined in a systematic review involving 554 unaffected and KOA individuals (Simic *et al.*, 2011). Nonetheless, more detailed descriptions of gait modifications, training methods and participant instructions might have affected these strategies' reproducibility and clinical application. Also, a systematic review by Pereira *et al.* (2021) examined the impact of multiple gait modifications, such as knee brace, insoles, and retraining, on KOA symptoms. The review found that knee loading reductions correlated with improved pain and function. Nevertheless, there was a call for more in-depth research to validate this association.

- **Manual and Alternative therapies:**

Manual therapies such as mobilisation and soft tissue techniques should be combined with therapeutic exercise for better outcomes. However, the effectiveness of manual therapy alone is limited. Acupuncture and electrotherapy modalities like transcutaneous electrical nerve stimulation (TENS) and ultrasound are not recommended due to insufficient evidence of benefit (Brophy and Fillingham, 2022; NICE, 2022). The AAOS also notes that while manual therapy can provide short-term pain relief, it should not be used as a standalone treatment.

While some studies suggested potential short-term benefits of manual therapy for KOA, the evidence for long-term efficacy was lacking. Xu *et al.* (2017) highlighted that manual therapy might offer short-term pain relief and functional improvement. Nevertheless, its long-term efficacy was questionable due to poor methodological quality in many studies, necessitating further high-quality research to confirm these findings. The evidence for other alternative therapies like acupuncture and electrotherapy was also limited and inconsistent. A review by (Bennell, Buchbinder and Hinman, 2015) found no

significant clinical benefits of TENS or acupuncture for KOA, underscoring the need for more robust clinical trials to establish their efficacy. High-quality, long-term studies were necessary to provide definitive conclusions.

- **Pharmacologically:**

Pharmacologic treatments are recommended when non-pharmacologic measures are insufficient.

Topical non-steroidal anti-inflammatory drugs (NSAIDs) are recommended as the first-line pharmacologic treatment for KOA. If topical treatments are ineffective, oral NSAIDs can be considered. However, they should be used at the lowest effective dose for the shortest duration possible to minimize side effects, always considering gastroprotective treatments to minimize side effects (NICE, 2022). Intra-articular corticosteroid injections can provide short-term pain relief, especially when other pharmacologic treatments are unsuitable or ineffective (Kolasinski *et al.*, 2020; Brophy and Fillingham, 2022; NICE, 2022). Meanwhile, OARIS conditionally recommends intra-articular corticosteroids and hyaluronic acid for short-term and long-term relief, respectively (Bannuru *et al.*, 2019).

Pharmacologic treatments, particularly NSAIDs, proved effective for short-term pain relief in KOA. A review by da Costa *et al.* (2017) highlighted the efficacy of topical and oral NSAIDs in managing KOA symptoms. However, long-term use was associated with significant side effects, including gastrointestinal and cardiovascular risks. This necessitated a careful balance between benefits and risks, with a preference for the lowest effective dose and duration (da Costa *et al.*, 2017).

Pain control and ineffective daily life changes make the disease hard to treat. Analgesics, nonsteroidal anti-inflammatory drugs and prescription drugs are prescribed to relieve KOA pain (Gore *et al.*, 2012). In addition, da Costa *et al.* (2017) highlighted the efficacy of topical and oral NSAIDs in managing KOA symptoms. However, long-term use was associated with significant side effects, including gastrointestinal and cardiovascular risks. This necessitated a careful balance between benefits and risks, with a preference for the lowest effective dose and duration. Secondary prevention and treatment steps

including corticosteroids or injecting hyaluronic acid, platelet-rich plasma (PRP) or autologous micro fragmented, stream-vascular fractionated adipose tissue can slow the condition (Primorac *et al.*, 2020).

- Surgical interventions for KOA:

Joint replacement surgery is considered for patients with severe KOA whose symptoms significantly impact their quality of life and who do not respond to non-surgical treatments.

NICE guidelines recommend not excluding patients from surgery based on age, sex, or comorbidities (NICE, 2022). The AAOS supports arthroscopic partial meniscectomy for meniscal tears in patients with mild to moderate KOA who have not benefited from other treatments and high tibial osteotomy for patients with unicompartmental KOA (Brophy and Fillingham, 2022). However, arthroscopic procedures are not recommended for managing KOA (Brophy and Fillingham, 2022; NICE, 2022). Conversion to knee arthroplasty is the most expensive late effect of the procedure. As years increase postoperatively, conversion rates to TKA rise. No studies were identified which adequately addressed the cost-benefit of knee replacement options versus osteotomy (Brophy and Fillingham, 2022).

The primary challenge in surgery lies in deciding the timing and choosing the optimal surgical approach (Hunter & Bierma-Zeinstra, 2019).

Joint Replacement Surgery is clinically meaningful and cost-effective for end-stage KOA, especially for those with significant functional impairment (Higashi and Barendregt, 2011; Ruiz Jr *et al.*, 2013; Ferket *et al.*, 2017). By age 50, the mortality-adjusted lifetime risk of Total Knee Replacement (TKR) was 10.8% for women and 8.1% for men. In addition, patients with severe osteoarthritis were advised to only consider surgery if conservative treatments failed for six months and if their quality of life was significantly affected (Culliford *et al.*, 2012). Although TKR resulted in more significant pain reduction and functional improvement, than non-surgical treatments, up to 25% of patients still experienced some pain and impairment a year after the TKR procedure (Singh and Lewallen, 2010; Wylde *et al.*, 2011). Complications ranged from venous thromboembolism, surgical site infection, neurovascular

injury, prosthetic joint infection, peri-implant fractures and problems with prosthetic wear and tear (Price *et al.*, 2018).

Despite its popularity, knee arthroscopy surgery lacked substantial evidence of effectiveness for osteoarthritis (Reichenbach *et al.*, 2010; Thorlund *et al.*, 2015; Brignardello-Petersen *et al.*, 2017). Risks and high costs often outweighed the potential benefits. Adverse outcomes included deep vein thrombosis and the acceleration of osteoarthritis development (Englund and Lohmander, 2004; Roemer *et al.*, 2017). Furthermore, arthroscopy often resulted in a later joint replacement and was not typically recommended by professional guidelines (G. Hawker *et al.*, 2008; Rongen *et al.*, 2017).

Furthermore, knee osteotomy was considered beneficial for pain and function, although it had not been rigorously compared to non-surgical treatments (Brouwer *et al.*, 2014). Suited for younger patients with mild osteoarthritis, it potentially delayed joint replacement by up to ten years (Kim and Lee, 2017). High Tibial Knee Osteotomy (HTKO) was especially recommended for younger patients, while the uni-compartmental knee prosthesis was seen as more beneficial for older individuals because of the shorter recovery times (Santoso *et al.*, 2017). Lastly, knee distraction – a newer technique – involved using an external fixator to distract the knee joint for six to eight weeks. However, a significant issue was infection; 60% of patients experienced pin-track infections during this treatment (Van Der Woude *et al.*, 2017).

Moreover, studies on knee replacement surgery for KOA provided distinct insights into its efficacy. A study by Altman *et al.* (2005) found knee replacements effective in alleviating severe pain and improving function in patients with end-stage osteoarthritis. However, it highlighted limitations such as a lack of standardised criteria for surgery timing and the significant financial burden associated with surgery and rehabilitation. The study recommended further research into pre-surgical indicators and called for consistent guidelines to optimise patient outcomes.

Also, Bayliss *et al.* (2017) examined the long-term survival of knee implants, showing high 10-year (96.1%) and 20-year (89.7%) survival rates. A

higher revision operation risk in younger patients, especially males, due to longer life expectancy and increased activity levels. Recommendations emphasised the need for careful patient selection, particularly among younger individuals and suggested that lifetime risk estimates of revision be integrated into the shared decision-making process to better manage patient expectations.

For all these surgical interventions, careful patient selection was paramount. Factors such as depression, minor pain, minor radiographic findings, or extreme obesity had the potential to affect outcomes negatively. Emphasising shared decision-making and setting realistic expectations minimises post-surgical dissatisfaction (Dowsey *et al.*, 2016).

- Follow-Up and Review:

Regular follow-up and review are essential to monitor patient progress and adjust treatment plans as necessary. NICE guidelines advise against routine imaging for follow-up and emphasize clinical assessment and patient-reported outcomes instead (NICE, 2022). The AAOS also recommends individualised follow-up strategies to ensure optimal management (Brophy and Fillingham, 2022). The EULAR recommends regular follow-up for patients with KOA to manage the disease effectively. This approach involves educating patients, making lifestyle modifications, and regularly assessing their physical condition to optimise treatment plans and improve patient adherence and outcomes (Fernandes *et al.*, 2013). Consistent follow-up visits are crucial for monitoring the effectiveness of interventions and making necessary adjustments.

A meta-analysis on long-term pharmacological treatments for KOA emphasised the importance of regular follow-ups to evaluate the effectiveness and safety of ongoing medication use. Regular assessments identified the most effective treatments and managed adverse effects, ensuring sustained pain control and functional improvement (Gregori *et al.*, 2018). This ongoing evaluation was critical for optimising long-term management strategies.

Regular follow-up is essential in managing KOA to ensure the optimal application of treatment strategies, monitor disease progression and adjust

interventions as needed. This ongoing care helps maintain function, manage pain and improve the overall quality of life for patients with KOA.

2.11 Biomechanics of KOA:

Biomechanics are the study of life movement through mechanical science (Hatze, 1974). The force exerted on living tissue could stimulate growth or lead to injury. Biomechanics used mathematical instruments to highlight how kinesiology practitioners enhanced movement safety (Knudson, 2007).

This discipline aimed to refine movement accuracy and assist those with motion disorders (Knudson, 2007). Concepts like movement, concave and convex, and range of motion were integrated with therapeutic walking aids (Jayaraman et al., 2018; Tröster et al., 2020). Biomechanical interventions, such as knee valgus brace, foot orthoses- lateral wedge insoles and variable stiffness shoes, were used for KOA to improve knee pain, function and potentially slow the disorder (McAlindon *et al.*, 2014) although evidence was limited (Parkes *et al.*, 2013; Hinman *et al.*, 2016).

Kinematics studied body motion, without considering forces in action and emphasizing the distinction between the time the foot is in and out of contact with the ground. These periods are referred to as both the 'stance phase' (60% of the gait cycle) and the 'swing phase' (40% of the gait cycle), respectively (Figure 7). The classifiable stance phase parameters include heel strike, flat foot, mid-stance, heel off and toe off. The swing phase categories include early swing, mid-swing and late swing (Richards *et al.*, 2013).

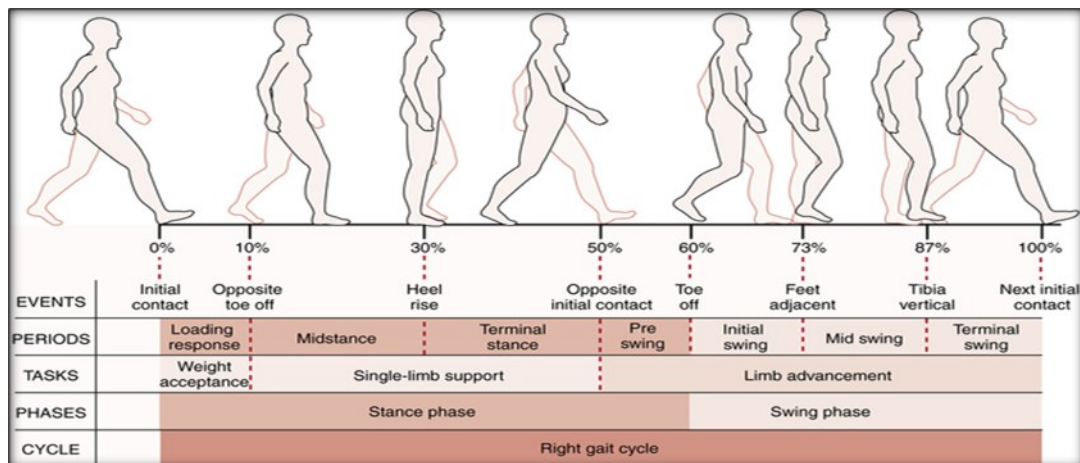


Figure 7: Gait phase visual representation & terminology adapted from (Neumann, 2016).

- **Loading on KOA and its Generation:**

KOA affects the medial, lateral and patellofemoral joints of the knee and takes 10–15 years to progress (Jüni *et al.*, 2015). Studies have concentrated on quantifying articular loads in KOA patients (Hurwitz *et al.*, 1999; Chang *et al.*, 2004; Astephen *et al.*, 2008; Tanaka *et al.*, 2008). The medial tibiofemoral compartment of the knee was most susceptible, experiencing increased body load during 60–80% of the gait cycle (Hurwitz *et al.*, 1998; Chang *et al.*, 2004). This excessive loading influenced KOA's onset (Andriacchi *et al.*, 2009; Duffell *et al.*, 2014).

The intricate relationship between the magnitude, frequency, and duration of joint loading ultimately influenced whether joint tissues adapted or maladapted response. Research supported this idea, showing that mechanical loading encouraged bone formation and shaped bone size and strength with important factors affecting bone adaptation, including strain magnitude, strain rate, and frequency (Cullen, Smith and Akhter, 2001).

While excessive loading was linked to the development of KOA (Costello *et al.*, 2021), the dynamic modulus and hydraulic permeability of cartilage were particularly sensitive to loading rates. This indicated that early osteoarthritic cartilage was more exposed to higher loading rates than to loading magnitude alone (Nia *et al.*, 2013). Therefore, understanding and treating joint conditions required considering all aspects of loading dynamics.

Evaluating joint loading directly *in vivo* was challenging. Hence, external knee adduction moment (KAM) was a surrogate for medial tibiofemoral joint

loading (Paterson *et al.*, 2017). KAM was influenced by the ground reaction force (GRF) and the vertical distance from the knee centre (Farrokhi *et al.*, 2013). In a neutrally aligned limb, GRF caused a KAM (Figure 8), which compressed the tibiofemoral medial compartment (Andriacchi, 1994). This contributed to a higher occurrence of medial compartment KOA (McAlindon *et al.*, 1992; Ledingham *et al.*, 1993; Dillon *et al.*, 2006).

Furthermore, KAM offered valuable biomechanical insights but did not consider all the dynamic variables and intrinsic factors that influenced medial tibiofemoral loading, such as muscle and ligament forces, as well as external loads on the knee joint (Baliunas *et al.*, 2002; Manal *et al.*, 2015). Besides, there is uncertainty regarding the causal relationship between KAM and medial KOA, and the epidemiological evidence supporting this link remains inconsistent (Henriksen *et al.*, 2014). It is crucial to clarify the distinction between association and causation to avoid overstating the implications of KAM.

Combining personalised musculoskeletal modelling with KAM analysis could have provided a deeper understanding of joint loading patterns in KOA (Baniasad *et al.*, 2022). This approach might have guided targeted interventions to adjust KAM and possibly slow disease progression. However, long-term studies were necessary to confirm the effectiveness of strategies to modify KAM with KOA.

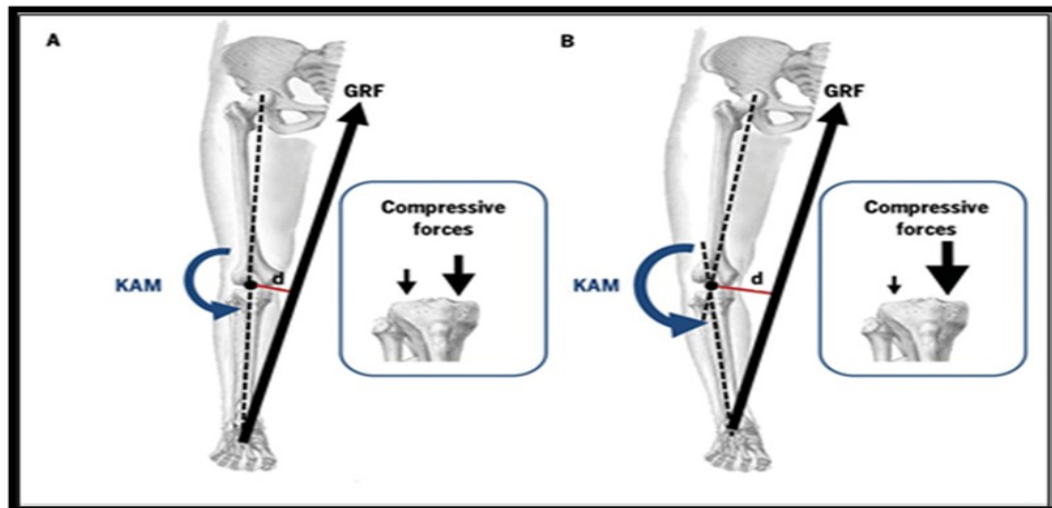


Figure 8: (A) In a neutrally aligned lower limb, the GRF shifts medial to the knee's centre, focusing forces on the medial tibiofemoral aspect. A 0-degree angle is formed by the intersection of the femur's and tibia's mechanical axis. (B) An increased perpendicular alignment between the GRF and the knee's rotation centre elevates the KAM. In a varus alignment, the angle between the femur and tibia exceeds 0°. (Farrokhi *et al.*, 2013).

KAM displayed two peaks during a gait phase, with the first peak observed in the medial aspect in KOA patients (Figure 9), (Hunt *et al.*, 2006; Hurwitz *et al.*, 2002; Mundermann, Dyrby and Andriacchi, 2005). A unit increase in KAM correlated with a six-fold growth in medial knee OA over six years (Miyazaki *et al.*, 2002). Given KAM's significance in clinical KOA studies (Lim *et al.*, 2008; Bennell *et al.*, 2010; Sled *et al.*, 2010; Foroughi *et al.*, 2011; McQuade and De Oliveira, 2011), and understanding the factors influencing KAM was vital (Farrokhi *et al.*, 2013).

The multifactorial nature of OA suggested that KAM was one of several contributing factors. For instance, (Ulrich *et al.*, 2023)Ulrich *et al.* (2023) found that KAM correlated with KOA severity, indicating a biomechanical influence on OA progression. Additionally, variables such as participants' characteristics (age and BMI) and utilised analysis methods impacted KAM results across different trials.

Furthermore, Chehab *et al.* (2014) demonstrated that baseline KAM significantly influenced femoral cartilage changes over five years, supporting the role of biomechanical loading in KOA development. Rutherford *et al.* (2008) indicated that walking velocity and foot progression angle significantly affected KAM during walking analysis, highlighting the complexity of factors influencing KOA.

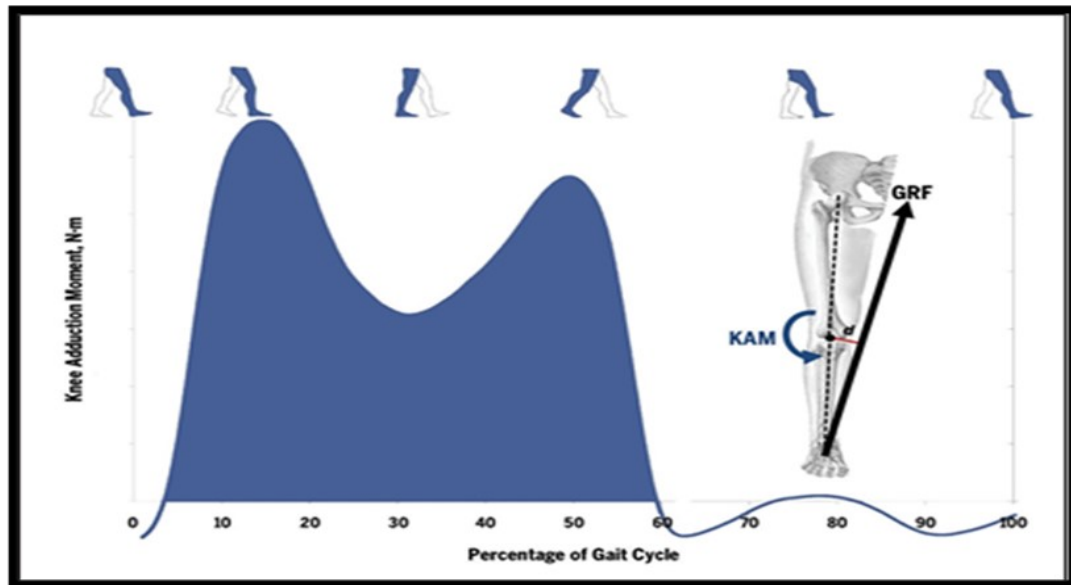


Figure 9: During the stance process of gait, the KAM usually shows two peaks. Each peak has to do with the GRF vertical peak. The first, greater peak is during the period of load acceptance. (Between 0%-12% of the gait cycle), The second smaller peak comes in the late position (50% –62% of the gait cycle). During the swing phase of gait, the KAM is irrelevant (62%-100% of gait cycle) (Farrokhi *et al.*, 2013)

- **Joint Forces Measurement and Relation with KOA:**

Mechanical load played a pivotal role in KOA's pathophysiology (Hunt *et al.*, 2010). Although, measuring this load *in vivo* was challenging (Paterson *et al.*, 2017), the KAM from 3-D gait analysis provided insights into dynamic joint loading in the medial knee compartment (Birmingham *et al.*, 2007; D Zhao *et al.*, 2007). Commonly, knee biomechanics patterns (e.g., walking speed, spatiotemporal, KAM and knee flexion moment (KFM)) were assessed using non-invasive motion capture systems in gait laboratories (Andriacchi *et al.*, 2005; Cappozzo *et al.*, 2005).

Furthermore, instrumented knee implants shed light on knee loads (Kutzner *et al.*, 2010), but their use was limited. Therefore, the prevalent method was a capture motion system paired with GRF measurements, producing consistent KAM readings (Birmingham *et al.*, 2007; Andriacchi *et al.*, 2005). However, while traditional gait systems are widely available, the cost of the study may be prohibitive in some clinical settings (Wilson and Kobsar, 2021). Also, other variables, such as participant characteristics (age, BMI, disease location) or statistical methodology may also impact findings and restrict gait study comparability (Fvare & Jolles, 2016).

Thus, treatment options for KAM reduction focused on GRF control and its frontal plane lever arm (Farrokhi *et al.*, 2013). Sharma *et al.*, (2001) noted knee alignment conditions affecting GRF and KAM. An increased transverse GRF lever arm, stretching from the foot's centre of pressure to the body's centre of mass, leads to lateral knee displacement in the frontal plane, thereby intensifying KAM (Weidenhielm *et al.*, 1994; Hunt *et al.*, 2006).

However, accuracy of KAM measurements depended on precise marker placement and the calibration of the motion capture system, which could introduce variability and affect reproducibility across studies (Fairus, Nordin and Singh, 2018). Although gait-laboratory settings provided controlled environments, they might not have fully mirrored real-world conditions, potentially limiting the external validity of the findings. Moreover, the complexity and cost of these systems posed significant barriers to widespread clinical use, particularly in resource-limited settings.

Despite these limitations, the future of KAM analysis in KOA research looked promising. Advances in wearable technology and machine learning algorithms promised more accessible and accurate in vivo assessments, which could have improved both the diagnostic and therapeutic processes.

To address this, strategies such as valgus bracing (Pollo *et al.*, 2002; Pagani *et al.*, 2010; Pagani *et al.*, 2012; R. K. Jones *et al.*, 2013), and a medial thrust gait (Fregly *et al.*, 2008; Schache *et al.*, 2008; Barrios *et al.*, 2010) have been proposed. These align the rotary knee centre closer to the GRF's operational line, consequently reducing KAM. Moreover, adjustments, such as lateral trunk or adopting a toe-out pattern, have proven effective (Hunt *et al.*, 2011; Fregly *et al.*, 2007; Lynn *et al.*, 2008; Abdallah and Radwan, 2011).

On a similar note, techniques that decrease the influence of a patient's body mass on GRF, like using a cane or reducing gait speed, can also diminish KAM. (Lyu *et al.*, 2000; Kemp *et al.*, 2008) or minimising the movement of the patient's centre of mass (decreased gait speed) (Mündermann, Dyrby, Hurwitz, Sharma and Andriacchi, 2004). Lastly, techniques that decrease the frontal plane length of the KAM lever arm via lower-lift reorganisation or lateral pressure centre displacement can minimise KAM (Farrokhi *et al.*, 2013).

While strategies such as valgus bracing, medial thrust gait, lateral trunk lean and toe-out gait had shown promise in reducing KAM, their long-term outcomes, impact on disease progression and patient adherence remained uncertain (Richards *et al.*, 2018). Moreover, the complex interplay between KAM, GRF and other biomechanical factors, such as knee adduction angle and centre of pressure location, complicated the interpretation of these parameters in the context of KOA (Schmitz and Noehren, 2014).

Current trials had provided valuable insights into the potential of gait modification strategies. Future studies should focus on uncovering the long-term effects of these interventions on joint health and patient outcomes.

2.12 Muscle Contribution and Activation in KOA Subjects:

Neuromuscular changes were observed in KOA subjects in multiple investigations. Childs *et al.* (2004) found prolonged activity durations in certain muscles (medial hamstrings, medial gastrocnemius, vastus lateralis and tibialis anterior) and efficient muscle co-contractions in KOA subjects. These internal forces played a pivotal role in joint loading, essential for evaluating biomechanical therapies to minimise joint loading (Ramsey, Snyder - Mackler, *et al.*, 2007). Moreover, prior studies revealed differences in muscle activity amplitude and duration in KOA subjects compared to healthy participants. Hubley-Kozey *et al.*, (2006) that KOA subjects exhibited increased muscle activations in the hamstring, quadriceps and gastrocnemius muscle activation than healthy participants during walking. The implications of these neuromuscular alterations were believed to have clinical significance, potentially influencing disease progression (Hortobagyi *et al.*, 2005; Rutherford *et al.*, 2013).

Many KOA studies did not fully explore the intricate relationships between muscle weakness, co-activation patterns, and joint instability, which were crucial for understanding the pathophysiology and progression of the condition. Research showed that activation of the hamstrings and quadriceps acted as a compensatory mechanism for muscle weakness. However, this may have increased joint stress, leading to cartilage degradation (Smith,

Woodburn and Steultjens, 2019). Moreover, abnormal co-activation patterns, possibly worsened by muscle weakness, could reduce joint stability, creating a cycle of degeneration (Hubley-Kozey et al., 2008). Additionally, claiming that increased muscle activation in KOA patients was clinically significant remained uncertain without support from long-term intervention trials.

Exploring the relationship between muscle activity and disease progression, Wilson *et al.*, (2011) and Rutherford *et al.*, (2013) found associations between muscle activations, pain and the severity of KOA. These studies underlined a connection between lower limb muscle activity changes and KOA progression. However, the causal nature of these muscle changes remained ambiguous, leaving uncertainties about their origins and implications. It became evident that alterations in knee muscle activity in KOA subjects were not solely attributed to pain or joint instability. A biomechanical basis could also have role.

- Knee Loading and muscle co-contraction in KOA subjects:

Muscle co-contraction, the simultaneous contraction of agonist and antagonist muscles around a joint, is crucial in joint stability (Hirokawa *et al.*, 1991; McGill *et al.*, 2003) and movement accuracy (Gribble *et al.*, 2003; Missenard, Mottet and Perrey, 2008). An increased tendency for muscle co-contraction was observed in cases of orthopaedic injuries or neuromuscular impairments (Rudolph *et al.*, 2000; Ramsey *et al.*, 2001; Higginson *et al.*, 2006; McGinnis *et al.*, 2013). This enhancement in joint stiffness could benefit stability and movement accuracy (Kuitunen *et al.*, 2002; Mohr *et al.*, 2018), albeit at the cost of increased energy expenditure (Moore *et al.*, 2014). Thus, quantifying joint stiffness is valuable in understanding how this quantity effectively contributes to dynamic motions such as gait.

Extensive research, such as those by Childs *et al.*, (2004), Hortobagyi *et al.*, (2005), Ramsey, Snyder-Mackler *et al.*, (2007), Zeni, Rudolph and Higginson (2010), Hodges *et al.*, (2016), focused on diagnostics muscle (quadriceps and hamstring) co-contraction in KOA subjects. Notably, Hortobagyi *et al.*, (2005) highlighted a significant rise in muscle co-contractions in KOA subjects during daily activities (walking, stair ascent and descent).

Additionally, research by Heiden, *et al.*, (2009) emphasised increased co-contraction patterns in both KOA and healthy subjects. These studies revealed that KOA subjects walk with increased quadriceps and hamstring co-contraction compared to equivalent healthy participants.

Research on knee muscle co-contraction related to KOA showed a complex connection with stiffness and joint loading. During weight acceptance, subjects with KOA showed stiffening knees characterised by increased muscle co-contraction (Childs *et al.*, 2004; Lewek, Rudolph and Snyder-Mackler, 2004; Schmitt and Rudolph, 2007). Schmitt and Rudolph (2007), also observed that while some co-contraction was essential for knee stabilisation, the co-contraction in the OA group was associated with reduced knee motion. This reduced motion during gait has been linked to elevated tibiofemoral cartilage contact pressures, contributing to joint degradation and the progression of OA (Lafortune, Hennig and Lake, 1996; Gustafson *et al.*, 2015). Furthermore, increased co-contraction of knee muscles, particularly in the medial compartment, had been associated with higher joint contact pressures, exacerbating the condition (Tsai, Scher and Powers, 2013).

Conversely, Khandha *et al.* (2019) found that higher muscle co-contraction did not necessarily lead to higher joint forces during gait, indicating that the relationship between muscle activation and joint loading was complex and not fully understood. This suggested that while increased muscle co-contraction could contribute to OA progression, it also provided stability to the knee joint, and its role was not entirely detrimental.

While these studies robustly demonstrated the biomechanical changes in KOA patients, they did not fully explore the longitudinal impact of these adaptations. Future research should focus on long-term studies to assess whether increased co-contraction directly correlates with accelerated joint degeneration.

Addressing knee loading, it is essential to note that four main factors influence the overall compressive load in human joints. These factors include the activation muscles surrounding the joint (Pandy and Andriacchi, 2010; Sowers and Karvonen-Gutierrez, 2010), the GRF, gravitational force and

restriction impact of ligament and soft tissue (Pandy & Andriacchi, 2010). Moreover, understanding joint loading in KOA necessitated considering muscle action contributions. In this context, Brandon *et al.*, (2014) and Sritharan *et al.*, (2017) used musculoskeletal modelling to extrapolate how variations in muscle activation sequences could lead to altered joint loads. Their findings underscored the significance of muscle activations in determining joint load, emphasising the relationship between increased muscle co-contractions and augmented loading on the knee joint cartilage.

2.13 Gait Abnormalities in KOA subjects:

Walking was the most common physical activity among older individuals with KOA (Barbour *et al.*, 2014). The walking patterns of these individuals were possibly influenced by joint conditions in the lower limbs, such as hip and knee OA (Park *et al.*, 2021). Previous studies (Silva *et al.*, 2002; Brisson, Gatti and Maly, 2020) discovered that an individual's average daily number of steps ranged between 5,000 and 15,000. Ignoring even a minor aberrant gait pattern might lead to significant joint issues. By analysing the gait differences shown by KOA patients, it was believed that regimens could be developed to delay or prevent the progression of KOA. Thus Landry *et al.* (2007) studied differences in gait patterns between a group of 41 KOA subjects and 43 asymptomatic individuals, focusing on temporal-spatial, kinematic and kinetic data.

- Spatial and Temporal Parameters:

Compared to healthy subjects, those with KOA often showed decreased temporal-spatial characteristics such as walking velocity, stride length and cadence (Baan *et al.*, 2012; Sims, 2012). These decreases were attributed to unstable and lax knees, resulting in the affected knee side spending more time in the stance phase (Gök, Ergin and Yavuzer, 2002; Farrokhi *et al.*, 2015). With gait speed correlated with GRF, individuals with KOA tended to reduce their walking speed to alleviate pain and joint stress (Stansfield *et al.*, 2001; Liu *et al.*, 2008; Schwartz, Rozumalski and Trost, 2008; Stoquart, Detrembleur and Lejeune, 2008). Moreover, Mundermann *et al.*, (2004) observed that patients with less severe KOA chose to walk slower than a control group, as a reduced

speed might have lowered KAM during locomotion, potentially slowing the disease's progression.

Studies indicated that the severity of KOA significantly affected gait parameter variability. As the disease advanced, decreased variability in angular parameters of the affected knee led to reduced joint flexibility and movement consistency, resulting in greater spatial-temporal variability (Kiss, 2011; Magyar, Knoll and Kiss, 2012).

However, Brunelli *et al.* (2015) found no significant differences in temporal-spatial gait parameters between Kellgren-Lawrence grades II and III in bilateral KOA subjects under 65. This finding challenged the assumption that gait alterations consistently worsened with disease progression. Additionally, regarding gender differences in gait parameters and their correlations with clinical measures, Debi *et al.* (2009) identified substantial gender differences in spatio-temporal gait parameters among patients with KOA, particularly across all gait cycle phases and foot placement angles. These differences suggested that males and females might employ distinct gait strategies in response to KOA, emphasising the importance of considering gender effects when assessing patients with KOA.

Future studies should focus on longitudinal assessments of gait parameters in KOA patients, considering age, KOA severity, and gender differences.

- Kinematic Parameters:

Explanation of body motion. In kinematic there are five variables of interest: motion type, location, path, quantity and motion/displacement intensity (Alderink, 2006). Increasing severity of KOA was associated with significant reductions in hip flexion angle, ankle dorsiflexion angle, knee flexion angle and knee joint range of motion (Asthephen *et al.*, 2008; Miyazaki *et al.*, 2021; Bensalma *et al.*, 2023). Some studies pinpointed that knee flexion was limited to about 50 degrees during level walking in KOA patients, helping to ease pain during load bearing (Stephen *et al.*, 2008; Walker *et al.*, 2001). Other studies have shown that normal individuals' peak knee flexion angles were

less during gait (Messier *et al.*, 1992; Kaufman *et al.*, 2001; A. . J. Baliunas *et al.*, 2002; Childs *et al.*, 2004; Mundermann, Dyrby and Andriacchi, 2005).

Furthermore, Bejek *et al.*, (2006) noted decreased hip and knee joint range of motion in KOA patients, suggesting possible compensation mechanisms at the hip and pelvis due to knee joint degeneration. Gök, Ergin and Yavuzer (2002) reported pronounced knee varus degree during the stance phase and increased knee valgus degree during the swing phase in KOA subjects, emphasizing the link between knee malalignment and the onset of KOA (Wei *et al.*, 2019; Faschingbauer *et al.*, 2020; Han, Yan and Yu, 2021).

Studies consistently reported that KOA patients showed decreased hip flexion, ankle dorsiflexion and knee flexion angles (van Tunen *et al.*, 2018). However, further investigation is needed to understand the interplay of these changes with KOA progression. Further, the clinical significance of these reductions should also be explored. For example, Hicks-Little *et al.* (2011) found that KOA altered hip and ankle kinematics during stair climbing, indicating a broader impact on lower limb function.

The observed limitation in knee flexion during walking, likely an adaptation to alleviate pain during load-bearing, raised questions about the long-term consequences on joint health and functional capacity (Rühling *et al.*, 2023). Additionally, the decreased range of motion in the hip and knee joints suggested potential compensatory mechanisms at the hip and pelvis, which might contribute to secondary musculoskeletal issues (Fu *et al.*, 2023).

In addition, Matsumoto *et al.* (2005) showed the influence of hip position on knee flexion angle, highlighting the correlation of joint biomechanics in KOA patients. Understanding how hip and pelvis adjustments occur in response to knee joint degeneration could inform targeted rehabilitation strategies.

Another important aspect is the relationship between knee malalignment and the onset of KOA. Evidence shows increased knee varus during stance and valgus during swing, highlighting the significance of biomechanical factors in the development of the disease (van Tunen *et al.*, 2018). However, the direction of this relationship remains unclear, and therefore, longitudinal studies are necessary to determine causality.

In KOA progression, knee varus and valgus deformities are essential factors. Weidow, Mars and Kärrholm, (2005) highlighted the contribution of pelvic and hip anatomy to these misalignments, while Henriksen *et al.* (2009) showed that decreased hip abductor function could change knee joint loads, emphasizing the interconnected biomechanical changes in KOA.

Future studies should focus on longitudinal assessments of kinematic changes and their impact on KOA progression. Integrating multi-joint rehabilitation approaches that address compensatory mechanisms could significantly enhance therapeutic outcomes.

- Kinetic Parameters:

This deals for the body's movement and the forces that allow it to move (Alderink, 2006). Numerous studies associated kinetic parameters (e.g., KAM) with KOA's cause and severity. Even though some studies focused on biomechanical changes in KOA individuals (Sharma *et al.*, 1998; Thorp *et al.*, 2006a; Landry *et al.*, 2007), there was a knowledge gap regarding differences at other joints. So, two studies compared gait between KOA participants and healthy controls to bridge this gap. It was found that there were significant variations in various joint moments (knee flexion, extension, knee internal rotation, hip flexion and abduction, hip internal rotation, and ankle dorsiflexion) during the stance phase (Astephen *et al.*, 2008a, b). The findings showed substantial reductions in those parameters among KOA participants. Conversely, the KAM, which measures medial knee loading, was higher.

Additional studies by Al-Zahrani and Bakheit (2002) and Farrokhi *et al.* (2015) demonstrated similar reductions in joint moments and altered gait characteristics in KOA patients. These findings were reinforced by observations that patients with severe KOA exhibited significantly reduced walking speed, shorter stride length, and prolonged stance phase due to joint instability.

Moreover, Zeni and Higginson (2009), found that differences in gait parameters, except for knee excursion, were primarily due to slower walking speeds rather than disease progression. This indicated the need for standardised walking speeds in future research to isolate the effects of KOA

on kinetic parameters accurately. The increased KAM suggested higher medial knee loading, which correlated with pain and functional limitations in KOA patients. Gholami *et al.*, (2023) discovered a significant inverse correlation between peak KAM and pain, highlighting the clinical relevance of KAM in assessing KOA severity and treatment efficacy.

Research should prioritise longitudinal assessments of kinetic parameters to better understand the progression of KOA and the efficacy of targeted interventions.

Research indicated that knee loading during walking correlated with the intensity of clinical symptoms in KOA (Sharma *et al.*, 1998; Thorp *et al.*, 2006b; Landry *et al.*, 2007). Thus, reducing KAM was essential for symptom relief (Baliunas *et al.*, 2002). However, Astephen *et al.*, (2008a) found differences from prior studies (Kaufman *et al.*, 2001; Hurwitz *et al.*, 2002), noting that those with KOA did not always show increased 1st peak KAM. Instead, mid-stance KAM, less speed-dependent, was elevated due to its less speed-dependent nature.

While some studies established a correlation between knee loading during gait and symptom severity in KOA patients (Nie *et al.*, 2019), the relationship was not as straightforward as initially thought. The focus on reducing KAM for symptom relief might have been oversimplified, as evidenced by conflicting findings.

Consequently, some researchers (Weidenhielm *et al.*, 1994; Landry *et al.*, 2007; Astephen *et al.*, 2008a) have suggested that mid-stance KAM provides more accurate measurements of knee loading during walking. However, it is not appropriate to assess knee loading solely with KAM. Due to this, several researchers, given KAM's speed-dependency, believed the knee angular abduction impulse (KAAl) was a better representation of cumulative knee loading (Thorp *et al.*, 2007).

Discrepancies in results, particularly regarding the 1st peak KAM, highlighted the need for more detailed analysis. The interesting observation that mid-stance KAM could be a more reliable indicator due to its reduced speed dependence warranted further investigation (Pang *et al.*, 2008).

The hip joint is one of the joints involved in KOA. According to studies by Chang *et al.*, (2005), Mundermann, Dyrby and Andriacchi (2005) and Astephen *et al.*, (2008a) KOA individuals have a lower hip adduction moment. In addition, research by Chang *et al.*, (2005) suggests that increasing hip abduction moment may reduce KOA onset and progression. During the single-limb stance phase of gait, due to weak hip abductor muscles in the stance limb, there is an excessive pelvic drop on the contralateral swing limb. Due to this decrease, the body shifts its centre of mass to its swinging limb. Consequently, the medial tibiofemoral compartment cartilage on the stance limb is stressed. In this way, Chang *et al.*, (2005) suggested that increasing hip abduction moments could effectively prevent medial KOA (figure 10).

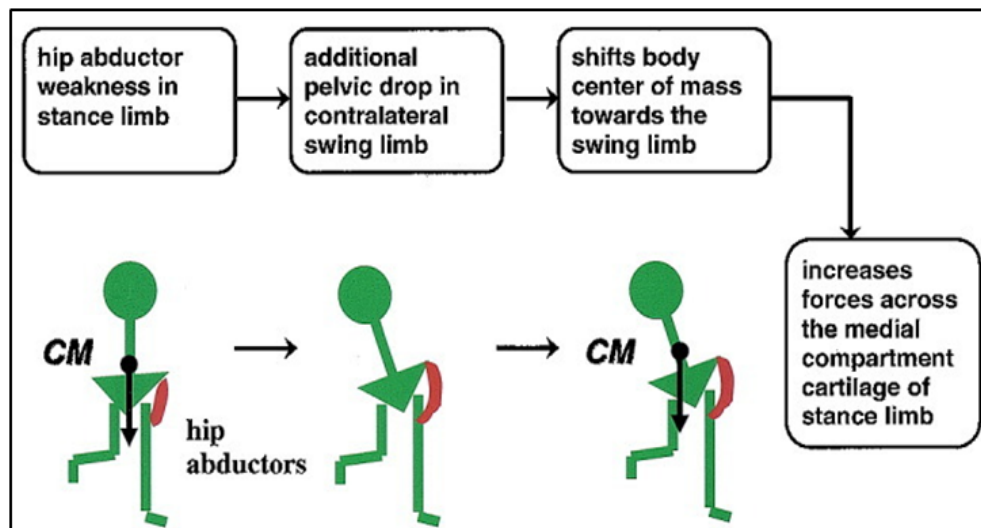


Figure 10: A weakening hip abductor mechanism in the stance limb may result in increased strain on the medial tibiofemoral aspect. CM= centre of mass, Chang *et al.*, (2005).

2.14 Gait modification as Intervention for KOA:

Gait modification served as a method to offload KAM. Training for KOA patients to amend their gait may reduce knee loads with or without external devices (Miyazaki *et al.*, 2002; Farrokhi *et al.*, 2013; Hinman *et al.*, 2013; Kim *et al.*, 2020). This technique, aimed to decrease medial knee load, has become a promising conservative strategy for KOA (Simic *et al.*, 2011). Consequently, many re-gait approaches intended to reduce KAM, such as the one proposed by (Hunt, 2012), focused on reducing the lever arm by bringing the GRF closer

to the knee. While earlier studies primarily emphasized KAM in walking, recent works have been expanded to include load frequency, pattern and three-dimensional (3D) joint loading (Wilson and Kobsar, 2021). Recent research targeted adjustments in kinematic or kinetic variables for medial compartment KOA patients (Hunt, 2012). However, only a few effective therapeutic methods have been identified (Simic *et al.*, 2011). Notably, two studies highlighted the benefits of gait modification over several months (Cheung *et al.*, 2018; Hunt *et al.*, 2018). Despite the promising results, more long-term trials are needed to confirm the effectiveness and safety of these gait modifications (Farrokhi *et al.*, 2013).

2.14.1 Learned Gait Modification Approaches:

Learned modified gait programmes have proven effective in reducing KAM through various techniques. These include toe-in (Shull *et al.*, 2013a; Shull *et al.*, 2013b; van den Noort *et al.*, 2013) and toe-out gaits (Hurwitz *et al.*, 2002; Guo *et al.*, 2007; Hunt *et al.*, 2018), ipsilateral trunks lean (Hunt *et al.*, 2008a; Mündermann *et al.*, 2008), altering rearfoot position (Reilly *et al.*, 2009; Hunt *et al.*, 2021), barefoot walking (Kerrigan *et al.*, 2003; Shakoor *et al.*, 2010) and backwards walking (Zhang *et al.*, 2015). Although, toe-in gait reduced KAM considerably and helped in KOA treatment, the toe-out gait requires further research for clinical implications. A change in rearfoot position, backwards walking exercises and ipsilateral trunk lean can improve balance but increase fall risks.

- Toe-in and Toe-out Gait Modifications:

According to Shull *et al.*, (2013a & 2013b), Lindsey *et al.*, (2020) and Gholami *et al.*, (2022), walking with a reduced foot progression angle (FPA), (toe-in) had diminished the 1st KAM. Shull *et al.*, (2013a) observed that the 1st peak KAM decreased by almost 13% when respondents walked with a toe-in gait. Additionally, van den Noort *et al.*, (2013) found a 40% KAM reduction, which suggests that toe-in gait benefits for KOA treatment. In their research, Shull *et al.*, (2013b) also highlighted improvements in knee pain and functioning due to toe-in gait training. Despite this, toe-in training is limited,

especially when the patient cannot walk due to severe KOA (Shull *et al.*, 2013b).

On the other hand, increased FPA, particularly toe-out gait, has shown potential in reducing KAM, as evidenced by van den Noort *et al.*, (2013), Guo *et al.*, (2007) and Jenkyn *et al.*, (2008). Specifically, van den Noort *et al.*, (2013) detailed how KAM changed during early and mid-stance phases, (24%) and (21%) respectively with a toe-out gait, while simultaneously reducing the KAM during the late stance by 56%. Also, Jenkyn *et al.*, (2008) reported a significant drop in KAM lever arm (6.7%) and 1st peak KAM (11.7%) with toe-out gait intervention.

Furthermore, the toe-out gait modification approach duration varied, with studies such as Cheung *et al.*, (2018) and Hunt *et al.*, (2018) reporting significant short-term effects (ranging from six weeks to six months). While some studies like Charlton, Kobsar and Hunt (2019), Richards *et al.*, (2018) and Uhlrich *et al.*, (2019) had focused on the impact of FPA on knee pain and function only. Hunt *et al.*, (2018) measured knee loading rather than pain and function. However, it emphasized FPA technique's clinical feasibility and potential economic benefits. In conclusion, future research has been suggested to explore the long-term effects of FPA techniques on KAM, to improve knee pain and function, as potential treatments for medial KOA.

- Walk training approaches:

Researchers have explored the influence of various walking techniques and foot positions on knee osteoarthritis (KOA). One significant focus of their investigations has been the relationship between the centre of pressure and KAM. Reilly *et al.*, 2009 & Hunt *et al.*, (2021) emphasized this connection. Their findings suggested that individuals with pronated feet exhibited lower KAM. Specifically, when the rear foot was shifted into pronation during the stance phase, there was a reduction in the KAM lever arm, which decreased the KAM (as noted by Kakihana *et al.*, 2005; Lidtke *et al.*, 2010). Even though changing the rear foot position lowers KAM, KOA sufferers need to adjust their stride constantly to keep decreasing KAM. In some KOA cases, this gait technique may be ineffective.

Alongside this, the role of footwear came under investigation. Regular shoes might exacerbate knee loading problems in KOA patients, potentially accelerating the condition's progression. Shakoor *et al.*, (2010) discussed how shoe height and flexibility influenced knee loading. In line with this, Kerrigan *et al.*, 2003 and Shakoor and Block. (2006) reported lower KAM during barefoot walking than when shoes were worn. Despite barefoot walking being beneficial in the short term, evidence to support its long-term benefits has yet to be published, particularly in randomised controlled trials (RCTs).

In another direction, there was an increasing interest in the benefits of backwards walking exercises (BWE) for enhancing balance and the lower limbs (Yang *et al.*, 2005; Hackney and Earhart, 2010). It was suggested that BWE complemented conventional KOA therapy by Gondhalekar and Deo. (2013). Thus, Zhang *et al.*, (2015) postulated that BWE could reduce KAM during exercises. However, individuals with KOA should take extra precautions when engaging in BWE training due to the increased risk of falling.

- Decreasing walking velocity, stride length and step width:

Walking places four times as much stress on the knees as body weight (Messier, *et al.*, 2005). A relationship between KOA and the distribution of force over the load-bearing surfaces of the tibiofemoral joint has been identified. Adults with KOA have shown higher peak KAM and a more significant KAM impulse than controls (Thorp *et al.*, 2007). These measures have been linked to the disease's progression (Miyazaki *et al.*, 2002; Kim L. Bennell *et al.*, 2011; Chang *et al.*, 2015). Since knee joint forces are influenced by internal and external muscle forces (Saxby *et al.*, 2016), they might not always represent the direct load on internal knee structures (Walter *et al.*, 2010). Musculoskeletal models have been employed to consider knee joint contact forces components. Moreover, studies have revealed that gait variables, such as step length and velocity, significantly impact these forces (Miller, Brandon and Deluzio, 2013; Haight *et al.*, 2014). Therefore, adjusting these aspects of gait (gait speed and stride length) are seen as a potential benefit for KOA treatment.

Additionally, temporal-spatial characteristics, including walking speed and stride length, have been associated with gait evaluations in KOA patients (Kaufman *et al.*, 2001; Mündermann *et al.*, 2004). Kaufman *et al.*, (2001) noted that individuals with severe KOA walked slower on flat surfaces and when descending and ascending stairs. A reduction in walking speed and stride length was believed to possibly decrease KAM (Mundermann *et al.*, 2004). Nevertheless, van den Noort *et al.*, (2013) found that walking slowly was linked to an increase (40%) in KAM at mid-stance and 28% with KAAI across all stances. Consequently, there was evidence that further research was needed to determine the therapeutic effects of gait alteration training (Clare E Milner *et al.*, 2018).

- Ipsilateral Trunks Lean & Medialising Knee:

During locomotion, many patients with medial KOA leaned ipsilaterally to alleviate symptoms. This inclination was closely linked to more significant disease severity (Mündermann *et al.*, 2008; Hunt *et al.*, 2010). As the body leaned this way, the centre of gravity shifted closer to the knee, effectively reducing the KAM lever arm (Hunt *et al.*, 2008a), (Figure 11). Remarkably, adopting self-induced lateral trunk tilt towards the stance leg can reduce the 1st peak in KAM by 65%. Furthermore, patients with medial compartment KOA showed greater spontaneously adopted lateral trunk lean angles, leading to notable KAM reduction (Hunt *et al.*, 2011; Simic *et al.*, 2012). However, while this approach held promise, long-term training in this movement had challenges. Risks such as increased chances of falls and other injuries such as to the hip and lumbar spine, and excessive loading of the lateral tibiofemoral compartment (Allum and Carpenter, 2005; Farrokhi *et al.*, 2013). Moreover, since this type of gait modification requires a lot of practice, some people with KOA may not be appropriate candidates (Allum and Carpenter, 2005).

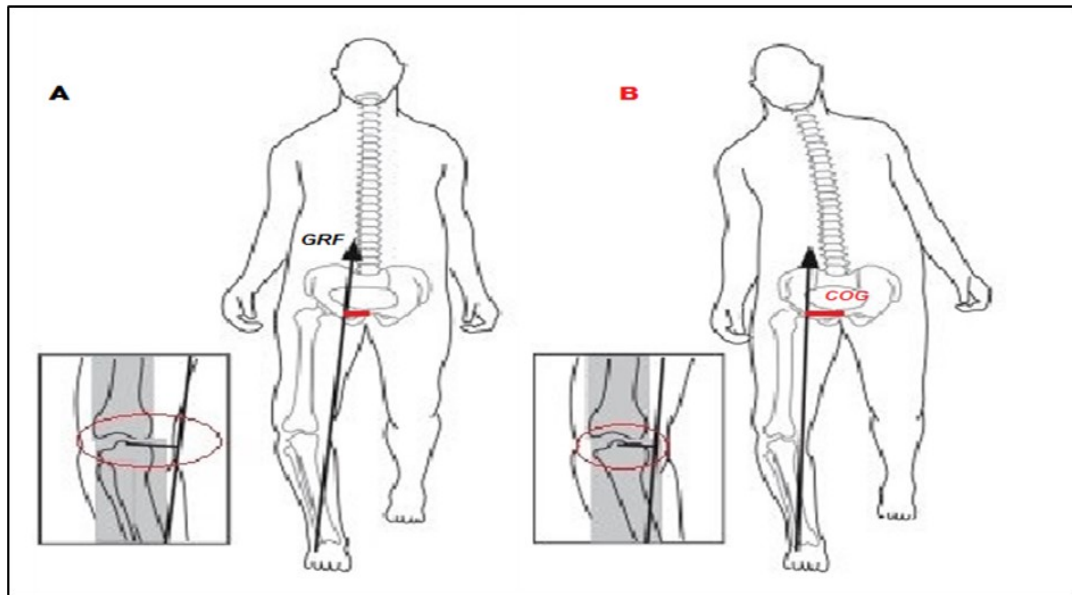


Figure 11: In (A): KAM is largely determined by the frontal plane GRF vector and the frontal plane lever arm distance. In (B): because of ipsilateral trunk lean leaning across the stance limb, the COG displaced laterally, resulting in a reduced KAM lever arm and a correspondingly reduced KAM magnitude. KAM= knee adduction moment, GRF= ground reaction force, COG= centre of gravity. (Hunt *et al.*, 2008).

In a related development, the focus on hip and ankle joints emerged as a potential strategy to decrease medial knee loading in KOA patients. The "medial knee thrust" or "knee medialisation" pattern was introduced to reduce KAM by prompting the knee to move medially (Fregly, D'Lima and Colwell, 2009; Fregly, 2012). Some studies documented notable KAM reductions. Modelling simulations of a single-subject patient with KOA predicted 50% reduction in KAM for the 1st peak and 55% for the 2nd peak (Fregly *et al.*, 2007). In another study of medial-thrust gait patterns trained using real-time knee alignment feedback, KAM was reduced by 19% after eight training sessions for eight participants (Barrios, Crossley and Davis, 2010). However, while these findings were promising, applying this method was challenging. Equipment requirements, and their varying efficacy for specific patient groups, raised concerns (Simic *et al.*, 2011).

Furthermore, when combining "knee medial thrust" with trunk lean, research suggested decreased KAM during walking (Gerbrands *et al.*, 2017). Emphasis was placed on the importance of individualised gait modification techniques to minimise dynamic knee stress during locomotion (Gerbrands *et al.*, 2017). Also, it is important to consider the effects of knee medial thrust's and knee medialisation's on hip abduction moments before implementing them

clinically. Nevertheless, it was clear that further investigations were imperative to fully understand these modifications, especially considering their relationship with hip moments and the progression of KOA (Kettlety *et al.*, 2020).

2.14.2 Assistive Gait Modification Approaches:

An aid tool, like a walking stick, was suggested to support gait modification techniques (Fregly, 2012). Studies indicated that LWI with subtalar strapping (Kuroyanagi *et al.*, 2007), LWI only (Kakihana *et al.*, 2005; Butler *et al.*, 2007; Thompson *et al.*, 2020), high mobility shoes (Shakoor *et al.*, 2008), variable stiffness shoes (Erhart *et al.*, 2008 & 2010; Trombini-Souza *et al.*, 2012), and valgus knee braces (NB) with three-point bending (Lindenfeld *et al.*, 1997; Draganich *et al.*, 2006) effectively reduced the KAM.

Moreover, Pereira *et al.* (2021) identified the most effective methods for reducing knee pain and improving function in patients with KOA: variable stiffness shoes, LWI and knee braces. However, the Pereira *et al.* (2021) review was limited by heterogeneity among studies, a need for more high-quality RCTs, short follow-up periods, and potential biases. Future research should aim for more standardised methodologies and longer follow-up periods to strengthen the evidence base.

- Knee brace:

Knee bracing (KB) has been demonstrated to be an effective biomechanical strategy for treating KOA. It shifts the strain from the middle to the lateral side, alleviating discomfort and enhancing performance (Ostrander *et al.*, 2016). Moreover, KB transfers joint stress and maintains a consistent position during movement (Birmingham *et al.*, 2001). This results in a reduction of KAM caused by a hinge that offers valgus alignment along with three-point force through straps (Figure 12).

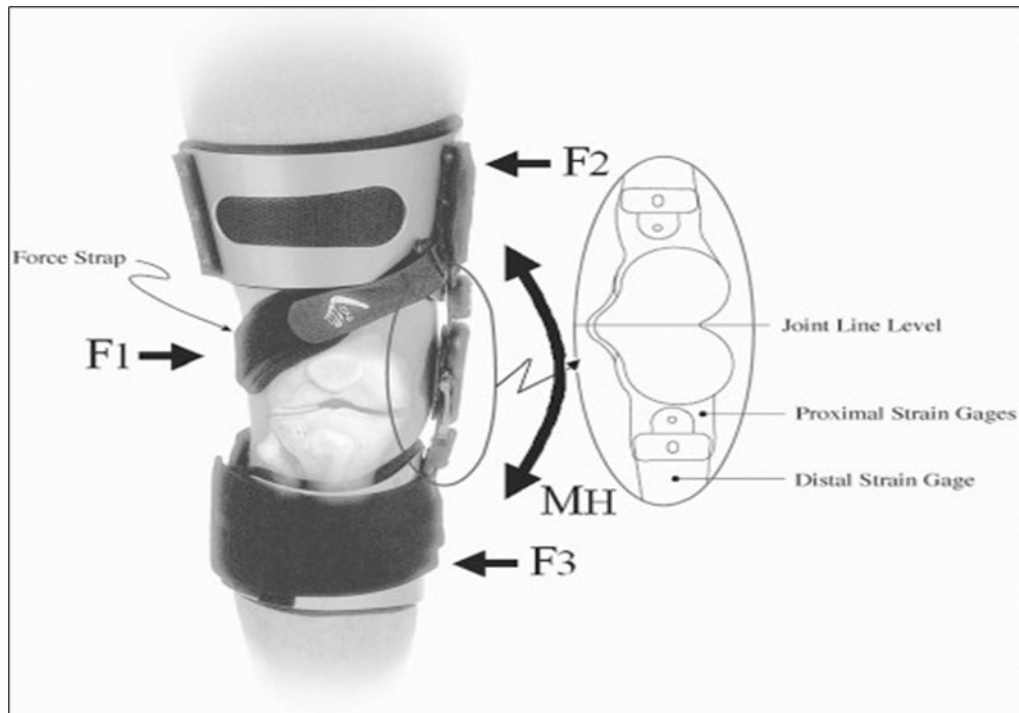


Figure 12: An upper and lower cuff support and a Dynamic Force Strap are applied to a KB (unloader brace) on a limb. The moment at the hinge (MH) represents the hinge's contribution to valgus moments. Three-point bending forces are produced by tension in the force trap, denoted by F1, F2, and F3 (Pollo *et al.*, 2002).

Numerous studies have investigated the use of KB for KOA management. According to past research (Matsuno, 1997; Draper *et al.*, 2000; Ramsey, *et al.*, 2007; Kapadia *et al.*, 2016), KB can improve function and alleviate pain in KOA patients. Specifically, Draper *et al.*, (2000) has shown that participants with KOA experienced an immediate improvement in function after the initial fitting. On the other hand, Ramsey *et al.*, (2007) discovered that KB could reduce knee pain, enhance joint function and stability. However, it was also recommended to reduce the contraction of muscles around the knee to maintain therapeutic effects without bracing.

In a biomechanical context, Kapadia *et al.*, (2016) reported that individuals with KOA who used KB for at least three hours daily for three months saw improvements in various gait parameters (knee extension at heel strike, total range of motion (ROM), walking speed, knee joint forces and knee flexion), suggesting its efficacy as a treatment option. In addition to its main benefits, Birmingham *et al.*, (2001) found that KB might also enhance postural control and proprioception for patients with KOA. Gaining insight into these mechanisms contributed to a better understanding of KB's role in KOA treatment.

While many studies, including those by Kapadia *et al.*, (2016), Ramsey *et al.*, (2007), Draper *et al.*, (2000), and Birmingham *et al.*, 2001, supported the pain-relieving and gait-improving properties of KB, more evidence was needed before making a conclusive recommendation. Despite its potential, discomfort and fitting issues have reduced adherence, potentially limiting KB's long-term success (Farrokhi *et al.*, 2013). Moreover, KB could reduce KOA symptoms by offloading and correcting alignment, but it was more expensive and heavier than other solutions like LWI (Raaij *et al.*, 2010).

- Insoles and Walking shoes:

The application of LWI to KOA management was first introduced by Sasaki and Yasuda, (1987) as a method for treating medial compartment KOA. Subsequently, it has gained attention as an affordable and non-invasive intervention. This intervention alleviated pain and reportedly enhanced the quality of life for those with KOA (Fang *et al.*, 2006; Jones, Zhang, *et al.*, 2013).

Furthermore, numerous studies have indicated that the LWI was pivotal in reducing the KAM. The LWI also reduces KAM (Fang *et al.*, 2006; Barrios *et al.*, 2009; Rafiaee and Karimi, 2012; Jones, *et al.*, 2013; Hatef *et al.*, 2014; Felson *et al.*, 2019), which is responsible for KOA onset and progression (Miyazaki *et al.*, 2002; Alshawabka *et al.*, 2014; Baert *et al.*, 2014; Yilmaz *et al.*, 2016). In managing KOA discomfort, LWI not only alleviates some associated pain (Fang *et al.*, 2006; Rafiaee and Karimi, 2012; Jones *et al.*, 2013; Hatef *et al.*, 2014), but some patients reported adverse side effects like ankle pain during walking.

On the other hand, research focused on walking shoes and their impact on KOA management has yielded varied results. Some specific shoe types, like variable stiffness shoes (Erhart *et al.*, 2010a) and those promoting prolonged use of minimal footwear (Trombini-Souza *et al.*, 2015), were found to have influenced KAM, pain and function. Conversely, other types, including rock-bottom or mobility shoes, were observed to have a limited impact on KAM (Gross *et al.*, 2016). Additionally, previous studies have demonstrated that walking shoes reduce KAM (Shakoor *et al.*, 2008; Erhart *et al.*, 2010a; Erhart *et al.*, 2010b; Erhart-Hledik *et al.*, 2012; Hinman *et al.*, 2012; Teoh *et al.*, 2013; Jones *et al.*, 2015).

A study by Shakoor *et al.*, (2008) determined that mobility footwear, closely similar to barefoot walking, reduced KAM in KOA patients. Haim *et al.*, (2012) also conducted an in-depth study on All Phases of Step-cycle (APOS) therapy shoes (Figure 13), and their findings over nine months were encouraging (1st & 2nd KAM with the KAAI all improved). Variable stiffness footwear emerged as a potential treatment option. Several studies, (including those by Erhart *et al.*, 2008; Erhart *et al.*, 2010a; Erhart *et al.*, 2010b; Jenkyn, Erhart & Andriacchi, 2011; Erhart-Hledik *et al.*, 2012), pointed to reductions in KAM peaks (13%) and their associated benefits. Moreover, clinical evidence has also shown that variable-stiffness shoes reduce knee pain and improve function after six and 12 months of continuous use (Erhart *et al.*, 2010b; Erhart-Hledik *et al.*, 2012). Wearing shoes with varied stiffness can help reduce symptoms and stress on the medial compartment during walking in those with KOA.

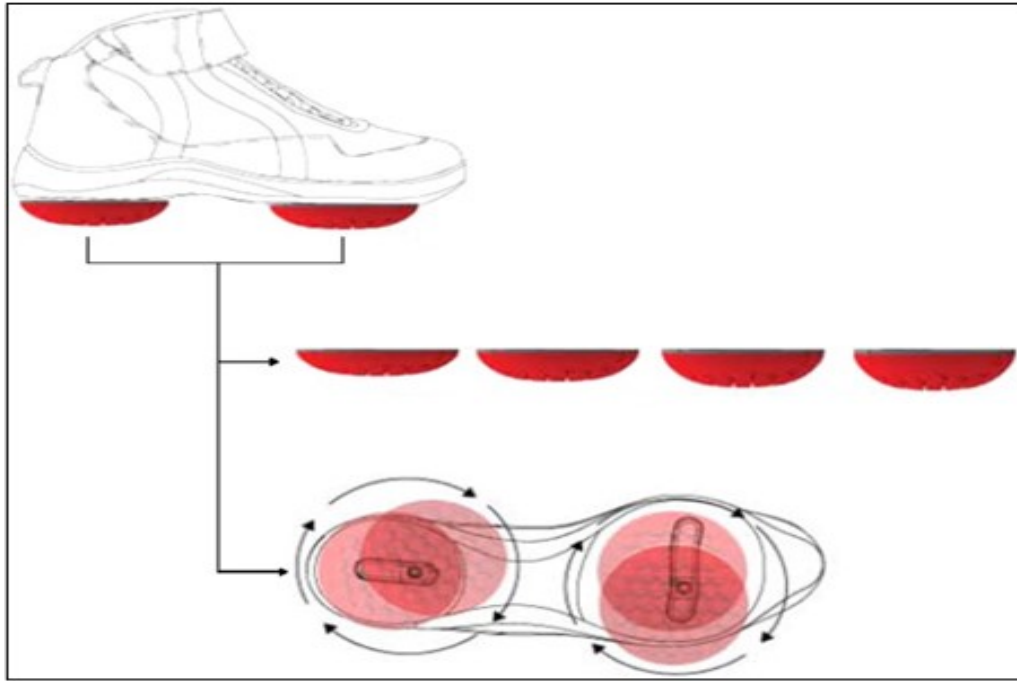


Figure 13: APOS therapy, is a biomechanical device worn on the foot that changes the COP and, consequently, the KAM. COP= centre of pressure, adapted from (Haim, *et al.*, 2012).

In terms of combined effect, Duivenvoorden *et al.*, (2015) noted that combining LWI and KB did not produce synergistic biomechanical effects for varus medial KOA subjects. Jones *et al.*, (2015) further indicated that while LWI successfully reduced KOA pain associated with medial knee loading, mobility shoes did not significantly impact. Interestingly, other findings, such as those from Metcalfe *et al.*, (2017), suggested limited benefits of medial arch support in unloading shoes.

2.15 Real-time biofeedback and gait modification:

Gait retraining with real-time biofeedback (RTB) was shown to reduce the 1st peak KAM in medial KOA patients immediately and in the short term. However, during subsequent follow-ups, some patients reported no sustained effects. This suggested that actively maintaining a changed gait pattern was essential (Richards *et al.*, 2018).

Research underscored RTB's effectiveness across different conditions. For instance, it benefitted those with strokes (Hegde *et al.*, 2015), cerebral palsy (van Gelder *et al.*, 2017), Parkinson's disease (Rabin *et al.*, 2013; Caudron *et al.*, 2014) and even amputee rehabilitation (Isakov, 2006; Crea *et*

al., 2014). Studies, such as those by Richards *et al.*, (2016) and Eddo *et al.*, (2017), investigated the influence of RTB on KAM reduction. Their findings indicated that using RTB alongside gait adjustments, such as knee medial thrust, medial weight shifting, trunk lean, toe-in, and toe-out, was influential in minimising KAM. Although the review of the studies predominantly utilised indirect feedback, other research focused on direct feedback based explicitly on KAM. Interestingly, these studies often reported even more significant KAM reductions (Wheeler *et al.*, 2011; Van den Noort *et al.*, 2015).

Additionally, when integrated with gait modifications like foot progression angle, RTB immediately reduced the 1st peak KAM after training sessions. Nonetheless, subsequent follow-ups sometimes revealed reduced effects. This observation emphasised the consistent effort needed to maintain altered gait patterns for lasting KAM reductions (Richards *et al.*, 2018).

While some studies established a correlation between knee loading during gait and symptom severity in KOA patients, the majority focused on indirect feedback mechanisms rather than direct KAM measurements, potentially limiting the precision of intervention outcomes. Studies by Wheeler *et al.* (2011) and Van den Noort *et al.* (2015) suggested that direct KAM feedback resulted in more substantial reductions in KAM. This discrepancy highlighted the need for a more standardised approach to feedback types in future research (Eddo *et al.*, 2017).

Moreover, while the benefits of RTB were documented, the long-term adherence and sustainability of these interventions remained unclear. The reviewed literature often lacked follow-up studies to assess whether reductions in KAM were maintained over time (Lindsey *et al.*, 2019).

Additionally, there was inconsistency in the effectiveness of various gait modifications and feedback modes. Eddo *et al.* (2017) found visual feedback more effective than auditory feedback, yet there was no consensus on the optimal combination of these strategies. This variability suggested a need for personalised intervention protocols based on individual biomechanics.

Forthcoming investigations should emphasise long-term follow-ups, standardised protocols, and integrating patient-reported outcomes to enhance

the clinical applicability of RTB-based gait modifications. While the potential of RTB in reducing KAM was promising, future studies should also focus on direct feedback mechanisms and personalised intervention strategies to improve the consistency and efficacy of RTB protocols.

2.16 Clinical obstacles & difficulties:

One of the challenges with learned gait changes was motivating individuals. Verbal prompting alone often proved insufficient. Previously, most research on gait modification primarily relied on verbal commands or explicit guidance to advise participants on how to adopt the changed gait style. For instance, tape on the floor to directed foot rotation (Podlipská *et al.*, 2017), while verbal instructions were used to teach medial knee thrust and trunk sway (Goldring *et al.*, 2010). As a result, the issue involves determining whether patients can implement and maintain a desired gait adjustment.

While many aided methods did result in modest improvements in KAM or medial contact force, their therapeutic significance remains questionable. Moreover, ensuring that patients use gait modification tools correctly is another challenge. To some patients, the relief from knee pain simply does not justify the discomfort from using an aid (Fregly, 2012). Additionally, there have been instances where individuals have self-prescribed aids without proper instruction, thereby risking exacerbating KAM issues (Van Der Esch, Heijmans and Dekker, 2003; Ajemian *et al.*, 2004).

Interestingly, alterations that have benefited the knee may negatively impact other joints, such as the ankle or lower back (Toriyama *et al.*, 2011). Furthermore, many studies missed important KAM measurement details, which complicated result comparisons (Fregly, 2012). The LWI, which were commonly recommended for KOA, had trials that indicated limited efficacy in symptom alleviation (Pham *et al.*, 2004; Baker *et al.*, 2007; Barrios *et al.*, 2009; Bennell *et al.*, 2011). There were also concerns that LWIs could cause discomfort inside the shoe (Bennell *et al.*, 2011). For many clinical applications, the accessibility of standard gait systems might make analysis prohibitive (Wilson and Kobsar, 2021). Even though 3D motion analysis-based

biofeedback devices can give comprehensive data, they are also prohibitively expensive (Hunt, 2012).

Real-time biofeedback (RTB) could improve KAM symptoms (Richards *et al.*, (2016; Eddo *et al.*, 2017). However, challenges persisted using RTB, and its effectiveness for broader applications, especially for early-stage KOA, which remained largely untested (S. Wang, Chan, *et al.*, 2021). As well, kinematics and kinetics data comparing conventional walking with slanted treadmill walking was also notably limited (Widhalm, Durstberger and Putz, 2021). These knowledge gaps must be addressed for gait biofeedback to be used effectively (Spencer, Wolf and Kesar, 2021).

2.17 Research aims and questions:

This study aims to evaluate the suitability and acceptance of gait modification strategies for reducing knee pain and enhancing functionality among KOA patients in Saudi Arabia. By include research approaches: a systematic review followed by mixed methods, encompassing a qualitative study and a feasibility study, this research intends to address the following questions:

- 1- How is the effectiveness of various gait modification strategies, including learning, assistive and combined approaches, in reducing knee biomechanical loading, pain and improving functional outcomes in KOA patients assessed by randomised controlled trials (RCT)?
- 2- How do chronic KOA patients and physiotherapists perceive gait modification?
- 3- How feasible is the implementation of LWI in a Saudi outpatient physiotherapy setting for KOA patients, and what are the associated challenges and facilitators in terms of recruitment, retention, adherence and satisfaction?

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction:

This chapter describes the mixed-methods framework that is used throughout the thesis and discusses the rationale for selecting and conducting a mixed-methods study. In addition, it discusses the pragmatist philosophy to provide an overview of the foundation and milestones for subsequent research and describes the theoretical concepts, underlying presumptions and conceptual framework that inform this study. For the researcher, these provided a roadmap for selecting appropriate techniques and methodologies as well as developing the study topic. A description of the mixed-methods framework is presented at the beginning of this chapter.

3.2 Overview of the PhD Studies:

This PhD research comprised a series of studies evaluating the effectiveness of various gait modification strategies for individuals with KOA. The studies were organised into different phases, each aiming to address and evaluate specific aspects of the gait modification intervention.

- **Systematic Review and Meta-Analysis (Chapter 4):**

The initial phase involved a systematic review and meta-analysis to investigate the impact of different gait modification approaches on knee biomechanical loading, pain, and functional outcomes in patients with KOA. This review generated evidence-based recommendations for future gait modification strategies and research designs. **Objective:** To evaluate the effectiveness of various gait modification techniques, including learned, assistive and combined methods, in reducing knee loading and improving pain and function.

- **Qualitative Study (Chapter 5):**

The second phase examined the perceptions and acceptability of gait modification strategies among Saudi Arabian KOA patients and physiotherapists. This qualitative study aimed to understand both groups' awareness, expectations and preferences regarding gait modification

treatments with KOA. **Objective:** To investigate the acceptance and perceived benefits of gait modification strategies in KOA rehabilitation from the perspectives of KOA patients and physiotherapists in SA.

- **Proposed Lateral Wedge Insole as Intervention (Chapter 6):**

Based on the findings of previous studies (both systematic reviews and qualitative research), which provided limited and general insights into the appropriate intervention, and considering the logical justifications presented in Chapter 6, this phase focused on the rationale for selecting lateral wedge insoles (LWI) as a gait modification intervention. This section also examined the biomechanical and clinical effects of LWI on knee loading, pain, and function.

- **Objective:** To present a rationale and justify the selection of LWI as a suitable gait modification intervention based on biomechanical effects on knee loading, pain and function, systematic review findings and qualitative feedback.
- **Justifications:** (a) The SR indicated that most gait modification methods did not significantly impact the KAM 1st peak. However, re-gait training with toe-out techniques and lateral stiffener shoes showed promise in improving knee loading. While LWI demonstrated potential benefits in reducing the KAM 2nd peak and KAAI, though its overall effectiveness in reducing knee loading was limited. (b) The qualitative study supported the acceptability of insoles among patients with KOA and physiotherapists in SA. Besides other preferred assistive gait modifications such as canes, knee braces and specialised footwear, participants noted that insoles, in general, were a practical, non-invasive and easy-to-implement option for managing KOA symptoms. (c) Logistical and financial challenges, such as the availability of specialised wedged footwear and customised knee braces, were significant hindering factors in choosing LWI. However, the availability of 'Salford LWI' from local UK companies, the University of Nottingham bench fees

for the PhD candidate, and the feasibility of shipping them to Saudi Arabia further supported this choice.

- **Feasibility Study (Chapter 7):**

The final phase assessed the feasibility and acceptability of implementing the LWI intervention in a physiotherapy outpatient setting in SA. This study aimed to determine recruitment, retention, adherence, and the potential impact of LWI on knee pain and function over six weeks. **Objective:** To evaluate the feasible and practical implementation of LWI in a Saudi physiotherapy outpatient setting and assess its acceptability and impact on knee KOA pain and function.

3.3 Mixed-methods Frameworks:

In the Medical Research Council (MRC) framework for developing complex interventions, Craig *et al.*, (2013) highlights the need for defined research methodologies and the importance of understanding processes when assessing or designing treatments. Creswell, (2018) stated that at its core, mixed methods research requires at least one qualitative and one quantitative approach within a research project to be termed as employing mixed methods. This methodology has become the method of choice for numerous experts and scholars across various disciplines (Creswell, 2018). Relying exclusively on a quantitative study during the research process might have addressed only some research queries, and in contrast, a quantitative study would have been suited for specific research questions. Incorporating a qualitative approach in the research proved beneficial as it allowed for exploring personal experiences, societal circumstances and the factors shaping perceptions (Gelling, 2015).

A qualitative technique was commonly used to assess the extent to which an intervention needed adjustment, identify effective recruitment tactics, recognize facilitators and barriers, provide feedback, describe outcomes, understand an intervention's process, assess fidelity to the treatment protocol and address aspects of real-world implementation (Gitlin, 2016). Regarding the generalisability of findings, the primary objective of using a qualitative approach was not to generalize the results. Instead, it aimed to provide deeper

insight into specific experiential aspects by exploring unique situations in-depth, leading to rich data (Polit and Beck, 2010). Such a methodology could be employed at the onset, during evaluation, or after the completion of follow-up or assessment.

On the other hand, collection of numerical data is the primary emphasis of a quantitative investigation. The initial advantage of this research strategy was using statistical data as a timesaving and resource-efficient tool. As noted by Bryman (2012), quantitative research methods prioritised numbers in data collection and analysis. In addition, statistical tools such as SPSS) in quantitative research allow for establishing connections, hypothesis testing and prediction, as Field (2018) highlighted. This approach was often viewed as scientific due to the reliance on statistical data; the researcher spent fewer resources elaborating on their findings. Such a methodology facilitated generalisation using scientific techniques (Eyisi, 2016).

Furthermore, due to its structured nature, quantitative research could easily be replicated, ensuring consistent results across studies (Lichtman, 2013). Moreover, having clear objectives and guidelines, research using this method could be duplicated elsewhere, yielding consistent outcomes (Shank & Brown, 2007, p. 27). Lastly, structured data collection in quantitative research minimised bias risks (Creswell, 2018).

In the evidence-based intervention research, evaluation and testing phases, the use of mixed methods was found to be advantageous. Unlike the traditional "does it work?" question, participating in a mixed-methods study allows a researcher to answer, "why does it work?" and "how does it work?" while conducting a trial. This was achieved by using mixed methods that complemented each other. John W. Creswell, (2018) previously described various mixed methods designs. These included convergent, explanatory sequential and exploratory sequential designs. Figure 14 is based on comparing these commonly used mixed methods designs.

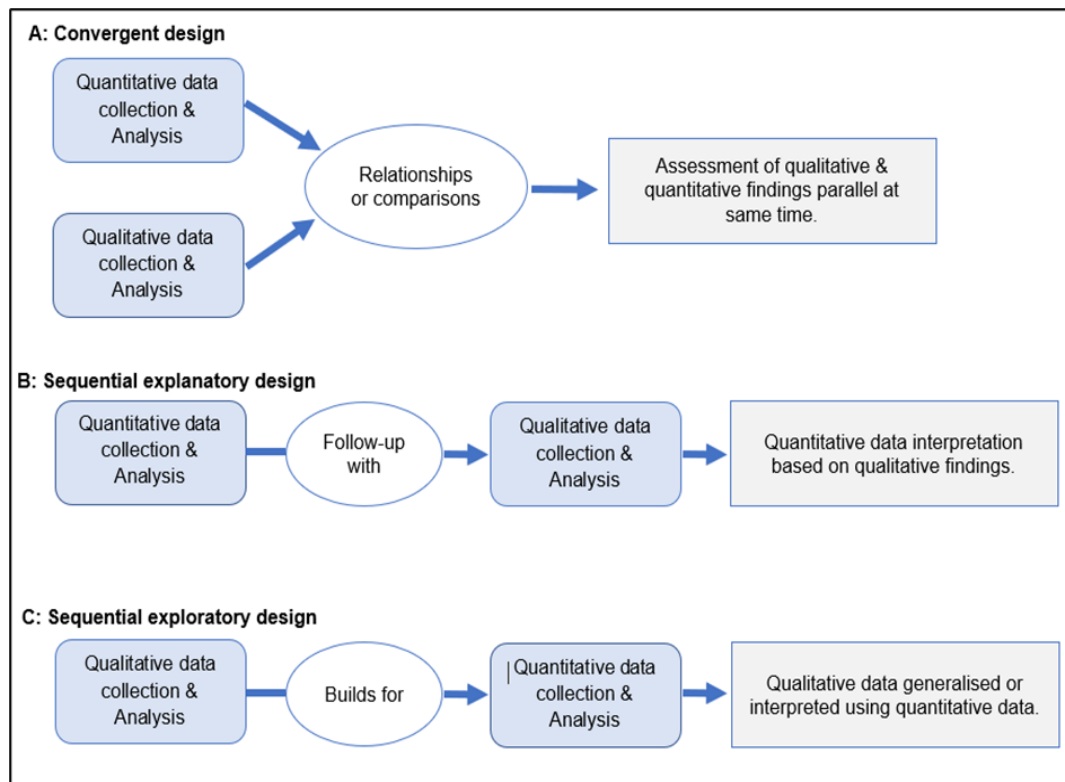


Figure 14: Types of Mixed-Methods Research Designs According to (Creswell, 2018)

In the sequential explanatory design, quantitative data are initially collected and analysed. This is followed by a qualitative phase aimed at constructing explanations. Notably, the qualitative method delves into the quantitative results, ensuring a more profound understanding before making interpretations (Creswell, 2018). Conversely, the exploratory sequential design begins with a qualitative phase, transitioning next to quantitative methods. This method proves invaluable when exploring phenomena with limited available quantitative measurements. Insights derived from the qualitative phase can guide the creation or modification of treatments, which are subsequently analysed quantitatively (Creswell, 2018).

Additionally, the convergent mixed-methods design stands as another integral design in the realm of mixed research. This paradigm gathers and evaluates data using quantitative and qualitative methods, potentially concurrently. The data sets from both methods are juxtaposed, enriching interpretations. This is achieved by translating qualitative data into quantitative numerical values. Crucially, when selecting an ideal design for a study, a

researcher must possess clarity regarding the amalgamation of methods, their sequence, and the anticipated outcomes (Lipscomb, 2008).

Following the completion of the qualitative data collection and analysis, the MRC framework (2013) dictates progressing to the quantitative data collection and analysis. In alignment with this, the sequential exploratory design, deemed most fitting, underpins the entire study within this thesis.

3.4 Exploratory sequential design used in this thesis:

This thesis employed the exploratory sequential design to examine appropriate and well received gait modification techniques among KOA patients and physiotherapists. Initially, perspective data from KOA subjects and physiotherapists regarding various gait modifications were gathered through qualitative techniques, and subsequently, the results of this data were analysed. Based on these findings, decisions were made regarding the selection or adaptation of the intervention, leading to the execution of a feasibility experimental study. The guidelines (Creswell, 2018) set forth were followed throughout this process:

- i. Qualitative (KOA subjects and therapists) perspective data related to general gait modification use were gathered and analysed.
- ii. Data from the qualitative analysis, particularly themes related to gait modification usage and feedback, were reviewed and evaluated. These findings were then integrated to refine the gait modification design, enhance its quantitative aspects, and determine outcome measurements.
- iii. The feasibility of the quantitative metrics related to gait modification effectiveness was considered. This included determining the intervention's feasibility and acceptability for pre- and post-test measurements based on user comfort and performance.
- iv. Describe how the proposed gait intervention benefited from the insights and feedback from the qualitative study.

Systematic Review and Meta-Analysis Context: The systematic review and meta-analysis analysed randomised controlled trials (RCTs) to investigate the impact of various gait modification approaches (learned, assistive) on biomechanical knee loading, pain and function with KOA individuals. This review was conducted as part of the Development phase of the MRC framework to identify an evidence base for the intervention. The objective was to create evidence-based recommendations to inform future gait modification approaches and research designs.

In the design detailed by Creswell & Plano Clark (2018), three key stages were identified. The first stage involved finding an evidence-based intervention strategy for assessment in the non-surgical biomechanical context. This stage was outlined in Chapter 4 (Systematic review & Meta-analysis) and corresponded to Phase 1.

The second and third phases, which were quantitative, followed the initial qualitative phase. However, in this research, those stages were divided into two to align with the MRC recommendations, as shown in Figure 15, but the selection methods remained the same.

Given that patients with KOA in SA are understudied, the initial phase of this research aimed to explore the phenomenon using a qualitative approach. While there was limited knowledge about the challenges in KOA care in SA, implementing the LWI gait modification programme aimed to shed light on patients' perspectives. This was further discussed in Chapter 5 (Qualitative study), detailing the methods used.

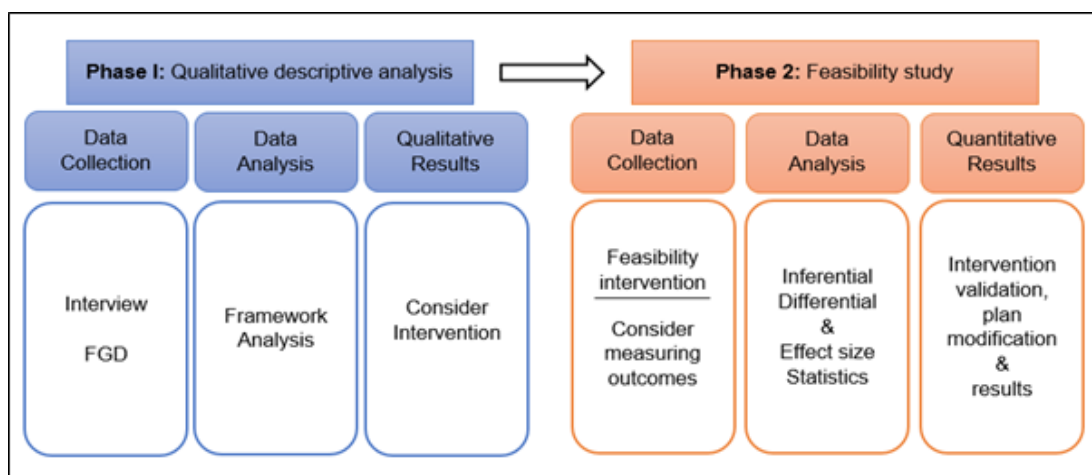


Figure 15: A sequential exploratory design adapted from (Creswell, 2018) and MRC guidelines (2013).

Specific quotations from the participants were obtained through the qualitative data collection. In qualitative research, the researcher acted as the instrument for data collection. Consequently, the researcher might have unconsciously or intentionally influenced how the data was collected and analysed (Baillie, 2015). Moreover, this design was the most intricate among the three basic designs, as it took more time than the explanatory and convergent sequential methods (Creswell, 2018). Figure 16 overviews the fundamental techniques involved in a sequential exploratory research design.

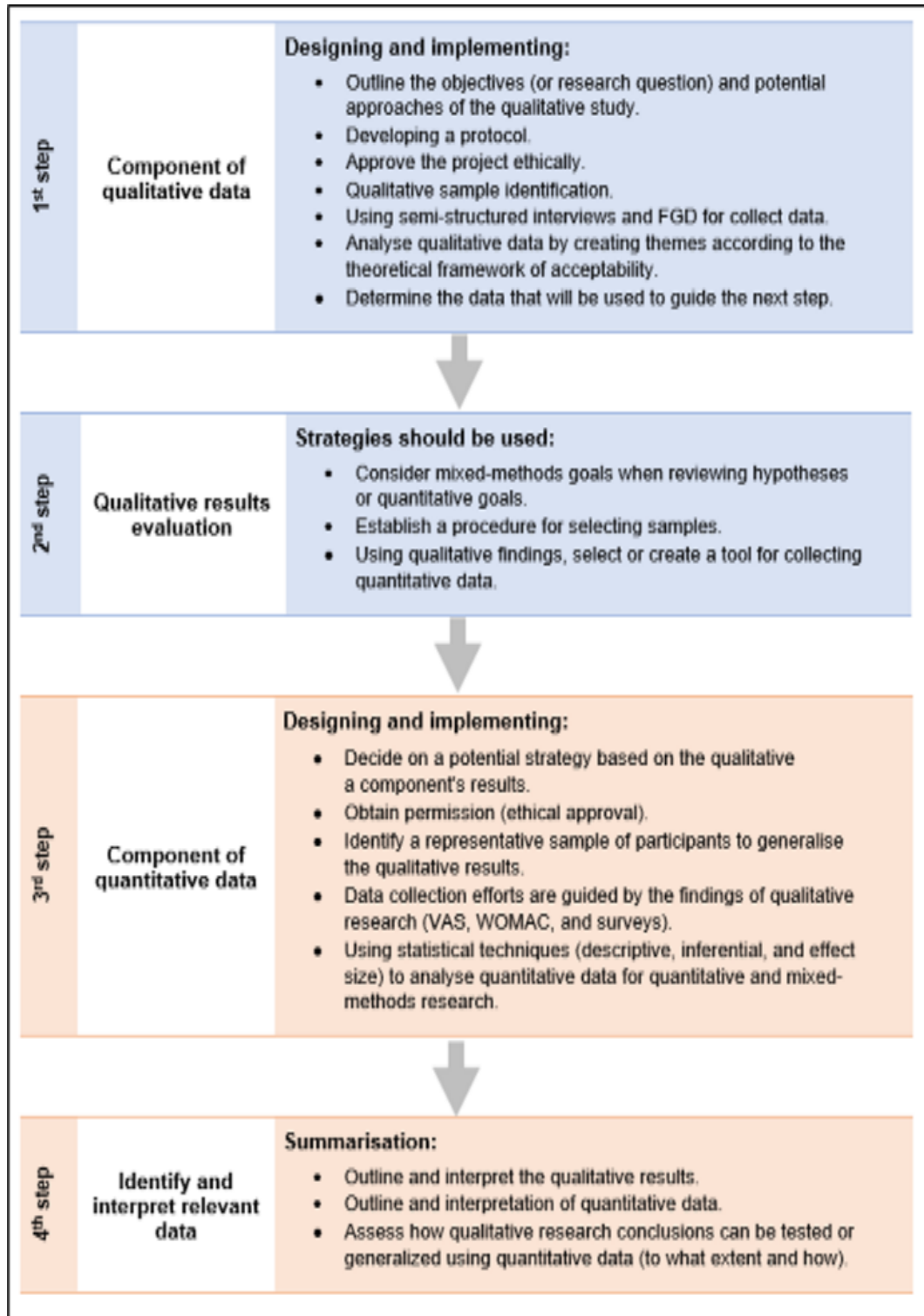


Figure 16: The fundamental steps of exploratory sequential design (Creswell, 2021).

3.5 Theoretical Framework for Qualitative Studies:

- **Rationale for the design:**

The study was part of an interpretive research paradigm which utilised individual experiences to explain the significance of phenomena (phenomenology) (Liamputtong, 2005). The phenomena of interest included the daily challenges faced by KOA patients and physiotherapists, their interactions with treatment options, and their perceptions of gait modification as a therapeutic intervention. This qualitative study comprised semi-structured face-to-face interviews with osteoarthritic knee patients and a focus group discussion (FGD) with physiotherapists. Through this qualitative approach, participants expressed opinions which informed a tailored gait modification intervention for the subsequent feasibility study phase. Qualitative methods were frequently employed in mixed-methods studies for a thorough understanding (Kroll *et al.*, 2005; Moffatt *et al.*, 2006).

In qualitative research, individual interviews (Wengraf, 2001) and focus groups (Sim, 1998; Morgan, 2012) were common. The chosen techniques allowed for an in-depth evaluation of participant characteristics, an understanding of their KOA experiences, insights into facilitators and barriers against treatments like gait modification (Ritchie and Lewis, 2003).

In this study, a phenomenological approach was applied to understand the lived experiences of KOA patients and their interactions with gait modification interventions. The aim was to explore their broader experiences and perceptions of KOA rather than their prior knowledge of the specific intervention. This methodology was consistent with similar phenomenological studies, which aimed to describe and interpret the lived experiences of individuals regarding a specific phenomenon (Buxton and Snethen, 2013).

Furthermore, some participants might have found it challenging to discuss sensitive topics in group settings, such as their attitudes and barriers towards gait modification treatments (Barbour and Kitzinger, 1999). FGDs enabled participants to explore deeply into their ideas (Kitzinger, 1995) and were believed to yield more information than individual interviews. FGDs were also instrumental in developing health interventions and can contribute to

creating health interventions, evaluating intervention materials in advance, and determining acceptable delivery methods for interventions (Ayala & Elder, 2011). However, FGDs demanded more resources (Thomas *et al.*, 1995). Hence, face-to-face interviews and FGDs were deemed suitable for this phase of the mixed-method approach.

- **Theoretical Framework of Acceptability (TFA):**

Three publications by MRC have guided best practices for developing and evaluating complex treatments (Craig *et al.*, 2008; Moore *et al.*, 2015; Skivington *et al.*, 2021). The increasing references to treatment acceptability in these documents highlight its growing importance. However, defining acceptability proves challenging. For instance, some define it as how an intervention is perceived by its audience and how it fits in their organisational context (Green & Kreuter, 1999; Steckler *et al.*, 2002), whereas Staniszewska *et al.*, (2010) relates it to "patients' assessment of the acceptability, suitability, adequacy or effectiveness of care and treatment". Treatment acceptability is further influenced by patients' pre-intervention attitudes and the intervention's alignment with their lifestyle (Sidani *et al.*, 2009). Numerous definitions like "treatment acceptability" (Tarrier *et al.*, 2006; Becker *et al.*, 2007; Sidani *et al.*, 2009) and "social acceptability" (Staniszewska *et al.*, 2010; Dillip *et al.*, 2012), reflect the diverse perspectives, underscoring the need to measure acceptability in healthcare intervention design and implementation.

Healthcare interventions, being complex (Sekhon *et al.*, 2017; 2022), often present challenges for developers who aim for resource efficiency and optimal results (Torgerson *et al.*, 1995; Say & Thomson, 2003). While an intervention's acceptability to receivers is crucial, it alone does not guarantee effectiveness (Sekhon *et al.*, 2017). Successful implementation requires acceptability to providers and recipients (Diepeveen *et al.*, 2013). However, reduced acceptability might compromise delivery, affecting overall effectiveness (Borrelli *et al.*, 2005; Proctor *et al.*, 2009). Various factors might shape a patient's perception of an intervention's appropriateness (e.g., content, setting and quality of care). Patients are more likely to adhere to medical advice if it is deemed acceptable, improving health outcomes (Fisher *et al.*, 2006; Hommel *et al.*, 2013).

The acceptability of an intervention can be gauged through the TFA by considering both providers' and recipients' viewpoints across different involvement stages; before, during and after intervention (Sekhon *et al.*, 2017; 2018). The TFA captures the extent to which providers and patients view an intervention as suitable, factoring in various acceptability types (Sekhon *et al.*, 2017). As per MRC guidance, interventions undergo several stages: development, feasibility, evaluation and implementation. Questionnaires or interview methods might pinpoint acceptability issues in specific contexts (Craig *et al.*, 2008; Moore *et al.*, 2015; Skivington *et al.*, 2021). The TFA's diverse conceptual categories made it ideal for this study to explore perceptions, understand intervention acceptability and tailor the intervention to the Saudi healthcare system. The TFA also holds the potential to refine acceptability evaluation in healthcare, benefiting the broader research community (Sekhon *et al.*, 2017). Figure (17).

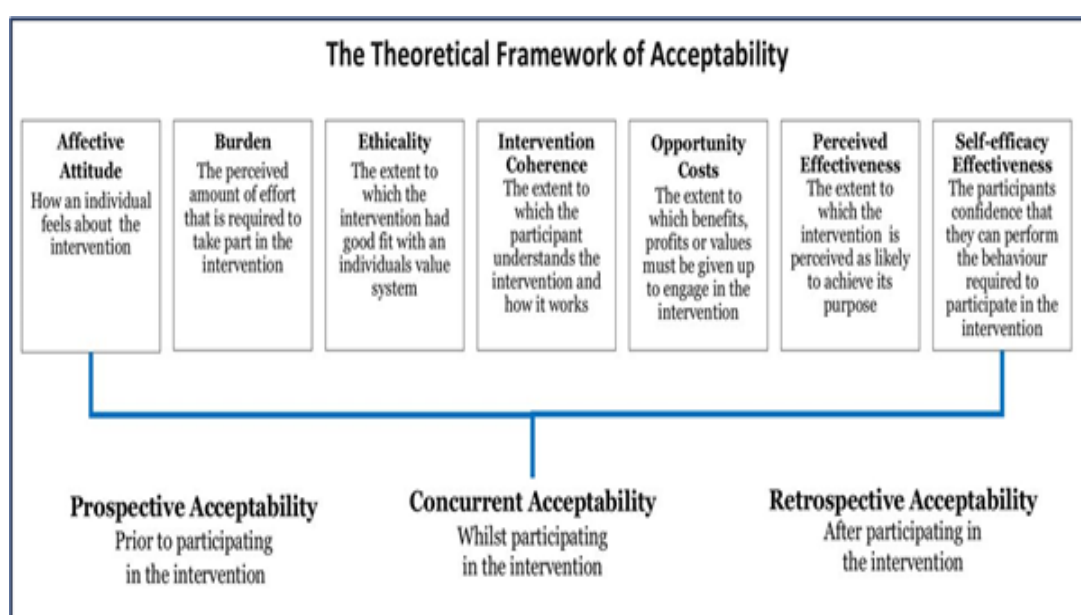


Figure 17: Acceptability framework constructs. Adapted from Sekhon *et al.*, (2017) with permission.

3.5.1 Rationale and explanation:

Combining different approaches may be challenging (Creswell, 2018). Therefore, the general framework helped conceptualise the objective and rationale behind the method combination. Several models exist for incorporating mixed-methods data (Cameron, 2011). Moreover, the framework by Greene, Caracelli and Graham, (1989) benefited a beginning researcher.

Many scholars appreciate its clarity and comprehensiveness (Creswell & Plano Clark, 2018). Table 3 describes the five-point structure that may be used to explain the reason for selecting mixed-methods research.

Table 3: The goals of mixed methods research (Greene, Caracelli and Graham, 1989).

Design	Objective
Triangulation	Identify confirmation (validation), agreement (correspondence), and convergence (merging) of results collected by various methodologies.
Complementarity	The objective is to describe, illustrate, clarify and enhance the findings of one method by referencing the conclusions of another.
Development	To improve the effectiveness of one method by utilising the results of another. The development concept encompasses elements like sampling, intervention and measurement.
Initiation	Identifying contradictions and disagreements, formulating innovative frameworks, and reshaping topics or outcomes from one method in light of issues or conclusions from another.
Expansion	The intent is to broaden the examination of a range of phenomena by employing diverse approaches.

The study questions and goals were determined to be best addressed by using this inquiry approach and were considered the most acceptable method. For this purpose, the study enrolled KOA participants into a single pre- and post-test group. Creswell, (2022) suggested that when there is a gap in knowledge about a phenomenon (proper gait modification awareness and acceptability), a quantitative experimental pre- and post-test study can fill this shortage.

WP1: Systematic Review and Meta-Analysis (Chapter 4): A systematic review and meta-analysis investigated the impact of various gait modification approaches on biomechanical knee loading, pain, and function in individuals with chronic knee osteoarthritis (KOA). The objective was to generate evidence-based recommendations to inform the development of future gait modification approaches and research designs.

WP2: Qualitative Study (Chapter 5): Following the systematic review and meta-analysis, a qualitative study was conducted to explore the perspectives of KOA patients and physiotherapists in SA regarding managing

gait modifications. This phase highlighted differing opinions on which gait modifications to offer and the differences between KOA patients and physiotherapists. The study found that assistive gait modifications, particularly footwear and insoles, were acceptable and recommended for more extensive trial evaluation.

WP3: Proposed Intervention (Chapter 6): This chapter presents the rationale for selecting the lateral wedge insole (LWI) as the proposed intervention. The justification was based on evidence from the previous chapters and practical considerations (For more details, refer to Chapter 6, section 6.3.), aimed at addressing the knee loading and symptoms (pain and function) of KOA patients.

WP4: Feasibility Study (Chapter 7): The feasibility study utilized a mixed-methods, single-centre approach with an embedded survey questionnaire to assess the acceptability of the LWI intervention for symptomatic KOA subjects in SA. This phase included a pre-and post-test group design, assessing outcomes such as NRPS, WOMAC, and Likert scale results. The survey questionnaire was developed based on findings from Chapters 4 and 5.

This structured approach, involving a systematic review, qualitative study, proposed intervention and feasibility study, ensured a comprehensive examination of the research question. The emergent mixed-methods design provided an in-depth perspective on the challenges and acceptability of gait modification within the KOA patient population in the SA healthcare system.

3.5.2 A mixed-methods study's applicability:

Formulating a comprehensive research topic (in-depth analysis of a particular gait intervention) facilitates better analysis and provides a rationale for combining methodologies (Teddlie, 2009). This study assessed the LWI's acceptability as a gait modification programme for KOA in SA. Utilising the MRC framework Craig *et al.*, (2013) and Greene, Caracelli and Graham's (1989) purpose design, the findings were presented in Table 4.

Table 4: Based on Greene, Caracelli and Graham (1989), the purposes of design.

Study Design	Objective of design
Evidence base identification	
Assessing the optimal gait biomechanical intervention programme for patients with KOA through a systematic study.	Complementation
1st Phase (Qualitative study)	
Analysed patient and physiotherapist perspectives about the gait modification programme based on semi-structured interviews and FGD.	The triangulation processes. The initiation
Creating, selecting, and delivering the appropriate materials for the modified gait intervention.	The initiation Selection or developing
2nd phase (Quantitative study)	
Assessing the feasibility and acceptability of selected gait modifications for recommendations and larger trials.	Complementarity Expanding

Table 4 shows the research process's two primary stages which complemented each other, using findings from studies with a single assessment method to offer evidence. It started with a systematic review and meta-analysis of multiple gait modification approaches for KOA patients. In the qualitative phase, discussions centred on the gait modification approaches with KOA patients, complemented by a FGD session with physiotherapists. Insights from these qualitative dialogues subsequently determined the gait intervention (LWI), identifying aspects like the content (outcomes concerned) delivery of the selected LWI under factors such as availability, application, adverse effect and duration of use. Additionally, this analysis revealed the relationships and differences found in the respondents' viewpoints.

The ensuing feasibility phase examined the acceptability of the LWI intervention among KOA patients and physiotherapists in SA, with a keen focus on feasibility metrics such as recruitment rate, retention rate, adherence to the intervention and treatment fidelity.

Treatment fidelity was ensured through multiple strategies. Pre-study preparation included discussing feasibility aims, establishing patient inclusion and exclusion criteria, and introducing the study's forms and outcome tools. Consistent screening, consent procedures and regular monitoring were

maintained. Clinicians followed a structured protocol for fitting and instructing LWI use, while participant adherence was supported through follow-up visits and surveys. Feedback from both participants and therapists was collected to ensure consistent implementation and promptly address any deviations. Please see section "7.3.7 Procedure" in Chapter 7 for more details.

Considering the MRC's (2013) guidelines, an additional Likert scale survey was conducted to assess participants' subjective experiences and perceptions of the intervention. This survey aimed to collect subjective feedback by measuring participants' satisfaction with the LWI as a preferred gait modification. The satisfaction levels were then presented as percentages and a median to indicate the degree of satisfaction. Furthermore, this feasibility study examined the clinical acceptance and adaptability of LWI as a preferred gait modification. More comprehensive findings are set to be elaborated on in subsequent sections.

3.6 Philosophical basis of this thesis:

Values or beliefs play a pivotal role in implementing a study. In this context, mixed-methods research should possess an underlying philosophy to effectively guide its quantitative and qualitative methodologies (Giddings and Grant, 2014). Researchers chose a specific philosophical approach based on the requirements and objectives of their projects. For example, pragmatism was often chosen to focus on practical solutions and outcomes. In contrast, dialectical pluralism emphasises the integration of multiple perspectives, while others might prefer dialectical pluralism or critical realism (Creswell, 2022).

Both critical realism and pragmatism have been observed to influence research similarly (Christ, 2013). Table 5 compares these three distinct philosophical approaches utilised in mixed-methods research for a deeper understanding. It is noteworthy that pragmatism, by its definition, emphasises "what works" within the realm of research (Teddlie and Tashakkori, 2009).

This research chose to favour pragmatism over dialectic pluralism or critical realism, due to its inherent ability to solve problems. Additionally, individuals who cannot tolerate divergence from qualitative or quantitative

research can only view them as mutually exclusive from the standpoint of traditional pragmatism (Florczak, 2014).

Table 5: Matrix of worldview drawn from Christ (2013).

Worldview	Pragmatism	Critical realism	Dialectic pluralism
Ontology <i>Reality (representation of what "exists").</i>	Many realities exist, with a focus on what works.	Several realities. Objectively (independent of human comprehension) and subjectively (identified and grasped when meaning is constructed).	The interrelationships between objective, subjective, and intersubjective realities.
Epistemology <i>A knowledge theory is derived from various domains. The analysing of data is influenced by research topics, objectives, and data sources.</i>	Researchers can combine etic and emic ideas into one study. Taking all the information from the study and combining and comparing it will improve its reliability.	Objectivity can be defined in various ways, but finding the absolute truth about social phenomena is impossible.	Several distinct types of views (e.g. differences, agreement, conflict and balance).
Axiology <i>The value of research. Conducting studies based on efficacy values.</i>	Insights into the importance of research. Conducting research based on effectiveness metrics.	The world view of researchers influences how knowledge is categorized, graded, shifted, and given meaning. The identification of representative reality is based on a variety of data sources.	Identify various moral precepts and incorporate them into each study's ethical theory.
Methodology <i>The research methods implementation.</i>	Various quantitative and qualitative data types are combined in a mixed-method approach to creating a representative model.	In conceptualizations, "objective" and "subjective" facts are interpreted and created through retrodiction and abduction.	A research study should be: a) examined for its methods. b) examined for its intended conclusions.

The overarching objective of this thesis is to devise a solution without sacrificing rigour and logic in advancing the general common good of all individuals. As elucidated by Creswell (2022), pragmatism consistently seeks the most optimal approach tailored to specific circumstances. Ensuring that such a pragmatic approach is consistently applied throughout the investigative process is paramount.

Adopting a pragmatic stance becomes justifiable when the intricate interconnections between both methodologies are well comprehended. However, any attempt to combine these methods without this detailed understanding might inadvertently introduce incoherence (Lipscomb, 2008). Unlike methods based on hypothetical scenarios, a pragmatic approach offers an assessment grounded in real-world contexts (Glasgow, 2013). As a result, it provides a more accurate picture of how a specific intervention will function in actual practice. Further, it might help direct judgements about practice in the therapeutic environment by amassing comprehensive data about phenomena due to the approach's pragmatism or practicality (Giddings & Grant, 2014).

3.7 Summary:

Adopting a mixed-methods approach, as highlighted in the MRC framework and guidance (2013), is deemed appropriate for evaluating the gait modification programme (LWI) for KOA patients in SA. By integrating both qualitative and quantitative research methods, greater accuracy is achieved. The qualitative component comprised semi-structured interviews with KOA patients and a FGD with physiotherapists. These methods facilitated a deep understanding of participant characteristics, their experiences with KOA, and their perspectives on treatments such as gait modification. While individual interviews were standard in qualitative research, focus groups often provided more depth, especially in exploring attitudes and barriers to treatments. Combining these methodologies provides comprehensive data on KOA patients' and physiotherapists' perspectives on gait modification in general and evaluating LWI acceptability and feasibility. This mixed-methods phase required both methodologies.

CHAPTER 4

SYSTEMATIC REVIEW & META- ANALYSIS

Evaluating the effectiveness of Gait Modification Strategies on Knee Biomechanical Loading, Pain and Functional Outcomes in Patients with Knee Osteoarthritis: A Systematic Review and Meta-Analysis of Randomised Controlled Trials.

4.1 Summary:

In this chapter, a systematic review (SR) and meta-analysis (MA) investigated the impact of various gait modification approaches on biomechanical knee loading, pain, and function in individuals with chronic knee osteoarthritis (KOA). Consequently, the objective is to generate evidence-based recommendations intervention informing the development of future gait modification approaches and research designs.

4.2 Background:

According to the Fregley et al. (2012) several gait modification programs are available, the KOA patient can used assistive approaches to modify their gait such as knee brace (Kapadia *et al.*, 2016), insoles such as LWI and medial arch insole (Jones *et al.*, 2015; T Duivenvoorden *et al.*, 2015), variable-stiffness footwear (Erhart, *et al.*, 2010a; Trombini-Souza *et al.*, 2012a; Elspas *et al.*, 2012; Goldenstein-Schainberg *et al.*, 2013; Trombini-Souza *et al.*, 2015), either by learned approaches to walk differently such as adjusting FPA (Reinbolt *et al.*, 2008; Shull *et al.*, 2013b; Simic *et al.*, 2013; Whelton *et al.*, 2017; Hunt *et al.*, 2018), increased stance width (Fregly, Reinbolt and Chmielewski, 2008; R. Richards *et al.*, 2018), gait velocity (Robbins and Maly, 2009; Clare E. Milner *et al.*, 2018), knee medialising (Barrios, Crossley and Davis, 2010; Walter *et al.*, 2010) and trunk lean gait (Hunt *et al.*, 2008b; Mündermann *et al.*, 2008; Simic *et al.*, 2012; Tokuda *et al.*, 2018) which are proposed as gait modifications intended to treat KAM, improve knee pain and enhance knee function.

1.4.1 Learned gait modification approaches:

In 24 studies, 14 multiple gait modifications such as FPA (toe-out and toe-in), modified gait speed, expanded step width, decreased stride length, various gait aids (including ipsilateral and contralateral cane use and Nordic walking poles), medial knee thrust (knee medialising), lateral trunk lean sway, and Tai Chi gait were examined in a SR involving 554 unaffected and osteoarthritic individuals, (Simic *et al.*, 2011). The reviewed studies non-randomised control trails (RCTs) had fair to moderate methodological quality based on the Downs & Black checklist. Common observations included a lack of explanations for gait modification, insufficient clarity in participants' instructions, and an inadequate description of the utilisation of training methods.

According to this SR, most gait modifications were unlikely to decrease medial knee joint loads. Interestingly, there is a high likelihood of reducing early-stance KAM when the lateral trunk leans, and the contralateral cane is used more frequently. Furthermore, increasing the toe-out angle in the re-gait might reduce late-stance KAM, though its clinical significance remains unknown.

Despite the review's broad inclusion of studies with diverse designs, its conclusions were limited by the moderate methodological quality of these studies and the absence of RCTs. The review indicated that many studies needed more detailed descriptions of gait modifications, training methods, and participant instructions, which might have affected these strategies' reproducibility and clinical application. It also discussed several strategies aimed at reducing medial knee joint load and underscored the need for further research to establish optimal modification magnitudes, training methods, and long-term adherence.

In another SR & MA study, Bowd *et al.* (2019) cited 11 multiple study designs (RCTs and non-RCTs) examining the adverse effects of learned gait modification, such as (hip internal rotation, toe- in/out, and trunk lean) on the hip and ankle joints. The included studies generally demonstrated good to

moderate methodological quality. From their findings, the most significant reductions in peak KAM were linked to trunk lean and medial thrust.

Bowd et al. (2019) explored the challenges of implementing learned gait modifications in healthy individuals without osteoarthritis. These modifications might have decreased knee loading while walking; however, their impact on ankles and hips remained unclear, as did the ease of implementation. Furthermore, the study did not address the sagittal or frontal planes of hip and ankle joint biomechanics. Limitations included a small sample size and single-visit assessments, which lowered the study's quality and lacked long-term data. The findings suggested benefits from gait retraining yet emphasised the need for long-term studies with larger samples and comprehensive analyses of all lower limb joints to fully understand the clinical effects of gait retraining.

Another MA of 16 studies involving 373 participants was conducted by Wang, Mo, *et al.* (2021). This study received moderate quality assessment scores using the Downs and Black checklist. It investigated the impact of FPA (toe-in and toe-out) on knee adduction moment (KAM) peaks and knee adduction angular impulse (KAAI) in healthy individuals and those with medial KOA. The results showed that healthy individuals with a toe-in gait exhibited lower KAM 1st peaks and KAAIs. For those with KOA, a toe-out gait reduced the KAM 2nd peak and KAAI, while a toe-in gait had no effect. Wang, Mo, *et al.* (2021) noted that FPA effects varied between individuals with and without medial KOA and could be influenced by age, body mass index (BMI), and knee alignment.

The authors also performed subgroup analyses on knee alignment and BMI, which enhanced the understanding of how these factors might influence KAM and KAAI. Although RCTs were included in short-term cross-sectional studies, this could have constrained any definitive conclusions about the long-term effects of FPA on KOA. Furthermore, although the review identified data gaps in early-stage KOA, it underlined the need for long-term studies across varying KOA severities to better understand FPA's benefits and drawbacks.

In a recent study, Silva *et al.* (2022) conducted an SR and MA examining the effect of neuromuscular gait modifications on knee load (KAM)

in patients with medial KOA. The study included 17 papers comprising randomised controlled trials (RCTs), randomised cross-over studies, case studies, and cohort studies, totalling 362 participants. The quality assessments were performed using the Downs and Black checklist, which indicated a moderate score.

The findings revealed that ipsilateral trunk lean moderately reduced the first KAM peak and slightly decreased the KAM impulse. Toe-out modestly lowered the second KAM peak, while toe-in moderately reduced the first KAM peak but slightly increased the second KAM peak. These modifications were clinically valuable for evaluating KAM peaks and impulses in subjects with medial KOA.

While this MA provided valuable insights into various gait modifications and their effects on knee loading parameters, it was important to note its limitations. The study did not address the impacts of these modifications on knee pain and function, and its focus on KAM in medial KOA patients might have limited its generalisability to other aspects of the knee. Moreover, the study's short-term durations, small sample sizes, and potential biases from the study designs underscored the necessity for high-quality, long-term follow-up trials to comprehensively assess these effects on knee loading, pain, and function.

Tamura *et al.* (2023) concluded an SR and MA to assess the clinical impact of gait modification on KOA pain. The review included nine studies, encompassing RCTs and non-RCTs, with 290 participants. These studies investigated various gait modification techniques, such as toe-out, toe-in, trunk lean, and symmetrical trunk and pelvis movements, using different pain scales such as, Western Ontario and McMaster Universities Osteoarthritis Index (WOAMC), Knee Injury and Osteoarthritis Outcome Score (KOOS), Visual Analogue Scale (VAS) and Numeric Rating Scale (NRS) over six weeks to 12 months.

The findings revealed limited evidence supporting gait modification for knee pain relief. However, the FPA approach (toe-in and toe-out) demonstrated significant knee pain relief in obese women over 60, with

increased patient satisfaction. The MA results were promising, emphasising clinically meaningful outcomes such as significant pain reduction beyond the minimum clinically important difference (MCID). Nevertheless, the review was limited by a small number of RCTs and variability in gait techniques, which could affect the generalisability of the findings. Furthermore, the absence of long-term follow-up data raised concerns about the sustainability of these therapies, highlighting the need for more comprehensive studies in the future.

1.4.2 Assistive gait modification approaches:

1.4.2.1 Assessed various knee braces:

Moyer *et al.* (2015) conducted an SR and MA of 30 trials, including observational cohort studies, randomised trials, and laboratory studies. This SR & MA included 478 patients using valgus knee braces (KB) to examine the biomechanical effects on medial KOA. The mean quality score was moderate to high, with an inter-rater agreement based on the Downs and Black scale.

Moyer *et al.* (2015) reported that walking with valgus KBs might improve load distribution, minimise medial knee load, and increase medial knee joint space. The MA showed that valgus KBs significantly lowered the KAM. Meta-regression revealed that the KAM effect size and KB usage duration were positively correlated; longer use was linked to lower treatment effects. However, compliance issues (such as blisters, skin irritation, and pain) and doubts about long-term effectiveness mitigated these results.

Moreover, Fan *et al.* (2020) conducted an MA of RCTs to evaluate the effects of valgus KBs on knee pain and function in KOA patients. This study included 10 RCTs with 539 participants. The quality assessment was at an upper-middle level based on the Risk of Bias (RoB). The MA concluded that KBs might not enhance long-term knee pain or function but are valuable for short-term rehabilitation. Fan *et al.* (2020) advocated longer follow-up RCTs to assess long-term effectiveness.

Similarly, another completed SR by Alfatafta *et al.* (2021) evaluated KB's effectiveness on KOA pain and function, including 643 participants in 17 cohort studies and seven RCTs. They found that wearing KBs for less than

three months reduced pain and increased knee activity levels in the short term. However, the long-term effectiveness and potential complications remain unknown. Most research focused on gait modification effectiveness rather than acceptability or dissatisfaction.

Furthermore, Fan *et al.* (2020) focused on RCTs, while Moyer *et al.* (2015) and Alfatafta *et al.* (2021) used SR and MA methods, potentially introducing biases. Although Fan *et al.* (2020) focused on RCTs and provided robust evidence, they might have overlooked broader conclusions.

In conclusion, valgus KBs hold promise in offering short-term pain reduction and functional advantages for KOA subjects. This potential for improving patients' quality of life is encouraging, but more research on long-term efficacy and patient compliance is needed. Future research should optimise KB designs, consider patient characteristics, and conduct long-term follow-up RCTs to improve compliance and efficacy.

1.4.2.2 Assessed various LWI designs:

Arnold *et al.* (2016) conducted an SR and MA examining the impact of lateral wedge insoles (LWI) on KAM peaks and KAAI in individuals with medial KOA. They analysed 18 variable studies, including RCTs, quasi-RCTs, non-RCTs, cohort studies, and case-control studies, involving 534 participants. They used the Downs & Black checklist for quality assessment, determining that the studies were of low to moderate quality.

The findings indicated that LWIs could reduce KAM peaks and KAAI in medial KOA patients. They might be particularly effective in specific biomechanical phenotypes, such as gait speed, stride length, varus and valgus knees, and the early stage of KOA, significantly decreasing knee loading. However, the review highlighted a lack of evidence for its effectiveness, noting small effect sizes, publication bias, and variability in patient responses as limitations.

Another SR and MA by Xing *et al.* (2017) assessed the efficacy of lateral wedge arch support (LWAS) insoles on knee KAM peaks and KAAI in people with medial KOA. Xing *et al.* (2017) reviewed nine studies, including RCTs, quasi-RCTs, and prospective cohorts, totalling 356 participants. The studies

were assessed for quality using the Downs & Black checklist and found to be high quality.

The review indicated that LWAS insoles significantly reduced KAM peaks and KAAI in medial KOA patients during walking. However, results varied across subgroups with different control settings, suggesting that LWAS insoles might not consistently lower knee loads in these subjects. The authors suggested further research to identify the optimal combination of arch support and lateral wedging for maximum benefits without compromising comfort.

Shaw *et al.* (2018) conducted an SR and MA to assess the impact of various shoe-worn insoles (LWIs, arch supports, medial arch supports, and shock-absorbing insoles) on KAM in KOA patients. The analysis included 27 studies with varied designs, such as RCTs and crossover trials, encompassing 580 knees. The studies were of moderate to high quality, though limitations included strict inclusion criteria and inconsistencies in insole design.

The MA revealed that LWIs reduced KAM peaks but increased ankle eversion. Incorporating arch supports lessened ankle eversion but diminished the reduction in KAM. However, the significant heterogeneity among studies due to varied insole features limited the findings. Shaw *et al.* (2018) recommended further research on different insole types to determine their effects on the lower limb kinetic chain and to evaluate clinically significant biomechanical changes post-intervention.

Regarding LWI design, Ferreira *et al.* (2019) conducted an SR and MA to determine the optimal degree of LWI ($\leq 5^\circ$, $> 5^\circ$ and $\leq 9^\circ$, $> 9^\circ$) for KAM first and second peaks and KAAI in KOA subjects. The review included 15 studies involving 415 participants. The quality assessment revealed a high risk of bias in random sequence generation and allocation concealment based on the RoB tool. Ferreira *et al.* (2019) found that LWIs immediately decreased the first and second peak KAM and KAAI, with no significant differences among varying degrees of angulation. The authors recommended customising insoles based on individual biomechanical parameters for optimal effectiveness.

Based on previous reviews, it was evident that LWIs, including those with arch support, had a small but statistically significant effect on reducing

knee joint load (KAM 1st & 2nd peaks and KAAI) in individuals with medial KOA. However, the clinical significance of these reductions still needed to be determined, with varying degrees of effectiveness and no consensus on the optimal wedge angle.

The variability in patient response and inconsistent results across different control conditions emphasised the need for additional research to identify specific biomechanical phenotypes (gait speed, step width, and stride length) that might benefit more significantly from these interventions. Customising the wedge angle based on individual biomechanical responses showed promise. Future studies should also explore the long-term impacts and determine the optimal design and combination of lateral wedging with arch support to enhance patient efficacy and comfort.

1.4.2.3 Combinations between KB and multi foot orthosis:

In 2011, Raja and Dewan, (2011) conducted an SR to evaluate the efficacy of various knee braces (Valgus KB, Unloader KB, and Customised KB), multi-foot orthoses (LWI, LWI with subtalar strapping, and medial wedge insole), and specialised footwear in managing knee pain, stiffness, mechanical alignment, and physical function. This SR analysed 25 different study designs involving 1196 participants. The studies were assessed for quality using the Structured Effectiveness Quality Evaluation Scale, which indicated high quality.

In subjects with varus and valgus KOA, the SR found that knee braces and foot orthoses effectively reduced knee pain and stiffness and improved balance, proprioception, condylar separation, and physical function. Despite analysing multiple interventions, the SR noted limitations due to the low quality of some included studies and intervention heterogeneity. It recommended high-quality trials with long-term follow-up and better controls for future research.

Furthermore, Khosravi *et al.* (2022) conducted another SR and MA study to evaluate knee pain and function in medial KOA patients after utilising knee braces and LWI. This study included 32 controlled trials (RCTs and quasi-experimental) with 1849 participants. The quality assessment for the included studies was mainly moderate based on the Downs and Black checklist.

The findings indicated that knee braces and LWI improved knee pain, function, and satisfaction in the short term, with no significant difference. Despite the comprehensive analysis by Khosravi *et al.* (2022), variations in interventions, methodologies, and short-term follow-ups led to differing results across studies. The authors suggested that future studies adopt unified orthosis design methodologies for improved comparative outcomes and that using both interventions together could be more effective over the long term.

Both reviews offered valuable insights into the effectiveness of knee braces and foot orthoses in managing KOA. Raja and Dewan (2011) presented a broad SR covering various study designs despite methodological limitations, while Khosravi *et al.* (2022) delivered a comprehensive MA, confirming the effectiveness of both interventions and suggested additional benefits when combined.

1.4.2.4 Combinations between LWI and footwears:

In an SR examining the impact of different footwear types (high heels, dress shoes, clogs, sneakers, and running shoes) and orthotics such as LWIs, medial wedged insoles, and shoes with variable stiffness on KAM during walking or running, Radzimski, Mündermann and Sole (2012) analysed 33 studies (RCTs, quasi-RCTs, laboratory-based studies, case series, and case reports) involving 955 healthy and KOA subjects. The Downs and Black checklist rated most studies moderately to highly methodological.

The findings suggested that LWIs typically reduced peak KAM in healthy and medial KOA subjects, whereas medial wedges tended to increase KAM. Other footwear, such as stability and mobility shoes, clogs, and high heels, frequently resulted in higher KAM than walking barefoot. Despite the high intervention variability and the shortage of long-term studies, this systematic review thoroughly analysed different footwear and orthotics. The authors emphasised the need for further long-term research on the impact of footwear and insoles on KAM and KOA symptoms.

In Parkes *et al.* (2013), an MA of twelve RCTs involving 885 participants assessed the impact of LWIs and variable stiffness shoes on self-reported knee pain. Despite the risk of unblinding participants and personnel in trials

and the lack of control therapy, LWIs reduced WOMAC-pain scores, whereas neutral insoles did not. Parkes *et al.* (2013) implemented a comprehensive search strategy and used standardised mean differences for comparison. However, they noted significant heterogeneity and potential bias in smaller studies. The authors recommended further long-term, well-designed trials with appropriate controls to confirm the benefits of insoles for KOA subjects.

Zafar *et al.* (2020) systematically reviewed how different LWIs, such as custom LWIs, full-length insoles, 5° elevation, shock absorption, and arch support, affected knee biomechanics, pain, and function in KOA patients. The study analysed 34 papers, including cohort studies, RCTs, and randomised crossover trials, involving 1922 participants. This systematic review reported that the methodological quality of the studies was moderate.

Moreover, the results indicated that LWIs with ideal features (full-length, 5° elevation, shock absorption, and arch support) reduced KAM; however, their impact on pain and function was inconclusive. Despite correcting knee posture, the effectiveness of LWIs on pain and function remained uncertain, compounded by a lack of comparative studies. Further research was essential to determine the most effective designs for LWIs and substantiate their claims. Additionally, footwear that mimics barefoot walking markedly improved KAM and held promise for future advancements, especially considering the severity of KOA and its effects on pain and function.

Previous reviews have provided valuable insights into how various LWIs and different types of footwear affect knee loading, pain, and function in KOA patients. Radzimski's systematic review evaluated the impact of different footwear on KAM, noting the benefits of LWIs and the drawbacks of modern footwear. However, the review's high intervention variability and the absence of long-term studies limited its relevance.

1.4.3 Combination between learned and assistive gait modifications:

Additionally, SR published by Pereira *et al.* (2021) examined the impact of multiple gait modifications, such as KB, insoles, and retraining, on KOA symptoms. This review encompassed 11 RCTs with 590 participants to investigate the relationship between non-surgical gait modification approaches, their effect on KAM, and changes in knee pain and function.

The review found that KAM reductions correlated with improved pain and function. Nevertheless, there was a call for more in-depth research to validate this association. Despite these findings, various gait modifications were unrelated to KAM changes, suggesting that KOA treatment might benefit from innovative approaches like retraining.

Pereira *et al.* (2021) offered valuable insights into how various gait modification techniques reduced KAM and alleviated KOA symptoms. The strength of the SR lies in its thorough research strategies and focus on RCTs, enhancing the reliability of its conclusions. However, the moderate to high bias risk, significant variability among the included RCTs and lack of long-term data prevented definitive conclusions. More high-quality RCTs with standardised outcome measures (e.g., KOOS, WOMAC) were essential to fully elucidate the connection between KAM and KOA symptoms.

4.3 Study aim:

Despite previous reviews exploring the biomechanics of KOA during walking, there were some concerns. For example, most previous reviews often combined data from healthy subjects and those with KOA, which could obscure the effects of gait modifications on outcomes such as loading, pain, and function. Additionally, limited RCTs examined the effects of particular gait modifications at different time points.

This SR & MA aimed to address the gaps in existing research on gait modifications for individuals with KOA. This study focused on RCTs involving KOA patients, examining the effects of various gait modification strategies at different timepoints. It aimed to evaluate the effectiveness of learning, assistive, or combined gait modification strategies. The review analysed their impact on

knee biomechanical loading, pain and functional outcomes, such as spatiotemporal parameters (gait speed, stride length and cadence) and physical activity (climbing stairs, walking distance and sit-to-stand).

4.4 Methods:

4.4.1 Protocol & Registration:

The meta-analysis and systematic review were conducted and presented analyses based on the Cochrane Handbook Guidelines (Higgins *et al.*, 2019). Furthermore, a protocol for this review was submitted to the International Prospective Register of Systematic Reviews (PROSPERO) on 17th May 2021, bearing the registration ID: CRD42021254234.

https://www.crd.york.ac.uk/prospERO/display_record.php?ID=CRD42021254234

4.4.2 Eligibility Criteria:

Randomised controlled trials (RCTs) selected focusing on human adults who were clinically diagnosed with KOA and written in English were included. Furthermore, RCTs that examined the effect of a gait modification approach on KAM loading during walking, while also analysing at least one knee joint biomechanical parameter, were deemed eligible. Notably, there were no limitations based on the study's location, the session's duration, or the follow-up period. However, dissertations, conference proceedings and studies were only available in abstract form, and those in languages other than English were excluded (Table 6).

Table 6: Meta-analysis & Systematic Review inclusion & exclusion criteria:

Inclusion Criteria	Exclusion Criteria
RCTs evaluate gait modifications such as toe-in/out, trunk lean, walking speed, step width/length, wedge insoles, cane/poles, and knee brace or sleeves.	Non-RCT studies.
RCTs with adults (≥ 40 years), both male and female, diagnosed with KOA either clinically or radiographically.	RCTs healthy participants or with OA participants having other illnesses or disabilities.
RCTs utilised 3D motion analysis and force plate for knee biomechanics.	RCTs lacking 3D motion analysis.
RCTs studying knee joint loading during walking. RCTs incorporating biofeedback in gait modification.	RCTs assessing the effects of gait modifications on ankle or hip joints. RCTs focus on specific activities like one-leg standing, squatting, or ascending/descending stairs.
Studies in English language.	Dissertations, conference proceedings, abstract-only publications, and non-English studies.

4.4.3 Population:

Explored the effectiveness of gait modification techniques on knee loading, pain and function in individuals with KOA during walking. The included RCTs focused on human adults aged over 40, encompassing both males and females with KOA diagnosed either clinically or radiographically.

4.4.4 Intervention:

RCTs have concentrated on treating KOA by using different gait modifications. These modification approaches involve assistive devices like LWI, variable stiffness shoes, and knee braces (KB), as well as learned techniques such as trunk lean, knee thrust, and FPA adjustments to decrease KAM. The use of these gait modifications for KOA patients has been endorsed by the Osteoarthritis Research Society International (Bannuru *et al.*, 2019) and the European League Against Rheumatism (Fernandes *et al.*, 2013). Additionally, these RCTs have utilised 3D motion analysis and force plate data to examine regular walking patterns and evaluate the effects of the adopted gait modifications.

4.4.5 Comparator/Control:

The studies included in the analysis compared different gait modifications (such as toe-in, toe-out, LWIs, KB, medial knee thrust, etc.) to each other or in combined form between two techniques or compared the gait modification to regular walking as the control/comparator condition. Additionally, certain studies compared gait modifications to other interventions like therapeutic exercises programs for reducing knee joint loading.

However, the analysis excluded RCTs that examined the impact of gait modifications on KAM, while the main objective of these studies was examining biomechanical components on the ankle or hip joints. Such studies were missed to prevent potential compensatory movements at other joints from influencing the knee joint loading (Stoltze *et al.*, 2018). Furthermore, RCTs that included a no-treatment control group were considered to offer a baseline comparison for the efficacy of the gait modifications (Gallin, Ognibene and Johnson, 2017).

Studies involving patients with conditions such as neurological disorders (stroke, Parkinson's disease, multiple sclerosis) (Bonanno *et al.*, 2023) and musculoskeletal conditions including joint inflammation (Pinto *et al.*, 2023), tibial-osteotomy (Primeau *et al.*, 2021) and ACL reconstruction (Hart *et al.*, 2016) were excluded. Studies altered gait or examined modifications not related to standard walking, such as squatting or transitioning from sitting to standing, due to varying knee joint loading also excluded (Steingrebe *et al.*, 2018).

4.4.6 Outcomes:

The primary outcome examined was the alteration in the KAM during the investigated gait modification or the difference in KAM pre & post-gait modification (KAM was usually presented as the first or second peaks of the gait phase). Also, other biomechanical outcomes of gait modification, such as KAAI and spatiotemporal gait variables, were evaluated. Furthermore, consider outcomes of knee pain and function between gait modifications and comparators using outcome measures such as VAS, NRPS, KOOS, and WOMAC. The primary time point for measuring these outcomes was

immediately post-intervention and at follow-up intervals specified in the included studies.

According to the Updated Method Guidelines for Cochrane Musculoskeletal Group Systematic Reviews and Meta-analyses (Ghogomu *et al.*, 2014), the most clinically considerable timeframes for outcome measurements providing summary estimates were categorised as short-term (up to 6 months), intermediate (between 6 to 12 months) and long-term (over a year). Table 7 provides outcomes in more detail.

Table 7: Outcomes and time points

Outcomes type	Specific outcome	Timeframes
Knee loading	KAM 1 st & 2 nd peaks	Immediately post-intervention, Follow-up intervals: short-term (up to 6 months), intermediate (6 to 12 months) and long-term (over a year).
Biomechanical details	KAAI, KFM	
Pain	VAS, NRPS	
Physical activity	Rane of motion (RoM). Spatiotemporal parameters (e.g. gait speed, stride length & cadence). Physical activity tests (Climbing stairs steps test. Sit to stand time test. Walking distance test).	

4.4.7 Information sources:

With the assistance of a qualified librarian, one reviewer (AA) conducted searches on multiple databases up to May 2022. These databases included MEDLINE-Ovid (1966-2022, March), EMBASE-Ovid (1974-2022, March), Allied and Complementary Medicine Database (Ovid-AMED) (1995-2022, March), Cumulative Index to Nursing and Allied Health-EBSCO (CINAHL, 1982-2022, March), Web of Science (1900-2022, February), Cochrane Library

(including DARE and Central), ClinicalTrials.gov, and ProQuest Dissertations and Theses (1986-2022 March). Furthermore, systematic reviews were examined within the International Prospective Register of Systematic Reviews to identify current or prior systematic reviews. For the formulation of this SR, the guidelines from the Preferred Reports for Systematic Reviews and Meta-Analyses were adhered to (Page *et al.*, 2021).

4.4.8 Search Strategy:

The search strategy was thoroughly designed to ensure comprehensive coverage and was formulated based on the population, intervention, comparison and outcomes (PICO) model (Huang *et al.*, 2006). This electronic search was conducted independently by two reviewers, AA and HC. The search incorporated keywords such as: osteoarthritis, knee, cartilage, tibiofemoral, gait modification, gait training, walk, biomechanical load, dynamic load, knee pain, range of motion, 3D analysis and Three-Dimensional. These key terms were systematically combined using the operators 'AND' or 'OR' (see Appendix 1).

4.4.9 Study selection:

The MA and SR articles were carefully reviewed by (AA), (HC), and (BS). During a collaborative meeting, they outlined the essential data to be extracted from each study. Subsequently, (AA) and (HC) took the lead in the next stage of study selection. The most relevant RCTs were detected after carefully examining the titles and abstracts.

Studies that failed to include the terms 'knee osteoarthritis', 'gait modification interventions', and 'loading impact' in the title were set aside. This decision was based on their abstracts, which indicated either an absence of knee osteoarthritic patients or gait modification. However, the complete text was retrieved and thoroughly analysed in cases where clarity was missing from the abstract only. In discrepancies, the third investigator (BS) was consulted for insights. A complete record of excluded trials was kept throughout this process, accompanied by the rationale behind their deletion. A detailed flow diagram illustrating the RCTs' selection process was crafted to describe the selection process in detail.

4.4.10 Data extraction process:

Publication details selected included study design, first author, year, location, sample size, participant characteristics (age, gender, height, BMI, KOA side and severity based on K/L scale), intervention type, follow-up duration and results (Higgins *et al.*, 2019). Further, all included studies detailed intervention specifics, like the type of gait modification, training programme duration and frequency.

Outcomes reported the main findings relating to the biomechanical effects on KOA, while any secondary effects arising from gait modifications were also noted. Descriptive data, including means and standard differences, and interpretive statistics, like p-values and confidence intervals, were presented. Using this data, standardised mean differences (SMDs) were calculated to show the difference in biomechanical outcomes between the intervention and comparison groups (Hedges, 1981). For additional clarity, the primary reviewer (AA) reached out to the authors of the studies to gather more information.

All findings were compiled into a standard table by the primary reviewer (AA). This compilation was later cross verified by a second reviewer (HC). Both reviewers agreed upon the presented findings. Third reviewers (BS) were available in cases of disagreement, but consensus was always achieved.

4.4.11 Synthesis of results:

The MA was conducted using Review Manager Software for Windows (RevMan version 5.4, 2020). This software presented results through the inverse variance analysis. The study's heterogeneity was subsequently assessed via the (I^2) statistic test, considering the values of (I^2) and the statistical effect (P). The χ^2 and Cochran Q-test further corroborated this. Following the Cochrane Collaboration guidelines, 25%, 50%, and 75% indicated low, moderate, and high levels of heterogeneity, respectively (Higgins *et al.*, 2003). Where possible a fixed-effects model was used to produce pooled estimates, and 95% confidence intervals for standardised mean differences (SMDs) in outcomes change if ($I^2 < 50\%$ and $P > 1$). However, a random-effects model was more conservatively applied to estimate the

pooled impact due to anticipated differences in comparators and participant characteristics like age and KOA severity.

Utilising the RevMan software, the SMD for both samples (intervention comparator) was determined by dividing the mean change within participants by the pooled standard deviation. Essential details were systematically reported, including statistical significance, sample sizes, baseline and post-intervention mean, and standard deviations. For studies providing both mean and standard error data (SE), the standard deviation (SD) was deduced using the formula $SD = SE \times \sqrt{n}$ (Higgins *et al.*, 2019). When only the mean and confidence intervals (CI) were given, and the sample size was notably large (over 100 in each group), the SD was derived from a specific formula, $SD = N \times (\text{upper limit} - \text{lower limit}) / 3.92$.

For smaller sample sizes, the formula was adjusted to include a (t) distribution, which is represented in an excel sheet as [=tinv (1- 0.95, sample size-1)], then the above value (3.92) replaced by [2x (t) formula result] (Higgins *et al.*, 2019). Furthermore, in studies that only provided mean and range, the SD was calculated as $SD = \text{max} - \text{min} / 4$, as proposed by Walter and Yao (2007).

Cohen's d is a measure used to determine the size of the treatment effect in research. It involves finding the averages and standard deviations of the groups being compared and then calculating the pooled standard deviation by averaging the variances of these groups. Cohen's d is computed as the difference between the means divided by the pooled standard deviation, providing a standardized measure of effect size to interpret the efficacy of the intervention in different research scenarios. The effect size for continuous outcomes was then ascertained based on the SMDs paired with 95% confidence intervals (CIs). Cohen's d-test was instrumental in classifying these effect sizes into small (0.2), medium (0.5) or large (0.8) categories (Cohen, 1992).

When data was scant, or authors could not provide the necessary information, a specific method was introduced to estimate or impute missing data. Notably, P values were adjusted to (P =0.05 or P =0.0) when research reported significant results that did not correspond to an exact P value (e.g., P

=0.05, $P = 0.01$) (Higgins and Green, 2008). Moreover, when non-significant results were presented with a non-exact P value, the SMD calculation involved a paired correlation value of $r = 0.5$ (Borenstein *et al.*, 2009). A consistent significance level was set where $P = 0.05$, or when the 95% confidence interval failed to overlap the line denoting no significance.

Higgins *et al.*, (2019) proposed a classification for heterogeneity: I^2 less than 30% represents mild heterogeneity, between 30% and 50% denotes moderate heterogeneity, and anything above 50% suggests severe heterogeneity. Occasionally, studies used graphical representations to convey findings. In such cases, data was extracted using Web plot digitisers (Rohatgi, 2014).

4.4.12 Risk of Bias Assessment:

The evaluation of the risk of bias for all relevant RCTs was independently carried out by two reviewers, AA and HC, using the Cochrane risk of bias tool (RoB), as adapted from Higgins *et al.*, (2019). This tool comprises six domains: selection bias (random sequence generation and allocation concealment); performance bias (blinding of participants and personnel); detection bias (blinding of outcome assessment); attrition bias (incomplete outcome data); reporting bias (selective reporting); and other bias (additional pre-specified concerns). In disagreements, a third reviewer, BS, was consulted. A 'risk of bias graph' and 'risk of bias review' were produced. Green indicated low risk, yellow unclear risk, and red high risk.

4.4.13 Certainty assessment:

When assessing gait modification interventions for KOA, it is essential to ensure the reliability and strength of the findings. The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) framework provides a structured and transparent approach to evaluating the certainty of evidence, as outlined in the Cochrane Handbook for Systematic Reviews of Interventions. This framework assesses the quality of evidence across essential domains, including risk of bias, inconsistency, indirectness, imprecision, and publication bias. These factors are crucial for making well-

informed recommendations and ensuring clinical decisions are based on the best available evidence.

This systematic review will use the GRADE approach to assess the certainty of the evidence for the outcomes (biomechanical loading, pain, and function) related to gait modification strategies (learned, assistive, or combined). This will ensure that SR conclusions are reliable and clinically relevant. The GRADE approach systematically evaluates the certainty of evidence, helping to identify areas where the evidence is strong and where further research is needed (Schünemann *et al.*, 2019).

4.5 Results:

4.5.1 Study Selection:

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (Figure 18) and Table (8) reveals that 6,424 studies were identified through the search strategy for potential inclusion. After removing duplicates, 6,298 studies underwent title and abstract examination. This led to the exclusion of 5,710 studies, leaving 588 for a full review. Upon applying the eligibility criteria, 511 papers were excluded, resulting in 77 primary eligible trials.

Based on the consensus of the second (HC) and third (BS) reviewers, a final 15 RCTs were selected for SR inclusion. These RCTs were primarily focused on reducing KAM, and most also included improved knee pain and function as additional outcomes. Out of these 15 RCTs, 13 were included in MA, providing sufficient comparator data.

The SR was formulated using the best evidence synthesis reported in all 15 RCTs (van Tulder *et al.*, 2003), whereas the MA used comparable data from the 13 other studies to perform quantitative analysis. Additionally, subgroup analyses were performed within the MA to pinpoint potential group differences (Sun *et al.*, 2018).

Table 8: Search resource details and number of results after applying limiters

Resource	Time Coverage	Search Interface	Number of Hits
AMED	Until Search Date	Ovid SP	1,233
CINAHL	1937–Search Date	EBSCOhost	756
ClinicalTrials.gov	Until Search Date	ClinicalTrials.gov	159
Cochrane Library	Until Search Date	Cochrane Library	696
EMBASE	1974–2017 (Week 35)	Ovid SP	222
MEDLINE	1946–Search Date	Ovid SP	224
ProQuest	Until Search Date	Theses & Diss.	118
Web of Science	Until Search Date	Web of Science	3,016
Total	6,424 Studies		

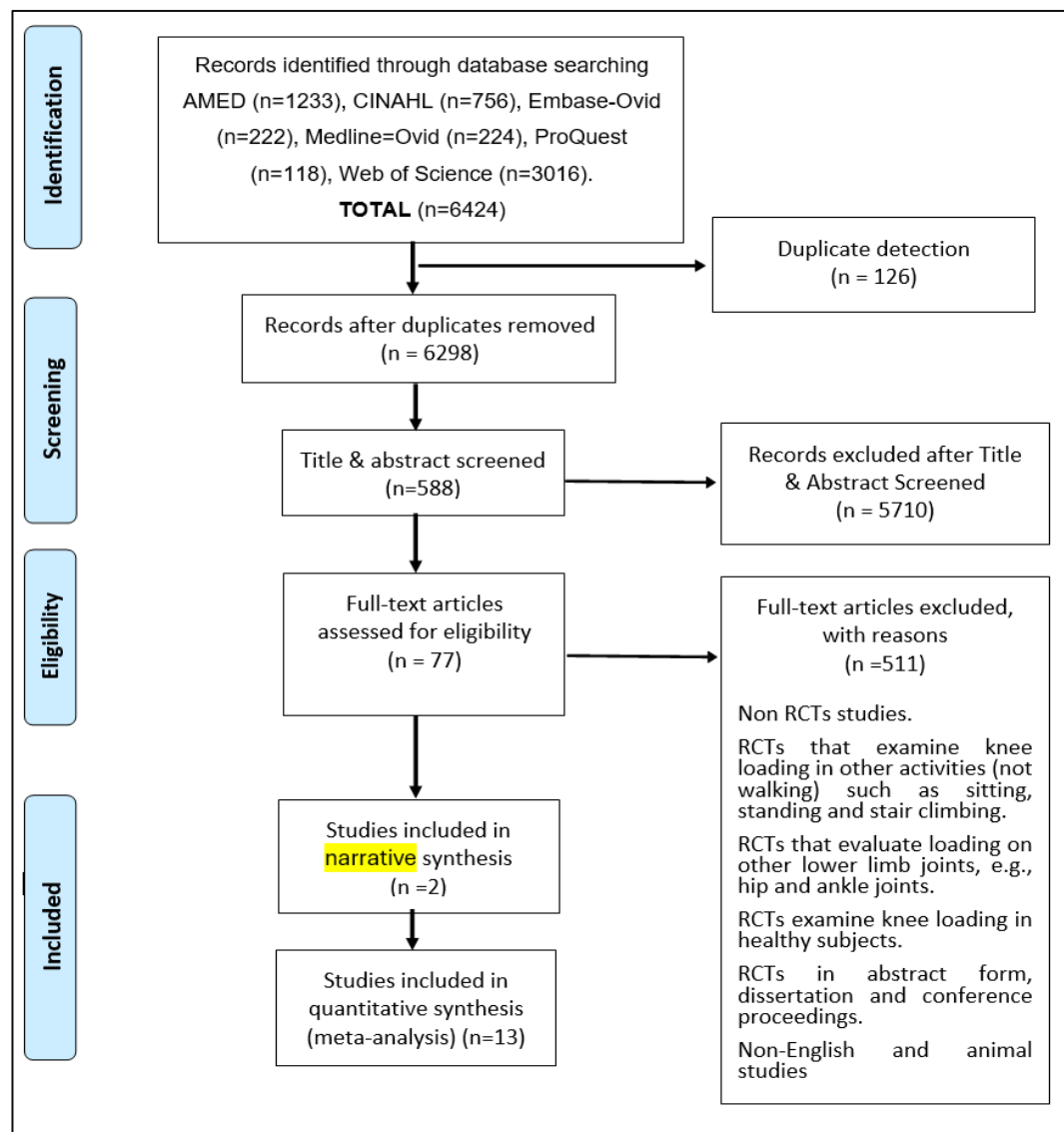


Figure 18: PRISMA flow chart for studies selection, Moher et al., (2009).

4.5.2 Characteristics of Included Studies:

The review includes 15 RCTs conducted between 2010 and 2021 across various countries. These studies employed various designs, including parallel RCTs, single- and double-blinded RCTs and prospective RCTs, reflecting multiple methodological approaches to investigating multiple gait modification efficacy in KAO patients.

Furthermore, every study employed the K/L grades for radiographic assessment. A breakdown of these results indicates that the majority of the studies (six RCTs) centred on grades 2 and 3 (Trombini-Souza, *et al.*, 2012; 2015 Jones *et al.*, 2015; Mirzaei *et al.*, 2018; Ferreira *et al.*, 2021; Khosravi *et al.*, 2021). Two RTCs focused on grades 1 or 2 (Arazpour *et al.*, 2013; Cheung *et al.*, 2018), grade 2 and above in 3 articles (Barrios *et al.*, 2013; Hunt *et al.*, 2018; Paterson *et al.*, 2018) for grade 1 and above only one RCT (Duivenvoorden *et al.*, 2014), between grade 3 & 5 in one study (Kapadia *et al.*, 2016). Notably, Erhart *et al.*, (2010; 2012) used MRI-based criteria for KOA diagnosis and assessed the severity of participants' knees from grades 0 to 4 (K/L). Several studies also touched on knee alignment, particularly varus-valgus (Duivenvoorden *et al.*, 2015; Erhart *et al.*, 2012; Ferreira *et al.*, 2021; Kapadia *et al.*, 2016 & Mirzaei *et al.*, 2018). The 15 RCTs assessed the impact of 12 different gait modification techniques on KOA biomechanical parameters alongside other clinical influences (see Table 9).

Though Erhart *et al.* (2010a) and Kapadia *et al.* (2016) met our inclusion criteria, they were not incorporated into the meta-analysis because they were narrative reviews (van Tulder *et al.*, 2003). Thus, our meta-analysis synthesised data from the remaining 13 trials, ensuring that the data were both sufficient and comparable. Notably, Patterson *et al.*, (2018) provided the 1st KAM peak based on mean and interquartile range instead of standard deviation, which required further calculation to determine SD.

Notably, several studies have documented additional outcomes. These include walking distance, as reported by Duivenvoorden *et al.* (2014), the 12-step climb-stair and 30 sec. sit-to-stand test by Ferreira *et al.* (2012), pain assessment on a 5-point scale according to Jones *et al.* (2015), knee extension

at heel strike by Kapadia et al. (2016), and the 6-minute walking test by Trombini-Souza et al. (2012b; 2015). Which these results will be statistically report.

Furthermore, the studies utilised patient-reported outcomes (PROs) such as WOMAC, KOOS, improvement, satisfaction and feedback scales, which varied. Additionally, certain studies selected particular subscale outcomes from these scales. Therefore, as these outcomes did not correspond with the primary objectives of the SR and MA, they were not incorporated into the statistical synthesis.

4.5.3 Risk of bias within studies:

Following the Cochrane Collaboration's guidelines (Higgins and Green, 2012) reviewers AA and HC assessed the risk of bias in the included trials, focusing on areas of random sequence generation, allocation concealment, blinding, incomplete outcome data and selective outcome reporting. If any domain had a high or unclear risk of bias, the trial was considered at significant risk.

All 15 trials were assessed for bias. Only two trials (Cheung *et al.*, 2018; Jones *et al.*, 2015) were free from high risk across all domains, while the remaining 13 showed high risk in at least one domain. Trombini-Souza (2012), (2015) indicated minimal risk in most areas, except blinding. Eight RCTs had low risk in randomisation sequences, but six RCTs, Arazpour *et al.*, (2013), Barrios *et al.*, (2013), Kapadia *et al.*, (2016), Khosravi *et al.*, (2019), Mirzaei *et al.*, (2018) and Paterson *et al.*, (2018) were unclear. Allocation was the most ambiguous domain, and blinding participants often led to high-performance bias. Further, when participants' awareness of their group assignment affects their actions or replies, performance bias results, affecting the research findings (Hróbjartsson *et al.*, 2014).

Overall, the studies showed moderate methodological quality (reviewers AA and HC agreed on the bias assessment of included studies). Many lacked details on blinding and masking assessors but clearly outlined their randomisation methods. Most provided complete outcome data but did

not disclose selective outcomes. Kapadia *et al.*, (2016) reported allocation but not sequence generation (Figures 19 & 20).

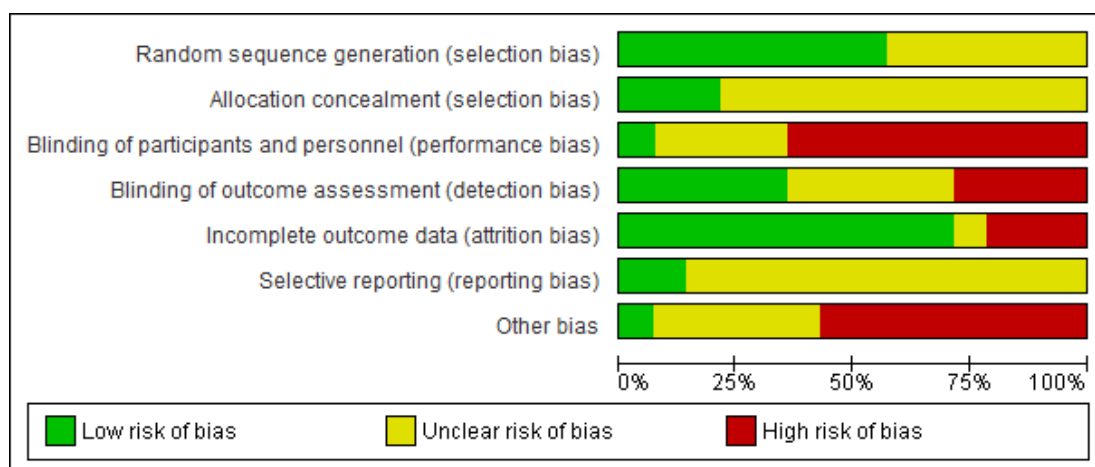


Figure 19: Summary of Risk of Bias.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arazpour et al., 2013	?	?	-	-	+	?	-
Barrios et al., 2012	?	?	-	+	+	?	-
Cheung et al., 2018	+	?	?	+	+	+	?
Duivenvoorden et al., 2014	+	?	-	-	+	?	?
Erhart et al., 2010	+	?	-	?	-	?	-
Erhart et al., 2011	+	?	-	?	+	?	-
Ferreira et al., 2021	+	+	?	-	+	+	?
Hunt et al., 2018	+	?	-	+	+	?	?
Jones et al., 2015	+	?	?	?	+	?	?
Kapadia et al., 2016	?	?	-	?	?	?	-
Khosravi et al., 2019	?	+	?	?	+	?	-
Mirzaei et al., 2018	?	?	-	-	-	?	-
Paterson et al., 2018	?	?	+	+	-	?	-
Trombini-Souza et al., 2012;2015	+	+	-	+	+	?	+

Figure 20: Individual Study's Quality Assessment

4.5.4 Randomisation and blinding bias:

Review studies have consistently highlighted significant issues related to the lack of randomisation. Such randomisation bias can potentially mislead treatment impact estimates, leading to incorrect conclusions in RCTs (Kahan *et al.*, 2015). Furthermore, due to the inherent nature of the interventions, none of the studies implemented blinding for either the therapist or the subject. Such an absence of blinding for participants and personnel complicates accurate assessment of the benefits gait modifications. Consequently, deciding to carry out a biomechanical intervention often rests on its anticipated effectiveness. Notably, during the experiment conducted by (Foroughi *et al.*, 2011), participants were blinded to the investigator's hypothesis and asked to report which group they believed to be enrolled. It was not possible to determine whether the blinding experiment had been successful.

This lack of clarity is significant, as unblinding can induce systematic differences. For instance, if subjects know their group assignments, it might influence their behaviour and subsequent responses (Karanicolas *et al.*, 2010). Given this, the review categorised all unblinded studies as bearing a high risk of bias for all outcomes unless the gait modifications were executed in a blinded setting.

4.5.5 Results of individual study:

Population:

In total, 15 RCTs incorporated 857 participants. These participants ranged in age from 54 to 66 years old. Most of the studies had a balanced sex distribution, except for Trombini-Souza *et al.* (2012) and (2015), which only included female participants. Moreover, participants' BMIs varied from around 24.5 kg/m² to 33.6 kg/m², suggesting a mix of average-weights. The studies did not include any subjects without KOA. Most participants had medial KOA.

Intervention:

Most studies investigated the effects of gait modifications on knee biomechanics, mainly through the ankle joint. A variety of gait modifications were utilised, including re-gait training, LWI, valgus KB, variable footwears

(lateral stiffener sole). Notably, seven RCTs represented the gait modification using LWI (Arazpour et al., 2013; Duivenvoorden et al., 2014 ; Ferreira et al., 2021; Jones et al., 2015; Khosravi et al., 2016; Mirzaei et al., 2018; Paterson et al., 2017). As highlighted by Ferreira et al., (2021), insoles typically inclined between 2 and 10 degrees, with 5 to 8.7 degrees commonly observed (Arazpour et al., 2013; Duivenvoorden et al., 2014 and Paterson et al., 2017). Interestingly, Khosravi et al., (2016) and Mirzaei et al., (2018) reported LWI inclinations of 6mm to 10mm without specifying degrees.

Regarding the duration of LWI use, studies showed variations. Jones et al., (2015) reported two to three hours per session, Paterson et al., (2017) indicated about four hours/day, while three other studies cited six to nine hours/day (Arazpour et al., 2013; Duivenvoorden et al., 2014, and Mirzaei et al., 2018). Some studies, including Ferreira et al., (2021) and Khosravi et al., (2016), did not report average daily use.

Moreover, two RTCs evaluated different gait-retraining interventions. Cheung et al. (2018) focused on modifying walking patterns, while Hunt et al. (2018) concentrated on adjusting the FPA during walking. Cheung et al. (2018) and Hunt et al. (2018) both implemented gait training programs aimed at modifying foot progression angles, albeit with different durations and methods. In Cheung et al. (2018) study, participants underwent six gait training sessions over six weeks, starting with 15 minutes and increasing till 30 minutes per session. They received visual feedback and were prompted to adjust their gait pattern accordingly. Similarly, Hunt et al. (2018) conducted an eight-session program over 15 weeks, with session durations extending from 20 minutes to 40 minutes. Participants were instructed to walk with a 15-degree toe-out angle at their self-selected speed, using mirror-guided biofeedback to achieve this.

Six studies investigated the impact of various footwear types. Barrios et al. (2013) studied the use of lateral wedge shoes (lateral stiffness) featuring full-length insoles, while Erhart et al. (2010a; 2012) conducted the first two studies, comparing variable stiffness shoes (lateral stiffness) with constant stiffness (control) shoes as controllers. Erhart et al. (2010a; 2012) also developed a specialized athletic shoe that appeared normal but featured a lateral side that was compression-moulded 1.3–1.5 times stiffer than the

medial side. Barrios et al. (2013) involved a treatment group that received lateral wedging using Orthofeet wedges. The amount of wedging was determined individually, and the wedges extended from the posterior heel to the metatarsal heads. Additionally, Trombini-Souza et al. (2012b; 2015) examined minimal shoes, and Jones et al. (2015) explored the effects of mobility shoes compared to regular shoes, which served as the control group.

The duration of these studies varied. The research by Barrios et al. (2013) extended 12 months from baseline, while Erhart et al. (2010a; 2012) spanned from baseline to 6 months and then extended to 12 months post-intervention. The studies conducted by Trombini-Souza et al. (2012b; 2015) lasted from baseline to 6 months, whereas the study by Jones et al. (2015) was conducted in a single session.

Given the diverse interventions in the included studies to ascertain gait modification efficacy, comprehensive results analysis was essential. The studies ranged widely in their timeframes, spanning from one session to one year, highlighting the importance of scrutinising findings in line with SR review's objectives.

Comparators:

In terms of comparisons, four compared LWIs with knee braces, namely Arazpour et al., (2013), Duivenvoorden et al., (2014), Khosravi et al. (2019) and Mirzaei et al., (2018). Additionally, Khosravi et al. (2016) and Mirzaei et al. (2018) examined the impact of valgus KB compared to LWI. Also, they conducted a comparative study between valgus KB and LWI in a combined approach that included valgus KB with LWI.

In contrast, three trials by Ferreira et al. (2021), Paterson et al. (2017), and Jones et al. (2015) compared LWI with neutral shoes. Another approach Jones et al. (2015) developed compared LWIs with and without medial arch support to footwear as controller. Jones et al. (2015) assessed the effectiveness of barefoot, mobility shoe, and LWI as gait modifications. Furthermore, Barrios et al. (2013) and Erhart et al. (2010a; 2011) compared footwear involving LWIs (lateral stiffener sole) with neutral insole footwear.

Other researchers, such as Cheung et al. (2018) and Hunt et al. (2018), assessed learned gait modification via a control group in which both trials performed walking exercises without a specific gait modification approach. However, Hunt et al. (2018) reported that the control group participants gradually increased their walking duration over the study period.

In an extension of this concept, three studies, including Trombini-Souza et al., (2012b; 2015) and Jones et al., (2015), compared variable stiffness shoes with control shoes. On a different note, Kapadia et al., (2016) exclusively assessed the contrast between physiotherapy usual care and a pneumatic KB as gait modifications.

Outcomes:

The primary outcome measured in all the included studies was knee loading, assessed by the KAM. Three LWI studies (Jones et al., 2015; Mizaei et al., 2018; Paterson et al., 2018) reported significant reductions in KAM across several trial time points, including baseline, a single session, two weeks, and six months.

However, the four RCTs (Arazpour et al., 2013; Duivenvoorden et al., 2015 at 6-weeks post-intervention; Khosravi et al., 2019 at 3-month follow-up; and Barrios et al., 2013 at one-year follow-up) did not demonstrate significant differences between groups. Furthermore, the trial of Ferreira et al. (2021) reported significant differences at three months for the first KAM but not for the second KAM at the same timepoint.

Both re-gait training studies (Cheung et al., 2018; Hunt et al., 2018) assessed KAM. Cheung et al. (2018) identified a significant difference in KAM relative to the control group at the 6-month. In contrast, Hunt et al. (2018) observed a significant difference in KAM five months post-intervention. Conversely, while Erhart *et al.* (2010a; 2012) found significant differences in the first trial evaluating the efficacy of variable stiffness shoes at six months, no significant differences were found in the second trial at 12 months post-intervention. Similarly, Trombini-Souza *et al.* (2012b; 2015) observed no significant differences at both trials' post-intervention time points (baseline and six months).

Regarding the KB effect, two RCTs by Kapadia et al. (2016) at 3 months follow-up and Khosravi et al. (2019) on 6th weeks noted a non-significant difference in KAM between groups. In the context of Knee Adduction Angular Impulse (KAAI), significant reductions compared to control groups were reported in studies by Barrios et al. (2013) at a 12-month follow-up, Hunt et al. (2018) at a 5-month follow-up, Jones et al. (2015) during a baseline session only and Duivenvoorden et al. (2015) over six weeks. In contrast, no significant differences were observed in the studies by Paterson et al. (2018) and Trombini-Souza *et al.* (2012b; 2015) following their interventions at six months post-intervention. Furthermore, Ferreira et al. (2021) and Kapadia et al. (2016) reported results three months post-intervention.

Pain assessment methods varied across four trials (Arazpour et al., 2013; Ferreira et al., 2021; Khosravi et al., 2019; Mirzaei et al., 2018), utilising the Visual Analog Scale (VAS) to measure knee pain, with reported levels above 3/10. Notably, only Khosravi et al. (2019) recorded a significant reduction in pain between groups with LWI vs valgus KB only at 6 weeks post-intervention. In addition, using the Numeric Rating Pain Scale (NRPS), Hunt et al. (2018) noted significant differences between groups at the five-month follow-up, while no differences were observed with Paterson et al. (2018) after gait modification at the six-month follow-up timepoint.

Meanwhile, significant pain reductions were observed between groups post-gait modification when assessed using the clinical importance of pain (Erhart et al., 2010a) at the six-month time point and using the 5-point Likert scale for pain (Jones et al., 2015) after one session of intervention.

In contrast, seven studies used the WOMAC-pain subscale, which showed pain levels above 15/100 (Cheung *et al.*, 2018; Erhart *et al.*, 2010b; 2012; Hunt *et al.*, 2018; Khosravi *et al.*, 2019; Trombini-Souza *et al.*, 2012b; 2015). Six months after the intervention, Cheung et al. (2018) and Trombini-Souza et al. (2012b; 2015) identified significant differences in WOMAC scores for pain, stiffness, and function between the groups. Similarly, Khosravi et al. (2019) observed significant differences in the same measures at the six-week follow-up. The studies conducted by Erhart et al. (2010b; 2012) and Hunt et al.

(2018) found no significant differences among the groups at six, twelve, and five months respectively, following the intervention periods.

Furthermore, numerous RCTs have examined the effects of gait modification. Gait speed was evaluated in five of these trials. Significant differences were reported by Kapadia et al. (2016) three months post-intervention and by Mirzaei et al. (2018) at a two-week follow-up. However, Arazpour et al. (2013) and Hunt et al. (2018) observed no significant changes at the six-week and five-month time points, respectively. However, Jones et al. (2015) noted that among intervention groups, only the "mobility shoes" and "barefoot" groups reported significant differences between groups at the baseline time point.

Furthermore, stride length was analysed in three RCTs. Arazpour et al. (2013) and Mirzaei et al. (2018) observed no significant differences in stride length among groups at six and three weeks of follow-up, respectively. In contrast, Khosravi et al. (2019) identified a significant difference six weeks post-intervention. Regarding knee range of motion (ROM) following gait modification, significant enhancements were noted at six weeks of follow-up in studies by Arazpour et al. (2013) and Khosravi et al. (2019). Additionally, Kapadia et al. (2016) reported improvements at three months, and Mirzaei et al. (2018) observed positive changes as early as two weeks compared to control groups, see Table (9).

Table 9: Characteristics and results of included studies:

Study ID, year, design and location	N	Intervention vs. Comparator size, sex, age (mean $\pm$ SD) & BMI mean $\pm$ (SD)	Outcomes Measures	Data collection timepoints	Results
Arazpour et al. (2013) <i>RCT, quasi-experimental. Iran</i>	24	LWI n=12 (M: 5), (F: 7) Age: 59.83 $\pm$ 2.48 BMI= 26.7 $\pm$ 1.67 kg/m ² .	Unloader KB. n= 12 (M: 8), (F: 4) Age: 58.75 $\pm$ 2.2 BMI= 27.3 $\pm$ 1.76 kg/m ² .	- Knee loading (KAM) - Pain (VAS). - Functional performance tests (RoM, Gait speed & Stride length).	- Baseline - 6-weeks post intervention - KAM = No Signif. Diff. between groups at 6-weeks post-inter (p=0.20). - VAS = No Signif. Diff. between groups at 6-weeks post-inter (p=0.65). - RoM = Signif. Diff. between groups at 6-weeks post-inter (p=0.000). - Gait speed & Stride length = No Signif. Diff. between groups at 6-weeks post-inter (p=0.060) & (p=0.687) respectively.
Barrios et al. (2013) <i>RCT, single blinded. USA</i>	38	Lateral stiffener shoes (orthotic shoes) n=19 (M & F; N/A) Age: 62.6 $\pm$ (7.4) BMI= 33.6 $\pm$ 7.6 kg/m ² .	Neutral insole shoes. n= 19 (M & F; N/A) Age: 61.2 $\pm$ (9.4) BMI= 30.4 $\pm$ 7.1 kg/m ² .	- Knee loading (KAM) - Biomechanical details (KAAI)	- Baseline - 1 year post intervention - KAM = No Signif. Diff. between groups at 1 year post-inter (p=0.06). - KAAI = No Signif. Diff. between groups at 1 year post-inter (p=0.628).
Cheung et al. (2018) <i>RCT, single blinded. Hong Kong</i>	20	Re-gait n=10 (M: 5), (F: 5) Age: 60.8 $\pm$ (6.4) BMI=24.5 $\pm$ 2.4 kg/m ² .	Walking Exercise n= 10 (M: 5), (F: 5) Age: 63.1 $\pm$ (5.9) BMI= 25.2 $\pm$ (1.1) kg/m ² .	- Knee loading (KAM). - Biomechanical details (KFM). - PROs (WOMAC) scores.	- Baseline. - Post training. - 6-months post intervention. - KAM = Signif. Diff. between groups (p=0.027) at 6-month post-inter. - KFM = No Signif. Diff. between groups at 6-month post-inter (p=0.580). - WOMAC (activity & total) = Signif. Diff. between groups at 6 months follow-up (p=0.028) & (p=0.009) respectively.

Table 9: Continue Characteristics and results of included studies:

Duivenvoorden et al. (2015) <i>Parallel RCT.</i> <i>Netherlands.</i>	80 LWI n=42 (M: 14), (F: 28) Age: 54 ± (7) BMI= 30 ± (5) kg/m².	v Valgus KB. n= 38 (M: 25), (F: 13) Age: 54 ± (7) BMI= 31 ± (5) kg/m².	- Knee loading (KAM peak) & (KAM mean). - Biomechanical details (KAAI, GRF & moment arm). - Functional performance tests (walking distance). - PROs (compliance).	- Baseline. - 6-weeks post intervention.	- KAM-peak, (p=0.328). KAM-mean, (p=0.035). GRF (p=0.969) & M/A (p=0.188). There were no Signif. Diff. between groups at 6-weeks post-inter. - KAAI= Signif. Diff. between groups at 6-weeks (p=0.036) - compliance (p=0.213) & walking distance (p=0.375) between both groups at 6-weeks post-inter showed No signif. difference.
Erhart et al. (2010) <i>Prospective, Parallel RCT.</i> <i>USA</i>	79 Lateral stiffener shoes (orthotic shoes) n=40 (M: 24), (F: 16) Age: 59.8± (9.0) BMI= 27.6 ± (4.5) kg/m².	v Constant stiffness footwear n= 39 (M: 17), (F: 22) Age: 54 ± (7) BMI= 27.4± (5.4) kg/m².	- Knee loading (KAM peak). - PROs (WOMAC) scores. - Pain Clinical importance (%)	- Baseline. - 6-months post intervention.	- KAM peak= Signif. Diff. between groups at 6-months post-inter (p=0.03). - WOMAC (pain and total)= No Signif. Diff. between groups at 6-month post-inter for subscales (p=0.31) & (p=0.50) respectively. - Pain Clinical reductions= Signif. Diff. between groups (p=0.012).
Erhart-Hledik et al. (2011) <i>Prospective, Parallel RCT.</i> <i>USA</i>	55 Lateral stiffener shoes (orthotic shoes) n=32 (M: 18), (F: 14) Age: 63.4 ± (5.86) BMI= 27.7 kg/m².	v Constant stiffness footwear n= 23 (M: 10), (F: 13) Age: 61.0 ± (7) BMI= 28.5 kg/m².	- Knee loading (KAM) - PROs (WOMAC).	- Baseline. - 12 months post inter.	- KAM peak= No signif. Diff. between groups at 12-months post-inter (p= 0.55). - WOMAC (pain and total)= No Signif. Diff. between groups at 12-month post-inter.

Table 9: Continue Characteristics and results of included studies:

Ferrira et al. (2021) <i>Prospective, single blinded RCT.</i> <i>Portugal</i>	38 LWI n=20 (M: 5), (F: 15) Age: 62.6 ± (8.0) BMI= 29.7 ± 5.9 kg/m².	v s Neutral insole n= 18 (M: 10), (F: 8) Age: 60.6 ± (8.9) BMI= 28.9 ± 4.2 kg/m².	- Knee loading KAM 1st & 2nd peaks). - Biomechanical details (KAAI). - Pain (VAS). - PROs (KOOS & Global improvement). - Functional performance tests (12-steps climb-stair, 40m fast walk & 30 sec. sit to stand).	- Baseline. - 3 months post inter.	- KAM 1st peak= Signif. Diff. between groups at 3 months post-inter (p<0.001). While 2nd peak= Did not, (p=0.122). - KAAI = No Signif. Diff. between groups at 3 months post-inter (p=0.495). - VAS= No Signif. Diff. between groups at 3 months (p= 0.38). - KOOS= Signif. Diff. between groups at 3 months post-inter (p=0.027). - 12-steps climb-stair, 40m fast walk & 30 sec. sit to stand= No Signif. Diff. between groups at 3 months post-inter. - Global impro. = Signif. Diff. between groups at 3 months post-inter.
Hunt et al. (2018) <i>Parallel , RCT.</i> <i>Canada</i>	79 Toe-out (Re-gait) n=40 (M:13), (F: 27) Age: 64.6 ± (7.6) BMI= 27.3± (3.5) kg/m².	v s Progressive walking n= 39 (M: 11), (F: 28) Age: 65.4 ± (9.6) BMI= 27.4± (3.5) kg/m².	- Knee loading (KAM 1st & 2nd peaks). - Biomechanical details (KAAI, KFM & FPA). - Pain (NRPS). - Functional performance tests (Gait speed & Stair climbing). - PROs (WOMAC).	- Baseline. - 4 months post-inter. - 5 months post-inter.	- KAM peaks= Signif. Diff. between groups at 5 months post-inter (p=0.003). - KAAI (p= 0.39), KFM (p=0.90) & only FPA showed Signif. Diff. between groups at 5 months post-inter (p<0.001). - NRPS= Signif. Diff. between groups at 5 months post-inter (p=0.01). - Gait speed & Stair Climbing= No Signif. Diff. between groups at 5 months post-inter (p=0.4), (p=0.7) respectively. - WOMAC (pain & activity)= No Signif. Diff. between groups at 5 months post-inter (p=0.13) & (p=0.23) respectively.
Jones et al. (2015) <i>Single centre, RCT.</i> <i>United Kingdom</i>	70 1- LWI 2- Supported LWI 3- Mobility Shoes 4- Barefoot n=70 (M:43), (F: 27) Age: 60.3 ± (9.6) BMI= 30.5± (4.9) kg/m².	v s 1- Control Shoes “Ecco Zen” n=70 (M:43), (F: 27) Age: 60.3 ± (9.6) BMI= 30.5± (4.9) kg/m².	- Knee loading (KAM 1st & 2nd peaks). - Biomechanical details (KAAI & KFM). - Functional performance tests (Gait speed). - Pain (5-points Likert scale). - PROs (Comfort rating scale)	- Baseline (one session).	- KAM 1st peak: Both LWIs & Barefoot groups showed signif. diff. (p=0.001) vs control group post-inter at baseline. - KAM 2nd peak: Both LWIs groups only showed signif. diff. vs control group post-inter. at baseline (p<0.001). - KAAI: Both LWIs & Barefoot showed signif. Diff. vs control group post-inter at baseline (p<0.001) & (p= 0.023) respectively. - KFM: Only “Bare foot” showed signif. diff. vs control group post-inter (p=0.023). - Gait speed: Mobility shoes & Barefoot groups reported signif. diff. between groups post-inter at baseline (p<0.001). - Pain 5-points likert scale: Both “Supp.LWI & Mobi. shoes” showed Signif. Diff. vs control group post-inter (p<0.001). - Comfort scale: Both “LWIs” and “Mobility shoes” rated more comfortable vs control group post-inter at baseline (p<0.001).

Table 9: Continue Characteristics and results of included studies:

Kapadia et al. (2016) <i>Prospective, Single centre blinded, RCT.</i> USA	36	Valgus KB. n=24 (M: 10), (F: 14) Age: 59 ± (45–79) BMI= N/A	Physiotherapy Care v s n=12 (M: 5), (F: 7) Age: 54± (41–69) BMI= N/A	- Knee loading (KAM). - Biomechanical details (KAAI). - Functional performance tests (RoM, Gait speed & Knee Exten. at heel strike).	- Baseline. - 3 months post inter.	- KAM= No Signif. Diff. of varus KB group (p= 0.33) & valgus KB (p= 0.57) vs control groups at 3 months post-inter. - KAAI= No Signif. Diff. of varus KB (p=0.090) & valgus KB (p= 0.08) vs control groups 3 months post-inter. - Knee ROM= Valgus KB showed Signif. Diff. at 3 months post-inter (p=0.006). - Gait speed= Valgus KB showed Signif. Diff. at 3 months post-inter (p=0.003). - Knee exten. at heel strike= Valgus KB showed Signif. Diff. between groups at 3 months post-inter (p=0.006).
Khosravi et al. (2019) <i>Single centre blinded RCT</i> Iran	21	1- LWI n=7 (M:4), (F: 3) Age: : 60.3 ± (5.28) BMI=29.1 ± (3.2) <i>kg/m²</i>. 2- Valgus KB n=7 (M:4), (F: 3) Age:59.2 ± (8.07) BMI=30.4 ± (2.8) <i>kg/m²</i>.	3- Valgus KB 4- Valgus KB + LWI v s n=7 (M: 2), (F: 5) Age: 57.4 ± (7.48) BMI= 31.0 ± (3.1) <i>kg/m²</i>.	- Knee loading (KAM). - Functional performance tests (Gait speed, Cadence, Stride length & RoM). - Pain (VAS). - PROs (WOMAC & Satis.Likert Scale).	- Baseline. - 6 weeks post inter.	- KAM peaks= No Signif. Diff. at 6 weeks post-inter with LWI vs valgus KB (p=0.897), Valgus KB vs combination, (p=1.0) and LWI vs combination (p=0.9). - Gait speed= No Signif. Diff. at 6 weeks post-inter with LWI vs valgus KB (p=0.8), Valgus KB vs combination, (p=0.6) and LWI vs combination (p=0.3). - Cadence= No Signif. Diff. at 6 weeks post-inter with LWI vs valgus KB (p=0.4), Valgus KB vs combination, (p=0.7) and LWI vs combination (p=0.1). - Sride length= Signif. Diff. at 6 weeks post-inter showed only with LWI vs valgus KB (p=0.01). - RoM= Signif. Diff. at 6 weeks post-inter, showed with LWI vs valgus KB (p=0.01) and LWI vs combination, (p=0.001). - VAS= Signif. Diff. at 6 weeks post-inter, showed with LWI vs valgus KB (p=0.03) only. - WOMAC (pain, stiff. & activity)= Signif. Diff. Showed with LWI vs KB for pain, stiff. & activitiy subscales (p=0.04), (p=0.01) & (p=0.01) respectively. Also, LWI vs combination for WOMAC activity only subscale at (p=0.001) 6 weeks post-inter.. - Satis. Likert S.= No Signif. Diff. cross LWI vs valgus KB (p=0.6), KB vs combination (p=0.4) and LWI vs combination (p=0.1) at 6 weeks post-inter.

Table 9: Continue Characteristics and results of included studies:

Mirzaei et al. (2018) Single centred RCT. Iran	21 1- LWI n=6 (M: 1), (F: 5) Age: 54.50 ± (4.2) BMI=24.74± (2.5) kg/m². 2- Valgus KB n=6 (M: 3), (F: 3) Age: 55.16 ± (4.8) BMI=27.92 ± (5.4) kg/m². 3- Valgus KB 4- Valgus KB + LWI n=6 (M: 2), (F: 4) Age: 53.2 ± (6.18) BMI= 26.77 ± (0.5) kg/m². V S	- Knee loading (KAM 1st & 2nd peaks). - Functional performance tests (Gait speed, Cadence, Stride length & Hip, Knee & Ankle RoM). - Pain (VAS). - Baseline. 2 weeks post inter.	- KAM 1st peak= Both LWI vs combination and valgus KB vs combination showed significance. Diff. (p= 0.02) & (p=0.05) respectively at two weeks post-inter. - KAM 2nd peak: Both LWI vs. combination and valgus KB vs. combination showed significant difference (p=0.001) and (p=0.02) respectively at 2 weeks post-inter. - Gait speed: the only significant difference observed was between LWI and the combination at 2 weeks post-intervention (p=0.03). - Cadence: No Signif. Diff. between inter-groups at 2 weeks post-inter. - Stride length: the only significant difference observed was between LWI and the combination at 2 weeks post-intervention (p=0.045). - Knee ROM: significant differences were observed between LWI vs valgus KB (p=0.002) and LWI vs combination (p=0.000) at 2 weeks post-intervention. - VAS: No Signif. Diff. observed between inter-groups at 2 weeks post-inter.
Paterson et al. (2018) Exploratory RCT Australia	164 LWI n=83 (M: 41), (F: 42) Age: 65.2 ± (6.9) BMI= 29.7± (3.6) kg/m². Conventional shoes n=81 (M: 39), (F:42) Age: 63.3 ± (7.9) BMI= 29.7± (3.7) kg/m². V S	- Knee loading (KAM). - Biomechanical details (KAAI). - Pain (NRPS). - Baseline. - 6 months post inter.	- KAM: Signif. Diff. between groups at 6 months post-inter (p=0.02). - KAAI: Signif. Diff. between groups at 6 months post-inter (p<0.001). - NRPS: No significant differences between groups at 6 months post-inter.
Trombini-Souza et al. (2012; 2015) Parallel, blinded & comparative ,RCTs. Brazil	56 Minimal Shoes n=28 (feamle) Age: 66.0 ± (5.0) BMI= 30.2± (4.7) kg/m². Habitual Shoes n=28 (feamle) Age: 66.0 ± (6.0) BMI= 30.2± (4.0) kg/m². V S	- Knee loading (KAM). - Biomechanical details (KAAI). - Functional performance tests (6-min. walking test). - PROs (WOMAC, Lequesne Scale & Mediacal asses.& Pat. Self-asses). - Baseline. - 6 months post inter.	- KAM: No Signif. Diff. between groups at 6 months post-inter (p=0.493). - KAAI: No Signif. Diff. between groups at 6 months post-inter (p=0.053). - 6-min. walking test: No Signif. Diff. between groups at 6 months post-inter (p=0.9). - WOMAC-pain, stiff., activ. & total: Signif. Diff. between groups at 6 months post-inter with effect size (1.41), (0.76), (1.22) & (1.27) respectively. - Lequesne scale: Signif. Diff. between groups at 6 months post-inter (p<0.001). - Med. & Pat. Global assessment = Signif. Diff. between groups at 6 months post-inter was observed (p = 0.0108) for medical asse. While no signif. Diff. was between groups with Pat. Self asses. (p = 0.228).

BMI: Body Mass Index, **F**: Female, **FPA**: Foot Progression Angle, **GRF**: Ground Reaction Force, **KAAI**: Knee Adduction Angular Impulse, **KAM**: Knee Adduction Moments, **KB**: Knee Brace, **KFM**: Knee Flexion Moment, **kg/m²**: Kilograms per Meter Square, **KOOS**: Knee Injury and Osteoarthritis Outcome Score, **LWI**: Lateral Wedge Insole, **M**: Male, **M/A**: Moment Ar, **N**: Numbers, **NRPS**: Numeric Pain Rating Scale, **PROs**: Patient Report Outcomes, **RCT**: Randomised Control Trial, **ROM**: Range of Motion, **SD**: Standard Deviation, **VAS**: Visual Analog Scale, **VS**: Versus, **WOMAC**: Western Ontario and McMaster Universities Osteoarthritis Index.

4.5.6 Studies Analysis:

4.5.6.1 KAM 1st peak short term effect (up to 6 months):

LWI vs. valgus KB effect:

67 KOA subjects versus 63 subjects participated in four RCTs to evaluate the short-term effect of LWI versus valgus KB on knee loading (1st KAM) during walking. There was no significant reduction difference of KAM 1st peak (SMD= -0.07 with [95% CI -0.44 to 0.31], $p= 0.73$). The heterogeneity among the studies was low ($I^2= 7\%$ and $p= 0.36$), indicating that there was no statistically significant difference between LWI and valgus KB in terms of the 1st-peak KAM for up to 6 months.

LWI vs (valgus KB + LWI) effect:

Two RCTs were conducted to compare the effectiveness of LWI versus a combination of valgus KB and LWI. The total sample size was 13 in both the experimental and control groups. The overall reduction effect on KAM 1st-peak was not significant (SMD= 0.46, [95% CI; -0.33 to 1.25], $p= 0.26$). The analysis showed no heterogeneity among studies ($I^2= 0\%$ & $p=0.46$), indicating no statistically significant difference between the interventions.

LWI vs control shoes effect:

The effectiveness of LWI compared to control shoes was assessed through three RCTs that included 154 participants for the intervention and 152 participants in the control group. The overall effect demonstrated no significant reduction difference in KAM 1st peak (SMD= -0.06 and [95% CI; -0.28 to 0.16], $p= 0.60$). Moreover, the heterogeneity was absent between the studies ($I^2= 0\%$, $p=0.56$), indicating no statistically significant difference between LWI and control shoes.

Interventional shoes vs control shoes effect:

Two trials, Jones et al. (2015) and Trombini-Souza et al. (2012; 2015), were included, comprising 96 participants in the experimental group versus 94 in the control group. The overall effectiveness of intervention shoes on KAM 1st peak reduction was not significant (SMD = -0.11 with [95% CI; -0.44 to

0.22], $p = 0.51$). Additionally, the reported heterogeneity was low ($I^2 = 19\%$, $p = 0.27$), suggesting that no significant difference among interventions was observed.

Gait re-training vs. walking exercise effect:

Two RCTs evaluating gait re-training compared to walking exercises were completed to assess KAM 1st peak. The experimental group included 45 subjects, and the control group included 42 subjects. However, the overall effect illustrated no significant reduction difference in KAM 1st peak between the interventional comparatives (SMD= -0.38 and [95% CI; -0.80 to 0.05], $p = 0.08$). Furthermore, the heterogeneity did not exist ($I^2 = 0\%$, $p = 0.92$), revealing no significant statistical difference between gait re-training and walking exercise.

Valgus KB vs. (Valgus KB + LWI) effect:

Regarding the combination concept, two RTCs compared the efficacy of valgus KB alone to the combination of LWI and valgus KB. These trials included a sample size of 13 participants in both the intervention and comparator groups. Despite this, there was no significant difference between the groups (SMD = 0.00 with [95% CI; -0.76 to 0.77], $p = 0.99$). Moreover, there was no heterogeneity observed. ($I^2 = 0\%$, $p = 0.84$), demonstrating no statistically significant difference between valgus KB and the combination form.

In summary, the meta-analysis findings for the six subgroups as shown in Figure 21.

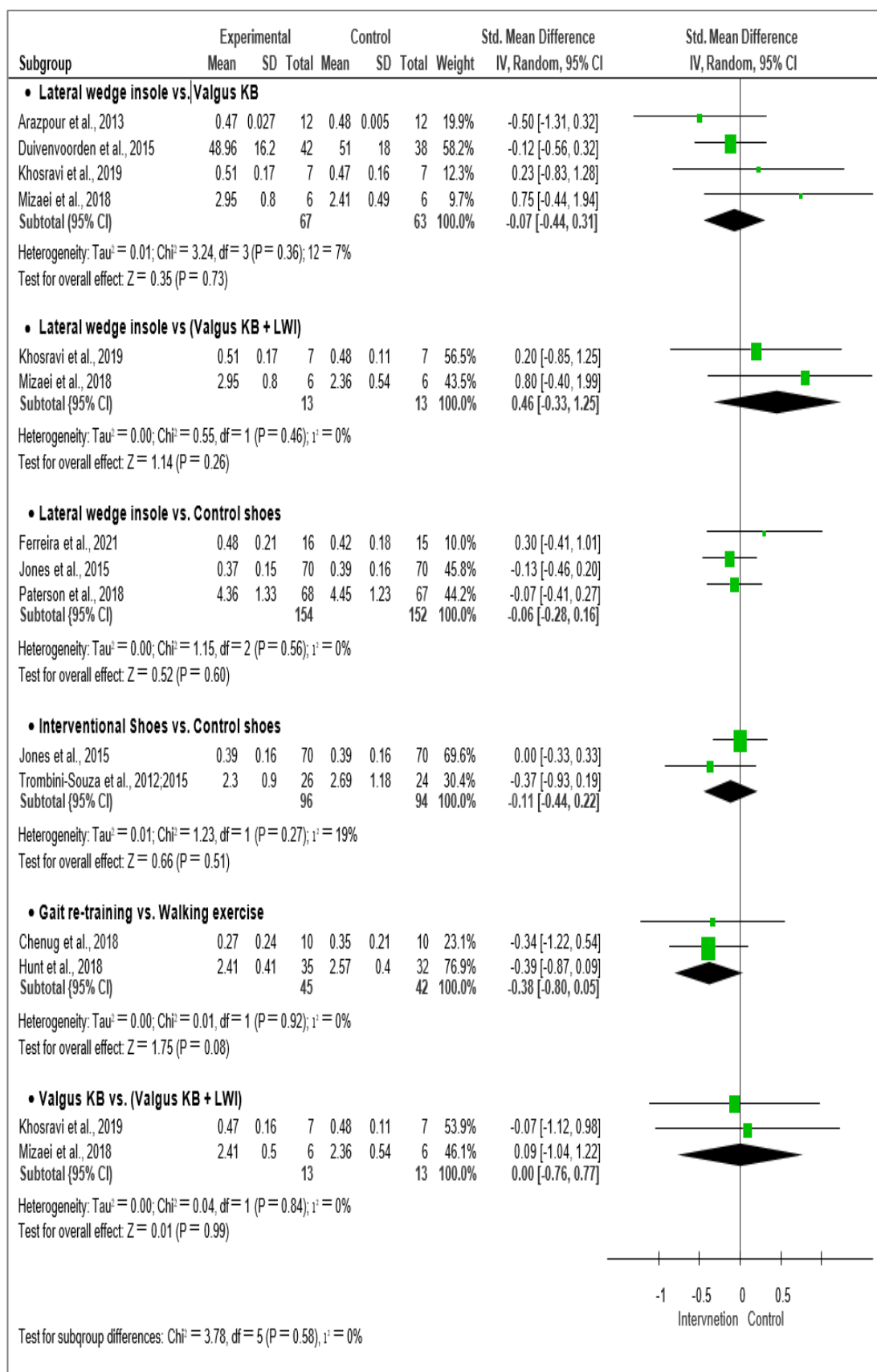


Figure 21: KAM 1st peak short term effect forest plot.

The subsequent parts quantitatively describe several gait modifications to reduce KAM 1st peak at short-term effects (up to 6 months).

In a study by Jones et al. (2015), 70 participants wearing supported LWI were compared with 70 subjects in control shoes. According to Jones et al. (2015), the supported LWI group showed a mean KAM 1st peak reduction of $0.37 \pm (0.15)$ Nm/kg, while the control group showed a reduction of $0.39 \pm (0.16)$ Nm/kg. The analysis revealed that the supported LWI intervention resulted in a small reduction in KAM1st peak compared to the control group, with no statistically significant difference detected between groups (SMD= -0.13 [95% CI: -0.46 to 0.20], $p = 0.44$).

Additional reviews of two further RCTs, Erhart et al. (2010) and Kapadia et al. (2016), evaluated the effectiveness of lateral stiffener shoes and pneumatic KB on KAM 1st peak, respectively. Both studies compared these interventions with controls, using either control shoes or PT usual care, to measure their short-term effects.

Erhart et al. (2010) included 34 participants who used lateral stiffener shoes and 26 participants who used control shoes. Initially, the reduction in KAM was -3.50 %Nm/kg. standard error (SE= -1.11%). Six months after the intervention, the mean KAM reduction increased to -6.58 %Nm/kg (SE=1.12%), with a mean difference of -3.08 %Nm/kg. The effect size (Cohen's d) was -2.76, indicating a very large and significant impact of the lateral stiffener shoes over a short time (up to 6 months).

In a study by Kapadia et al. (2016), two groups of KOA patients were analysed based on their knee deformities (varus and valgus). The first group consisted of 16 varus KOA participants who decreased mean KAM from 43.5 Nm*Bw (15.7 to 61) to 38.5 Nm*Bw (23 to 48.1) over three months with pneumatic KB intervention. In contrast, the eight participants in the PT usual care group had their mean KAM remain almost unchanged, from 38.9 Nm*Bw (range: 17.6 to 91) to 38.5 Nm*Bw (range: 13.4 to 61). The effect size (Cohen's d) was 0, indicating that the pneumatic KB did not significantly affect varus KOA patients.

In the second group, eight participants with valgus KOA who wore pneumatic KB showed an increase in mean KAM from 9.8 Nm*Bw (range: 2.8 to 19.1) to 11.5 Nm*Bw (range: -2.4 to 20.3) over three months. On the other hand, the four participants who received PT usual care reported a KAM decrease from 11.9 Nm*Bw (range: 19 to 31.3) to 8.5 Nm*Bw (range: 5.5 to 16.1). The analysis showed a large effect mean difference in KAM 1st peak reduction (SMD = 0.67 [CI 95%; 0.19 to 1.54]). However, this reduction was not significant ($p = 0.09$).

4.5.6.2 KAM 1st peak mid-term effect (6 to 12 months):

Lateral stiffener shoes vs. control shoes:

Two RCTs evaluating lateral stiffener shoes compared to control footwear were completed. The interventional group consisted of 50 subjects, while the control group had 41. However, the overall results showed no significant difference in KAM 1st peak between the two groups (SMD= -0.38 and [95% CI; -0.88 to 0.12], $p = 0.13$). Additionally, there was low heterogeneity ($I^2 = 27\%$, $p = 0.24$), indicating no significant statistical difference between lateral stiffener shoes and control shoes. (Figure 22).

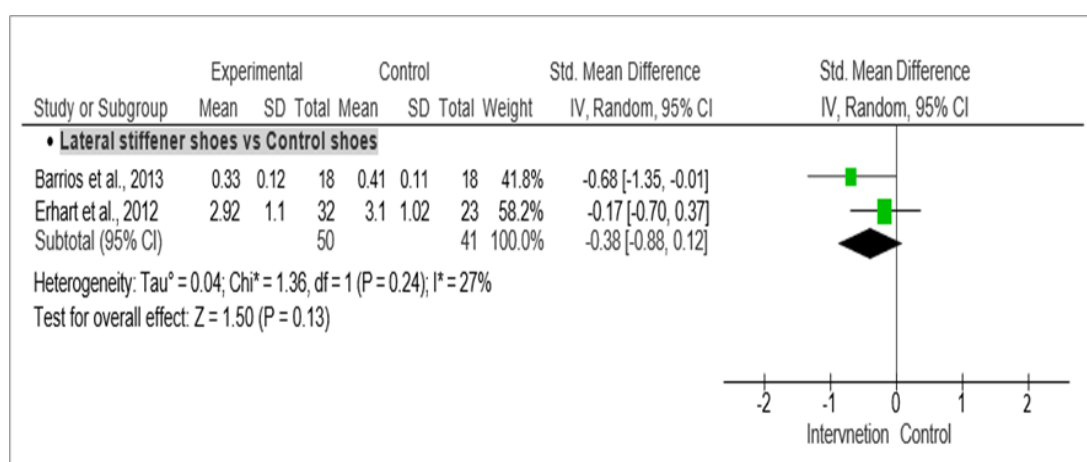


Figure 22: KAM 1st peak Mid-term effect forest plot

4.5.6.3 KAM 2nd peak short term effect:

International shoes vs. control shoes effect:

Two RCTs, Jones et al. (2015) and Ferreira et al. (2021) included 86 subjects in the interventional shoe group versus 85 in the control group. The overall effectiveness of interventional shoes on KAM 2nd peak was insignificant (SMD = -0.22 with [95% CI; -0.52 to 0.08], $p = 0.15$). Additionally, there was no reported heterogeneity ($I^2 = 0\%$, $p = 0.99$), indicating no statistically significant difference among groups. (Figure 23).

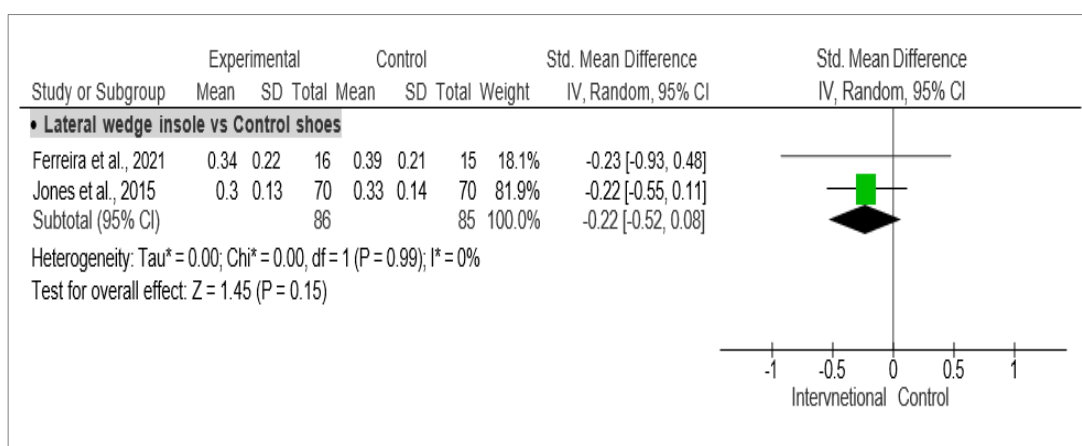


Figure 23: KAM 2nd peak short term effect forest plot

The following sections provide a quantitative description of various walking adjustments to reduce KAM 2nd peak for short-term effects (up to 6 months).

As per Hunt et al. (2018), the 35 subjects of re-gait training (toe-out) group exhibited a mean KAM 2nd peak reduction of 2.50 ± 0.41 %BW*Ht., while 32 subjects in the walking control group showed a reduction of 2.70 ± 0.39 %BW*Ht. over five months of follow-up. The analysis indicated that the toe-out group led to a moderate reduction in KAM 2nd peak compared to the control group, with statistically significant differences observed between groups (SMD= -0.50 [CI 95%; -0.99 to -0.01], $p=0.04$).

As reported by Jones et al. (2015), the 70 subjects with supported LWI group showed an average reduction of 0.31 ± 0.14 Nm/kg in the KAM 2nd peak, while the same subjects were in the walking control group exhibited a reduction of 0.33 ± 0.14 Nm/kg over one follow-up session. The analysis displayed that

the supported LWI group resulted in a small reduction in KAM 2nd peak compared to the control group, and no statistically significant differences were marked between the groups (SMD= -0.14 [CI 95%; -0.41 to 0.12], p= 0.40).

In the same study with same participants, the mobility shoes showed an average reduction of 0.32 ± 0.14 Nm/kg in the KAM 2nd peak, while the walking control group exhibited a reduction of 0.33 ± 0.14 Nm/kg over one follow-up session. The analysis indicated that the mobility resulted in a small reduction in KAM 2nd peak compared to the control group. However, no statistically significant differences were observed between the groups (SMD= -0.07 [CI 95%; -0.12 to -0.03], p= 0.7).

In a study by Mirzaei et al. (2018), six participants were assigned to the LWI group, while another six wore valgus KB for two weeks to measure the 2nd peak KAM. The LWI group exhibited an average reduction in KAM 2nd of 2.33 ± 0.6 Nm/Bw*Ht, while the valgus KB group showed a decrease of 1.76 ± 0.5 Nm/Bw*Ht over the two weeks. The analysis revealed a significant mean difference between the groups, but no statistically significant difference was detected in the short term (SMD= 1.03 [CI 95%; -0.33 to 2.4], p=0.10).

Additionally, Mirzaei et al. (2018) conducted six subjects placed in the LWI group, while another six used a combination of LWI and valgus KB. The LWI group exhibited an average reduction of 2.33 ± 0.6 Nm/Bw*Ht. in KAM 2nd peak, whereas the combination group showed a reduction of 1.63 ± 0.25 Nm/Bw*Ht. at two weeks post-intervention. The analysis revealed a significant decrease in KAM 2nd peak in the LWI group, and a statistically significant difference was observed between the groups (SMD= 1.5 [CI 95%; 0.06 to 3.0], p=0.025).

Lastly, Mirzaei et al. (2018) included six additional subjects in the valgus KB group compared to the combination form (LWI+valgus KB). They found that the KAM 2nd peak reduced to 1.76 ± 0.5 Nm/Bw*Ht, compared to 1.63 ± 0.25 Nm/Bw*Ht, respectively. The analysis showed a slight reduction in KAM 2nd peak with the valgus KB group. However, this reduction was not statistically significant between the groups (SMD= 0.4 [CI 95%; -0.81 to 1.5], p= 0.6) at the short-term timepoint.

4.5.6.4 KAAI short term effect:

LWI vs control shoes effect:

The efficacy of LWI versus control shoes was evaluated across three RCTs involving 154 individuals in the intervention group and 152 in the control group. The overall effect showed no substantial difference in KAAI between the groups (SMD = -0.18, [95% CI; -0.40 to 0.04], $p = 0.21$). Additionally, no heterogeneity was detected among the studies ($I^2 = 0\%$, $p = 0.71$), suggesting no significant statistical difference between LWI and control shoes.

International shoes vs. control shoes effect:

Two trails, Jones et al. (2015) and Trombini-Souza et al. (2012; 2015) were included, involving 96 participants in the experimental group and 94 in the control group. The overall impact of intervention shoes on KAAI was insignificant (SMD= - 0.17 [95% CI; -0.45 to 0.12], $p = 0.25$). Furthermore, no heterogeneity was observed ($I^2 = 0\%$, $p = 0.78$), indicating that the interventions did not significantly differ.

In general, the meta-analysis findings for the two subgroups KAAI in short-term effect results are shown in Figure (24).

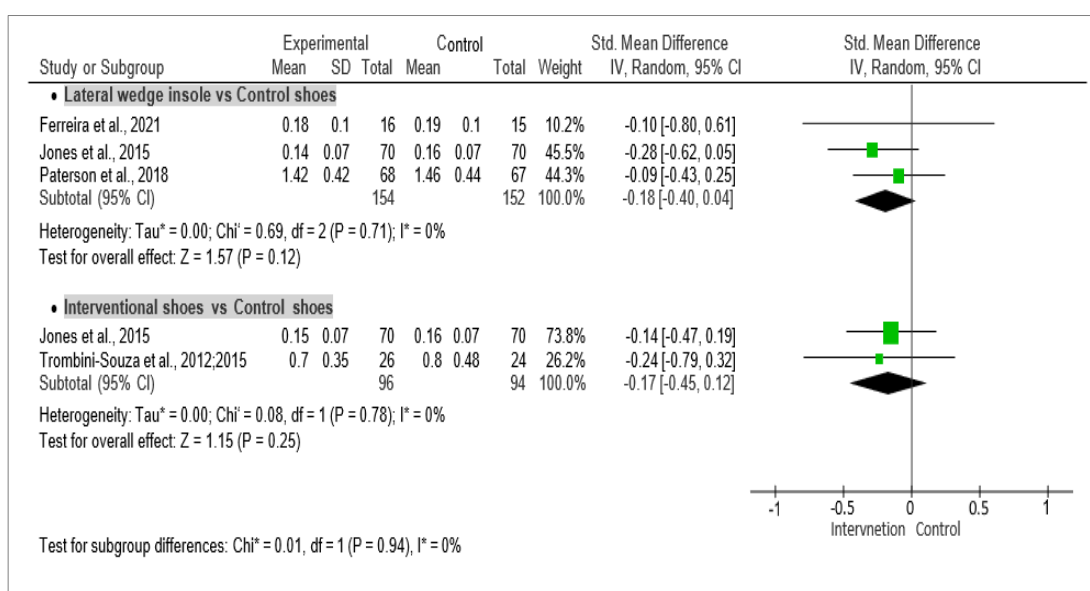


Figure 24: KAAI short term effect forest plot.

The following sections statistically describe some other various modified gait approaches to reduce KAAI and provide an overview of their impact over a short duration (up to 6-months).

In a study by Duivenvoorden et al. (2015), 42 subjects were included in the LWI group and 38 in KB group. The study found that the LWI group showed a mean KAAI reduction of -2% ($\pm 16\%$) Nm/sec., while the KB group showed a reduction of 6% ($\pm 22\%$) Nm/sec. The analysis revealed that the LWI intervention resulted in a greater reduction in KAAI than the valgus KB intervention, with a statistically significant difference (SMD= -0.42 [95% CI; -0.86 to 0.02], $p = 0.036$) and small effect size. This suggests that LWI may be more effective in reducing KAAI than the KB intervention in the short term.

In a short-term study over 5 months, Hunt et al. (2018) compared 35 subjects in the gait re-training (toe-out) group with 32 subjects in the walking exercise group. They reported a mean KAAI of 0.81 ± 0.2 % Nm/BW*Ht/sec for the re-gait training group and 0.87 ± 0.11 % Nm/BW*Ht/sec. for the walking exercise group. The findings showed that the re-gait training group experienced a small reduction in KAAI compared to the walking exercise group but not statistically significant (SMD= -0.37 [95% CI; -0.85 to 0.12], $p = 0.06$).

Moreover, In a study by Jones et al. (2015), 70 subjects were evaluated while wearing supported LWI and control shoes. The study found that the mean KAAI was 0.15 ± 0.07 Nm/kg*sec. for supported LWI, representing a reduction of -5.52%, compared to 0.16 ± 0.07 Nm/kg*sec. for control shoes. The results indicated no notable effect of supported LWI versus control shoes (SMD= -0.14 [CI 95%; -0.03 to 0.013]) with a non-statistically significant ($p = 0.39$). In the same study, there were almost identical results compared to previous findings when Jones et al. (2015) included the same 70 subjects in both the mobility and the control shoe groups to evaluate KAAI reduction. The findings for the mobility shoes group showed KAAI = (0.15 ± 0.07) Nm/kg*sec., with a reduction of -2.74%, while the control shoes group showed KAAI = (0.16 ± 0.07) Nm/kg*sec. The analysis also indicated a negligible effect (SMD = -0.14 [95% CI; -0.48 to 0.19]) with no statistical significance difference ($p > 0.05$) at the same short-term.

In a study by Kapadia et al. (2016), 16 participants in the pneumatic KB group showed a reduction in varus KAAI from 23.3 to 17.1 Nm/sec ($p = 0.05$), while 8 participants in the PT usual care group reduced from 18.0 to 14.7 Nm/sec ($p = 0.48$). In the same study, for valgus KAAI, 8 participants in the pneumatic KB group reduced from 2.86 to 0.49 Nm/sec ($p = 0.49$), while four subjects in the PT usual care group increased from 2.20 to 2.47 Nm/sec ($p = 0.71$).

The analysis of the study results showed that for varus KAAI, SMD was 4.53 (CI 95%: 3.69 to 5.37, $p = 0.05$), indicating a large effect size favouring the pneumatic KB group in reducing varus KAAI compared to the PT usual care group. Additionally, for valgus KAAI, the SMD was 3.70 (95% CI; 2.94 to 4.46, $p = 0.5$), representing a large effect size favouring the pneumatic KB group in reducing valgus KAAI compared to the PT usual care group, although this result was not statistically significant.

In summary, the pneumatic KB group exhibited significantly greater reductions in varus KAAI measures at three months post-intervention compared to the PT usual care, with large effect sizes. This indicates that the pneumatic KB intervention was more effective than PT's usual care in improving KAAI.

4.5.6.5 KAAI med-term effect:

Among the included studies in this review, only one RCT investigated KAAI at the medium-term time point. Barrios et al. (2013) compared 19 subjects in the lateral stiffener shoes to 19 subjects in the control shoes group to assess KAAI reduction. The KAAI mean findings for the LWI group were 0.15 ± 0.10 , and for the control shoes group, the KAAI findings were 0.19 ± 0.06 at 12 months of follow-up. The SMD based on these results indicated that the LWI has a moderate effect size in reducing KAAI, suggesting that it could be a potentially beneficial treatment (SMD= -0.59 [95% CI; -1.2 to 0.06]). However, the difference was not statistically significant ($p = 0.06$).

4.5.6.6 KFM short term effect:

Gait re-training vs. walking exercise effect:

Cheung et al. (2018d) Hunt et al. (2018) conducted gait re-training versus walking exercises to assess KFM in two RCTs. The intervention group included 45 participants, while the control group had 42 total. The overall effect showed no significant difference in KFM between the intervention groups (SMD = 0.07, [95% CI; -0.35 to 0.49], $p = 0.74$). No heterogeneity was observed ($I^2 = 0\%$), and there was no significant statistical difference between the two approaches ($p = 0.73$) at a short time point. Figure (25).

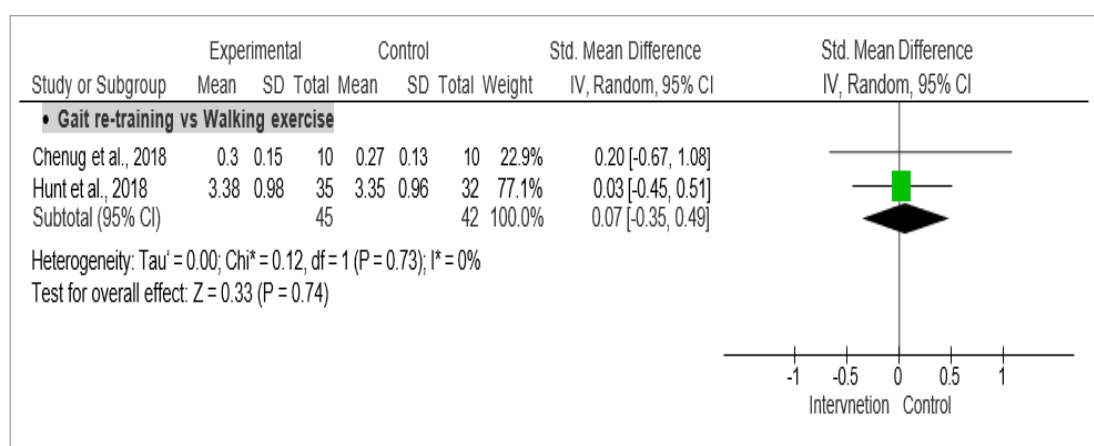


Figure 25: KFM short term effect forest plot.

Further individual analysis was conducted on the study by Jones et al. (2015) to examine the short-term effects of multiple gait modifications (LWI, supported LWI and mobility shoes) versus control shoes on KFM. The research assessed 70 subjects in both LWI and control footwear. Findings showed that the average KFM was 0.61 ± 0.23 Nm/kg for LWI, with a reduction of 0.39%, compared to 0.61 ± 0.24 Nm/kg. Results revealed no significant or notable effects between the groups (SMD= 0 [95% CI; -0.33 to 0.33]), with an insignificant difference between groups ($p = 1.00$).

In the same study, 70 participants were divided into two groups: those using supported LWI and those wearing control shoes. The supported LWI group demonstrated a KFM of 0.62 ± 0.23 Nm/kg, decreasing by 2.17%, while the control group recorded a KFM of 0.61 ± 0.24 Nm/kg. Analysis revealed an

insignificant effect between the groups (SMD = 0.042 [95% CI; -0.29 to 0.37]), with no statistical difference between groups ($p = 0.80$).

Additional KFM assessments were performed on the same 70 subjects across both the mobility and control shoe groups. The mobility shoe group recorded a KFM of 0.60 ± 0.24 Nm/kg, slightly reducing 0.99%, whereas the control group reported 0.16 ± 0.07 Nm/kg. Further analysis revealed the minimal impact between the two groups (SMD = -0.042 [95% CI; -0.37 to 0.29]), with no statistical differences ($p = 0.08$).

Overall, the comparisons showed that there were no statistically significant effects, suggesting that different foot orthotic interventions did not significantly differ from the control group in reducing KFM. Although there was a slight variation in the direction of the effects, with some tendency towards the foot orthotics and others towards the control shoes, these variations were not statistically significant.

4.5.6.7 Pain level short term effect:

LWI vs. valgus KB effect:

In three RCTs, twenty-five subjects with KOA were compared to twenty-five subjects to assess the short-term impact of LWI versus valgus KB on knee pain during walking. The results showed no significant difference in the reduction of knee pain level between the two interventions (SMD= -0.37 with [95% CI -1.19 to 0.45], $p = 0.38$). The studies exhibited moderate heterogeneity ($I^2 = 48\%$ and $p = 0.15$), suggesting no statistically significant distinction between LWI and valgus KB in reducing knee pain for short-term effects.

LWI vs (valgus KB + LWI) effect:

Two RTCs were included to evaluate the effectiveness of LWI compared to a combination of valgus KB and LWI, with a total sample size of 13 in both the experimental and control groups. The overall reduction effect on knee pain was insignificant (SMD= -0.18, [95% CI; 1.19 to 0.83], $p = 0.73$). The analysis showed medium heterogeneity among studies ($I^2 = 39\%$ & $p = 0.20$), indicating no statistically significant difference between the interventions.

LWI vs control shoes effect:

Two RCTs evaluating the effectiveness of LWI compared to control shoes involved 84 participants in the intervention group and 82 in the control group. The overall effect showed no significant reduction in knee pain (SMD= 0.03 and [95% CI; -0.39 to 0.46], $p= 0.87$). Additionally, the studies had moderate heterogeneity ($I^2= 31\%$), indicating no statistically significant difference between LWI and control shoes ($p=0.23$).

Valgus KB vs. (Valgus KB + LWI) effect:

Two RTCs compared valgus KB's effectiveness versus a combination of LWI and valgus KB. In total, 13 participants were in both the intervention and comparison groups. The results showed a moderate pain effect but no statistical difference between groups (SMD = 0.66 [95% CI; -0.14 to 1.46], $p= 0.11$). No heterogeneity was observed ($I^2 = 0\%$, $p= 0.84$). This demonstrates no statistically significant difference between using valgus KB versus combination of LWI and valgus KB. In summary, the meta-analysis pain results for the four subgroups at short term are displayed in Figure (26).

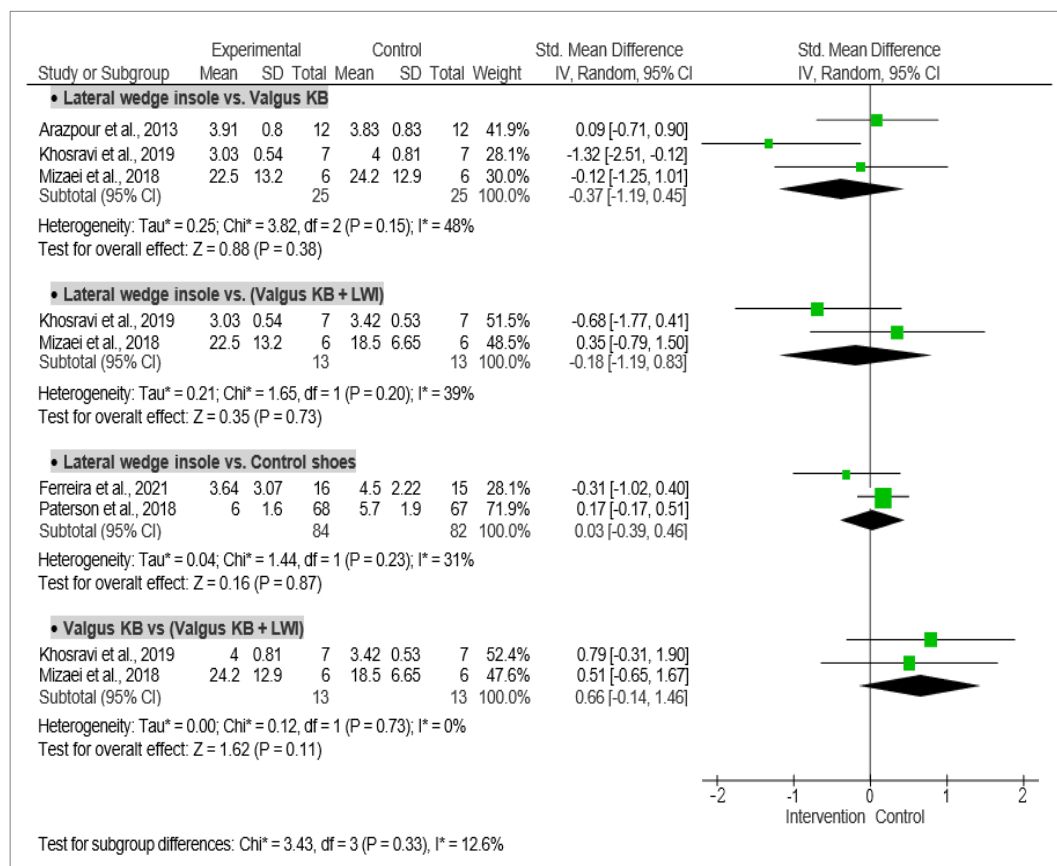


Figure 26: Knee pain short term effect forest plot

The Hunt et al. (2018) study examined the use of NRPS for reducing knee pain. In a short-term study over five months, 35 subjects underwent gait re-training (toe-out) while 32 subjects participated in a walking exercise group. The mean NRPS for the toe-out group was 1.9 ± 1.78 , compared to 2.6 ± 1.70 in the walking exercise group. The findings indicated that the toe-out group experienced lower average knee pain scores than the control group, suggesting a moderate reduction in knee pain (SMD= -0.37 [95% CI; -0.85 to 0.12]). However, this result was not statistically significant ($p= 0.10$) in the short term.

In addition, Jones et al. (2015) conducted a knee pain analysis to study the short-term effects of different gait modifications (LWI, supported LWI and mobility shoes) compared to control shoes. The study involved 70 participants in both intervention groups, and the effects were measured using a 5-point Likert scale. However, due to the lack of sufficient data provided by Jones et al. (2015) regarding pain reduction outcomes, a descriptive statistical analysis of the effects of the various gait modifications versus control shoes was carried out.

The analysis revealed that both supported LWI and mobility shoes significantly reduced knee pain ($p<0.001$). In contrast, individuals wearing control shoes reported a noticeable increase in knee pain ($p=0.015$), as did those walking barefoot ($p=0.054$) over the short term.

4.5.6.8 Knee ROM short term effect:

LWI vs. valgus KB effect:

In three RCTs, twenty-five subjects with KOA were compared to twenty-five subjects to assess the short-term impact of LWI versus valgus KB on knee ROM. The results showed a significant effect in the improved knee ROM towards the control direction (SMD= 1.42 [95% CI 0.60 to 2.23]) with a statistically significant difference ($p< 0.001$). The studies indicated moderate heterogeneity ($I^2= 30\%$ and $p= 0.24$), suggesting no statistically significant distinction between LWI and valgus KB in improving knee ROM for short-term effects.

LWI vs (valgus KB + LWI) effect:

Two RCTs were conducted to compare the effectiveness of LWI with a combination of valgus KB and LWI. The total sample size was 13 in both the experimental and control groups. The overall effect on knee ROM improvement was significantly higher in the combination group direction (SMD= 2.02, [95% CI; 1.00 to 3.03], $p < 0.001$). However, the analysis showed no heterogeneity among studies ($I^2 = 0\%$ & $p = 0.67$), indicating no statistically significant difference between the intervention groups.

Valgus KB vs. (Valgus KB + LWI) effect:

Two RCTs compared valgus KB alone versus a combination of LWI and valgus KB with knee ROM. A total of 13 participants were included in both the intervention and comparison groups. The results indicated no significant effect on knee ROM, and there was no statistical difference between the two groups (SMD = 0.13 [95% CI; -0.64 to 0.90], $p = 0.74$). No heterogeneity was observed among the studies ($I^2 = 0\%$, $p = 0.86$). This demonstrates no statistically significant difference in knee ROM between using valgus KB and a combination of LWI and valgus KB in the short term.

In summary, Figure 27 displays the meta-analysis of knee range of motion results for the three subgroups in the short term.

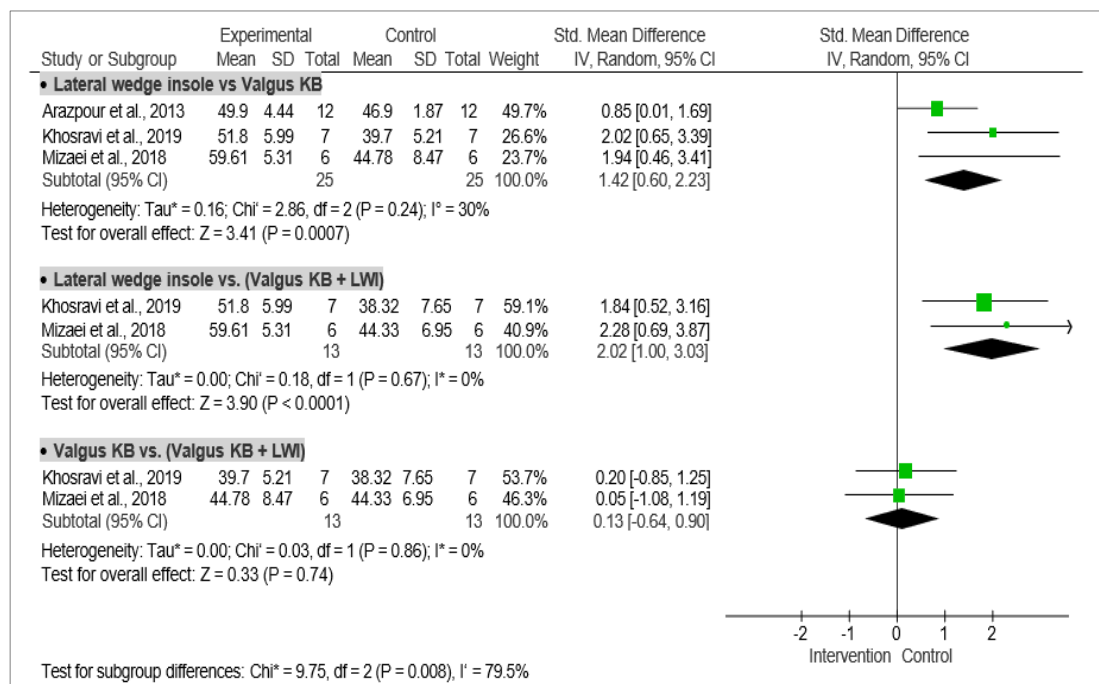


Figure 27: Knee ROM short term effect forest plots

In Kapadia et al. (2016), 24 participants in the pneumatic KB group showed an improvement in knee range of motion (ROM) from 41° to 45°, while 12 participants receiving the usual PT care reported an enhancement in knee ROM from 46° to 47° over a three-month follow-up period.

The analysis of the study results revealed that the pneumatic KB group experienced a moderate improvement in their knee ROM compared to the PT usual care group (SMD= 0.3 [95% CI; -0.48 to 0.99]). However, the groups had no statistically significant difference ($p = 0.48$). In summary, the pneumatic KB group could provide an improvement in knee ROM measures compared to the PT usual care group at the short-term timepoint.

Furthermore, Kapadia et al. (2016) compared the previous number of subjects using pneumatic KB and those receiving PT usual care to evaluate knee extension at heel strike. It was observed that knee extension in the pneumatic KB group measured 4.4°, ranging (from 1.5° to 12.7°), while in the PT care group, it was 7.7°, ranging from (3.2° to 15.2°). Analysis of the results indicated that the improvement in knee extension was significant in the pneumatic KB group compared to the PT care group (SMD= -1.15 [95% CI: -1.84 to -0.46]) with a statistically significant difference between the groups ($p < 0.01$) over a three-month post-intervention timeframe.

4.5.6.9 Gait speed short term effect:

LWI vs. valgus KB effect:

In three RCTs, twenty-five KOA subjects were compared to twenty-five subjects to assess the short-term impact of LWI versus valgus KB on gait speed. The results showed that there was no significant difference in gait speed between the two interventions (SMD= -0.40 [95% CI; -2.50 to 1.7], $p = 0.71$). The studies revealed high heterogeneity ($I^2 = 90\%$ and $p < 0.0001$), suggesting that there was no statistically significant distinction between LWI and valgus KB in improving gait speed for short-term effects.

LWI vs (valgus KB + LWI) effect:

Two RCTs were conducted to assess the efficacy of LWI as compared to a combination of valgus KB and LWI on gait speed. The study involved 13

participants in both the interventional and control groups. The overall improvement in gait speed was found to be significant (SMD= 1.57, [95% CI; 0.64 to 2.5]) in favour of the control group, with a statistically significant difference between the interventions ($p= 0.001$). The analysis indicated no heterogeneity among the studies ($I^2= 0\%$ & $p= 0.43$), suggesting no statistically significant difference between the interventions over short term.

LWI vs control shoes effect:

Two RCTs compared the effectiveness of LWI to control shoes on gait speed level, involving 86 participants in the intervention group and 85 in the control group. The overall effect revealed no significant improvement in gait speed (SMD= 0.00 and [95% CI; -0.30 to 0.30], $p= 1.00$). Furthermore, the studies exhibited no heterogeneity ($I^2= 0\%$), indicating no statistically significant difference between LWI and control shoes ($p= 1.00$) at short term timepoint.

Valgus KB vs. (Valgus KB + LWI) effect:

Two RTCs compared the effectiveness of valgus KB versus a combination of LWI and valgus KB for the gait speed level. In total, 13 participants were in both the intervention and comparison groups. The results showed a moderate gait speed effect but no statistical difference between groups (SMD = 0.40 [95% CI; -0.38 to 1.18], $p= 0.32$). No heterogeneity was observed ($I^2 = 0\%$, $p= 0.75$). This demonstrates no statistically significant difference between using valgus KB versus combining LWI and valgus KB during the short term.

In summary, the meta-analysis gait speed results for the four subgroups at short term are displayed in Figure (28).

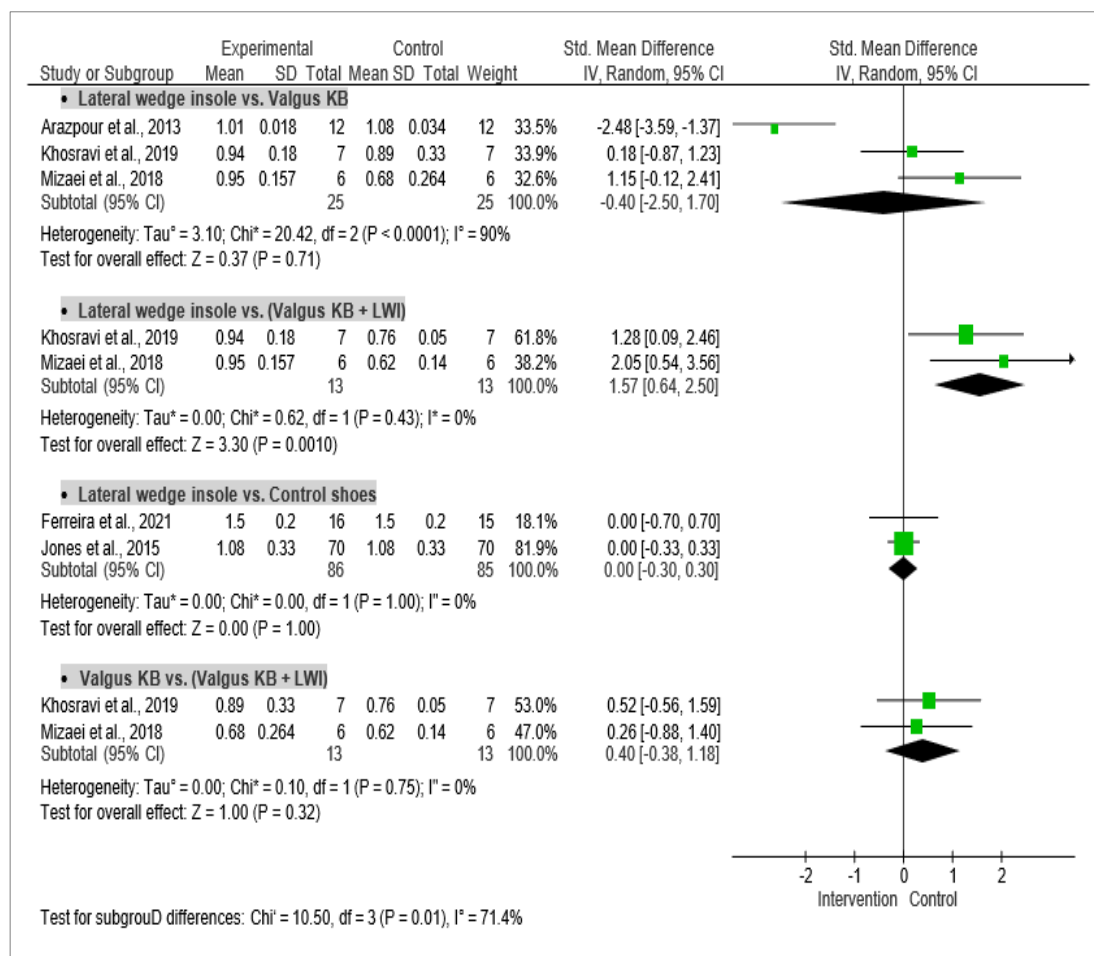


Figure 28: Gait speed short term effect forest plot

The results from other trials focusing on the gait speed outcome are presented in the following section.

The Hunt et al. (2018) study examined the gait speed. In a short-term study over five months, 35 subjects underwent gait re-training (toe-out) while 32 subjects participated in a walking exercise group. The mean gait speed for the toe-out group was 1.23 ± 0.059 m/sec., compared to 1.25 ± 0.057 m/sec. in the walking exercise group at five months of follow-up. The toe-out group showed slightly improved gait speed compared to the control group, but the difference was not statistically significant ($SMD = -0.35$ [95% CI: -0.83 to 0.14]) and ($p = 0.16$).

In addition, Jones et al. (2015) evaluated gait speed during the short-term effects of various gait modifications (supported LWI and mobility shoes) compared to control shoes. The study included 70 participants in both

intervention groups. The analysis found that both supported LWI and mobility shoes led to a slight increase in gait speed, but with no statistically significant difference in gait speed (SMD= 0.03 [95% CI; -0.08 to 0.14], $p = 0.77$), (SMD= 0.1 [95% CI; -0.02 to 0.2], $p = 0.37$) respectively.

In a study by Kapadia et al. (2016), 24 participants in the pneumatic KB group showed an improvement in gait speed from 89.16 cm/sec. ranged (51–128) to 98.5 cm/sec. ranged (54–157). In contrast, the 12 participants in the PT usual care group's mean gait speed was 92.5 cm/sec. ranged (57–123) to 95.5 cm/sec. ranged (58–107) during three months of follow-up.

The analysis of the Kapadia et al. (2016) results revealed that the pneumatic KB group experienced a small to moderate improvement in gait speed (SMD= 0.41), while the PT usual care group (SMD= 0.21) suggested a small effect on gait speed. Moreover, Based on the pooled SMD, the pneumatic KB group demonstrated more gait speed enhancement than the PT usual care group, with a small effect size (SMD= 0.33 [CI 95%; -0.08 to 0.74]). Nevertheless, this difference in gait speed was not statistically significant ($p=0.11$) at three months of follow-up.

4.5.6.10 Stride length short term effect:

LWI vs. valgus KB effect:

In three RCTs, twenty-five KOA subjects were compared to twenty-five subjects to assess the short-term impact of LWI versus valgus KB on stride length. The results showed that there was a significant effect size in the stride length towards the control group (SMD= 1.33 [95% CI; 0.70 to 1.96]) with a significant statistical difference in stride length between groups ($p < 0.0001$). The studies revealed no heterogeneity ($I^2 = 0\%$ and $p = 0.91$), indicating no statistically significant difference between groups in short-term time points.

LWI vs (valgus KB + LWI) effect:

Two RCTs were conducted to assess the efficacy of LWI as compared to a combination of valgus KB and LWI on stride length. The study involved 13 participants in both the interventional and control groups. The overall improvement in stride length was found to be significant (SMD= 1.39, [95% CI;

0.36 to 2.42]) in favour of the control group, with a statistically significant difference between the interventions ($p= 0.008$). The analysis indicated low heterogeneity among the studies ($I^2= 20\%$ & $p= 0.26$), suggesting no statistically significant difference between the interventions over the short term.

Valgus KB vs. (Valgus KB + LWI) effect:

Two RTCs compared the effectiveness of valgus KB versus a combination of LWI and valgus KB for the gait speed level. In total, 13 participants were in both the intervention and comparison groups. The results showed an insignificant effect on stride length with no statistical difference between groups (SMD = -0.28 [95% CI; -1.33 to 0.77], $p= 0.60$). moderate heterogeneity was observed ($I^2 = 43\%$, $p= 0.19$). This demonstrates no statistically significant difference between using valgus KB versus combining LWI and valgus KB of stride length during the short term.

In summary, Figure (29) displays the three subgroups' short-term meta-analysis gait stride length results.

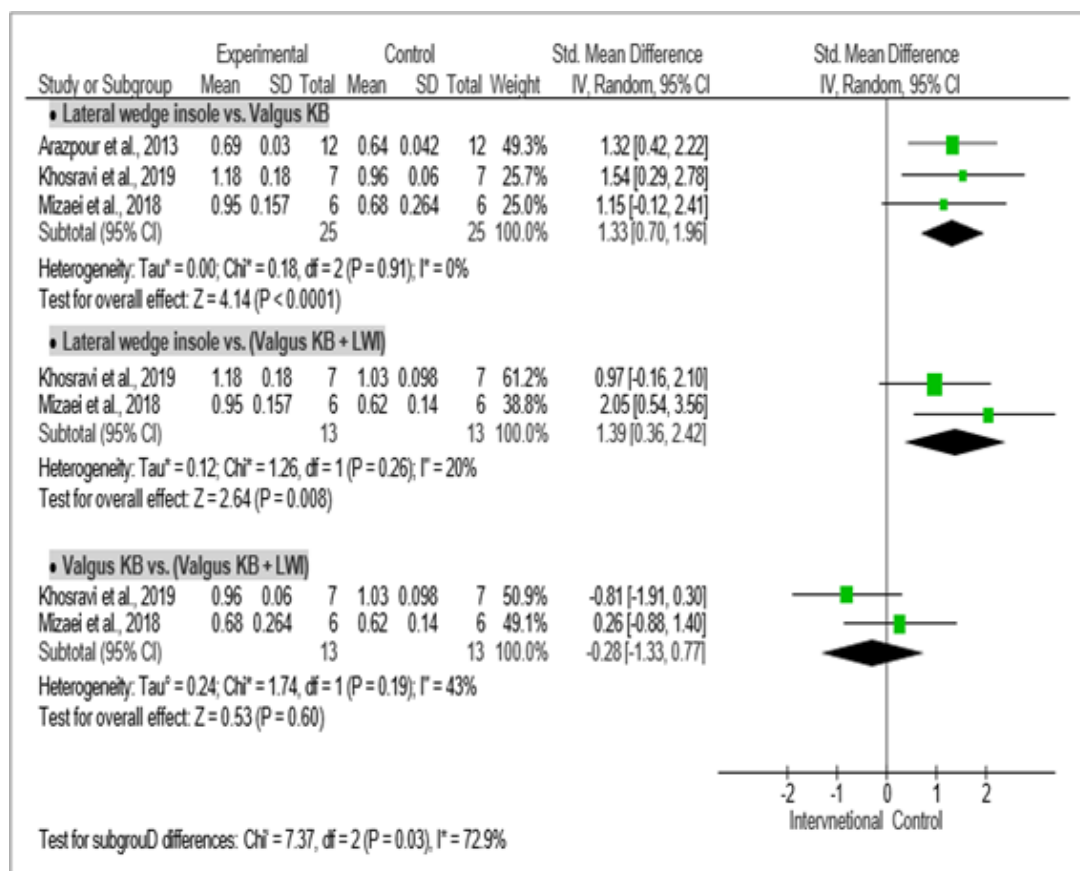


Figure 29: Stride length short term effect forest plot.

4.5.6.11 Cadence short term effect:

LWI vs. valgus KB effect:

In two RTCs, 13 KOA subjects (KOA) were compared to an equal number of controls to evaluate the short-term effects of LWI versus valgus KB on their cadence. Analysis revealed a moderate effect size favouring the control group regarding cadence (SMD= 0.62 [95% CI; -0.17 to 1.42]). However, the two groups had no statistically significant difference in cadence ($p=0.13$). Additionally, the studies showed no heterogeneity ($I^2=0\%$ and $p=0.76$), confirming the lack of statistically significant differences in short-term outcomes between the groups.

LWI vs (valgus KB + LWI) effect:

Two RCTs were conducted to evaluate the effectiveness of LWI versus a combined valgus KB and LWI approach on cadence. The research included 13 participants in both the intervention and control groups. A significant increase in science was observed, demonstrating a substantial effect (SMD= 1.14, [95% CI; 0.29 to 2.00]) that favoured the control group with a statistically significant difference between the interventions ($p= 0.009$). The analysis revealed no heterogeneity between the studies ($I^2 = 0\%$ and $p = 0.88$), indicating no significant variations between the interventions in the short term.

Valgus KB vs. (Valgus KB + LWI) effect:

Two RTCs compared the efficacy of valgus KB alone to the combination of LWI with valgus KB on cadence levels. The studies included 13 participants for each intervention and comparison group. The findings had minimal impact on cadence, showing no statistically significant differences between the two approaches (SMD = 0.26 [95% CI; -0.52 to 1.03], $p = 0.51$). Additionally, no heterogeneity was detected ($I^2 = 0\%$, $p = 0.67$), indicating no significant distinction between employing only valgus KB and using a combination of LWI and valgus KB in the short term.

In summary, Figure (30) displays the three subgroups' short-term meta-analysis cadence results.

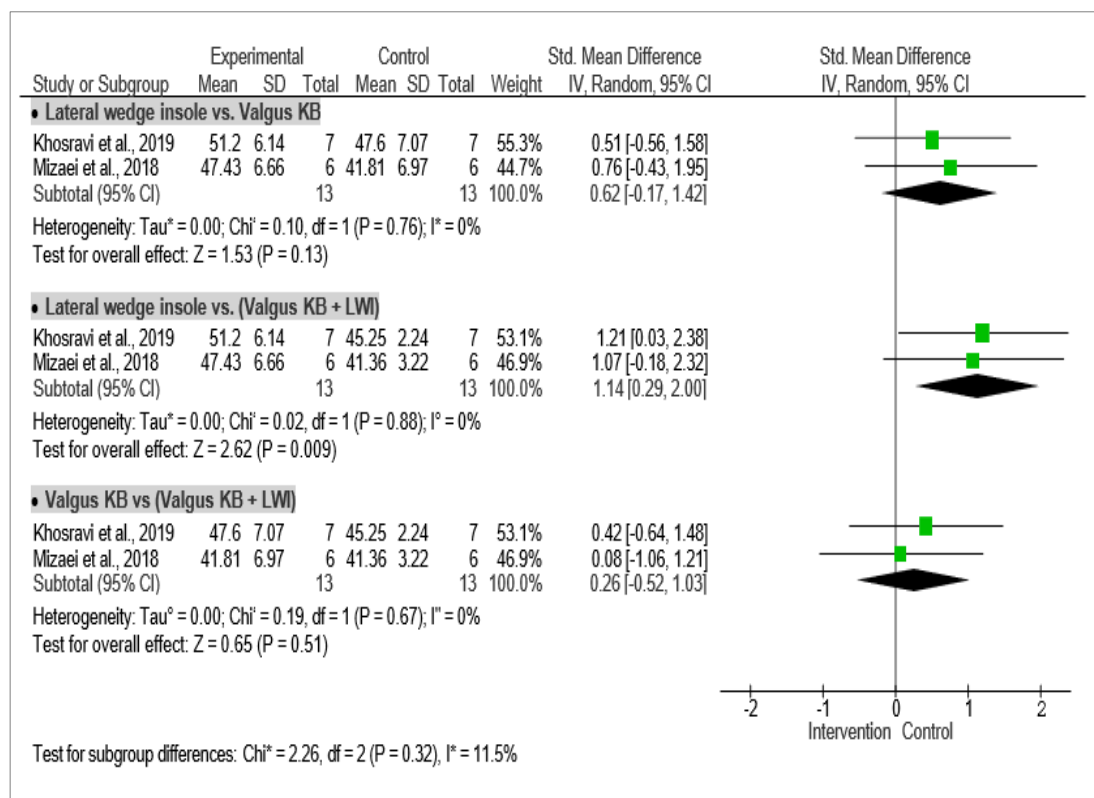


Figure 30 Cadence short term effect forest plot.

4.5.6.12 Variable physical activity tests short term effect:

Particular trials reported some additional outcomes related to physical activity tests, such as walking distance, climbing stairs, and sit-stand tests. The following sections will systematically represent these.

In a study by Duivenvoorden et al. (2015), the walking distance during the short-term effects of LWI was compared to valgus KB. The study involved 42 LWI group participants with a walking distance improvement of $11\% \pm (29\%)$. In comparison, 38 subjects in the valgus KB group reported a walking distance improvement of about $7\% \pm (17\%)$. The results showed that the mean walking distance for the LWI group was slightly higher than that of the valgus KB group (SMD=0.17 [CI 95%; -0.27 to 0.61]). However, the two groups had no statistically significant difference ($p=0.38$).

Moreover, In a study conducted by Ferreira et al. (2021), the 12-step stair climbing test was performed by 20 subjects in the LWI group, resulting in an average time of 13.6 seconds (± 3.0), and by 18 subjects in the control group, resulting in an average time of 16.3 seconds (± 6.6). These results indicated a moderate effect, with subjects in the LWI group showing a faster time climbing

stairs. However, the difference between the groups was not statistically significant at short-term time points (SMD = -0.54 [95% CI; -1.19 to 0.11]), ($p = 0.1$).

Another test, the 30-second sit-to-stand test, was conducted with the same 20 subjects in the LWI group, achieving an average of 13.6 seconds (± 3.1) repetitions, and 18 subjects in the control group achieving an average of 12.9 seconds (± 2.6) repetitions. The analysis showed that the control group performed slightly better in terms of repetitions, with a small effect size (SMD = 0.24 [95% CI; -0.42 to 0.09]) and no statistically significant difference between the groups ($p = 0.47$).

In the same activity test for climbing stairs time, Hunt et al. (2018) found that the 35 participants who underwent re-gait training (toe-out) achieved a time of 5.33 seconds ± 1.30 , while the 32 subjects in the walking exercise group achieved a time of 5.44 seconds ± 1.30 over five months of follow-up. The re-gait training group performed slightly better (lower time) than the walking exercise group, showing a small effect (SMD= -0.09 [CI 95%; -0.57 to 0.40]). However, there was no statistically significant difference between the groups ($p = 0.8$) in the short-term timepoint for climbing stairs time.

Lastly, Trombini-Souza et al. (2012; 2015) evaluated a 6-minute distance walking test during the short-term effects of minimal shoes compared to control shoes. The study included 26 participants in the minimal shoes group and 24 in the control shoes group. The results revealed that the average distance covered in the 6-minute distance walking test was 439.3 m ± 34.7 (ranging from 433.5 m to 439.3 m) for the minimal shoes group, whereas it was 428.3 m ± 44.2 (ranging from 430.6 m to 428.3 m) for the control shoes group. The study found that the minimal footwear group achieved a slightly greater average distance in the 6-minute distance walking trial than the control footwear group (SMD=0.28 [CI 95%; -0.28 to 0.83]). However, this difference was not statistically significant ($p= 0.92$).

4.5.7 Certainty of evidence:

The certainty of evidence for various outcomes in gait modification approaches was assessed, focusing on KAM, KAAI, knee pain, knee ROM, and gait speed.

The certainty for KAM 1st peak was low due to a serious risk of bias and imprecision, shown by wide confidence intervals overlapping the null value. Despite low heterogeneity and direct evidence, quality was downgraded. Reducing KAM was rated as critically important for managing KOA and enhancing patient quality of life. Moreover, KAAI certainty was very low due to significant bias and imprecision from wide confidence intervals and small sample sizes, resulting in a two-level downgrade. Despite serious inconsistency in results and follow-up periods, reducing KAAI was important for KOA, reflecting cumulative knee load during walking (Thorp *et al.*, 2007).

The certainty of evidence for pain reduction was low, based on seven RCTs, due to a serious risk of bias, particularly in randomization and blinding. Despite moderate heterogeneity and consistent findings, imprecision led to a downgrade. The outcome was highly important, significantly impacting patient quality of life.

Knee ROM certainty was low due to bias, inconsistency, and imprecision. Evidence from four RCTs showed inconsistency ($I^2 = 53\%$) and imprecision, leading to downgrades. Despite the relevance, the certainty was diminished by these factors.

Gait speed showed very low certainty due to a serious risk of bias, inconsistency ($I^2 = 77\%$ overall and $I^2 = 90\%$ in one subgroup), and imprecision. The importance of this outcome was significant for patient mobility and quality of life.

The certainty of evidence for gait modification approaches varied from low to very low across outcomes, mainly due to bias, inconsistency, and imprecision. Knee loading (KAM and KAAI) and knee pain were critical, while outcomes like cadence, stride length, and physical activity were less important. For detailed evidence certainty, see Appendix 2.

4.6 Discussion:

The MA and SR results comprehensively evaluated different gait modification approaches with KOA patients during walking, focusing on knee loading, pain levels and functional outcomes.

In terms of knee loading, the analysis revealed that most gait modification methods did not significantly decrease the KAM 1st peak at both short-term and medium-term time points. Notably, the SR of lateral stiffener shoes significantly affected the KAM 1st peak in the short term. Similarly, the KAM 2nd peak exhibited notable improvement with toe-out re-gait training, while the LWI significantly impacted both the KAM 2nd peak and the KAAI at short-term intervals. The findings highlighted that although some particular gait modifications provided advantages, the general effectiveness of gait modifications to decrease knee loading was still limited at various time intervals.

The general findings regarding pain levels indicated that most gait modification methods did not exhibit a statistically notable difference in reducing knee pain compared to control interventions in the short timepoint. Thus, the absence of significant pain reduction from various gait modification interventions highlighted the difficulty of addressing knee pain with KOA subjects and it could indicated that gait modifications on their own may not be adequate for relieving pain.

For functional outcomes, the MA and SR emphasised that gait modification interventions did not demonstrate potential advantages in improving knee ROM, gait speed, stride length, and cadence over the short term. Also, the outcomes of the physical activity tests did not show statistical significance, revealing that the advantages of the gait modification approaches might be limited in the short term with these functional outcomes.

4.6.1 Knee loading (KAM 1st & 2nd peaks and KAAI):

The MA & SR results for the KAM 1st and 2nd peaks and the KAAI summarised various gait modification approaches. These approaches aim to reduce the KAM 1st peak in the short term (up to 6 months) and medium term

(6 to 12 months). Additionally, they focus on reducing the KAM 2nd peak and KAAI in the short term only.

The examined interventions consist of LWI, valgus KB, control shoes, supported LWI, interventional shoes, gait retraining, walking exercises, lateral stiffener shoes, and pneumatic KB. The studies have different sample sizes, with some having small groups (e.g., 13 participants in each group) and others having larger groups (e.g., 154 participants in the intervention group and 152 in the control group).

The overall comprehensiveness and relevance of the data on the outcomes of the KAM 1st peak from the 13 trials in the MA and two trials in the SR, along with two trials from the MA for the KAM 2nd peak and six RCTs within the MA for KAAI, suggest that the interventions such as LWI, valgus KB, supported LWI, lateral stiffening shoes, and gait retraining do not have a significant impact on the KAM 1st & 2nd peaks and KAAI in the short and medium term time points. However, the evidence might not be widely applicable due to the small sample sizes in certain studies, which could potentially impact the generalisability of the results (Walters *et al.*, 2019).

The MA findings were inconsistent with those of Arnold *et al.* (2016), who showed small effect size results for LWI intervention to reduce KAM and KAAI during short time points. However, the lack of significant findings for LWI in (Arnold *et al.*, 2016) aligns with the current results of the SR by Jones *et al.* (2015), reinforcing that these interventions may not effectively reduce KAM in the short term. Furthermore, the current MA findings were also inconsistent with those of (Xing *et al.*, 2017), who reported a small effect size of supported LWI with KAM peaks and KAAI during short time points.

Although this MA & SR conducted various trials with variable LWI lengths (short to full length), the findings also contradict previous reviews, such as the angle degree of LWI by Ferreira *et al.* (2019) and Zafar *et al.* (2020). These SR & MA studies reported that full-length LWIs with a 5° elevation, shock absorption, and arch support reduced both peaks of KAM and KAAI in the short term. The authors recommend customisation of insoles based on individual biomechanical parameters for optimal effectiveness.

Consequently, the LWI could have an impact at the beginning of the stance phase rather than at a later stage. However, wedges might exacerbate KAM under certain conditions (Butler *et al.*, 2007; Kakihana *et al.*, 2007; Hinman *et al.*, 2008b). Their effects might be influenced by factors such as osteoarthritis progression and knee realignment (Butler *et al.*, 2007) or insole length (Kakihana *et al.*, 2004). The severity of KOA among study participants might vary, aligning with findings that KAM reductions were seen in those with mild osteoarthritis but not in moderate or more severe cases (Shimada *et al.*, 2006; Erhart-Hledik *et al.*, 2015), related to degenerative severity and progression, Chehab *et al.*, (2014) suggesting that disease severity may be critical.

Moreover, the MA for the lateral stiffener shoes was not in line with the review of Shaw *et al.* (2018), who reported that LWIs reduced KAM peaks but increased ankle eversion. This finding suggests that LWIs may be affected by ankle movement, represented by everted ankle subjects, causing the KAM not to improve. Additionally, the reduction in KAM during stance is associated with increased rear-foot eversion, rear-foot internal rotation and forefoot inversion. This suggests that patients with knee KOA who walk with more foot pronation (eversion) experience less medial knee loading (Levinger *et al.*, 2013).

Additionally, Shaw *et al.* (2018) concluded that incorporating arch supports lessened ankle eversion but diminished the reduction in KAM in the short term. However, the current SR with Jones *et al.* (2015) indicated no significant impact of the supported LWI over a short time on both KAM peaks reduction, contradicting Shaw *et al.*'s (2018) review findings regarding supported LWI. However, this discrepancy might be affected by the single session conducted by Jones *et al.* (2015), which required a long-term effect to demonstrate KAM peak reduction.

The MA of re-gait training concerning KAM and KAAI showed inconsistency with previous studies by Wang *et al.* (2021), Silva *et al.* (2022). However, in terms of KAM 2nd peak and KAAI, the current SR result based on the Hunt *et al.* (2018) analysis found that the re-gait training group experienced a small reduction in KAM 2nd peak and KAAI only, consistent with the previous reviews by Wang *et al.* (2021), Silva *et al.* (2022).

Furthermore, all these reviews concluded that studies covered time points ranging from immediate to 12 months, showing moderate to high effect sizes for KAM peaks and KAA reductions. Wang et al. (2021) noted that FPA effects varied between individuals with and without medial KOA and could be influenced by age, body mass index (BMI), and knee alignment. Meanwhile, Silva (2022) reported that toe-in gait modestly lowered the 2nd KAM peak, while toe-in moderately reduced the KAM 1st peak but slightly increased the KAM 2nd peak. These modifications were clinically valuable for evaluating KAM peaks and KAAI in medial KOA subjects.

Besides, MA results also reveal a discrepancy within Huang et al. (2022) research results, which support using LWI and valgus KB in combination form and re-gait training to reduce the KAM 1st peak and KAAI during short- and medium-term time points. The current MA & SR findings regarding LWI alone, intervention shoes (mobility and minimal), and lateral stiffener shoes (variable stiffness) were in line with Huang et al. (2022) results, which did not significantly reduce the KAM 1st peak over short- and medium-term time points.

Moreover, using LWI versus LWI plus KB in this MA's findings opposed to Huang et al. (2022), which reported the most effective reduction of the KAM 1st peak (93%) when using the combination form. Also, this MA of re-gait training and valgus KB versus controls found results that were not aligned with Huang et al. (2022), which reported re-gait training as the second most effective (85.7%) and valgus KB as the third most effective (79.3%) interventions to reduce the KAM 1st peak.

However, within this SR, the study by Duivenvoorden et al. (2015) confirmed the results with those of Huang et al. (2022), whose analysis revealed that the LWI intervention resulted in a slight reduction in KAAI compared to the valgus KB intervention. Based on this, LWI may be more effective in reducing KAAI than the KB intervention in the short term. This discrepancy in the KAM and KAAI results emphasizes the importance of conducting additional high-quality, extended research studies to understand the effectiveness of these interventions.

Regarding KAM reduction with valgus KB efficacy in this MA contradicted Moyer et al. (2015) MA findings, which showed that valgus KBs significantly (a moderate-to-high effect size) lower the KAM during the short and mid-term (2 weeks to 12 months). Furthermore, Kapadia et al. (2016) SR results differ from those of Moyer et al. (2015), showing mixed results for pneumatic KB, varying effectiveness by knee deformity type. Specifically, the pneumatic KB did not significantly affect varus KOA patients. At the same time, for valgus KOA subjects, it indicated a medium effect size, suggesting that the pneumatic KB intervention had some impact on KAM at short time points, confirmed Moyer et al. (2015) MA findings. Therefore, it is understood that the biomechanical effects of interventions can differ based on KB brace design and individual patient characteristics. Moreover, a brace's effectiveness in lowering KAM may also be affected by the brace's fit, which may result in patient pain (Singer and Lamontagne, 2008). The brace design and patient fit will likely determine its efficiency.

On the other hand, regarding KB concerning KAAI outcomes, this MA's findings were inconsistent with Huang et al. (2022) regarding KAAI reduction in the short-term effect. Moreover, Kapadia et al. (2016), in the current SR findings, disagreed with Huang et al. (2022), who reported insignificant improvement in KAAI among KB studies. The mixed results from Kapadia et al. (2016) regarding pneumatic KB, with Huang et al. (2022) showing varying effectiveness of KB studies based on knee deformity type (varus and valgus), were consistent with the understanding that the biomechanical effects of interventions can differ based on individual patient knee deformity.

4.6.2 Knee flexion moment (KFM):

The findings of this MA and SR, which were limited based on the included studies' results, were consistent with Silva et al.'s (2022) research that showed no significant results for toe-out re-gait training interventions to reduce KFM during a short timepoint. However, Jones et al. (2015) showed only a small improvement in KFM during walking in the short term when barefoot but not significant difference between groups. Moreover, the discrepancy in the learned gait modifications related to the effectiveness of

KFM may be because KAM primarily affects the femoral medial cartilage, while KFM influences the tibial medial cartilage. This differential impact indicates that interventions focusing solely on KAM might overlook the contributions of KFM to the overall load on the knee joint and the health of the cartilage (Chehab et al., 2014).

4.6.3 Pain level:

For the LWI insole and valgus KB interventions, this MA did not agree with previous reviews (Raja and Dewan, 2011; Khosravi *et al.*, 2022), which both showed significant knee pain reduction and improved physical function during short and mid-term time points.

The main strengths of the review by Raja & Dewan *et al.* (2011) and Kohsravi *et al.* (2022) were their thorough inclusion of studies and detailed analysis of clinical outcomes. However, the interventions' heterogeneity and the included studies' moderate quality pose limitations. Future research should prioritise high-quality, long-term RCTs with unified intervention designs to yield more conclusive evidence regarding the effectiveness of KB and foot orthoses. Additionally, investigating the impact on muscle strength and other biomechanical parameters (e.g., gait speed and stride length) could provide further insights into their benefits for knee osteoarthritis patients.

However, for the LWI vs. control shoes, these MA findings were consistent with previous research by (Parkes *et al.*, 2013), which reported that LWI did not show a substantial impact on pain when compared to neutral insoles, indicating that its functional benefits were limited during short and mid-term time points. Further, Parkes *et al.* (2013) MA examines the effectiveness of LWIs in pain reduction alone, finding no significant advantage over neutral insoles. Despite focusing on RCTs, this MA also argues with heterogeneity and potential biases in smaller studies.

Furthermore, the systematic review findings about supported LWI by Jones et al. (2015) were not in line with the pain reduction outcomes reported by (Zafar, Zamani and Akrami, 2020), who conducted a review on multiple LWI designs (including full-length and arch support LWIs) and found inconclusive results regarding pain reduction during short and mid-term timepoints. The

authors claimed that despite correcting knee posture, the effectiveness of LWIs on pain and function remains uncertain, which is compounded by a lack of comparative studies.

Additionally, Zafar, Zamani and Akrami (2020) extended the investigation by exploring various LWI designs and footwear types, pointing out inconsistencies in long-term benefits and highlighting the need for further research into optimal LWI designs. While LWIs may reduce KAM and improve self-reported pain and function, their effectiveness in achieving these objectives remains uncertain. Future research should focus on well-designed LWIs and long-term trials with proper controls to yield more conclusive results. Finally, regarding LWI intervention, the findings for MA & SR were consistent with those of another study by (Zhang *et al.*, 2018; Yu *et al.*, 2021), indicating that LWI does not result in improved outcomes for KOA pain and function. Zhang *et al.* (2018) proposed that although LWI can enhance the femorotibial angle, it does not improve pain and function for KOA.

On the other hand, pain reduction by LWI might stem from a placebo effect, as pain is subjective. Also, factors influencing intervention effect size include active treatment effectiveness, baseline disease severity, delivery method, and participant numbers (Zhang *et al.*, 2008; Doherty and Dieppe, 2009). Parkes *et al.*, (2013) suggested that LWI does not significantly relieve pain and conservative LWI therapy was not recommended. However, this could be confirmed through specific three-group studies (an intervention, a placebo, and no intervention) which the authors advocated in the end; it was possible to corroborate this conclusion (Berthelot, 2011).

The current SR on re-gait training for Hunt *et al.* (2018) aligns with the findings of Pereira *et al.* (2021) and Tamura *et al.* (2023) reviews. Pereira *et al.* (2021) reported that reductions in KAM correlate with improved self-reported pain and function outcomes during short and mid-term time points. Despite these findings, various gait modifications are unrelated to changes in KAM, suggesting that KOA treatment might benefit from innovative approaches like re-gait training.

Moreover, Tamura et al. (2023) utilised toe-out and toe-in gait modifications and evaluated their effects using different pain scales (WOAMC, KOOS, VAS, NRS) over periods ranging from 6 weeks to 12 months. The FPA approach (toe-in and toe-out) demonstrated significant knee pain relief in obese women over 60 years old, along with increased patient satisfaction. Tamura et al. (2023) provide valuable insights into the potential benefits of re-gait modification for a specific group of older, overweight subjects. Besides, Tamura et al. (2023) underscore the need for further high-quality, long-term RCTs to strengthen the evidence base.

Furthermore, concerning KB, the MA findings were inconsistent with previous reviews by Fan et al. (2020) and Alfatafta et al. (2021), which reported that valgus KB improved knee pain and increased knee function. Fan et al. (2020) concluded that KBs may not enhance long-term knee pain or function but are valuable for short-term rehabilitation. Similarly, Alfatafta et al. (2021) reported that KBs reduced pain for less than three months and increased knee activity levels in the short term. Therefore, the long-term effectiveness and potential complications still need to be discovered. Overall, these reviews provide an in-depth examination of the impact of valgus KB on KOA pain management. Short-term benefits in reducing knee pain and increasing activity levels were observed consistently. However, the long-term effectiveness was debatable, with no noticeable improvement. This underscores the urgent need for ongoing, high-quality and long-term research.

4.6.4 Knee ROM:

The MA and SR results regarding LWI versus valgus KB showed significant outcomes. However, these results were conflicted with previous studies by Khosravi et al. (2022) and Raja and Dewan et al. (2011), which reported that LWI and valgus KB could improve knee ROM despite no significant difference between LWI and braces in improving function (with knee ROM discussed in the context of overall function improvements) at a short-term time point for the same comparative parameters. However, the Khosravi MA review does not explicitly measure changes in knee ROM in all studies but indicates enhancements in functional results that suggest potential

advantages in knee ROM. Furthermore, enhancements in functionality assessed by scales such as the WOMAC and KOOS frequently correspond with improved knee ROM.

4.6.5 Gait speed:

The gait speed data within this MA were consistent with Zhang et al. (2018b) meta-analysis, suggesting that LWIs do not effectively manage KOA active functions like gait speed. Knee pain, potentially influencing walking kinetics and kinematics, leads to slower walking speeds, shorter strides, and an increased KAM (Divine and Hewett, 2015). Additionally, foot posture, KOA severity, and walking behaviour could impact knee function assessment (Yonclas *et al.*, 2006). Therefore, considering the foot's physical condition along with the severity of KOA could improve gait speed when applying LWI.

Regarding re-gait training, this SR with Hunt et al. (2018) found insignificant results within toe-out training groups. This finding was inconsistent with the review of Simic et al. (2011), who argued that changes in toe-out or walking speed varied in different studies and stages of walking. Also, Simic et al. (2011) reported that changes in velocity could influence the KAM by altering the centre of mass acceleration in the vertical and frontal planes, thus impacting the magnitude of the GRF.

Moreover, knee loading parameters, especially peaks in KAM and KAAI, can influence gait speed. Telfer, Lange and Sudduth (2017) study assessed different ambulation speeds (20 meters at an average speed of 1 meter per second and 40 meters at a self-selected speed). However, the gait speed findings of this MA & SR were inconsistent with those of a prior MA by (Telfer, Lange and Sudduth, (2017), underscoring the importance of controlling gait velocity in KAM research due to its significant influence on KAM measurements. Additionally, the gait speed findings of this MA contradicted the results of Huang *et al.* (2022), which claimed that using variable-stiffness shoes resulted in noticeable advantages in reducing KAM in patients walking at higher speeds. Furthermore, studies highlight that increased GRF and joint loading at faster speeds generate more energy. It is evident that walking speed affects KAM assessment (Khan, Khan and Usman, 2017) and is inversely

related to KAAI, with slower walkers recording a higher KAAI (Thorp *et al.*, 2006b; Robbins *et al.*, 2009).

4.6.6 Stride length and Cadence:

The MA & SR results of comparing LWIs and valgus KBs showed improvements in stride length in the valgus KB group, suggesting the effectiveness of valgus KBs. This is aligned with (Maleki *et al.*, 2016), who proposed that valgus KBs can improve gait speed and stride length. Additionally, the findings were in agreement with Feehan *et al.* (2012), who reported improvements in cadence but no changes in stride length when using valgus KBs. Nevertheless, it was also noted that using valgus KBs may result in a decrease in stride length and foot clearance (Richards *et al.*, 2005; Gaasbeek *et al.*, 2007). The reason for these variances in gait function findings across studies remains ambiguous but may be influenced by factors like sole wedge design, footwear style and valgus KB type.

Furthermore, the current MA indicates that comparisons of valgus KB show insignificant differences in stride length and cadence outcomes, consistent with the findings of (Raja and Dewan, 2011; Gohal *et al.*, 2018). Wearing a valgus KB significantly reduces flexion while walking, leading to potential issues such as decreased foot clearance and a shorter stride length. The limited range of movement may stem from the valgus brace's size and single-hinge design, which make it prone to misalignment and twisting (Raja *et al.*, 2011). Moreover, Gohal *et al.* (2018) advocated assessing KB functionality (e.g., stride length and cadence) through larger prospective RCTs utilising consistent outcome assessment tools and accounting for patient compliance.

4.6.7 Variable physical activities:

The SR included studies on physical activity tests such as climbing stairs, sit-to-stand, and the 6-minute walking test, which showed inconsistencies with the review results for LWI intervention by Khan *et al.* (2020). Additionally, the SR results of LWI studies did not correspond with the patient-reported outcome measures (PROMs) like KOOS from Richards *et al.* (2016), which indicated a short-term effect. However, due to a few studies'

limited number of participants, further comparison against another intervention or a usual care control group is necessary to evaluate effectiveness. Moreover, the findings on climbing stairs from Hunt et al. (2018) on gait training and Trombini-Souza (2012; 2015) on the 6-minute walking test contradicted Khan et al. (2020) reviews. Khan et al. (2020) identified immediate functional improvement through stair climbing tests and the efficacy of 6-minute testing in increasing physical stamina and diminishing discomfort during extended walking. However, Khan et al. (2020) suggested conducting long-term RCTs to assess how long functional enhancements and symptom alleviation from orthoses and gait retraining last.

4.6.8 Strength and Limitations:

This SR and MA has limitations as it requires more specific gait modification RCT studies for accurate data analysis in KOA patients. The MA and SR focused only on RCTs with multiple gait modifications, in line with this study objective (O'Brien and Craven, 1995). Many studies did not clearly outline allocation concealment, resulting in an "unclear risk" quality assessment, potentially causing selection bias (Viera and Bangdiwala, 2007).

Additionally, "un-blindness" might influence self-reported assessments. While blinding to a gait modification is hard, concealed data assessment can reduce bias. Since the gait modifications were not randomly sequenced, substantial clinical effects were undetected. Notably, the small sample size in some studies might reduce the effect size when the intervention is beneficial (Walters *et al.*, 2019).

The MA and SR faced challenges in analysing for publication bias due to the diverse nature of the 15 included studies. Because of the limited number of RCTs for specific gait modification, neither funnel plot asymmetry nor Egger's intercept testing was possible (Higgins *et al.*, 2019). Also, the heterogeneity in included studies is commonly low (Higgins *et al.*, 2019), indicating that the results were consistent across various populations (sample size) and environments (KOA severity) (Dechartres *et al.*, 2013).

Also, for KAM 1st peak, most RCTs (11 studies) have focused on short-term effects, covering a duration of up to six months, while only two RCTs have

examined their effects over the medium term (6 to 12 months). Moreover, only two RCTs in the short term were assessed for the KAM 2nd peak. As a result, the long-term impact (beyond 12 months) of these interventions on KAM peaks has not been adequately studied. Therefore, when applying these findings to clinical practice, it's important to consider this limitation, as these interventions' long-term sustainability and effectiveness are still uncertain (Kennedy-Martin *et al.*, 2015).

In the included studies, outcomes were reported and quantified differently. When evaluating the efficacy of clinical gait modification, combining findings from multiple trials, or comparing separate trial results, consistent measures for outcome reporting should be provided (Tunis *et al.*, 2016). There was uncertainty regarding the correlation between knee loading, represented through KAM, and muscle contraction, which needs to be fully addressed in the included studies (Arnold *et al.*, 2016b).

Factors like biomechanics, knee alignment (Nie *et al.*, 2019), KFM (Marriott *et al.*, 2019), disease severity, intervention compliance and expectations, subjects' ages and pain/function reporting alongside genetic elements (Thakur *et al.*, 2013), gait analysis (e.g., barefoot and gait speed) (Telfer *et al.*, 2017), and occupation and activity level (Kwon *et al.*, 2019; Goh *et al.*, 2019) can influence self-reported assessments. Lastly, although every effort was made to contact all authors when data had yet to be submitted, some mathematical computations, like deriving SD, might have errors.

4.6.9 Future Recommendations:

Larger sample sizes in trials would better determine the efficacy of gait modifications. High-quality RCTs, rigorous in allocation concealment and blindness, are essential to establish the most effective gait modification for reducing knee joint loading, alleviating knee symptoms, and fostering acceptance in early-stage knee osteoarthritis patients. A tailored training plan could be devised using collected data on gait modification performance and its impact on biomechanical and symptomatic KAO. A thorough assessment, considering factors such as KOA severity, deformity, activity level, muscle

contraction and obesity, might produce more effective results for suitable KOA patients.

Future studies should also consider meaningful criteria for measuring improvement against KAM reduction (Ulrich *et al.*, 2020). The interaction between KOA subjects and gait modification biomechanics during sessions remains uncertain. Clinical and subjective reviews, through questionnaires or scales, are vital to ascertain whether aspects like compliance, comfort, usability, availability and affordability significantly impact knee load and joint pain. Adopting this technique could delay the onset of KOA and address gaps in previous studies related to patient dissatisfaction.

4.7 Conclusion:

This SR and MA aimed to address gaps regarding the most effective gait modification method (learned, assistive, or combined) with KOA subjects. The MA and SR specifically examined RCTs that included KOA patients and investigated the impact of various gait modification techniques on knee biomechanical loading, pain, and functional outcomes.

The included studies were RCTs that assessed variable gait modification interventions such as re-gait training, foot progression angle, wedge insoles and various knee braces. The analysis showed that most gait modification approaches did not significantly decrease KAM's first peak in the short and mid-terms. However, according to the SR, lateral stiffener shoes could impact the KAM first peak in the short term, while re-gait training with the toe-out might significantly improve the KAM second peak. Additionally, LWI significantly affected both the KAM second peak and the KAAI in the short term. Despite these particular advantages, the overall efficiency of gait modification in reducing knee loading was limited. Also, the differences between the findings in the MA and those reported in the SR could be due to variations in study populations, methodologies and statistical approaches.

Regarding pain levels, most gait modification techniques did not show a statistically significant reduction in knee pain compared to control interventions in the near term. This suggests that gait modifications alone

might not suffice for easing KOA pain. Functionally, gait modification methods did not significantly improve knee ROM, gait speed, stride length and cadence over the short term. Additionally, no statistical significance was found for physical activity outcomes such as climbing stairs, walking distance and sit-to-stand tests, indicating that the benefits of gait modification methods might be limited in the short term for these functional outcomes.

The included studies showed moderate methodological quality. Significant issues related to the lack of randomisation and potential unblinding could affect the reliability of the results. Also, variable effect size and statistical significance suggested that sample size and methodology factors could improve effectiveness.

Future research must enhance methodological rigour, such as improving randomisation and blinding processes. Furthermore, long-term studies are essential to evaluate the lasting effects of gait modification on knee loading, pain and functional outcomes. Combining gait modifications with other approaches (e.g. gait modification or therapeutic exercises) could offer a more comprehensive understanding of managing KOA. Factors like KOA severity, onset duration, deformity, weight, and activity level were essential in assessing the efficacy of gait modifications for KOA patients. The findings highlight the importance of conducting further high-quality research to reach more conclusive findings and guide clinical decision-making.

CHAPTER 5

QUALITATIVE STUDY

The perceptions and acceptability of gait modification strategies among Saudi Arabian osteoarthritis patients and physiotherapists. A theoretically framed qualitative study.

5.1 Summary:

This chapter discusses the perspectives of KOA patients and physiotherapists in SA regarding the management of gait modifications with KOA treatment. It highlighted differing opinions on which gait modifications to offer and the differences between KOA patients and physiotherapists. Patients who undertook specific gait modifications reported reduced knee pain and improved function. According to the findings, participants detailed the effort needed for selected gait interventions and contributed to the concept of physiotherapy. Knee braces, canes, footwear and insoles and offered acceptable benefits, enhancing daily activities. In conclusion, assistive gait modifications, particularly cane, footwear and insoles, proved acceptable, and they were well-received and deserved further extensive evaluation through larger trials. Physiotherapists could have further aided KOA patients during follow-ups by incorporating these gait modifications into treatment plans.

5.2 Introduction:

To the researcher's knowledge, no comprehensive and integrated gait modification programme is currently available within the SA healthcare system. Both physiotherapists and patients have limited awareness of the significance of gait modification techniques during KOA treatment. Moreover, the necessary facilities and biomechanical protocols are not broadly accessible. Therefore, as a first step, the focus was on introducing gait modification strategies rather than directly conducting a trial on patients. This introduction aims to understand how these strategies are received and whether they gain acceptance among patients and physiotherapists. This aim was met by implementing the gait modification programme and gathering in-depth feedback.

The primary objective of this qualitative research was to gather opinions from KOA patients and physiotherapy practitioners concerning the current gait modification knowledge, their practice and the environment in SA used for treating KOA. This study was designed to provide insights into the acceptability and practicality of the introduced gait modification programme with a view to recommending potential alterations or adjustments, setting the stage for evaluating the overall feasibility of the programme.

This study aimed to explore the awareness and expectations of both KOA subjects and physiotherapy specialists about managing KOA using gait modification. It also investigated their preferences regarding the acceptance of preferred gait modification treatment in KOA rehabilitation practice in SA.

5.3 Methods, research paradigm and approach:

Generally, qualitative research systematically explores social interactions, attitudes, experiences and behaviours within natural settings (Teherani *et al.*, 2015). This encompassed the behaviours of individuals and groups and people's daily experiences. In a qualitative study, the researcher acted as the primary data collector, aiming to understand "what happened," "why," and "what this meant" for the community or subjects being studied (Creswell, 2015).

This study utilised qualitative methods to investigate KOA patients' and physiotherapists' opinions and perceptions regarding various gait modifications in KOA management within the Saudi Arabian healthcare system.

In-depth insights into the personal experiences of KOA patients with gait modifications were gathered through face-to-face interviews. This approach allowed an examination of KOA individuals' perceptions, challenges and the effects of these modifications on their KOA management. Physiotherapists participated in focus group discussions (FGD) to share their professional insights on multiple gait modifications for KOA patients. The interactive group environment encouraged conversations, revealing shared themes and various opinions.

The study was influenced by the interpretivist paradigm, which highlights the importance of understanding individuals' experiences (Smith, 2011 & Tuohy et al., 2013). The TFA, which examines factors such as emotional attitude, perceived effectiveness, and self-efficacy, was suited for this as it delved into how subjects perceived and reacted to healthcare interventions like gait modification (Sekhon, Cartwright and Francis, 2017). Moreover, the study used the Standards for Reporting Qualitative Research (SRQR) checklist to enhance transparency (O'Brien *et al.*, 2014).

5.3.1 Participants:

(a) Sampling:

According to Palinkas *et al.*, (2015), this qualitative study used purposeful sampling to select participants with rich, relevant insights into the subject. Both participants (KOA and physiotherapists) came from various healthcare settings throughout the South region of SA, including MOH hospitals or centres, military hospitals, and private clinics. These individuals were diagnosed with KOA and received physiotherapy. In the study, both male and female patients over 40 years of age attended physiotherapy outpatient clinics and could communicate verbally. Neither the participants' employment status, nor their geographic location within the country, were restricted in this sample. To sample therapists, registered physiotherapists with experience treating KOA, both male and female, were selected.

Initially, the study intended to include policymakers (Officials drafting and implementing orthopaedic care). However, their participation could have been more feasible due to time constraints and logistical challenges. The significant distances between organisations in SA, which required varied transportation needs and needs for specialised fields (e.g. KOA physicians, physical medicine and occupational therapists) of the prospective participants, made coordination particularly difficult. Additionally, the extensive time required to conduct comprehensive interviews and focus groups further complicated the inclusion of these officials.

Consequently, this study's findings regarding decision makers' perspectives on gait modification topics and non-surgical biomechanical

management options for KOA may not be generalisable to the entire country. Although policymakers could not participate, this study obtained beneficial insights from physiotherapists. These findings will help develop treatment plans for KOA rehabilitation services in Saudi Arabia, which could improve KOA management in the country.

(b) Sample Size:

The goal was to explore the perceptions and attitudes of KOA individuals and therapists regarding the appropriateness, feasibility and acceptance of gait modification approaches, such as re-gait training, wedging shoes and insoles in clinical practice. Additionally, this study aimed to gather therapists' insights into the practical application of these gait modifications in SA. An ideal sample would reflect diverse characteristics and conditions (Creswell, 2015). Due to data richness and the challenges of large samples in qualitative research, small samples were advocated (Ritchie *et al.*, 2013). Such research prioritises reaching saturation, where additional data will not yield new relevant information (Fusch & Ness, 2015).

Initially, participants with KOA and physiotherapists were to be included in the study. Using purpose sampling, 26 participants from both groups were selected: 11 face-to-face interviewees from KOA and 15 therapists from FGD. As a result of the diverse sample chosen, a comprehensive investigation of the study issues could be undertaken according to their experience and clinical characteristics to explain the phase 1 outcomes of the study (Bryman, 2016).

(c) Participants Recruitment:

- Recruitment of KOA Patients:

Participants for this study were recruited from the Aseer region during their follow-up appointments at Aseer Central Hospital. The inclusion criteria for the KOA patients were as follows:

- Males and females over 45 years of age.
- Diagnosed with KOA by a healthcare professional based on radiographic evidence or clinical symptoms.
- Able to speak and provide signed consent.
- Exclusion criteria included:

- Recent knee injuries.
- Knee pain referred from the lower back.
- Other forms of arthritis (e.g. Rheumatoid and Psoriatic Arthritis and Gout).
- Individuals waiting for or undergoing arthroplasty surgery (ensures a more focused and relevant investigation into the non-surgical management of KOA).
- Individuals with chronic mobility-impairing conditions such as Parkinson's Disease.

The severity of KOA was not limited, as its severity was believed not to impact results related to the challenges and benefits of gait modification, personal experiences with the condition, or healthcare-seeking interactions.

- Recruitment of Physiotherapists:

Physiotherapists were recruited to participate in a FGD to provide insights into the feasibility and challenges of utilising gait modification approaches in clinical practice recommendations in Saudi Arabia. The recruitment process for physiotherapists involved the following steps:

- Physiotherapists working in different regional hospitals were invited via WhatsApp.
 - Physiotherapists at Aseer Central Hospital were invited through email.
- Eligibility criteria for physiotherapists included:
- Holding at least a bachelor's degree.
 - Possessing a license from the Saudi Commission for Health Specialties (SCHS).
 - Having at least three years of experience treating musculoskeletal conditions.

The recruitment process aimed to ensure that the selected physiotherapists had sufficient experience with KOA to navigate discussions on gait modification acceptance, awareness, motives, barriers and expectations.

5.3.2 Participant information and informed consent:

During the interview and FGD, participants had the opportunity to ask questions and express concerns regarding the information sheet. In addition

to a patient/therapist information sheet and consent form in hard copy format, the researcher received signed consent forms from potential participants. Printed and signed consent forms were collected and secured in a safe place.

Informed consent of participants was obtained under the recommendations of the Research Ethics Committee (REC), Good Clinical Practice (GCP), and any other regulatory requirements that may be adopted. A consent form was signed and dated by both the participant and the researcher before a participant took part in a study involving face-to-face interviews and FGD. The original completed forms were kept in the study files, and a duplicate was provided to the participant.

In the interview and FGD, which were conducted in person, the participants could choose a convenient time for them with the researcher adjusting to their preferences. The interviews and discussions were conducted in appropriate settings (i.e., private rooms) to maintain participants' confidentiality and ensure that records were accurate.

5.3.3 Data Management and Storage:

It was agreed that the research team, and the transcriber, would share access to the audio data files by uploading them to a confidential on-line platform. The audio files were removed from the site when the transcripts were created, uploaded and downloaded by the research team. All raw audio data sets and transcripts were stored on a password-protected, encrypted server at the University of Nottingham.

5.3.4 Data Collection:

(a) Semi-structured interview:

Traditionally, qualitative research recommends employing one of three interview types: structured, semi-structured, or unstructured (Edwards & Holland, 2013). Structured interviews, often used in survey research, maintain a consistent format, and set of questions (Edwards & Holland, 2013). Semi-structured interviews, with a foundational discussion framework, allow for flexibility, introducing additional questions as discussions develop (Galletta & Cross, 2013). Such interviews enable open questions with theory-driven

inquiries, evaluating experiences and particular subjects (Galletta and Cross, 2013). On the other hand, unstructured interviews encourage an unrestricted dialogue, collating data and deriving themes (Edwards & Holland, 2013). For example, the life history interview would commence with one central question, expanding to obtain further information (Edwards & Holland, 2013).

This research adopted a semi-structured approach, addressing critical themes while enabling the generation of new ideas. Through interviews, unique insights were gathered that other methods could not capture (Ritchie *et al.*, 2013). Even although the dialogue might seem typical, it is directed with specific goals and expectations, and questions are tailored to ensure clarity for the interviewee. Another notable advantage of interviews, as highlighted by Alshenqeeti (2014), is the cost-effectiveness compared to other research methods.

Nevertheless, using interviews, as a research tool, has not been without criticism. There have been concerns about the authenticity of responses due to their subjective nature (Hammersley, 2008; Holstein and Gubrium, 2011). Issues include: the need for genuine responses from interviewees and the time-intensive processes of protocol development, transcription and analysis (Ritchie *et al.*, 2013; Alshenqeeti, 2014; Taylor *et al.*, 2015). Still, Ritchie *et al.*, (2013) suggested a more balanced perspective, underscoring the value of interviews in obtaining fresh qualitative data.

(b) Focus Group Discussion:

Focus group discussions can be defined as "group interviews on a certain topic, guided by a professional moderator..." aimed at providing deeper insights (Collins and O'Brien, 2011, p.124). This method, an extension of interviews, utilised group discussions for in-depth insights (Gundumogula, 2020). The group setting illuminated the study's theme (Ritchie *et al.*, 2013). With FGD, themes were systematically explored with a moderator's aid (Collins & O'Brien, 2011, p.124). In FGDs, participants discussed diverse concerns. Joining FGDs enabled participants to hear diverse perspectives, enhancing understanding and reflection. Using stimulating materials or projective tactics

may be more effective, which may seem ineffective in a one-to-one setting (Ritchie *et al.*, 2013).

In focus groups, participant interaction gave the best insights, especially when interviewees interacted and were open with each other. However, in spite of this, caution should be exercised to ensure that everyone has the opportunity to speak and that no one person dominates the discussion (Creswell, 2018). Preparing for FGD involved estimating their duration (Gundumogula, 2020). Research varied, suggesting optimal time was anywhere between 30 minutes to three hours (Schmidt, 2001; Greenbaum, 2003; Stewart, 2015). Literature indicated varied ideal participant numbers, ranging from three to twelve (Morgan *et al.*, 1998; Ohman, 2005; Ritchie *et al.*, 2013; Krueger, 2014). Also, moderators consistently set the theme and guidelines for each session, ensuring focus (Gundumogula, 2020; Ohman, 2005).

Despite their merits, focus groups had limitations: obtaining representative samples was exhausting, distinguishing collective versus individual views were tricky, and extrapolating findings to broader populations took much work. Moreover, data analysis could be intricate (Litosseliti, 2003). However, group discussions reflected natural social settings, revealing how opinions evolve through interaction. Despite being designed for research, these settings often resembled genuine social settings (Ritchie *et al.*, 2013).

(c) Face-to-face interview & FGD Combination:

Researchers often found combining FGD and individual interviews beneficial, despite their distinct methodologies, as they offered complementary perspectives. Lambert & Loiselle, (2008) outlined three primary reasons: (1) pragmatic convenience, (2) comparing participant viewpoints, and (3) ensuring comprehensive and validated data. Pragmatically, some interviews allowed for a FGD, which could reduce drop-out rates by offering diverse participation options (Rees, Ford and Sheard, 2003; Taylor, 2005). In examining a topic, each method often involves unique participants; for instance, a health education programme might be assessed using focus groups of delivering professionals and individual interviews with programme attendees (Leung *et*

al., 2005). Both methods could yield more comprehensive data (Adami and Kiger, 2005; Halcomb and Andrew, 2006).

Furthermore, FGD can be used to analyse people's attitudes toward the phenomenon. At the same time, interviews can dig deeper into people's experiences (Molzahn *et al.*, 2005). Lambert & Loiselle, (2008) noted that integrating data from both methods facilitated. (1) an iterative process enriching the conceptualisation of a phenomenon (2) understanding the phenomenon's structure by pinpointing individual and contextual variables and (3) reinforcing the findings' credibility through convergence. Considerations during integration included the phenomenon studied, data types from each method, and insights from data comparison (Lambert & Loiselle, 2008). In summary, combining interviews and FGD enhanced the understanding of a phenomenon, like gait modification, in KOA subjects. Such combinations deepened the context in which specific approaches or outcomes transpired (Lambert & Loiselle, 2008).

(a) In this study:

In this study, semi-structured face-to-face interviews were conducted with patients suffering from KOA to determine their experiences with gait modification treatments. As each interview followed a carefully prepared guide, participants could discuss their experiences, perceptions and feelings. Additionally, it facilitated a FGD with physiotherapists to generate a collective dialogue about implementing gait modification strategies in their clinical practices. During these discussions, therapists could constructively build upon one another's experiences. This would enable them to gain a deeper understanding of the intervention's practicalities and challenges.

Integrating KOA individual interviews with therapists' FGD optimised both qualitative methods. During the interviews, KOA patients described their experiences with gait modification in rich, comprehensive detail. In addition, the FGD provided physiotherapists with a platform to articulate their professional perspectives and discuss contextual factors affecting gait modification treatment acceptance and outcomes. These methods not only allowed for a comprehensive examination of the phenomenon, but they also

integrated sources so the phenomenon's structure or context could be better understood. These conditions are under which gait modification approaches, incidents, and acceptable outcomes can be achieved, according to Lambert & Loiselle (2008).

5.3.5 Topic Guide:

When designing the topic guide, a broad framework was considered. A practical topic guide offers flexible guidance vital for the fieldwork process. A poorly structured guide could confuse and inhibit exploratory and analytical research. Using topic guides in qualitative research was strongly advised, irrespective of the study type (Ritchie and Lewis, 2003).

The primary researcher (AA) developed the interview and FGD categories using the TFA guide, drawing on literature about non-surgical biomechanical intervention with KOA and prior qualitative research with KOA patients. These guides were trialled in an interview with a physiotherapist (MS). After review by MS and AA, modifications were made (see appendixes 3 and 4).

The face-to-face interview measured participants' understanding of gait modification as a KOA treatment and their beliefs about its efficacy. They were also asked about prior treatment experiences and feelings towards adherence to this therapy. For instance, initial questions examined their comprehension of gait modification, impact and expectations. Patients detailed their experiences with gait modifications for KOA, while physiotherapists shared their views on its therapeutic potential.

The FGD began with gait modification orientation, progressing to discuss potential motivations and challenges for therapists using these non-surgical interventions for KOA patients. The therapists' expectations of this therapy concluded the discussion. Throughout, the interviewer sought clarity from participants to grasp their experiences better. Although a semi-structured approach was used, participants could introduce other topics, allowing flexibility in the conversation. During the discussions, participants were presented with various gait modification programmes like knee braces, insoles and customised footwear. Examples were shown to enhance comprehension.

5.3.6 Duration & Data Management:

Interviewees were expected to spend 25 to 35 minutes in face-to-face interviews. Furthermore, following the topics guide, the FGD with therapists was estimated to last between 60 and 90 minutes. Digital recordings of the interviews and focus groups were stored on a secure server at the University of Nottingham and backed-up on a separate drive in the researcher's office at the School of Medicine. Once all participants had been interviewed, the primary researcher (AA) transcribed the Arabic interviews. Transcripts were verified against the original recordings to ensure accuracy and reduce the risk of misinterpretation. To protect confidentiality, identifying details were removed during transcription and analysis (Ritchie *et al.*, 2013; Al-Amer *et al.*, 2016).

- Transcript and Translation Processes:

Initially, in Arabic, transcripts were translated into English by the primary researcher (AA) for appropriate processing. This translation was based on AA's proficiency in both languages. Additionally, an external Arabic-speaking authorised translator's office (TM) independently reviewed and translated the data. After a meeting between AA and TM to review the translation agreement, disagreements were resolved with the help of a third translator (MS). As a result of this, minor discrepancies concerning fewer than 15 terms were addressed and resolved. An impartial reviewer in the translation process was vital for enhancing the research's credibility (Squires, 2009). See Figure (31).

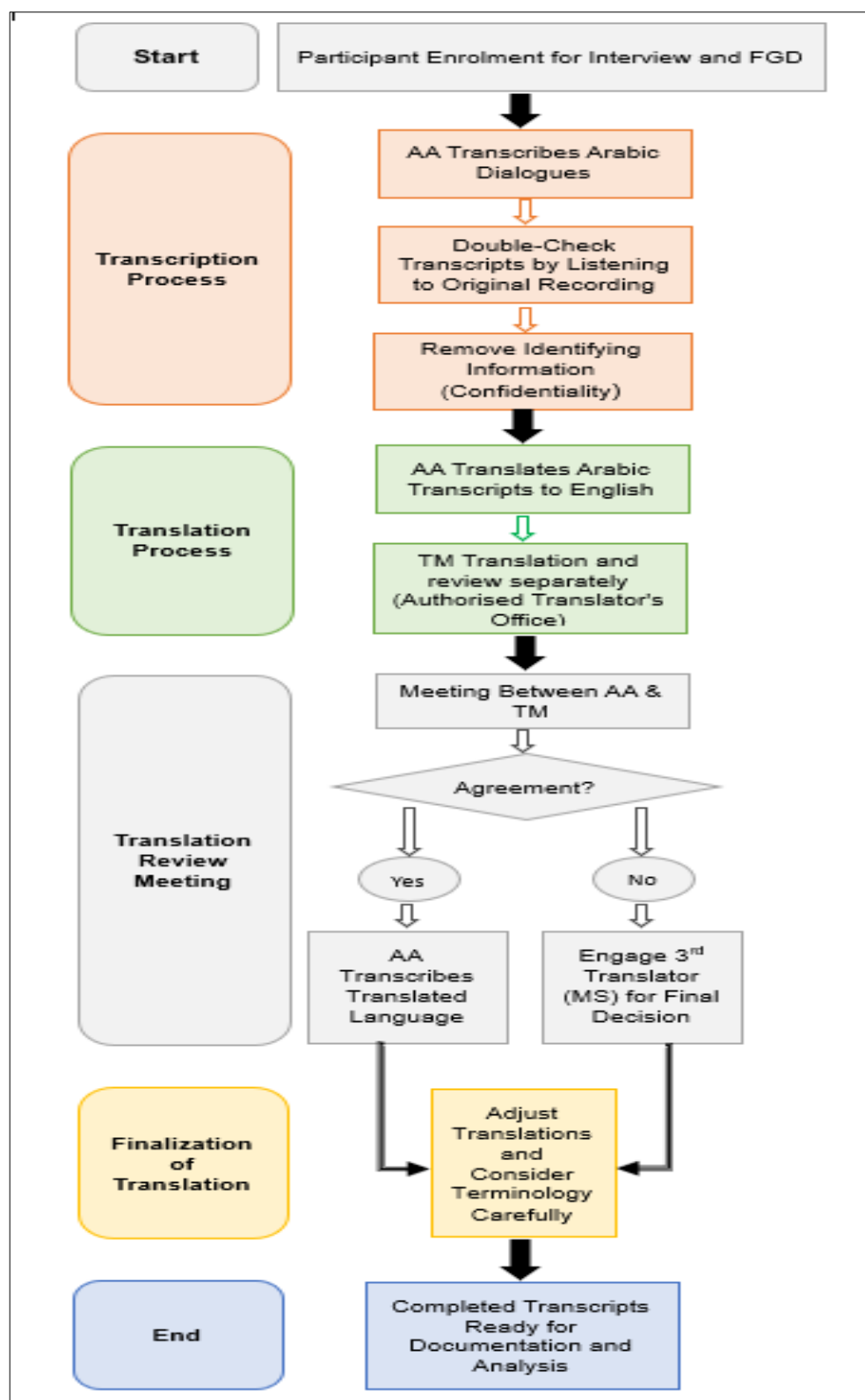


Figure 31: An illustration of the transcript and translation processes.

5.3.7 Data organisation:

Data organisation is a critical step in qualitative research, ensuring that the data collected is systematically categorised and easily accessible for analysis (Burnard *et al.*, 2008). This study followed several key steps to achieve effective data organisation. In Figure 32, the data analysis process is explained.

- **Transcription:** All audio recordings were transcribed from verbatim semi-structured interviews and FGDs. AA and MS meticulously reviewed each transcript to ensure completeness and accuracy. This thorough review involved listening to the original recordings while reading the transcripts.
- **Coding Preparation:** Descriptive codes were developed based on the first three interviews and the FGD. AA and MS discussed and refined these codes to establish a preliminary coding framework.
- **Coding Process:** Using NVivo 12.0 software, the data were coded deductively according to the Theoretical Framework of Acceptability (TFA) domains. This involved reading each transcript and identifying incidents related to each TFA domain, ensuring the data were systematically categorised.
- **Theme Development and Categorisation:** The inductive method was used to develop explanatory themes. Specific codes were organised into broader themes reflecting the core of the participants' experiences and perspectives. This approach allowed for new insights that were not initially anticipated. The codes were grouped into larger categories that captured the main themes found in the data. This method included continuous refinement, regularly reviewing and modifying categories to represent the data patterns accurately.
- **Review and Consensus:** AA developed the initial codes and grouped them into themes, then shared the coding system and illustrative quotes with MS. Both researchers reviewed the themes and reached a consensus on the primary themes, ensuring that the coding was comprehensive and reflective of the data.

- **Data Management and Storage:** NVivo software was utilised to manage and organise data. NVivo facilitated the systematic organisation of data, allowing for easy retrieval and analysis of coded segments. All transcriptions, codes and themes were securely stored on a password-protected, encrypted server at the University of Nottingham. This ensured that the data were not only accessible for analysis but also protected from unauthorised access.

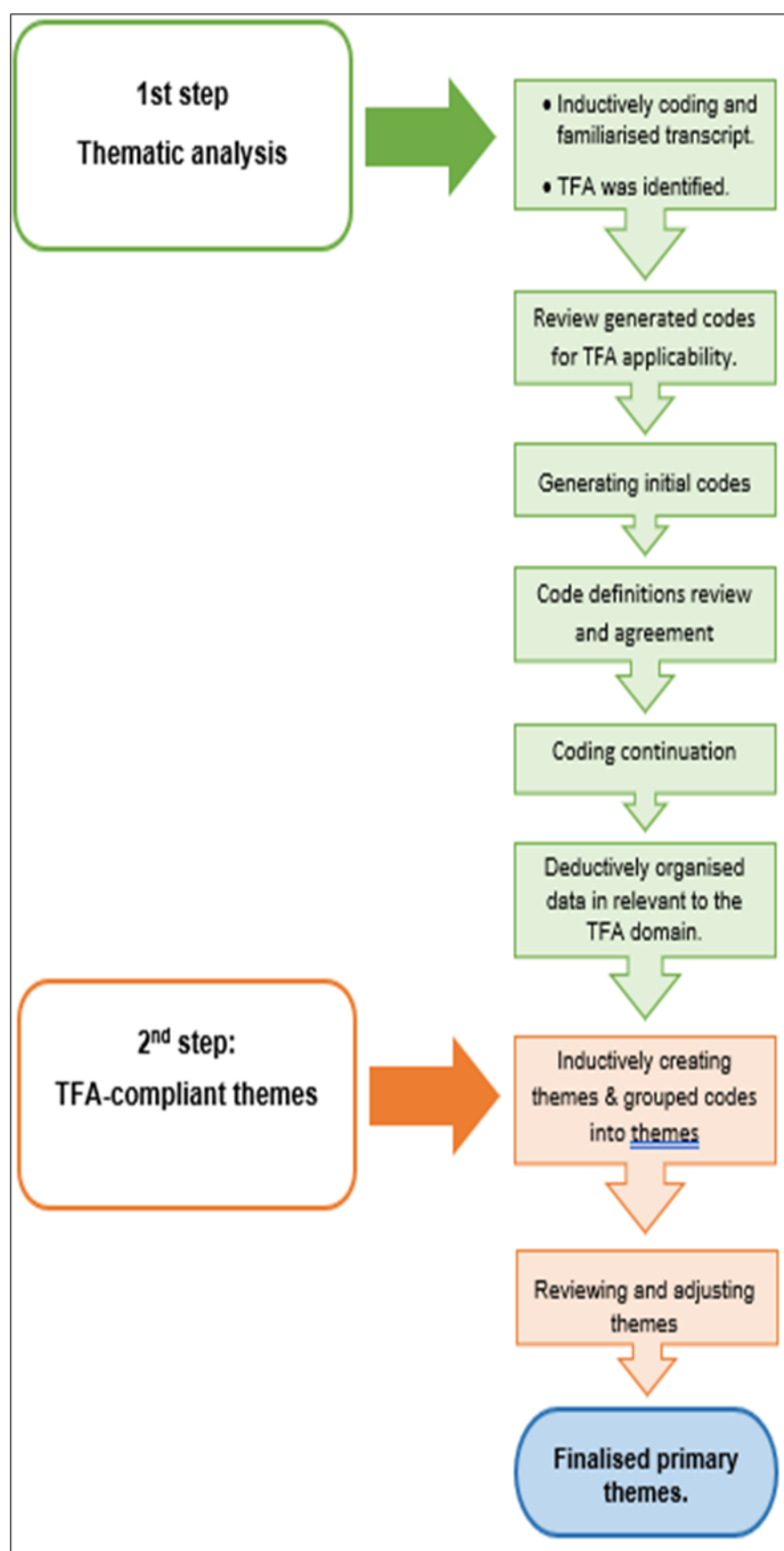


Figure 32: Summary of the study processes

5.4 Saturation:

In data analysis, saturation occurs when good themes are developed, and further insights cannot be derived (Fusch & Ness, 2015). Adler, (2011) recommended a graduate student's sample of between 12 and 60, but Baker & Edwards, (2012) suggested that a sample size of 12 is sufficient to obtain saturation. Additionally, Ritchie *et al.*, (2013) noted several factors that affect sample size, including the possibility of a larger total sample size if multiple categories or groups of participants are included in a study.

In this study, data saturation was determined using 12 KOA participants for the interview and 15 therapists for the FGD, according to Adler's (2011) recommendation for graduate research. Face-to-face semi-structured interviews and FGD were conducted during the data collection phase, and continuous analysis was conducted to identify emerging themes. Through an iterative process, themes were monitored until they became repeated, and no new themes were apparent. By the concept of saturation described by Fusch and Ness (2015), additional data from the interviews of 12 KOA participants did not yield new insights or themes. To ensure robustness, saturation was assessed after every data collection point, and (MS), as a reviewer, was consulted to confirm that no new information had been collected. The approach was consistent with Baker & Edwards' (2012) saturation criteria and factors highlighted by Ritchie *et al.*, (2013), particularly the diversity of participant groups, which informed the depth and breadth of the inquiry into the research question.

5.5 Ethical Approval:

This qualitative approach is a part of a mixed methods study. The Faculty of Medicine and Health Sciences Research Ethics Committee approved the protocol at the University of Nottingham, United Kingdom (FMHS 448-0122). Additionally, granted local ethical approval based on the setting area for each phase. This study was approved by the Aseer Institutional Review Board, Abha, SA (H-06-B-091), (Appendixes 5 & 6).

5.6 Data Analysis:

An interpretive method was appropriate for research to understand and interpret participants' experiences to determine their feelings and acceptance (Tuohy *et al.*, 2013). Given that the results of the initial qualitative phase would inform a subsequent feasibility study, an exploratory interpretive function of qualitative research was selected (Ritchie *et al.*, 2013). The demographic data were descriptively analysed.

Control of the data was maintained using the NVivo qualitative data analysis programme (QSR International Pty Ltd. (2018) NVivo (Version 12)), (*Data Analysis Software NVivo*, 2018). This programme was not purely analytical but organised the data (Zamawe, 2015). It facilitated faster and more accurate analysis using diverse qualitative designs and techniques. Also, NVivo's flexibility is suited to diverse research projects, highlighted by its character-based coding and multimedia capabilities (Zamawe, 2015).

Various methods were employed to analyse qualitative data, including thematic analysis (Braun and Clarke, 2006), framework analysis (Gale *et al.*, 2013) and content analysis (Titscher *et al.*, 2000). This study organised and analysed data using theoretical framework of acceptability (TFA). The researcher discerned relationships and meaning in the analysis transcript, adding rigour to the process, and enabling structured results through data comparison (Gale *et al.*, 2013). Framework analysis gave clear data flow comprehension, benefited novice qualitative researchers and allowed collaborative analysis with flexibility for concept reconsideration (Smith & Firth, 2011; Ward *et al.*, 2013). This made the data easily accessible for deeper exploration, affirming its suitability for this phase of the study (Ritchie *et al.*, 2013). According to Sekhon *et al.*, (2017), the TFA can be divided into three constructs and seven phases, with the following definitions in Table 10.

Table 10: The theoretical framework for acceptability terms (Sekhon *et al.*, 2017):

Term	Definition
Affective Attitude	"How an individual feels about taking part in an intervention".
Burden	"The perceived amount of effort that is required to participate in the intervention".
Ethicality	"The extent to which the intervention has good fit with an individual's value system".
Intervention Coherence	"The extent to which the participant understands the intervention, and how the intervention works".
Opportunity	"The extent to which benefits, profits, or values must be given up engaging in an intervention".
Perceived Effectiveness	"The extent to which the intervention is perceived as likely to achieve its purpose".
Self-efficacy	"The participant's confidence that they can perform the behaviour(s) required to participate in the intervention".

In TFA, deductive coding limits analysis to a predetermined code rather than accurately representing participant beliefs (Creswell, 2018). Deductively (by explaining the study objectives) or inductively (by generating and discovering relevant codes) can be used in the thematic analysis (Braun and Clarke, 2006), see Table 11. The approachability of thematic analysis was significant, as was its ability to elucidate unexplored topics without meaning loss (Elo *et al.*, 2014), proving beneficial for this study's focus group data. Conversely, an inductive approach reads raw data extensively for ideas (Thomas, 2006). Using this method, data lines are examined line by line and codes are assigned as ideas related to the study goals unfold (Bradley *et al.*, 2007; Curry *et al.*, 2009). Thus, this study used inductive analysis to interpret data, generating codes, themes and conclusions (Vanover, Mihas and Saldaña, 2021).

Table 11: Thematic Analysis in Six Stages (based on Braun and Clarke, 2006):

Stage	Activation
1. Familiarisation with the data	This stage entails reading data several times to understand its meaning entirely.
2. Coding	Labelling/coding relevant aspects of the data that may contribute to answering the research question. Coding of the full dataset is followed by extracting the codes and related data.
3. Searching for themes	Identification of potential themes based on codes and collected data. Next, analyse each candidate topic/theme by collecting information.
4. Reviewing themes	Assessing the data to determine if potential themes provide an answer to the search question. In this stage, themes are mixed, divided, or discarded.
5. Defining and naming themes	Analysing each theme, determining its scope and focus, determining its own "story," and naming each theme descriptively.
6. Writing up	Lastly, the analytical narrative and data extracts are combined and contextualized within the existing literature.

NVivo 12.0 software was utilised for thematic analysis. Skilled in qualitative data collection and analysis, the researchers (AA) & (MS) carefully reviewed each transcript, to identify any preliminary themes, ensuring the data was accurate and complete, and confirming the data was ready for detailed analysis. This step was crucial to maintain the integrity of the research findings and to develop a coding framework that aligned with the research goals. Coding strategies were deployed using inductive and directed content analysis approaches (Braun & Clark, 2006). In addition, a directed content analysis approach was used to identify and categorise the TFA domains (Atkins *et al.*, 2017; Murphy and Gardner, 2019).

Based on the first three initial interviews and the FGD, descriptive codes were developed and discussed between the two researchers. Afterwards, eight additional interviews were conducted. After the 11 codes (Review initial codes in NViVO) and three sub-codes were created by an independent

researcher (AA), the other reviewer (MS) evaluated them for TFA analysis suitability.

According to the TFA domains, the data were deductively coded. Directed content analysis was used to categorize TFA domains (Hsieh and Shannon, 2005). It required reading each transcript and coding incidents related to each TFA domain (Ritchie and Spencer, 2002). The process involved coding specific segments from each interview and FGD related to the seven TFA domains (Sekhon et al., 2017).

The second step of inductive coding involved creating explanatory themes under the TFA domains found through the first (deductive) coding level. Themes are created by grouping specific codes. During the study, AA developed codes and grouped them into themes, then shared the coding system and meaningful illustrative quotes with MS. A consensus was reached on the primary themes.

5.7 Results:

In both the interview and FGD, participants' demographics, statistics and response rates were detailed. Differences in acceptability between SA and other cultures were considered to devise a gait modification plan for the country's rehabilitation sector. Semi-structured interviews and an FGD took place at two SA hospitals. Interview and FGD results for KOA patients and physiotherapists were outlined, followed by a discussion of the main themes and conclusions.

5.7.1 Participants:

Through clinic appointments, twelve participants completed the consent form for the semi-structured face-to-face interviews. The group included both genders (five males and seven females), aged 48 to 74 years, with an average age of 61. Seven participants expressed literacy concerns; the others had varied educational backgrounds. Three were public employees during the interview, while the rest were retired. Their condition's duration ranged from nine months to 15 years.

The FGD had 22 attending therapists, but only 15 signed the consent form and participated. This group comprised nine males and six females registered with SCHS from the Ministry of Health (MOH) and private hospitals. They had diverse educational qualifications: three held Master's degrees, and the remainder had a Bachelor of Science in physiotherapy. All had musculoskeletal physiotherapy experience, ranging from three to ten years.

Most participants from the interview and FGD hailed from the southern Saudi cities of Abha and Khamis Mushatt. The sessions concluded once all insights were gathered (saturation). Table 12 below lists the demographics of the 12 interviewees and 15 FGD participants.

Table 12: An overview of participant characteristics:

Characteristics of (12) KOA participants		No. (%)
Gender	Male	5 (42%)
	Female	7 (58%)
Age	Overall mean (SD)	62.90 ± (7.45)
	< 40 years	0
	40 – 50 years	1 (8.3%)
	50 – 60 years	3 (25.0%)
	> 60 years	8 (66.6%)
Physical features	Height (cm)	1.65 ± (0.05)
	Weight (kg)	80.75 ± (8.20)
	BMI (kg/m ²)	62.78 ± (5.71)
Education level	University or college graduate	3 (25%)
	3 years or more of high school	2 (16.7%)
	Work-related	3 (25.0%)
	Uneducated	4 (33.3%)
Occupation status	Working	4 (33.3%)
	Unable to work (due to health reasons)	2 (16.7%)
	Retired (not due to health reasons)	6 (50%)
Knee sides	Unilateral	7 (58.3%)
	Bilateral	5 (41.7%)
Diagnosis Duration	≤ 1 year	2 (16.7%)
	1 to 5 years	4 (33.3%)
	5 to 10 years	4 (33.3%)
	> 10 years	2 (16.6%)
Characteristics of (15) therapists of FGD:		No. (%)
Genders	Male	8 (53%)
	Female	7 (47%)
Qualifications	Master	3 (20%)
	Bachelor	12 (80%)
Years of Experience	0 - 3 years	6 therapists
	4 - 10 years	9 therapists
	10+ years	1 therapist
	Overall mean (SD)	4.5 ± (1.8)
		years
Healthcare division	Public (Ministry of health)	12 (80%)
	Private (Hospital/Clinics)	3 (20%)

No.= Numbers, SD= Standard deviation, FGD= Focus group discussion, KOA= Knee osteoarthritis, BMI= Body Mass Index, cm= centimetres, kg= Kilograms, kg/m²= kilograms per meters squared.

5.7.2 Themes and Main findings:

All seven TFA domains were related to the perceptions and acceptability of gait modification techniques among KOA patients and physiotherapists in SA. These domains comprised affective attitude, burden, ethicality, intervention coherence, opportunity costs, perceived effectiveness and self-efficacy. Table 13 displays the sub-themes derived from these primary themes. Each domain was detailed, supported by examples for clarity.

Table 13: Interviews and focus groups identified themes and sub-themes:

Theoretical Framework of Acceptability	1. Affective attitude
	1.1 Patients' feelings towards therapy environment and facilities.
	1.2 Gain knowledge and confidence about gait modification.
	1.3 Attitude toward obstacles.
	1.4 Physical & Psychological barriers.
	2. Burden
	2.1 Commitment to group therapy and pre-training sessions.
	2.2 Integration with Physiotherapy sessions.
	2.3 Place preferences.
	2.4 Recipients & Deliverer requests.
	3. Ethicality
	4. Intervention coherence
	4.1 Knowledge & Awareness.
	4.2 Timeframe for implementation.
	5. Opportunity costs
	5.1 Motivation & Encouragement
	6. Perceived effectiveness
	6.1 Approach effectiveness
	7. Self-efficacy
	7.1 Self-management tools

According to all participants following interviews and discussions, the most prevalent theme from the findings was associated with perceived efficacy, precisely the expectations of gait modification.

5.7.2.1 Affective attitude:

In their interactions with specific gait modifications (knee brace, cane, insoles, and comfort shoes), interview participants described awareness and

feelings to foster protective factors, especially in situations like walking or using stairs, where they desired independence.

a) Patients' feelings towards the therapy environment and facilities:

- Patients' quotes:

Several inhibiting factors were reported when using various gait modifications, such as knee braces, canes or insoles. The effectiveness of different gait modifications under specific conditions, like the presence of assistive devices or based on clinicians' recommendations, was discussed. However, limitations existed concerning the timing of applying these techniques, available space for gait training, and established clinical protocols or guidelines.

“The place should be prepared, whether in a clinic or a centre. Make sure the area is ready for walking or anything else. Because availability of the facilities and access to these items will helping us as patient reaches these approach” Pat.1921. “Depending on the availability of these approaches. The lack of support materials, such as knee support, a cane, and an insole, has been an issue for me for a long time. in addition, a specialist's or doctor's recommendation facilitates the implementation of this type of treatment” Pat 2038.

- Therapists' quotes:

Additionally, the FGD participants suggest that the environment therapy, equipped with the necessary facilities and supported by clear protocols, is essential for delivering effective gait modification therapy.

“If there is a good area, the intervention, especially those depending on exercise or physical movement, will be effective. If there is a fully equipped gym, there will be good and expected results”. Phys. 10, “It is difficult because there needs to be a clear protocol available”. Phys.1. “Therapists who have practised gait analysis for many years can begin suggesting patients' gait problems. For example, using a motion analysis system in a specific training place (kinesiology lab) will make the data highly reliable, contributing to substantial effectiveness”. Phys. 2.

Overall, according to participants, gait modification resources, facilities, tools, and support resources might influence the success of therapy. A conducive environment and precise protocol could prove beneficial for both patient and therapist experiences. As a result, both the patient and the therapist might potentially have an excellent gait modification experience.

b) Gain knowledge and confidence about gait modification:

- Patients' quotes:

The KOA participants used gait modifications, including knee braces, comfort shoes, or trunk lean on a cane, without fully realising these were part of KOA treatment. Patients acknowledged that clinicians had not fully informed them about these treatment options for their KOA during their initial sessions. They expressed a need for more information and guidance regarding gait modifications, such as toe-out, toe-in, or trunk leaning and assistive devices like knee braces, comfortable footwear, or insoles.

Despite some initial awareness, they often felt inadequately informed about specific gait modification techniques and need for more information and guidance, indicating a gap in their understanding, which impacts their confidence in using these approaches.

"I do not have enough medical background to select which one is good for me. However, the most suitable option will depend on the patient's condition" Pat. 1019. "I don't know; it's my first time. Nobody tells me to walk differently. I've done physiotherapy before, which I've never been told to do" Pat. 1045.

Moreover, Patients found it challenging to continue applying and accepting gait modification approaches due to insufficient explanations from clinicians. This lack of clarity hindered their ability to fully understand and commit to the interventions.

"Less explanation this is could a main challenge I could face it..." Pat. 1019. "Described by the doctor and understood by the patient. Accepting the situation after explaining it will be a good thing" Pat. 1018. "Maybe. the

less explanation becoming an obstacle. but with keep asking and follow-up with therapist can solve these issues” Pat. 2032.

- Therapists’ quotes:

According to the participants, they illustrated a multifaceted theme centred around gaining knowledge and confidence in gait modification. Moreover, they highlighted the importance of bridging the gap between practical application and scientific validation. Additionally, they addressed concerns about side effects and emphasised the need to increase professional awareness, which was crucial for advancing this aspect of therapy. This demonstrates that therapists recognised the need for more robust educational frameworks and scientific backing to confidently recommend and implement gait modifications.

“Logically, the idea of the application area and how we applied it” makes sense. However, I am not sure from a scientific standpoint” Phys. 1.

“According to studies, it has side effects. It will change the body's biomechanics. It will be back to normal after something unusual. It will be questionable here” Phys. 9. “It may be due to our lack of knowledge that we don't pay attention to or give it importance” Phys 6.

In response to the opinions of KOA participants, it was suggested that understanding and clear communication with specialists might influence the success of gait modification in KOA management. Additionally, therapists may provide a more robust and confident gait modification approach, benefiting patient outcomes, by balancing patient education with effective treatment practicalities through practical and learning strategies.

c) Attitude toward application:

- Patients’ quotes:

KOA participants found gait modification approaches, especially learned techniques such as turning the foot during walking and trunk lean gait, frustrating and uncomfortable. Although it looks they have not tried these methods of treatment, they required more time and training.

“Firstly, I'm uncomfortable and need to exercise under a specialist's supervision to find out where it is..... It will be scary for me. I'll be close to a wall or handling something. But, assistive tools, I think, are more concerned with comfort than falling. This is becoming more related to physical changes” Pat. 1045. “Irritated skin a little bit. because this will happen if I'm keeping it for long time” Pat. 1907. “When we're in the centre, they teach us this, and we apply it according to our time. If there is a place and enough time, we use it, and they'll tell us what's right and what mistakes are. That will be great.” Pat. 1021.

It appears that KOA participants focus on convenience, security and professional direction. Learning gait modification may be beneficial, but it may also be challenging due to physical discomfort. Modified gait techniques may be helpful in this case with medical advice and medication (as well as regular observations).

Some participants, however, did not express any concerns regarding modified gait (stride length) without confidence that these practical methods were effective.

“it doesn't cross my mind that I could fall if I expand my steps. It could be the turn feet, but I'm not sure. Probably not” Pat. 2032. “At first, I expect there to be pressure on the knee itself” Pat. 2033. “I do not find it practical or fitting, so if I choose a tight one, it irritates me, and if I choose a wide one, it will not fit” Pat. 842.

Lastly, participants' opinions regarding the effectiveness of gait modification devices (assistive devices) varied. While most were optimistic, some were concerned about fit and suitability. Additionally, assistive gait modification tools sometimes caused knee discomfort, skin irritation, or falls.

In contrast, for assistive gait interventions such as canes, knee supports, comfort shoes and insoles, an easy-to-use tool was preferred. This preference was because it enabled people to use the device for its primary purpose, which was to alleviate knee pain and improve function.

“I think the tilting trunk is not suitable during the walk. However, using something easy like a cane, knee support, or inner insole could be good. Q:

Why? A: Because you need time to see the doctor or do physiotherapy, these methods can help me” Pat. 1921. “I think this is related to something I can control, such as footwear it is easy to control and use it. While the other such as tilting the trunk or rotate foot needs whole body change, I think is difficult for me to do it” Pat. 2033.

According to participants, simpler, more accessible gait modification therapies eased pain or improved mobility. Consider basic aids such as canes, knee supports, footwear or insoles instead of undertaking extensive changes. Using straightforward gait modification methods might be beneficial, and these factors may contribute to gait modification success.

- Therapists’ quotes:

According to the therapists who discussed their attitudes and behaviours regarding gait modification as the primary KOA treatment, physiotherapists often note that any modified gait (learned or assisted) technique used in KOA treatment may not suit patients due to learning difficulties or the need for patient acceptability. Additionally, pain relief priorities, patient expectations and acceptance also contributed to this.

“Looking for a fast, effective intervention can prevent us from using this approach. Also, the patient will not accept this as alone treatment, especially with advanced conditions” Phys. 12. “When we confirm that this approach is effective, its application will be straightforward, but still, I wonder if the patient will accept it. When applying this type of technique, patient acceptance will be a challenge” Phys. 1. “The possibility of being unsatisfied, not feeling relieved or being uncomfortable exists among patients” Phys. 5.

In light of the participants' views, the success of the gait therapy intervention might have been influenced by individual responses (potential acceptability) and difficulties in learning or the need for assistive devices. These factors could have affected their willingness to adopt this approach in clinical practice. Thus, tailoring a patient's gait strategy to their needs could have simplified addressing these challenges.

d) Physical & Psychological challenges:

- Patients quotes:

When KOA patients utilised both learned modifications, such as turning the foot or trunk leaning, or assistive gait approaches, including knee braces, canes and insoles, the most common issue they reported during interviews was a fear of falling.

“I think the fear of fall is becoming more of a turn-foot since the balance is affected. It is only from the comfort point that the assistive tool will give a fair feeling” Pat. 1019. “My first practice session will be exhausting, so I don't know if I can do it. Sure, I'll be tired at first. Similarly, I am trembling, and my muscles are weak, making it difficult to do exercises correctly. Once I get used to it, I can do better” Pat. 1045. “If I wore the knee support, I would be scared. I'm afraid I'm going to fall” Pat. 843.

- Therapists' quotes:

The therapists noted that constant knee pain, muscle weakness, poor balance, KOA severity, obesity and fear of falling were factors preventing or limiting gait modification. This perspective stemmed not only from gait modification approaches but also from previous experiences dealing with KOA subjects during therapeutic exercises.

“I think being concerned about treating or solving a primary patient complaint, such as pain, prevents us from learning more about this type of treatment” Phys. 7. “It may be that the patient has more muscle weakness, so the objective or goal of modifying gait is not the patient's priority” Phys. 5. “As a result, there will be a limited range of motion and balance difficulty” Phys. 4. “How can it be a feeling of danger? If there is a fall due to loss of balance, these things hinder the patient because it's difficult at first, and they are not used to walking this way” Phys. 9.

Overall, therapy tends to focus on pain and muscle strength, so a narrow focus may compromise gait modification therapy on pain and muscle strength. Patients with KOA also expressed concerns about falling, compromised balance and muscle weakness. When implementing gait

modification therapies, it may be critical to strike the right balance between ensuring patient satisfaction and preventing complications such as discomfort, poor balance and muscle weakness.

5.7.2.2 Burden:

In discussions about gait modification strategies, participants considered if needing assistance might make the approach burdensome. Certain situations, like the first clinic session or a home programme, could heighten negative emotions. The study found that patients cooperating with therapists, and open to new methods, more readily adjusted to a unique gait.

a) Commitment to group therapy and pre-training sessions:

- Patients' quotes:

Gait modification approaches are highly recommended by KOA participants. However, gait modification should be adopted and implemented after a training session, especially for learned gait modification (e.g. turning foot) approaches.

"Yes, I prefer there will be training sessions. We need a therapist who understands us and provides enough information in a specific area" Pat.

1922. "Yes, as the introduction. Also, this will help therapists to tailor effective approaches according to my ability and effort" Pat. 2033. "If there is a benefit to the training session, then yes, I prefer it. There is no problem for me. Yes, I would like to do that." Pat. 1045.

- Therapists' quotes:

Therapists stress the significance of group therapy and pre-training sessions for both learned and assistive gait modification, tailored to fit patients' needs. These perspectives highlight the significance of collaborative therapeutic methods in improving patient care.

"I think the therapist needs to work hard to explain and prepare the patient to accept this technique. How could that happen? For example, by providing group therapy or training sessions" Phys. 6. "It is more convenient for me if the patient has completed all sessions with me; although it will be a

high load, group therapy may be a good option.” Phys. 1. “Excellent by introducing “group therapy” as solving some difficulties” Phys. 4.

Commonly, pre-training sessions and group therapy were considered essential for tailored planning. Based on patients' opinions, therapists could adapt interventions from these insights, leading to more personalised gait therapy. Most therapists felt that discussing treatment options like group therapy improved their understanding and communication with patients.

b) Integration with physiotherapy program:

- Patients' quotes:

Several interviewees with KOA emphasised the importance of incorporating learned or assistive gait modification into their physiotherapy treatments. This choice was influenced by potential treatment efficacy.

“That will be a good idea to integrated these with other physiotherapy approaches” Pat. 1045. “If they put it in the physiotherapy system, I'll be familiar with it, practice it, and benefit from it. It will be helpful when it is available” Pat. 2032. “I can express that by concentrating on treatment for the specific issue. In the end, this could save time and give positive results” Pat. 2038.

- Therapists' quotes:

The therapists agreed, however, that the KOA physiotherapy treatment programme would not include them as part of a comprehensive programme. Thus, they can stand on the effectiveness side.

“No, as independent. However, it was a correction and additional to the treatment plan. I prefer to separate it from physiotherapy treatment. My first session includes all physiotherapy modalities, and I modify patient's gait in the next day or the day after PT session. I am checking to see if it made a difference for the patient. Even, though I added it to my treatment, I am unsure where the benefits come from” Phys. 2. “Partly, sometimes was applied as a combined therapy during treatment sessions” Phys. 10.

Predominantly, most KOA participants and physiotherapists believed that adding gait modification to the routine KOA physiotherapy treatment might

enhance outcomes, especially for chronic issues like KOA. Instead of pre-determining their combination, there was a preference to apply both flexibly.

c) Place preferences:

There was a difference in opinion among participants about the preferred location for walking modification programmes.

- Patients' quotes:

Patients typically felt that in-clinic applications were best, citing available modalities, the presence of a therapist, and the opportunity for questions.

"I have tried different treatments before; I got more acceptable improvement from the clinic than at home. Also, I can send my feedback and question to the therapists during my session" Pat. 1019. "No. In the clinic, there are tools. Here is a better place to do this than at home if it is related to trying something new for the first time. For the first time, it is better here in the clinic. In the next step, after applying correctly and getting full instructions from a therapist, treatment at home will be more effective" Pat. 2038.

For those preferring home or outside-clinic locations, continuity and patient comfort were key reasons.

"I will adhere to it at home if it is easy and clear. Thus, I prefer a clear and easy technique to stay home for longer-term follow-up" Pat. 1019. "As long as it's easy to apply, I can do it at home and It's so perfect that I use it at home in my comfort" Pat. 2033.

- Therapists' quotes:

However, therapists believed these methods (learned or assistive) were used in the clinic primarily during the initial session to acquaint the patient and ensure correct performance.

"Depending on the patient and the technique itself or how it is applied, it can vary. It must be used the first time with the patient at the clinic and then remotely followed up to be effective." Phys. 6. "In the first session, I will demonstrate how to do it in the clinic and explain it to the patient at home."

Phys. 7.

Therapists often chose non-clinic settings to save time and focus on more urgent cases requiring clinic visits.

“For mild cases, is it more appropriate to stay at home and have sessions there? Those with severe and moderate cases must attend an application session at the clinic” Phys. 10. “Instead of showing up to patients repeatedly to have sessions with me. The gait modification program will be designed as home therapy, reducing my time as a therapist and relieving the patient's knee pain.” Phys. 1.

Overall, in reaction to participants' views, many KOA individuals prefer clinical gait modification techniques, particularly those that are easy to understand and can be used immediately. As confidence grew, they might have shifted towards home-based therapy for convenience. While many therapists found home-based modifications appealing, consensus on regular clinical monitoring needed to be improved. Depending on the gait modification (learned or assistive), a home application might have needed extra clinical oversight due to KOA severity or arising complications.

d) Deliverer & Recipients requests:

- Patients' quotes:

Patients' opinions indicated that the effectiveness of these methods depends on the therapist's skill, follow-up time and availability of these approaches.

“Okay, this kind of program is better; I would like to see it continue with the patient. The tips should be given constantly, and follow-ups should be done. It will benefit the patient more if developed and applied correctly than surgical intervention” Pat. 2033. “Provide comfortable walking methods and knee-supporting tools. This is what I'm hoping to be in the future for these techniques and everything related to the healthcare system” Pat. 1045.

Many KOA patients expressed satisfaction with non-surgical treatments, such as gait modifications, emphasising the importance of regular supervision and follow-up. Due to concerns about surgery, patients often favoured exploring non-invasive treatment options before considering surgical

interventions, highlighting the importance of developing effective and personalised gait modification programs.

- Therapists' quotes:

Most therapists indicated that training facilities and practice areas are essential (environment factor). Providing training and protocols to enhance skills is also considered a key role for therapists.

"There is no doubt there will benefit if there are enough guidelines and studies that could provide a good reference for us" Phys. 12. "Using a motion analysis system in a specific training place (kinesiology lab), the data will be highly reliable, contributing to substantial effectiveness. It is usually the case that virtual gait analysis takes place in a room where the patient is present during the evaluation process" Phys. 2. "Sure, if there is a clear and updated protocol. This will let us become more committed regarding this type of approach" Phys. 3. "It is also, important of protocols that based on the evidence-based practice. It is necessary to maintain the continuity of workshops, especially since the scientific literature is updated regularly" Phys. 12.

Accordingly, most therapists believed that proper facilities, resources, clinical protocols and a gait lab could improve data reliability and outcome predictability. They typically favoured evidence-based techniques for gait modification, regularly updated. The clarity of protocols might influence their use. Additional training, such as courses, indicated their dedication to offering the latest effective gait modification treatments.

5.7.2.3 Ethicality:

- Patients' quotes:

Due to varied patient perspectives on the ease of use of assistive gait modification such as insoles, footwear, or knee braces and the specialist selection or prescription, it was vital to determine the suitability of the gait modification approach for them..

"Assistive is better, why? It is suitable for me and does not require a lot of effort" Pat. 1907. "An insole or knee support. Maybe they are mostly

because it is easier to use” Pat. 2032. “Suitable footwear is the most comfortable” Pat. 1922. “It’s better to listen to doctors or therapists first. I think the tilting trunk is not suitable during the walk. However, using something easy like a cane, knee support, or inner insole could be good. Q: Why? A: Because you need time to see the doctor or do physiotherapy, these methods can help me” Pat. 1921.

- Therapists’ quotes:

The specialists’ opinions regarding the preferred assistive gait modification tool (cane and insole) were based on a scientific and analytical perspective of the patient’s condition.

“It is always best to use assistive tools. Why is that? Because patient prefers seeing intervention during treatment, such as a cane & insole, something can be seen. Something real. Yes, perceptible/tangible items can be seen” Phys. 2. “More security. As far as security is concerned, the assistive tool is superior” Phys. 4. “At some point, there may be a tutorial. In the absence of an assistive device, to prevent recurrent periods” Phys. 9.

Many physiotherapists and KOA participants previously agreed that simple gait modification tools might be beneficial. While professional advice was valued, more straightforward interventions were preferred and could enhance confidence and safety and underscored professional expertise. Notably, comfortable and easy-to-use assistive tools likely improved patient compliance.

5.7.2.4 Intervention coherence:

a) Knowledge and awareness of gait modifications:

- Patients’ quotes:

Participants indicated limited orientation to either (learned or assistive) gait modification approaches, during KOA treatment when introduced to them or adding them with the usual physiotherapy treatment program. Often using terms like "first time" and "not mentioned" which shows a lack of prior knowledge and exposure to gait modification techniques, leading to their novelty during the treatment sessions.

“I’ve never heard that before, just instructions and exercises” Pat. 843.
“No, this the first time heard about it. Is this something related to my
walkway?....., no one has told me such thing it is could apart from the
treatment” Pat. 842. “I don’t know; it’s my first time. Nobody tells me to walk
differently. I’ve done physiotherapy before, which I’ve never been told to do”
Pat. 1045. “Never. This is the first time for me to hear something like that”
(Pat. 2038).

- Therapists’ quotes:

Most therapists incorporated gait modification (learned or assistive approach) into physiotherapy sessions as part of a general home programme (secondary treatment). Additionally, most therapists addressed providing or implementing assistive devices (knee braces, insoles and comfort footwear) based on patients' requests rather than their clinical decisions. However, they did not view these devices as treatments or protective measures for KOA that could improve patients' symptoms.

“No, I do not realise it is a part of treatment” Phys. 2. “I note, there is
relation between KOA patient and walk defect. But I should deal with this
together by providing the usual treatment plan followed by a home program
and ending by providing supported devices such as knee sleeves, a cane or
proper shoes” Phys. 1. “I noticed that I applied this type of treatment
without knowing. However, I included this type at the end of the treatment
plan” Phys. 12. “It was requested by the patient.(e.g. cane and insoles).”
Phys. 3. “I expect specialists who make gait modifications in some way
might not be aware of this type of treatment, which may be included in the
instructions, but not aware that it is a cure. It could be a type of intervention
leading to the walking activity, which leads to correction walking style”.
(Phys. 5). “As a gait modification concept, No” (Phys. 7).

Typically, from the quotes of both KOA patients and physiotherapists, it is clear that there was a general lack of familiarity with gait modifications in KOA therapy. This lack of awareness could stem from differing training emphases among therapists and communication gaps with patients.

Consequently, KOA therapies might have been limited or outdated treatment protocols might have been applied.

b) Time-frame for implementation:

- Patients' quotes:

Participants discussed gait modifications in terms of follow-up duration. Patients often recommended prolonged therapy if knee symptoms improved.

"It may not necessarily last for a long time. I should take care of myself. It will be a daily routine if there is a variable benefit. However, other severity levels could be good for a short time. Other definitive solutions, like surgery, are also important for advanced cases" Pat. 1019. "Of course. We need to apply continuously so that we can discover advantages and disadvantages" Pat. 1045. Follow-up by the same physiotherapist is essential because if no one is following you, it will not work. More follow-up, I mean." Pat. 2032.

- Therapists' quotes:

While therapists emphasised the necessity for prolonged observation to verify the success of interventions, particularly those for learned gait, such as turning foot walking modification, they noted that these interventions require time to be correctly applied.

"Long-term follow-up is required to be used as a prevention tool" Phys. 1. "A week or two after the first session, ensure that the patient applies correctly. If a mistake is made, it will be corrected, and a follow-up session will be scheduled after one to two months". Phys. 7 "There will be follow-up sessions, but not every week." Phys. 9. "Continue doing that for 3 to 4 weeks until the patient becomes more confident and can apply the technique well. Then a long follow-up will be conducted." Phys. 2.

Both therapists and KOA subjects believed that gait modification could be beneficial if consistently applied. They also felt that long-term follow-up was crucial for KOA management, aiding a deeper understanding of gait modifications.

5.7.2.5 Opportunity costs:

Gait modification as an acceptable intervention required measuring respondents' motivation and encouragement factors.

a) Motivation and encouragement:

- Patient quotes:

Previous experiences with knee braces, comfortable shoes, or insoles influenced patients' motivation, which was evaluated based on pain progression, therapists' follow-up and ease of application of the modified gait intervention.

"It wasn't something I used every day, but if I felt pain, I did. If it's easy to apply, I can do it at home" Pat. 1018. "My pain progression or my situation has improved in general. In addition, I will be encouraged to keep performing by therapists following up" Pat. 1019. "Follow-up by the same physiotherapist is essential because if no one is following you, it will not work." Pat. 2032.

Patient interviews suggested a preference for application ease, effectiveness in knee symptom treatment, and consistent therapist follow-up as motivating factors for gait modification.

- Therapists' quotes:

For previous experience, most therapists dealing with gait modification, like any other physiotherapy intervention, were motivated by training, protocols, training courses and patient feedback.

"The gait modification program will be designed as home therapy, reducing my time as a therapist, and relieving the patient's knee pain" Phys. 1. "For me, positive feedback from my patients will encourage the patient and will motivate me to use these techniques widely with other patients" Phys. 9. "Sure, workshops are a helpful way for therapists to update their knowledge and skills" Phys. 1. "By applying protocols or guidelines that will delivering them to patients correctly" Phys.2.

Therapists believed that intervention effectiveness, their education, patient feedback, and the availability of clinical protocols could motivate them towards promoting modified gait.

5.7.2.6 Perceived effectiveness:

The perceived effectiveness of gait modification was discussed based on patient and therapist experiences.

a) Approach effectiveness:

- Patients' quotes:

During interviews, some patients who had self-prescribed these methods without medical guidance shared their experiences. They reported positive impacts, particularly with comfort footwear and insoles, indicating that these methods could be beneficial (improved knee mobility and pain) even when not fully integrated into a therapeutic plan.

Pat. 1019. "Yes. I began to feel better after using the prescribed footwear for a while. My walking has become easier and more restful" Pat. 1045. "There was pain, and it has improved after I'm using the medical footwear with knee sleeves" Pat. 1907. "The insole has been prescribed for me; I am using it with shoes, and my condition has improved. Becoming more active" Pat. 2038. "I find that shortening my steps helps me and reduces my pain." Pat. 820.

- Therapists' quotes:

Therapists provided feedback based on their experiences with KOA therapeutic exercises. They did not fully utilise gait modification methods for further improvement, indicating a gap in recognising their full benefits. Their opinions on the effectiveness of gait modification were shaped by their experiences with other treatments efficacy, such as therapeutic exercises, reflected in the patient's condition.

As pain decreased, mobility increased, leading to improved daily activities. Also, well-equipped facilities improved the success of exercise-based treatments. However, therapists' opinions varied due to differing

knowledge levels, with their input based on their experiences with KOA therapeutic exercises.

“Initially, if the patient felt it would benefit him. When the pain subsides, and the movement increases. All the previously mentioned (daily activities, quality of life, and social participation) issues will be improved”
Phys. 1. “ Yes, as a result, self-confidence and social contributions will increase.” Phys. 9. “ If there is a good area, the intervention, especially those depending on exercise or physical movement, will be effective. If there is a fully equipped gym, there will be good and expected results.” Phys. 10 “The patient will not accept this as alone treatment, especially with advanced conditions.” Phys. 12. “The physiotherapy treatment plan can include increasing movement before gait modification, which can have a positive effect.” Phys. 7

Participants and physiotherapists previously indicated that medical footwear and insoles were beneficial. From interviews and discussions, these gait modifications could enhance mobility and reduce knee pain, potentially improving the quality of life and outcomes for patients. Furthermore, the importance of an appropriate environment and a clear gait modification plan, considering the severity of knee osteoarthritis, could improve gait modification outcomes and overall patient satisfaction.

5.7.2.7 Self-efficacy:

During interviews and discussions, this study explored patients' ability to implement walking modification programmes using various explanation resources. In addition, therapists must decide which support tools they prefer to use to explain walking modifications to patients.

a) Self-management tools:

- Patients' quotes:

A confidence interview was conducted to assess the abilities of KOA subjects in both methods of gait modification, with some expressing concern about learned gait modification. It was reported that some tools helped remind and teach patients how to master this kind of treatment.

“It would be better to do it with a therapist. Because I can ask and understand more” Pat. 1019. “The paper has instructions to be with me all the time. This is the way how I understand any information that has been given to me” Pat. 1045. “In my opinion, following the therapist is better. The therapist explains, and I hear what they say.” Pat. 1922. “The application in front of me is the best. The sheet may be given to me later” Pat. 2032.

- Therapists' quotes:

Therapists use their experience of therapeutic exercise in general when dealing with KOA patients to present the preferred method to patients. However, few of them, due to their lack of awareness about different gait modification approaches, decide to have time to handle the best delivery tool.

A specialist who is satisfied with a specific delivery tool (an instruction sheet, video, or practical training) will use it. With therapist's experience, videos and instructions that are clear” Phys. 1. “Firstly, the patient's awareness and knowledge of these methods with their ability to learn them. then deliver it to the patients” Phys. 6. “it takes time. It will take time to master these techniques.” Phys. 9.

Overall, participants' feedback revealed that direct communication with therapists could aid patients in understanding and applying gait modification techniques. Direct demonstrations by therapists may have promoted this understanding for many KOA patients. Meanwhile, written materials like instruction sheets may be valued for their accessibility. Thus, in the context of KOA, combining hands-on demonstrations with instruction sheets was deemed advantageous and may enhance acceptance and commitment.

5.8 Discussion:

This study aimed to explore the awareness and expectations of KOA patients and physiotherapy specialists regarding the management of KOA through gait modification in SA. Using the TFA, the study assessed the suitability and acceptance of various gait modifications within the Saudi healthcare system. The data represented all seven dimensions of the TFA, highlighting its relevance and applicability.

Key findings indicated that participants initially exhibited limited awareness and knowledge regarding the role of gait modification in KOA treatment. However, some participants employed gait modifications without recognising their potential benefits. Many participants mentioned that they tried different gait modifications suddenly without medical recommendation. This included using assistive tools like footwear and insoles. Both patients and therapists recognised the benefits of these devices, noting their ease of use and effectiveness in reducing pain and improving mobility.

During the interview phase with KOA patients, the potential influence of gait modification on their decision to undergo physiotherapy became evident. This highlighted the need to understand physiotherapists' views on the feasibility and challenges of utilising gait modification approaches in clinical practice recommendations in SA.

The study also identified significant barriers, such as the lack of standardised protocols and the unavailability of essential materials, which could hindered the effective application of these strategies. These insights underscore the importance of establishing comprehensive protocols and ensuring resource availability to enhance the feasibility and acceptance of gait modifications in KOA rehabilitation within the Saudi healthcare context. Furthermore, targeted educational and training courses are needed to bridge the knowledge gap among both patients and therapists, thereby improving confidence and consistent use of different gait modifications.

- **Affective Attitude:**

- (a) **Feelings about environment therapy and facilities:**

Both KOA and therapist participants favoured utilising gait modification techniques, but perceptions of accessibility varied. While gait modification such as; comfort footwear, insole and knee braces were favoured, challenges such as the lack of clear protocols for therapists and the unavailability of required materials (e.g. supported knee braces, insoles and comfort footwear) had compounded the issue of selecting the most appropriate modification. Such challenges could have acted as obstacles, leading to potential delays or even preventing the application of gait modification.

Furthermore, a critical area for improvement is the need for standardised protocols for the gait modification concept. The absence of clear guidelines has led to uncertainty and inconsistency in implementing gait modifications, potentially impacting treatment outcomes. This study's findings align with previous research, underlining the importance of standardised treatment protocols in managing KOA to ensure consistent and effective care (Egerton *et al.*, 2016). Moreover, the unavailability of essential materials for gait modification posed a significant barrier. Both patients and physiotherapists struggled to implement recommended strategies effectively due to the lack of access to appropriate tools and resources. This challenge indicates that resource limitations often limit the successful implementation of rehabilitation interventions in various healthcare settings (Ferreira de Meneses, Rannou and Hunter, 2016).

Thorstensson *et al.* (2006) emphasised that the effective management of osteoarthritis through gait modifications heavily depends on the physical environment and the availability of assistive devices. The study highlighted the importance of well-equipped clinical settings for the effective implementation of these strategies. Moreover, recognising these difficulties is also reinforced by broader research on managing KOA. A clinical guideline consistently emphasised the need for precise, evidence-based practice and proper resources to improve the success of biomechanical modification intervention strategies. For example, Kolasinski *et al.* (2020), conducted a study showing that biomechanical lower extremities modification programmes enhanced patient outcomes when appropriate instructions and resources were accessible.

This is particularly evident in SA, where disparities in infrastructure can significantly affect the accessibility and effectiveness of gait modification treatments. Therefore, to enhance the feasibility and acceptance of gait modification in the rehabilitation sector in SA, it is essential to establish comprehensive protocols and ensure the availability of necessary resources, particularly assistive tools such as proper footwear, insoles and knee braces.

(b) Gain knowledge and confidence:

There was obvious confusion among KOA patients and FGD therapists concerning the role of gait modifications in KOA rehabilitation. Such misunderstandings potentially led to the misapplication or neglect of gait modifications, while confidence in other KOA therapeutic interventions, including thermal treatments, electrotherapy, and therapeutic exercises, persisted.

This finding was consistent with the studies that advocate the importance of knowing how to perform physiotherapy interventions. O'Keeffe *et al.*, (2016) stressed the importance of patient education and expertise in physiotherapy, stressing the importance of educated patients in following treatment plans and improving results, and emphasizing the need for targeted educational approaches for improving gait modifications to address the identified misconceptions.

Also, Pincus *et al.*, (2013), too, endorsed this view, describing education as crucial for achieving successful treatment outcomes and ensuring patient satisfaction, indicating that a lack of clear and consistent information about gait modifications might result in incorrect application of these approaches. Pincus *et al.* (2013) suggested that addressing these educational shortcomings through focused interventions could enhance the effectiveness of gait modification strategies. However, it could be argued that more emphasis might have been placed on addressing these misconceptions ensuring that gait modifications are used appropriately.

While O'Keeffe *et al.* (2016) and Pincus *et al.* (2013) highlight the importance of education, simply providing information may not suffice. It is crucial to offer customised and engaging education tailored to each patient's level of understanding and specific condition, including patient-specific goals to address individual needs and misunderstandings. Petursdottir, Arnadottir and Halldorsdottir, (2010) reinforce this, proposing that personalised interventions that consider internal (e.g., motivation, exercise history, and knowledge of diseases) and external (e.g., social support, environmental factors, and access to resources) obstacles are more likely to succeed.

Additionally, O'Keeffe *et al.*, (2016) advocated integrating research with clinical knowledge, which is reflected in the feedback from physiotherapists who valued evidence-based practices and the continuous update of clinical protocols. The integration of patient feedback with clinical expertise to tailor treatment plans further supports the need for collaborative goal setting in therapeutic practices.

(c) Attitude toward application:

The findings of this study aligned with previous research, but they also contributed a unique perspective. Earlier studies underscored the impact of patient expectations (Campbell *et al.*, 2001) satisfaction (Potter *et al.*, 2003), therapist's beliefs (Daykin & Richardson, 2004), and positive feedback (Nicolson *et al.*, 2017) in determining the success of physiotherapy. The study highlighted the understanding of participants' orientation, particularly their preference for supervised and straightforward procedures.

Moreover, Campbell *et al.* (2001) noted that patients' adherence to physiotherapy was influenced by their expectations and perceived effectiveness of the treatment. Patients who believed in significant improvement were more likely to follow prescribed exercises and engage in rehabilitation. This highlighted the importance of therapists managing patient expectations through clear communication and realistic outcomes.

Also, high patient satisfaction was linked to better adherence to physiotherapy and improved results. Potter *et al.* (2003) stressed the importance of good communication, professional behaviour, and organisational skills in boosting patient satisfaction. Their study showed that patients appreciated understanding physiotherapists who provided clear explanations and involved them in the treatment process.

Therapists' beliefs and attitudes played a crucial role in patient outcomes. Daykin and Richardson (2004) found that therapists who were confident in their interventions and maintained a positive attitude were more successful in motivating patients and achieving better results. Nicolson *et al.* (2017) also emphasised the importance of providing positive feedback, which could increase patients' confidence and adherence to treatment protocols.

Lastly, a preference for supervised and straightforward procedures suggested a cultural tendency towards structured interventions. This indicated that tailored physiotherapy programs could improve patient engagement and outcomes. Consequently, delivering evidence-based gait modifications became increasingly important. Further exploration of the intricate dynamics between patient expectations, satisfaction, attitude, and therapeutic outcomes would have enhanced the study's findings. Future research should explore how different cultural contexts affect patient perceptions and acceptance of physiotherapy.

(d) Physical & psychological challenges:

In essence, an understanding of gait modifications was essential for both patients and therapists. The likelihood of progress was enhanced when patients expressed confidence in these approaches and therapists were sufficiently informed. However, engagement with the treatment programme relies on understanding the patient's stance on gait modification, with several barriers identified, including acceptance, psychological factors (fear and safety), and perceived efficacy. The findings mirrored Reichenbach *et al.*, (2020), where patients felt untreated after using assistive gait modification therapy.

Nevertheless, the study by Reichenbach *et al.* (2020) only covered a 24-week follow-up, highlighting the need for longer-term studies to fully understand the impact and acceptance of these interventions. Additionally, Kanavaki *et al.* (2017) stated that psychological factors, such as patients' beliefs and views about their health and treatment, significantly influence their engagement in therapeutic physical activities. This aligns with this study's findings and suggests that providing psychological assistance alongside educational programs could be crucial for improving the understanding and acceptance of gait modifications.

Laerum *et al.* (2006) highlighted the importance of patient-centred communication and collaborative goal-setting in clinical consultations for chronic conditions like low back pain. Their study underscores that effective clinical communication, including mutual understanding and shared decision-

making between patients and healthcare providers, can significantly improve treatment outcomes and patient satisfaction. Moreover, Laerum *et al.*, (2006) emphasised collaborative goal setting and treatment planning, suggesting that a more integrated approach between patients and therapists might have reduced confusion.

This aligns with findings from our interviews and FGDs, where participants highlighted the importance of clear communication and cooperation between patients and therapists. For instance, the data revealed that patients needed more thorough explanations and continuous follow-up from their therapists to effectively implement gait modification techniques. This indicates a desire for a more collaborative approach, where therapists and patients work together to set realistic and achievable goals, thereby improving the acceptability and success of interventions.

In addition, Laerum *et al.* (2006) propose that effective clinical communication, which includes providing clear explanations and engaging in active listening, is essential for fostering trust and minimising confusion. Therefore, physiotherapists should ensure their communication approaches are patient-centred, actively solicit patient feedback and integrate it into the treatment process.

- **Burden:**

- (a) **Group therapy and pre-training sessions:**

Study participants indicated that those with KOA, and therapists recently introduced to gait modification methods, might not be adequately prepared. This lack of readiness could hinder engagement and acceptance due to integration demands such as group therapy and training commitments.

The results indicated that group sessions on gait modification could be beneficial. Previously, the value of group exercise and social support was underscored in literature, according to Kaptein *et al.* (2013), people with OA found physical activity combined with social support beneficial, as it assisted them in managing their condition within their daily lives and work roles. Similarly, Fisker *et al.* (2016) discovered that older individuals with OA reported increased physical capability and social interaction as significant

advantages of engaging in water-based training, despite encountering obstacles such as cold water and inadequate instructor knowledge. Moreover, Stone and Baker (2017) stressed that individuals felt more motivated and comfortable when exercising with people of similar ages and abilities, thereby improving their adherence to exercise programs.

While the current study findings aligned with previous research, they did not necessarily explore new areas or provide novel insights. In addition, Fisker et al. (2016) found that barriers to aqua-based exercises included unsuitable class intensity, the absence of age-specific classes, and cold temperature environments. These issues might have affected other group exercises, indicating that group sessions might not have been suitable for all patients. Participants in Fisker's study desired classes tailored to their age and abilities, suggesting that a one-size-fits-all approach might not have worked for everyone.

Moreover, Kaptein *et al.* (2013) study was constrained by its focus on employed OA individuals, potentially not representing the experiences of all OA patients, and its use of focus groups, which might not have fully captured overall patterns. Furthermore, the cross-sectional design and the limited regional participant pool restricted the generalisability of the findings. Additionally, Stone and Baker (2017) study had a small sample size, a short follow-up period, and relied on self-reported data, which may have limited the applicability of their findings.

However, this study's contribution lies in its cultural context, focusing on KOA patients in SA. This cultural perspective was often underrepresented in the literature, thus providing novel insights into the preferences and barriers this specific population faced during rehabilitation. Future research should investigate the effectiveness of personalised group sessions for varying age groups and functional or physical abilities, as this could enhance the inclusivity and efficacy of these interventions. Additionally, exploring the long-term impact of group sessions on therapeutic outcomes and patient satisfaction across diverse cultural contexts was essential.

(b) Integration with physiotherapy program:

Despite the benefits of incorporating gait modification strategies into physiotherapy, therapists did not show interest in including these approaches in the standard treatment plan for KOA. This hesitation could be attributed to a need for more awareness and understanding of gait modification techniques among both patients and therapists at the beginning of their dialogue, as shown in section (b) (5.7.2.4) of the results. Although these gait modifications had proven efficacy, the lack of knowledge about them could hinder their widespread integration into clinical practice. Therefore, enhancing awareness and training regarding gait modifications among physiotherapists was crucial to ensure these strategies were effectively utilised in KOA treatment.

Incorporating gait modification in physiotherapy KOA treatment aligned with the Dutch guidelines, which emphasised a combination of muscle-strengthening, aerobic, and functional exercises alongside tailored gait training (Peter *et al.*, 2011). This multifaceted approach aimed to improve overall joint function and reduce pain in KOA patients. Furthermore, a review by (Somaia, Samal and Boob, 2024) on sensor-based gait training, which provided real-time feedback. This enabled patients to adjust their gait patterns effectively, thus reducing pain and improving mobility. Somaia found that combining this training with standard physiotherapy could improve the quality of life for KOA patients.

Nevertheless, one might question whether this approach fully maximises the potential of gait modification. Andersen *et al.*, (2011) highlighted the challenges of devising an integrated test in the biomedical field, emphasising the need for solutions that catered for all users, including patients and therapists, to ensure effectiveness and accessibility. Both the effectiveness and accessibility of interventions depend on this. Although gait modification depends on the patient's capacity, which is also a crucial element of rehab, there remains a noticeable gap in its consistent inclusion and emphasis in treatment plans, often due to limited awareness and training among healthcare providers.

(c) Place preference:

Walking modification programmes were previously applied in various locations among participants. Clinics, with their array of modalities and supervising therapists, were typically viewed as the optimal setting for KOA participants. These methods were initially applied in clinics; afterwards, therapists often suggested home-based gait modification. This perspective aligns with Hunt *et al.*, (2018) and Xia *et al.*, (2019), who focused on FPA for gait modification. However, after an initial visit to a gait lab to determine the best FPA adjustment, the question arose: Was gait retraining best continued at home or in a clinic? While the clinical setting provided supervision and specialised equipment, the home-based approach offered flexibility.

Hunt *et al.* (2018) conducted an RTC comparing clinical and biomechanical changes associated with a 4-month walking program with and without toe-out gait modification in people with medial KOA. The study found significant improvements in the toe-out group regarding KAM, indicating biomechanical benefits. However, both groups experienced improvements in self-reported pain and function, with no statistically significant differences, suggesting mixed evidence on the clinical superiority of one setting over the home-based training program (Hunt *et al.*, 2018).

Similarly, Xia *et al.* (2019) explored the feasibility of a smart shoe capable of estimating FPA and providing haptic feedback to train different target FPA magnitudes. Their study demonstrated that the smart shoe could be used effectively in real-world settings to train a variety of FPAs, with acceptable training errors, indicating potential benefits for home-based gait modification programs (Xia *et al.*, 2019).

These studies highlight the potential benefits and challenges of both clinical and home-based settings for gait modification. Nevertheless, the evidence did not definitively favour one over the other, suggesting a potential gap in the literature and indicating the need for further exploration. This raises considerations about the consistency, adherence and effectiveness of the programme in varied settings, highlighting areas where past research could have explored deeper. Furthermore, while the cited studies provided valuable

insights, future research is needed to assess the broader applicability and comparative effectiveness of these two settings.

(d) Deliverer & Recipients requests:

Moreover, for KOA patients, planning training classes, or allocating training areas like gyms for gait modification, was considered beneficial for their treatment. This could also make the techniques more accessible for therapists. Therapists expressed the need for training areas, and facilities, for effective gait modification (environment factor), aligning with studies by Petursdottir *et al.*, (2010), Kaptein *et al.*, (2013) and Fiskén *et al.*, (2016). Additionally, the importance of a protocol was echoed by therapists, which was discussed earlier in this discussion.

This was noted by Khalaj *et al.*, (2014), which highlighted the value of varied gait modification protocols based on age, gender and KOA severity. Crucially, quality gait training required appropriate locations and specialised spaces for the success and acceptability of gait modification treatments. Nevertheless, implementing various protocols required significant resources, such as specialised spaces and equipment, which were not universally accessible (Egerton *et al.*, 2020). Additionally, the need for suitable locations to ensure the success and acceptance of gait modification underscored a significant gap in the current healthcare infrastructure.

Despite their concerns, therapists viewed the patient as committed, capable, and cooperative. Morgan *et al.*, (2016) identified that support from therapists, peers, and family significantly enhanced adherence to post-programme exercise routines. Conversely, inconvenient appointments, cost, location, unsuitable gym conditions (hot/cold), and unfamiliarity with equipment were barriers (Morgan *et al.*, 2016; Egerton *et al.*, 2020). Therefore, addressing these barriers could improve gait modification acceptance and outcomes among KOA subjects.

Another prospect, Veenhof *et al.*, (2006), suggested that setting long-term goals and active involvement in the intervention process were linked to sustained adherence. It is crucial to address systemic barriers and patient commitment, according to these external findings. As this study focuses on

therapist perceptions, it highlights the patient's role and emphasises the need to recognise more overall challenges in treatment.

- **Ethicality:**

The participant experience, particularly their comfort and ease of use, emerged as the most important consideration when assessing the gait modification (assistive approach such as insoles, footwear, or knee braces).

Studies by Hinman *et al.*, (2009), Jones *et al.*, (2015) found that foot orthoses, such as insoles and specific footwear, were effective and relatively comfortable treatments for KOA. These interventions were inexpensive and generally well-received by patients, highlighting their practicality and accessibility (Hinman *et al.*, 2009; Jones *et al.*, 2015). Furthermore, 3D-printed orthoses provided a more personalised fit for custom-made LWI, potentially enhancing comfort and adherence (Lin *et al.*, 2021). The variability in individual responses to insoles and their biomechanical impacts underscored the necessity for personalised treatment plans. Custom orthoses, such as those created through 3D printing, offered a promising solution by providing tailored support based on individual biomechanics. Ensuring patient comfort and addressing potential adverse effects, such as increased ankle eversion moment with lateral wedges, were essential for long-term adherence.

Skou *et al.* (2013) emphasised that custom-made laterally wedged insoles significantly reduced pain and improved function and quality of life in patients with medial KOA. Concerning the adherence rate with custom-made insoles, comfort suggested that better fit and comfort led to consistent use, enhancing therapeutic outcomes. Discomfort and poor fit, often reported with prefabricated insoles, resulted in lower adherence and reduced therapeutic benefits (Skou *et al.*, 2013). The customisation to individual biomechanical needs and higher adherence rates were critical to their effectiveness.

The choice of materials and the precision of the fit were critical for comfort. For example, materials adapted to the user's foot shape and evenly distributed pressure could prevent discomfort and improve adherence.

On the contrary, several studies have explored the challenges and discomfort experienced by participants during gait modifications (learned

approaches) (Hunt *et al.*, 2011; Caldwell, Laubach and Barrios, 2013; Takacs *et al.*, 2014). Despite demonstrating the efficacy of the toe-in gait modification for mechanical knee loading, Shull *et al.*, (2013) ignored participant comfort – a potential oversight.

Further, Hunt *et al.* (2011) reported significant difficulty and discomfort among participants performing increased trunk lean gait modifications, with one-third experiencing knee, hip and lower spine discomfort. This suggests that while effective in reducing KAM, such modifications have adverse effects (Hunt *et al.*, 2011).

Shull *et al.* (2013) found that toe-in gait effectively reduced the 1st peak KAM without increasing the external knee flexion moment. However, the study primarily focused on biomechanical outcomes and lacked comprehensive data on participant comfort, essential for practical application and patient compliance (Shull *et al.*, 2013). However, Caldwell *et al.* (2013) and Takacs *et al.* (2014) noted that participants might experience initial challenges and discomfort during the learning phase, highlighting the need for gradual adaptation and comprehensive training to minimise discomfort and enhance ease of application.

While gait modifications such as increased trunk lean and toe-in gait show promise in reducing knee loading, the associated participant discomfort and challenges cannot be overlooked. Some individuals initially struggled with gait changes, but guidance from healthcare professionals often enabled them to adapt and reduce discomfort. This raises the question: could physiotherapy, or assistive gait methods, enhance the benefits of gait modifications? Even when the primary outcomes, like mechanical knee loading, are achieved, these findings illustrate the importance of therapists' skills and patient comfort.

However, The study highlighted challenges faced by patients, suggesting a need for broader therapeutic strategies such as strengthening exercises, balance training, and the use of assistive devices. Future studies should prioritise evaluating and addressing these comfort issues to enhance the practical application and patient adherence to these interventions.

- **Intervention Coherence:**

- a) **Knowledge and awareness:**

It became apparent during exploring the KOA treatment journey (Intervention coherence) that participants wished to gain a deeper understanding of gait modification. In line with other studies, KOA should be oriented appropriately towards patients and therapists to modify gait. However, there remains a significant gap in knowledge that needs to be addressed.

As Fregly (2012) had previously stated, merely understanding kinematic changes is insufficient. It was imperative to assist patients in achieving and maintaining targeted gait modifications. Furthermore, Fregly (2012) identified several methods for gait modification, such as walking with increased stance width or using assistive devices like LWI and variable stiffness shoes, which can reduce peak KAM. However, there were challenges associated with gait modifications. Verbal instructions alone were often insufficient for patients to achieve the desired changes, and there was a lack of clarity on why some patients could achieve these modifications while others could not.

Farrokhi *et al.* (2013) stressed the importance of a comprehensive understanding of various treatment options, including gait modifications, LWI, valgus KB, footwear and cane use, for managing KOA. They reviewed biomechanical evidence supporting different treatment options to reduce excessive joint loading while offering symptomatic relief and functional improvements. They underlined the necessity for patient and therapist education to understand how interventions like gait modification, LWI and valgus KB impact the knee joint's mechanical environment. By improving this understanding, patients could achieve better adherence to these interventions, leading to more effective long-term management of KOA.

According to Larmer *et al.*, (2014), therapeutic exercises, insoles, knee braces, footwear and education are key recommendations for the physical management of KOA. The study claimed that these interventions were well-supported by evidence and were effective for managing KOA. However, education about the disease and its management, combined with personalised therapeutic exercises, could improve patient outcomes.

As a result, even though the study successfully identified gaps in understanding, it could have explored more strategies for ensuring long-term adherence and effectiveness of gait modifications, contributing to the continuation of the proposed modified gait intervention. These findings support existing literature and suggest that strategies for ensuring sustained adherence to gait modification should be explored further.

While some research suggested physiotherapists were confident in promoting training (Shirley *et al.*, 2010), others believed therapists needed more profound knowledge by professional development for effective clinical implementation (MacKay, Hawker and Jaglal, 2020).

Shirley *et al.* (2010) underscored that physiotherapists generally noticed promoting physical activity as part of their role, but they faced significant barriers such as lack of time and inadequate training in behavioural counselling. These limitations restricted intervention effectiveness in encouraging patients to adopt and maintain beneficial gait modifications. Additionally, Shirley *et al.* (2010) emphasised the importance of integrating physical activity promotion into routine consultations to enhance feasibility and patient adherence.

MacKay, Hawker and Jaglal (2020) also explored how physiotherapists manage early KOA, emphasising the central role of exercise and physical activity in treatment. The study found that therapists' clinical experiences and ongoing professional development significantly influenced their decision-making. This highlights the necessity of continuous education and training for therapists on different gait modification approaches to stay updated with evidence-based strategies for managing early KOA effectively.

b) Time-frame for implementation:

Most patients expressed a preference for extended treatment durations; this sentiment was consistent with the findings of Farrokhi *et al.* (2013). Farrokhi *et al.* (2013) highlighted that biomechanically, extended therapy approaches, mainly targeting knee joint loading, require longer durations to be effective. This study underscored the necessity of sustained gait modification interventions, whether learned or assistive, to facilitate significant biomechanical changes.

As suggested by Booij *et al.*, (2020), that short-term follow-ups may not provide sufficient time for the natural evolution of gait patterns, which is crucial for assessing the long-term impact of treatment strategies. This indicates that studies with extended follow-up periods are essential for capturing the true efficacy of therapeutic interventions on gait and functional outcomes.

Hinman *et al.* (2013), recognised the immediate benefits of training, noting improvements in pain and function through gait retraining, insoles and appropriate footwear. However, they also emphasised the importance of understanding the long-term sustainability and cost-effectiveness of these interventions for informed therapeutic practices. Despite short-term improvements, their research calls for more comprehensive studies to evaluate the prolonged impact and economic viability of these treatments.

In light of these studies, it is evident that while short-term improvements were valuable, long-term outcomes and economic considerations are paramount in developing practical, sustainable treatment protocols for KOA. Therefore, future research should prioritise extended follow-up periods and cost-benefit analyses to ensure the practical applicability of these therapeutic strategies.

Moreover, the SA physiotherapy clinic's follow-up approach may have highlighted a missed opportunity: focusing on a suitable duration of gait modification, crucial for patient acceptance, could have further improved patients' outcomes.

- **Opportunity Costs:**

- a) **Motivation and encouragement:**

As the gait modification phase progressed, motivation became increasingly important. Interviews revealed that KOA patients' motivation was primarily driven by their expectation of reducing knee symptoms, especially pain. The appeal of consistent follow-ups and the simplicity of the intervention have been demonstrated in previous studies.

For example, Fregly, D'Lima and Colwell (2009) highlighted that gait modification offers a non-invasive alternative to surgical interventions for offloading the medial compartment of the knee. Patterns such as medial thrust

gait were easy to adopt without special equipment, enhancing patient adherence. Barrios, Crossley and Davis (2010) supported this by demonstrating that re-gait training can significantly reduce KAM, making it appealing due to its simplicity and immediate biomechanical benefits observed through 3D analysis.

Hinman and Bennell (2009) examined the impact of insoles and footwear on KOA, focusing on knee load, symptoms, and disease progression. LWI was found to reduce KAM and alleviate knee symptoms but did not consistently slow disease progression. Modifications in footwear design, such as variable stiffness or lateral wedging, aim to redistribute load away from affected areas of the knee, potentially offering symptomatic relief. Despite being simple and cost-effective, the effectiveness of insoles and specialised footwear as treatment strategies for KOA has not been conclusively established.

According to previous studies, the simplicity of interventions such as medial thrust gait and insoles or knee braces lies in their non-invasive nature and lack of requirement for special equipment, making them more acceptable to patients. This simplicity can lead to better adherence compared to more complex or invasive interventions. However, there needs to be a more direct discussion on the ease of implementing various gait modification approaches, such as gait training, insoles, or footwear, for treating KOA. Further research is necessary to reach more definitive conclusions in this field.

Regarding therapist training, the FGD highlighted the importance of courses that improve their gait modification skills. In line with Gyllensten *et al.*, (1999), Gard. (2007) findings, physiotherapists' ongoing skill development is essential for improving patient care and strengthening the therapeutic relationship. However, a detailed examination of course quality and content, and their direct impact on gait modification practices, remains unexplored. Evaluating these aspects could provide insights into how specific training components contribute to practical skills.

Moreover, FGD participants perceived training as a means of specialisation. According to Peersman *et al.*, (2013), expertise plays a

fundamental role in developing patient trust. Yet, connecting perceived specialisation with clinical efficiencies would clarify its impact on patient outcomes. Investigating whether specialised training leads to measurable improvements in clinical practice and patient recovery rates would be beneficial. Studies focusing on the correlation between specialised training and enhanced clinical outcomes could offer valuable insights.

In their perspective, physiotherapists believed patient compliance feedback should guide gait modifications for KOA patients, consistent with past findings. Notably, Campbell *et al.*, (2001) had previously highlighted significant non-compliance rates in physiotherapy, with KOA intervention adherence surfacing as particularly challenging (Carr, 2001). Interestingly, the outcomes of compliance decisions from the patient's view were often based on rational considerations from the patient's perspective. This complexity underscored an apparent disconnect; despite possessing clinical insights, clinicians and researchers had historically struggled to accurately forecast these compliance outcomes (Campbell *et al.*, 2001). This pattern begged the question: While the physiotherapists' predicted outcomes aligned with scientific bases, had there been an over-reliance on intervention findings without adequately considering evolving patient perspectives? Addressing this disconnect by incorporating patient feedback into intervention strategies could enhance adherence and outcomes.

Moreover, the existing literature, while informative, might not have delved deeply enough into the factors influencing individual patient decisions, such as belief in effectiveness, fear and intervention understanding of the treatment. Bridging this gap is crucial to ensure more effective and personalised gait modification interventions. Overall, factors like therapeutic effectiveness, patients' feedback, therapist training and patients' orientation availability may play critical roles in gait modification adoption, aiding both KOA patients and physiotherapists in achieving therapeutic goals and enhancing the quality of life. Future research should focus on evaluating the practical impact of these factors in SA, particularly concerning gait modification practices, to provide more localised and relevant insights.

- **Perceived Effectiveness:**

a) **Approach effectiveness:**

Participants' prior opinions on self-prescribed gait modifications indicated that various techniques effectively reduced pain and improved function. This is in line with previous studies that have identified several techniques for improving knee pain and mobility from the perspective of KOA subject (Turpin *et al.*, 2012; Parkes *et al.*, 2013; Arnold *et al.*, 2016; Reichenbach *et al.*, 2020).

Turpin *et al.* (2012) investigated the biomechanical and clinical outcomes of shock-absorbing insoles in patients with KOA. Their study revealed that while these insoles did not significantly change knee joint loading, they significantly reduced self-reported knee pain and improved physical function after one month. These findings suggest that shock-absorbing insoles may enhance comfort and reduce pain, potentially improving overall mobility despite the lack of observed biomechanical changes.

Moreover, Parkes *et al.* (2013) studied the effectiveness of LWIs in reducing pain and improving function in patients with medial KOA. They found that LWIs significantly reduced knee pain and improved physical function over six months. The effectiveness of these insoles might vary depending on the severity of KOA and individual patient biomechanics (e.g., gait patterns and knee alignment).

Another study by Arnold *et al.* (2016) evaluated the impact of LWIs on KAM and pain in KOA patients. Their findings indicated that LWIs effectively reduced KAM, which was associated with decreased medial knee joint loading, alleviating pain and enhancing function. This study highlights the potential of LWIs as a non-invasive intervention for managing KOA symptoms. Although the exact duration was not specified, their focus on sustained reductions in KAM suggests an interest in longer-term outcomes.

Lastly, Reichenbach *et al.* (2020) explored the effects of biomechanical footwear designed to optimise load distribution across the knee joint. Their randomised clinical trial demonstrated that these shoes significantly reduced knee pain and improved physical function after six months. The study

concluded that biomechanical footwear could be viable for KOA patients, particularly those seeking non-pharmacological interventions.

Considering this, it is essential to understand that not all gait modifications are appropriate for all KOA individuals. Apart from age, activity level and severity of the condition, were there any specific differences in the Saudi context that could influence patient and therapist preferences? Although the consensus on potential benefits was promising, further studies would help determine the most universally accepted and effective gait modifications for diverse patient populations.

Although their experiences with therapeutic exercise approaches varied, therapists' opinions on the perceived effectiveness of different gait modifications for KOA symptoms were consistent with other studies.

For example, Khan *et al.* (2020) highlighted the importance of individualised gait retraining methods, which involve customising training to each patient's biomechanical characteristics, such as natural gait pattern, joint alignment and muscle strength. The study found that while toe-out gait modifications could limit physical function, knee braces showed immediate improvements in performance measures like the 40-m fast-paced walk and stair climb tests. This suggests that individualised gait retraining can be highly effective when tailored to the patient's biomechanical profile.

Moreover, Page, Hinman and Bennell (2011), emphasised that patient-specific biomechanical factors, such as knee alignment and gait patterns, significantly influence the outcomes of these interventions. For instance, LWI reduced KAM, but its clinical effectiveness varied depending on individual patient characteristics (e.g. BMI and KOA severity). This highlights the need for personalised assessments to optimise the benefits of footwear and insoles in KOA management.

Farrokhi *et al.* (2013) explored the effectiveness of various biomechanical treatments for KOA, including gait modifications, LWI, footwear and knee braces. The role of individual patient factors encompasses a wide range of attributes, such as the severity of OA, physical fitness levels and lifestyle habits. The study found that these biomechanical methods could

significantly reduce pain and improve function when carefully considering individual factors during treatment planning. This underscores the importance of a personalised approach in applying assistive or learned gait modification to maximise therapeutic outcomes.

The perceived effectiveness of gait modifications, insoles, and knee braces is well-supported by empirical evidence but shows variability across different studies and patient populations. This variability highlights the importance of customisation and personalisation, as tailored interventions yield better outcomes. For instance, the efficacy of LWI varies based on the wedge angle, patient weight, and severity of knee malalignment. Continuous therapist involvement is crucial for optimising benefits. Regular therapist contact improves patient adherence and allows for real-time adjustments to treatment plans. Long-term efficacy and adherence are significant concerns, as short-term benefits are well-documented, but sustained outcomes need further research. Factors affecting long-term adherence include the acceptability and practicality of the intervention.

- **Self-efficacy:**

- a) **Self-management tool:**

Based on the study's findings, KOA participants with confidence in gait modification relied heavily on therapist explanations and instruction sheets for gait modification self-management. The findings aligned with international standards, linking self-management with KOA therapy success. Hochberg *et al.* (2012) emphasised the importance of self-management programs, recommending their inclusion in nonpharmacologic treatment strategies for KOA. These programs often include therapist-led education, which participants found crucial for successful self-management.

Similarly, Fregly *et al.*, (2011) documented the importance of teaching patients proper walking techniques. Their study showed that tailored gait modifications can significantly reduce knee adduction torque, which is critical for slowing disease progression. This supports our finding that therapist-guided gait training is vital for self-management.

However, the literature also highlights areas needing further investigation. While Hochberg et al. (2012) provided firm recommendations for self-management programs, they noted variability in patient outcomes, suggesting that more personalised approaches may be necessary. This variability was evident in this study, where some participants reported more significant benefits than others, indicating that self-management tools must be tailored to individual needs and capabilities.

Furthermore, the critical role of patient education in these programs cannot be overstated. Effective self-management relies not only on the availability of resources (e.g., instruction sheets and therapists' guidance) but also on the patient's understanding and application of the information provided. As Hochberg et al. (2012) noted, the inconsistency in outcomes across different studies underscores the need for more robust educational frameworks within self-management programs to ensure all patients can benefit equally.

Self-management in KOA therapy has been consistently advocated across various studies (Lorig and Holman, 2003; Marks *et al.*, 2005; Lorig *et al.*, 2006), and it has even been recommended as a means of promoting function and independence by the American College of Rheumatology (ARC) (Kolasinski *et al.*, 2020).

Lorig & Holman (2003) identified three core self-management tasks: medical management, role management, and emotional management. These tasks involve taking medications as prescribed, maintaining meaningful life activities and managing the emotional impacts of chronic disease. The efficacy of self-management programs is often attributed to the enhancement of self-efficacy, which is the belief in one's ability to effectively manage one's health condition.

Research by Marks *et al.* (2005) demonstrated that self-management interventions focusing on self-efficacy can significantly reduce disability and improve psychological functioning among arthritis patients. These interventions often include goal setting, problem-solving, and fostering patient-provider partnerships to support sustained behavioural changes. Self-

management programs tailored to individual needs have shown substantial improvements in pain management, exercise adherence and overall quality of life for osteoarthritis patients.

However, self-efficacy assessments vary according to the patient and setting, making it crucial to monitor slow improvements in self-efficacy (Pekmezi *et al.*, 2009). They emphasised that patient confidence can fluctuate based on individual circumstances and settings. Therefore, it is crucial to support gradual improvements in self-efficacy to achieve long-term benefits. This approach aligns with findings from Lorig *et al.* (2006), who documented sustained improvements in health behaviours and reduced healthcare utilisation among participants in chronic disease self-management programs.

Although this study provided insight, further exploring factors contributing to variations in self-efficacy assessments might have enhanced the study's depth. Additionally, refining these interventions to ensure they are tailored to the specific needs of different patient subgroups is essential to maximise their efficacy and impact. Moreover, while instructional materials and therapist guidance were regarded as essential, further research is needed to evaluate their effectiveness across various healthcare settings and therapist backgrounds. Finally, although this study offered novel insights into self-efficacy's role in gait modification, a better understanding of its broader application is required.

5.8.1 Strength and Limitations:

The detailed data collection and analysis methods, and the practical and detailed procedures necessary for effective qualitative research as highlighted by Gelling (2015), that were followed in this study provide evidence that a strength of the study is the rigor of the data. Also, by using the TFA, this study offered a theoretical explanation for the results of gait modification to manage and increase the acceptability of gait modification implementation among both KOA patients and healthcare providers in SA. Seven TFA categories were identified to indicate gait modification's acceptability for KOA patients and therapists, including: affective attitude, burden, ethicality, intervention coherence, opportunity costs, perceived effectiveness, and self-

efficacy. Unlike other methods, the TFA provided an in-depth analysis of essential stakeholder perspectives on gait intervention participation.

It is essential to acknowledge the limitations of this study and how these impact on the findings. Even although this is the first evaluation of the acceptance of gait modification treatments among patients with KOA and physiotherapists within the Saudi healthcare system.

There was a potential for interviewer bias since physiotherapists in the focus groups knew the researcher had a physiotherapy background. The presence of a researcher with a similar professional background could have introduced confirmation bias. This bias happens when researchers favour evidence that supports their pre-existing beliefs, indirectly affecting participants' responses or the interpretation of data. For instance, a researcher with a similar background may unintentionally influence participants, thereby reinforcing their assumptions (McSweeney, 2021).

In this case, the researcher's background in physiotherapy might have led to an unconscious preference for certain types of responses, shaping the data collection and analysis process. This bias can misrepresent research findings, leading to conclusions that reflect the researcher's initial beliefs rather than objective truth.

Another potential bias was acquiescence bias during focus group discussions in this study, which happens when participants tend to agree with statements or questions posed by the interviewer, regardless of their beliefs or opinions. This bias can be particularly problematic in qualitative research, where open-ended questions and discussions are used to gather detailed responses. Acquiescence bias may lead to an overrepresentation of agreement with the researcher's prompts or questions, thus distorting the data (Meisenberg and Williams, 2008).

On the other hand, there was potential for interviewer bias, which might have led interviewees to respond in ways they believed matched the researcher's expectations, known as social desirability bias. Social desirability bias happens when participants provide answers they think are more socially acceptable or favourable to the interviewer rather than their true thoughts or

behaviours (Bergen and Labonté, 2020). This could have influenced the findings related to gait modification, as participants might have highlighted aspects they thought the researcher valued.

To mitigate these biases, topic-guided prompts guided interviews and discussions objectively, ensuring conversations remained focused on the research questions and minimising the influence of the researcher's background (Ritchie *et al.*, 2013). The influence of confirmation, acquiescence and social desirability biases should be considered when interpreting the findings, as they may have affected the depth and authenticity of responses and could leading to skewed or incomplete conclusions.

Additionally, one researcher conducted interviews, handled discussions, transcribed, and initially coded the data. Despite this, the approach allowed for an in-depth understanding of the data, which can prove helpful for qualitative analysis (Fossey *et al.*, 2002). In addition, it raises concerns about how the researcher's interpretations could influence the study's conclusions (Tilley, 2003; MacPhail *et al.*, 2015). To mitigate these concerns, transcription and translation were done with the assistance of a third party, and a third party resolved any conflicts. Although it is essential to understand how KOA patients accept gait modification treatments, it is also important to realise that the researcher's preconceptions could have influenced the derived insights and themes negatively. A collaborative approach to data analysis may enhance objectivity and the validity of future studies (Richards and Hemphill, 2017).

Despite these limitations, the study has explored the acceptability of gait modification in Saudi healthcare. The findings offer a preliminary understanding of both patient and therapist perspectives, which may help increase awareness and curiosity about gait modifications. However, these results should be interpreted with caution, considering the potential implications of research bias and subjectivity.

Also, there was a possible drawback: the study's focus on one primary governmental site could affect its geographical transferability (Ritchie *et al.*, 2013). Nevertheless, collaborations with other Saudi researchers, from

different areas, could ensure that study findings are transferrable and valuable for various healthcare scenarios.

5.9 Conclusion:

The acceptability of gait modification strategies was assessed through interviews with KOA patients and therapists in SA. According to the dialogues, the concept of gait modification heavily relied on the presence of experienced physiotherapists, along with therapeutic protocols, training areas and the availability of materials.

Moreover, both KOA participants and physiotherapists pointed out the potential benefits of assistive gait modification devices. These devices were potential solutions for patient safety, confidence and compliance. Combining this approach with the current KOA approaches of clinical protocols, consistency evaluations, and long-term follow-up may create optimism for its potential benefits. The study also highlighted the importance of patient commitment and proper orientation to the prescribed gait modification as part of the KOA rehabilitation process.

Participants generally preferred simpler, more accessible gait modification therapies, such as canes, knee supports, comfort footwear, and insoles. These tools were favoured for their ease of use, helping alleviate pain and improving mobility. Within the Saudi healthcare system, and based on the current availability of gait modification, patients and therapists may be more accepting of assistive modified gait interventions, such as footwear and insoles, as they are easy to implement and could help achieve the aforementioned objectives.

The findings underscored the importance of standardising protocols and ensuring resource availability to enhance the feasibility and acceptance of gait modifications in KOA rehabilitation. Additionally, the study highlighted the need for targeted educational approaches to bridge the knowledge gap between patients and therapists, improving confidence in using gait modifications.

While some gait modification approaches showed promise in managing KOA, their successful implementation in Saudi healthcare required addressing

the identified barriers and enhancing support structures, future research should continue to refine these interventions, focusing on patient-specific needs and the practicalities of the Saudi healthcare environment to optimise outcomes for KOA patients.

CHAPTER 6

PROPOSED INTERVENTION

6.1 Summary:

This chapter presents a snapshot of the lateral wedge insole rationale for selecting LWI, detailing the justification, biomechanical effects on knee loading, clinical effects on pain and function, and a comparison of the effect of different lateral wedge designs' on knee osteoarthritis subjects.

6.2 Introduction:

Following the Medical Research Council's guidelines (2000, 2008), a systematic review and primary research informed the intervention. Consequently, during this research, physiotherapy practitioners and KOA patients in SA shared their opinions and perspectives on the gait modification programme for KOA treatment. The qualitative study's findings influenced the selection of the gait modification techniques and identified survey participants among KOA patients and therapists. This event marked a transition from qualitative to quantitative phases of the sequential mixed-methods strategy. Systematic review and meta-analysis (Chapter 4) and qualitative study (Chapter 5) determined the LWI as an appropriate gait modification. Based on the qualitative chapter's TFA, the LWI was deemed suitable for KOA patients and physiotherapists in SA.

6.3 Justification for LWI Intervention selection:

The proposed intervention for KOA in this study was the use of LWI, based on findings from a systematic review, meta-analysis and qualitative studies, along with practical considerations.

The systematic review and meta-analysis examined various gait modification interventions, such as re-gait training, foot progression angle, lateral wedging footwear, LWI, and valgus KB. The results indicated that most gait modification approaches did not significantly reduce knee loading (KAM). Metrics such as pain levels, knee ROM, gait speed, and stride length also showed no significant improvement with different gait modifications, including LWI.

However, lateral stiffener shoes impacted the first peak of KAM, while re-gait training with toe-out significantly improved the second peak of KAM. Additionally, LWI affected both the second peak of KAM and the knee adduction angular impulse (KAAI). Despite these specific benefits, the overall effectiveness of gait modification in reducing knee loading was limited.

The qualitative study provided insights into the views and acceptance of gait modification methods among KOA patients and physiotherapists in Saudi Arabia. Key themes identified included the seven theoretical framework of acceptability (TFA) domains. Participants showed varying levels of awareness and acceptance of gait modifications, highlighting the need for proper awareness and training. Simpler, more accessible gait modification therapies, such as canes, knee supports, comfort footwear, and insoles, were generally preferred for their ease of use and ability to alleviate pain and improve mobility.

Logistical and financial challenges hindered the provision of some interventions, such as specialised wedging footwear or customised knee braces. Conversely, through the "PhD student's bench fees," the University of Nottingham could acquire tools from local UK companies, such as various sizes of the "Salford LWI." These tools, which have been scientifically validated, could then be stored and shipped easily to Saudi Arabia for the feasibility study. Re-gait training, such as toe-out, required training sessions and was acceptable only to particular KOA subjects based on the KOA severity and activity level, necessitating more clinical screening time and training sessions for final approval.

Challenges also arose due to time restrictions. In Saudi Arabia, obtaining final ethical approvals takes time, and arranging clinic times for patient appointments proved complex without direct researcher supervision. However, coordinating clinic schedules and scheduling appointments for participants were necessary for the short-term clinical experiment based on the space and therapists' time limit, which lasted 30 to 45 minutes for each participant. Additionally, the period available under Saudi government sponsorship for the researcher to collect data for the study was limited to three to four months outside the UK. This made it impractical to simultaneously

collect participants and data for qualitative and feasibility studies without a fast and easy proposed intervention.

Given these constraints, accessible gait modification therapies, such as re-gait training (toe-out or toe-in), wedging footwear and knee supports, might not be used within this feasibility study. Therefore, insoles and "Salford LWI" may be the proposed interventions. Particularly, the findings of the systematic review and meta-analysis suggested that assistive gait modifications, such as lateral wedging footwear, insoles and knee braces, did not significantly reduce knee loading or show notable improvements in pain and function compared to other interventions. However, the qualitative study emphasized that patients found comfort footwear and insoles to be practical and advantageous due to their ease of use, accessibility, and minimal need for clinical visits among different gait modification approaches. Therefore, these findings, alongside the previously mentioned constraints and practical considerations explained within this chapter, established LWI as a viable option.

6.4 Lateral Wedge Insole (LWI) Rationale:

As described by Sasaki and Yasuda in 1987, the LWI is a conservative treatment for medial compartment KOA. These low-cost shoe inserts have a thicker lateral border, moving the centre of pressure and the GRF line laterally to the knee joint, adjusting the angle of the calcaneus into a valgus position (Kakihana *et al.*, 2005; Pollo & Jackson, 2006) Figure 33. This shifts the knee joint towards the body's centre, reducing the KAM and varus knee alignment (Sasaki & Yasuda, 1987; Kerrigan *et al.*, 2002; Kakihana *et al.*, 2005; Pagani *et al.*, 2012).

Therefore, both the National Collaborating Centre for Chronic Conditions (2008) and the National Institute of Clinical Excellence (NICE, 2022) endorsed LWI, but in 2008, the American Academy of Orthopaedic Surgeons (AAOS) did not, according to (Jordan *et al.*, 2003; W Zhang *et al.*, 2010). The LWI affordability, ease of application, and popularity have made them attractive to patients and healthcare providers (Bennell *et al.*, 2011).

Subsequent sections will discuss LWI's biomechanical and clinical effects in KOA.

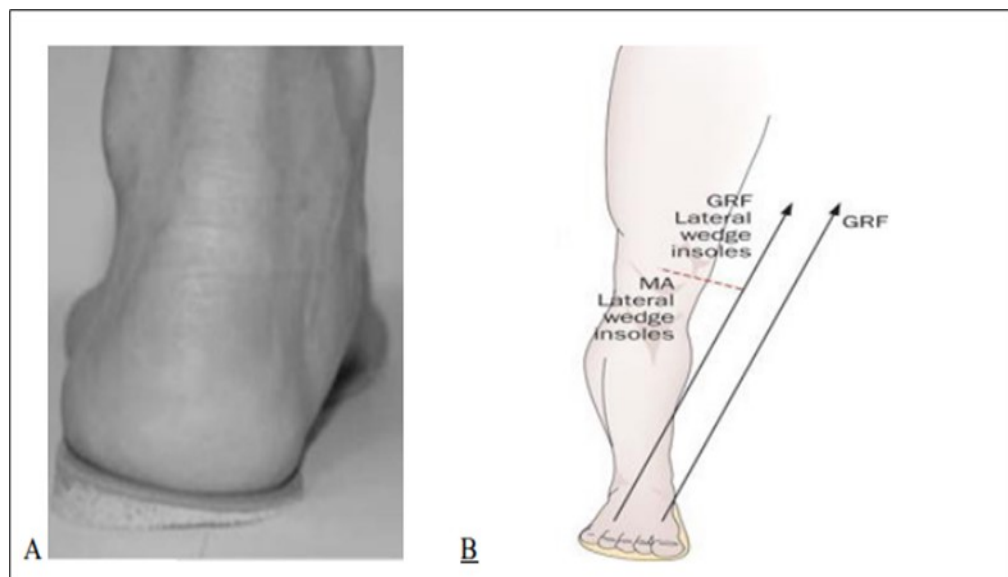


Figure 33: (A) Posterior view of a typical LWI, (B) Anterior view of LWI's effect on GRF line and moment arm. Adapted from (Reeves and Bowling, 2011) with permission.

6.5 Biomechanical effects of LWI:

In a foundational study by Ogata, Yasunaga and Nomiya. (1997), the effects of LWI and medial wedged insoles were assessed in 90 participants (50 participants with medial KOA). The study revealed that LWIs reduced the load on the medial compartment of the knee. Nevertheless, they focused more on the insoles' biomechanics than kinetic impacts, such as KAM. Based on their findings, Ogata *et al.*, (1997) recommended LWIs for patients who experienced pain during medial KOA.

Kerrigan *et al.*, (2002) compared the effects of neutral insoles (flat insoles) and shoes without insoles on LWIs. They found that LWIs significantly reduced KAM peaks, demonstrating their biomechanical efficiency in patients with medial KOA. In those with medial KOA, the KAM-1st peak during early stance was considerably reduced by 5.3% compared to those without insoles. Additionally, Kerrigan *et al.*, (2002) reported that 5° LWI participants showed a significant decrease in the KAM-1st peak (3.8%) compared to neutral insoles. In the LWI group, the KAM-2nd peak was significantly lower than in the control group (no insole) and neutral insole group. Consequently, Kerrigan *et al.*,

(2002) demonstrated that wearing neutral insoles and walking with LWI reduced KAM more. Lastly, Kerrigan *et al.*, (2002) found that LWIs reduced stress in patients with medial KOA compartments.

In an RCT, Hinman, *et al.*, (2008) explored the immediate effects of LWIs (5-degree inclination) on people with medial KOA. They reported that wearing LWIs decreased the KAM-1st peak by 0.22 Nm/Bw.Ht% and reduced walking pain by 24% and walking pain significantly. Similarly, Jones *et al.*, (2013) found a significant reduction in KAM by 12% and KAAI by 16.15% after wearing 5-degree LWIs for two weeks.

Subsequent studies, including one by Hinman, Bowles and Bennell. (2009), examined the long-term effects of LWIs. Compared to the control group (no insoles), KAM 1st & 2nd peaks and KAAI were significantly reduced in the treatment group when wearing a 5° LWI for an average of eight hours a day. They concluded that the initial positive effects of the LWIs persisted even after a month of wear.

Another study by Barrios *et al.*, (2013) analysed the 12-month impact of LWIs and found significant reductions in KAM and KAAI. In 12 months, LWI (high density-70 durometer) reduced KAM and KAAI significantly on two visits (baseline and one month later). Thus, LWI significantly impacted KAM across both groups over a 12-month period, emphasising the long-term benefits of LWIs.

Shimada *et al.*, (2006) concentrated on patients with varying stages of medial KOA. The findings indicated that KAM peaks during gait were higher in KOA patients. LWIs reduced peak KAM for early-stage Kellgren-Lawrence grade (I) by 5.1% and grade (II) by 6.6%. However, they minimally affected advanced grades (III) and (IV), with reductions of 3.3% and 5.0% respectively. Despite LWIs' benefits for early-stage KOA, there was no correlation between the kinetic and kinematic effects. Therefore, Shimada *et al.*, (2006) recommended LWIs mainly for those with early and mild KOA.

According to Hinman *et al.* (2012), a 5-degree LWI reduced the knee GRF lever arm, decreasing peak KAM and KAAI by 5.8% and 6.3%,

respectively, in those with KOA. They suggested that LWI shifted the centre of pressure laterally, shortening the moment arm and thus decreasing the KAM.

A meta-analysis by Arnold *et al.*, (2016) showed that the LWI reduced both the 1st, 2nd KAM peaks and KAAI which are critical factors in knee loading and joint stress. This reduction in KAM peaks suggests that although the insoles might not directly slow the progression of KOA, they can alleviate some biomechanical stresses associated with medial KOA patients. Notably, a 1% increase in the KAM 1st peak elevated the risk of KOA by 6.46 times (Miyazaki *et al.*, 2002). Thus, any decrease in knee loading could benefit the disease's course. Other factors, like alterations in physical activity, might have influenced the limited observed progression of KOA with LWI use. Increased physical activity was contraindicated for those with KOA, as it has been linked to 1.35 times increased risk of disease progression (Doré *et al.*, 2013; Lin *et al.*, 2013). However, the studies did not specifically address activity levels in patients with medial KOA despite the demonstrated efficacy of the LWI intervention.

Lastly, Jones *et al.*, (2014) found that individuals with medial KOA experienced 6.29% and 5.55% decreases in KAM and KAAI, respectively, when wearing 5-degree LWIs with medial support compared to control shoes. Nevertheless, there were no significant differences between the treatment groups. LWIs with support decreased KAM by 1.08% and proved 55% more comfortable than those without. Discomfort from wearing the unsupported LWI for six weeks led to a 1% KAM reduction (Duivenvoorden *et al.*, 2014). Despite a 2.73% rise in KFM in the supported LWI group, the differences between control shoes and LWIs were insignificant (Jones *et al.*, 2014).

6.6 The clinical effects of LWI:

In a study by (Falihatgar *et al.*, 2022), 29 medial KOA patients were split into two groups: one using a lateral wedge with medial arch support (combined insole) while barefoot, and the other using a lateral wedge fitted within a sandal. The gait was analysed with and without orthoses (VAS for Pain, the WOMAC questionnaire, Timed Up-and-Go tests and 30-second chair stands), followed by a follow-up test one month later.

Despite daily orthosis use (five hours/day), results indicated that both orthoses significantly reduced pain immediately after walking, as measured by VAS ($p < 0.001$), and this effect persisted over the one-month period. Both interventions led to significant improvements in functional performance ($p < 0.01$). However, there was no significant difference between the two groups in terms of KAM, suggesting that both orthoses were similarly effective biomechanically. Sandals had 92% satisfaction; combined insoles had 81%.

The relatively small sample size of this study might not be representative of the larger population. Additionally, the short duration of one month may not be sufficient to fully capture the long-term effects of the interventions. The study did not assess biomechanical parameters at the one-month follow-up, which could have provided more comprehensive insights into the sustained impacts of the orthoses. Both groups experienced reduced VAS and WOMAC scores after one month. However, there was no significant difference between the two treatments, allowing patients to choose based on comfort and personal preference. Larger and longer-term studies are needed to further validate these findings and assess the long-term efficacy of these orthotic interventions.

The study by Felson *et al.* (2019) aimed to investigate the efficacy of LWIs in reducing knee pain in medial KOA patients. The study included a rigorous pre-screening process to exclude participants with patellofemoral osteoarthritis and those who did not exhibit at least a 2% reduction in KAM when using the insoles.

This RCT included 83 participants who were randomised to receive either a LWI or a neutral insole for eight weeks, followed by an eight-week washout, and then switched to the alternate insole for another eight weeks. The primary outcome measure was knee pain over the past week, assessed on a 0-10 NRPS, while secondary measures included the KOOS questionnaire.

The results showed that LWIs produced a statistically significant reduction in knee pain compared to neutral insoles, with a mean difference of 0.7 points on the 0-10 scale. However, this reduction was of modest clinical

significance, as it did not meet most participants' threshold for a minimally significant difference.

The duration of LWI use was prescribed as at least four hours per day, with actual usage averaging around seven hours daily. Despite the positive findings for pain reduction, the study highlighted several limitations, including the small effect size and the potential lack of generalisability due to the specific pre-screening criteria. Furthermore, the need for a gait laboratory to identify responders limits the practical applicability of the intervention.

While the Felson *et al.* (2019) study demonstrated a statistically significant reduction in knee pain using LWIs, the overall clinical significance of this finding is limited. The modest clinical effect and the requirement for pre-screening suggest that LWIs may benefit only a minority of patients with medial KOA. Future studies should focus on refining patient selection criteria and exploring ways to enhance the clinical efficacy of this intervention.

Moreover, Parkes *et al.*, (2013) conducted meta-analysis aimed at evaluating the efficacy of LWIs as a treatment for pain in patients with medial KOA. The analysis included RCTs comparing shoe-based treatments, specifically LWIs or shoes with variable stiffness soles, against neutral or no wedge controls. A total of 12 trials with 885 participants were included, of which 502 received the lateral wedge treatment.

The primary outcome measured was the change in self-reported knee pain at follow-up, utilising tools such as WOMAC. The meta-analysis employed a random-effects approach due to substantial heterogeneity among the included studies ($I^2 = 82.7\%$). The pooled SMD suggested a favourable association with LWI compared to control (SMD= -0.47; 95% CI, -0.80 to -0.14), representing an effect of -2.12 points on the 20-point WOMAC pain scale. However, larger trials with a lower risk of bias suggested a null association. Specifically, trials using a neutral insole as a control showed no significant association with pain reduction (SMD= -0.03; 95% CI, -0.18 to 0.12).

The duration of LWI use varied across studies, ranging from two weeks to two years. The analysis highlighted limitations, including substantial heterogeneity and potential bias due to small study effects. Parkes *et al.*,

(2013) suggested that the lack of significant knee pain reduction could be due to a placebo effect from the use of neutral comparator insoles. In the 12 trials that included neutral insole control group, no link was identified between LWI and WOMAC pain levels. They concluded that LWIs did not reduce discomfort more effectively than neutral insoles. Nonetheless, even minimal pain relief from LWI use could have public health importance, particularly as small decreases in pain were associated with beneficial biomechanical outcomes.

The large sample size of 885 participants across multiple trials provided robust data. However, the substantial heterogeneity and risk of bias in several studies limit the strength of the conclusions. The study's methodological rigor, including the use of the Cochrane RoB tool, strengthens the validity of the findings. Nonetheless, need for further research with rigorous controls to definitively determine the efficacy of LWIs in managing KOA pain.

6.7 Knee Function effect:

Patients with KOA using LWIs significantly reduced knee pain and physical function after three months compared to those without insoles (Hinman, Payne, *et al.*, 2008). According to the WOMAC index, knee pain and function decreased by 22% and 20% in these subjects. In another study, the efficacy of 5° LWIs and neutral insoles was assessed over a month and then at a one-year follow-up (Barrios *et al.*, 2009). Both insole types showed improved pain and function scores, with no notable differences, suggesting a possible placebo effect in the neutral insole group. Barrios *et al.*, (2009) did not evaluate the KAM.

Additionally, a study by Barrios *et al.*, (2013) revealed that individuals with medial KOA had greater KAM and KAAI using neutral insoles compared to 5-degree LWIs. Increased activity (more steps taken) in the LWIs group over a year might have elevated cumulative knee loading, leading to more discomfort. Bennell *et al.*, (2011) observed similar outcomes over 12 months between 5-degree LWIs and neutral insoles, noting a slight improvement in WOMAC pain and function subscales. Despite these minimal changes being

moderately clinically significant, they might have arisen because knee function and pain were assessed only at the beginning and end of the year.

The Bennell *et al.*, (2011) study monitored steps using pedometers (Omron HJ-005) at baseline and over 12 months. The steps did not significantly increase compared to the baseline or between groups over the year. However, the neutral group's steps decreased by -874 steps/day (11.5%). Knee pain, which has been shown to affect activity levels in KOA participants (Goubert *et al.*, 2004; Van Damme, Crombez and Eccleston, 2004; Cavanaugh *et al.*, 2007; Rakel *et al.*, 2012), might account for this decline.

Conversely, using a 5-degree LWI led to 151 more daily steps (+1.9%) and decreased knee pain. The lack of significant knee discomfort reduction might be attributed to several factors. The influence of LWI on biomechanical outcomes was not assessed, leaving uncertainty about its effects on KAM. Consequently, pain for medial KOA individuals might have increased up to their tolerance before the second evaluation. The alterations in knee loading during activity could have reduced the LWI's efficacy in managing knee discomfort. The back and foot pain reported in the 5-degree LWI group may not directly link to the insole use but might indicate that these insoles alleviate discomfort and boost activity. Further, Bennell *et al.*, (2011) mentioned that 5-LWIs made from ethyl-vinyl acetate could be uncomfortable, aligning with Jones *et al.*, (2014), who found a correlation between insole comfort and pain rating. Finally, the participants' low adherence to the pedometer could mean some activity levels were not recorded due to lack of commitment.

6.8 LWI: Effective Delivery, Consistent Use and Integration:

While the systematic review's findings (chapter 4) informed most aspects of the proposed intervention, not all intervention details were directly based on these findings. Some aspects, such as inclination and timing with usual care, require further clarification from other literature.

- LWI Delivery:

Full-length LWIs with inclinations ranging from 2° to 10° were constructed and inserted into patients' shoes, as described by Arazpour *et al.*

(2012), Mirzaei *et al.* (2018), and Ferreira *et al.* (2021). Previous research suggested that an optimal inclination of 6° was more effective in repositioning the ground reaction force laterally during the stance phase, thus reducing the KAM (Kerrigan *et al.*, 2002; Kakihana *et al.*, 2004). In the RCT by Ferreira *et al.* (2021), the LWIs were custom-made with specific inclinations tailored to each participant based on prior biomechanical analysis. These inclinations ranged from 2° to 10° and were adjusted to achieve a 5% reduction in the first peak of the KAM. Notably, 65% of participants achieved this reduction with a 4° inclination. (for inclination, more details were explained in section 6.9 in this chapter).

- Monitoring and Consistent Daily Use of LWI:

Studies investigating the efficacy of LWIs for knee pain found that the ideal usage time ranged between five and ten hours per day (Toda *et al.*, 2005). Consistent daily use of LWIs was essential for achieving the desired biomechanical adjustments and therapeutic benefits. This duration was established to evaluate compliance and effectiveness in reducing knee pain and improving gait parameters over a six-week period (Arazpour *et al.*, 2012).

Reported usage durations, such as 7-8 hours per day in Arazpour *et al.* (2012), aligned with typical daily activities, enabling participants to integrate LWIs into their routines without significant disruption. Participants were instructed to wear LWIs continuously over 12 weeks, although specific daily usage hours were not detailed, ensuring the efficacy of the biomechanically adjusted insoles (Ferreira *et al.*, 2021). Studies by Khosravi *et al.* (2019) and Ferreira *et al.* (2021) included monitoring mechanisms, such as follow-up calls and regular assessments, to ensure adherence to the intervention protocol.

Overall, the planned and monitored daily usage duration of LWIs averaged 7-8 hours daily. The insoles were designed to be worn inside the participants' shoes continuously for a period of 6 to 12 weeks, which was crucial for ensuring compliance and effectiveness. Participants were instructed to use the insoles consistently throughout their daily activities, with adherence monitored through follow-ups and regular assessments.

- Timing with Usual Care and Application knee side:

In evaluating the timing of interventions with usual care, LWIs were implemented alongside standard treatments, including physiotherapy and the use of analgesics. This approach aligned with the protocols followed in studies by Erhart *et al.* (2010), Barrios *et al.* (2013) and Mirzaei *et al.* (2018). However, to ensure the observed effects were specifically attributable to the LWI intervention, participants were advised to refrain from attending additional rehabilitation programs during the intervention period, as emphasised by Khosravi *et al.* (2019).

Furthermore, (Maillefert *et al.*, 2001; Pham *et al.*, 2004) studies explored the efficacy of LWIs with or without usual care. These prospective RCTs compared the clinical effects of LWI and neutrally insoles in patients with medial femorotibial knee osteoarthritis. While the study did not identify a significant short and long-term symptomatic effect of LWIs compared to control insoles, it highlighted a decrease in NSAID consumption and better compliance among patients using LWIs, suggesting a beneficial effect when these insoles were combined with usual care.

The LWI was explicitly applied to the affected knee for individuals with unilateral KOA, while a neutral insole was used for the unaffected knee (Toda and Tsukimura, 2004; de Campos *et al.*, 2015). This targeted approach aimed to reduce the load on the damaged joint, potentially alleviating pain and improving function. However, their effectiveness compared to other interventions, such as neutral insoles, remains to be determined. Conversely, according to SR (Chapter 4), in cases where patients suffered from bilateral KOA, insoles were utilised on both knees. This bilateral application was intended to maintain symmetry in the lower limbs and optimise gait patterns, which are crucial for overall mobility and reducing the strain on both knees (Arazpour *et al.*, 2012; Mirzaei *et al.*, 2018; Khosravi *et al.*, 2019; Ferreira *et al.*, 2021).

6.9 Influence of Designs and Inclinations:

Research and clinical treatments previously categorised LWIs by length and inclination angle. Full-length LWIs, extending from heel to forefoot, positively influenced knee loading (Crenshaw *et al.*, 2000; Kerrigan *et al.*, 2002; Kakihana *et al.*, 2005; Hinman *et al.*, 2008). In contrast, heel-length (short) LWIs had less impact (Maly *et al.*, 2002; Nester *et al.*, 2003; Hinman *et al.*, 2008). The extended moment arm of the full-length LWI, which increases the subtalar joint valgus moment, and unclear heel strikes might explain these differences (Hinman *et al.*, 2008).

The difference in KAM reduction between past studies might have been due to the degree of LWI wedging. While higher wedges provided more reduction, they also made users more uncomfortable (Kerrigan *et al.*, 2002; Butler *et al.*, 2007; Radzimski *et al.*, 2012), which could have decreased compliance (Butler *et al.*, 2007; Arnold, 2016). Therefore, Jones *et al.*, (2014) concluded that knee pain might have resulted from long-term use of LWIs, and this pain could have reduced LWI efficacy. Butler *et al.*, (2007) also suggested increasing rearfoot momentum and joint moment to prevent subtalar joint injuries.

As a result, LWIs selected for these investigations had to consider a wedging degree. In Miyazaki *et al.*, (2002), a 1% increase in KAM on the first peak had led to a 6.46 times greater likelihood of developing KOA. The first peak KAM had been reduced by 2% by a lateral displacement of 1mm on the line of GRF, according to Shelburne *et al.*, (2008). Therefore, any decrease in KAM was essential.

Kerrigan *et al.*, (2002) examined the effects of LWIs tilted at 10° and 5° on KAM in individuals with medial KOA. Both angles effectively reduced KAM, but the 5° wedge was more comfortable inside shoes, decreasing KAM by 6%. Also, Butler *et al.*, (2007) studied the comfort of wedging levels between 5 and 15 degrees, finding increased discomfort with greater wedging. Consequently, due to comfort and efficacy in reducing KAM, a 5-degree LWI was recommended for patients with medial KOA (Kakihana *et al.*, 2004; Radzimski, Mündermann and Sole, 2012b; Hatef *et al.*, 2014).

Additionally, Mannisi *et al.*, (2019) studied LWI inclination degrees about knee medial contact force (MCF). Using subject-specific musculoskeletal models, they assessed how LWIs influenced MCF in a session with 15 adults, comprising eight healthy controls and seven KOA participants. Based on captured foot shapes, 3D printed LWIs were created in three variations: 0°, 5°, and 10°. The Anybody Modelling System estimated normalised body weight for each condition. The results indicated that the LWIs did not significantly change the MCF for the KOA group, with variations ranging between -12% to +10% in impulse and -5% to +7% in peak loading. While LWIs impacted patients with medial KOA, they did not consistently shift the load from the medial to the lateral compartment. Mannisi *et al.*, (2019) highlighted the need for more research to refine LWI's effect on knee biomechanics.

6.10 Conclusion:

Based on research and clinical results, LWI was recognised as an essential conservative treatment for medial KOA. Despite some debate regarding their direct benefits, LWIs are an effective, non-invasive method of managing KOA. In addition, the LWI has knee-loading advantages, including reduced knee pain and increased physical functionality.

This study found that full-length LWIs with an optimal inclination of 4° to 6° could effectively reduce KAM during walking, alleviating knee pain and improving function in patients with medial KOA. Consistent daily use, averaging 7-8 hours per daily activity over a 6 to 12-week period, was crucial for achieving these therapeutic benefits and combining LWIs with usual care, such as physiotherapy and analgesics, notably improved effectiveness, especially in bilateral knee applications. Also, LWI balances biomechanical effectiveness with patient comfort, cost-effective consideration and a straightforward method, making it the best option. Patient adherence and pain perception depended on insole design, material and comfort. As a result of this knowledge, LWI benefits might be optimised while problems may be addressed. Future research should focus on design, long-term outcomes and patient feedback to completely understand KOA therapy.

CHAPTER 7

FEASIBILITY STUDY

Evaluating the Impact and Acceptability of Lateral Wedge Insoles on Knee Osteoarthritis based on the perceptions of patients and physiotherapists. A Feasibility Study in a Saudi Physiotherapy Outpatient Setting.

7.1 Summary:

This study utilised a mixed-methods, single-centre feasibility approach with an embedded survey questionnaire. A specific gait modification approach (LWI) and survey questionnaire were determined from Chapters Four and Five. Outcomes such as NRPS, WOMAC, and Likert scale results measured the acceptability of the LWI intervention for symptomatic KOA subjects in SA. Eligible patients received LWI, and the knee pain (NRPS) and (WOMAC) outcomes were assessed before and after the LWI intervention, while the KOA participants' and physiotherapists' Likert scales were evaluated six weeks post-implementation.

7.2 Introduction:

The altered biomechanics and the cumulative impact might cause tissue damage, leading to structural changes, joint pain and limited movement (Van Tunen *et al.*, 2016). KOA therapeutic strategies varied, ranging from educating KOA patients to offering surgical options. Nevertheless, biomechanical methods such as gait modification are considered effective conservative measures. In addition to these gait modification approaches, LWI is an affordable, accessible and straightforward intervention.

Primary studies demonstrated that LWI reduced knee loading in KOA patients, but they did not yield a notable improvement in pain or function (Radzimski *et al.*, 2012; Hinman *et al.*, 2013; Zhang *et al.*, 2018; Felson *et al.*, 2019). However, although LWI decreased medial knee loading, they did not consistently alleviate pain or enhance function in such patients (Sawada *et al.*, 2016; Zhang *et al.*, 2018a; Zhang *et al.*, 2018b).

In contrast, a trial by Felson *et al.*, (2019) found that those using LWI reported less knee pain than those with a neutral insole. Consequently, as Hinman and Bennell. (2009) suggested, further research is needed to evaluate this treatment and determine the most responsive patient group. Notably, a systematic review by Parkes *et al.* (2013) concluded that LWI did not significantly improve pain, though it provided a comprehensive analysis of the available studies. Furthermore, Zhang *et al.*, (2018), compared to flat insoles, LWI did not significantly change WOMAC pain but did impact quality of life and WOMAC function.

Patient commitment and acceptance are critical factors that can influence the effectiveness of LWI. Studies indicate that osteoarthritis patients often do not consistently adhere to treatments (Pham *et al.*, 2004). Also, adherence to home exercises has been shown to improve pain management, self-reported physical function, and perceived benefits in hip and knee osteoarthritis patients (Pisters *et al.*, 2007).

Furthermore, Yamamoto *et al.*, (2022) suggested that home exercise programs could motivate patients, potentially supporting adherence to LWI. Since LWI is a self-administered intervention (Bennell *et al.*, 2007), patients need clear instructions, and healthcare professionals should monitor and guide its use to ensure effectiveness (Zhang *et al.*, 2018). Consistent use of LWI appeared beneficial in KOA treatment. However, it is noteworthy that osteoarthritis patients often displayed reduced compliance with treatment strategies (Pham *et al.*, 2004).

Overall, most previous studies did not address the importance of satisfaction and acceptance of LWI's impact on KOA pain and function. The effectiveness of LWI may vary based on individual patient characteristics, particularly adherence and acceptability. It is crucial for healthcare professionals to monitor patient adherence and address concerns. Consequently, studying how factors like patient and therapist satisfaction influence LWI's effectiveness is necessary.

This study aims to evaluate the feasibility and acceptability of LWI on KOA subjects in SA, specifically within a physiotherapy outpatient setting. The

feasibility study objectives included determining recruitment, retention, and adherence. Additionally, the study considered secondary outcomes, assessing LWI's potential impact on knee pain and function over six weeks.

The novelty of this research lies in its patient- and therapist-centered approach, which incorporates satisfaction levels into the LWI evaluation aspects such as efficacy, clarification, treatment time, and side effects, making it more comprehensive. Furthermore, the study is unique in focusing on the Saudi Arabian context, addressing specific cultural and healthcare system factors that have yet to be extensively explored in previous studies.

7.3 Methods:

7.3.1 Study Design:

In this study, the feasibility of the intervention was assessed using a quasi-experimental design. LWI programme was initially implemented in a preliminary manner. Following this, an evaluation compared NRPS and WOMAC results before and after the LWI intervention. Additionally, KOA subjects and physiotherapists were surveyed to understand their reactions to the programme. This study was reported following the Consolidated Standards of Reporting Trials (CONSORT) (Moher *et al.*, 2001).

7.3.2 The research environment:

In addition to their significant contribution to research and clinical treatment of musculoskeletal disorders, a feasibility study on LWI was conducted at the outpatient physiotherapy department of King Faisal Specialist Hospital & Research Centre, Jeddah (KFSH&RC-J), in SA.

7.3.3 Participants:

This research enrolled participants aged 40-85 (the upper age limit reflected the level of walking involved in the study) who had been diagnosed with KOA. The study's eligibility criteria were presented below in Table 14.

Table 14: Feasibility study eligibility criteria:

Inclusion criteria
- Adults aged above 45 to 85 years old. - Both Male & Female. - Radiographically or KOA participants meet any diagnostic classification guidelines/criteria (American College of Rheumatology classification criteria) or any eligible diagnostic guidelines. - Ability to move independently, whether using a walking aid. - Typical knee pain while walking > 3 on an 11-point scale (0-10) in at least one knee pain or tenderness, primarily in the medial knee.
Exclusion criteria
- Severe KOA subjects (on the waiting list for knee arthroplasty). - Knee post-operation or corticosteroid intra-articular injection last 6 months. - Inability to walk for longer than 20 minutes without experiencing severe pain. - Walking on a treadmill is painful or requires heavy assistance, like a lifting belt. <i>(A clinician will assess this during the initial screening based on the review of medical history records containing notes about walking pain.)</i> - Significant knee effusion, musculoskeletal or neurological diseases that influence gait parameters. <i>(A clinician will determine this during the initial screening according to the review of medical history records indicating these abnormalities.)</i> - It is presently undergoing physiotherapy treatment. - Rheumatoid Arthritis (RA), gout, one or both knees replaced, low back pain, hip OA, any serious knee or lower limb injuries in the past 24 months.

7.3.4 Recruitment:

Patients were contacted from the KOA patient registration list and files at the physiotherapy clinic by telephone through a KFSH&RC staff clinic in outpatient physiotherapy. During these calls, a clinician – a specialist, nurse, or physiotherapist explained the study to them and assessed their initial interest in participating. Patients who expressed interest were invited to attend an information session. During this session, they were provided with the Participant Information Sheet (PIS) and given time to consider their participation. Those who agreed to participate were then scheduled for a study

intervention appointment. If patients required more time to decide, they were given 24 hours to consider.

If the patient consented, the intervention day appointment was confirmed at a suitable time in the physiotherapy clinic. Here, it was provided with the participants' information sheet (PIS), the case report form (CRF) and recorded baseline data, followed by obtaining written consent and scheduling a specific LWI (proper size). Participant consent forms, CRF and baseline data were gathered independently in the clinic. Simultaneously, participants had the opportunity to address any queries or concerns.

7.3.5 Blinding & Randomisation:

Blinding is not typically considered essential in feasibility studies, as the primary aim is to assess the practicality of procedures and interventions rather than to test their efficacy (Eldridge *et al.*, 2010). In this study, participants were not blinded to the intervention due to the visible nature of LWI therapies (Parkes *et al.*, 2013). Treatment allocations were determined by therapists without blinding, and no placebo controls were used. Despite this, clinical outcomes (NPRS and WOMAC) were assessed independently by an independent assessor unaware of participant group assignments. This blinding of the assessor helps minimised potential bias in data collection, ensuring their expectations or knowledge of group assignments did not influence participant responses.

This study involved a single group undergoing a pre-and post-intervention assessment. For a clearer overview of the study design and group allocations, please refer to the study protocol diagram for the detailed study flow, Figure (34).

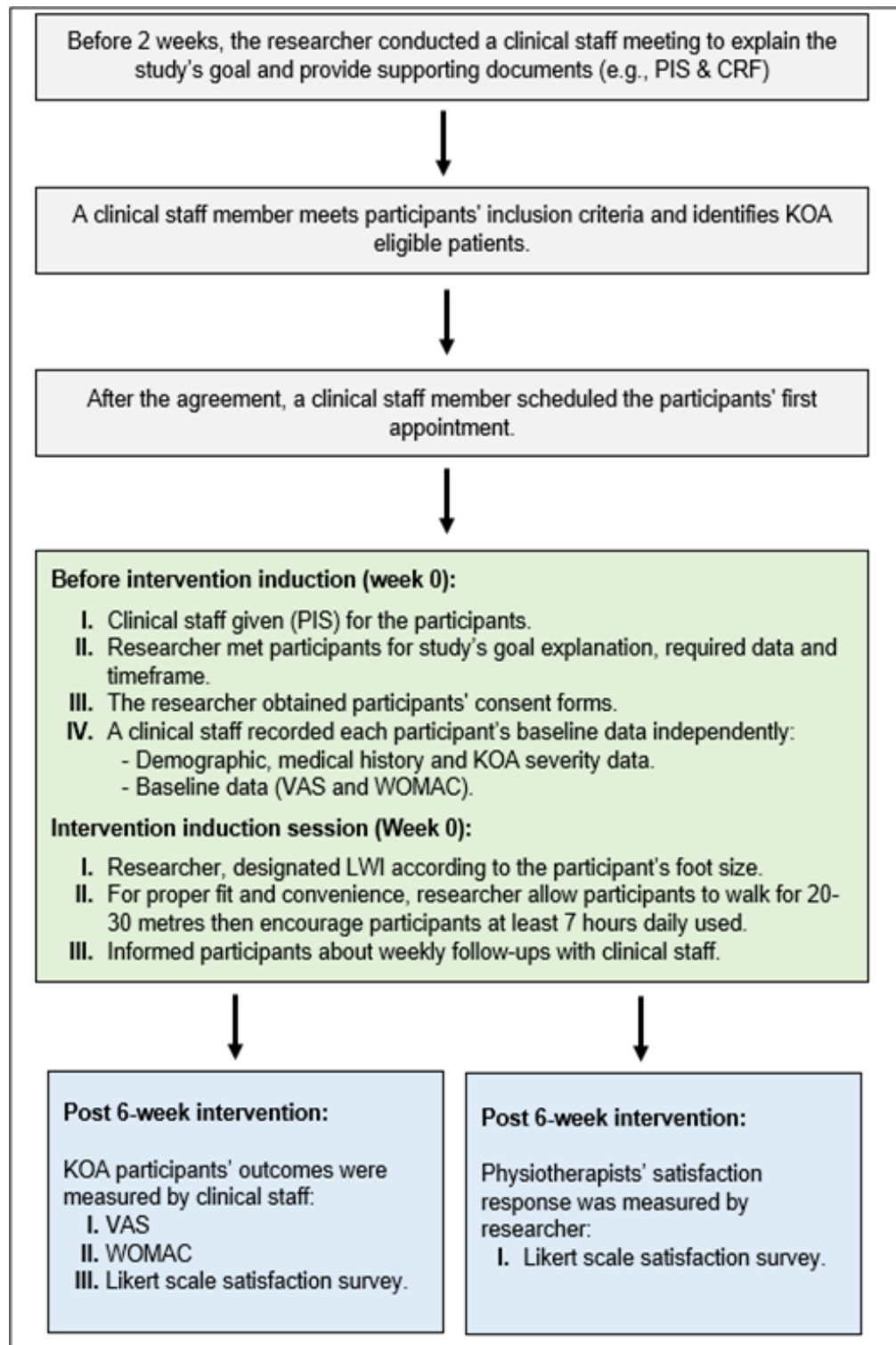


Figure 34: Diagram of the study protocol.

7.3.6 Procedure:

With the approval of both the KFSH & RC Director and the department head, the recruitment process was as follows:

- **Two weeks before the study started:**

- a) The researcher met with clinicians about the feasibility aims and patient criteria. In this meeting, the PIS & CRF (see Appendixes 7 & 8) were presented to clinicians to ensure they understood the study tools and procedures, including the NRPS, WOMAC tools and a Likert scale survey. Patients were briefed about the study and given the PIS and CRF to review. Additionally, patients were informed about the study and given the PIS & CRF to review. Consents were obtained from each patient before any screening, examination or data collection began.
- b) Patients who had completed their KOA physiotherapy but had not shown improvement or were not currently receiving physiotherapy for KOA were contacted. Clinical screening was carried out by a nurse or physiotherapist according to the set criteria. The clinician collected a list of interested KOA participants during their routine follow-up visits two weeks before the designated appointment. The patients were then scheduled for their study-related appointments. The continuity of care ensured an efficient recruitment process.
- c) Patients were provided with the PIS during their routine follow-up appointments two weeks prior to the study start date. If participants had questions, they could contact the clinical team or researcher after receiving the PIS. If a participant failed to attend or altered their appointment, the clinical team followed up on their intentions, offering an option to reschedule.

- **Prior to the intervention (Consent and Baseline stage - Week 0):**

- a) On the scheduled appointment day, the clinical staff presented patients with an additional copy of the original signed-off PIS. This copy was identical to the original, and patients were instructed to keep it until the study concluded (6 weeks post-intervention). The PIS

included the researcher's contact details (phone and email) for any inquiries during the study period. Following this, the researcher and another clinical team member introduced the study's intervention (LWI) and answered any remaining questions.

- b) After obtaining verbal consent, the researcher outlined the study's objectives, data collection methods and other participation details. Participants were allowed to seek clarification regarding the study.
- c) Participants signed consent forms after being informed (Appendix 9).
- d) A clinical team member recorded initial data on the CRF, including demographic information, medical background, and a preliminary assessment of KOA severity and baseline data (NRPS and WOMAC). In the clinic, all baseline data were collected independently by each participant.

- Conducting LWI and training session (Week 0):

- a) The researcher, AA, supplied and explained the intervention (LWI) tailored to the foot size of each participant, then inserted it into the participant's footwear.
- b) Participants were then asked to walk a short distance (15 to 30 meters) to ensure comfort and fit.
- c) Subsequently, participants were instructed to use the LWI for at least seven hours daily. They were also asked about their willingness to receive follow-ups during the study's 6-week duration.
- d) It was explained to the participant that they could withdraw from the study at any stage without affecting their healthcare, even after signing the consent form (Appendix 10).

- Post-intervention (6 weeks later):

- a) Six weeks post-LWI initiation, during the second visit, the clinical staff gathered responses from NRPS & WOMAC and patients' Likert scale (see Appendixes 11, 12 & 13).

- b) Throughout the study, participants were reminded of its objectives and the potential benefits of using LWI. They were also encouraged to contact the clinical team with any questions.
- c) Once all participant data was collected, the therapists' Likert scale survey (Appendix 13) was distributed via a Google form to gather feedback from involved therapists and clinical staff.

7.3.7 Intervention:

- a) LWI as gait modification intervention:

A systematic review and meta-analysis (Chapter 4) and qualitative data approaches (Chapter 5) were used for the selection of the appropriate gait modification approach (LWI), and according to the TFA used in the qualitative chapter, the LWI was straightforward and acceptable for KOA patients and physiotherapists. See Figure 35.

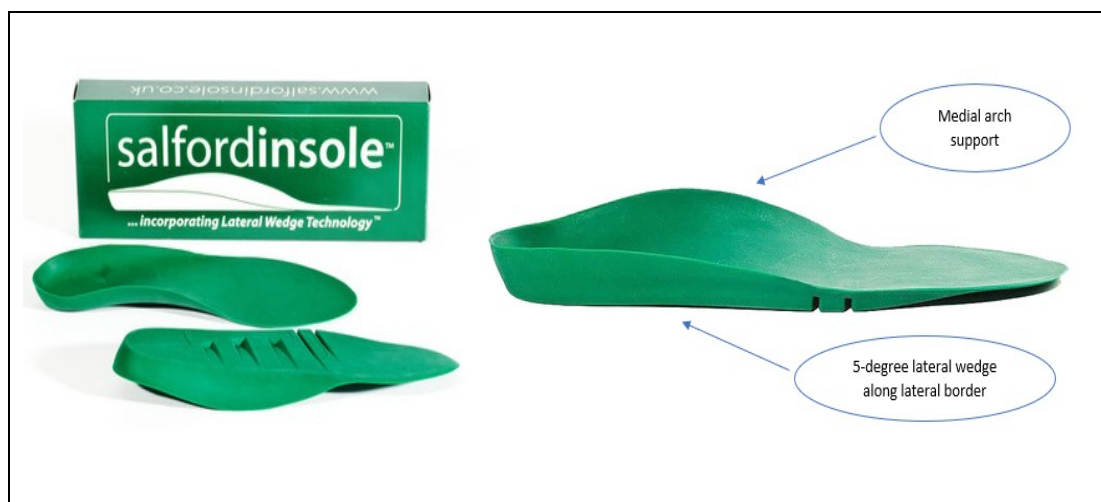


Figure 35: Salford lateral wedge insole.

Details on LWI rationale, biomechanical impacts on KOA loading, pain, and function. In addition, about how to influence wedging degree. Please refer to Chapter 6, page 155.

- b) Application and use duration:

In an experimental study, it was found that the ideal LWI usage time would be between five and ten hours per day (Toda, Tsukimura and Segal, 2005). Therefore, it was advised that each participant should wear a pair of lateral wedge insoles (LWI) for six to seven hours a day.

c) Monitoring participants:

Each participant was required to keep a daily record of their LWI usage (Appendix 14). They were monitored weekly, either through visits to the clinic or by phone. This monitoring aimed to evaluate their treatment adherence and to document summaries of insole applications. Participants were reminded to attend the next session or contact the coordinators in each follow-up event. The researcher's phone number was provided if they needed further information.

7.3.8 Outcomes:

The primary outcome was the feasibility outcomes, which focused on the acceptability of the prescribed LWI intervention and the satisfaction rates of both KOA participants and therapists. Secondary outcomes included knee pain, function and quality of life. These were measured at baseline using the NRPS and WOMAC scales and then again at the 6-week follow-ups, providing more comprehensive background knowledge.

Baseline measures were obtained immediately after consent had been secured. The designated clinician collected the baseline data, but the thesis researcher gathered all end point data. The Likert scale was employed six weeks post-intervention (during the seventh week) to estimate participants' satisfaction.

7.3.8.1 Feasibility outcomes:

To provide a clear overview of the study's feasibility metrics, the following (Table 15) summarises the key outcome measures. This includes recruitment, retention, and attrition rates. Detailed definitions and calculations were provided for each measure, allowing for a concise understanding based on Nic *et al.*, (2022) feasibility findings.

Table 15: Feasibility Study's Outcomes:

Outcome Measure	Definition	Calculation Formula	Reference
Recruitment Rate	The proportion of eligible participants who consented to participate after screening.	Recruited Participants / Eligible Participants	Nic <i>et al.</i> , 2022
Retention Rate	The proportion of participants who completed the assigned LWI programme.	Participants Completed / Participants Enrolled	
Attrition Rate	The percentage of participants who dropped out or were lost to follow-up at a given time during the study period.	Dropouts / Total Participants	

Note: Attrition rates were assessed at three points: post-LWI initiation, midway, and at the end of the programme (6 weeks). During the study, there was a maximum attrition rate of 20%.

7.3.8.2 Acceptability:

- Compliance and Adherence rates:

A feasibility study monitored participants' compliance and adherence to LWIs. Participants maintained hourly diaries of LWI use to ensure detailed tracking of compliance. The diary entries of each participant were reinforced, and additional insights were acquired by follow-ups every week. A follow-up was conducted in person at the clinic or over the phone.

The percentage of compliance was quantified. In this process, participants' average hourly LWI usage from their diaries was aggregated over six weeks. Based on the number of participants who consistently used the LWI throughout the six weeks, the total was divided by the number of participants.

As for adherence, the emphasis was on participants adhering to the prescribed hourly application schedule for LWI each day. Adherence was monitored using the follow-up schedules, as detailed in Appendix 15. This

statistic is based on the proportion of participants who applied the LWI consistently each day compared to the total number of participants. In accordance with the protocol, this measured participants' commitment to daily LWI usage.

7.3.8.3 Satisfaction rate:

Likert-type scales are frequently used in medical education and research for trainee feedback, faculty evaluations and performance assessments. The Likert scale, is an ordinal scale with five or seven points, allowing respondents to express their reactions (Sullivan & Artino, 2013).

This study assessed the impact of LWI treatment satisfaction on KOA participants and therapists using a 5-point Likert scale. After the intervention, surveys for KOA participants and therapists were introduced in the seventh week. At the end of the study, participants indicated their satisfaction levels, ranging from "Not at all satisfied" to "Extremely satisfied". Based on this 5-point scale, satisfaction was presented as a percentage and median (indicating the degree of satisfaction). As therapists implemented and followed the intervention, their agreement levels were added to the Likert scale, ranging from strongly disagreeing to strongly agreeing. By the seventh week, the therapists' predominant agreement levels were "Agree" or "Strongly Agree".

7.3.8.4 Self-reported outcomes:

- Numeric pain rating scale (NPRS):

The outcome of the pain measurement NPRS is recognised as one of the most notable patient-reporting outcomes for pain (Kahl & Cleland, 2013). It has been used extensively across clinical populations, ages and cultures (Hjermstad *et al.*, 2011). Scores on the NPRS for pain during rest and movement were recorded at baseline (before the LWI intervention) and after six weeks of treatment. The left-hand anchor indicated "no pain", whereas the right-hand anchor denoted "worst possible pain". Using this scale, the patient could communicate their pain intensity. Participants' responses were recorded in Appendix 11.

- WOMAC:

The WOMAC has been used in research for over 25 years (Bellamy *et al.*, 1988; Bellamy, 2002). It has been translated into 80 languages (Ackerman, 2009). In this context, the WOMAC components (pain, stiffness, function and total) were measured at the baseline (week 0) before and after a six-week treatment period. The study in question utilised an Arabic-language version of the WOMAC (Alghadir *et al.*, 2016), which comprised 24 items across three domains: pain, stiffness and activity. Scales, observed from right to left, ranged from 'none' to 'extreme'. The patient was then asked to select the number that best represented the pain, stiffness, and disability experienced (see Appendix 16 for Arabic version).

7.4 Data Management:

When participants returned their questionnaires, the researcher reviewed the outcomes data. When necessary, participants were asked to provide missing information. At the KFSH & RC, the collected data was input into Excel Version 2302 after each data-collection session. Before analysis, data entry into Excel was checked. Although this study collected confidential information, only data accessible by an identifying number and password was entered into the statistical software (SPSS). Original forms, consent forms and documents with personal details were securely stored in a locked locker at the University of Nottingham. Both the laptop and other devices utilised encryption and password protection. Data was saved on the university's central servers, specifically the P-drive, a backed-up drive. All recorded sessions were anonymised, with only the researcher accessing identification information.

7.5 Analysis:

7.5.1 Sample size:

The target sample sizes for pilot and feasibility studies ranged from 24 to 50 participants (Billingham *et al.*, 2013). However, from registration data at the physiotherapy reception at KFSC & RC-J, it was found that 75 people with general knee issues visited the clinic each month. Thus, 25 was considered

optimal to fulfil the study's aims and objectives. Given the time-frame and patient flow at the KFSC & RC's physiotherapy department, the target was adjusted to 24 participants. However, accounting for an anticipated attrition rate of 20%, the target sample size was adjusted to 30 participants, ensuring sufficient data collection (Arain *et al.*, 2010; Burmeister and Aitken, 2012). For the feasibility study, the researcher (AA) aimed to survey the satisfaction levels of KOA participants and therapists, targeting all patients involved in LWI and between six to ten therapists.

7.5.2 Data Analysis:

Since this was a feasibility study, the primary data analysis was descriptive, encompassing sociodemographic information on participants, drop-out rates, refusals to consent and loss rates for follow-up investigations. Statistical analysis took place using Excel (version 15.29.1) and SPSS (version 23). Clinical outcome measures were descriptively analysed using mean (standard deviation: SD), 95% confidence intervals (95% CI) and effect sizes. Independent t-tests determined a significance level of $p > 0.05$ (Lancaster *et al.*, 2004). Feasibility outcomes, such as recruitment, retention and acceptability rates, were detailed as continuous data (percentages) (Craig *et al.*, 2013).

The minimum clinical importance difference (MCID) in clinical practice denotes the smallest noticeable improvement (Copay *et al.*, 2007). In this study, according to Salaffi *et al.*, (2004), chronic pain patients could significantly benefit from a 2-point reduction from the baseline on the NRPS scale. The MCID of WOMAC indicated a change of 17 to 22% from baseline values (Angst *et al.*, 2002).

In this study, each participant's baseline, and post-intervention NRPS and WOMAC scores were compiled. NRPS and WOMAC score changes were then calculated as absolute changes and percentage changes. The changes were evaluated against the MCID thresholds. Clinically significant improvements were considered to have been achieved if the NRPS changed by at least 2 points. Also, WOMAC considered a change within the 17-22% range to be clinically significant. These calculations were presented in a

tabular format, clearly showing which participants met the MCID criteria and providing insight into individual and collective clinical benefits.

The statistical responses on the Likert scale were presented as frequencies (n) and percentages (%), as recommended for ordinal data (Sullivan and Artino, 2013). Furthermore, Likert scales, commonly used to measure attitudes and opinions, consisted of a series of statements where respondents indicated their level of agreement or frequency on a scale ranging from 1 to 5 or 1 to 7. These scales were ordinal, meaning the responses had a rank order, but the intervals between them were not necessarily equal (Jamieson, 2004). Reporting central tendency using medians or modes was appropriate, as it provided a more accurate representation of the data distribution without assuming equal intervals between scale points (Jamieson, 2004).

7.5.3 Analysis of Missing data:

This study monitored and analysed missing data to understand its impact on findings. Participants discontinued for various reasons, such as no symptom improvement, discomfort with the LWI or other personal factors. Importantly, the study did not use imputation methods for missing data, presenting results based on available data only (Little and Rubin, 2014).

7.6 Feasibility study criteria:

Based on the methods evaluated by Eldridge *et al.* (2016), specific criteria were established to assess the study's success and inform the design of subsequent trials with a larger sample size. To determine efficiency, the study evaluated the time and resources involved in implementing the intervention and collecting data. Efficiency was assessed by comparing the proportion of resources used to those planned. Eldridge *et al.* (2016) found that most of the planned resources were utilised effectively, supporting the feasibility of scaling up the intervention in future trials.

The consistency of the outcome measures was assessed by examining their stability across different time points and settings. The benchmark for

consistency was set at over 75%, indicating reliable measures. Regarding generalisability, the study evaluated whether the intervention could be applied to diverse patient populations within SA healthcare.

An assessment of outcome variation across participants was conducted to determine whether findings could be generalised to a broader KOA population. In addition, the completeness of outcome data collection was crucial. The primary and secondary outcome measures were benchmarked at 75% completeness to ensure sufficient data for analysis (see Table 16). As recommended by the MRC (Moore *et al.*, 2015), a process evaluation component was included to identify external factors that could affect the results. As part of this study, participants and therapists were asked to provide qualitative feedback, adherence rates and contextual factors that may affect the impact of the intervention (this was done using a Likert scale).

Table 16: Feasibility study success criteria:

Outcomes	Measure	Successful
• Recruitment rate	Eligible & consented participants	15 to 25 participants
• Retention rate	Complete treatment	>75%
• Attrition rate	Drop-outs or lost follow-up	< 20%
• Compliance	Average LWI hourly usage/day	> 5 hours daily
• Adherence to hourly used	Adherence to hourly used/day	>75%
- Satisfaction level	KOA patients' satisfaction level	> 75%
	Therapists' satisfaction level	

7.7 Ethical Approval:

The University of Nottingham's Research Ethics Committee has ethically approved this study. (FMHS 448-0122) (Appendix 5). Also, the Institutional Review Board at KFSH&RC, Jeddah, SA, approved the study on ethical grounds (IRB 2022-60) (Appendix 17).

7.8 Results:

7.8.1 Participants Flow:

The data collection occurred at KFSH & RC in Jeddah, SA, from 24th October 2022 to 1st November 2022. This period was reserved for recruiting patients who attended the clinic for baseline data collection.

Out of 24 patients diagnosed with KOA, the eligibility of each was assessed, and 21 consented to participate. By the fifth week post-intervention, two participants were lost to follow-up; one withdrew due to a medical issue, and another was withdrawn because of discomfort with the LWI application. As a result, the feasibility study included 21 participants. Seventeen completed the final assessment using the Likert scale, representing their satisfaction with the investigation. In addition, at the study's conclusion, in the seventh week, 13 physiotherapists shared their opinions on the LWI application for KOA patients through the Likert scale. Of these therapists, four had been involved in following up with the participants during the feasibility study. A detailed overview of the participants can be seen in the flow chart presented in figure 36.

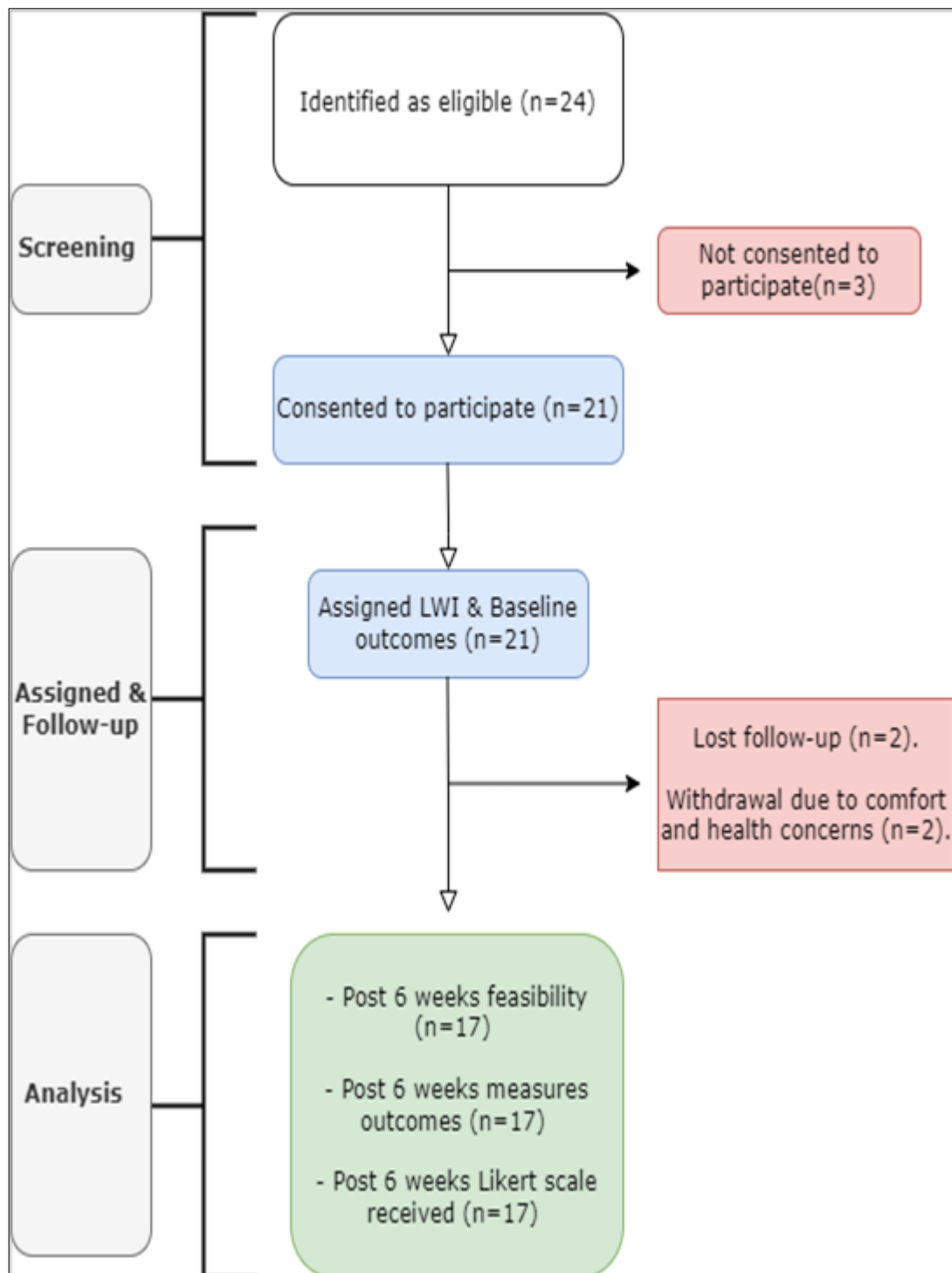


Figure 36: Participants' flow diagram during feasibility study.

7.8.2 Participants Recruitment:

Over the seven day recruitment period for this feasibility intervention study, the recruitment efforts yielded 21 participants, representing 87.5%. This result exceeded our initial expectations and surpassed the proposed standard of 75% for this type of study. This robust recruitment rate set a strong foundation for the subsequent phase of our intervention study.

7.8.3 Baseline Data:

A summary of participants' demographics and clinical characteristics was detailed, presenting gender, age, weight, height and BMI. Nominal data, frequency distribution and percentage were showcased, whereas continuous data were illustrated through means and SD. Ages spanned from 47 to 82 years, with females making up 57.1% and males 42.9%. Also, the radiological examinations and physician diagnoses in the patients' documents revealed that 62% of participants had moderate KOA. Almost half, 48%, exhibited unilateral KOA, while 52% had bilateral manifestations. Furthermore, both genders' demographic and clinical characteristics were balanced, as evidenced by the lack of gender-based variation. Table (17).

Table 17: Participants' baseline characteristics.

Variables	Count.	%	
Gender	Male (<i>n</i> =9)	42.9%	
	Female (<i>n</i> = 12)	57.1%	
Knee affected side	Unilateral (<i>n</i> =10)	47.62%	
	Bilateral (<i>n</i> =11)	52.38%	
KOA severity	Minimal (<i>n</i> =8)	38.10%	
	Moderate (<i>n</i> =13)	61.90%	
Self-reported walking ability	Unlimited (<i>n</i> =7)	41.20%	
	500m – 1 km (<i>n</i> =7)	41.20%	
	100 – 500 m (<i>n</i> =2)	11.80%	
	<100 m (<i>n</i> =1)	5.9%	
Variables		Mean ($\pm$ SD)	Range
Age		63.19 $\pm$ 7.67	47 – 82 years.
Height (cm)		161 $\pm$ 7.0	149 – 174 cm.
Weight (kg)		80.27 $\pm$ 13.69	56.90 – 106.00 kg.
BMI (kg/m ²)		30.81 $\pm$ 4.80	23.60 – 41.70 kg/m ² .

7.8.4 Feasibility Outcomes and Estimation:

The feasibility outcome summary is presented in Table 18.

7.8.4.1 Retention and Attrition rates:

Following the successful recruitment process, 17 out of 21 participants consented to participate and completed all stages over the six-week study period, achieving an 81% retention rate. Impressively, this retention exceeded the recommended rate of 75%. For the feasibility study, two participants withdrew due to lost follow-up, and another two participants due to comfort issues. Attrition was measured at three distinct time points: immediately after the LWI assignment, it held at 0%, rose slightly to 10% by the fourth week post-intervention, and concluded at 19% by the study's end, which was comfortably below the defined feasibility criteria threshold.

7.8.4.2 Intervention compliance and adherence:

The analysis of adherence and compliance rates for hourly/day implementation revealed notable trends. On average, the compliance rate was recorded at 5.47 hours/day, marking the lower commitment threshold compared to hourly rates suggested in prior studies. Regarding adherence, 71% of participants committed to five to seven hours/day of LWI usage, falling short of the anticipated benchmark. Notably, 12 LWI users consistently used it for over five hours daily throughout the feasibility period.

7.8.4.3 Likert scale satisfaction rates:

- KOA subjects' Likert scale results:

Using an five-item Likert scale, participant satisfaction was determined, spanning from 1 (Not at all) to 5 (Extremely satisfied). The outcomes proved positive. The average score among participants who finished the study was 81.75%, aligning with the anticipated feasibility rate for the six-week LWI intervention.

In the survey of KOA patients regarding the utilisation of the LWI over six weeks, notable findings emerged. Satisfaction with pain relief was predominantly high, with 47.1% of patients very satisfied and 41.2% extremely satisfied, resulting in a median value of 4. Satisfaction with ease of application and clarification during sessions was exceptionally high, with both categories showing a majority of 52.9% and 76.5% extremely satisfied, respectively, leading to a median value of 5. However, satisfaction with the ability to perform daily activities had the least high ratings, with 35.3% of patients reporting very satisfied and extremely satisfied, also resulting in a median value of 4. Overall, the survey indicated a very satisfied direction in patient responses, reflecting the positive effects of using the LWI. Table (19) and Figure (37) provide a descriptive detailed of statistical analysis based on the responses from KOA patients.

- Physiotherapists' Likert scale results:

During the six weeks of using the LWI, therapists' responses on the Likert scale showed revealing patterns. For the satisfaction items, many

therapists reported being "Very satisfied" with the improvement in practical skills, with 53.8% expressing this opinion. In contrast, the item "Ease and clarity of application" had the lowest "Not at all satisfied" rating at 7.7%, showing a generally positive reception. The overall satisfaction median was "Very satisfied," highlighting a positive response towards the practical skills enhancement provided by the insole.

Regarding the agreement items, the highest agreement was for the statement that the LWI should be included in the KOA treatment plan, with 61.5% agreeing. Conversely, the statement concerning specific requirements needing to be met received the highest disagreement, with 23.1% of therapists expressing this view. The overall median for the agreement items was "Agree," indicating a general consensus among therapists on the insole's beneficial impact on their treatment routine. Table (20) and Figure (38) provided descriptive details of statistical analysis based on the three Likert scale outcomes.

Table 18: Feasibility parameters results.

Outcomes	Measure	Successful	Result	Feasible	Recommendations
• Recruitment rate	Eligible & consented participants	15 to 25 participants	<i>n</i> =21 87.5%	Yes	
• Retention rate	Complete treatment	>75%	81%	Yes	
• Attrition rate	Drop-outs or lost follow-up	< 20%	19%	Yes	
• Compliance	Average LWI hourly usage/day	> 5 hours daily	5.47 hours/day	Yes	
• Adherence to hourly used	Adherence to hourly used/day	>75%	71%	No	Educate patients more about LWI long term benefit. Keeping follow-up and encouragement through phone calls, messages, emails & appointments. Insoles should be kept in the most worn shoes. Non-adherents may be motivated by interacting with successful insole users.
- Satisfaction level	KOA patients' satisfaction level	For both > 75%	81.75%	Yes	
	Therapists' satisfaction & agreement levels		S.= 58.75% A.= 68.5%	No	Provide therapists with training or education about LWI. Supports therapists' decision-making (choose insoles). Share patient feedback, exchange therapist experiences, and learn best practices. Communicate LWI objectives and progress to other stakeholders (physiotherapists, patients).

- N= numbers, LWI= Lateral wedge insole, S= Satisfaction, A= Agreement.

Table 19: KOA participants' descriptive statistics with frequencies of the 8 Likert scale outcomes:

Likert scale item	Not at all	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	Median
	N (%)	N (%)	N (%)	N (%)	N (%)	
Pain relief satisfaction	0 (0.0%)	0 (0.0%)	2 (11.8%)	8 (47.1%)	7 (41.2%)	4
Ability & perform daily activities satisfaction	0 (0.0%)	2 (11.8%)	3 (17.6%)	6 (35.3%)	6 (35.3%)	4
Easy application satisfaction	0 (0.0%)	1 (5.9%)	0 (0.0%)	7 (41.2%)	9 (52.9%)	5
Commitment throughout day satisfaction	0 (0.0%)	2 (11.8%)	2 (11.8%)	8 (47.1%)	5 (29.4%)	4
Clarification during session satisfaction	0 (0.0%)	1 (5.9%)	0 (0.0%)	3 (17.6%)	13 (76.5%)	5
Session time duration satisfaction	0 (0.0%)	1 (5.9%)	1 (5.9%)	4 (23.5%)	11 (64.7%)	5
Side effects satisfaction	1 (5.9%)	2 (11.8%)	2 (11.8%)	3 (17.6%)	9 (52.9%)	5
In general, symptoms improved satisfaction	0 (0.0%)	0 (0.0%)	1 (5.9%)	11 (64.7%)	5 (29.4%)	4
Overall median direction of all Likert scale satisfaction items						4.5 Very satisfied direction

- N= numbers of respondents, %= percentage.

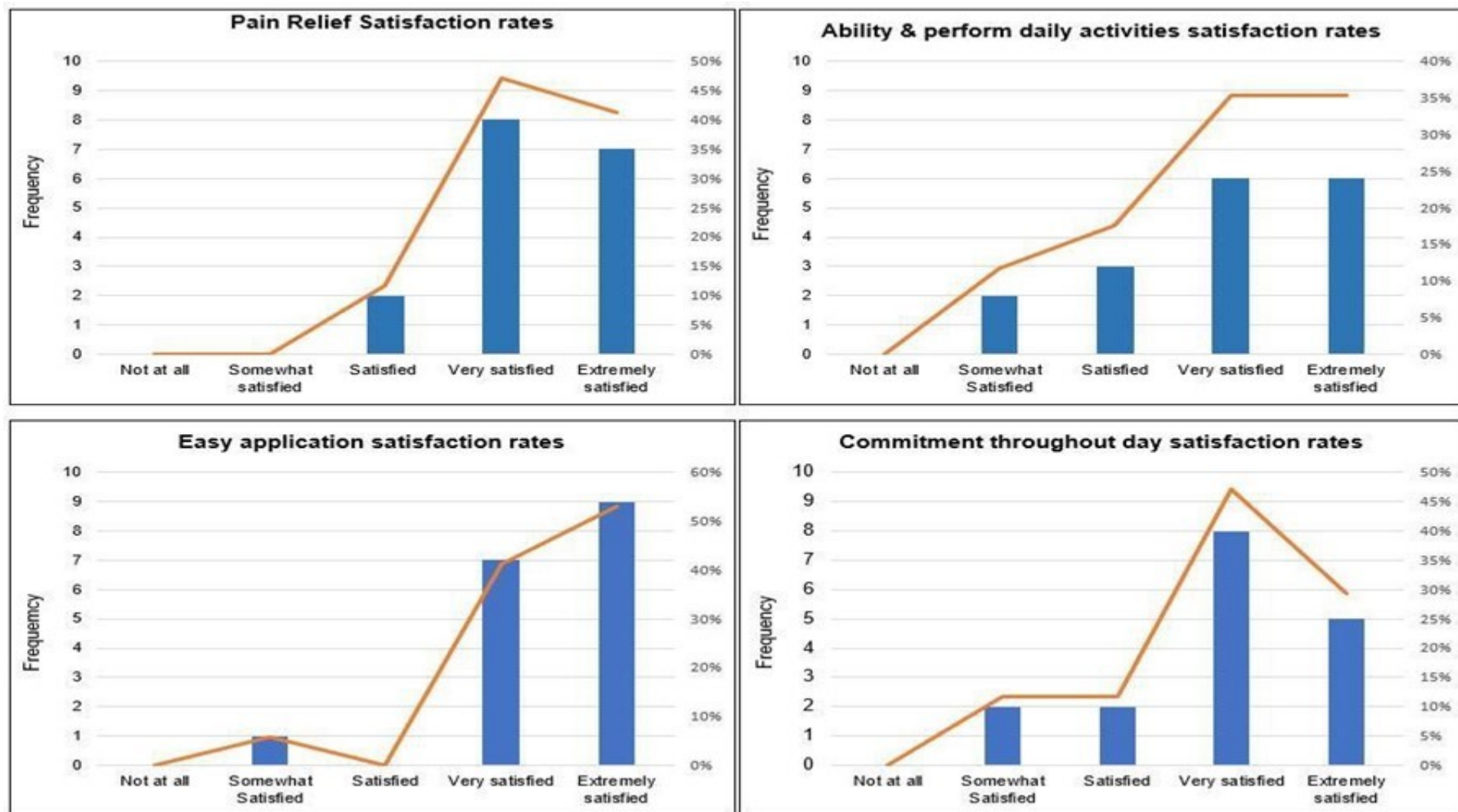


Figure 37: Likert scale-based clustered bar chart of KOA patient satisfaction rates.

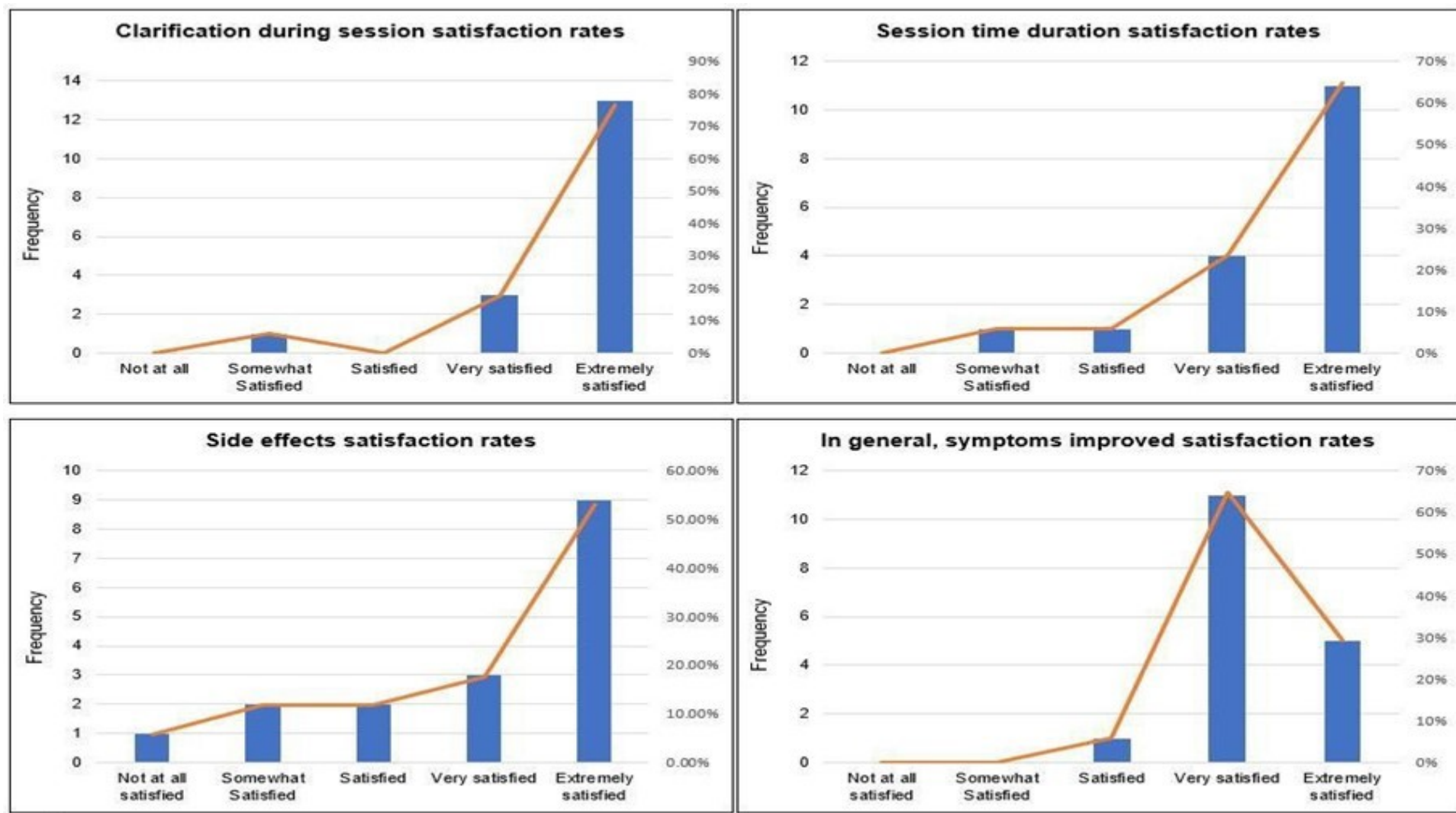


Figure 37: Continue Likert scale-based clustered bar chart of KOA patient satisfaction rates.

Table 20: Description of the three items Likert scale satisfaction outcomes and their frequencies among physiotherapists:

Satisfaction items	Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	Median
	N (%)	N (%)	N (%)	N (%)	N (%)	
The LWI enhanced my knowledge of gait modification in the context of KOA.	0 (0.0%)	1 (7.7%)	7 (53.8%)	5 (38.5%)	0 (0.0%)	3
The LWI has increased my practical skills in applying gait modification techniques.	0 (0.0%)	1 (7.7%)	5 (38.5%)	7 (53.8%)	0 (0.0%)	4
The LWI is easy to understand and apply assistive gait modification in practice.	1 (7.7%)	2 (15.4%)	3 (23.1%)	6 (46.2%)	1 (7.7%)	4
Overall median direction of 3 Likert scale satisfaction items						4 (Very satisfied)

Agreement items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Median
	N (%)	N (%)	N (%)	N (%)	N (%)	
I agree that specific requirements must be met to implement the LWI in the KOA treatment plan effectively. (lab gait, orthosis, tools, etc.)	0 (0.0%)	3 (23.1%)	2 (15.4%)	6 (46.2%)	2 (15.4%)	4
I agree that clear guidelines are necessary to properly apply the LWI in the KOA treatment plan.	0 (0.0%)	1 (7.7%)	5 (38.5%)	5 (38.5%)	2 (15.4%)	4
I support the inclusion of the LWI as a part of the KOA treatment plan.	0 (0.0%)	0 (0.0%)	2 (15.4%)	8 (61.5%)	3 (23.1%)	4
Overall median direction of 3 Likert scale agreement items						4 (Agree)

- N= numbers of respondents, %= percentage.

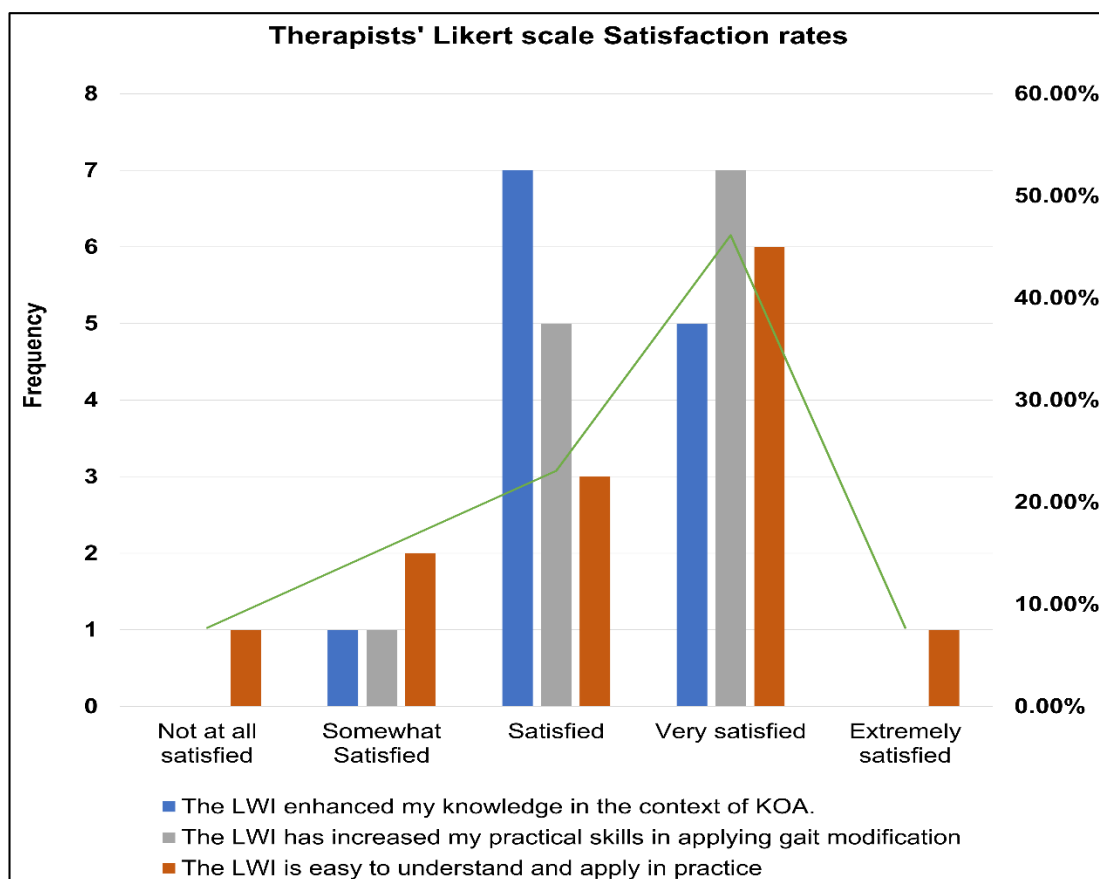


Figure 38: Likert scale-based clustered bar chart of KOA patient satisfaction rates.

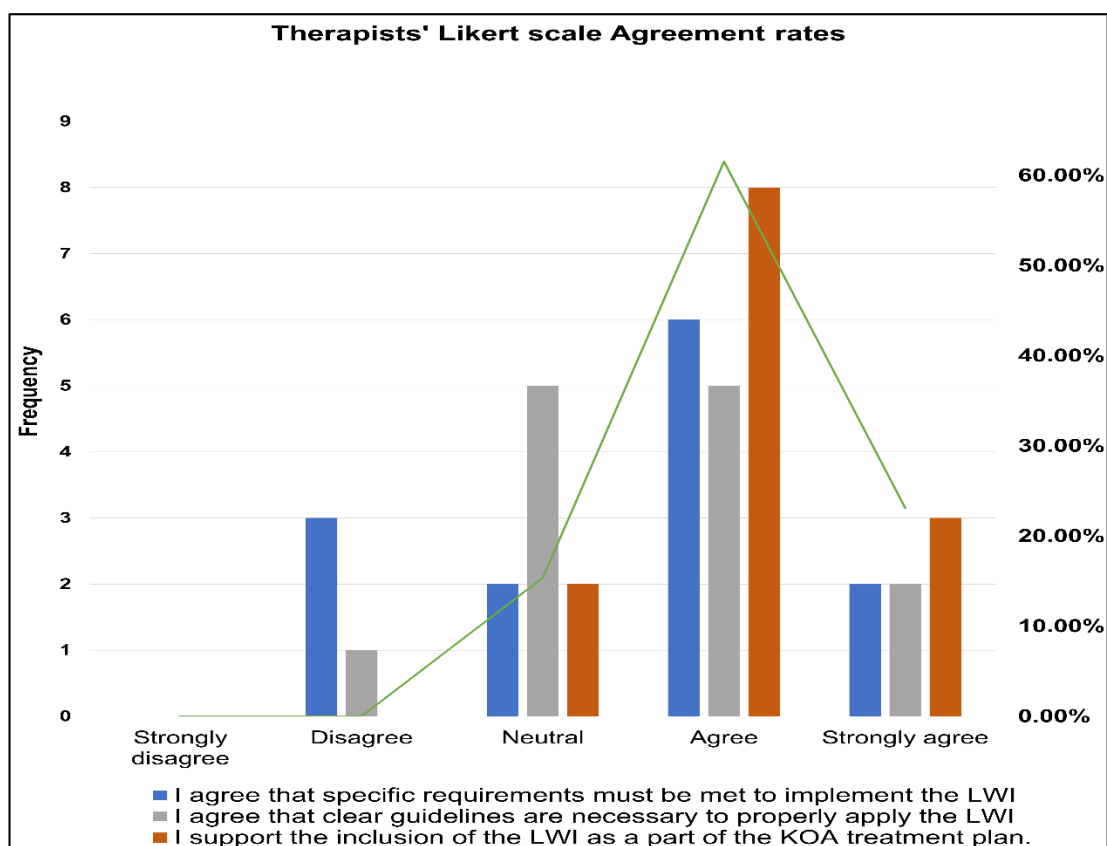


Figure 38: Likert scale-based clustered bar chart of KOA patient agreement rates.

7.8.5 Patients Self-reported Outcomes:

Data were presented as mean, standard deviation, and 95% confidence intervals (95% CI). A significance level of ($p=0.05$) was used to interpret the results. According to these results, the sample was designed to uncover an indication of benefit that might not represent the entire population through a feasibility study (Lancaster *et al.*, 2004).

According to (Salaffi *et al.*, 2004), a reduction of 2 points from baseline is clinically significant for the NRPS considerable. Eight participants achieved this benchmark, indicating that their pain levels were significantly reduced during rest time. In addition, 14 participants showed clinically significant NRPS improvements during walking activities. A change in NRPS was recorded for all participants at rest (1.65 points), and a reduction of (3.29) points was recorded during walking.

Furthermore, (Angst *et al.*, 2002) defined the MCID for the WOMAC-total index as a change of 17-22% from baseline. As a result of our study, 17 participants reached this threshold; the average was (78.82%) demonstrating substantial improvement in a broad range of KOA symptoms, including joint pain, stiffness, and physical function. (see Appendix 18). A comparison of the pre-and post-intervention scores for all 17 participants who provided baseline and six-week scores following LWI intervention is shown in Table 21 and Figure (39 and 40).

a) NRPS tests:

For the NRPS data during rest, pre- and post-intervention pain levels were significantly different, with a mean difference of (1.65). Also, Cohen's d was (0.98), indicating a large effect size, and this indicated a significant reduction in pain. Moreover, a statistically significant difference was found by statistical analysis ($p=0.007$). NRPS during walking showed a mean difference of 3.29 between pre- and post-intervention. To quantify the effect, Cohen's d was (1.90). Therefore, the intervention reduced pain levels clinically significantly. Additionally, the NRPS scores varied significantly ($p= 0.001$) before and after the intervention.

b) WOMAC tests:

Based on the WOMAC-pain data, a t-test revealed statistically significant ($p < 0.001$) results and a large effect size (*Cohen's d* = 1.56) comparing pre- and post-LWI intervention periods. Based on these results, there was a statistically significant difference between pre- and post-LWI on WOMAC-pain outcomes.

On WOMAC stiffness, significantly different results were observed between baseline and six weeks post-LWI intervention ($p = 0.0014$), meaning LWI significantly impacts KOA stiffness, and a large effect size (*Cohen's d* = 1.19) was detected. In addition, there was a significant effect on WOMAC-physical function after six weeks of implementing LWI ($p < 0.001$) and a large effect size between pre- and post-implementation (*Cohen's d* = 1.29).

Overall, the WOMAC-total scores also showed a significant difference between pre-and post-six weeks of LWI intervention, resulting in substantial effects between intervals, and effect size (*Cohen's d* = 1.45), $p < 0.001$.

Table 21: The baseline and 6-week outcomes of the LWI intervention:

Variables	N	Pre. M. ±SD	Pos. M. ±SD	MD ±SD; (95%CI)	Cohen's d	P * value
NRPS rest	17	3.05 ±1.67	1.41 ±1.70	-1.65 ±1.5; (-2.4; -0.8)	-0.98	0.0078
NRPS walking	17	5.65 ±1.72	2.35 ±1.73	-3.29 ±2.4; (-4.5; -2.1)	-1.90	0.0001
WOMAC pain	17	10.65 ±3.90	5.00 ±3.18	-5.64 ±2.9; (-7.15; -4.15)	-1.56	0.0001
WOMAC Stiff.	17	3.82 ±2.15	1.58 ±1.54	-2.24 ±2.2; (-3.4; -1.11)	-1.19	0.0014
WOMAC Fun.	17	30.82 ±13.75	14.47 ±11.46	16.35 ±11.4; (-22.2; -10.5)	-1.29	0.0007
WOMAC Total	17	45.29 ±18.35	21.17 ±14.83	-24.12 ±61.0; (-31.5; - 16.75)	-1.45	0.0002

NRPS= numeric rating pain scale; WOMAC= Western Ontario and McMaster Universities Osteoarthritis Index; stiff= stiffness; Fun.= physical function; Pre.= before; Post.= after; M= mean; SD= standard deviation; MD= mean difference, CI= confidence interval; *t- test.

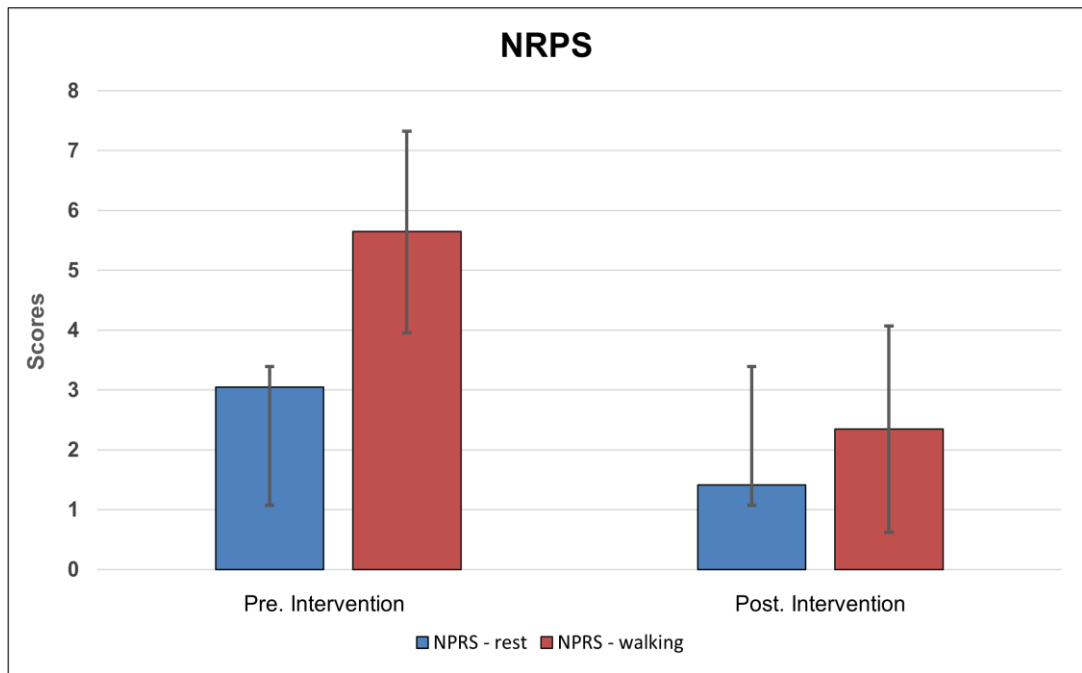


Figure 39: Bar plot of pre- and post-intervention means with standard deviations for NRPS

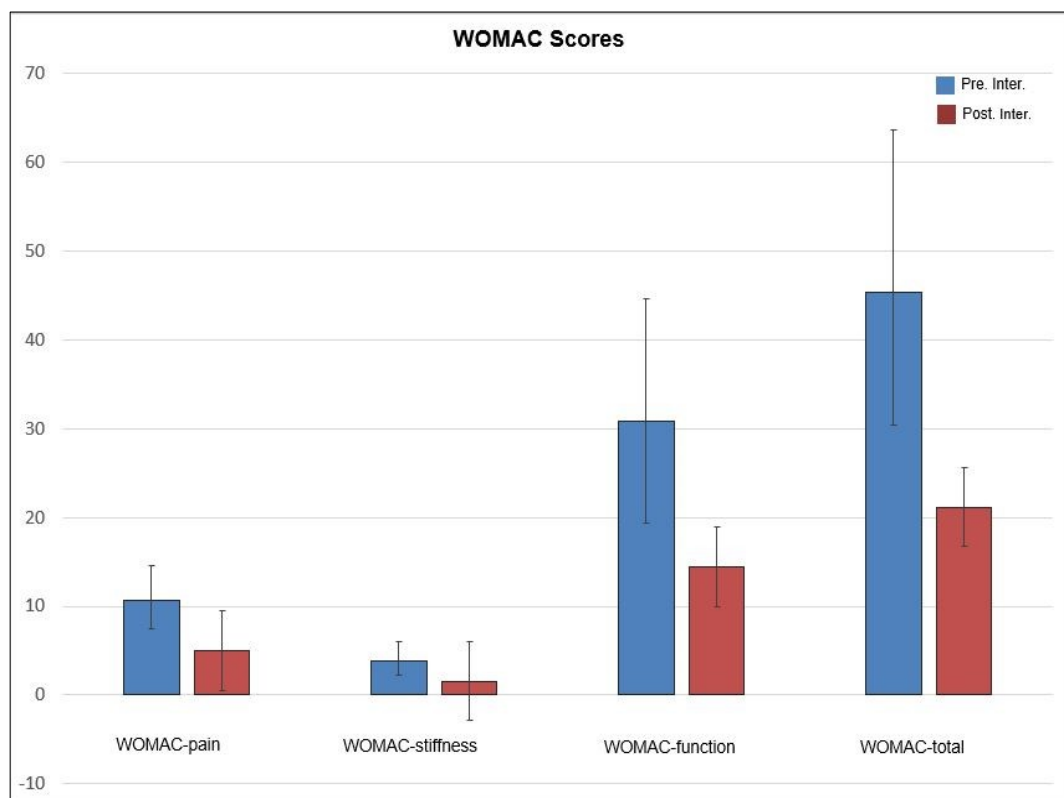


Figure 40: Bar plot of pre- and post-intervention means with SD for WOMAC scores.

7.8.6 Adverse Event:

Despite some anticipated knee pain and ankle discomfort at the beginning of treatment, no significant adverse events were observed during the intervention plan. In the following days, all additional symptoms disappeared after participants visited their primary care physician or used over-the-counter medications.

Several adverse events were identified during the feasibility study. They are listed below. The participants reported experiencing two instances of minor foot discomfort and two instances of seeking other medical complication such as back pain. No intervention was required for any mild events, and they all resolved without intervention within a specified time-frame. A detailed account of each adverse event, including participant responses and the measures taken by the research team, can be found in Appendix 19.

7.9 Discussion:

The main findings of this study indicated that the LWI programme for KOA patients in a physiotherapy outpatient setting within Saudi's healthcare system was feasible and well received. Recruitment, retention, clinical outcomes (NRPS & WOMAC), and patient satisfaction showed promise. However, concerns arose due to potential systematic bias from inconsistent LWI daily adherence, reported discomfort and unimpressive therapist feedback. Despite these challenges, the feasibility results implied that LWI for KOA intervention in Saudi was practical. Future studies need to address daily patient challenges, enhance therapist satisfaction, and evaluate the efficacy and cost-effectiveness of the LWI programme.

In Jeddah City, SA, using LWI on KOA patients showed promising results for specific feasibility criteria but could presented challenges in others area. This feasibility study indicated broad applicability in areas like recruitment, retention, patient satisfaction and clinical outcomes in this region.

Over a single week, 21 participants, equating to 87.5%, were successfully recruited primarily through patient referrals to the physiotherapy department. In such a short period of time, a significant number of participants

indicated high conversion rates monthly. However, this raised concerns about the importance of robust resources for data management, particularly when participant numbers exceed expectations. Studies, such as the systematic review by Parkes *et al.*, (2013), have shown that detailed analyses of numerous studies demonstrate the positive recruitment rate associated with LWI, and Baker *et al.*, (2007) have shown a positive trend in LWI recruitment rates among KOA patients. As a result, such interventions were appreciated.

Despite this, Treweek *et al.*, (2013) noted that reaching high recruitment rates consistently is challenging, especially when aiming for an adequate sample size. Recruitment efforts can often be hindered by factors such as participants' acceptance, rigorous eligibility criteria and financial limitations (Carlisle *et al.*, 2015). To succeed in navigating these challenges, it was crucial to communicate clearly about the study's scope and promote relationships with health professionals (Fletcher *et al.*, 2012). It is likely that some strategies, such as compensation for time and travel, will boost recruitment, but it is important to consider the ethical implications of such motivations (Treweek *et al.*, 2013).

Regarding retention, 81% of participants showed significant progress between pre- & post-intervention. In a study where more than 20% of follow-up is lost, (Dumville *et al.*, (2006), stated that there is an increased risk of bias. There were 19% drop-outs in this study. Despite this drop-out rate, many participants reported high satisfaction with pain relief (47.1%) and adverse effects (52.9%). In foot-insole therapy studies, Bennell *et al.*, (2007) offered explanations for such low follow-up rates, including discomfort from the insole, a perceived lack of benefit, or exacerbation of KOA symptoms. Having addressed these concerns earlier on may have mitigated the drop-out rate. Moreover, as suggested by Robinson *et al.*, (2015), enhanced retention could also be achieved through more straightforward communication, regular reminders, and more flexible appointment scheduling.

Interestingly, early attention to these potential concerns might have mitigated the drop-out rate. It would have been helpful if participants were better informed about potential discomforts, encouraged to wait patiently for

results, and offered more robust follow-up support. Additionally, the insole's materials should be improved to target comfort and efficiency simultaneously.

On examining adherence, patients' compliance with the recommended five to seven hours per day use of LWI was noteworthy. Over six weeks, the average use was around 5.47 hours/day. As a result, 71% of participants reported committing to this period, which was below the feasibility study's expectations. Patients' compliance with LWI is a critical factor in evaluating KOA's effectiveness. Although wedged insoles have the greatest therapeutic effects when used from five to ten hours a day (Toda, Tsukimura and Segal, 2005; Kemp *et al.*, 2008). However, there is uncertainty around the optimal duration for wearing the insole daily (Raaij *et al.*, 2010; Duivenvoorden *et al.*, 2015). Factors like the insole's ease of use, appropriate size, efficacy and potential side effects can influence compliance and adherence rates (Bennell, 2011).

Interestingly, walking has been shown to amplify the benefits of LWI (Kerrigan *et al.*, 2002; Butler *et al.*, 2007; Hinman *et al.*, 2008; Arnold *et al.*, 2016). Despite being advised to walk during LWI usage, 18% of participants reported limited walking abilities, which may explain their lower compliance. Considerations like a tailored orthotic device with a LWI may improve compliance (Butler *et al.*, 2007), insole comfort (Maillefert *et al.*, 2001), efficacy perception (expected outcomes communication) (Jones *et al.*, 2013) and regular follow-up (Mazières *et al.*, 2008) are keys factors to improved compliance. Accordingly, as mentioned in the retention rate, future studies should focus on improving the insole's design to enhance comfort, ease of use and clinical effectiveness. Optimal therapeutic outcomes require comprehensive patient education, sustained support and consistent compliance.

Patient satisfaction levels with LWI were high, 81.75% on an eight-point Likert scale, exceeding the feasibility threshold. This satisfaction could be attributed to perceived symptom relief, ease of use, clarity of use throughout the session and side effect feedback. Numerous studies investigated the acceptability of LWIs in KOA patients using Likert scales. Patients demonstrated high satisfaction and acceptance on a 5-point Likert scale (K L

Bennell *et al.*, 2011; Esfandiari *et al.*, 2013; Jones *et al.*, 2015; Khosravi *et al.*, 2019). However, despite KOA patients finding LWIs acceptable, Likert scales holding drawbacks in assessing acceptance. Patients' reactions, background in Likert scales, can vary due to expectations and interpretation, culture and health literacy levels (Krosnick, 1991). Furthermore, they might need to capture the variables affecting acceptance. Sullivan and Artino (2013) argued that Likert scales assess subjective impressions and attitudes which may not match verifiable facts or observable behaviours (a survey question may not adequately capture the idea).

Biases like "Central tendency Bias" when respondents select a neutral or centre option rather than an extreme option, which may reflect their accurate opinions (Taherdoost, 2019) and "Acquiescence Bias" is possible, which occurs when confident respondents concur with assertions regardless of their content. The results may be skewed due to this (Lorenzo-Seva and Ferrando, 2009). Additionally, "Cultural Bias" suggests that respondents from varied cultural backgrounds might react differently (Lee *et al.*, (2002).

Interestingly, physiotherapists showed lower satisfaction concerning LWI's use for KOA patients. The satisfaction rate (58.75%) and agreement (68.5%) both fell below the feasible threshold limits. Various factors might influence this, such as doubts about the scientific validity supporting LWI (MacKay *et al.*, 2018), challenges in patient compliance (KOA degenerative condition that typically worsens with time) and a future emphasis on joint replacement surgery (Nissen *et al.*, 2022). Physiotherapists perceived their role as delivering short-term treatments and personalised exercises (Teo *et al.*, 2020). While considering knee surgery as a last option, physiotherapists prepared those who chose that route. Despite this, they encountered clinical difficulties such as co-existing disorders, low patient compliance and patients' demands for quick fixes. (Teo *et al.*, 2020).

This satisfaction disparity between KOA patients and physiotherapists indicated different priorities and expectations in treating KOA within the SA healthcare system. Addressing patients' positive experiences with LWI and physiotherapists' concerns and reservations were critical. In-depth analysis into these differing perspectives can foster a more comprehensive KOA care

approach, prioritising patient satisfaction and clinician endorsement. However, cultural influences could affect how patients respond, leading to response bias, and they might not have detected subtle, clinically meaningful changes. As a result of ceiling and floor effects, high or low scores may not have captured further changes. These scales could have oversimplified experiences and missed detailed aspects of conditions. Furthermore, participants might have shown response patterns, impacting validity. Overall, while Likert scales had their merits, they also presented challenges that researchers needed to consider when interpreting data.

Regarding clinical outcomes, this feasibility study showcased promising results for LWI as a conservative KOA treatment over six weeks. According to the NRPS outcome, multiple studies have shown that LWIs significantly improve pain. While RCT studies, like those by Paterson *et al.*, (2018) and Felson *et al.*, (2019), supported the efficacy of LWI in NRPS scores over six months and eight weeks, respectively. Moreover, Duivenvoorden *et al.*, (2015) found that patients wearing LWI had lower levels of pain (NRPS) and better physical function (WOMAC) after 12 months. A meta-analysis based on Parkes *et al.*, (2013) reviewed LWI effectiveness. Based on the WOMAC scale, they found moderate effects.

In contrast, Bennell *et al.*, (2011) found no significant impact on the NPRS and WOMAC scales in their 12-month RCT. According to Toda and Tsukimura, (2008), non-standardised shoe participants might have influenced the variance, compromising the insoles' effectiveness. Additionally, Baker *et al.*, (2007) failed to find clinically significant improvements in pain or WOMAC scores following 16 weeks of LWI for medial KOA. For primarily sedentary individuals, LWI might be more effective if paired with worn-out, non-supportive shoes.

Regarding very large effect sizes, the NPRS and WOMAC were commonly utilised and validated tools for assessing pain and function in KOA patients. The sensitivity of these tools to changes likely contributed to the substantial effect sizes observed (Parkes *et al.*, 2016). This information aligns with standard clinical research practices, as Maher, Markey and Ebert-May, (2013) reported, which emphasises using validated measurement tools for

accurate data collection. Using these validated tools ensured that the changes in pain and function were accurately captured, leading to significant effect sizes that were both statistically and practically meaningful.

Furthermore, Feasibility studies often had small sample sizes. The within-group pre- and post-intervention design enhanced the ability to detect significant changes due to the intervention, contributing to the large effect sizes observed (Sim, 2019). According to Teresi *et al.* (2022), the duration of a pilot or feasibility study influenced the estimation of effect sizes. Shorter studies led to larger effect sizes due to less variability and fewer external influences such as environmental changes (participants experienced changes in their living conditions that affected their behaviour or health outcomes), lifestyle alterations (variations in diet, physical activity or stress levels impacted study results), condition state (severity of KOA) and adherence challenges (longer studies faced difficulties in maintaining participant adherence and engagement, altering the effectiveness of the intervention).

In contrast, longer studies might provide more stable and reliable estimates but could show smaller effect sizes due to increased variability and external factors. This variability underscored the importance of considering the duration when interpreting effect sizes from pilot studies and using them to design larger trials.

Based on this feasibility study, it appears that LWI has great potential for alleviating KOA symptoms in the Saudi demographic. Discrepancies in results across studies could result from differences in patient demographics or characteristics (age and BMI), KOA severity (Shimada *et al.*, 2006), biomechanical variations (D. Casey Kerrigan *et al.*, 2002), and insole designs (Ferreira *et al.*, 2021).

For instance, Shimada *et al.* (2006) found that LWI offered significant kinetic and kinematic benefits for patients with early and mild KOA (KL grades I and II), but not for those with moderate to severe OA. They examined a sample with a mean age of 67.0 years (± 8.7), slightly higher than in this study. The gender distribution was 26.1% male and 73.9% female, indicating a higher

proportion of female participants compared to this study. The mean BMI was also 26.4 kg/m², lower than this study's mean BMI.

While, Ferreira *et al.* (2021) investigated the effect of different tailored LWI degrees on knee loading and symptoms. Their sample had a mean age of 62.6 years (± 8.0) in the experimental group and 60.6 years (± 8.9) in the control group, with 75% female and 25% male in the experimental group, and 44% female and 56% male in the control group. The mean BMI was 29.7 kg/m² in the experimental group and 28.9 kg/m² in the control group, both slightly lower than in this study. Ferreira *et al.* (2021) found no significant improvement in biomechanical or clinical outcomes with tailored LWI compared to neutral insoles, except for minor symptom improvement.

Kerrigan *et al.* (2002) studied a sample with an average age of 69.7 years (± 7.6), comprising 53.3% male and 46.7% female participants. The KOA severity included 67% with grade III and 33% with grade IV, closely aligning with this study's KOA severity. They reported that 5° and 10° LWI significantly reduced knee varus torque during walking, indicating reduced knee loading and potential symptom relief.

These comparisons revealed that this study sample was generally representative of the typical demographic profile in KOA studies but had a slightly higher average BMI. This could influence the generalisability of the findings, especially regarding the efficacy of LWI in populations with lower BMI. The higher BMI might suggest a greater burden of KOA symptoms, potentially enhancing the benefits of LWI due to increased mechanical load on the knees (Russell and Hamill, 2011).

Considering these demographic differences, the findings might be more applicable to populations with similar BMI and age profiles, particularly in SA. Future research should include a more diverse and representative sample to enhance the generalisability of the results across different demographic profiles.

- Strengths & Limitations:

Based on current knowledge, this emerged as the first study assessing the feasibility and acceptability of LWI on KOA patients in SA. The sample size

was sufficient for feasibility questions, in line with previous KOA studies (Lewis *et al.*, 2021). The native Arab researcher, familiar with KOA treatment nuances, could understand the participants' cultural and linguistic backgrounds. While instructors' perspectives could be influenced by their backgrounds concerning older participants in LWI (Hawley *et al.*, 2012), the researcher strictly adhered to the LWI programme protocols, minimising potential bias. High recruitment and retention rates, alongside positive clinical outcomes, highlighted the study's merits. Furthermore, patient preference for the tested LWI intervention was evident from the recruitment rate. The recruitment rate indicated a patient preference for the intervention, and tailored LWIs might have gained approval, underscoring patient satisfaction's significance (Beattie *et al.*, 2005).

The pragmatic design assessed treatment efficacy in authentic clinical scenarios (Thorpe *et al.*, 2009). Moreover, the research incorporated patients during standard physiotherapy department sessions, ensuring the intervention could be offered smoothly without extra resources (Maly *et al.*, 2002; Bennell *et al.*, 2011; Hinman *et al.*, 2012; Alnahdi *et al.*, 2014).

However, several limitations arose. The absence of randomisation might have induced selection bias, potentially affecting the internal validity of the findings and limiting their generalisability to the broader population (Stuart, Ackerman and Westreich, 2018). Blinding and randomisation were not applied in this study, which is essential to consider when interpreting the results. The intervention's visibility can influence gait behaviour and introduce bias in LWI therapies (Parkes *et al.*, 2013). Moreover, study designs could be enhanced using placebo insoles, such as flat insoles without structural support, in future studies. In other studies, placebo insoles have been used as a control to more accurately assess the LWI's effectiveness (Bennell *et al.*, 2011; Parkes *et al.*, 2013). Prospective randomised controlled trials (RCTs) could apply these modifications to address limitations observed in this study, such as small sample sizes and insufficient power (Thabane *et al.*, 2010) and time and cost constraints (Bowen *et al.*, 2009).

Notably, four participants withdrew from the study before its conclusion, resulting in a drop-out rate of 19%. It is notable because it represents a substantial proportion of the initial participant pool, potentially skewing the

results (Bell *et al.*, 2013). During this study, two reasons for drop-outs were found, including discomfort with LWI and the lack of follow-ups of participants. Due to the loss of these specific individuals from the study, the effectiveness of the intervention may have been overestimated.

Moreover, the observed benefits could be from osteoarthritis's natural progression instead of the intervention. OA is a slow-progressing disorder, but pain variability is common and may have influenced perceived improvements (Wang *et al.*, 2018). Also, patient adherence to the intervention was lower than expected, possibly due to the gradual revelation of LWI benefits (Hinman *et al.*, 2012). In this feasibility study, one major limitation lay in its relatively brief duration, which constrained the ability to assess the long-term adherence and sustainability of LWI in treating KOA. While monitored adherence during this study, the short time-frame implies that the results may not accurately reflect the long-term treatment patterns required to manage a chronic condition like KOA (Maillefert *et al.*, 2001; Kerrigan *et al.*, 2002; Picavet and Hoeymans, 2004; Guner *et al.*, 2012; Liu *et al.*, 2018; Ferreira *et al.*, 2019).

Moreover, based on the adherence data, 71% of participants maintained adherence to the intervention throughout the study. Non-adherence, or reduced adherence over time, may be attributed to participants' dissatisfaction with LWI, lack of motivation, or limited awareness of LWI effectiveness. Providing patients with more information about the long-term benefits of LWIs and maintaining communication and encouragement through phone calls, emails and appointments is imperative. Additionally, the most worn shoes should include the insoles. Fostering an interaction between non-adherents and successful insole users could motivate and improve the adherence rate.

According to radiograph reports, the study might have exhibited selection bias (Higgins *et al.*, 2011) by including 24 subjects with 62% moderate KOA. This could negatively impact this patient group. The study's sample exhibited specific characteristics that limit its generalisability. According to radiographic reports in the participants' records, most participants (62%) had moderate KOA, and the remainder (38%) had minimal KOA. Despite this, the study didn't adequately account for age, gender and Body

Mass Index (BMI), which are all factors that can affect KOA progression and management. Research in the future should use a more diverse sample that reflects a broader spectrum of the population with KOA to enhance external validity.

In selecting subjects for the study, radiographic evaluations of KOA severity were pivotal. As a result, including subjects primarily with moderate KOA may not accurately represent the spectrum of KOA severity. This selection may affect the LWI's effectiveness and may not reflect outcomes for different KOA severity levels (Maly *et al.*, 2002; Mundermann *et al.*, 2004; Shimada *et al.*, 2006; Bennell *et al.*, 2011). For future studies, a more detailed classification of KOA severity using a standardised and validated radiographic scoring system would be beneficial to evaluate the effects of the intervention.

Even so, clinical support employees in the department provided the researcher with a list of accepted KOA patients, ensuring that intervention allocation could not be predicted before enrolment. A performance bias could skew results towards the intervention based on the investigator's subjective judgement (Spieth *et al.*, 2016). It became evident that participants had discovered their insoles after selection. It would have been better if the researcher had concealed LWI during enrolment.

However, achieving blinding was challenging as the nature of the LWI procedure required direct demonstration by clinicians. In clinical trials, blinding participants was difficult when the intervention was obvious, such as in physical or procedural interventions (Monaghan, 2021).

One potential solution could have been using placebo insoles to help maintain blinding. Placebo insoles were designed to look and feel like active insoles but lacked the therapeutic component, and they had been used in clinical trials to maintain blinding. However, sham insoles had inconsistent construction, blinding and biomechanical validation. This inconsistency raised substantial doubt on the quality and reliability of the evidence base supporting the prescription of insoles (Morrow *et al.*, 2021).

Detection bias had been another concern, especially when assessors were unblinded. It was particularly crucial to blind assessors in physical activity

trials where participants and those administering interventions might have been aware of participants' status. This bias could have been reduced by employing blinded or masked outcome assessors (Higgins *et al.*, 2011; El-Kotob and Giangregorio, 2018). In addition, the implementation and follow-up of the LWI intervention had posed challenges. Due to participant withdrawal, attrition bias could have led to incomplete data (Higgins *et al.*, 2011). Also, Billingham *et al.*, (2013) suggested a participant count between 24 and 50 for feasibility and pilot studies. To counter this measures such as frequent communication with participants, shorter questionnaires, trial assistants handling participant follow-up, rewards for maintaining participation and goal-setting workshops have been recommended Brueton *et al.*, (2011).

A distinction had been observed between published and unpublished findings, introducing a potential reporting bias that might have called for a more precise presentation of the study's results (Higgins *et al.*, 2011). Selective reporting could have exacerbated this bias (Karanicolas *et al.*, 2010). In the research protocols, all outcomes and analyses had been specified. Nevertheless, the study utilised SPSS for all outcome assessments and adhered to reporting guidelines such as the CONSORT statement (Moher *et al.*, 2001).

Further limitations were the study's localisation to KFSH & RC, Jeddah, in Saudi's Western region. This specific healthcare setting was not generalisable due to several factors, such as differences in healthcare infrastructure, patient demographics, and disease prevalence compared to other regions. For instance, KFSH & RC was a highly specialised tertiary care centre. Therefore, its capabilities and patient profiles might not accurately reflect those of general hospitals or primary care settings in Saudi Arabia or other countries (Almalki, FitzGerald and Clark, 2011). Variances across healthcare environments could skew generalisability, marking the importance of broader RCTs (Karanicolas *et al.*, 2010). A conclusive RCT must be multicentred to improve generalisability (Karanicolas *et al.*, 2010), which would improve its external validity (Godwin *et al.*, 2003; Eldridge *et al.*, 2008).

Moreover, the entire study was overseen by a single researcher, potentially introducing bias. Several factors may contribute to bias, such as

misrepresenting or understating facts based on expectations or hope (Rosenthal & Rosnow, 2008). However, protective measures like secondary review, supervisory consultations and medical statistician input were established to minimise this bias.

The short time-frame for the planned research raised some issues. PhD sponsors, who allow only three-month trips during PhD studies, limited the author's travel to SA for data collection. Also, obtaining ethical permission and recruiting participants took a long time during the three-month data collection period for both (qualitative and feasibility) studies. Lastly, although this study was conducted in SA, the results may need to be generalized to other cultures and regions due to differences in lifestyle, attitudes and healthcare systems.

7.10 Conclusion:

A feasibility study was conducted to evaluate using LWI for treating KOA symptoms in a first-time outpatient physiotherapy setting. Despite its feasibility stage, the study received positive participant feedback, providing early evidence that the LWI programme could be successfully implemented. The results showed that LWI was practical, easy to administer, and was highly acceptable among KOA participants in a Saudi physiotherapy clinic, proving effective as a gait modification strategy.

Nevertheless, the findings of this feasibility study suggest that future definitive research on LWI in Saudi Arabia should incorporate several strategic enhancements to maximise its applicability and generalisability. Recruitment and instruction should be diversified across multiple regions to ensure a diverse patient demographic is represented in future trials. Various instructors with physiotherapy and gait modification expertise could significantly enhance intervention delivery and improve understanding of its effectiveness. A randomised controlled trial (RCT) with assessor blindness is expected to strengthen the study's rigour regarding study design and long-term follow-up. Furthermore, the cost-effectiveness analysis should also be conducted to evaluate the economic feasibility of interventions based on the feasibility study's results to ensure statistical robustness in future research. As a result

of the feasibility study and therapists' feedback, structured practical guidelines are expected to enhance the programme's effectiveness.

This approach will help improve KOA management in the long run. However, it is essential to incorporate therapists' perspectives and address any existing concerns if LWI is to be successfully integrated into Saudi therapeutic settings. By adhering to these recommendations, future research could significantly improve treatment protocols and patient outcomes.

CHAPTER 8

THESIS DISCUSSION, STRENGTHS, LIMITATIONS, FUTURE DIRECTIONS AND CONCLUSION.

8.1 Summary:

This chapter summarises the entire thesis, encompassing the three contributing chapters (4, 5, and 7) that examined LWI as a gait modification method. Different evidence-based gait modification approaches were evaluated with KOA patients during walking at the initial stage. Subsequently, the discussion revolved around implementing gait modification as a treatment strategy for KOA in the Saudi healthcare context, considering the perspectives of both patients and physiotherapists. Further analyses were conducted to assess the feasibility of the selected LWI as a gait modification technique in the Saudi healthcare setting. Additionally, the chapter explains the strengths and limitations of the thesis and offers reflections on the research process.

8.2 Findings from main chapters of the thesis:

According to the thesis' primary objective, the results indicated that implementing the LWI programme for adults with KOA in a Saudi physiotherapy outpatient clinic was feasible and generally acceptable. However, it is vital to note that this finding contrasts with the relatively lower satisfaction levels reported by physiotherapists. This discrepancy underscores the need for further investigation into the factors influencing physiotherapist satisfaction and how these might impact the overall efficacy and implementation of the LWI programme in clinical practice.

Nevertheless, it is essential to highlight inconsistencies in follow-up losses and a notably low daily adherence rate, which cast some uncertainty over certain feasibility aspects. To address these issues, a more comprehensive investigation might be required before utilising LWI as a gait modification for KOA in a broader clinical trial. Consequently, this would enable a more in-depth assessment of the clinical and financial benefits of integrating LWI into routine physiotherapy programmes for those with KOA within the Saudi healthcare system.

Chapter 2 discussed the role of gait modification as a conservative method to reduce knee loading and improve knee symptoms. Despite numerous techniques, there was limited agreement from authors on the most effective ones for alleviating knee loading, pain and function. There needed to be more understanding of the acceptability and commitment levels. Furthermore, it was recommended that patients need to be motivated and apply the chosen gait modification correctly. This is especially important since the evidence states that the long-term ability of patients to maintain suitable gait changes remains uncertain (Richards *et al.*, 2018). It was proposed that using the most straightforward, and most accessible, gait modification might reduce knee pain and function for those with KOA.

- Systematic review and meta-analysis:

Chapter 4 presented a systematic review and meta-analysis examining the evidence for gait modification in KOA subjects. The UK MRC (2013) highlighted the importance of seeking studies that addressed gait modification outcomes, selecting appropriate measures and noting changes.

This chapter examined the effects of various gait modification strategies at different time points and it aimed to evaluate the effectiveness of learning, assistive, or combined gait modification strategies. The review analysed their impact on knee biomechanical loading, pain, and functional outcomes, such as spatiotemporal parameters (gait speed, stride length, and cadence) and physical activity (climbing stairs, walking distance, and sit-to-stand). Moreover, the chapter emphasised RCTs, and considered the most trustworthy indicators of a treatment's efficacy.

This review analysed eight databases, comparing 12 gait modification strategies for KOA regarding their biomechanical parameters and clinical effects. Included RCTs outcomes revealed varying degrees of improvement across different gait therapies compared to controls. Furthermore, no significant change was observed in short to medium-term follow-ups, supported by moderate to low-quality evidence. The analysis revealed that most gait modification methods did not significantly decrease the KAM 1st peak in both short-term and medium-term periods, except lateral stiffener shoes,

which showed short-term effects. Toe-out re-gait training and the LWI significantly impacted the KAM 2nd peak and KAAI in the short term. However, most gait modifications did not notably reduce knee pain or improve functional outcomes.

- Qualitative study findings:

According to the MRC framework and guidance (2013), involving relevant stakeholders, namely MSK physiotherapists and KOA patients, was vital throughout the research process. This ensured optimal outcomes, including the creation or selection of an intervention likely to enhance the health of KOA subjects and boost the probability of effecting policy and practice changes. Accordingly, semi-structured interviews and focus group discussion were undertaken with KOA patients and physiotherapists using a pragmatic qualitative method.

The primary objective of this qualitative research was to gather insights from KOA patients and physiotherapy practitioners in SA concerning their knowledge, practices and the environment related to gait modification for KOA treatment. The study aimed to assess the acceptability and practicality of the newly introduced gait modification programme to recommend potential adjustments and to evaluate its overall feasibility. It also explored the awareness, expectations, and preferences of both KOA patients and physiotherapists regarding this approach in KOA rehabilitation practices in SA.

This qualitative investigation explored the perspectives of KOA patients and therapists in SA concerning the most favourable gait modification technique during KOA rehabilitation. Moreover, employing the TFA, the study identified a consensus favouring assistive gait modification approaches. Notably, simpler and more accessible gait modification therapies, such as canes, knee supports, comfort footwear and insoles, emerged as the preferred choices. This intervention could be easily integrated into KOA treatment strategies within a clinic or at home. Within the Saudi healthcare system, these options were appreciated for its simplicity, clarity and safety, eliminating the need for a prosthesis factory and special training for therapists and patients.

Following in-depth dialogues with healthcare professionals and patients with KOA, several critical factors were identified as crucial to the success of gait modification strategies. These factors were thoroughly considered in the feasibility study: **Therapeutic protocols:** LWI was selected as the gait modification intervention based on a systematic review, qualitative study and other justifications detailed in Chapter 6. Also, ethical approval for the study was obtained from both the University of Nottingham and KFSH-J. The **provision of training spaces and materials:** Although LWI does not require extensive training, initial meetings with clinicians were held to explain the LWI conduction processes and subsequent steps (7.3.6 procedure-chapter 7). Participants were provided with LWIs tailored to their foot size and instructed on their use during clinic visits.

Physiotherapists' expertise: The study involved only MSK therapists who were informed and prepared through initial meetings. These therapists managed their KOA patients' participation in the study. Accessing detailed years of experience for each therapist was confirmed verbally but not officially, which was beyond the researcher's authorisation. **Importance of patient commitment and proper orientation to the prescribed gait modification:** Patients were thoroughly oriented about the study aims, procedures and the importance of adherence. They received PIS and CRF, and regular follow-ups were conducted to monitor their adherence and progress. These steps, detailed in the feasibility study chapter, ensured the integration of critical success factors into the study design and implementation.

Assistive gait modifications like footwear, knee braces and insoles were well-received by both professionals and patients. They believed these modifications could improve care, particularly when adapted to the KOA condition. This suggests their potential inclusion into a broader gait modification programme. Both patients and physiotherapists were keen to expand their knowledge of gait modification techniques in the KOA rehabilitation journey. In addition, footwear and insoles demonstrated potential, though further refinement, addressing comfort and availability, might be needed. Nonetheless, it is expected to be an invaluable tool for both KOA patients and physiotherapists. These results back the initial feasibility of

introducing assistive gait modifications in Saudi outpatient physiotherapy clinics, particularly emphasising the footwear or insole.

- Choosing Lateral Wedge Insole:

Chapter 4 (systematic review, meta-analysis) did not identified the most effective gait modification approaches. After conducting the qualitative analysis, the most suitable gait modification intervention was also determined to be among the assistive methods (footwear, knee braces and insoles). However, due to the cost-effectiveness and logistical challenges of footwear and knee braces which might have introduced discrepancies among participants regarding which brand or type to select, and given the time constraints faced by the researcher, the LWI as a gait modification intervention was chosen for the subsequent phase (feasibility study). In addition, for other justifications for selecting LWI, please refer to section 6.3, "Justification for LWI. This choice was mainly because it was easy to provide and straightforward to implement. Additionally, a qualitative study was undertaken to recommend the outcome measurement tools and formulate satisfaction questions for the targeted stakeholder group, forming part of the final phase of this thesis (feasibility study).

- Feasibility (Quantitative) findings:

Primary objectives included assessing recruitment, retention and adherence rates. Secondary outcomes measured LWI's impact on knee pain and function over six weeks. This study's novelty evaluated the feasibility and acceptability of LWI for KOA patients in SA physiotherapy outpatient settings. It was the first study, incorporating patient and therapist satisfaction into evaluating LWI's efficacy, clarity, treatment duration and side effects. Additionally, the study addressed unique cultural and healthcare system factors in Saudi Arabia, which had not been explored in prior research.

The feasibility study examined recruitment, retention, clinical outcomes (NRPS & WOMAC), and satisfaction with the LWI in SA physiotherapy outpatient settings. As detailed in Chapter 7, the LWI programme proved feasible and was warmly received by patients with KOA over the six-week intervention period.

The study found that the LWI programme for KOA patients in SA's physiotherapy outpatient settings was feasible and well-received. Recruitment, retention, clinical outcomes (NRPS & WOMAC) and patient satisfaction were promising. However, challenges included inconsistent daily adherence, reported discomfort and mixed therapist feedback. Despite these issues, the results implied the practicality of LWI for KOA in Saudi Arabia.

Future studies should address daily patient challenges, enhance therapist satisfaction and evaluate the programme's efficacy and cost-effectiveness. Strategic enhancements, such as diversifying recruitment, involving various instructors and conducting RCT with assessor blindness, are recommended. Additionally, a cost-effectiveness analysis is needed to ensure economic feasibility. Incorporating therapists' perspectives and addressing their concerns will be crucial for successfully integrating LWI into Saudi therapeutic settings, ultimately improving KOA management.

Though many study components had been positive, including recruitment, retention and patient satisfaction, notable concerns existed. Patients reported discomfort and somewhat unsatisfactory feedback from therapists. These factors might have introduced a systematic bias (FitzGerald and Hurst, 2017). Thus, there were areas in which the programme might require adjustments based on these challenges. Nevertheless, despite these setbacks, the feasibility results from the study suggested that the LWI approach held potential as a gait modification intervention for KOA patients within the Saudi healthcare context. Additionally, a critical need for more comprehensive research existed. It would be beneficial to take a deeper look into the daily challenges patients face with the LWI, address the levels of therapists' satisfaction and agreement, and evaluate the therapeutic and financial viability of the LWI engagement programme.

8.3 Discussion Aligned with Qualitative and Feasibility

Research Questions:

Question 2: How do chronic KOA patients and physiotherapists perceive gait modification?

The qualitative study was distinguished by application of the TFA. This framework outlined seven crucial categories (Sekhon *et al.*, 2017), reflecting on the acceptability of gait modification. Moreover, it provided invaluable insights into potential barriers and facilitators associated with the gait modification concept. It also deepened our understanding of stakeholder viewpoints.

In the dialogues, participants identified several critical factors. Their knowledge about the effects of gait modification was limited, a finding that aligned with the insights of O'Keeffe *et al.*, (2016) and Pincus *et al.*, (2013) underscored the importance of educating patients and therapists about such interventions. Moreover, the availability of therapeutic protocols and materials was also highlighted as vital, as confirmed by Thorstensson *et al.*, (2006), Petursdottir *et al.*, (2010) and Kanavaki *et al.*, (2017).

Additionally, the discussions revealed that the provision of training areas specifically for gait training would facilitate accessibility for therapists, thus echoing the needs identified by Petursdottir *et al.*, (2010), Kaptein *et al.*, (2013) and Fisker *et al.*, (2016). The presence of experienced physiotherapists was deemed crucial, not only for promoting confident gait retraining but also for mirroring the views expressed by Morgan *et al.*, (2016), Shirley *et al.*, (2010), Gyllenstein *et al.*, (1999), Gard, (2007) and the emphasis placed by Fregly *et al.*, (2011) on the importance of teaching patients correct walking techniques.

Furthermore, assistive gait modification devices were pivotal in enhancing safety, boosting confidence and fostering compliance (Hsu *et al.*, 2015; Khan *et al.*, 2020). When these devices were integrated with established KOA strategies encompassing clinical protocols, consistent evaluations, and extended follow-ups, there was an apparent optimism about their potential benefits.

The discussions also underscored the necessity for patient commitment and adequate orientation towards prescribed gait modifications during rehabilitation. Within the context of the Saudi healthcare system and considering the gait modification resources available, there was a noticeable

preference among patients and therapists for assistive modifications, such as footwear and insoles, due to their simplicity and effectiveness in meeting the study's objectives.

Although limitations such as interviewer bias (McSweeney, 2021) and concerns about geographical transferability existed (Ritchie *et al.*, 2013), mitigation measures like topic-guided prompts ensured the research's core integrity (Ritchie and Lewis, 2003). Moreover, the findings demonstrated that comprehensive therapeutic protocols, training and the availability of assistive gait modification were essential for effective rehabilitation.

Question 3: How feasible is the implementation of LWI in a Saudi outpatient physiotherapy setting for KOA patients, and what are the associated challenges and facilitators in terms of recruitment, retention, adherence and satisfaction?

The feasibility study represented a novel endeavour, marking the first investigation into LWI conducted in SA. It yielded several advantages, including improved clinical outcomes, compliance with feasibility standards, and affirmative feedback from stakeholders regarding LWI's clinical utility. This quantitative data enhanced the study's robustness, correlating with the dynamics between participants, mediators, and outcomes (Creswell, 2018). Nevertheless, the study faced hurdles such as a constrained timeline, absence of randomisation and potential biases.

Primary outcomes showed LWI's viability in a Saudi outpatient physiotherapy setting for KOA patients, with promising indicators like recruitment, retention, clinical measures and patient satisfaction. Despite this, concerns arose, particularly relating to adherence issues, reported discomforts and therapist doubt. Still, these challenges did not undermine the practicability of LWI as an intervention for KOA in SA.

Regarding recruitment, the rate was deemed acceptable, in line with previous LWI study findings (Baker *et al.*, 2007). In our feasibility study, the recruitment rate was 87.5%, aligning with the findings of Baker *et al.* (2007). Offering LWI for free was pivotal in achieving this rate, resulting in 17 participants joining. Financial barriers were significant factors affecting

attendance, as identified in previous research. In this study, removing these barriers by providing free LWI (3.6 justification in Chapter 6) significantly contributed to the high recruitment rate. Based on the given rate, a larger-scale RCT could recruit about 65 participants per group (Kaptein, 2019), assuming similar conditions and incentives. The estimate was based on the idea that removing financial barriers could sustain or improve recruitment rates, as demonstrated by studies that examined how cost affects clinical trial enrolment (Campbell *et al.*, 2007; Fletcher *et al.*, 2012; Adams *et al.*, 2015).

Within the feasibility study, the LWI's free availability contributed to a respectable number of participants joining the study. Furthermore, the LWI's role in communicating the significance of treatment for KOA bolstered recruitment efforts. In line with the qualitative study, patients wanted ongoing communication and adequate explanations to facilitate application and cooperation with therapists during the LWI sessions. This suggestion was considered in the feasibility study, in which participants were informed they would receive consistent contact and could visit the clinic if they had any concerns. This way, reassurance was provided, and recruitment rates were maintained satisfactorily, (see appendix 15 for follow-up schedule). As a result, providing ongoing communication and clear explanations enabled cooperation with therapists during the LWI sessions, ensuring reassurance and maintaining satisfactory recruitment levels.

Assessing the feasibility study's retention rate aspects, several insights emerged. Bennell *et al.*, (2007) had already suggested that the loss in follow-up rates in foot-insole therapy studies might be due to discomfort issues, a perceived lack of treatment benefit (less knowledge) or worsening of KOA symptoms. This study confirmed comfort issues, as two participants withdrew, citing insole discomfort—this detail is substantiated in appendix 19 as copy for adverse event. Moreover, the qualitative chapter corroborated these findings, revealing that participants had low orientation and comfort with insole use. This was compounded by a limited understanding of LWI as gait modification's role and effectiveness in KOA treatment. However, the study could have benefited from an earlier identification of these factors. This might have informed a more tailored approach to patient orientation and education.

Robinson *et al.*, (2015) proposed that retention could be improved with better communication, consistent reminders and flexible scheduling. These strategies were implemented in the feasibility study, notably through a clear LWI endorsement session and ongoing participant communication to address questions and updates (On page 168 of chapter 7, it is called week 0 of the LWI process). Also, the Likert scale responses of the KOA participants, detailed in Table 19 support these claims.

Regarding satisfaction, the qualitative study indicated that patients were willing to adopt any safe and effective gait modification. They were positive towards interventions that managed pain and enhanced physical activity; findings mirrored in the Likert scale responses of the feasibility study. Conversely, therapists showed hesitation in adopting a clear gait modification strategy based on scientific evidence orientation and integration within the therapeutic KOA protocol, as revealed in the focus group discussion.

Patient satisfaction levels were encouraging, with notable findings emerging from the six-week survey of KOA patients using the LWI. Satisfaction with pain relief had been high, with 47.1% of patients very satisfied and 41.2% extremely satisfied. Additionally, satisfaction with the ease of application and clarity during sessions had been exceptionally high, with 52.9% and 76.5% of patients extremely satisfied, respectively. However, satisfaction with the ability to perform daily activities received lower ratings, with only 35.3% of patients being very or extremely satisfied. Overall, the survey indicated a trend towards high satisfaction, reflecting the positive effects of using the LWI.

Therapists' responses revealed a cautious yet generally positive stance. Specifically, 53.8% of therapists were very satisfied with the improvement in practical skills, while only 7.7% were not at all satisfied with the ease and clarity of application. The median overall satisfaction was very high. Regarding the inclusion of LWI in the KOA treatment plan, 61.5% of therapists agreed, though there was significant disagreement (23.1%) on specific requirements for effective implementation. These mixed responses highlighted the need to address therapist concerns and align their perspectives with patient preferences to facilitate the integration of new interventions.

These findings aligned with broader research highlighting the challenge of integrating new treatment modalities into clinical practice, especially when this requires reorientation of established protocols (MacKay *et al.*, 2018; Teo *et al.*, 2020). The conflict between patient acceptance and professional hesitation underscored the need for evidence-based approaches to translate patient-preferred interventions into standard practices. Therapists' doubts mainly stemmed from differing perspectives, emphasising the complexity of adopting new interventions despite patient preference.

The resistance from therapists revealed a gap in current practices that needed to be addressed to effectively integrate patient-preferred solutions into routine clinical care. Additionally, as shown in this study, the differing perspectives between KOA patients and therapists on gait modification warranted further exploration to bridge this gap and improve patient outcomes.

In summary, while confirming the feasibility and positive reception of the LWI programme, it is essential to acknowledge the challenges encountered. These challenges include variable adherence and therapist doubt. Addressing these barriers and exploring the long-term impact of LWI in a broader healthcare framework remain imperative for future research.

8.4 Synthesis of the Qualitative and Feasibility Findings:

The thesis assessed the acceptability and feasibility of gait modification strategies within the Saudi healthcare system for KOA rehabilitation. Qualitative research highlighted that healthcare professionals and KOA patients favoured the LWI for its simplicity, clarity and safety. It required no specialised training and could be easily integrated into clinics and homes. Despite its promise, LWI still needed improvements in awareness, comfort, continuity, availability and clinical protocols to ensure consistent, practical use and cost-effectiveness (Garbi, 2021).

In addition to these qualitative findings, the feasibility study provided quantitative insights, showing positive outcomes in recruitment, retention, knee symptoms, and patient satisfaction, despite some therapists' reservations.

Challenges included adherence to the schedule, discomfort, and the need for more precise LWI implementation guidelines within the KOA treatment plan.

Overall, LWI appeared promising in terms of acceptability and feasibility. Future studies should focus on addressing patient challenges like discomfort and adherence, improving therapist satisfaction, refining the KOA therapeutic protocol, and exploring the economic implications of LWI engagement.

The qualitative chapter's emphasis on patient education in improving adherence was confirmed by recruitment and compliance rates. The study's findings align with previous research, such as Bennell *et al.*, (2011), underscoring that enhanced individual awareness is crucial for better compliance. Factors like the insole's ease of use, appropriate size, efficacy and potential side effects can influence compliance and adherence rates (Bennell, 2011). In this study, the novel contribution is the demonstrated relationship between patient education (well-informed about the benefits and proper use of LWIs), LWI comfort (who found the insoles comfortable and easy to use), and the resulting adherence rates and patient satisfaction levels. By educating patients on the efficacy of LWI, they are more likely to appreciate the benefits, leading to better adherence. Similarly, that the LWI was comfortable and easy to use further supported consistent use. These findings not only resonate with existing literature, they provide insight into how KOA LWI treatment adherence is managed in real-world situations.

Research could build on this by examining long-term compliance and clinical outcomes after these and other interventions have been implemented (Pisters *et al.*, 2010). Furthermore, patient education and engagement strategies should be refined by understanding the psychological underpinnings of patients' acceptance and adherence to treatment (Kanavaki *et al.*, 2017). Factors like insole comfort, efficacy perception and regular follow-up were critical for improved compliance. Comfortable insoles reduced discomfort and encouraged consistent use (Jones *et al.*, 2013). When patients perceived the insoles as effective, they were more likely to continue using them (Hsieh & Lee, 2014; Hinman *et al.*, 2013). Regular follow-ups ensured that patients felt supported and could address any issues, reinforcing adherence (Duong *et al.*,

2021). These strategies collectively enhanced patient compliance and led to better clinical outcomes.

- Cultural and education context:

This study highlighted several essential aspects of the cultural and educational context in SA that impacted the outcomes and applicability of the LWI as a gait modification. This thesis was notable for being the first in the region to evaluate gait modification based on the TFA and to test the feasibility of LWI for KOA.

Moreover, it included the first qualitative study in the southern region of SA, conducted at a central hospital considered a second-level healthcare system. This study provided insights into how people from small cities and rural areas accepted gait modification. These participants, characterised by specific demographics (age and KOA severity) and limited cultural exposure, had unique perspectives on the intervention. Additionally, the lack of training courses and workshops for therapists due to limited educational resources (one main regional university with some unspecialised colleges) underscored the need for better professional development opportunities (Day *et al.*, 2021). The region's natural landscape, with its hills and mountains, posed significant challenges for elderly participants using any gait modification approaches, exacerbated by limited physical activity.

Conversely, the feasibility study of LWI conducted in the western region's second-largest city in SA included a more diverse group of participants, offering a wider range of cultural perspectives and patient demographics. This study took place at a major hospital considered a high-level healthcare system in SA (Almalki, FitzGerald and Clark, 2011), benefiting from multiple universities and educational institutes, which ensured broad knowledge among participants. Coastal sidewalks and large malls supported walking activities to avoid high temperatures, especially during the daytime. Additionally, the Likert scale survey measured satisfaction and acceptability, demonstrating the novelty of the feasibility study and the thesis.

This research was unique in its tailored approach to KOA rehabilitation in SA, emphasising the importance of culturally and geographically sensitive

intervention strategies. Future studies should aim to expand training opportunities for healthcare professionals and consider the unique environmental challenges faced by patients in different regions (Sivan, Smith and Al-khayer, 2011). Additionally, broader implementation studies are needed to confirm if these findings can apply to other Saudi regions with similar cultural norms.

- A bridge between the two studies:

Both studies underscored the significance of adapting KOA treatment regimens to SA's distinct cultural and medical environment. Although the qualitative study offered insights into a more suitable and fitting approach to gait modification, the feasibility study gave a success metric. Moreover, it sheds light on the challenges and advantages of integrating LWI into the treatment procedure. Consequently, both studies indicated that KOA management in SA held promise as long as the issues were resolved, and the recommendations thoroughly conducted.

The findings demonstrated that the LWI gait modification method could be incorporated into KOA management in SA. In both investigations, the primary concerns revolved around acceptance and feasibility. Nevertheless, focusing on patient-centred care (Gard, 2007), intensive training for healthcare practitioners (MacKay, Hawker and Jaglal, 2020), and developing assistive devices (Thorstensson *et al.*, 2006) might lay the groundwork for a transformative treatment landscape for KOA. Even though both investigations had their strengths and limitations, they offered indispensable backing for prospective research that was centred on elevating KOA patient care and enhancing treatment guidelines within the SA healthcare framework.

8.5 Contribution to the Existing Knowledge:

Theoretical Implications: This research significantly contributed to knowledge on gait modification strategies for KOA, particularly within the SA healthcare context. Previous studies had explored various assistive devices for gait modification, but this study uniquely contextualised these interventions within SA. By integrating qualitative insights from stakeholders with

quantitative feasibility data, the research emphasised the importance of culturally and geographically sensitive approaches. Furthermore, using the TFA, the study provided a structured understanding of the acceptability of gait modification techniques among Saudi KOA patients and physiotherapists. The application of TFA in this context revealed critical factors such as patient education, comfort, and ease of use, which are essential for the successful adoption and acceptance of gait modification, particularly assistive devices. This framework could be applied in future research to assess the acceptability of other health interventions in similar cultural settings.

Practical Implications: The findings suggested that LWI could be effectively integrated into KOA management strategies within SA outpatient physiotherapy settings. The high recruitment and retention rates and positive patient feedback indicated that LWIs were acceptable and practical for clinical use. Clinicians should consider incorporating LWI into their treatment plans for KOA patients, focusing on patient education and regular follow-ups to ensure adherence and maximise benefits. Additionally, the study highlighted the need for healthcare policy to support the widespread adoption of simple and cost-effective gait modification devices like LWIs. Also, policymakers should consider providing funding and resources for distributing LWIs and training programmes for physiotherapists. Healthcare policies should emphasise the importance of culturally sensitive interventions and patient education to improve adherence and clinical outcomes.

Furthermore, there was a clear need for enhanced professional development opportunities for physiotherapists in SA regarding biomechanical intervention with KOA. Training programmes should focus on the application and benefits of gait modification strategies, ensuring that healthcare providers are well-equipped to implement these interventions. By addressing the educational gaps identified in the study, healthcare systems could improve KOA patients' overall quality of care. Moreover, the study's findings underlined the importance of considering cultural and environmental factors in designing and implementing healthcare interventions.

Future research and healthcare industries should aim to develop and promote effective strategies aligned with the target population's cultural

practices and preferences. This approach would likely increase the acceptability and success of health interventions in diverse settings. By integrating these theoretical and practical implications, this research provided a comprehensive foundation for improving KOA management in SA and potentially in other regions with similar cultural contexts.

8.6 Strengths and limitations of the thesis:

In the research study, several strengths became evident. Using the MRC guidelines, the researcher undertook a structured literature search to evaluate gait modification techniques and specify specific evidence-based practices. This inspiration for the study stemmed from complaints by KOA patients in the SA clinic about their regular physical therapy care and the researcher's prior experiences, highlighting a real need to enhance or renew conservative treatment.

Furthermore, the systematic review and meta-analysis relied exclusively on RCTs for their conclusions, lending significant credibility and accuracy to their findings (Moher *et al.*, 2000). Incorporating various methods to alter an individual's gait gave more comprehensive and trustworthy results alongside evidence-based practices.

The TFA provided a robust theoretical underpinning (Sekhon *et al.*, 2017), illustrating gait modifications and estimating their acceptance amongst SA KOA patients and healthcare professionals. Following the systematic review, meta-analysis, and qualitative study, LWI was chosen due to its effectiveness and participants' preferences. Both KOA therapists and patients anticipated it would fulfil their requirements, with the aspiration that participants would persist and continue to use it post-project.

Initiating a qualitative method of how healthcare professionals and KOA patients perceive gait modification programmes was considered an excellent place to begin adapting and testing the proposed LWI programme (to identify the most acceptable gait modification approach and to develop survey questions). Also, the comfort and preferences of participants were recognised

as potential influences on retention and drop-out rates (Lin et al., 2021) during the feasibility phase.

Moreover, in addressing participants' inquiries about LWI before the intervention, the researcher determined barriers, such as availability and therapist expertise, and facilitators, like patient dissatisfaction with routine physiotherapy. Hence, it was imperative to explain the advantages of LWI for the target stakeholders to influence behavioural change (Marks *et al.*, 2005).

The satisfaction survey was an integral component of the feasibility phase, which helped shape how, and where, the final trials would occur. Although the data analysis was time-consuming and required more participants from different regions, it is helpful for future SA healthcare practices.

Remarkably, this was the initial mixed-method study assessing the acceptance of LWI within SA healthcare. The deep involvement of patients and therapists in qualitative and practical research enriched the accuracy and applicability of the findings. Lastly, the researcher's SA background enriched the study's authenticity and depth, offering a personal understanding of the local culture and language.

On the other hand, the **limitations** of the thesis were as follows:

- 1- The thesis studies centred on the adaptability and acceptance of gait modification. Nonetheless, a vast array of knowledge was pertinent to a broader context, implying that future research should have concentrated on potential advancements in SA's healthcare environments.
- 2- During the focus group discussion with physiotherapists, many participants discussed gait modification at length. In contrast, during the semi-structured interviews, patients were urged to express their views through probing and exploration. This difference in separate settings created a limitation, as it may have influenced the depth and variety of patient perspectives gathered compared to the more focused discussion among therapists (Tausch and Menold, 2016).

- 3- A feasibility study without randomisation might have led to selection bias, which could affect the ability to generalise the findings (Stuart, Ackerman and Westreich, 2018). Moreover, the sample size was modest, making it impossible to generalise the findings to the wider population. Additional studies with larger and more diverse samples were necessary to ensure the generalisability of the results (Walters *et al.*, 2019).
- 4- The researcher's role, being a physiotherapist, might have affected the qualitative study's outcomes due to the participants' awareness of physiotherapy positions (Meisenberg and Williams, 2008; McSweeney, 2021). Additionally, the principal researcher independently supervised the entirety of the feasibility study's research method, potentially undermining its impartiality (Rosenthal & Rosnow, 2008). Despite the outlined biases in chapter 5 & 7, this PhD research could not avoid them.
- 5- Furthermore, KOA participants might have felt overwhelmed due to previous therapeutic exercise and guidance during the LWI intervention, which could influence their self-reported symptoms and quality of life (Hunt *et al.*, 2013). Since the outcome measures, NRPS & WOMAC were self-reported, the data might have been insufficient to grasp the subjects' actual circumstances (Terwee *et al.*, 2006). Future clinical trials might have necessitated further examinations.
- 6- In the feasibility study, time constraints led to a short follow-up of six weeks, and the scope of post-intervention qualitative interviews was limited. A more in-depth interview approach could have offered profound insights into the programme's acceptability and feasibility. Moreover, in the feasibility trial, patient adherence had been lower than anticipated, complicating the assessment of the LWI intervention's efficacy and long-lasting effects.
- 7- Additionally, due to their packed timetables and limited availability, other healthcare experts, including MSK physicians and occupational therapists, could not observe the LWI programme with KOA patients. However, it had been monitored by a physiotherapy team during its application to KOA patients.

- 8- The researchers believe that the delivery of LWI, participant engagement, and subsequent follow-up might help physiotherapists or healthcare specialists in offering feedback regarding its practical application. Additionally, as both studies were situated in specific regions, the west and south of SA, their findings might have needed to be more generalisable to other regions of the nation or globally (Aitken *et al.*, 2008).
- 9- The population specificity of this study represents one of its primary limitations. The choice of intervention is influenced by the knowledge of physiotherapists and patients' cultural norms (Lee *et al.*, (2002), even though it is pragmatic and grounded in the perspectives of stakeholders and the Saudi healthcare system. Consequently, while the results hold relevance and utility within Saudi healthcare, their applicability to other nations' settings may be challenging.
- 10- Although insoles and footwear were well-accepted interventions in the Saudi context, they may not receive the same level of acceptance in other countries. Divergent cultural standards, unique physiotherapy techniques, or distinct healthcare practices or protocols may lead to varying perspectives and preferences. Taking the USA or India as examples, cultural viewpoints, societal means, or medical procedures could lead to outright rejection or uneven acceptance of LWI as a viable KOA intervention. As a result, the generalisability of this study's findings is constrained to the specific sociocultural and healthcare landscape of SA, and any extension of these findings to other nations must consider their unique circumstances.

8.7 Initial recommendations and future research:

It is obvious that the insights gathered were valuable, but they should not have been interpreted as absolute or definitive recommendations. In this research, they are presented as areas for consideration and further exploration. The results, although promising, would benefit from broader and more in-depth investigations in the future. Considering the limitations of any single study, including this one, this was especially important. Thus, the subsequent

sections should have been considered options for further research and reflection rather than conclusive solutions.

As a result of this research's findings and in-depth analysis, initial recommendations were developed to enhance biomechanical strategies for KOA patients, focusing specifically on integrating LWI as a gait modification method in SA. These recommendations, currently in the developmental phase, are intended to inform the design and implementation of future interventions, potentially progressing towards an RCT. This approach underscores the intervention's gradual progression towards practical application, anchored in ongoing research and refinement.

1. Considerations for Incorporating LWI into KOA Treatment in SA as a Gait Modification Strategy:

- In SA, it is essential that simple gait modification strategies, such as LWI, are viewed as integral components of conservative treatment plans for KOA patients.
- Consequently, it is recommended that Saudi KOA treatment protocols should be modified to encompass LWI as a standard treatment option. This should consider the preferences of KOA patients and resource constraints, including facility shortages, the proficiency of therapists, and treatment areas.
- Moreover, it is vital that the healthcare system supports and funds physiotherapy training programmes, introducing therapists to the most recent evidence-based gait modification practices. This would help to engage them in various biomechanical approaches, thus enhancing their biomechanical understanding and therapeutic competencies.
- To further the cause, introducing rewards, improved access to group therapy, and accessible and cost-effective gait programs for KOA patients could facilitate behaviour change (Lamb *et al.*, 2010; Brueton *et al.*, 2011; Stanley *et al.*, 2016). This could promote LWI as a gait modification and increase adherence rates among KOA patients. In addition, providing practical resources (the kinesiology analysis lab and

affordable tools) and addressing therapists' obstacles (lack of skills and knowledge) were the greatest motivators for physiotherapists to adhere to KOA gait modification standards. Moreover, offering online gait retraining modules can serve as cost-effective alternatives to gait labs, enhancing adherence and accessibility (Ginis *et al.*, 2016).

- Lastly, feasibility research provides insight into how KOA patients in SA demonstrate low physical activity levels, as evidenced by the self-reported walking ability data in the demographic section of the feasibility study (table 17). Specifically, 59.0% of patients reported walking less than 1 km, with 18.0% walking less than 500 meters. This is attributed to inadequate muscular fitness, balance and mobility (Hafer, Kent and Boyer, 2019). As a result, it is imperative that gait modification treatment plans not only address the primary concern but also integrate physical fitness components like balance, mobility, strength training and weight management. Furthermore, patients should receive orientation sessions before endorsing LWI as a suitable gait modification option. This step might ensure appropriate awareness and ability levels and assess the likelihood of patient commitment.

2. Considerations on Research & Future Definitive trial:

- To achieve a greater understanding and bolster participation from KOA patients, an extended data collection phase should be used in a RCT focusing on the LWI intervention. This phase should be separate from any comparisons with alternative therapies.
- Moreover, the cluster randomised trial methodology, as discussed by Hemming *et al.*, (2017), can mitigate the risks of participant dissatisfaction and potential unreliability in outcome assessments, as noted by Sedgwick (2014). After the trial ends, it is crucial to note that participants from the control group will be afforded the same advantages as their counterparts in the intervention group. Furthermore, each outcome measurement must be captured at distinct intervals.
- For forthcoming LWI-RCT research efforts, there is a real need to incorporate concise self-reported outcomes. For instance, instruments

like the Short Form-36 (SF-36), (Ware and Gandek, 1998) can be instrumental in evaluating life quality and overall health status. Simultaneously, the Exercise Adherence Rating Scale (EARS), (Newman-Beinart *et al.*, 2017) can be beneficial in estimating commitment levels, while the 12-item Oxford Knee Score (OKS) (Dawson *et al.*, 1998) determines knee health. It might also be worthwhile to consider the integration version of the KOOS (Roos and Lohmander, 2003) to understand comprehensively. Additionally, compliance with these recommended core outcome sets for OA trials should be ensured to standardise and enhance result comparability.

- Interestingly, combining LWI with standard physiotherapy approaches, encompassing electrotherapy and therapeutic exercise, may offer enhanced outcomes for KOA patients (Sharma and Chandrasekar, 2011). However, one must approach this assumption with caution, primarily due to the absence of a comparator group. This underscores the need for further investigative studies on this concept.
- Lastly, to maintain research integrity in upcoming LWI investigations, roles such as the statistician, outcome assessor, instructor and recruiter must remain blinded (Higgins *et al.*, 2011; El-Kotob and Giangregorio, 2018). This strategic approach can significantly reduce the likelihood of apparent performance and selection biases.

3. Considerations for Implementation & Future Direction:

- KOA patients should receive optimal care and therapeutic interventions from the rehabilitation team, including orthopaedic specialists and occupational and physiotherapy therapists. Clinicians who are in regular contact with KOA patients are best placed to promote the adoption of gait modification techniques such as LWI and to address patients' queries (Fletcher *et al.*, 2012). The likelihood of adhering to the LWI programme increases when the rehabilitation team, and the social support network, consistently offer support.
- To enhance adherence during LWI implementation, reminders can be sent via social media platforms (WhatsApp, SMS and emails) (Dar *et al.*,

2014; Brix *et al.*, 2019) or through family members to prompt participants to attend each LWI session, ensuring continuity (Ilori *et al.*, 2016). In the future, KOA participants might benefit from robust reminder systems like MS Teams and telemedicine to minimise distractions, keep observing, and save time.

- Given the potential of LWI as a gait modification technique within the SA healthcare system, a cost-effectiveness study is crucial. Improving access to LWI, promoting research, and enhancing long-term outcomes can be achieved by securing funding sources and ensuring that financial efficiencies and patient benefits are effectively managed.
- Technical advancements in gait modification are vital for a more objective assessment of LWI's influence on knee loads, muscle contractions, pain and function in KOA patients and to underpin further rigorous studies. It would be highly advantageous if SA's upcoming biomechanical research incorporated wearable technologies such as real-time monitoring, 3D gait analysis and biofeedback systems (He, Liu and Yi, 2019; Young, Oliver and Gordon, 2021).
- Given the limitations noted above (limited generalisability), future research should employ multicentre designs in SA to boost generalisability (Aitken *et al.*, 2008). Upcoming studies should focus on LWI implementation and comprehensive follow-ups to assess the pros, cons, long-term adherence, and benefits of LWI across different Saudi healthcare settings.

8.8 Conclusion:

This mixed-methods approach was employed for the effectiveness and acceptability of the LWI as gait modification for chronic KOA patients in SA. Within the Saudi healthcare context, the LWI has gained traction as a feasible and acceptable treatment option, attracting significant attention from KOA patients and scientific aspects regarding physiotherapists.

Initially, the clinical adaptation of the LWI for KOA patients was challenging. However, a six-week intervention demonstrated its practicality

with notable outcomes such as knee pain relief, increased daily activity and improved walking skills. Participants' motivation, as measured by a Likert scale survey, grew during this time, suggesting a sustained activity level with continued healthcare professional support that was key for consistent adherence. Moreover, the LWI boosts self-confidence, satisfaction and safety in KOA patients due to its clear and straightforward application. While valuable for KOA rehabilitation, the LWI has not maximised its potential. Outstanding issues include updates in the KOA clinical protocol, infrastructure details, therapist expertise and LWI accessibility. Additionally, further research is vital for the LWI's long-term success. Moreover, a follow-up trial after the six-week intervention would determine the programme's viability and cost-effectiveness.

While the study's focus on the Saudi population limits the generalisability of the results, it also provided essential insights into how cultural and educational contexts influence the success of rehabilitation interventions. The positive outcomes of the LWI intervention in SA highlighted the importance of culturally tailored approaches in improving patient outcomes in KOA rehabilitation.

By addressing these challenges, SA can improve KOA rehabilitation clinical procedures and reduce patient inconvenience and complications associated with current KOA treatment. Improving KOA health outcomes is achievable by integrating new therapies grounded in scientific evidence and a patient-centric approach. Furthermore, prioritising patient perspectives, refining therapeutic approaches and promoting therapist clinical education are essential for advancing KOA rehabilitation in SA. Additionally, specific research is needed to expand LWI treatments and understand the subtleties of KOA rehabilitation within SA's healthcare setting.

REFERENCES:

- Abaraogu, U.O. *et al.* (2019) 'Physiotherapist–patient communication in entry-level physiotherapy education: A national survey in Nigeria', *Hong Kong physiotherapy journal*, 39(1), pp. 77–87. Available at: <https://doi.org/10.1142/S1013702519500070>.
- Abdallah, A.A. and Radwan, A.Y. (2011) 'Biomechanical changes accompanying unilateral and bilateral use of laterally wedged insoles with medial arch supports in patients with medial knee osteoarthritis', *Clinical Biomechanics*, 26(7), pp. 783–789. Available at: <https://doi.org/10.1016/J.CLINBIOMECH.2011.03.013>.
- Ackerman, I. (2009) 'Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)', *Australian journal of physiotherapy*, 55(3), pp. 213–213. Available at: [https://doi.org/10.1016/S0004-9514\(09\)70088-1](https://doi.org/10.1016/S0004-9514(09)70088-1).
- Adam, M.S. *et al.* (2024) 'The metabolic characteristics and changes of chondrocytes in vivo and in vitro in osteoarthritis', *Frontiers in Endocrinology*, 15, p. 1393550.
- Adami, M.F. and Kiger, A. (2005) 'The use of triangulation for completeness purposes', *Nurse researcher*, 12(4), pp. 19–29. Available at: <https://doi.org/10.7748/nr2005.04.12.4.19.c5956>.
- Adams, M., Caffrey, L. and McKevitt, C. (2015) 'Barriers and opportunities for enhancing patient recruitment and retention in clinical research: findings from an interview study in an NHS academic health science centre', *Health research policy and systems*, 13(1), pp. 8–8. Available at: <https://doi.org/10.1186/1478-4505-13-8>.
- Adler, P.A. (2011) *The tender cut inside the hidden world of self-injury*. Edited by P. Adler and ProQuest (Firm). New York: New York University Press.
- Afzali, T. *et al.* (2018) 'Cost-effectiveness of treatments for non-osteoarthritic knee pain conditions: A systematic review', *PloS one*, 13(12), p. e0209240.
- Aitken, L.M. *et al.* (2008) 'Effective strategies for implementing a multicenter international clinical trial.', *Journal of nursing scholarship: an official publication of Sigma Theta Tau International Honor Society of Nursing*, 40(2), pp. 101–108. Available at: <https://doi.org/10.1111/j.1547-5069.2008.00213.x>.
- Ajemian, S. *et al.* (2004) 'Cane-assisted gait biomechanics and electromyography after total hip arthroplasty', *Archives of physical medicine and rehabilitation*, 85(12), pp. 1966–1971.
- Akin-Akinyosoye, K. *et al.* (2021) 'The Central Aspects of Pain in the Knee (CAP-Knee) questionnaire; a mixed-methods study of a self-report instrument for assessing central mechanisms in people with knee pain', *Osteoarthritis and cartilage*, 29(6), pp. 802–814. Available at: <https://doi.org/10.1016/j.joca.2021.02.562>.
- Al-Abbad, H. and Madi, S. (2020) 'Perception of tertiary care clients toward the availability of physical therapy service at primary health care centers in Saudi Arabia: a cross-sectional survey', *Journal of Physical Therapy Science*, 32(5), pp. 323–331.
- Al-Abbad, H.M. and Al-Haidary, H.M. (2016) 'The perception of physical therapy leaders in Saudi Arabia regarding physical therapy scope of practice in primary health care', *Journal of physical therapy science*, 28(1), pp. 112–117.
- Al-Ahmadi, B. and Al-mohandis, E. (2018) 'Knowledge and Attitude of Osteoarthritis Management Among Primary Health Care Physicians at Primary Health Care Centers of Ministry of Health Inside Makkah Al-Mukarramah City, 2018.'

- Al-Amer, R. *et al.* (2016) 'Language translation challenges with Arabic speakers participating in qualitative research studies', *International journal of nursing studies*, 54, pp. 150–157. Available at: <https://doi.org/10.1016/J.IJNURSTU.2015.04.010>.
- Al-Arfaj, A. and Al-Boukai, A.A. (2002) 'Prevalence of radiographic knee osteoarthritis in Saudi Arabia', *Clinical Rheumatology*, 21(2), pp. 142–145. Available at: <https://doi.org/10.1007/s10067-002-8273-8>.
- Al-Ghamdi, S. *et al.* (2020) 'Current self-medication practices in the Kingdom of Saudi Arabia: an observational study', *The Pan African medical journal*, 37(51), p. 51. Available at: <https://doi.org/10.11604/pamj.2020.37.51.24098>.
- Al-Khlaifat, L. *et al.* (2016) 'The effectiveness of an exercise programme on dynamic balance in patients with medial knee osteoarthritis: A pilot study', *The knee*, 23(5), pp. 849–856.
- Al-Modeer, M.A., Hassanien, N.S. and Jabloun, C.M. (2013) 'Profile of morbidity among elderly at home health care service in Southern Saudi Arabia', *Journal of family & community medicine*, 20(1), pp. 53–57. Available at: <https://doi.org/10.4103/2230-8229.108187>.
- Al-Otaibi, M.L. (2021) 'Total knee replacement at Southwestern Saudi Arabia: A single-center experience.', *Journal of family medicine and primary care*, 10(6), pp. 2166–2170. Available at: https://doi.org/10.4103/jfmpc.jfmpc_2440_20.
- Al-Sobayel, H. *et al.* (2014) 'Rehabilitation Services in Saudi Arabia: An Overview of its Current Structure and Future Challenges', *Journal of general practice*, 2, pp. 1–4. Available at: <https://api.semanticscholar.org/CorpusID:31328347>.
- Al-Zahrani, K.S. and Bakheit, A.M.O. (2002) 'A study of the gait characteristics of patients with chronic osteoarthritis of the knee', *Disability and rehabilitation*, 24(5), pp. 275–280. Available at: <https://doi.org/10.1080/09638280110087098>.
- Alanazi, A.M. *et al.* (2023) 'The Intersection of Health Rehabilitation Services with Quality of Life in Saudi Arabia: Current Status and Future Needs', in *Healthcare*. MDPI, p. 389.
- Albaker, A.B. *et al.* (2024) 'Awareness and Management of Knee Pain and Osteoarthritis in Saudi Arabia: A Cross-Sectional Analysis', *Curēus (Palo Alto, CA)*, 16(1), pp. e52736–e52736. Available at: <https://doi.org/10.7759/cureus.52736>.
- Alderink, G.J. (2006) 'Joint Structure and Function: A Comprehensive Analysis, ed 4', *Physical Therapy*, 86(4), pp. 598–599. Available at: <https://doi.org/10.1093/ptj/86.4.598a>.
- Aleisa, E. *et al.* (2014) 'Rehabilitation services in Saudi Arabia: An overview of its current structure and future challenges', *Journal of General Practice* [Preprint].
- Alfadda, A.A. *et al.* (2016) 'The Saudi clinical practice guideline for the management of overweight and obesity in adults.', *Saudi medical journal*, 37(10), pp. 1151–1162. Available at: <https://doi.org/10.15537/smj.2016.10.14353>.
- Alfatafta, H. *et al.* (2021) 'Effect of using knee valgus brace on pain and activity level over different time intervals among patients with medial knee OA: systematic review', *BMC musculoskeletal disorders*, 22(1), pp. 1–9.
- Alghadir, A. *et al.* (2015) 'Physical therapy education in Saudi Arabia', *Journal of Physical Therapy Science*, 27(5), pp. 1621–1623. Available at: <https://doi.org/10.1589/jpts.27.1621>.

Alghadir, A. *et al.* (2016) 'Cross-cultural adaptation, reliability and validity of the Arabic version of the reduced Western Ontario and McMaster Universities Osteoarthritis index in patients with knee osteoarthritis', *Disability and rehabilitation*, 38(7), pp. 689–694.

Alghadir, A., Anwer, S. and Brismée, J.-M. (2015) 'The reliability and minimal detectable change of Timed Up and Go test in individuals with grade 1 - 3 knee osteoarthritis', *BMC musculoskeletal disorders*, 16(1), pp. 174–174. Available at: <https://doi.org/10.1186/s12891-015-0637-8>.

Alkalash, S.H. *et al.* (2023) 'Public Knowledge of Osteoarthritis in Al- Qunfudah Governorate, Saudi Arabia', *Cureus (Palo Alto, CA)*, 15(2), pp. e34892–e34892. Available at: <https://doi.org/10.7759/cureus.34892>.

Allum, J.H.J. and Carpenter, M.G. (2005) 'A speedy solution for balance and gait analysis: Angular velocity measured at the centre of body mass', *Current opinion in neurology*, 18(1), pp. 15–21. Available at: <https://doi.org/10.1097/00019052-200502000-00005>.

Almaawi, A. *et al.* (2022) 'Awareness about total knee replacement among Saudi population', *Journal of Family Medicine and Primary Care*, 11(4). Available at: https://journals.lww.com/jfmpc/fulltext/2022/04000/awareness_about_total_knee_replacement_among_saudi.14.aspx.

Almalki, M., FitzGerald, G. and Clark, M. (2011) 'Health care system in Saudi Arabia: an overview', *EMHJ-Eastern Mediterranean Health Journal*, 17 (10), 784-793, 2011 [Preprint].

Almohammed, B.A. (2023) 'Frequency and knowledge of analgesics self-use and their adverse effects in the Eastern Province of Saudi Arabia', *Cureus*, 15(1).

Almubark, R.A. and Alqahtani, S.A. (2023) 'Epidemiology of obesity and control interventions in Saudi Arabia.', *Eastern Mediterranean health journal = La revue de sante de la Mediterranee orientale = al-Majallah al-sihhiyah li-sharq al-mutawassit*, 29(12), pp. 987–994. Available at: <https://doi.org/10.26719/emhj.23.086>.

Alnahdi, A.H., Zeni, J.A. and Snyder-Mackler, L. (2014) 'Hip abductor strength reliability and association with physical function after unilateral total knee arthroplasty: a cross-sectional study', *Physical therapy*, 94(8), pp. 1154–1162. Available at: <https://doi.org/10.2522/PTJ.20130335>.

Alrowaili, M.G. (2019) 'Magnetic resonance evaluation of knee osteoarthritis among the Saudi population', *Pakistan journal of medical sciences*, 35(6), pp. 1575–1581. Available at: <https://doi.org/10.12669/pjms.35.6.874>.

Alshahrani, A. *et al.* (2023) 'Society's Misconceptions About Intra-articular Injections: A Cross-Sectional Study From Saudi Arabia', *Cureus*, 15(12).

Alshammari, S.Z. (2023) 'Enhancing Awareness of Diclofenac as an Over-the-Counter Analgesic in the Northern Border Region of Saudi Arabia', *Journal of Pharmaceutical Research International*, 35(34), pp. 44–56.

Alshawabka, A.Z. *et al.* (2014) 'The use of a lateral wedge insole to reduce knee loading when ascending and descending stairs in medial knee osteoarthritis patients', *Clinical biomechanics (Bristol)*, 29(6), pp. 650–656. Available at: <https://doi.org/10.1016/j.clinbiomech.2014.04.011>.

Alshehri, M.A. *et al.* (2017) 'Physiotherapists' behaviour, attitudes, awareness, knowledge and barriers in relation to evidence-based practice implementation in

Saudi Arabia: A cross-sectional study', *International journal of evidence-based healthcare*, 15(3), pp. 127–141. Available at: <https://doi.org/10.1097/XEB.000000000000106>.

Alshehri, M.A. *et al.* (2018) 'Factors affecting the extent of utilization of physiotherapy services by physicians in Saudi Arabia', *Journal of Physical Therapy Science*, 30(2), pp. 216–222. Available at: <https://doi.org/10.1589/jpts.30.216>.

Alshenqeeti, H. (2014) 'Interviewing as a Data Collection Method: A Critical Review', *English Linguistics Research*, 3, p. 39.

Althomali, O.W. *et al.* (2023) 'Prevalence of Symptomatic Knee Osteoarthritis in Saudi Arabia and Associated Modifiable and Non-Modifiable Risk Factors: A Population-Based Cross-Sectional Study.', *Healthcare (Basel, Switzerland)*, 11(5). Available at: <https://doi.org/10.3390/healthcare11050728>.

Altman, R. *et al.* (1986) 'Development of criteria for the classification and reporting of osteoarthritis: Classification of osteoarthritis of the knee', *Arthritis & Rheumatism*, 29(8), pp. 1039–1049. Available at: <https://doi.org/10.1002/art.1780290816>.

Altman, R.D. *et al.* (2005) 'Total joint replacement of hip or knee as an outcome measure for structure modifying trials in osteoarthritis', *Osteoarthritis and cartilage*, 13(1), pp. 13–19.

Altowijri, A.A. *et al.* (2023) 'The Prevalence of Knee Osteoarthritis and Its Association With Obesity Among Individuals in Saudi Arabia', *Cureus*, 15(11).

Alyami, A.H. *et al.* (2020) 'General population knowledge about osteoarthritis and its related risk factors in Jeddah Saudi Arabia', *Saudi Medical Journal*, 41(5), pp. 516 LP – 523. Available at: <https://doi.org/10.15537/smj.2020.5.25061>.

Anan, M. *et al.* (2015) 'Do patients with knee osteoarthritis perform sit-to-stand motion efficiently?', *Gait & posture*, 41(2), pp. 488–492. Available at: <https://doi.org/10.1016/j.gaitpost.2014.11.015>.

Anandacoomarasamy, A. and March, L. (2010) 'Current evidence for osteoarthritis treatments', *Therapeutic advances in musculoskeletal disease*, 2(1), pp. 17–28.

Andersen, R.M. *et al.* (2011) *Changing the U.S. Health Care System: Key Issues in Health Services Policy and Management*. Wiley. Available at: <https://books.google.co.uk/books?id=tUJAdvvOKfgC>.

Andriacchi, T.P. (1994) *Dynamics of knee malalignment*, *Orthopedic Clinics of North America*. Elsevier. Available at: [https://doi.org/10.1016/s0030-5898\(20\)31924-6](https://doi.org/10.1016/s0030-5898(20)31924-6).

Andriacchi, T.P. *et al.* (2004) 'A framework for the in vivo pathomechanics of osteoarthritis at the knee', *Annals of Biomedical Engineering*, 32(3), pp. 447–457. Available at: <https://doi.org/10.1023/B:ABME.0000017541.82498.37>.

Andriacchi, T.P. *et al.* (2005) 'Musculoskeletal dynamics, locomotion, and clinical applications', *Basic orthopaedic biomechanics and mechano-biology*, 3, pp. 91–121.

Andriacchi, T.P., Koo, S. and Scanlan, S.F. (2009) 'Gait mechanics influence healthy cartilage morphology and osteoarthritis of the knee', *The Journal of Bone and Joint Surgery. American volume.*, 91(Suppl 1), p. 95.

Andriacchi, T.P. and Mündermann, A. (2006) 'The role of ambulatory mechanics in the initiation and progression of knee osteoarthritis', *Current Opinion in Rheumatology*, pp. 514–518. Available at: <https://doi.org/10.1097/01.bor.0000240365.16842.4e>.

- Angst, F. *et al.* (2002) 'Minimal clinically important rehabilitation effects in patients with osteoarthritis of the lower extremities.', *The Journal of rheumatology*, 29(1), pp. 131–138.
- Arain, M. *et al.* (2010) 'What is a pilot or feasibility study? A review of current practice and editorial policy', *BMC medical research methodology*, 10(1), pp. 1–7. Available at: <https://doi.org/10.1186/1471-2288-10-67>.
- Arazpour, M. *et al.* (2013) 'Comparison of the efficacy of laterally wedged insoles and bespoke unloader knee orthoses in treating medial compartment knee osteoarthritis', *Prosthetics and orthotics international*, 37(1), p. 50-57. Available at: <https://doi.org/http://dx.doi.org/10.1177/0309364612447094>.
- Arendt-Nielsen, L. *et al.* (2010) 'Sensitization in patients with painful knee osteoarthritis', *Pain (Amsterdam)*, 149(3), pp. 573–581. Available at: <https://doi.org/10.1016/j.pain.2010.04.003>.
- Arendt-Nielsen, L. *et al.* (2018) 'Assessment and manifestation of central sensitisation across different chronic pain conditions.', *European journal of pain (London, England)*, 22(2), pp. 216–241. Available at: <https://doi.org/10.1002/ejp.1140>.
- Arendt-Nielsen, L. and Yarnitsky, D. (2009) 'Experimental and Clinical Applications of Quantitative Sensory Testing Applied to Skin, Muscles and Viscera', *The journal of pain*, 10(6), pp. 556–572. Available at: <https://doi.org/10.1016/j.jpain.2009.02.002>.
- Arnold, J. (2016) 'Lateral wedge insoles for people with medial knee osteoarthritis: One size fits all, some or none?', *Osteoarthritis and Cartilage*, 24(2), pp. 193–195.
- Arnold, J.B. *et al.* (2016) 'Lateral Wedge Insoles for Reducing Biomechanical Risk Factors for Medial Knee Osteoarthritis Progression: A Systematic Review and Meta-Analysis', *ARTHRITIS CARE & RESEARCH*, 68(7), pp. 936–951. Available at: <https://doi.org/10.1002/acr.22797>.
- Asmri, M. Al *et al.* (2020) 'The public health care system and primary care services in Saudi Arabia: a system in transition', *Eastern Mediterranean Health Journal*, 26(4), pp. 468–476.
- Astephen, J.L., Deluzio, K.J., Caldwell, G.E. and Dunbar, M.J. (2008) 'Biomechanical changes at the hip, knee, and ankle joints during gait are associated with knee osteoarthritis severity', *Journal of orthopaedic research*, 26(3), pp. 332–341. Available at: <https://doi.org/10.1002/jor.20496>.
- Astephen, J.L., Deluzio, K.J., Caldwell, G.E., Dunbar, M.J., *et al.* (2008) 'Gait and neuromuscular pattern changes are associated with differences in knee osteoarthritis severity levels', 41(4), pp. 868–876. Available at: <https://doi.org/10.1016/j.jbiomech.2007.10.016>.
- Atkins, L. *et al.* (2017) 'A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems', *Implementation science: IS*, 12(1), pp. 77–77. Available at: <https://doi.org/10.1186/s13012-017-0605-9>.
- Aweid, O. *et al.* (2018) 'Treatment modalities for hip and knee osteoarthritis: A systematic review of safety', *Journal of Orthopaedic Surgery*, 26(3), p. 2309499018808669.
- Ayala, G.X. and Elder, J.P. (2011) 'Qualitative methods to ensure acceptability of behavioral and social interventions to the target population', *Journal of Public Health Dentistry*, 71(SUPPL. 1). Available at: <https://doi.org/10.1111/J.1752-7325.2011.00241.X>.

AYIS, S. and DIEPPE, P. (2009) 'The Natural History of Disability and Its Determinants in Adults with Lower Limb Musculoskeletal Pain', *The Journal of Rheumatology*, 36(3), pp. 583 LP – 591. Available at: <https://doi.org/10.3899/jrheum.080455>.

Baan, H. *et al.* (2012) 'Gait Analysis of the Lower Limb in Patients with Rheumatoid Arthritis: A Systematic Review', *Seminars in arthritis and rheumatism*, 41(6), pp. 768-788.e8. Available at: <https://doi.org/10.1016/j.semarthrit.2011.11.009>.

Badley, E.M. (2005) 'Arthritis in Canada: what do we know and what should we know?', *The Journal of Rheumatology Supplement*, 72.

Baert, I.A.C. *et al.* (2014) 'The effect of lateral wedge insoles in patients with medial compartment knee osteoarthritis: balancing biomechanics with pain neuroscience', *Clinical rheumatology*, 33(11), pp. 1529–1538. Available at: <https://doi.org/10.1007/s10067-014-2668-1>.

Bahdailah, A.A. (2019) 'Pattern use of Non-steroidal Anti-inflammatory Drugs among Saudi Community: Patients' Perspective', *Pharmacology, Toxicology and Biomedical Reports*, 5(2).

Baker, K., Goggins, J., Xie, H., Szumowski, K., LaValley, M., Hunter, D.J. and Felson, D.T. (2007) 'A randomized crossover trial of a wedged insole for treatment of knee osteoarthritis', *Arthritis and rheumatism*, 56(4), pp. 1198–1203. Available at: <https://doi.org/10.1002/art.22516>.

Baker, K., Goggins, J., Xie, H., Szumowski, K., LaValley, M., Hunter, D.J., Felson, D.T., *et al.* (2007) 'A randomized crossover trial of a wedged insole for treatment of knee osteoarthritis', *Arthritis and Rheumatism*, 56(4), p. 1198-1203. Available at: <https://doi.org/10.1002/art.22516>.

Baker, S.E. and Edwards, R. (2012) 'How many qualitative interviews is enough'.

Baliunas, A. J. *et al.* (2002) 'Increased knee joint loads during walking are present in subjects with knee osteoarthritis', *OSTEOARTHRITIS AND CARTILAGE*, 10(7), pp. 573–579. Available at: <https://doi.org/10.1053/joca.2002.0797>.

Baliunas, A.J. *et al.* (2002) 'Increased knee joint loads during walking are present in subjects with knee osteoarthritis', *Osteoarthritis and Cartilage*, 10(7), pp. 573–579. Available at: <https://doi.org/10.1053/joca.2002.0797>.

Baniasad, M. *et al.* (2022) 'Knee adduction moment decomposition: Toward better clinical decision-making', *Frontiers in Bioengineering and Biotechnology*, 10, p. 1017711.

Bannuru, R.R. *et al.* (2019) 'OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis', *Osteoarthritis and cartilage*, 27(11), pp. 1578–1589.

Bannuru, R.R.R. *et al.* (2019) 'OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis', *Osteoarthritis and cartilage*, 27(11), pp. 1578–1589. Available at: <https://doi.org/10.1016/J.JOCA.2019.06.011>.

Barbour, K.E. *et al.* (2014) 'Meeting Physical Activity Guidelines and the Risk of Incident Knee Osteoarthritis: A Population-Based Prospective Cohort Study', *Arthritis care & research* (2010), 66(1), pp. 139–146. Available at: <https://doi.org/10.1002/acr.22120>.

Barbour, R. and Kitzinger, J. (1999) *Developing Focus Group Research: Politics, Theory and Practice, Developing Focus Group Research*.

- Barrios, J.A. *et al.* (2009) 'Walking shoes and laterally wedged orthoses in the clinical management of medial tibiofemoral osteoarthritis: a one-year prospective controlled trial.', *The Knee*, 16(2), pp. 136–142. Available at: <https://doi.org/https://dx.doi.org/10.1016/j.knee.2008.10.002>.
- Barrios, J.A. *et al.* (2013) 'Mechanical effectiveness of lateral foot wedging in medial knee osteoarthritis after 1 year of wear', *Journal of Orthopaedic Research*, 31(5), pp. 659–664. Available at: <https://doi.org/10.1002/jor.22252>.
- Barrios, J.A., Crossley, K.M. and Davis, I.S. (2010) 'Gait retraining to reduce the knee adduction moment through real-time visual feedback of dynamic knee alignment', *Journal of biomechanics*, 43(11), pp. 2208–2213. Available at: <https://doi.org/10.1016/j.jbiomech.2010.03.040>.
- Bartlett, S.J. *et al.* (2011) 'Identifying common trajectories of joint space narrowing over two years in knee osteoarthritis', *Arthritis care & research*, 63(12), pp. 1722–1728.
- Barton, C.J. *et al.* (2021) 'Program evaluation of GLA:D® Australia: Physiotherapist training outcomes and effectiveness of implementation for people with knee osteoarthritis', *Osteoarthritis and cartilage open*, 3(3), pp. 100175–100175. Available at: <https://doi.org/10.1016/j.ocarto.2021.100175>.
- Batarfi, M.A. *et al.* (2018) 'Quality of life of patients after total knee arthroplasty at King Abdulaziz University Hospital, Jeddah, Saudi Arabia', *The Egyptian Journal of Hospital Medicine*, 70(9), pp. 1448–1454.
- Bayliss, L.E. *et al.* (2017) 'The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study', *The Lancet*, 389(10077), pp. 1424–1430.
- Beattie, P.P. *et al.* (2005) 'The MedRisk Instrument for Measuring Patient Satisfaction With Physical Therapy Care: A Psychometric Analysis'. Available at: www.jospt.org (Accessed: 5 June 2023).
- Becker, C.B., Darius, E. and Schaumberg, K. (2007) 'An analog study of patient preferences for exposure versus alternative treatments for posttraumatic stress disorder', *Behaviour research and therapy*, 45(12), pp. 2861–2873. Available at: <https://doi.org/10.1016/J.BRAT.2007.05.006>.
- Bedson, J. and Croft, P.R. (2008) 'The discordance between clinical and radiographic knee osteoarthritis: a systematic search and summary of the literature', *BMC musculoskeletal disorders*, 9(1), pp. 1–11. Available at: <https://doi.org/10.1186/1471-2474-9-116>.
- Bejek, Z. *et al.* (2006) 'The influence of walking speed on gait parameters in healthy people and in patients with osteoarthritis', *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA*, 14(7), pp. 612–622. Available at: <https://doi.org/10.1007/s00167-005-0005-6>.
- Bell, M.L. *et al.* (2013) 'Differential dropout and bias in randomised controlled trials: when it matters and when it may not', *BMJ (Online)*, 346(jan21 1), pp. e8668–e8668. Available at: <https://doi.org/10.1136/bmj.e8668>.
- Bellamy, N. *et al.* (1988) 'Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee.', *Journal of rheumatology* [Preprint].

Bellamy, N. (2002) 'WOMAC: a 20-year experiential review of a patient-centered self-reported health status questionnaire.', *The Journal of rheumatology*, 29(12), pp. 2473–2476.

Bennell, K. *et al.* (2007) 'Effects of laterally wedged insoles on symptoms and disease progression in medial knee osteoarthritis: A protocol for a randomised, double-blind, placebo controlled trial', *BMC musculoskeletal disorders*, 8, p. 96. Available at: <https://doi.org/10.1186/1471-2474-8-96>.

Bennell, K.L. *et al.* (2010) 'Hip strengthening reduces symptoms but not knee load in people with medial knee osteoarthritis and varus malalignment: a randomised controlled trial', *OSTEOARTHRITIS AND CARTILAGE*, 18(5), pp. 621–628. Available at: <https://doi.org/10.1016/j.joca.2010.01.010>.

Bennell, Kim L. *et al.* (2011) 'Higher dynamic medial knee load predicts greater cartilage loss over 12 months in medial knee osteoarthritis', *ANNALS OF THE RHEUMATIC DISEASES*, 70(10), pp. 1770–1774. Available at: <https://doi.org/10.1136/ard.2010.147082>.

Bennell, K L *et al.* (2011) 'Lateral wedge insoles for medial knee osteoarthritis: 12 month randomised controlled trial', *BMJ (Clinical research ed.)*, 342, p. d2912. Available at: <https://doi.org/10.1136/bmj.d2912>.

Bennell, Kim L *et al.* (2011) 'Lateral wedge insoles for medial knee osteoarthritis: 12 month randomised controlled trial', *BMJ (Clinical research ed.)*, 342(7808), p. d2912. Available at: <https://doi.org/10.1136/bmj.d2912>.

Bennell, K.L., Buchbinder, R. and Hinman, R.S. (2015) 'Physical therapies in the management of osteoarthritis: current state of the evidence', *Current Opinion in Rheumatology*, 27, pp. 304–311. Available at: <https://api.semanticscholar.org/CorpusID:3605345>.

Bensalma, F. *et al.* (2023) 'Multimodal data analysis of knee osteoarthritis assessment: factors selection for conservative care decision making', *Computer methods in biomechanics and biomedical engineering*, 26(4), pp. 450–459. Available at: <https://doi.org/10.1080/10255842.2022.2066973>.

Berenbaum, F., Eymard, F. and Houard, X. (2013) 'Osteoarthritis, inflammation and obesity', *Current Opinion in Rheumatology*, 25(1). Available at: https://journals.lww.com/co-rheumatology/fulltext/2013/01000/osteoarthritis_inflammation_and_obesity.20.aspx.

Bergen, N. and Labonté, R. (2020) "Everything Is Perfect, and We Have No Problems": Detecting and Limiting Social Desirability Bias in Qualitative Research.', *Qualitative health research*, 30(5), pp. 783–792. Available at: <https://doi.org/10.1177/1049732319889354>.

Berlinberg, A. *et al.* (2019) 'Diagnostic performance of knee physical exam and participant-reported symptoms for MRI-detected effusion-synovitis among participants with early or late stage knee osteoarthritis: data from the Osteoarthritis Initiative.', *Osteoarthritis and cartilage*, 27 1, pp. 80–89. Available at: <https://api.semanticscholar.org/CorpusID:52337061>.

Bijlsma, J.W., Berenbaum, F. and Lafeber, F.P. (2011) 'Osteoarthritis: an update with relevance for clinical practice', *The Lancet (British edition)*, 377(9783), pp. 2115–2126. Available at: [https://doi.org/10.1016/S0140-6736\(11\)60243-2](https://doi.org/10.1016/S0140-6736(11)60243-2).

Bijlsma, J.W.J. and Knahr, K. (2007) 'Strategies for the prevention and management of osteoarthritis of the hip and knee', *Best practice & research Clinical rheumatology*,

21(1), pp. 59–76.

Billingham, S.A., Whitehead, A.L. and Julious, S.A. (2013) 'An audit of sample sizes for pilot and feasibility trials being undertaken in the United Kingdom registered in the United Kingdom Clinical Research Network database', *BMC Medical Research Methodology*, 13(1), pp. 1–6. Available at: <https://doi.org/10.1186/1471-2288-13-104/TABLES/3>.

Birmingham *et al.* (2001) 'Knee bracing for medial compartment osteoarthritis: effects on proprioception and postural control', *Rheumatology (Oxford, England)*, 40(3), pp. 285–289. Available at: <https://doi.org/10.1093/rheumatology/40.3.285>.

Birmingham, T.B. *et al.* (2007) 'Test–retest reliability of the peak knee adduction moment during walking in patients with medial compartment knee osteoarthritis', *Arthritis Care & Research*, 57(6), pp. 1012–1017.

Bliddal, H., Leeds, A.R. and Christensen, R. (2014) 'Osteoarthritis, obesity and weight loss: evidence, hypotheses and horizons—a scoping review', *Obesity reviews*, 15(7), pp. 578–586.

Bombardier, C. *et al.* (1995) 'Comparison of a Generic and a Disease-Specific Measure of Pain and Physical Function after Knee Replacement Surgery', *Medical care*, 33(4), pp. AS131–AS144.

Bonanno, M. *et al.* (2023) 'Gait Analysis in Neurorehabilitation: From Research to Clinical Practice', *Bioengineering (Basel)*, 10(7), p. 785. Available at: <https://doi.org/10.3390/bioengineering10070785>.

Booij, M.J.J. *et al.* (2020) 'Effect of walking with a modified gait on activation patterns of the knee spanning muscles in people with medial knee osteoarthritis', *KNEE*, 27(1), pp. 198–206. Available at: <https://doi.org/10.1016/j.knee.2019.10.006>.

Borenstein, M. *et al.* (2009) 'Effect sizes for continuous data', *The handbook of research synthesis and meta-analysis*, 2, pp. 221–235.

Borrelli, B. *et al.* (2005) 'A new tool to assess treatment fidelity and evaluation of treatment fidelity across 10 years of health behavior research', *Journal of consulting and clinical psychology*, 73(5), pp. 852–860. Available at: <https://doi.org/10.1037/0022-006X.73.5.852>.

Bowd, J. *et al.* (2019) 'Does Gait Retraining Have the Potential to Reduce Medial Compartmental Loading in Individuals With Knee Osteoarthritis While Not Adversely Affecting the Other Lower Limb Joints? A Systematic Review', *Archives of Rehabilitation Research and Clinical Translation*, 1(3–4), p. 100022. Available at: <https://doi.org/10.1016/j.arrct.2019.100022>.

Bradley, E.H., Curry, L.A. and Devers, K.J. (2007) 'Qualitative data analysis for health services research: developing taxonomy, themes, and theory', *Health services research*, 42(4), pp. 1758–1772. Available at: <https://doi.org/10.1111/J.1475-6773.2006.00684.X>.

Brandon, S.C.E. *et al.* (2014) 'Selective lateral muscle activation in moderate medial knee osteoarthritis subjects does not unload medial knee condyle', *Journal of Biomechanics*, 47(6), pp. 1409–1415.

Brandt, K.D. *et al.* (2006) 'Yet more evidence that osteoarthritis is not a cartilage disease'. BMJ Publishing Group Ltd.

Braun, V. and Clarke, V. (2006) 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, 3(2), pp. 77–101. Available at:

<https://doi.org/10.1191/1478088706qp063oa>.

Briani, R. V *et al.* (2017) 'Different pain responses to distinct levels of physical activity in women with patellofemoral pain', *Brazilian Journal of Physical Therapy*, 21(2), pp. 138–143.

Brignardello-Petersen, R. *et al.* (2017) 'Knee arthroscopy versus conservative management in patients with degenerative knee disease: a systematic review', *BMJ open*, 7(5), p. e016114.

Brinkmann, J.R. and Perry, J. (1985) 'Rate and range of knee motion during ambulation in healthy and arthritic subjects.', *Physical therapy*, 65(7), pp. 1055–1060. Available at: <https://doi.org/10.1093/ptj/65.7.1055>.

Brisson, N.M., Gatti, A.A. and Maly, M.R. (2020) 'Association of Pain and Steps Per Day in Persons With Mild-to-Moderate, Symptomatic Knee Osteoarthritis: A Mixed-Effects Models Analysis of Multiple Measurements Over Three Years', *Arthritis care & research* (2010), 72(1), pp. 114–121. Available at: <https://doi.org/10.1002/acr.23842>.

Brix, L.D. *et al.* (2019) 'The Effect of Text Messaging on Medication Adherence After Outpatient Knee Arthroscopy: A Randomized Controlled Trial.', *Journal of perianesthesia nursing : official journal of the American Society of PeriAnesthesia Nurses* [Preprint]. Available at: <https://api.semanticscholar.org/CorpusID:73725828>.

Brophy, R.H. and Fillingham, Y.A. (2022) 'AAOS Clinical Practice Guideline Summary: Management of Osteoarthritis of the Knee (Nonarthroplasty), Third Edition', *JAAOS - Journal of the American Academy of Orthopaedic Surgeons*, 30(9). Available at: https://journals.lww.com/jaaos/fulltext/2022/05010/aaos_clinical_practice_guideline_summary_10.aspx.

Brouwer, G.M. *et al.* (2007) 'Association between valgus and varus alignment and the development and progression of radiographic osteoarthritis of the knee', *Arthritis and Rheumatism*, 56(4), pp. 1204–1211. Available at: <https://doi.org/10.1002/art.22515>.

Brouwer, R.W. *et al.* (2014) 'Osteotomy for treating knee osteoarthritis', *Cochrane Database of Systematic Reviews* [Preprint], (12).

Brown, T.D. *et al.* (2006) 'Posttraumatic osteoarthritis: a first estimate of incidence, prevalence, and burden of disease', *Journal of orthopaedic trauma*, 20(10), pp. 739–744.

Brueton, V. *et al.* (2011) 'Strategies to reduce attrition in randomised trials', *Trials*, 12, p. 1.

Brunelli, R. *et al.* (2015) 'Comparison of spatial and temporal variables of gait between individuals above and below 65 years with bilateral knee osteoarthritis', *Physiotherapy*, 101. Available at: <https://api.semanticscholar.org/CorpusID:79381254>.

Bryman, A. (2016) *Social research methods*. 4th ed. Oxford: Oxford university press.

Buckwalter, J.A., Mankin, H.J. and Grodzinsky, A.J. (2005) 'Articular cartilage and osteoarthritis', *Instructional Course Lectures-American Academy of Orthopaedic Surgeons*, 54, p. 465.

Buckwalter, J.A., Martin, J.A. and Brown, T.D. (2006) 'Perspectives on chondrocyte mechanobiology and osteoarthritis', *Biorheology*, 43(3, 4), pp. 603–609.

Bullough, P.G. (2007) 'Joints', *Histology for pathologists*, 3rd edn. Lippincott Williams

& Wilkins, Philadelphia, pp. 97–121.

Burmeister, E. and Aitken, L.M. (2012) 'Sample size: how many is enough?', *Australian critical care : official journal of the Confederation of Australian Critical Care Nurses*, 25(4), pp. 271–274. Available at: <https://doi.org/10.1016/j.aucc.2012.07.002>.

Burnard, P. *et al.* (2008) 'Analysing and presenting qualitative data'. Available at: <https://doi.org/10.1038/sj.bdj.2008.292>.

Burr, D.B. (2004) 'Anatomy and physiology of the mineralized tissues: role in the pathogenesis of osteoarthritis', *Osteoarthritis and cartilage*, 12, pp. 20–30.

Butler, R.J. *et al.* (2007) 'The effect of a subject-specific amount of lateral wedge on knee mechanics in patients with medial knee osteoarthritis', *Journal of Orthopaedic Research*, 25(9), pp. 1121–1127. Available at: <https://doi.org/10.1002/jor.20423>.

Buxton, B.K. and Snethen, J. (2013) 'Obese Women's Perceptions and Experiences of Healthcare and Primary Care Providers: A Phenomenological Study', *Nursing Research*, 62(4). Available at: https://journals.lww.com/nursingresearchonline/fulltext/2013/07000/obese_women_s_perceptions_and_experiences_of.6.aspx.

Caldwell, L.K., Laubach, L.L. and Barrios, J.A. (2013) 'Effect of specific gait modifications on medial knee loading, metabolic cost and perception of task difficulty', *CLINICAL BIOMECHANICS*, 28(6), pp. 649–654. Available at: <https://doi.org/10.1016/j.clinbiomech.2013.05.012>.

Cameron, R. (2011) 'Mixed methods research: The five Ps framework', *Electronic journal of business research methods*, 9(2), pp. 96–108.

Campbell, M. *et al.* (2007) 'Recruitment to randomised trials: strategies for trial enrolment and participation study. The STEPS study', *Health technology assessment (Winchester, England)*, 11(48). Available at: <https://doi.org/10.3310/hta11480>.

Campbell, R. *et al.* (2001) 'Why don't patients do their exercises? Understanding non-compliance with physiotherapy in patients with osteoarthritis of the knee', *J Epidemiol Community Health*, 55, pp. 132–138. Available at: <https://doi.org/10.1136/jech.55.2.132>.

de Campos, G.C. *et al.* (2015) 'Lateral wedge insole for knee osteoarthritis: randomized clinical trial', *Sao paulo medical journal*, 133(1), p. 13-19. Available at: <https://doi.org/10.1590/1516-3180.2013.6750002>.

Canetti, E.F.D. *et al.* (2020) 'Risk factors for development of lower limb osteoarthritis in physically demanding occupations: A systematic review and meta-analysis', *Applied ergonomics*, 86, p. 103097.

Cao, Y., Tang, S. and Ding, C. (2021) 'Inflammatory phenotype of osteoarthritis and its potential therapies', *Rheumatology & Autoimmunity*, 1(02), pp. 92–100.

Cappozzo, A. *et al.* (2005) 'Human movement analysis using stereophotogrammetry: Part 1: theoretical background', *Gait & posture*, 21(2), pp. 186–196.

Carlisle, B. *et al.* (2015) 'Unsuccessful trial accrual and human subjects protections: An empirical analysis of recently closed trials', *Clinical trials (London, England)*, 12(1), pp. 77–83. Available at: <https://doi.org/10.1177/1740774514558307>.

Carlson, A.K. *et al.* (2019) 'Characterization of synovial fluid metabolomic phenotypes of cartilage morphological changes associated with osteoarthritis', *Osteoarthritis and Cartilage*, 27(8), pp. 1174–1184. Available at:

<https://doi.org/10.1016/j.joca.2019.04.007>.

Carr, A. (2001) 'Barriers to the effectiveness of any intervention in OA', *Best Practice and Research: Clinical Rheumatology*, 15(4), pp. 645–656. Available at: <https://doi.org/10.1053/berh.2001.0179>.

Caudron, S. *et al.* (2014) 'Evaluation of a visual biofeedback on the postural control in Parkinson's disease', *Neurophysiologie Clinique/Clinical Neurophysiology*, 44(1), pp. 77–86.

Cavanaugh, J.T. *et al.* (2007) 'Using Step Activity Monitoring to Characterize Ambulatory Activity in Community-Dwelling Older Adults', *Journal of the American Geriatrics Society (JAGS)*, 55(1), pp. 120–124. Available at: <https://doi.org/10.1111/j.1532-5415.2006.00997.x>.

Centers for Disease Control and Prevention, (CDC). (2007) 'National and state medical expenditures and lost earnings attributable to arthritis and other rheumatic conditions--United States, 2003', *MMWR. Morbidity and mortality weekly report*, 56(1), pp. 4–7.

Chan, P.P. *et al.* (2017) 'Reliability and Validity of the Timed Up and Go Test With a Motor Task in People With Chronic Stroke', *Archives of physical medicine and rehabilitation*, 98(11), pp. 2213–2220. Available at: <https://doi.org/10.1016/j.apmr.2017.03.008>.

Chang, A. *et al.* (2004) 'Thrust during ambulation and the progression of knee osteoarthritis', 50(12), pp. 3897–3903. Available at: <https://onlinelibrary.wiley.com/doi/full/10.1002/art.20657> (Accessed: 21 April 2021).

Chang, A. *et al.* (2005) 'Hip abduction moment and protection against medial tibiofemoral osteoarthritis progression', 52(11), pp. 3515–3519. Available at: <https://doi.org/10.1002/art.21406>.

Chang, A.H. *et al.* (2015) 'External knee adduction and flexion moments during gait and medial tibiofemoral disease progression in knee osteoarthritis', *OSTEOARTHRITIS AND CARTILAGE*, 23(7), pp. 1099–1106. Available at: <https://doi.org/10.1016/j.joca.2015.02.005>.

Charlton, J.M.J.M., Kobsar, D. and Hunt, M.A.M.A. (2019) 'Does dynamic knee adduction angle impact clinical response to a toe-out gait modification intervention?', *Osteoarthritis and cartilage*, 27, p. S112-S113. Available at: <https://doi.org/10.1016/j.joca.2019.02.168>.

Chen, H. *et al.* (2008) 'Inverse association of general joint hypermobility with hand and knee osteoarthritis and serum cartilage oligomeric matrix protein levels', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 58(12), pp. 3854–3864.

Chen, L. *et al.* (2020) 'Pathogenesis and clinical management of obesity-related knee osteoarthritis: Impact of mechanical loading', *Journal of Orthopaedic Translation*, 24, pp. 66–75. Available at: <https://doi.org/https://doi.org/10.1016/j.jot.2020.05.001>.

Chesworth, B.M. *et al.* (2008) 'Willingness to go through surgery again validated the WOMAC clinically important difference from THR/TKR surgery', *Journal of clinical epidemiology*, 61(9), pp. 907–918. Available at: <https://doi.org/10.1016/j.jclinepi.2007.10.014>.

Cheung, R.T.H. *et al.* (2018) 'Immediate and short-term effects of gait retraining on the knee joint moments and symptoms in patients with early tibiofemoral joint

osteoarthritis: a randomized controlled trial', *Osteoarthritis and cartilage*, 26(11), p. 1479-1486. Available at: <https://doi.org/10.1016/j.joca.2018.07.011>.

Childs, J D *et al.* (2004) 'Alterations in lower extremity movement and muscle activation patterns in individuals with knee osteoarthritis', *CLINICAL BIOMECHANICS*, 19(1), pp. 44–49. Available at: <https://doi.org/10.1016/j.clinbiomech.2003.08.007>.

Childs, John D *et al.* (2004) 'Alterations in lower extremity movement and muscle activation patterns in individuals with knee osteoarthritis', *CLINICAL BIOMECHANICS*, 19(1), pp. 44–49. Available at: <https://doi.org/10.1016/j.clinbiomech.2003.08.007>.

Chow, Y.Y. and Chin, K.-Y. (2020) 'The Role of Inflammation in the Pathogenesis of Osteoarthritis', *Mediators of Inflammation*, 2020(1), p. 8293921. Available at: <https://doi.org/https://doi.org/10.1155/2020/8293921>.

Chowdhury, S., Mok, D. and Leenen, L. (2021) 'Transformation of health care and the new model of care in Saudi Arabia: Kingdom's Vision 2030', *Journal of medicine and life*, 2021(3), pp. 347–354. Available at: <https://doi.org/10.25122/jml-2021-0070>.

Christ, T.W. (2013) 'The worldview matrix as a strategy when designing mixed methods research', *International journal of multiple research approaches*, 7(1), pp. 110–118. Available at: <https://doi.org/10.5172/mra.2013.7.1.110>.

Christensen, R. *et al.* (2007) 'Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis', *Annals of the Rheumatic Diseases*, 66(4), pp. 433 LP – 439. Available at: <https://doi.org/10.1136/ard.2006.065904>.

Cirillo, D.J. *et al.* (2006) 'Effect of hormone therapy on risk of hip and knee joint replacement in the Women's Health Initiative', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 54(10), pp. 3194–3204.

Clouet, J. *et al.* (2009) 'From osteoarthritis treatments to future regenerative therapies for cartilage', *Drug discovery today*, 14(19–20), pp. 913–925.

Cohen, J. (1992) 'A power primer.', *Psychological bulletin*, 112(1), p. 155. Available at: <https://doi.org/10.1037//0033-2909.112.1.155>.

Colbert, C.J.C.J. *et al.* (2012) 'Knee Confidence as it Relates to Physical Function Outcome in Persons with or at Higher Risk for Knee Osteoarthritis in the Osteoarthritis Initiative', *Arthritis and rheumatism*, 64(5), pp. 1437–1446. Available at: <https://doi.org/10.1002/art.33505>.

Collins, J.W. and O'Brien, N.P. (2011) *The Greenwood dictionary of education*. ABC-CLIO.

Collins, N.J., Hart, H.F. and Mills, K.A.G. (2019) 'Osteoarthritis year in review 2018: rehabilitation and outcomes', *Osteoarthritis and cartilage*, 27(3), pp. 378–391.

Colloca, L. and Benedetti, F. (2006) 'How prior experience shapes placebo analgesia', *Pain (Amsterdam)*, 124(1), pp. 126–133. Available at: <https://doi.org/10.1016/j.pain.2006.04.005>.

Conaghan, P.G., Emerton, M. and Tennant, A. (2007) 'Internal construct validity of the Oxford Knee Scale: Evidence from Rasch measurement', *Arthritis and rheumatism*, 57(8), pp. 1363–1367. Available at: <https://doi.org/10.1002/art.23091>.

Copay, A.G. *et al.* (2007) 'Understanding the minimum clinically important difference: a review of concepts and methods.', *The spine journal: official journal of the North American Spine Society*, 7(5), pp. 541–546. Available at:

<https://doi.org/10.1016/j.spinee.2007.01.008>.

Corrêa Dias, R., Domingues Dias, J.M. and Ramos, L.R. (2003) 'Impact of an exercise and walking protocol on quality of life for elderly people with OA of the knee', *Physiotherapy Research International*, 8(3), pp. 121–130.

da Costa, B.R. *et al.* (2017) 'Effectiveness of non-steroidal anti-inflammatory drugs for the treatment of pain in knee and hip osteoarthritis: a network meta-analysis', *The Lancet*, 390(10090), pp. e21–e33. Available at: [https://doi.org/10.1016/S0140-6736\(17\)31744-0](https://doi.org/10.1016/S0140-6736(17)31744-0).

Costello, K.E. *et al.* (2021) 'Ground reaction force patterns in knees with and without radiographic osteoarthritis and pain: descriptive analyses of a large cohort (the Multicenter Osteoarthritis Study).', *Osteoarthritis and cartilage*, 29(8), pp. 1138–1146. Available at: <https://doi.org/10.1016/j.joca.2021.03.009>.

Covinsky, K.E. *et al.* (2008) 'Effect of arthritis in middle age on older-age functioning', *Journal of the American geriatrics society*, 56(1), pp. 23–28.

Craig, P. *et al.* (2008) 'Developing and evaluating complex interventions: the new Medical Research Council guidance', *BMJ (Clinical research ed.)*, 337(7676), pp. 979–983. Available at: <https://doi.org/10.1136/BMJ.A1655>.

Craig, P. *et al.* (2013) 'Developing and evaluating complex interventions: the new Medical Research Council guidance.'

Crea, S. *et al.* (2014) 'Providing time-discrete gait information by wearable feedback apparatus for lower-limb amputees: usability and functional validation', *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 23(2), pp. 250–257.

Creamer, P., Lethbridge-Cejku, M. and Hochberg, M.C. (1999) 'Determinants of pain severity in knee osteoarthritis: Effect of demographic and psychosocial variables using 3 pain measures', *JOURNAL OF RHEUMATOLOGY*, 26(8), pp. 1785–1792.

Crema, M.D. *et al.* (2011) 'The association of magnetic resonance imaging (MRI)-detected structural pathology of the knee with crepitus in a population-based cohort with knee pain: the MoDEKO study', *Osteoarthritis and cartilage*, 19(12), pp. 1429–1432.

Crenshaw, S.J., Pollo, F.E. and Calton, E.F. (2000) 'Effects of lateral-wedged insoles on kinetics at the knee', *Clinical orthopaedics and related research*, (375), p. 185–192. Available at: <https://doi.org/10.1097/00003086-200006000-00022>.

Creswell, J.W. (2015) *Qualitative inquiry & research design: choosing among five approaches*. 4th ed., I. Edited by C.N. Poth. London: SAGE Publications.

Creswell, J.W. (2018) *Designing and conducting mixed methods research*. Third edit. Edited by V.L. Plano Clark. SAGE.

Creswell, J.W. (2022) *A concise introduction to mixed methods research*. Second edi. SAGE.

Creswell, J.W. (2023) *Research design: qualitative, quantitative, and mixed methods approaches*. Sixth edition. Edited by J.D. Creswell. SAGE.

Cui, A. *et al.* (2020a) 'Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)', *EClinicalMedicine*, 29–30, p. 100587. Available at: <https://doi.org/10.1016/j.eclinm.2020.100587>.

Cui, A. *et al.* (2020b) 'Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies', *EClinicalMedicine*, 29, p. 100587. Available at: <https://doi.org/10.1016/j.eclim.2020.100587>.

Cullen, D.M., Smith, R.T. and Akhter, M.P. (2001) 'Bone-loading response varies with strain magnitude and cycle number.', *Journal of applied physiology*, 91 5, pp. 1971–1976. Available at: <https://api.semanticscholar.org/CorpusID:7472978>.

Culliford, D.J. *et al.* (2012) 'The lifetime risk of total hip and knee arthroplasty: results from the UK general practice research database', *Osteoarthritis and cartilage*, 20(6), pp. 519–524.

Curry, L.A., Nembhard, I.M. and Bradley, E.H. (2009) 'Qualitative and Mixed Methods Provide Unique Contributions to Outcomes Research', *Circulation*, 119(10), pp. 1442–1452. Available at: <https://doi.org/10.1161/CIRCULATIONAHA.107.742775>.

Van Damme, S., Crombez, G. and Eccleston, C. (2004) 'Disengagement from pain: the role of catastrophic thinking about pain', *Pain (Amsterdam)*, 107(1), pp. 70–76. Available at: <https://doi.org/10.1016/j.pain.2003.09.023>.

Dar, G. *et al.* (2014) 'The Effectiveness of a Multimedia Messaging Service Reminder System in the Management of Knee Osteoarthritis: A Pilot Study', *International Journal of Physical Medicine and Rehabilitation*, 05, pp. 483–489. Available at: <https://api.semanticscholar.org/CorpusID:16650089>.

Data Analysis Software Blog | NVivo (no date). Available at: <https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/resources/blog/whats-new-in-nvivo-12> (Accessed: 27 January 2023).

Dawson, J. *et al.* (1998) 'Questionnaire on the perceptions of patients about total knee replacement.', *The Journal of bone and joint surgery. British volume*, 80(1), pp. 63–69. Available at: <https://doi.org/10.1302/0301-620x.80b1.7859>.

Day, S. *et al.* (2021) 'Professional development training preferences of occupational therapists working with older adults in Australia: A discrete choice experiment.', *Australian occupational therapy journal* [Preprint]. Available at: <https://api.semanticscholar.org/CorpusID:233277787>.

Daykin, A.R. and Richardson, B. (2004) 'Physiotherapists' Pain Beliefs and Their Influence on the Management of Patients with Chronic Low Back Pain', *Spine (Philadelphia, Pa. 1976)*, 29(7), pp. 783–795. Available at: <https://doi.org/10.1097/01.BRS.0000115135.19082.97>.

Deandrea, S. *et al.* (2010) 'Risk factors for falls in community-dwelling older people: A systematic review and meta-analysis', *Epidemiology*, pp. 658–668. Available at: <https://doi.org/10.1097/EDE.0b013e3181e89905>.

Debi, R. *et al.* (2009) 'Differences in gait patterns, pain, function and quality of life between males and females with knee osteoarthritis: a clinical trial.', *BMC musculoskeletal disorders*, 10, p. 127. Available at: <https://doi.org/10.1186/1471-2474-10-127>.

Dechartres, A. *et al.* (2013) 'Influence of trial sample size on treatment effect estimates: meta-epidemiological study', *BMJ : British Medical Journal*, 346, p. f2304. Available at: <https://doi.org/10.1136/bmj.f2304>.

Diepeveen, S. *et al.* (2013) 'Public acceptability of government intervention to change health-related behaviours: A systematic review and narrative synthesis', *BMC Public Health*, 13(1), pp. 1–11. Available at: <https://doi.org/10.1186/1471-2458-13->

Dieppe, P.A. and Lohmander, L.S. (2005) 'Pathogenesis and management of pain in osteoarthritis', *The Lancet*, 365(9463), pp. 965–973. Available at: [https://doi.org/10.1016/S0140-6736\(05\)71086-2](https://doi.org/10.1016/S0140-6736(05)71086-2).

van Dijk, G.M. *et al.* (2010) 'Prognosis of Limitations in Activities in Osteoarthritis of the Hip or Knee: A 3-Year Cohort Study', *Archives of physical medicine and rehabilitation*, 91(1), pp. 58–66. Available at: <https://doi.org/10.1016/j.apmr.2009.08.147>.

Dillip, A. *et al.* (2012) 'Acceptability - A neglected dimension of access to health care: Findings from a study on childhood convulsions in rural Tanzania', *BMC Health Services Research*, 12(1), pp. 1–11. Available at: <https://doi.org/10.1186/1472-6963-12-113/TABLES/2>.

Dillon, C.F. *et al.* (2006) 'Prevalence of knee osteoarthritis in the United States: Arthritis data from the Third National Health and Nutrition Examination Survey 1991-94', *Journal of Rheumatology*, pp. 2271–2279. Available at: <https://europepmc.org/article/med/17013996> (Accessed: 5 May 2021).

Dionyssiatis, Y. (2012) 'Analyzing the problem of falls among older people', *International Journal of General Medicine*, 5(default), pp. 805–813. Available at: <https://doi.org/10.2147/IJGM.S32651>.

Divine, J.G. and Hewett, T.E. (2015) 'Valgus Bracing for Degenerative Knee Osteoarthritis', <http://dx.doi.org/10.3810/psm.2005.02.48>, 33(2), pp. 40–46. Available at: <https://doi.org/10.3810/PSM.2005.02.48>.

Dobson, F. *et al.* (2013) 'OARSI recommended performance-based tests to assess physical function in people diagnosed with hip or knee osteoarthritis', *Osteoarthritis and cartilage*, 21(8), pp. 1042–1052. Available at: <https://doi.org/10.1016/j.joca.2013.05.002>.

Dolan, A.L. *et al.* (2003) 'The relationship of joint hypermobility, bone mineral density, and osteoarthritis in the general population: the Chingford Study.', *The Journal of rheumatology*, 30(4), pp. 799–803.

Dominick, K.L. *et al.* (2004) 'Health-related quality of life and health service use among older adults with osteoarthritis', *Arthritis Care & Research*, 51(3), pp. 326–331. Available at: <https://doi.org/https://doi.org/10.1002/art.20390>.

Doré, D.A. *et al.* (2013) 'The association between objectively measured physical activity and knee structural change using MRI', *Annals of the rheumatic diseases*, 72(7), pp. 1170–1175. Available at: <https://doi.org/10.1136/annrheumdis-2012-201691>.

Dorleijn, D.M.J. *et al.* (2014) 'Associations between weather conditions and clinical symptoms in patients with hip osteoarthritis: A 2-year cohort study', *PAIN®*, 155(4), pp. 808–813. Available at: <https://doi.org/https://doi.org/10.1016/j.pain.2014.01.018>.

Dougados, M. *et al.* (1992) 'Longitudinal radiologic evaluation of osteoarthritis of the knee', *The Journal of rheumatology*, 19(3), pp. 378–384. Available at: <http://europepmc.org/abstract/MED/1578451>.

Dowsey, M.M. *et al.* (2012) 'Associations between pre-operative radiographic changes and outcomes after total knee joint replacement for osteoarthritis', *Osteoarthritis and Cartilage*, 20(10), pp. 1095–1102.

Dowsey, M.M. *et al.* (2016) 'Associations between pre-operative radiographic

osteoarthritis severity and pain and function after total hip replacement', *Clinical rheumatology*, 35(1), pp. 183–189.

Draganich, L. *et al.* (2006) 'The effectiveness of self-adjustable custom and off-the-shelf bracing in the treatment of varus gonarthrosis', *Journal of Bone and Joint Surgery - Series A*, 88(12), pp. 2645–2652. Available at: <https://doi.org/10.2106/JBJS.D.02787>.

Draper, E.R.C. *et al.* (2000) 'Improvement in function after valgus bracing of the knee - An analysis of gait symmetry', *JOURNAL OF BONE AND JOINT SURGERY-BRITISH VOLUME*, 82B(7), pp. 1001–1005. Available at: <https://doi.org/10.1302/0301-620X.82B7.10638>.

Duffell, L.D. *et al.* (2014) 'Balance and gait adaptations in patients with early knee osteoarthritis', *Gait and Posture*, 39(4), pp. 1057–1061. Available at: <https://doi.org/10.1016/j.gaitpost.2014.01.005>.

Duivenvoorden, T. *et al.* (2014) 'Do laterally wedged insoles and valgus knee braces really unload the medial compartment of the knee? Results of a RCT', *Osteoarthritis and cartilage*, 22, p. S455-S456. Available at: <https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01064054/full>.

Duivenvoorden, Tijs *et al.* (2015) 'Braces and orthoses for treating osteoarthritis of the knee', *Cochrane Database of Systematic Reviews*, 2015(3). Available at: <https://doi.org/10.1002/14651858.CD004020.pub3>.

Duivenvoorden, T *et al.* (2015) 'Do laterally wedged insoles or valgus braces unload the medial compartment of the knee in patients with osteoarthritis?', *Clinical orthopaedics and related research*, 473(1), p. 265-274. Available at: <https://doi.org/10.1007/s11999-014-3947-5>.

Dumville, J.C., Torgerson, D.J. and Hewitt, C.E. (2006) 'Reporting attrition in randomised controlled trials', *BMJ (Clinical research ed.)*, 332(7547), pp. 969–971. Available at: <https://doi.org/10.1136/BMJ.332.7547.969>.

Dunlop, D.D. *et al.* (2005) 'Risk factors for functional decline in older adults with arthritis', *Arthritis and rheumatism*, 52(4), pp. 1274–1282. Available at: <https://doi.org/10.1002/art.20968>.

Dunlop, D.D. *et al.* (2011) 'Physical activity levels and functional performance in the osteoarthritis initiative: A graded relationship', *Arthritis and rheumatism*, 63(1), pp. 127–136. Available at: <https://doi.org/10.1002/art.27760>.

Dydyk, A.M. and Givler, A. (2020) 'Central pain syndrome'.

Eddo, O. *et al.* (2017) 'Current evidence of gait modification with real-time biofeedback to alter kinetic, temporospatial, and function-related outcomes: a review'.

Edwards, R. and Holland, J. (2013) *What is Qualitative Interviewing?* 1st edn. London: Bloomsbury Publishing Plc ('What is?' research methods series). Available at: <https://doi.org/10.5040/9781472545244>.

Egerton, T. *et al.* (2016) 'Barriers and enablers in primary care clinicians' management of osteoarthritis: protocol for a systematic review and qualitative evidence synthesis', *BMJ Open*, 6(5), p. e011618. Available at: <https://doi.org/10.1136/bmjopen-2016-011618>.

Egerton, T. *et al.* (2020) 'PARTNER: a service delivery model to implement optimal primary care management of people with knee osteoarthritis: description of development', *BMJ open*, 10(10), p. e040423.

El-Kotob, R. and Giangregorio, L.M. (2018) 'Pilot and feasibility studies in exercise, physical activity, or rehabilitation research', *Pilot and feasibility studies*, 4(1), pp. 137–137. Available at: <https://doi.org/10.1186/s40814-018-0326-0>.

Eldridge, S. *et al.* (2008) 'Internal and external validity of cluster randomised trials: systematic review of recent trials', *BMJ. International edi...*, 336(7649), pp. 876–880. Available at: <https://doi.org/10.1136/bmj.39517.495764.25>.

Eldridge, S.M. *et al.* (2016) 'Defining feasibility and pilot studies in preparation for randomised controlled trials: Development of a conceptual framework', *PloS one*, 11(3), pp. e0150205–e0150205. Available at: <https://doi.org/10.1371/journal.pone.0150205>.

Eldridge, S.M. *et al.* (no date) 'CONSORT 2010 statement: extension to randomised pilot and feasibility trials'. Available at: <https://doi.org/10.1136/bmj.i5239>.

Elmisbah, H.O. *et al.* (2024) 'Awareness and Perception Toward Obesity and Knee Osteoarthritis and Their Preventive Measures Among the Adult Population in the Northern Borders Region, Saudi Arabia', *Cureus*, 16(2).

Elo, S. *et al.* (2014) 'Qualitative Content Analysis', *SAGE open*, 4(1), p. 215824401452263. Available at: <https://doi.org/10.1177/2158244014522633>.

Englund, M. *et al.* (2008) 'Incidental Meniscal Findings on Knee MRI in Middle-Aged and Elderly Persons', *New England Journal of Medicine*, 359(11), pp. 1108–1115. Available at: <https://doi.org/10.1056/NEJMoa0800777>.

Englund, M. and Lohmander, L.S. (2004) 'Risk factors for symptomatic knee osteoarthritis fifteen to twenty-two years after meniscectomy', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 50(9), pp. 2811–2819.

Englund, M., Roos, E.M. and Lohmander, L.S. (2003) 'Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: a sixteen-year followup of meniscectomy with matched controls', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 48(8), pp. 2178–2187.

Erhart-Hledik, J.C. *et al.* (2012) 'Effect of variable-stiffness walking shoes on knee adduction moment, pain, and function in subjects with medial compartment knee osteoarthritis after 1 year', *Journal of orthopaedic research*, 30(4), p. 514-521. Available at: <https://doi.org/10.1002/jor.21563>.

Erhart, J.C. *et al.* (2008) 'A variable-stiffness shoe lowers the knee adduction moment in subjects with symptoms of medial compartment knee osteoarthritis', 41(12), pp. 2720–2725. Available at: <https://doi.org/10.1016/j.jbiomech.2008.06.016>.

Erhart, Jennifer C, Dyrby, C.O., *et al.* (2010) 'Changes in In Vivo Knee Loading with a Variable-Stiffness Intervention Shoe Correlate with Changes in the Knee Adduction Moment', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 28(12), pp. 1548–1553. Available at: <https://doi.org/10.1002/jor.21183>.

Erhart, Jennifer C. *et al.* (2010) 'Changes in knee adduction moment, pain, and functionality with a variable-stiffness walking shoe after 6 months', *Journal of Orthopaedic Research*, 28(7), pp. 873–879. Available at: <https://doi.org/http://dx.doi.org/10.1002/jor.21077>.

Erhart, Jennifer C, Mündermann, A., *et al.* (2010) 'Changes in knee adduction moment, pain, and functionality with a variable-stiffness walking shoe after 6 months', *Journal of Orthopaedic Research*, 28(7), pp. 873–879.

Van Der Esch, M., Heijmans, M. and Dekker, J. (2003) 'Factors Contributing to

Possession and Use of Walking Aids among Persons with Rheumatoid Arthritis and Osteoarthritis', *Arthritis Care and Research*, 49(6), pp. 838–842. Available at: <https://doi.org/10.1002/art.11463>.

Escobar, A. *et al.* (2007) 'Responsiveness and clinically important differences for the WOMAC and SF-36 after total knee replacement', *Osteoarthritis and cartilage*, 15(3), pp. 273–280. Available at: <https://doi.org/10.1016/j.joca.2006.09.001>.

Esfandiari, E. *et al.* (2013) 'The Immediate Effect of Lateral Wedge Insoles, With and Without a Subtalar Strap, on the Lateral Trunk Lean Motion in Patients With Knee Osteoarthritis', *Geriatric Orthopaedic Surgery and Rehabilitation*, 4(4), pp. 127–132. Available at: https://doi.org/10.1177/2151458513512327/ASSET/IMAGES/LARGE/10.1177_2151458513512327-FIG2.JPEG.

Excellence, N.I. for H. and C. (2022) 'Osteoarthritis in over 16s: Diagnosis and management'.

Eyisi, D. (2016) 'The usefulness of qualitative and quantitative approaches and methods in researching problem-solving ability in science education curriculum.', *Journal of education and practice*, 7(15), pp. 91–100.

Ezzat, A.M. and Li, L.C. (2014) 'Occupational physical loading tasks and knee osteoarthritis: a review of the evidence', *Physiotherapy Canada*, 66(1), pp. 91–107. Available at: <https://doi.org/10.3138/ptc.2012-45BC>.

Fairus, F.Z., Nordin, N.A.M. and Singh, D.K.A. (2018) 'TEST-RETEST RELIABILITY OF KNEE KINEMATICS MEASUREMENT DURING GAIT WITH 3D MOTION ANALYSIS SYSTEM', *Journal of Fundamental and Applied Sciences*, 9, pp. 1236–1249. Available at: <https://api.semanticscholar.org/CorpusID:117659100>.

Falahatgar, M. *et al.* (2022) 'Comparing Two Orthoses for Managing Medial Knee Osteoarthritis: Lateral Wedge with Subtalar Strap While Barefoot Versus Lateral Wedged Insole Fitted Within Sandal', *Indian Journal of Orthopaedics*, 56, pp. 319–326. Available at: <https://doi.org/10.1007/s43465-021-00477-4>.

Fan, Y. *et al.* (2020) 'Valgus knee bracing may have no long-term effect on pain improvement and functional activity in patients with knee osteoarthritis: a meta-analysis of randomized trials', *JOURNAL OF ORTHOPAEDIC SURGERY AND RESEARCH*, 15(1), pp. 1–10. Available at: <https://doi.org/10.1186/s13018-020-01917-x>.

Fang, M.A. *et al.* (2006) 'Effects of footwear on medial compartment knee osteoarthritis', *Journal of rehabilitation research and development*, 43(4), pp. 427–434. Available at: <https://doi.org/10.1682/JRRD.2005.10.0161>.

Farrokhi, S. *et al.* (2013) 'A biomechanical perspective on physical therapy management of knee osteoarthritis', *Journal of Orthopaedic and Sports Physical Therapy*, 43(9), pp. 600–619. Available at: <https://doi.org/10.2519/jospt.2013.4121>.

Farrokhi, S. *et al.* (2015) 'Altered gait characteristics in individuals with knee osteoarthritis and self-reported knee instability', *Journal of orthopaedic and sports physical therapy*, 45(5), p. 351-359. Available at: <https://doi.org/10.2519/jospt.2015.5540>.

Faschingbauer, M. *et al.* (2020) 'Cartilage survival of the knee strongly depends on malalignment: a survival analysis from the Osteoarthritis Initiative (OAI)', *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA*, 28(5), pp. 1346–1355. Available at: <https://doi.org/10.1007/s00167-019-05434-1>.

- Fautrel, B. *et al.* (2005) 'Impact of osteoarthritis: Results of a nationwide survey of 10,000 patients consulting for OA', *Joint Bone Spine*, 72(3), pp. 235–240. Available at: <https://doi.org/10.1016/j.jbspin.2004.08.009>.
- Favero, M. *et al.* (2015) 'Early knee osteoarthritis', *RMD open*, 1(Suppl 1), p. e000062.
- Feehan, N.L. *et al.* (2012) 'The effectiveness of off-loading knee orthoses in the reduction of pain in medial compartment knee osteoarthritis: A systematic review', *Journal of Prosthetics and Orthotics*, 24(1), pp. 39–49. Available at: <https://doi.org/10.1097/JPO.0B013E318240AF8D>.
- Felson, D.T. *et al.* (1997) 'Risk factors for incident radiographic knee osteoarthritis in the elderly. The framingham study', *Arthritis & Rheumatism*, 40(4), pp. 728–733. Available at: <https://doi.org/https://doi.org/10.1002/art.1780400420>.
- Felson, D.T. *et al.* (1998) 'Evidence for a Mendelian gene in a segregation analysis of generalized radiographic osteoarthritis: the Framingham Study', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 41(6), pp. 1064–1071.
- Felson, D.T. *et al.* (2000) 'Osteoarthritis: new insights. Part 1: the disease and its risk factors', *Annals of internal medicine*, 133(8), pp. 635–646.
- Felson, D.T. *et al.* (2005) 'Osteophytes and progression of knee osteoarthritis', *Rheumatology (Oxford, England)*, 44(1), pp. 100–104. Available at: <https://doi.org/10.1093/rheumatology/keh411>.
- Felson, D.T. (2005) 'The sources of pain in knee osteoarthritis', *Current opinion in rheumatology*, 17(5), pp. 624–628. Available at: <https://doi.org/10.1097/01.bor.0000172800.49120.97>.
- Felson, D.T. *et al.* (2009) 'The effects of impaired joint position sense on the development and progression of pain and structural damage in knee osteoarthritis', *Arthritis and rheumatism*, 61(8), pp. 1070–1076. Available at: <https://doi.org/10.1002/art.24606>.
- Felson, D.T. *et al.* (2019) 'The Efficacy of a Lateral Wedge Insole for Painful Medial Knee Osteoarthritis After Prescreening: a Randomized Clinical Trial', *Arthritis & rheumatology (hoboken, N.J.)*, 71(6), p. 908-915. Available at: <https://doi.org/10.1002/art.40808>.
- Felson, D.T. and Zhang, Y. (1998) 'An update on the epidemiology of knee and hip osteoarthritis with a view to prevention', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 41(8), pp. 1343–1355.
- Ferket, B.S. *et al.* (2017) 'Impact of total knee replacement practice: cost effectiveness analysis of data from the Osteoarthritis Initiative', *bmj*, 356.
- Fernandes, L. *et al.* (2013) 'EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis', *Annals of the rheumatic diseases*, 72(7), pp. 1125–1135.
- Ferreira de Meneses, S., Rannou, F. and Hunter, D.J. (2016) 'Osteoarthritis guidelines: Barriers to implementation and solutions', *Annals of Physical and Rehabilitation Medicine*, 59(3), pp. 170–173. Available at: <https://doi.org/https://doi.org/10.1016/j.rehab.2016.01.007>.
- Ferreira, V. *et al.* (2019) 'The optimal degree of lateral wedge insoles for reducing knee joint load: a systematic review and meta-analysis', *Archives of physiotherapy*, 9(1), pp. 18–18. Available at: <https://doi.org/10.1186/s40945-019-0068-1>.

Ferreira, V. *et al.* (2021) 'Effects of tailored lateral wedge insoles on medial knee osteoarthritis based on biomechanical analysis: 12-week randomized controlled trial', *Clinical Rehabilitation*, 35(9), pp. 1235–1246. Available at: <https://doi.org/10.1177/0269215521997988>.

Field, A.P. (2018) *Discovering statistics using IBM SPSS statistics*. 5th edition. Sage Publications Inc.

Fink, B. *et al.* (2007) 'Morphologic changes in the vastus medialis muscle in patients with osteoarthritis of the knee.', *Arthritis and rheumatism*, 56 11, pp. 3626–3633. Available at: <https://api.semanticscholar.org/CorpusID:6005374>.

Fisher, P. *et al.* (2006) 'Evaluation of specific and non-specific effects in homeopathy: feasibility study for a randomised trial', *Homeopathy: the journal of the Faculty of Homeopathy*, 95(4), pp. 215–222. Available at: <https://doi.org/10.1016/J.HOMP.2006.07.006>.

Fisken, A.L. *et al.* (2016) 'Perceptions towards aqua-based exercise among older adults with osteoarthritis who have discontinued participation in this exercise mode', *Australasian journal on ageing*, 35(1), pp. 12–17. Available at: <https://doi.org/10.1111/ajag.12167>.

FitzGerald, C. and Hurst, S. (2017) 'Implicit bias in healthcare professionals: a systematic review.', *BMC medical ethics*, 18(1), p. 19. Available at: <https://doi.org/10.1186/s12910-017-0179-8>.

Fletcher, B. *et al.* (2012) 'Improving the recruitment activity of clinicians in randomised controlled trials: a systematic review', *BMJ open*, 2(1), pp. e000496–e000496. Available at: <https://doi.org/10.1136/bmjopen-2011-000496>.

Florczak, K.L. (2014) 'Purists Need Not Apply', <http://dx.doi.org/10.1177/0894318414546419>, 27(4), pp. 278–282. Available at: <https://doi.org/10.1177/0894318414546419>.

Foreman, S.C. *et al.* (2019) 'Longitudinal MRI structural findings observed in accelerated knee osteoarthritis: data from the osteoarthritis initiative', *Skeletal radiology*, 48(12), pp. 1949–1959.

Foroughi, N. *et al.* (2011) 'Lower limb muscle strengthening does not change frontal plane moments in women with knee osteoarthritis: a randomized controlled trial', *Clinical biomechanics (Bristol, Avon)*, 26(2 CC-Musculoskeletal), p. 167-174. Available at: <https://doi.org/10.1016/j.clinbiomech.2010.08.011>.

Fossey, E. *et al.* (2002) 'Understanding and evaluating qualitative research', *Australian & New Zealand journal of psychiatry*, 36(6), pp. 717–732.

Fransen, M. *et al.* (2011) 'Hip and knee pain: Role of occupational factors', *Best Practice & Research Clinical Rheumatology*, 25(1), pp. 81–101.

Fransen, M. *et al.* (2015) 'Exercise for osteoarthritis of the knee: A Cochrane systematic review', *British Journal of Sports Medicine*. BMJ Publishing Group, pp. 1554–1557. Available at: <https://doi.org/10.1136/bjsports-2015-095424>.

Fransen, M. and McCONNELL, S. (2009) 'Land-based exercise for osteoarthritis of the knee: a metaanalysis of randomized controlled trials', *The Journal of rheumatology*, 36(6), pp. 1109–1117.

Fregly, B.J. *et al.* (2007) 'Design of patient-specific gait modifications for knee osteoarthritis rehabilitation', *IEEE Transactions on Biomedical Engineering*, 54(9), pp. 1687–1695. Available at: <https://doi.org/10.1109/TBME.2007.891934>.

- Fregly, B.J. (2012) 'Gait Modification to Treat Knee Osteoarthritis', *HSS Journal*, 8(1), pp. 45–48. Available at: <https://doi.org/10.1007/s11420-011-9229-9>.
- Fregly, B.J., D'Lima, D.D. and Colwell, C.W. (2009) 'Effective gait patterns for offloading the medial compartment of the knee', *Journal of Orthopaedic Research*, 27(8), pp. 1016–1021. Available at: <https://doi.org/10.1002/jor.20843>.
- Fregly, B.J., Reinbolt, J.A. and Chmielewski, T.L. (2008) 'Evaluation of a patient-specific cost function to predict the influence of foot path on the knee adduction torque during gait', *Computer Methods in Biomechanics and Biomedical Engineering*, 11(1), pp. 63–71. Available at: <https://doi.org/10.1080/10255840701552036>.
- Frobell, R.B. (2011) 'Change in cartilage thickness, posttraumatic bone marrow lesions, and joint fluid volumes after acute ACL disruption: a two-year prospective MRI study of sixty-one subjects', *JBJS*, 93(12), pp. 1096–1103.
- Frobell, R.B. *et al.* (2015) 'Treatment for acute anterior cruciate ligament tear: five year outcome of randomised trial', *British journal of sports medicine*, 49(10), p. 700.
- Fu, K., Robbins, S.R. and McDougall, J.J. (2018) 'Osteoarthritis: the genesis of pain', *Rheumatology*, 57(suppl_4), pp. iv43–iv50. Available at: <https://doi.org/10.1093/rheumatology/kex419>.
- Fu, P. *et al.* (2023) 'Relationship between spinal imbalance and knee osteoarthritis by using full-body EOS.', *BMC musculoskeletal disorders*, 24(1), p. 402. Available at: <https://doi.org/10.1186/s12891-023-06508-5>.
- Fusch, P.I. and Ness, L.R. (2015) 'Are we there yet? Data saturation in qualitative research', *Qualitative report*, 20(9), pp. 1408–1416. Available at: <https://doi.org/10.46743/2160-3715/2015.2281>.
- Gaasbeek, R.D.A. *et al.* (2007) 'Valgus bracing in patients with medial compartment osteoarthritis of the knee', *Gait & Posture*, 26(1), pp. 3–10. Available at: <https://doi.org/10.1016/j.gaitpost.2006.07.007>.
- Gale, N.K. *et al.* (2013) 'Using the framework method for the analysis of qualitative data in multi-disciplinary health research', *BMC Medical Research Methodology*, 13(1), pp. 1–8. Available at: <https://doi.org/10.1186/1471-2288-13-117/PEER-REVIEW>.
- Galletta, A. and Cross, W.E. (2013) *Mastering the Semi-Structured Interview and Beyond*. New York: NYU Press (Qualitative studies in psychology). Available at: <https://doi.org/10.18574/9780814732953>.
- Gallin, J.I., Ognibene, F.P. and Johnson, L.L. (2017) *Principles and Practice of Clinical Research*. Fourth edi. San Diego: San Diego: Elsevier Science & Technology.
- Garbi, M. (2021) 'National Institute for Health and Care Excellence clinical guidelines development principles and processes', *Heart*, 107(12), pp. 949 LP – 953. Available at: <https://doi.org/10.1136/heartjnl-2020-318661>.
- Gard, G. (2007) 'Factors important for good interaction in physiotherapy treatment of persons who have undergone torture: A qualitative study', *Physiotherapy theory and practice*, 23(1), pp. 47–55. Available at: <https://doi.org/10.1080/09593980701209584>.
- Garratt, A.M., Brealey, S. and Gillespie, W.J. (2004) 'Patient-assessed health instruments for the knee: a structured review', *Rheumatology (Oxford, England)*, 43(11), pp. 1414–1423. Available at: <https://doi.org/10.1093/rheumatology/keh362>.
- Gauchard, G.C. *et al.* (2010) 'On the role of knee joint in balance control and postural

strategies: Effects of total knee replacement in elderly subjects with knee osteoarthritis', *Gait & Posture*, 32(2), pp. 155–160. Available at: <https://doi.org/https://doi.org/10.1016/j.gaitpost.2010.04.002>.

GBD 2015 Disease and Injury Incidence and Prevalence Collaborators (2016) 'Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015', *The Lancet*, 388(10053), pp. 1545–1602.

van Gelder, L. *et al.* (2017) 'Real-time feedback to improve gait in children with cerebral palsy', *Gait & posture*, 52, pp. 76–82.

Gelling, L. (2015) 'Qualitative research', *Nursing standard*, 29(30), pp. 43–47. Available at: <https://doi.org/10.7748/ns.29.30.43.e9749>.

General Authority for Statistics | (2022). Available at: <https://www.stats.gov.sa/en> (Accessed: 3 January 2023).

Georgiev, T. and Angelov, A.K. (2019) 'Modifiable risk factors in knee osteoarthritis: treatment implications', *Rheumatology international*, 39(7), pp. 1145–1157.

Gerbrands, T.. A. *et al.* (2017) 'Lateral trunk lean and medializing the knee as gait strategies for knee osteoarthritis', *Gait & posture*, 51, pp. 247–253. Available at: <https://doi.org/10.1016/j.gaitpost.2016.11.014>.

Ghogomu, E.A.T. *et al.* (2014) 'Updated Method Guidelines for Cochrane Musculoskeletal Group Systematic Reviews and Metaanalyses', *The Journal of Rheumatology*, 41(2), pp. 194 LP – 205. Available at: <https://doi.org/10.3899/jrheum.121306>.

Gholami, S. *et al.* (2022) 'Gait modification with subject-specific foot progression angle in people with moderate knee osteoarthritis: Investigation of knee adduction moment and muscle activity', *The knee*, 35, pp. 124–132. Available at: <https://doi.org/10.1016/j.knee.2022.03.001>.

Gholami, S. *et al.* (2023) 'The Relationship Between Knee Moments and Function with Western Ontario and McMaster Universities in Moderate Knee Osteoarthritis', *Journal of modern rehabilitation (Online)*, 17(3). Available at: <https://doi.org/10.18502/jmr.v17i3.13072>.

Giddings, L.S. and Grant, B.M. (2014) 'Mixed methods research for the novice researcher', <https://doi.org/10.5172/conu.2006.23.1.3>, 23(1), pp. 3–11. Available at: <https://doi.org/10.5172/CONU.2006.23.1.3>.

Ginis, P. *et al.* (2016) 'Feasibility and effects of home-based smartphone-delivered automated feedback training for gait in people with Parkinson's disease: A pilot randomized controlled trial.', *Parkinsonism & related disorders*, 22, pp. 28–34. Available at: <https://doi.org/10.1016/j.parkreldis.2015.11.004>.

Gitlin, L.N. (2016) *Behavioral intervention research: designing, evaluating, and implementing*. Edited by S.J. Czaja and J. Beilenson. Springer Publishing Company.

Glasgow, R.E. (2013) 'What Does It Mean to Be Pragmatic? Pragmatic Methods, Measures, and Models to Facilitate Research Translation', *Health education & behavior*, 40(3), pp. 257–265. Available at: <https://doi.org/10.1177/1090198113486805>.

Godwin, M. *et al.* (2003) 'Pragmatic controlled clinical trials in primary care: The struggle between external and internal validity', *BMC medical research methodology*, 3(1), pp. 1–7. Available at: <https://doi.org/10.1186/1471-2288-3-28>.

Gohal, C. *et al.* (2018) 'Effectiveness of valgus offloading knee braces in the treatment of medial compartment knee osteoarthritis: a systematic review', *Sports health*, 10(6), pp. 500–514.

Gök, H., Ergin, S. and Yavuzer, G. (2002) 'Kinetic and kinematic characteristics of gait in patients with medial knee arthrosis', *Acta orthopaedica Scandinavica*, 73(6), pp. 647–652. Available at: <https://doi.org/10.1080/000164702321039606>.

Goldring, M.B. and Goldring, S.R. (2007) 'Osteoarthritis', *Journal of Cellular Physiology*, 213(3), pp. 626–634. Available at: <https://doi.org/https://doi.org/10.1002/jcp.21258>.

Goldring, M.B. and Goldring, S.R. (2010) 'Articular cartilage and subchondral bone in the pathogenesis of osteoarthritis', *Annals of the New York Academy of Sciences*, 1192(1), pp. 230–237.

Gooberman-Hill, R. *et al.* (2009) 'Expressing pain and fatigue: A new method of analysis to explore differences in osteoarthritis experience', *Arthritis Care and Research*, 61(3), pp. 353–360. Available at: <https://doi.org/10.1002/art.24273>.

Gore, M. *et al.* (2012) 'Use and Costs of Prescription Medications and Alternative Treatments in Patients with Osteoarthritis and Chronic Low Back Pain in Community-Based Settings', *Pain Practice*, 12(7), pp. 550–560. Available at: <https://doi.org/10.1111/j.1533-2500.2012.00532.x>.

Goubert, L. *et al.* (2004) 'Distraction from chronic pain during a pain-inducing activity is associated with greater post-activity pain', *Pain (Amsterdam)*, 110(1), pp. 220–227. Available at: <https://doi.org/10.1016/j.pain.2004.03.034>.

Graven-Nielsen, T. and Arendt-Nielsen, L. (2002) 'Peripheral and central sensitization in musculoskeletal pain disorders: an experimental approach', *Current rheumatology reports*, 4(4), pp. 313–321. Available at: <https://doi.org/10.1007/s11926-002-0040-y>.

Green, L.W. and Kreuter, M.W. (1999) 'Health promotion planning : an educational and ecological approach', p. 621.

Greenbaum, T. (2003) 'The gold standard', *Why the focus group deserves to be the most respected of all qualitative research tools. Quirk's Marketing Research Review*, 17, pp. 22–27.

Greene, J.C., Caracelli, V.J. and Graham, W.F. (1989) 'Toward a Conceptual Framework for Mixed-Method Evaluation Designs', *Educational evaluation and policy analysis*, 11(3), pp. 255–274. Available at: <https://doi.org/10.3102/01623737011003255>.

Gregori, D. *et al.* (2018) 'Association of Pharmacological Treatments With Long-term Pain Control in Patients With Knee Osteoarthritis: A Systematic Review and Meta-analysis', *JAMA*, 320(24), pp. 2564–2579. Available at: <https://doi.org/10.1001/jama.2018.19319>.

Gribble, P.A., Hertel, J. and Plisky, P. (2012) 'Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: A literature and systematic review', *Journal of athletic training*, 47(3), pp. 339–357. Available at: <https://doi.org/10.4085/1062-6050-47.3.08>.

Gribble, P.L. *et al.* (2003) 'Role of cocontraction in arm movement accuracy', *Journal of neurophysiology*, 89(5), pp. 2396–2405.

Griffin, T.M. and Guilak, F. (2005) 'The role of mechanical loading in the onset and progression of osteoarthritis', *Exercise and sport sciences reviews*, 33(4), pp. 195–

Gross, K.D. *et al.* (2016) 'Relation of foot pronation during walking to risk of worsening lateral patellofemoral and medial tibiofemoral cartilage damage', *Arthritis and rheumatology. Conference: american college of rheumatology/association of rheumatology health professionals annual scientific meeting, ACR/ARHP 2016. United states. Conference start: 20161111. Conference end: 20161116*, 68, p. 366-368. Available at: <https://doi.org/10.1002/art.39977>.

Guccione, A.A. *et al.* (1994) 'The effects of specific medical conditions on the functional limitations of elders in the Framingham Study.', *American journal of public health*, 84(3), pp. 351–358.

Gudbergson, H. *et al.* (2012) 'Weight loss is effective for symptomatic relief in obese subjects with knee osteoarthritis independently of joint damage severity assessed by high-field MRI and radiography', *Osteoarthritis and Cartilage*, 20(6), pp. 495–502. Available at: <https://doi.org/http://dx.doi.org/10.1016/j.joca.2012.02.639>.

guideline NG226, N. (2022) 'Osteoarthritis in over 16s: diagnosis and management', *Methods* [Preprint].

Guilak, F. *et al.* (2004) 'The role of biomechanics and inflammation in cartilage injury and repair', *Clinical Orthopaedics and Related Research®*, 423, pp. 17–26.

Guilak, F. (2011) 'Biomechanical factors in osteoarthritis', *Best practice & research Clinical rheumatology*, 25(6), pp. 815–823.

Gundumogula, M. (2020) 'Importance of focus groups in qualitative research', *International Journal of Humanities and Social Science (IJHSS)*, 8(11), pp. 299–302.

Guner, S., Inanici, F. and Alsancak, S. (2012) 'Long term effects of laterally wedged insoles on knee frontal plane biomechanics in patients with medial knee osteoarthritis', *Turkish Journal of Physiotherapy and Rehabilitation*, 23(3), pp. 111–118.

Guo, M. *et al.* (2007) 'The influence of foot progression angle on the knee adduction moment during walking and stair climbing in pain free individuals with knee osteoarthritis', *Gait and Posture*, 26(3), pp. 436–441.

Gustafson, J.A. *et al.* (2015) 'Knee motion variability in patients with knee osteoarthritis: The effect of self-reported instability.', *Clinical biomechanics*, 30 5, pp. 475–480. Available at: <https://api.semanticscholar.org/CorpusID:5608237>.

Gyllensten, A.L. *et al.* (1999) 'Interaction between patient and physiotherapist: a qualitative study reflecting the physiotherapist's perspective', *Physiotherapy research international : the journal for researchers and clinicians in physical therapy*, 4(2), pp. 89–109. Available at: <https://doi.org/10.1002/pri.156>.

Györy, A.N., Chao, E.Y. and Stauffer, R.N. (1976) 'Functional evaluation of normal and pathologic knees during gait.', *Archives of physical medicine and rehabilitation*, 57(12), pp. 571–577.

Hackney, M.E. and Earhart, G.M. (2010) 'The effects of a secondary task on forward and backward walking in Parkinson's disease', *Neurorehabilitation and neural repair*, 24(1), pp. 97–106. Available at: <https://doi.org/10.1177/1545968309341061>.

Hafer, J.F., Kent, J.A. and Boyer, K.A. (2019) 'Physical activity and age-related biomechanical risk factors for knee osteoarthritis.', *Gait & posture*, 70, pp. 24–29. Available at: <https://api.semanticscholar.org/CorpusID:73508319>.

Haight, D.J. *et al.* (2014) 'A Comparison of Slow, Uphill and Fast, Level Walking on

Lower Extremity Biomechanics and Tibiofemoral Joint Loading in Obese and Nonobese Adults', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 32(2), pp. 324–330. Available at: <https://doi.org/10.1002/jor.22497>.

Haim, A. *et al.* (2012) 'Reduction in knee adduction moment via non-invasive biomechanical training: A longitudinal gait analysis study', *JOURNAL OF BIOMECHANICS*, 45(1), pp. 41–45. Available at: <https://doi.org/10.1016/j.jbiomech.2011.10.017>.

Halcomb, E. and Andrew, S. (2006) 'Triangulation as a method for contemporary nursing research', *Nurse researcher*, 13(2), pp. 78–82.

Hall, A.J. *et al.* (2016) 'Association between osteoarthritis and cardiovascular disease: systematic review and meta-analysis', *European journal of preventive cardiology*, 23(9), pp. 938–946.

Hame, S.L. and Alexander, R.A. (no date) 'Knee osteoarthritis in women'. Available at: <https://doi.org/10.1007/s12178-013-9164-0>.

Hammersley, M. (2008) *Questioning qualitative inquiry: Critical essays*. Sage.

Han, X., Yan, M. and Yu, Z. (2021) 'Abnormal subchondral trabecular bone remodeling in knee osteoarthritis under the influence of knee alignment', *Osteoarthritis and cartilage*, 29, p. S169. Available at: <https://doi.org/10.1016/j.joca.2021.02.235>.

Hart, H.F. *et al.* (2016) 'Immediate Effects of a Brace on Gait Biomechanics for Predominant Lateral Knee Osteoarthritis and Valgus Malalignment After Anterior Cruciate Ligament Reconstruction', *AMERICAN JOURNAL OF SPORTS MEDICINE*, 44(4), pp. 865–873. Available at: <https://doi.org/10.1177/0363546515624677>.

Hartvigsen, J., Kamper, S.J. and French, S.D. (2022) 'Low-value care in musculoskeletal health care: Is there a way forward?', *Pain practice*, 22(2), pp. 65–70. Available at: <https://doi.org/10.1111/papr.13142>.

Hatef, M.R. *et al.* (2014) 'Superiority of laterally elevated wedged insoles to neutrally wedged insoles in medial knee osteoarthritis symptom relief', *International journal of rheumatic diseases*, 17(1), p. 84–88. Available at: <https://doi.org/10.1111/1756-185X.12036>.

Hatze, H. (1974) 'The meaning of the term "biomechanics"', *Journal of Biomechanics*. Elsevier, pp. 189–190. Available at: [https://doi.org/10.1016/0021-9290\(74\)90060-8](https://doi.org/10.1016/0021-9290(74)90060-8).

Hawker, G. *et al.* (2008) 'Knee arthroscopy in England and Ontario: patterns of use, changes over time, and relationship to total knee replacement', *JBJS*, 90(11), pp. 2337–2345.

Hawker, G.A. *et al.* (2008) 'Understanding the pain experience in hip and knee osteoarthritis—an OARSI/OMERACT initiative', *Osteoarthritis and cartilage*, 16(4), pp. 415–422.

Hawker, G.A. (2009) 'Experiencing painful osteoarthritis: what have we learned from listening?', *Current opinion in rheumatology*, 21(5), pp. 507–512.

Hawley, H. *et al.* (2012) 'Are the attitudes of exercise instructors who work with older adults influenced by training and personal characteristics?', *Journal of aging and physical activity*, 20(1), pp. 47–63. Available at: <https://doi.org/10.1123/japa.20.1.47>.

Hayashi, D. *et al.* (2012) 'Knee malalignment is associated with an increased risk for incident and enlarging bone marrow lesions in the more loaded compartments: the

MOST study', *OSTEOARTHRITIS AND CARTILAGE*, 20(11), pp. 1227–1233. Available at: <https://doi.org/10.1016/j.joca.2012.07.020>.

He, Z., Liu, T. and Yi, J. (2019) 'A Wearable Sensing and Training System: Towards Gait Rehabilitation for Elderly Patients With Knee Osteoarthritis', *IEEE SENSORS JOURNAL*, 19(14), pp. 5936–5945. Available at: <https://doi.org/10.1109/JSEN.2019.2908417>.

Hedges, L. V (1981) 'Distribution theory for Glass's estimator of effect size and related estimators', *Journal of Educational Statistics*, 6(2), pp. 107–128.

Hegde, N., Fulk, G.D. and Sazonov, E.S. (2015) 'Development of the RT-GAIT, a Real-Time feedback device to improve Gait of individuals with stroke', in *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. IEEE, pp. 5724–5727.

Heidari, B. (2011) 'Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I', *Caspian journal of internal medicine*, 2(2), p. 205.

Heiden, T.L., Lloyd, D.G. and Ackland, T.R. (2009) 'Knee joint kinematics, kinetics and muscle co-contraction in knee osteoarthritis patient gait', *CLINICAL BIOMECHANICS*, 24(10), pp. 833–841. Available at: <https://doi.org/10.1016/j.clinbiomech.2009.08.005>.

Heijink, A. *et al.* (2016) 'Biomechanical considerations in the pathogenesis of osteoarthritis of the elbow', *Knee Surgery, Sports Traumatology, Arthroscopy*, 24(7), pp. 2313–2318.

Heijman, M.G.J. *et al.* (2022) 'OP0210-HPR THE OCCURRENCE OF OVERWHELMING FATIGUE IN INDIVIDUALS WITH KNEE OSTEOARTHRITIS: A DAILY DIARY STUDY', *Annals of the Rheumatic Diseases* [Preprint]. Available at: <https://api.semanticscholar.org/CorpusID:250108031>.

Henriksen, M. *et al.* (2009) 'Experimentally reduced hip abductor function during walking: Implications for knee joint loads', *JOURNAL OF BIOMECHANICS*, 42(9), pp. 1236–1240. Available at: <https://doi.org/10.1016/j.jbiomech.2009.03.021>.

Henriksen, M. *et al.* (2014) 'Is there a causal link between knee loading and knee osteoarthritis progression? A systematic review and meta-analysis of cohort studies and randomised trials', *BMJ OPEN*, 4(7). Available at: <https://doi.org/10.1136/bmjopen-2014-005368>.

Hertel, J. *et al.* (2006) 'Simplifying the star excursion balance test: Analyses of subjects with and without chronic ankle instability', *The journal of orthopaedic and sports physical therapy*, 36(3), pp. 131–137. Available at: <https://doi.org/10.2519/jospt.2006.36.3.131>.

Hicks-Little, C.A. *et al.* (2011) 'Lower Extremity Joint Kinematics during Stair Climbing in Knee Osteoarthritis', *MEDICINE AND SCIENCE IN SPORTS AND EXERCISE*, 43(3), pp. 516–524. Available at: <https://doi.org/10.1249/MSS.0b013e3181f257be>.

Higashi, H. and Barendregt, J.J. (2011) 'Cost-effectiveness of total hip and knee replacements for the Australian population with osteoarthritis: discrete-event simulation model', *PloS one*, 6(9), p. e25403.

Higgins, J.P.T. *et al.* (2011) 'The Cochrane Collaboration's tool for assessing risk of bias in randomised trials', *BMJ*, 343(7829). Available at: <https://doi.org/10.1136/BMJ.D5928>.

Higgins, J.P.T. *et al.* (2019) *Cochrane handbook for systematic reviews of*

interventions. 2nd edn. Newark: John Wiley & Sons (Wiley Cochrane Series). Available at: <https://doi.org/10.1002/9781119536604>.

Higgins, J.P.T. and Green, S. (2008) 'Cochrane handbook for systematic reviews of interventions'.

Higgins, J.P.T. and Green, S. (2012) 'Cochrane handbook for systematic reviews of interventions, version 5.1. 0, London: The Cochrane Collaboration, Updated March 2011'.

Higginson, J.S. *et al.* (2006) 'Muscle contributions to support during gait in an individual with post-stroke hemiparesis', *Journal of biomechanics*, 39(10), pp. 1769–1777.

Hill, C.L. *et al.* (2001) 'Knee effusions, popliteal cysts, and synovial thickening: association with knee pain in osteoarthritis.', *The Journal of rheumatology*, 28(6), pp. 1330–1337.

Hinman, R.S. *et al.* (2002) 'Balance impairments in individuals with symptomatic knee osteoarthritis: a comparison with matched controls using clinical tests', *Rheumatology (Oxford, England)*, 41(12), pp. 1388–1394. Available at: <https://doi.org/10.1093/rheumatology/41.12.1388>.

Hinman, R.S., Bowles, K.A., *et al.* (2008) 'Effect of Length on Laterally-Wedged Insoles in Knee Osteoarthritis'. Available at: <https://doi.org/10.1002/art.23249>.

Hinman, R.S., Payne, C., *et al.* (2008) 'Lateral wedges in knee osteoarthritis: What are their immediate clinical and biomechanical effects and can these predict a three-month clinical outcome?', *Arthritis Care & Research*, 59(3), pp. 408–415.

Hinman, R S *et al.* (2012) 'Lateral wedge insoles for medial knee osteoarthritis: effects on lower limb frontal plane biomechanics', *Clinical biomechanics (Bristol, Avon)*, 27(1), p. 27-33. Available at: <https://doi.org/10.1016/j.clinbiomech.2011.07.010>.

Hinman, Rana S *et al.* (2012) 'Lateral wedge insoles for medial knee osteoarthritis: effects on lower limb frontal plane biomechanics', *Clinical biomechanics (Bristol, Avon)*, 27(1), p. 27-33. Available at: <https://doi.org/10.1016/j.clinbiomech.2011.07.010>.

Hinman, R.S. *et al.* (2013) 'Exercise, gait retraining, footwear and insoles for knee osteoarthritis', *Current Physical Medicine and Rehabilitation Reports*, 1, pp. 21–28.

Hinman, R.S. *et al.* (2016) 'Unloading shoes for self-management of knee osteoarthritis a randomized trial', *Annals of Internal Medicine*, 165(6), pp. 381–389. Available at: <https://doi.org/10.7326/M16-0453>.

Hinman, R.S. *et al.* (2023) 'Exercise & Sports Science Australia (ESSA) updated Position Statement on exercise and physical activity for people with hip/knee osteoarthritis', *Journal of science and medicine in sport*, 26(1), pp. 37–45. Available at: <https://doi.org/10.1016/j.jsams.2022.11.003>.

Hinman, R.S. and Bennell, K.L. (2009) 'Advances in insoles and shoes for knee osteoarthritis', *Current opinion in rheumatology*, 21(2), pp. 164–170. Available at: <https://doi.org/10.1097/BOR.0b013e32832496c2>.

Hinman, R.S., Bowles, K.A. and Bennell, K.L. (2009) 'Laterally wedged insoles in knee osteoarthritis: do biomechanical effects decline after one month of wear?', *BMC musculoskeletal disorders*, 10, p. 146. Available at: <https://doi.org/10.1186/1471-2474-10-146>.

- Hirokawa, S. *et al.* (1991) 'Muscular co-contraction and control of knee stability', *Journal of Electromyography and Kinesiology*, 1(3), pp. 199–208.
- Hjermstad, M.J. *et al.* (2011) 'Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review', *Journal of pain and symptom management*, 41(6), pp. 1073–1093. Available at: <https://doi.org/10.1016/J.JPAINSYMMAN.2010.08.016>.
- HOCHBERG, M.C. *et al.* (2012) 'American College of Rheumatology 2012 Recommendations for the Use of Nonpharmacologic and Pharmacologic Therapies in Osteoarthritis of the Hand, Hip, and Knee', *Arthritis care and research*, 64(4), pp. 465–474.
- Hodges, P.W. *et al.* (2016) 'Increased duration of co-contraction of medial knee muscles is associated with greater progression of knee osteoarthritis', *Manual Therapy*, 21, pp. 151–158.
- Hofmann, G.O. *et al.* (2010) 'Detection and evaluation of initial cartilage pathology in man: A comparison between MRT, arthroscopy and near-infrared spectroscopy (NIR) in their relation to initial knee pain', *Pathophysiology (Amsterdam)*, 17(1), pp. 1–8. Available at: <https://doi.org/10.1016/j.pathophys.2009.04.001>.
- Holstein, J.A. and Gubrium, J.F. (2011) 'Animating Interview Narratives', in.
- Hommel, K.A. *et al.* (2013) 'Telehealth behavioral treatment for medication nonadherence: a pilot and feasibility study', *European journal of gastroenterology & hepatology*, 25(4), pp. 469–473. Available at: <https://doi.org/10.1097/MEG.0B013E32835C2A1B>.
- Hootman, J.M. *et al.* (2004) 'Lower extremity muscle strength and risk of self-reported hip or knee osteoarthritis', *Journal of Physical Activity and Health*, 1(4), pp. 321–330.
- Hortobagyi, T. *et al.* (2005) 'Altered hamstring-quadriceps muscle balance in patients with knee osteoarthritis', *CLINICAL BIOMECHANICS*, 20(1), pp. 97–104. Available at: <https://doi.org/10.1016/j.clinbiomech.2004.08.004>.
- Hróbjartsson, A. *et al.* (2014) 'Bias due to lack of patient blinding in clinical trials. A systematic review of trials randomizing patients to blind and nonblind sub-studies', *International journal of epidemiology*, 43(4), pp. 1272–1283.
- Hsieh, H.-F. and Shannon, S.E. (2005) 'Three Approaches to Qualitative Content Analysis', *Qualitative health research*, 15(9), pp. 1277–1288. Available at: <https://doi.org/10.1177/1049732305276687>.
- Hsu, H. and Siwec, R.M. (2018) 'Knee osteoarthritis'.
- Hsu, W.-C. *et al.* (2015) 'Immediate and long-term efficacy of laterally-wedged insoles on persons with bilateral medial knee osteoarthritis during walking', *BIOMEDICAL ENGINEERING ONLINE*, 14. Available at: <https://doi.org/10.1186/s12938-015-0040-6>.
- Hu, Y. *et al.* (2021) 'Subchondral bone microenvironment in osteoarthritis and pain', *Bone research*, 9(1), pp. 20–20. Available at: <https://doi.org/10.1038/s41413-021-00147-z>.
- Huang, X., Lin, J. and Demner-Fushman, D. (2006) 'Evaluation of PICO as a knowledge representation for clinical questions', in *AMIA annual symposium proceedings*. American Medical Informatics Association, p. 359.
- Huber, M., Trattig, S. and Lintner, F. (2000) 'Anatomy, biochemistry, and physiology

of articular cartilage', *Investigative radiology*, 35(10), pp. 573–580.

Hubley-Kozey, C., Deluzio, K. and Dunbar, M. (2008) 'Muscle co-activation patterns during walking in those with severe knee osteoarthritis.', *Clinical biomechanics (Bristol, Avon)*, 23(1), pp. 71–80. Available at: <https://doi.org/10.1016/j.clinbiomech.2007.08.019>.

Hubley-Kozey, C.L. *et al.* (2006) 'Neuromuscular alterations during walking in persons with moderate knee osteoarthritis', *Journal of Electromyography and Kinesiology*, 16(4), pp. 365–378. Available at: <https://doi.org/10.1016/J.JELEKIN.2005.07.014>.

Hudspith, M.J. (2019) 'Anatomy, physiology and pharmacology of pain', *Anaesthesia and intensive care medicine*, 20(8), pp. 419–425. Available at: <https://doi.org/10.1016/j.mpaic.2019.05.008>.

Hunt, M. *et al.* (2013) 'A physiotherapist-delivered, combined exercise and pain coping skills training intervention for individuals with knee osteoarthritis: A pilot study.', *Knee*, 20(2), pp. 106–112. Available at: <https://doi.org/10.1016/j.knee.2012.07.008>.

Hunt, M.A. *et al.* (2006) 'Associations among knee adduction moment, frontal plane ground reaction force, and lever arm during walking in patients with knee osteoarthritis', *JOURNAL OF BIOMECHANICS*, 39(12), pp. 2213–2220. Available at: <https://doi.org/10.1016/j.jbiomech.2005.07.002>.

Hunt, M.A. *et al.* (2008a) 'Lateral trunk lean explains variation in dynamic knee joint load in patients with medial compartment knee osteoarthritis', *Osteoarthritis and Cartilage*, 16(5), pp. 591–599. Available at: <https://doi.org/10.1016/j.joca.2007.10.017>.

Hunt, M.A. *et al.* (2008b) 'Lateral trunk lean explains variation in dynamic knee joint load in patients with medial compartment knee osteoarthritis', *OSTEOARTHRITIS AND CARTILAGE*, 16(5), pp. 591–599. Available at: <https://doi.org/10.1016/j.joca.2007.10.017>.

Hunt, M.A. *et al.* (2010) 'Individuals with severe knee osteoarthritis (OA) exhibit altered proximal walking mechanics compared with individuals with less severe OA and those without knee pain', *Arthritis care & research*, 62(10 CC-Musculoskeletal), p. 1426-1432. Available at: <https://doi.org/10.1002/acr.20248>.

Hunt, M.A. *et al.* (2011) 'Feasibility of a gait retraining strategy for reducing knee joint loading: Increased trunk lean guided by real-time biofeedback', *JOURNAL OF BIOMECHANICS*, 44(5), pp. 943–947. Available at: <https://doi.org/10.1016/j.jbiomech.2010.11.027>.

Hunt, M.A. (2012) 'Knee OA: The evidence for gait modification', *Knee* [Preprint].

Hunt, M.A. *et al.* (2018) 'Clinical and biomechanical changes following a 4-month toe-out gait modification program for people with medial knee osteoarthritis: a randomized controlled trial', *Osteoarthritis and cartilage*, 26(7), p. 903-911. Available at: <https://doi.org/10.1016/j.joca.2018.04.010>.

Hunt, M.A. *et al.* (2021) 'Frontal plane knee alignment mediates the effect of frontal plane rearfoot motion on knee joint load distribution during walking in people with medial knee osteoarthritis', *Osteoarthritis and cartilage*, 29(5), pp. 678–686. Available at: <https://doi.org/10.1016/j.joca.2021.02.003>.

Hunter, D.. *et al.* (2013) 'Structural correlates of pain in joints with osteoarthritis', *Osteoarthritis and cartilage*, 21(9), pp. 1170–1178. Available at: <https://doi.org/10.1016/j.joca.2013.05.017>.

Hunter, D.J. and Bierma-Zeinstra, S. (2019) 'Osteoarthritis', *The Lancet*, 393(10182),

pp. 1745–1759. Available at: [https://doi.org/10.1016/S0140-6736\(19\)30417-9](https://doi.org/10.1016/S0140-6736(19)30417-9).

Hunter, D.J. and Felson, D.T. (2006) 'Clinical review-Osteoarthritis', *BMJ-British Medical Journal-International Edition*, 332(7542), pp. 639–642.

Hunter, D.J., McDougall, J.J. and Keefe, F.J. (2009) 'The Symptoms of Osteoarthritis and the Genesis of Pain', *Medical Clinics of North America*. Elsevier, pp. 83–100. Available at: <https://doi.org/10.1016/j.mcna.2008.08.008>.

Hunter, D.J., Schofield, D. and Callander, E. (2014) 'The individual and socioeconomic impact of osteoarthritis', *Nature Reviews Rheumatology*, 10(7), p. 437.

Hurley, M. V *et al.* (2007) 'Clinical effectiveness of a rehabilitation program integrating exercise, self-management, and active coping strategies for chronic knee pain: A cluster randomized trial', *Arthritis care & research*, 57(7), pp. 1211–1219.

Hurwitz, D. E. *et al.* (2002) 'The knee adduction moment during gait in subjects with knee osteoarthritis is more closely correlated with static alignment than radiographic disease severity, toe out angle and pain', *Journal of orthopaedic research*, 20(1), pp. 101–107. Available at: [https://doi.org/10.1016/S0736-0266\(01\)00081-X](https://doi.org/10.1016/S0736-0266(01)00081-X).

Hurwitz, D.E. *et al.* (1998) 'Dynamic knee loads during gait predict proximal tibial bone distribution', *Journal of Biomechanics*, 31(5), pp. 423–430. Available at: [https://doi.org/10.1016/S0021-9290\(98\)00028-1](https://doi.org/10.1016/S0021-9290(98)00028-1).

Hurwitz, D.E., Sharma, L. and Andriacchi, T.P. (1999) 'Effect of knee pain on joint loading in patients with osteoarthritis', *Current Opinion in Rheumatology*. Curr Opin Rheumatol, pp. 422–426. Available at: <https://doi.org/10.1097/00002281-199909000-00017>.

Hush, J.M. *et al.* (2012) 'Patient satisfaction with musculoskeletal physiotherapy care in Australia: an international comparison', *The Journal of manual & manipulative therapy*, 20(4), pp. 201–208. Available at: <https://doi.org/10.1179/2042618612Y.0000000009>.

Huxham, F.E., Goldie, P.A. and Patla, A.E. (2001) 'Theoretical considerations in balance assessment', *Australian journal of physiotherapy*, 47(2), pp. 89–100. Available at: [https://doi.org/10.1016/S0004-9514\(14\)60300-7](https://doi.org/10.1016/S0004-9514(14)60300-7).

Ilori, T. *et al.* (2016) 'Knee osteoarthritis and perceived social support amongst patients in a family medicine clinic', *South African Family Practice*, 58(6), pp. 202–206. Available at: <https://doi.org/10.1080/20786190.2016.1198086>.

Imamura, M. *et al.* (2008) 'Impact of nervous system hyperalgesia on pain, disability, and quality of life in patients with knee osteoarthritis: A controlled analysis', *Arthritis and rheumatism*, 59(10), pp. 1424–1431. Available at: <https://doi.org/10.1002/art.24120>.

Ingham, S.L. *et al.* (2010) 'Development and validation of self-reported line drawings for assessment of knee malalignment and foot rotation: a cross-sectional comparative study', *BMC MEDICAL RESEARCH METHODOLOGY*, 10. Available at: <https://doi.org/10.1186/1471-2288-10-57>.

Institute of Medicine (2011) *Relieving Pain in America: A Blueprint for Transforming Prevention, Care, Education, and Research*. Washington, DC: The National Academies Press. Available at: <https://doi.org/10.17226/13172>.

Isakov, E. (2006) 'Gait rehabilitation: a new biofeedback device for monitoring and enhancing weight-bearing over the affected lower limb.', *Europa medicophysica*, 43(1), pp. 21–26.

Ismail, A.I., Al-Abdulwahab, A.H. and Al-Mulhim, A.S. (2006) 'Osteoarthritis of knees and obesity in Eastern Saudi Arabia', *Saudi medical journal*, 27(11), pp. 1742–1744.

Issa, R. and Griffin, T. (2012) 'Pathobiology of obesity and osteoarthritis: integrating biomechanics and inflammation', *Pathobiology of Aging & Age-related Diseases*, 2(1), p. 17470. Available at: <https://doi.org/10.3402/pba.v2i0.17470>.

Izumi, M. *et al.* (2022) 'Detection of altered pain facilitatory and inhibitory mechanisms in patients with knee osteoarthritis by using a simple bedside tool kit (QuantiPain).', *Pain reports*, 7(3), p. e998. Available at: <https://doi.org/10.1097/PR9.0000000000000998>.

Jadelis, K. *et al.* (2001) 'Strength, Balance, and the Modifying Effects of Obesity and Knee Pain: Results from the Observational Arthritis Study in Seniors (OASIS)', *Journal of the American Geriatrics Society (JAGS)*, 49(7), pp. 884–891. Available at: <https://doi.org/10.1046/j.1532-5415.2001.49178.x>.

Jamieson, S. (2004) 'Likert scales: how to (ab)use them', 38(12), pp. 1217–1218. Available at: <https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2929.2004.02012.x> (Accessed: 12 April 2023).

Järvholm, B. *et al.* (2008) 'Incidence of surgically treated osteoarthritis in the hip and knee in male construction workers', *Occupational and environmental medicine*, 65(4), pp. 275–278.

Javadian, Y. *et al.* (2017) 'Quadriceps muscle strength correlates with serum vitamin D and knee pain in knee osteoarthritis', *The Clinical journal of pain*, 33(1), pp. 67–70.

Jayaraman, C. *et al.* (2018) 'Impact of powered knee-ankle prosthesis on low back muscle mechanics in transfemoral amputees: A case series', *Frontiers in Neuroscience*, 12(MAR), p. 134. Available at: <https://doi.org/10.3389/fnins.2018.00134>.

Jenkyn, T. *et al.* (2008) 'Toe-out gait in patients with knee osteoarthritis partially transforms external knee adduction moment into flexion moment during early stance phase of gait: A tri-planar kinetic mechanism', *Journal of Biomechanics*, 41(2), pp. 276–283. Available at: <https://doi.org/10.1016/j.jbiomech.2007.09.015>.

Jenkyn, T.R., Erhart, J.C. and Andriacchi, T.P. (2011) 'An analysis of the mechanisms for reducing the knee adduction moment during walking using a variable stiffness shoe in subjects with knee osteoarthritis', *JOURNAL OF BIOMECHANICS*, 44(7), pp. 1271–1276. Available at: <https://doi.org/10.1016/j.jbiomech.2011.02.013>.

Jensen, L.K. (2005) 'Knee-straining work activities, self-reported knee disorders and radiographically determined knee osteoarthritis', *Scandinavian journal of work, environment & health*, pp. 68–74.

Jensen, L.K. (2008) 'Knee osteoarthritis: influence of work involving heavy lifting, kneeling, climbing stairs or ladders, or kneeling/squatting combined with heavy lifting', *Occupational and environmental medicine*, 65(2), pp. 72–89.

Jinks, C., Jordan, K. and Croft, P. (2002) 'Measuring the population impact of knee pain and disability with the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)', *Pain (Amsterdam)*, 100(1), pp. 55–64. Available at: [https://doi.org/10.1016/S0304-3959\(02\)00239-7](https://doi.org/10.1016/S0304-3959(02)00239-7).

Jones, R.K., Nester, C.J., *et al.* (2013) 'A comparison of the biomechanical effects of valgus knee braces and lateral wedged insoles in patients with knee osteoarthritis', *Gait & posture*, 37(3), p. 368-372. Available at:

<https://doi.org/10.1016/j.gaitpost.2012.08.002>.

Jones, R.K., Zhang, M., *et al.* (2013) 'The biomechanical effects of a new design of lateral wedge insole on the knee and ankle during walking', *Human movement science*, 32(4), pp. 596–604. Available at: <https://doi.org/10.1016/j.humov.2012.12.012>.

Jones, R.K. *et al.* (2014) 'The relationship between reductions in knee loading and immediate pain response whilst wearing lateral wedged insoles in knee osteoarthritis', *Journal of orthopaedic research*, 32(9), pp. 1147–1154. Available at: <https://doi.org/10.1002/jor.22666>.

Jones, R.K. *et al.* (2015) 'The effect of different types of insoles or shoe modifications on medial loading of the knee in persons with medial knee osteoarthritis: a randomised trial', *Journal of orthopaedic research*, 33(11), p. 1646–1654. Available at: <https://doi.org/10.1002/jor.22947>.

Jordan, J.M. *et al.* (2004) 'A Case-Control Study of Serum Tocopherol Levels and the Alpha- to Gamma-Tocopherol Ratio in Radiographic Knee Osteoarthritis: The Johnston County Osteoarthritis Project', *American Journal of Epidemiology*, 159(10), pp. 968–977. Available at: <https://doi.org/10.1093/aje/kwh133>.

Jordan, K.M. *et al.* (2003) 'EULAR Recommendations 2003: an evidence based approach to the management of knee osteoarthritis: Report of a Task Force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT)', *Annals of the rheumatic diseases*, 62(12), pp. 1145–1155. Available at: <https://doi.org/10.1136/ard.2003.011742>.

Jüni, P. *et al.* (2015) 'Intra-articular corticosteroid for knee osteoarthritis', *Cochrane Database of Systematic Reviews*. John Wiley and Sons Ltd. Available at: <https://doi.org/10.1002/14651858.CD005328.pub3>.

Kahl, C. and Cleland, J.A. (2013) 'Visual analogue scale, numeric pain rating scale and the McGill pain Questionnaire: an overview of psychometric properties', <https://doi.org/10.1179/108331905X55776>, 10(2), pp. 123–128. Available at: <https://doi.org/10.1179/108331905X55776>.

Kakahana, W. *et al.* (2004) 'Changes of Joint Moments in the Gait of Normal Subjects Wearing Laterally Wedged Insoles', *American journal of physical medicine & rehabilitation*, 83(4), pp. 273–278. Available at: <https://doi.org/10.1097/01.PHM.0000118035.71195.DE>.

Kakahana, W. *et al.* (2005) 'Effects of laterally wedged insoles on knee and subtalar joint moments', *Archives of Physical Medicine and Rehabilitation*, 86(7), pp. 1465–1471. Available at: <https://doi.org/10.1016/j.apmr.2004.09.033>.

Kanavaki, A.M. *et al.* (2017) 'Barriers and facilitators of physical activity in knee and hip osteoarthritis: a systematic review of qualitative evidence', *BMJ open*, 7(12), pp. e017042–e017042. Available at: <https://doi.org/10.1136/bmjopen-2017-017042>.

Kapadia, B.H. *et al.* (2016) 'Gait Using Pneumatic Brace for End-Stage Knee Osteoarthritis', *Journal of knee surgery*, 29(3), p. 218–223. Available at: <https://doi.org/10.1055/s-0036-1579790>.

Kaptein, M. (2019) 'A practical approach to sample size calculation for fixed populations', *Contemporary clinical trials communications*, 14, pp. 100339–100339. Available at: <https://doi.org/10.1016/j.conctc.2019.100339>.

Kaptein, S.A. *et al.* (2013) 'Choosing Where to Put Your Energy: A Qualitative

Analysis of the Role of Physical Activity in the Lives of Working Adults With Arthritis', *Arthritis care & research* (2010), 65(7), pp. 1070–1076. Available at: <https://doi.org/10.1002/acr.21957>.

Karami, N. *et al.* (2018) 'Knowledge and attitude of analgesics use among Saudi population: A cross-sectional study', *Int J Med Sci Public Health*, 7(2), pp. 137–142.

Karlinsky, K.T. *et al.* (2022) 'Static Balance Digital Endpoints with Mon4t: Smartphone Sensors vs. Force Plate', *Sensors (Basel, Switzerland)*, 22. Available at: <https://api.semanticscholar.org/CorpusID:249258744>.

Kaufman, K.R. *et al.* (2001) 'Gait characteristics of patients with knee osteoarthritis', *Journal of biomechanics*, 34(7), pp. 907–915. Available at: [https://doi.org/10.1016/S0021-9290\(01\)00036-7](https://doi.org/10.1016/S0021-9290(01)00036-7).

Kellgren, J.H. and Lawrence, J.S. (1957) 'Radiological assessment of osteo-arthritis', *Annals of the rheumatic diseases*, 16(4), p. 494. Available at: <https://doi.org/10.1136/ard.16.4.494>.

Kemp, G. *et al.* (2008) 'Reducing joint loading in medial knee osteoarthritis: Shoes and Canes', *ARTHRITIS & RHEUMATISM-ARTHRITIS CARE & RESEARCH*, 59(5), pp. 609–614. Available at: <https://doi.org/10.1002/art.23578>.

Kennedy-Martin, T. *et al.* (2015) 'A literature review on the representativeness of randomized controlled trial samples and implications for the external validity of trial results', *Trials*, 16(1), p. 495. Available at: <https://doi.org/10.1186/s13063-015-1023-4>.

Kerkhof, H.J.M. *et al.* (2010) 'A genome-wide association study identifies an osteoarthritis susceptibility locus on chromosome 7q22', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 62(2), pp. 499–510.

Kerrigan, D Casey *et al.* (2002) 'Effectiveness of a lateral-wedge insole on knee varus torque in patients with knee osteoarthritis', *Archives of physical medicine and rehabilitation*, 83(7), pp. 889–893.

Kerrigan, D. Casey *et al.* (2002) 'Effectiveness of a lateral-wedge insole on knee varus torque in patients with knee osteoarthritis', *Archives of Physical Medicine and Rehabilitation*, 83(7), pp. 889–893. Available at: <https://doi.org/10.1053/apmr.2002.33225>.

Kerrigan, D.C. *et al.* (2003) 'Men's shoes and knee joint torques relevant to the development and progression of knee osteoarthritis.', *The Journal of rheumatology*, 30(3), pp. 529–533.

Kettlety, S. *et al.* (2020) 'Changes in hip mechanics during gait modification to reduce knee abduction moment', *JOURNAL OF BIOMECHANICS*, 99. Available at: <https://doi.org/10.1016/j.jbiomech.2019.109509>.

Khalaj, N., Osman, Noor Azuan Abu, *et al.* (2014) 'Balance and risk of fall in individuals with bilateral mild and moderate knee osteoarthritis', *PloS one*, 9(3), pp. e92270–e92270. Available at: <https://doi.org/10.1371/journal.pone.0092270>.

Khalaj, N., Osman, Noor A.Abu, *et al.* (2014) 'Effect of exercise and gait retraining on knee adduction moment in people with knee osteoarthritis', *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, 228(2), pp. 190–199. Available at: <https://doi.org/10.1177/0954411914521155>.

Khalid W. AlKuwaity, Tasneem N. Mohammad, Malik A. Hussain, Annas Alkhanani, A.M.. A. (2018) 'Prevalence and Determinant Factors of Osteoarthritis of the Knee

- Joint among Elderly in Arar, KSA', *The Egyptian Journal of Hospital Medicine*, 72(9).
- Khan, S.J. *et al.* (2020) 'Orthoses versus gait retraining: Immediate response in improving physical performance measures in healthy and medial knee osteoarthritic adults', *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, 234(7), pp. 749–757.
- Khan, S.J.S.S., Khan, S.J.S.S. and Usman, J. (2017) 'Effects of toe-out and toe-in gait with varying walking speeds on knee joint mechanics and lower limb energetics', *GAIT & POSTURE*, 53, pp. 185–192. Available at: <https://doi.org/10.1016/j.gaitpost.2017.01.022>.
- Khandha, A. *et al.* (2019) 'High muscle co-contraction does not result in high joint forces during gait in anterior cruciate ligament deficient knees', *Journal of Orthopaedic Research*, 37(1), pp. 104–112. Available at: <https://doi.org/https://doi.org/10.1002/jor.24141>.
- Khosravi, M. *et al.* (2019) 'An evaluation of the use of a lateral wedged insole and a valgus knee brace in combination in subjects with medial compartment knee osteoarthritis (OA)', *Assistive technology*, 33(2), p. 1-8. Available at: <https://doi.org/10.1080/10400435.2019.1595788>.
- Khosravi, M. *et al.* (2022) 'Effect of knee braces and insoles on clinical outcomes of individuals with medial knee osteoarthritis: A systematic review and meta-analysis.', *Assistive technology: the official journal of RESNA*, 34(5), pp. 501–517. Available at: <https://doi.org/10.1080/10400435.2021.1880495>.
- Khosravi, M., Arazpour, M. and Sharafat Vaziri, A. (2021) 'An evaluation of the use of a lateral wedged insole and a valgus knee brace in combination in subjects with medial compartment knee osteoarthritis (OA)', *Assistive technology*, 33(2), pp. 87–94. Available at: <https://doi.org/10.1080/10400435.2019.1595788>.
- Kim, D. *et al.* (2018) 'The effects of pain on quadriceps strength, joint proprioception and dynamic balance among women aged 65 to 75 years with knee osteoarthritis', *BMC geriatrics*, 18(1), pp. 1–6.
- Kim, I. *et al.* (2010) 'The prevalence of knee osteoarthritis in elderly community residents in Korea', *Journal of Korean medical science*, 25(2), pp. 293–298.
- Kim, J.-H., Kim, H.-J. and Lee, D.-H. (2017) 'Survival of opening versus closing wedge high tibial osteotomy: a meta-analysis', *Scientific reports*, 7(1), pp. 1–7.
- Kim, J. *et al.* (2020) 'Foot Pressure Feedback Pneumatic Orthosis: Implication of Daily Life Walking Training for Knee Osteoarthritis Patients', *International journal of precision engineering and manufacturing*, 21(11), pp. 2191–2198. Available at: <https://doi.org/10.1007/s12541-020-00397-7>.
- Kiss, R.M. (2011) 'Effect of severity of knee osteoarthritis on the variability of gait parameters.', *Journal of electromyography and kinesiology: official journal of the International Society of Electrophysiological Kinesiology*, 21(5), pp. 695–703. Available at: <https://doi.org/10.1016/j.jelekin.2011.07.011>.
- Kitzinger, J. (1995) 'Qualitative Research: Introducing focus groups', *BMJ*, 311(7000), pp. 299–302. Available at: <https://doi.org/10.1136/BMJ.311.7000.299>.
- Klein-Wieringa, I.R. *et al.* (2011) 'The infrapatellar fat pad of patients with osteoarthritis has an inflammatory phenotype', *Annals of the Rheumatic Diseases*, 70(5), pp. 851 LP – 857. Available at: <https://doi.org/10.1136/ard.2010.140046>.
- Knudson, D. (2007) 'Fundamentals of Biomechanics and Qualitative Analysis', in

Fundamentals of Biomechanics. Springer US, pp. 23–37. Available at: https://doi.org/10.1007/978-0-387-49312-1_2.

Kolasinski, S.L. *et al.* (2020) '2019 American College of Rheumatology/Arthritis Foundation Guideline for the Management of Osteoarthritis of the Hand, Hip, and Knee', *Arthritis and Rheumatology*, 72(2), pp. 220–233. Available at: <https://doi.org/10.1002/ART.41142/ABSTRACT>.

Kornaat, P.R. *et al.* (2006) 'Osteoarthritis of the knee: Association between clinical features and MR imaging findings', *Radiology*, 239(3), pp. 811–817. Available at: <https://doi.org/10.1148/radiol.2393050253>.

Kosek, E. and Ordeberg, G. (2000) 'Abnormalities of somatosensory perception in patients with painful osteoarthritis normalize following successful treatment', *European journal of pain*. Received 1 July 1..., 4(3), pp. 229–238. Available at: <https://doi.org/10.1053/eujp.2000.0175>.

Kramarow, E.A. (2015) *Deaths from unintentional injury among adults aged 65 and over, United States, 2000-2013 / Ellen Kramarow [and three others]*. document. Maryland: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, 2015.

Kroll, T., Neri, M.T. and Miller, K. (2005) 'Using Mixed Methods in Disability and Rehabilitation Research', *Rehabilitation Nursing*, 30(3), pp. 106–113. Available at: <https://doi.org/10.1002/J.2048-7940.2005.TB00372.X>.

Krosnick, J.A. (1991) 'Response strategies for coping with the cognitive demands of attitude measures in surveys', *Applied cognitive psychology*, 5(3), pp. 213–236.

Krueger, R.A. (2014) *Focus groups: A practical guide for applied research*. Sage publications.

KS, A.-Z. *et al.* (2002) 'A study of the gait characteristics of patients with chronic osteoarthritis of the knee', *Disability and Rehabilitation*, 24(5), pp. 275–280. Available at: <https://doi.org/10.1080/09638280110087098>.

Kuitunen, S., Komi, P. V and Kyröläinen, H. (2002) 'Knee and ankle joint stiffness in sprint running.', *Medicine and science in sports and exercise*, 34(1), pp. 166–173.

Kuroyanagi, Y. *et al.* (2007) 'The lateral wedged insole with subtalar strapping significantly reduces dynamic knee load in the medial compartment - Gait analysis on patients with medial knee osteoarthritis', *OSTEOARTHRITIS AND CARTILAGE*, 15(8), pp. 932–936. Available at: <https://doi.org/10.1016/j.joca.2007.02.004>.

Kutzner, I. *et al.* (2010) 'Loading of the knee joint during activities of daily living measured in vivo in five subjects', *Journal of biomechanics*, 43(11), pp. 2164–2173.

Kutzner, I. *et al.* (2011) 'The Effect of Laterally Wedged Shoes on the Loading of the Medial Knee Compartment-In Vivo Measurements with Instrumented Knee Implants', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 29(12), pp. 1910–1915. Available at: <https://doi.org/10.1002/jor.21477>.

Laerum, E., Indahl, A. and Sture Skouen, J. (2006) 'WHAT IS THE GOOD BACK-CONSULTATION? A COMBINED QUALITATIVE AND QUANTITATIVE STUDY OF CHRONIC LOW BACK PAIN PATIENTS' INTERACTION WITH AND PERCEPTIONS OF CONSULTATIONS WITH SPECIALISTS', *Journal of rehabilitation medicine*, 38(4), pp. 255–262. Available at: <https://doi.org/10.1080/16501970600613461>.

Lafortune, M.A., Hennig, E.M. and Lake, M.J. (1996) 'Dominant role of interface over

knee angle for cushioning impact loading and regulating initial leg stiffness', *Journal of biomechanics*, 29(12), pp. 1523–1529.

Lajeunesse, D. and Reboul, P. (2003) 'Subchondral bone in osteoarthritis: a biologic link with articular cartilage leading to abnormal remodeling', *Current opinion in rheumatology*, 15(5), pp. 628–633.

Lamb, S.E. *et al.* (2010) 'A multicentred randomised controlled trial of a primary care-based cognitive behavioural programme for low back pain. The Back Skills Training (BeST) trial.', *Health technology assessment*, 14 41, pp. 1–253, iii–iv. Available at: <https://api.semanticscholar.org/CorpusID:40815430>.

Lambert, S.D. and Loiselle, C.G. (2008) 'Combining individual interviews and focus groups to enhance data richness', *Journal of advanced nursing*, 62(2), pp. 228–237. Available at: <https://doi.org/10.1111/j.1365-2648.2007.04559.x>.

Lancaster, G.A., Dodd, S. and Williamson, P.R. (2004) 'Design and analysis of pilot studies: recommendations for good practice', *Journal of evaluation in clinical practice*, 10(2), pp. 307–312. Available at: <https://doi.org/10.1111/j..2002.384.doc.x>.

Landry C, S. *et al.* (2007) 'Knee biomechanics of moderate OA patients measured during gait at a self-selected and fast walking speed', *Journal of Biomechanics*, 40(8), pp. 1754–1761. Available at: <https://doi.org/10.1016/j.jbiomech.2006.08.010>.

Larcom, K. *et al.* (2015) *Physical Demands Study-Focus Groups*. US Army Research Institute of Environmental Medicine Natick United States.

Larmer, P.J. *et al.* (2014) 'Systematic review of guidelines for the physical management of osteoarthritis', *Archives of physical medicine and rehabilitation*, 95(2), pp. 375–389. Available at: <https://doi.org/10.1016/j.apmr.2013.10.011>.

Larsen, P.D. (2021) *Lubkin's chronic illness: impact and intervention*. Jones & Bartlett Learning.

Lawrence, R.C. *et al.* (2008) 'Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part II', *Arthritis and Rheumatism*, 58(1), pp. 26–35. Available at: <https://doi.org/10.1002/art.23176>.

Ledingham, J. *et al.* (1993) 'Radiographic patterns and associations of osteoarthritis of the knee in patients referred to hospital', *Annals of the Rheumatic Diseases*, 52(7), pp. 520–526. Available at: <https://doi.org/10.1136/ard.52.7.520>.

Lee, J.W. *et al.* (2002) 'Cultural differences in responses to a likert scale', *Research in nursing & health*, 25(4), pp. 295–306. Available at: <https://doi.org/10.1002/nur.10041>.

Lespasio, M.J. *et al.* (2017) 'Knee Osteoarthritis: A Primer', *The Permanente journal*, 21, pp. 1–7. Available at: <https://doi.org/10.7812/TPP/16-183>.

Leung, C.M. *et al.* (2005) 'Small-group hypertension health education programme: a process and outcome evaluation', *Journal of Advanced Nursing*, 52(6), pp. 631–639.

Lewek, M.D., Rudolph, K.S. and Snyder-Mackler, L. (2004) 'Control of frontal plane knee laxity during gait in patients with medial compartment knee osteoarthritis', *Osteoarthritis and cartilage*, 12(9), pp. 745–751.

Lewis, M. *et al.* (2021) 'Determining sample size for progression criteria for pragmatic pilot RCTs: the hypothesis test strikes back!', *Pilot and Feasibility Studies*, 7(1), pp. 1–14. Available at: <https://doi.org/10.1186/S40814-021-00770-X/FIGURES/2>.

Li, F. *et al.* (2001) 'Tai Chi, Self-Efficacy, and Physical Function in the Elderly', *Prevention science*, 2(4), pp. 229–239. Available at: <https://doi.org/10.1023/A:1013614200329>.

Li, X. *et al.* (2011) 'Cartilage in anterior cruciate ligament–reconstructed knees: MR imaging T1p and T2—initial experience with 1-year follow-up', *Radiology*, 258(2), pp. 505–514.

Liamputtong, P. (2005) *Qualitative research methods*. 2nd ed. Edited by D. Ezzy. South Melbourne, Vic.: Oxford University Press.

Lidtke, R. *et al.* (2010) 'Foot center of pressure and medial knee osteoarthritis', *Journal - American Podiatric Medical Association*, 100(3), pp. 178–184.

Lim, B.-W. *et al.* (2008) 'Varus Malalignment and its association with impairments and functional limitations in medial knee osteoarthritis', *ARTHRITIS & RHEUMATISM-ARTHRITIS CARE & RESEARCH*, 59(7), pp. 935–942. Available at: <https://doi.org/10.1002/art.23820>.

Lim, B. *et al.* (2008) 'Does knee malalignment mediate the effects of quadriceps strengthening on knee adduction moment, pain, and function in medial knee osteoarthritis? A randomized controlled trial.', *Arthritis & Rheumatism: Arthritis Care & Research*, 59(7), pp. 943–951. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=105803648&site=ehost-live>.

Lin, D.-H. *et al.* (2009) 'Efficacy of 2 Non-Weight-Bearing Interventions, Proprioception Training Versus Strength Training, for Patients With Knee Osteoarthritis: A Randomized Clinical Trial', *JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY*, 39(6), pp. 450–457. Available at: <https://doi.org/10.2519/jospt.2009.2923>.

Lin, W. *et al.* (2013) 'Physical activity in relation to knee cartilage T2 progression measured with 3 T MRI over a period of 4 years: data from the Osteoarthritis Initiative', *Osteoarthritis and cartilage*, 21(10), pp. 1558–1566. Available at: <https://doi.org/10.1016/j.joca.2013.06.022>.

Lindenfeld, T.N., Hewett, T.E. and Andriacchi, T.P. (1997) 'Joint loading with valgus bracing in patients with varus gonarthrosis', *Clinical Orthopaedics and Related Research*, (344), pp. 290–297. Available at: <https://doi.org/10.1097/00003086-199711000-00029>.

Lindsey, B. *et al.* (2019) 'Single-Parameter Gait Modifications Cause Involuntary Secondary Gait Changes', *Journal is not defined within the JOURNAL database*. [Preprint]. Available at: <https://api.semanticscholar.org/CorpusID:198272823>.

Lindsey, B. *et al.* (2020) 'Reductions in peak knee abduction moment in three previously studied gait modification strategies', *KNEE*, 27(1), pp. 102–110. Available at: <https://doi.org/10.1016/j.knee.2019.09.017>.

Link, T.M. (2009) 'Correlations Between Joint Morphology and Pain and Between Magnetic Resonance Imaging, Histology, and Micro-Computed Tomography', *Journal of bone and joint surgery. American volume*, 91(Supplement_1 Suppl 1), pp. 30–32. Available at: <https://doi.org/10.2106/JBJS.H.01313>.

Lipscomb, M. (2008) 'Mixed method nursing studies: a critical realist critique', *Nursing philosophy*, 9(1), pp. 32–45. Available at: <https://doi.org/10.1111/j.1466-769X.2007.00325.x>.

- Litosseliti, L. (2003) *Using focus groups in research*. A&C Black.
- Little, R.J.A. and Rubin, D.B. (2014) *Statistical analysis with missing data, second edition*. 2nd ed. Wiley.
- Liu, A. *et al.* (2018) 'Do non-responders to lateral wedge insoles remain nonresponders after an eight week intervention?', *Osteoarthritis and cartilage*, 26, p. S386-S387. Available at: <https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01613475/full>.
- Liu, M.Q. *et al.* (2008) 'Muscle contributions to support and progression over a range of walking speeds', *Journal of biomechanics*, 41(15), pp. 3243–3252. Available at: <https://doi.org/10.1016/j.jbiomech.2008.07.031>.
- Loening, A.M. *et al.* (2000) 'Injurious mechanical compression of bovine articular cartilage induces chondrocyte apoptosis', *Archives of biochemistry and biophysics*, 381(2), pp. 205–212.
- Loeser, R.F. (2009) 'Aging and osteoarthritis: the role of chondrocyte senescence and aging changes in the cartilage matrix', *Osteoarthritis and cartilage*, 17(8), pp. 971–979.
- Loeulle, D. *et al.* (2011) 'Comparing non-enhanced and enhanced sequences in the assessment of effusion and synovitis in knee OA: associations with clinical, macroscopic and microscopic features.', *Osteoarthritis and cartilage*, 19 12, pp. 1433–1439. Available at: <https://api.semanticscholar.org/CorpusID:41196210>.
- Lohmander, L.S. *et al.* (2004) 'High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury', *Arthritis & Rheumatism*, 50(10), pp. 3145–3152. Available at: <https://doi.org/https://doi.org/10.1002/art.20589>.
- Long, H. *et al.* (2020) 'Burden of osteoarthritis in China, 1990–2017: findings from the Global Burden of Disease Study 2017', *The Lancet Rheumatology*, 2(3), pp. e164–e172. Available at: [https://doi.org/10.1016/S2665-9913\(19\)30145-6](https://doi.org/10.1016/S2665-9913(19)30145-6).
- Lorenzo-Seva, U. and Ferrando, P.J. (2009) 'Acquiescent responding in partially balanced multidimensional scales', *British journal of mathematical & statistical psychology*. Received 11 April..., 62(2), pp. 319–326. Available at: <https://doi.org/10.1348/000711007X265164>.
- Lorig, K.R. *et al.* (2006) 'Internet-Based Chronic Disease Self-Management: A Randomized Trial', *Medical care*, 44(11), pp. 964–971. Available at: <https://doi.org/10.1097/01.mlr.0000233678.80203.c1>.
- Lorig, K.R. and Holman, H.R. (2003) 'Self-management education: History, definition, outcomes, and mechanisms', *Annals of behavioral medicine*, 26(1), pp. 1–7. Available at: https://doi.org/10.1207/S15324796ABM2601_01.
- Losina, E. *et al.* (2011) 'Impact of Obesity and Knee Osteoarthritis on Morbidity and Mortality in Older Americans', *Annals of Internal Medicine*, 154(4), pp. 217–226. Available at: <https://doi.org/10.7326/0003-4819-154-4-201102150-00001>.
- Lowe, D.B., Taylor, M.J. and Hill, S.J. (2015) 'Communication Vulnerabilities in Working-age Australians with Musculoskeletal Conditions: A Cross-sectional Analysis', *The Journal of Rheumatology*, 42(8), pp. 1484 LP – 1493. Available at: <https://doi.org/10.3899/jrheum.140989>.
- Luc, B., Gribble, P.A. and Pietrosimone, B.G. (2014) 'Osteoarthritis prevalence following anterior cruciate ligament reconstruction: a systematic review and numbers-

needed-to-treat analysis', *Journal of athletic training*, 49(6), pp. 806–819.

Luger, M. *et al.* (2023) 'Not all questions are created equal: the weight of the Oxford Knee Scores questions in a multicentric validation study.', *Journal of orthopaedics and traumatology: official journal of the Italian Society of Orthopaedics and Traumatology*, 24(1), p. 44. Available at: <https://doi.org/10.1186/s10195-023-00722-6>.

Lund, H. *et al.* (2008) 'A randomized controlled trial of aquatic and land-based exercise in patients with knee osteoarthritis', *Journal of rehabilitation medicine*, 40(2), pp. 137–144.

Lundblad, H. *et al.* (2012) 'The value of preoperative grade of radiographic and histological changes in predicting pain relief after total knee arthroplasty for osteoarthritis', *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA*, 20(9), pp. 1815–1821. Available at: <https://doi.org/10.1007/s00167-011-1821-5>.

Luz, N. (2020) 'Pilgrimage and religious tourism in Islam', *Annals of tourism research*, 82, p. 102915. Available at: <https://doi.org/10.1016/j.annals.2020.102915>.

Lynn, S.K., Kajaks, T. and Costigan, P.A. (2008) 'The effect of internal and external foot rotation on the adduction moment and lateral–medial shear force at the knee during gait', *Journal of Science and Medicine in Sport*, 11(5), pp. 444–451.

Lyu, S.-R., Ogata, K. and Hoshiko, I. (2000) 'Effects of a cane on floor reaction force and center of force during gait', *Clinical Orthopaedics and Related Research*®, 375, pp. 313–319.

Macfarlane, G.J. (2010) 'Life-course influences on chronic pain in adults', in *Chronic Pain Epidemiology*. Oxford: Oxford University Press. Available at: <https://doi.org/10.1093/acprof:oso/9780199235766.003.0015>.

MacKay, C., Hawker, G.A. and Jaglal, S.B. (2018) 'Qualitative study exploring the factors influencing physical therapy management of early knee osteoarthritis in Canada', *BMJ open*, 8(11), pp. e023457–e023457. Available at: <https://doi.org/10.1136/bmjopen-2018-023457>.

MacKay, C., Hawker, G.A. and Jaglal, S.B. (2020) 'How do physical therapists approach management of people with early knee osteoarthritis? A qualitative study', *Physical therapy*, 100(2), pp. 295–306.

MacPhail, C. *et al.* (2015) 'Process guidelines for establishing Inter-coder Reliability in qualitative studies', *Qualitative Research*, 16(2), pp. 198–212. Available at: <https://doi.org/10.1177/1468794115577012>.

Madry, H. *et al.* (2016) 'Early osteoarthritis of the knee', *Knee Surgery, Sports Traumatology, Arthroscopy*, 24, pp. 1753–1762.

Magyar, M.O., Knoll, Z. and Kiss, R.M. (2012) 'The influence of medial meniscus injury and meniscectomy on the variability of gait parameters', *Knee Surgery, Sports Traumatology, Arthroscopy*, 20, pp. 290–297. Available at: <https://api.semanticscholar.org/CorpusID:21757039>.

Maher, J.M., Markey, J.C. and Ebert-May, D. (2013) 'The other half of the story: effect size analysis in quantitative research.', *CBE life sciences education*, 12(3), pp. 345–351. Available at: <https://doi.org/10.1187/cbe.13-04-0082>.

Mahmoudian, A. *et al.* (2021) 'Early-stage symptomatic osteoarthritis of the knee - time for action', *Nature reviews. Rheumatology*, 17(10), pp. 621–632. Available at:

<https://doi.org/10.1038/s41584-021-00673-4>.

Maillefert, J.F. *et al.* (2001) 'Laterally elevated wedged insoles in the treatment of medial knee osteoarthritis: a prospective randomized controlled study', *Osteoarthritis and cartilage*, 9(8 CC-Musculoskeletal CC-Bone, Joint and Muscle Trauma), p. 738-745. Available at: <https://doi.org/10.1053/joca.2001.0470>.

Maleki, M. *et al.* (2016) 'The effect of knee orthoses on gait parameters in medial knee compartment osteoarthritis: A literature review', *Prosthetics and orthotics international*, 40(2), pp. 193–201. Available at: <https://doi.org/10.1177/0309364614547411>.

Malorgio, A. *et al.* (2021) 'High intensity resistance training as intervention method to knee osteoarthritis.', *Sports medicine and health science*. Netherlands, pp. 46–48. Available at: <https://doi.org/10.1016/j.smhs.2021.02.005>.

Maly, M.R. *et al.* (2002) 'Static and dynamic biomechanics of foot orthoses in people with medial compartment knee osteoarthritis', *Clinical Biomechanics*, 17(8), pp. 603–610. Available at: <https://doi.org/http://dx.doi.org/10.1016/S0268-0033%2802%2900073-6>.

Maly, M.R., Culham, E.G. and Costigan, P.A. (2002) 'Static and dynamic biomechanics of foot orthoses in people with medial compartment knee osteoarthritis', *Clinical biomechanics (Bristol)*, 17(8), pp. 603–610. Available at: [https://doi.org/10.1016/S0268-0033\(02\)00073-6](https://doi.org/10.1016/S0268-0033(02)00073-6).

Manal, K. *et al.* (2015) 'A more informed evaluation of medial compartment loading: the combined use of the knee adduction and flexor moments', *OSTEOARTHRITIS AND CARTILAGE*, 23(7), pp. 1107–1111. Available at: <https://doi.org/10.1016/j.joca.2015.02.779>.

Manninen, P. *et al.* (1996) 'Overweight, gender and knee osteoarthritis', *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity*, 20(6), pp. 595–597. Available at: <http://europepmc.org/abstract/MED/8782738>.

Mannisi, M. *et al.* (2019) 'Effect of lateral wedged insoles on the knee internal contact forces in medial knee osteoarthritis', *Gait and Posture*, 68, pp. 443–448. Available at: <https://doi.org/10.1016/j.gaitpost.2018.12.030>.

Marconcin, P. *et al.* (2015) 'Predictors of Timed "Up-and-Go" Test in Elderly with Knee Osteoarthritis', in *International Congress on Sport Sciences Research and Technology Support*. SCITEPRESS, pp. 97–103.

Marks, R., Allegrante, J.P. and Lorig, K. (2005) 'A Review and Synthesis of Research Evidence for Self-Efficacy-Enhancing Interventions for Reducing Chronic Disability: Implications for Health Education Practice (Part II)', *Health promotion practice*, 6(2), pp. 148–156. Available at: <https://doi.org/10.1177/1524839904266792>.

Martel-Pelletier, J. *et al.* (2019) 'A new decision tree for diagnosis of osteoarthritis in primary care: international consensus of experts', *Aging clinical and experimental research*, 31(1), pp. 19–30.

Mashrai, S. *et al.* (2022) 'The extent of knee osteoarthritis patients adherence to exercise and reducing weight in Makkah, Saudi Arabia—A cross sectional study'.

Matsumoto, T. *et al.* (2005) 'Influence of hip position on knee flexion angle in patients undergoing total knee arthroplasty.', *The Journal of arthroplasty*, 20 5, pp. 669–673. Available at: <https://api.semanticscholar.org/CorpusID:38042504>.

Matsuno, H., KM, K. and Tsuji, H. (1997) 'Generation II knee bracing for severe medial

compartment osteoarthritis of the knee.’, *Archives of Physical Medicine and Rehabilitation*, 78(7), pp. 745–749.

Mazières, B. *et al.* (2008) ‘Adherence to, and results of, physical therapy programs in patients with hip or knee osteoarthritis. Development of French clinical practice guidelines’, *Joint Bone Spine*, 75(5), pp. 589–596. Available at: <https://doi.org/10.1016/J.JBSPIN.2008.02.016>.

McAlindon, T. E. *et al.* (2014) ‘OARSI guidelines for the non-surgical management of knee osteoarthritis’, 22(3), pp. 363–388. Available at: <https://doi.org/10.1016/j.joca.2014.01.003>.

McAlindon, T.E. *et al.* (1992) ‘Knee pain and disability in the community’, *British journal of rheumatology*, 31(3), pp. 189–192. Available at: <https://doi.org/10.1093/rheumatology/31.3.189>.

McAlindon, T. E. *et al.* (1992) ‘Radiographic patterns of osteoarthritis of the knee joint in the community: The importance of the patellofemoral joint’, *Annals of the Rheumatic Diseases*, 51(7), pp. 844–849. Available at: <https://doi.org/10.1136/ard.51.7.844>.

McAlindon, T.E. *et al.* (1993) ‘Determinants of disability in osteoarthritis of the knee.’, *Annals of the rheumatic diseases*, 52(4), pp. 258–262.

McAlindon, T.E., Jacques, P., *et al.* (1996) ‘Do antioxidant micronutrients protect against the development and progression of knee osteoarthritis?’, *Arthritis & Rheumatism*, 39(4), pp. 648–656. Available at: <https://doi.org/https://doi.org/10.1002/art.1780390417>.

McAlindon, T.E., Felson, D.T., *et al.* (1996) ‘Relation of dietary intake and serum levels of vitamin D to progression of osteoarthritis of the knee among participants in the Framingham Study’, *Annals of internal medicine*, 125(5), pp. 353–359.

McGill, S.M. *et al.* (2003) ‘Coordination of muscle activity to assure stability of the lumbar spine’, *Journal of Electromyography and Kinesiology*, 13(4), pp. 353–359. Available at: [https://doi.org/https://doi.org/10.1016/S1050-6411\(03\)00043-9](https://doi.org/https://doi.org/10.1016/S1050-6411(03)00043-9).

McGinnis, K. *et al.* (2013) ‘Dynamic joint stiffness and co-contraction in subjects after total knee arthroplasty’, *Clinical biomechanics*, 28(2), pp. 205–210.

McMahon, S.B. *et al.* (2013) *Wall & Melzack’s Textbook of Pain*. London: Elsevier.

McMillan, G. and Nichols, L. (2005) ‘Osteoarthritis and meniscus disorders of the knee as occupational diseases of miners’, *Occupational and environmental medicine*, 62(8), pp. 567–575.

McQuade, K.J. and De Oliveira, A.S. (2011) ‘Effects of progressive resistance strength training on knee biomechanics during single leg step-up in persons with mild knee osteoarthritis’, *Clinical biomechanics*, 26(7), pp. 741–748.

McSweeney, B. (2021) ‘Fooling ourselves and others: confirmation bias and the trustworthiness of qualitative research—Part 1 (the threats)’, *Journal of Organizational Change Management*, 34(5), pp. 1063–1075.

van Meer, B.L. *et al.* (2015) ‘Which determinants predict tibiofemoral and patellofemoral osteoarthritis after anterior cruciate ligament injury? A systematic review’, *British journal of sports medicine*, 49(15), pp. 975–983.

Meisenberg, G. and Williams, A. (2008) ‘Are acquiescent and extreme response styles related to low intelligence and education?’, *Personality and Individual Differences*, 44(7), pp. 1539–1550. Available at:

<https://doi.org/https://doi.org/10.1016/j.paid.2008.01.010>.

Merskey, H. (2014) 'Taxonomy and Classification of Chronic Pain Syndromes', in *Practical Management of Pain*. Fifth Edit, pp. 13-18.e1. Available at: <https://doi.org/10.1016/B978-0-323-08340-9.00002-5>.

Merskey, H. and Bogduk, N. (no date) 'Classification of chronic pain: description of chronic pain syndrome and definitions of pain terms. 2nd. ed1994'. Seattle: IASP Press.

Messier, S.P. *et al.* (1992) 'Osteoarthritis of the knee: effects on gait, strength, and flexibility.', *Archives of physical medicine and rehabilitation*, 73(1), pp. 29–36.

Messier, S.P. *et al.* (2004) 'Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis - The arthritis, diet, and activity promotion trial', *ARTHRITIS AND RHEUMATISM*, 50(5), pp. 1501–1510. Available at: <https://doi.org/10.1002/art.20256>.

Messier, S.P., DeVita, P., *et al.* (2005) 'Do older adults with knee osteoarthritis place greater loads on the knee during gait? A preliminary study', *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION*, 86(4), pp. 703–709. Available at: <https://doi.org/10.1016/j.apmr.2004.05.015>.

Messier, S.P., Gutekunst, D.J., *et al.* (2005) 'Weight loss reduces knee-joint loads in overweight and obese older adults with knee osteoarthritis', *ARTHRITIS AND RHEUMATISM*, 52(7), pp. 2026–2032. Available at: <https://doi.org/10.1002/art.21139>.

Messina, O.D., Vidal Wilman, M. and Vidal Neira, L.F. (2019) 'Nutrition, osteoarthritis and cartilage metabolism.', *Aging clinical and experimental research*, 31(6), pp. 807–813. Available at: <https://doi.org/10.1007/s40520-019-01191-w>.

Metcalfe, A.J. *et al.* (2017) 'Abnormal loading and functional deficits are present in both limbs before and after unilateral knee arthroplasty', *GAIT & POSTURE*, 55, pp. 109–115. Available at: <https://doi.org/10.1016/j.gaitpost.2017.04.008>.

Van Meurs, J.B.J. (2017) 'Osteoarthritis year in review 2016: genetics, genomics and epigenetics', *Osteoarthritis and cartilage*, 25(2), pp. 181–189.

Michael A. Hunt and January 2012 (no date) 'Knee OA: The evidence for gait modification | Lower Extremity Review Magazine'. Available at: <https://lermagazine.com/article/knee-oa-the-evidence-for-gait-modification> (Accessed: 4 May 2021).

Mikesky, A.E., Meyer, A. and Thompson, K.L. (2000) 'Relationship between quadriceps strength and rate of loading during gait in women', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 18(2), pp. 171–175. Available at: <https://doi.org/10.1002/jor.1100180202>.

Milentijevic, D., Helfet, D.L. and Torzilli, P.A. (2003) 'Influence of stress magnitude on water loss and chondrocyte viability in impacted articular cartilage', *J. Biomech. Eng.*, 125(5), pp. 594–601.

Miller, R.H., Brandon, S.C.E. and Deluzio, K.J. (2013) 'Predicting Sagittal Plane Biomechanics That Minimize the Axial Knee Joint Contact Force During Walking', *JOURNAL OF BIOMECHANICAL ENGINEERING-TRANSACTIONS OF THE ASME*, 135(1). Available at: <https://doi.org/10.1115/1.4023151>.

Milner, Clare E *et al.* (2018) 'Walking velocity and step length adjustments affect knee joint contact forces in healthy weight and obese adults', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 36(10), pp. 2679–2686. Available at:

<https://doi.org/10.1002/jor.24031>.

Milner, Clare E. *et al.* (2018) 'Walking velocity and step length adjustments affect knee joint contact forces in healthy weight and obese adults', *Journal of Orthopaedic Research*, 36(10), pp. 2679–2686. Available at: <https://doi.org/10.1002/jor.24031>.

Mirzaei, F. *et al.* (2018) 'Combined effects of a valgus knee brace and lateral wedge insole on walking in patients with medial compartment knee osteoarthritis', *JPO: Journal of Prosthetics and Orthotics*, 30(1), pp. 39–45. Available at: <https://doi.org/10.1097/JPO.0000000000000170>.

Missenard, O., Mottet, D. and Perrey, S. (2008) 'The role of cocontraction in the impairment of movement accuracy with fatigue', *Experimental brain research*, 185(1), pp. 151–156.

Miyazaki, T. *et al.* (2002) 'Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis', *Annals of the Rheumatic Diseases*, 61(7), pp. 617–622. Available at: <https://doi.org/10.1136/ard.61.7.617>.

Miyazaki, T. *et al.* (2021) 'The relationship between leg extension angle at late stance and knee flexion angle at swing phase during gait in community-dwelling older adults', *International journal of environmental research and public health*, 18(22), p. 11925. Available at: <https://doi.org/10.3390/ijerph182211925>.

Moffatt, S. *et al.* (2006) 'Using quantitative and qualitative data in health services research - What happens when mixed method findings conflict? [ISRCTN61522618]', *BMC Health Services Research*, 6(1), pp. 1–10. Available at: <https://doi.org/10.1186/1472-6963-6-28/FIGURES/1>.

Moher, D. *et al.* (2000) 'Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement', *British journal of surgery*, 87(11), pp. 1448–1454. Available at: <https://doi.org/10.1046/j.1365-2168.2000.01610.x>.

Moher, D., Schulz, K.F. and Altman, D.G. (2001) 'The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomised trials', *The Lancet (British edition)*, 357(9263), pp. 1191–1194. Available at: [https://doi.org/10.1016/S0140-6736\(00\)04337-3](https://doi.org/10.1016/S0140-6736(00)04337-3).

Mohr, M. *et al.* (2018) 'Reliability of the knee muscle co-contraction index during gait in young adults with and without knee injury history', *Journal of Electromyography and Kinesiology*, 38, pp. 17–27.

Molnar, V. *et al.* (2021) 'Cytokines and Chemokines Involved in Osteoarthritis Pathogenesis.', *International journal of molecular sciences*, 22(17). Available at: <https://doi.org/10.3390/ijms22179208>.

Molzahn, A.E. *et al.* (2005) 'Chinese Canadian Beliefs Toward Organ Donation', *Qualitative health research*, 15(1), pp. 82–98. Available at: <https://doi.org/10.1177/1049732304270653>.

Moore, G.F. *et al.* (2015) 'Process evaluation of complex interventions: Medical Research Council guidance', *BMJ*, 350. Available at: <https://doi.org/10.1136/BMJ.H1258>.

Moore, I.S., Jones, A.M. and Dixon, S.J. (2014) 'Relationship between metabolic cost and muscular coactivation across running speeds', *Journal of science and medicine in sport*, 17(6), pp. 671–676.

Morgan, D. (2012) 'Focus Groups as Qualitative Research', *Focus Groups as*

- Qualitative Research* [Preprint]. Available at: <https://doi.org/10.4135/9781412984287>.
- Morgan, D.L. *et al.* (1998) *The focus group guidebook*. Sage.
- Morgan, F. *et al.* (2016) 'Adherence to exercise referral schemes by participants – what do providers and commissioners need to know? A systematic review of barriers and facilitators'. Available at: <https://doi.org/10.1186/s12889-016-2882-7>.
- Morton, S. *et al.* (2011) *Finding What Works in Health Care: Standards for Systematic Reviews*. 3rd ed. Washington, D.C: Washington, D.C: National Academies Press. Available at: <https://doi.org/10.17226/13059>.
- Moseng, T. *et al.* (2024) 'EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis: 2023 update', *Annals of the rheumatic diseases* [Preprint].
- Moyer, R.F. *et al.* (2013) 'Combined effects of a valgus knee brace and lateral wedge foot orthotic on the external knee adduction moment in patients with varus gonarthrosis', *Archives of physical medicine and rehabilitation*, 94(1), p. 103-112. Available at: <https://doi.org/10.1016/j.apmr.2012.09.004>.
- Moyer, R.F. *et al.* (2015) 'Biomechanical effects of valgus knee bracing: A systematic review and meta-analysis', *Osteoarthritis and Cartilage*. W.B. Saunders Ltd, pp. 178–188. Available at: <https://doi.org/10.1016/j.joca.2014.11.018>.
- Muir, S.W. *et al.* (2010) 'Quantifying the magnitude of risk for balance impairment on falls in community-dwelling older adults: a systematic review and meta-analysis', *Journal of clinical epidemiology*, 63(4), pp. 389–406. Available at: <https://doi.org/10.1016/j.jclinepi.2009.06.010>.
- Mukharrib, M. *et al.* (2018) 'Knowledge of knee osteoarthritis among general population in Aseer region', *Journal of Family Medicine and Primary Care*, 7(6), p. 1385. Available at: https://doi.org/10.4103/jfmpc.jfmpc_290_18.
- Mundermann, A. *et al.* (2004) 'Potential strategies to reduce medial compartment loading in patients with knee osteoarthritis of varying severity - Reduced walking speed', *ARTHRITIS AND RHEUMATISM*, 50(4), pp. 1172–1178. Available at: <https://doi.org/10.1002/art.20132>.
- Mündermann, A., Dyrby, C.O., Hurwitz, D.E., Sharma, L. and Andriacchi, T.P. (2004) 'Potential strategies to reduce medial compartment loading in patients with knee osteoarthritis of varying severity: Reduced walking speed', *Arthritis & Rheumatism*, 50(4), pp. 1172–1178. Available at: <https://doi.org/10.1002/art.20132>.
- Mündermann, A., Dyrby, C.O., Hurwitz, D.E., Sharma, L., Andriacchi, T.P., *et al.* (2004) 'Potential strategies to reduce medial compartment loading in patients with knee osteoarthritis of varying severity - Reduced walking speed', *ARTHRITIS AND RHEUMATISM*, 50(4), pp. 1172–1178. Available at: <https://doi.org/10.1002/art.20132>.
- Mündermann, A. *et al.* (2008) 'Implications of increased medio-lateral trunk sway for ambulatory mechanics', *Journal of Biomechanics*, 41(1), pp. 165–170. Available at: <https://doi.org/10.1016/j.jbiomech.2007.07.001>.
- Mundermann, A., Dyrby, C.O. and Andriacchi, T.P. (2005) 'Secondary gait changes in patients with medial compartment knee osteoarthritis - Increased load at the ankle, knee, and hip during walking', *ARTHRITIS AND RHEUMATISM*, 52(9), pp. 2835–2844. Available at: <https://doi.org/10.1002/art.21262>.
- Munro, A.G. and Herrington, L.C. (2010) 'Between-session reliability of the star excursion balance test', *Physical therapy in sport*, 11(4), pp. 128–132. Available at:

<https://doi.org/10.1016/j.ptsp.2010.07.002>.

Murphy, A.L. and Gardner, D.M. (2019) 'Pharmacists' acceptability of a men's mental health promotion program using the Theoretical Framework of Acceptability', *AIMS public health*, 6(2), pp. 195–208. Available at: <https://doi.org/10.3934/publichealth.2019.2.195>.

Murphy, L. *et al.* (2008) 'Lifetime risk of symptomatic knee osteoarthritis', *Arthritis Care & Research: Official Journal of the American College of Rheumatology*, 59(9), pp. 1207–1213.

Murray, C.J.L. *et al.* (2012) 'Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010', *The lancet*, 380(9859), pp. 2197–2223.

Muthuri, S.G. *et al.* (2011) 'History of knee injuries and knee osteoarthritis: a meta-analysis of observational studies', *Osteoarthritis and Cartilage*, 19(11), pp. 1286–1293.

Nakatani, T. *et al.* (2002) 'Validation of a 30-sec chair-stand test for evaluating lower extremity muscle strength in Japanese elderly adults', *Taiikugaku kenkyu (Japan Journal of Physical Education, Health and Sport Sciences)*, 47(5), pp. 451–461. Available at: <https://doi.org/10.5432/jjpehss.KJ00003390725>.

National Institute for Health and Clinical Excellence, N. (2014) 'Osteoarthritis: care and management in adults'.

Nedunchezhiyan, U. *et al.* (2022) 'Obesity, Inflammation, and Immune System in Osteoarthritis', *Frontiers in immunology*, 13, p. 907750. Available at: <https://doi.org/10.3389/fimmu.2022.907750>.

Nelson, A.E. *et al.* (2010) 'Characterization of individual radiographic features of hip osteoarthritis in African American and White women and men: the Johnston County Osteoarthritis Project', *Arthritis Care & Research: Official Journal of the American College of Rheumatology*, 62(2), pp. 190–197.

Nelson, A.E. *et al.* (2014) 'A systematic review of recommendations and guidelines for the management of osteoarthritis: The Chronic Osteoarthritis Management Initiative of the U.S. Bone and Joint Initiative', *Seminars in Arthritis and Rheumatism*, 43(6), pp. 701–712. Available at: <https://doi.org/10.1016/j.semarthrit.2013.11.012>.

Nelson, A.E. and Jordan, J.M. (2017) 'Chapter 99 - Clinical Features of Osteoarthritis', in G.S. Firestein *et al.* (eds). Elsevier, pp. 1705–1718. Available at: <https://doi.org/https://doi.org/10.1016/B978-0-323-31696-5.00099-1>.

Neogi, T. *et al.* (2009) 'Association between radiographic features of knee osteoarthritis and pain: results from two cohort studies', *BMJ*, 339(7719), pp. 498–501. Available at: <https://doi.org/10.1136/bmj.b2844>.

Neogi, T. *et al.* (2012) 'Identifying trajectories of medial joint-space width loss and associated risk factors', *Osteoarthritis and Cartilage*, 20, pp. S182–S183.

Neogi, T. (2013) 'The epidemiology and impact of pain in osteoarthritis', *Osteoarthritis and Cartilage*, 21(9), pp. 1145–1153. Available at: <https://doi.org/10.1016/j.joca.2013.03.018>.

Neogi, T. *et al.* (2016) 'Association of Joint Inflammation With Pain Sensitization in Knee Osteoarthritis: The Multicenter Osteoarthritis Study', *Arthritis & rheumatology (Hoboken, N.J.)*, 68(3), pp. 654–661. Available at: <https://doi.org/10.1002/art.39488>.

Neptune, R.R. and Vistamehr, A. (2019) 'Dynamic Balance During Human Movement: Measurement and Control Mechanisms', *Journal of biomechanical engineering*, 141(7), pp. 0708011–07080110. Available at: <https://doi.org/10.1115/1.4042170>.

Nester, C.J., van der Linden, M.L. and Bowker, P. (2003) 'Effect of foot orthoses on the kinematics and kinetics of normal walking gait', *GAIT & POSTURE*, 17(2), pp. 180–187. Available at: [https://doi.org/10.1016/S0966-6362\(02\)00065-6](https://doi.org/10.1016/S0966-6362(02)00065-6).

Nevitt, M.C. *et al.* (2001) 'The effect of estrogen plus progestin on knee symptoms and related disability in postmenopausal women: the Heart and Estrogen/Progestin Replacement Study, a randomized, double-blind, placebo-controlled trial', *Arthritis & Rheumatism*, 44(4), pp. 811–818.

Newman-Beinart, N.A. *et al.* (2017) 'The development and initial psychometric evaluation of a measure assessing adherence to prescribed exercise: the Exercise Adherence Rating Scale (EARS)', *Physiotherapy*, 103(2), pp. 180–185. Available at: <https://doi.org/10.1016/j.physio.2016.11.001>.

Nia, H.T. *et al.* (2013) 'High-bandwidth AFM-based rheology reveals that cartilage is most sensitive to high loading rates at early stages of impairment.', *Biophysical journal*, 104 7, pp. 1529–1537. Available at: <https://api.semanticscholar.org/CorpusID:141711>.

Nicolson, P.J.A. *et al.* (2017) 'Interventions to increase adherence to therapeutic exercise in older adults with low back pain and/or hip/knee osteoarthritis: a systematic review and meta-analysis', *British journal of sports medicine*, 51(10), pp. 791–799. Available at: <https://doi.org/10.1136/bjsports-2016-096458>.

Nie, Y. *et al.* (2019) 'The Relationship between Knee Adduction Moment and Knee Osteoarthritis Symptoms according to Static Alignment and Pelvic Drop', *BIOMED RESEARCH INTERNATIONAL*, 2019. Available at: <https://doi.org/10.1155/2019/7603249>.

Nissen, N. *et al.* (2022) 'Clinicians' beliefs and attitudes to physical activity and exercise therapy as treatment for knee and/or hip osteoarthritis: a scoping review', *Osteoarthritis and cartilage*, 30(2), pp. 260–269. Available at: <https://doi.org/10.1016/j.joca.2021.11.008>.

van den Noort, J.C. *et al.* (2013) 'The effectiveness of voluntary modifications of gait pattern to reduce the knee adduction moment', *Human movement science*, 32(3), pp. 412–424. Available at: <https://doi.org/10.1016/j.humov.2012.02.009>.

Van den Noort, J.C. *et al.* (2015) 'Real-time visual feedback for gait retraining: toward application in knee osteoarthritis', *Medical & biological engineering & computing*, 53(3), pp. 275–286.

O'Brien, B.C. *et al.* (2014) 'Standards for reporting qualitative research: A synthesis of recommendations', *Academic Medicine*, 89(9), pp. 1245–1251. Available at: <https://doi.org/10.1097/ACM.0000000000000388>.

O'Keeffe, M. *et al.* (2016) 'What influences patient-therapist interactions in musculoskeletal physical therapy? Qualitative systematic review and meta-synthesis', *Physical therapy*, 96(5), pp. 609–622. Available at: <https://doi.org/10.2522/ptj.20150240>.

Ogata, K., Yasunaga, M. and Nomiya, H. (1997) 'The effect of wedged insoles on the thrust of osteoarthritic knees', *INTERNATIONAL ORTHOPAEDICS*, 21(5), pp. 308–312. Available at: <https://doi.org/10.1007/s002640050174>.

Ohashi, Y. *et al.* (2023) 'Mechanisms of Peripheral and Central Sensitization in

Osteoarthritis Pain.', *Cureus*, 15(2), p. e35331. Available at: <https://doi.org/10.7759/cureus.35331>.

Ohman, A. (2005) 'Qualitative methodology for rehabilitation research', *Journal of rehabilitation medicine*, 37(5), pp. 273–280. Available at: <https://doi.org/10.1080/16501970510040056>.

Oiestad, B.E. *et al.* (2013) 'Efficacy of strength and aerobic exercise on patient-reported outcomes and structural changes in patients with knee osteoarthritis: study protocol for a randomized controlled trial.', *BMC Musculoskeletal Disorders*, 14(1), p. 266. Available at: <https://doi.org/10.1186/1471-2474-14-266>.

Oliveria, S.A. *et al.* (1995) 'Incidence of symptomatic hand, hip, and knee osteoarthritis among patients in a health maintenance organization', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 38(8), pp. 1134–1141.

Olmsted, L.C. *et al.* (2002) 'Efficacy of the star excursion balance tests in detecting reach deficits in subjects with chronic ankle instability', *Journal of athletic training*, 37(4), pp. 501–506.

Ommen, O. *et al.* (2008) 'Trust, social support and patient type—Associations between patients perceived trust, supportive communication and patients preferences in regard to paternalism, clarification and participation of severely injured patients', *Patient education and counseling*, 73(2), pp. 196–204. Available at: <https://doi.org/10.1016/j.pec.2008.03.016>.

Ostrander, R. V. *et al.* (2016) 'Efficacy of Unloader Bracing in Reducing Symptoms of Knee Osteoarthritis', *American journal of orthopedics (Belle Mead, N.J.)*, 45(5), pp. 306–311.

Pagani, C.H.F., Potthast, W. and Brueggemann, G.-P. (2010) 'The effect of valgus bracing on the knee adduction moment during gait and running in male subjects with varus alignment', *CLINICAL BIOMECHANICS*, 25(1), pp. 70–76. Available at: <https://doi.org/10.1016/j.clinbiomech.2009.08.010>.

Pagani, C.H.F.F. *et al.* (2012) 'Kinetic and kinematic changes with the use of valgus knee brace and lateral wedge insoles in patients with medial knee osteoarthritis', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 30(7), pp. 1125–1132. Available at: <https://doi.org/10.1002/jor.22032>.

Page, C.J., Hinman, R.S. and Bennell, K.L. (2011) 'Physiotherapy management of knee osteoarthritis.', *International journal of rheumatic diseases*, 14(2), pp. 145–151. Available at: <https://doi.org/10.1111/j.1756-185X.2011.01612.x>.

Page, M.J. *et al.* (2021) 'Updating guidance for reporting systematic reviews: development of the PRISMA 2020 statement', *Journal of Clinical Epidemiology*, 134, pp. 103–112.

Palinkas, L.A. *et al.* (2015) 'Purposeful sampling for qualitative data collection and analysis in mixed method implementation research', *Administration and policy in mental health*, 42(5), p. 533. Available at: <https://doi.org/10.1007/S10488-013-0528-Y>.

Palmer, K.T. (2012) 'Occupational activities and osteoarthritis of the knee', *British medical bulletin*, 102(1), pp. 147–170.

Palmieri-Smith, R.M. *et al.* (2010) 'Isometric quadriceps strength in women with mild, moderate, and severe knee osteoarthritis', *American journal of physical medicine &*

rehabilitation/Association of Academic Physiatrists, 89(7), p. 541.

Palotie, A. *et al.* (1989) 'Predisposition to familial osteoarthritis linked to type II collagen gene', *The Lancet*, 333(8644), pp. 924–927.

Pandy, M.G. and Andriacchi, T.P. (2010) 'Muscle and joint function in human locomotion', *Annual review of biomedical engineering*, 12, pp. 401–433.

Pang, J. *et al.* (2008) '[Control study for muscle force and component of body of female patients with knee osteoarthritis].', *Zhongguo gu shang = China journal of orthopaedics and traumatology*, 21(11), pp. 828–830.

Park, J.H. *et al.* (2021) 'Effects of knee osteoarthritis severity on inter-joint coordination and gait variability as measured by hip-knee cyclograms', *Scientific reports*, 11(1), pp. 1789–1789. Available at: <https://doi.org/10.1038/s41598-020-80237-w>.

Parkes, M.J. *et al.* (2013) 'Lateral wedge insoles as a conservative treatment for pain in patients with medial knee osteoarthritis: a meta-analysis', *Jama*, 310(7), pp. 722–730. Available at: <https://doi.org/10.1001/jama.2013.243229>.

Parkes, M.J. *et al.* (2016) 'Sensitivity to Change of Patient-Preference Measures for Pain in Patients With Knee Osteoarthritis: Data From Two Trials.', *Arthritis care & research*, 68(9), pp. 1224–1231. Available at: <https://doi.org/10.1002/acr.22823>.

Parsons, C.M. *et al.* (2020) 'Predominant lifetime occupation and associations with painful and structural knee osteoarthritis: An international participant-level cohort collaboration', *Osteoarthritis and Cartilage Open*, 2(4), p. 100085. Available at: <https://doi.org/https://doi.org/10.1016/j.ocarto.2020.100085>.

Paterson, K.L. *et al.* (2017) 'Plug-in-Gait calculation of the knee adduction moment in people with knee osteoarthritis during shod walking: comparison of two different foot marker models', *JOURNAL OF FOOT AND ANKLE RESEARCH*, 10. Available at: <https://doi.org/10.1186/s13047-017-0187-4>.

Paterson, K.L. *et al.* (2018) 'Moderators and mediators of effects of unloading shoes on knee pain in people with knee osteoarthritis: an exploratory analysis of the SHARK randomised controlled trial', *Osteoarthritis and cartilage*, 26(2), p. 227-235. Available at: <https://doi.org/10.1016/j.joca.2017.11.002>.

Pazzinatto, M.F. *et al.* (2019) 'What are the clinical implications of knee crepitus to individuals with knee osteoarthritis? An observational study with data from the Osteoarthritis Initiative', *Revista brasileira de fisioterapia (São Carlos (São Paulo, Brazil))*, 23(6), pp. 491–496. Available at: <https://doi.org/10.1016/j.bjpt.2018.11.001>.

Pearson, N. *et al.* (2020) 'Guidance for conducting feasibility and pilot studies for implementation trials', *Pilot and Feasibility Studies*, 6(1), p. 167. Available at: <https://doi.org/10.1186/s40814-020-00634-w>.

Peersman, W. *et al.* (2013) 'Patients' priorities regarding outpatient physiotherapy care: A qualitative and quantitative study', *Manual therapy*, 18(2), pp. 155–164. Available at: <https://doi.org/10.1016/j.math.2012.09.007>.

Pekmezi, D., Jennings, E. and Marcus, B.H. (2009) 'Evaluating and enhancing self-efficacy for physical activity', *ACSM's health & fitness journal*, 13(2), p. 16.

Pereira, L.C. *et al.* (2021) 'Association between changes in the knee adduction moment and changes in knee pain and function in response to non-surgical biomechanical interventions for medial knee osteoarthritis: a systematic review.', *European Journal of Physical and Rehabilitation Medicine* [Preprint].

Peter, W.F.H. *et al.* (2011) 'Physiotherapy in hip and knee osteoarthritis: development of a practice guideline concerning initial assessment. Treatment and evaluation', *Acta reumatologica portuguesa*, 36(3), pp. 268–281.

Petursdottir, U., Arnadottir, S.A. and Halldorsdottir, S. (2010) 'Facilitators and Barriers to Exercising Among People With Osteoarthritis: A Phenomenological Study', *Physical therapy*, 90(7), pp. 1014–1025. Available at: <https://doi.org/10.2522/ptj.20090217>.

Pham, T. *et al.* (2004) 'Laterally elevated wedged insoles in the treatment of medial knee osteoarthritis. A two-year prospective randomized controlled study.', *Osteoarthritis and cartilage*, 12(1), pp. 46–55. Available at: <http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med5&NEWS=N&N=14697682>.

Picavet, H.S.J. and Hoeymans, N. (2004) 'Health related quality of life in multiple musculoskeletal diseases: SF-36 and EQ-5D in the DMC3 study', *Annals of the rheumatic diseases*, 63(6), pp. 723–729. Available at: <https://doi.org/10.1136/ard.2003.010769>.

Pietrosimone, B. *et al.* (2017) 'Certified athletic trainers' knowledge and perceptions of posttraumatic osteoarthritis after knee injury', *Journal of athletic training*, 52(6), pp. 541–559.

Pietrosimone, B. (2020) 'Managing the Early Risk of Posttraumatic Osteoarthritis Following Anterior Cruciate Ligament Injury', *Journal of Science in Sport and Exercise*, pp. 1–7.

Pincus, T. *et al.* (2013) 'Cognitive and affective reassurance and patient outcomes in primary care: A systematic review', *Pain (Amsterdam)*, 154(11), pp. 2407–2416. Available at: <https://doi.org/10.1016/j.pain.2013.07.019>.

Pinto, R.F. *et al.* (2023) 'Changes and Associations Between Gait Biomechanics and Knee Inflammation After Aspiration and Glucocorticoid Injection for Knee Osteoarthritis.', *Arthritis care & research*, 75(8), pp. 1764–1772. Available at: <https://doi.org/10.1002/acr.25064>.

Pinto, R.Z. *et al.* (2012) 'Patient-centred communication is associated with positive therapeutic alliance: a systematic review', *Journal of physiotherapy*, 58(2), pp. 77–87. Available at: [https://doi.org/10.1016/S1836-9553\(12\)70087-5](https://doi.org/10.1016/S1836-9553(12)70087-5).

Pisters, M.. *et al.* (2012) 'The course of limitations in activities over 5 years in patients with knee and hip osteoarthritis with moderate functional limitations: risk factors for future functional decline', *Osteoarthritis and cartilage*, 20(6), pp. 503–510.

Pisters, M.F. *et al.* (2007) 'Long-term effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: a systematic review', *Arthritis care & research*, 57(7), pp. 1245–1253.

Pisters, M.F. *et al.* (2010) 'Exercise adherence improving long-term patient outcome in patients with osteoarthritis of the hip and/or knee', *Arthritis Care & Research*, 62. Available at: <https://api.semanticscholar.org/CorpusID:205220838>.

Podlipská, J. *et al.* (2017) 'Structure-symptom relationship with wide-area ultrasound scanning of knee osteoarthritis', *Scientific reports*, 7(1), pp. 1–10.

Polit, D.F. and Beck, C.T. (2010) 'Generalization in quantitative and qualitative research: Myths and strategies', *International journal of nursing studies*, 47(11), pp. 1451–1458. Available at: <https://doi.org/10.1016/j.ijnurstu.2010.06.004>.

- Pollo, F E *et al.* (2002) 'Reduction of medial compartment loads with valgus bracing of the osteoarthritic knee', *AMERICAN JOURNAL OF SPORTS MEDICINE*, 30(3), pp. 414–421. Available at: <https://doi.org/10.1177/03635465020300031801>.
- Pollo, Fabian E. *et al.* (2002) 'Reduction of medial compartment loads with valgus bracing of the osteoarthritic knee', *AMERICAN JOURNAL OF SPORTS MEDICINE*, 30(3), pp. 414–421. Available at: <https://doi.org/10.1177/03635465020300031801>.
- Pollo, F.E. and Jackson, R.W. (2006) 'Knee bracing for unicompartmental osteoarthritis', *Journal of the American Academy of Orthopaedic Surgeons*, 14(1), pp. 5–11. Available at: <https://doi.org/10.5435/00124635-200601000-00003>.
- Potter, M., Gordon, S. and Hamer, P. (2003) 'The physiotherapy experience in private practice: The patients' perspective', *Australian journal of physiotherapy*, 49(3), pp. 195–202. Available at: [https://doi.org/10.1016/S0004-9514\(14\)60239-7](https://doi.org/10.1016/S0004-9514(14)60239-7).
- Price, A.J. *et al.* (2018) 'Knee replacement', *The Lancet*, 392(10158), pp. 1672–1682.
- Primeau, C.A. *et al.* (2021) 'Changes in pain, function and gait biomechanics 10 years after high tibial osteotomy for medial compartment knee osteoarthritis', *Osteoarthritis and Cartilage*, 29. Available at: <https://api.semanticscholar.org/CorpusID:234880908>.
- Primorac, D. *et al.* (2020) 'Knee osteoarthritis: A review of pathogenesis and state-of-the-art non-operative therapeutic considerations', *Genes*. MDPI AG, pp. 1–35. Available at: <https://doi.org/10.3390/genes11080854>.
- Proctor, E.K. *et al.* (2009) 'Implementation research in mental health services: an emerging science with conceptual, methodological, and training challenges', *Administration and policy in mental health*, 36(1), pp. 24–34. Available at: <https://doi.org/10.1007/S10488-008-0197-4>.
- Raaij, V. *et al.* (2010) 'Medial Knee Osteoarthritis Treated by Insoles or Braces: A Randomized Trial', *Clinical orthopaedics and related research*, 468(7), pp. 1926–1932. Available at: <https://doi.org/10.1007/s11999-010-1274-z>.
- Rabin, E. *et al.* (2013) 'Haptic feedback from manual contact improves balance control in people with Parkinson's disease', *Gait & posture*, 38(3), pp. 373–379.
- Radzimski, A.O., Mündermann, A. and Sole, G. (2012a) 'Effect of footwear on the external knee adduction moment—a systematic review', *The knee*, 19(3), pp. 163–175.
- Radzimski, A.O., Mündermann, A. and Sole, G. (2012b) 'Effect of footwear on the external knee adduction moment - A systematic review', *Knee*. Elsevier, pp. 163–175. Available at: <https://doi.org/10.1016/j.knee.2011.05.013>.
- Rafiaee, M., Karimi, M.T. and MT, K. (2012) 'The effects of various kinds of lateral wedge insoles on performance of individuals with knee joint osteoarthritis', *Int J Prev Med*, 3(10), pp. 693–698.
- Raja, K. and Dewan, N. (2011) 'Efficacy of knee braces and foot orthoses in conservative management of knee osteoarthritis: A systematic review', *American journal of physical medicine & rehabilitation*, 90(3), pp. 247–262. Available at: <https://doi.org/10.1097/PHM.0b013e318206386b>.
- Rakel, B.A. *et al.* (2012) 'Predictors of postoperative movement and resting pain following total knee replacement', *Pain (Amsterdam)*, 153(11), pp. 2192–2203. Available at: <https://doi.org/10.1016/j.pain.2012.06.021>.
- Ramsey, D.K. *et al.* (2001) 'Assessment of functional knee bracing: an in vivo three-

dimensional kinematic analysis of the anterior cruciate deficient knee', *CLINICAL BIOMECHANICS*, 16(1), pp. 61–70. Available at: [https://doi.org/10.1016/S0268-0033\(00\)00065-6](https://doi.org/10.1016/S0268-0033(00)00065-6).

Ramsey, D.K., Briem, K., *et al.* (2007) 'A Mechanical Theory for the Effectiveness of Bracing for Medial Compartment Osteoarthritis of the Knee', *Journal of bone and joint surgery. American volume*, 89(11), pp. 2398–2407. Available at: <https://doi.org/10.2106/JBJS.F.01136>.

Ramsey, D.K., Snyder-Mackler, L., *et al.* (2007) 'Effect of anatomic realignment on muscle function during gait in patients with medial compartment knee osteoarthritis', *Arthritis Care & Research*, 57(3), pp. 389–397.

Ready, L.B. and Edwards, W.T. (1992) *Management of acute pain: a practical guide*. IASP publications.

Rees, C.E., Ford, J.E. and Sheard, C.E. (2003) 'Patient information leaflets for prostate cancer: Which leaflets should healthcare professionals recommend?', *Patient Education and Counseling*, 49(3), pp. 263–272. Available at: [https://doi.org/10.1016/S0738-3991\(02\)00188-X](https://doi.org/10.1016/S0738-3991(02)00188-X).

Reichenbach, S. *et al.* (2010) 'Joint lavage for osteoarthritis of the knee', *Cochrane Database of Systematic Reviews* [Preprint], (5).

Reichenbach, S. *et al.* (2011) 'Association of bone attrition with knee pain, stiffness and disability: a cross-sectional study', *Annals of the rheumatic diseases*, 70(2), pp. 293–298. Available at: <https://doi.org/10.1136/ard.2010.132985>.

Reichenbach, S. *et al.* (2020) 'Effect of Biomechanical Footwear on Knee Pain in People With Knee Osteoarthritis: the BIOTOK Randomized Clinical Trial', *JAMA*, 323(18), p. 1802-1812. Available at: <https://doi.org/10.1001/jama.2020.3565>.

Reilly, K. *et al.* (2009) 'The role of foot and ankle assessment of patients with lower limb osteoarthritis', *Physiotherapy*, 95(3), pp. 164–169. Available at: <https://doi.org/10.1016/j.physio.2009.04.003>.

Rejeski, W.J. *et al.* (2001) 'Self-efficacy and the progression of functional limitations and self-reported disability in older adults with knee pain', *The journals of gerontology. Series B, Psychological sciences and social sciences*, 56(5), pp. S261–S265. Available at: <https://doi.org/10.1093/geronb/56.5.S261>.

Rhon, D.I., Perez, K.G. and Eskridge, S.L. (2019) 'Risk of post-traumatic knee osteoarthritis after knee injury in military service members', *Musculoskeletal care*, 17(1), pp. 113–119.

Richards, J., Chohan, A. and Erande, R. (2013) *Biomechanics. Fifteenth, Tidy's Physiotherapy: Fifteenth Edition*. Fifteenth. Elsevier Ltd. Available at: <https://doi.org/10.1016/B978-0-7020-4344-4.00015-8>.

Richards, J.D. *et al.* (2005) 'A comparison of knee braces during walking for the treatment of osteoarthritis of the medial compartment of the knee', *Journal of bone and joint surgery. British volume*, 87(7 CC-Musculoskeletal), p. 937-939. Available at: <https://doi.org/10.1302/0301-620X.87B7.16005>.

Richards, K.A.R. and Hemphill, M.A. (no date) 'A Practical Guide to Collaborative Qualitative Data Analysis', *Journal of Teaching in Physical Education*, 37(2), pp. 225–231. Available at: <https://doi.org/10.1123/jtpe.2017-0084>.

Richards, R. *et al.* (2016) 'Effects of gait retraining with real-time biofeedback in patients with knee osteoarthritis: systematic review and meta-analysis', *Osteoarthritis*

and Cartilage, 24, p. S470.

Richards, R. *et al.* (2018) 'Gait retraining using real-time feedback in patients with medial knee osteoarthritis: Feasibility and effects of a six-week gait training program', *KNEE*, 25(5), pp. 814–824. Available at: <https://doi.org/10.1016/j.knee.2018.05.014>.

Richards, R.E. *et al.* (2018) 'Relationship between knee joint contact forces and external knee joint moments in patients with medial knee osteoarthritis: effects of gait modifications', *Osteoarthritis and cartilage*, 26(9), pp. 1203–1214. Available at: <https://doi.org/10.1016/j.joca.2018.04.011>.

Ritchie, J. *et al.* (2013) 'Qualitative Research Practice: A Guide for Social Science Students and Researchers'.

Ritchie, J. and Lewis, J. (2003) 'QUALITATIVE RESEARCH PRACTICE A Guide for Social Science Students and Researchers Edited by'.

Ritchie, J. and Spencer, L. (2002) 'Qualitative data analysis for applied policy research', in *Analyzing qualitative data*. Routledge, pp. 187–208.

Robbins, S.M.K. *et al.* (2009) 'Developing an estimate of daily cumulative loading for the knee: Examining test-retest reliability', *GAIT \& POSTURE*, 30(4), pp. 497–501. Available at: <https://doi.org/10.1016/j.gaitpost.2009.07.118>.

Robbins, S.M.K. and Maly, M.R. (2009) 'The effect of gait speed on the knee adduction moment depends on waveform summary measures', *GAIT \& POSTURE*, 30(4), pp. 543–546. Available at: <https://doi.org/10.1016/j.gaitpost.2009.08.236>.

Robinson, K.A. *et al.* (2015) 'Updated systematic review identifies substantial number of retention strategies: using more strategies retains more study participants', *Journal of clinical epidemiology*, 68(12), pp. 1481–1487. Available at: <https://doi.org/10.1016/j.jclinepi.2015.04.013>.

Robinson, R.H. and Gribble, P.A. (2008) 'Support for a Reduction in the Number of Trials Needed for the Star Excursion Balance Test', *Archives of physical medicine and rehabilitation*, 89(2), pp. 364–370. Available at: <https://doi.org/10.1016/j.apmr.2007.08.139>.

Roemer, F. *et al.* (2009) 'MRI-detected subchondral bone marrow signal alterations of the knee joint: terminology, imaging appearance, relevance and radiological differential diagnosis', *Osteoarthritis and cartilage*, 17(9), pp. 1115–1131. Available at: <https://doi.org/10.1016/j.joca.2009.03.012>.

Roemer, F.W. *et al.* (2017) 'Partial meniscectomy is associated with increased risk of incident radiographic osteoarthritis and worsening cartilage damage in the following year', *European radiology*, 27(1), pp. 404–413.

Rohatgi, A. (2014) 'Web Plot Digitizer. ht tp', *arohatgi.info/WebPlotDigitizer/(accessed Aug 2014)*, 154.

Rongen, J.J. *et al.* (2017) 'Increased risk for knee replacement surgery after arthroscopic surgery for degenerative meniscal tears: a multi-center longitudinal observational study using data from the osteoarthritis initiative', *Osteoarthritis and cartilage*, 25(1), pp. 23–29.

Roos, E.M. *et al.* (1998) 'Knee Injury and Osteoarthritis Outcome Score (KOOS) - Development of a self-administered outcome measure', *The journal of orthopaedic and sports physical therapy*, 28(2), pp. 88–96. Available at: <https://doi.org/10.2519/jospt.1998.28.2.88>.

Roos, E.M. *et al.* (2001) 'Long-term outcome of meniscectomy: symptoms, function, and performance tests in patients with or without radiographic osteoarthritis compared to matched controls', *Osteoarthritis and Cartilage*, 9(4), pp. 316–324. Available at: <https://doi.org/https://doi.org/10.1053/joca.2000.0391>.

Roos, E.M. and Lohmander, L.S. (2003) 'The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis.', *Health and quality of life outcomes*, 1, p. 64. Available at: <https://doi.org/10.1186/1477-7525-1-64>.

Roos, E.M., Roos, H.P. and Lohmander, L.S. (1999) 'WOMAC Osteoarthritis Index--additional dimensions for use in subjects with post-traumatic osteoarthritis of the knee. Western Ontario and MacMaster Universities', *Osteoarthritis and cartilage*, 7(2), pp. 216–221.

Rosenthal, R. and Rosnow, R.L. (2008) *Essentials of behavioral research: Methods and data analysis*.

Rudolph, K.S., Axe, M.J. and Snyder-Mackler, L. (2000) 'Dynamic Stability in the ACL deficient knee: Who can hop', *Knee surgery, sports traumatology, arthroscopy*, 8, pp. 262–269.

Rudolph, K.S., Schmitt, L.C. and Lewek, M.D. (2007) 'Age-related changes in strength, joint laxity, and walking patterns: are they related to knee osteoarthritis?', *Physical therapy*, 87(11), pp. 1422–1432.

Rühling, M. *et al.* (2023) 'Functional gait analysis reveals insufficient hindfoot compensation for varus and valgus osteoarthritis of the knee.', *International orthopaedics*, 47(5), pp. 1233–1242. Available at: <https://doi.org/10.1007/s00264-023-05738-5>.

Ruiz Jr, D. *et al.* (2013) 'The direct and indirect costs to society of treatment for end-stage knee osteoarthritis', *JBJS*, 95(16), pp. 1473–1480.

Runhaar, J. *et al.* (2014) 'Malalignment: a possible target for prevention of incident knee osteoarthritis in overweight and obese women', *Rheumatology*, 53(9), pp. 1618–1624.

Runhaar, J. *et al.* (2019) 'Inflammatory cytokines mediate the effects of diet and exercise on pain and function in knee osteoarthritis independent of BMI', *Osteoarthritis and cartilage*, 27(8), pp. 1118–1123.

Russell, E.M. and Hamill, J. (2011) 'Lateral wedges decrease biomechanical risk factors for knee osteoarthritis in obese women', *Journal of Biomechanics*, 44(12), pp. 2286–2291. Available at: <https://doi.org/https://doi.org/10.1016/j.jbiomech.2011.05.033>.

Rutherford, D.J., Hubley-Kozey, C.L. and Stanish, W.D. (2013) 'Changes in knee joint muscle activation patterns during walking associated with increased structural severity in knee osteoarthritis', *Journal of Electromyography and Kinesiology*, 23(3), pp. 704–711.

Ryser, L. *et al.* (1999) 'A new look at the Western Ontario and McMaster Universities Osteoarthritis Index using Rasch analysis', *Arthritis and rheumatism*, 12(5), pp. 331–335. Available at: [https://doi.org/10.1002/1529-0131\(199910\)12:5<331::AID-ART4>3.0.CO;2-W](https://doi.org/10.1002/1529-0131(199910)12:5<331::AID-ART4>3.0.CO;2-W).

Salaffi, F. *et al.* (2004) 'Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale', *European journal of pain*, 8(4), pp. 283–291.

Salaffi, F., Carotti, M. and Grassi, W. (2005) 'Health-related quality of life in patients with hip or knee osteoarthritis: Comparison of generic and disease-specific instruments', *Clinical rheumatology*, 24(1), pp. 29–37. Available at: <https://doi.org/10.1007/s10067-004-0965-9>.

Salmon, J.H. *et al.* (2016) 'Economic impact of lower-limb osteoarthritis worldwide: a systematic review of cost-of-illness studies', *Osteoarthritis and Cartilage*. W.B. Saunders Ltd, pp. 1500–1508. Available at: <https://doi.org/10.1016/j.joca.2016.03.012>.

Santoso, M.B. and Wu, L. (2017) 'Unicompartmental knee arthroplasty, is it superior to high tibial osteotomy in treating unicompartmental osteoarthritis? A meta-analysis and systemic review', *Journal of Orthopaedic Surgery and Research*, 12(1), pp. 1–10.

Sasaki, T. and Yasuda, K. (1987) 'Clinical evaluation of the treatment of osteoarthritic knees using a newly designed wedged insole', *Clinical orthopaedics and related research*, 221(221), pp. 181–187. Available at: <https://doi.org/10.1097/00003086-198708000-00021>.

Sawada, T. *et al.* (2016) 'Biomechanical effects of lateral and medial wedge insoles on unilateral weight bearing', *JOURNAL OF PHYSICAL THERAPY SCIENCE*, 28(1), pp. 280–285. Available at: <https://doi.org/10.1589/jpts.28.280>.

Saxby, D.J. *et al.* (2016) 'Tibiofemoral contact forces during walking, running and sidestepping', *GAIT & POSTURE*, 49, pp. 78–85. Available at: <https://doi.org/10.1016/j.gaitpost.2016.06.014>.

Say, R.E. and Thomson, R. (2003) 'The importance of patient preferences in treatment decisions--challenges for doctors', *BMJ (Clinical research ed.)*, 327(7414), p. 542. Available at: <https://doi.org/10.1136/BMJ.327.7414.542>.

Schache, A.G. *et al.* (2008) 'The effect of gait modification on the external knee adduction moment is reference frame dependent', *Clinical Biomechanics*, 23(5), pp. 601–608. Available at: <https://doi.org/10.1016/j.clinbiomech.2007.12.008>.

Schipphof, D. *et al.* (2014) 'Sensitivity and associations with pain and body weight of an MRI definition of knee osteoarthritis compared with radiographic Kellgren and Lawrence criteria: a population-based study in middle-aged females', *Osteoarthritis and cartilage*, 22(3), pp. 440–446. Available at: <https://doi.org/10.1016/j.joca.2013.12.017>.

Schmidt, M. (2001) 'Using an ANN-approach for analyzing focus groups', *Qualitative market research*, 4(2), pp. 100–112. Available at: <https://doi.org/10.1108/13522750110388590>.

Schmitt, L.C. and Rudolph, K.S. (2007) 'Influences on knee movement strategies during walking in persons with medial knee Osteoarthritis', *ARTHRITIS & RHEUMATISM-ARTHRITIS CARE & RESEARCH*, 57(6), pp. 1018–1026. Available at: <https://doi.org/10.1002/art.22889>.

Schmitz, A. and Noehren, B. (2014) 'What predicts the first peak of the knee adduction moment?', *The Knee*, 21(6), pp. 1077–1083. Available at: <https://doi.org/10.1016/j.knee.2014.07.016>.

Schouten, J.S., van den Ouweland, F.A. and Valkenburg, H.A. (1992) 'A 12 year follow up study in the general population on prognostic factors of cartilage loss in osteoarthritis of the knee.', *Annals of the Rheumatic Diseases*, 51(8), pp. 932 LP – 937. Available at: <https://doi.org/10.1136/ard.51.8.932>.

Schünemann, H.J. *et al.* (2019) 'Completing "Summary of findings" tables and grading the certainty of the evidence', *Cochrane Handbook for systematic reviews of interventions*, pp. 375–402.

Schwab, J.M. and Serhan, C.N. (2006) 'Lipoxins and new lipid mediators in the resolution of inflammation.', *Current opinion in pharmacology*, 6(4), pp. 414–420. Available at: <https://doi.org/10.1016/j.coph.2006.02.006>.

Schwartz, M.H., Rozumalski, A. and Trost, J.P. (2008) 'The effect of walking speed on the gait of typically developing children', *Journal of biomechanics*, 41(8), pp. 1639–1650. Available at: <https://doi.org/10.1016/j.jbiomech.2008.03.015>.

Scott, D. and Kowalczyk, A. (2008) 'Osteoarthritis of the knee', *American Family Physician*, 77(8), p. 1149.

Segal, N.A. *et al.* (2009) 'Effect of thigh strength on incident radiographic and symptomatic knee osteoarthritis in a longitudinal cohort', *Arthritis Care & Research: Official Journal of the American College of Rheumatology*, 61(9), pp. 1210–1217.

Segal, N.A. *et al.* (2010) 'Quadriceps weakness predicts risk for knee joint space narrowing in women in the MOST cohort', *Osteoarthritis and cartilage*, 18(6), pp. 769–775.

Sekhon, M., Cartwright, M. and Francis, J.J. (2017) 'Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework', *BMC health services research*, 17(1), pp. 1–13.

Sekhon, M., Cartwright, M. and Francis, J.J. (2022) 'Development of a theory-informed questionnaire to assess the acceptability of healthcare interventions', *BMC Health Services Research*, 22(1), p. 279. Available at: <https://doi.org/10.1186/s12913-022-07577-3>.

Sellam, J. and Berenbaum, F. (2010) 'The role of synovitis in pathophysiology and clinical symptoms of osteoarthritis', *Nature Reviews Rheumatology*, 6(11), pp. 625–635.

Sethi, V., Anand, C. and Della Pasqua, O. (2024) 'Clinical Assessment of Osteoarthritis Pain: Contemporary Scenario, Challenges, and Future Perspectives', *Pain and Therapy*, pp. 1–18.

Shakoor, N. *et al.* (2008) 'Effects of specialized footwear on joint loads in osteoarthritis of the knee', *ARTHRITIS & RHEUMATISM-ARTHRITIS CARE & RESEARCH*, 59(9), pp. 1214–1220. Available at: <https://doi.org/10.1002/art.24017>.

Shakoor, N. *et al.* (2010) 'Effects of Common Footwear on Joint Loading in Osteoarthritis of the Knee', *ARTHRITIS CARE & RESEARCH*, 62(7), pp. 917–923. Available at: <https://doi.org/10.1002/acr.20165>.

Shakoor, N. and Block, J.A. (2006) 'Walking barefoot decreases loading on the lower extremity joints in knee osteoarthritis', *Arthritis and rheumatism*, 54(9 CC-Metabolic and Endocrine Disorders CC-Musculoskeletal), p. 2923-2927. Available at: <https://doi.org/10.1002/art.22123>.

Sharma, B. and Chandrasekar, L. (2011) 'Efficacy of Lateral Wedged Insole with Subtalar Strapping on the Functional Status of Medial Compartment 3rd Grade Osteoarthritis of the Knee', *Indian Journal of Physiotherapy and Occupational Therapy—An International Journal*, 5, pp. 27–30. Available at: <https://api.semanticscholar.org/CorpusID:70661358>.

Sharma, L. *et al.* (1998) *KNEE ADDUCTION MOMENT, SERUM HYALURONAN*

LEVEL, AND DISEASE SEVERITY IN MEDIAL TIBIOFEMORAL OSTEOARTHRITIS. Available at: <https://doi.org/10.1002/1529-0131>.

Sharma, L. *et al.* (1999) 'Laxity in healthy and osteoarthritic knees', *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 42(5), pp. 861–870.

Sharma, L. *et al.* (2001) 'The role of knee alignment in disease progression and functional decline in knee osteoarthritis', *Journal of the American Medical Association*, 286(2), pp. 188–195. Available at: <https://doi.org/10.1001/jama.286.2.188>.

Sharma, L. *et al.* (2003) 'Physical functioning over three years in knee osteoarthritis: Role of psychosocial, local mechanical, and neuromuscular factors', *Arthritis and rheumatism*, 48(12), pp. 3359–3370. Available at: <https://doi.org/10.1002/art.11420>.

Sharma, L. *et al.* (2013) 'The role of varus and valgus alignment in the initial development of knee cartilage damage by MRI: the MOST study', *Annals of the rheumatic diseases*, 72(2), pp. 235–240.

Shaw, K.E. *et al.* (2018) 'The effects of shoe-worn insoles on gait biomechanics in people with knee osteoarthritis: a systematic review and meta-analysis', *British journal of sports medicine*, 52(4), pp. 238–253. Available at: <https://doi.org/10.1136/bjsports-2016-097108>.

Shelburne, K.B. *et al.* (2008) 'Effects of foot orthoses and valgus bracing on the knee adduction moment and medial joint load during gait', *Clinical Biomechanics*, 23(6), pp. 814–821. Available at: <https://doi.org/10.1016/j.clinbiomech.2008.02.005>.

Shimada, S. *et al.* (2006) 'Effects of Disease Severity on Response to Lateral Wedged Shoe Insole for Medial Compartment Knee Osteoarthritis', *Archives of Physical Medicine and Rehabilitation*, 87(11), pp. 1436–1441. Available at: <https://doi.org/10.1016/j.apmr.2006.08.018>.

Shirley, D., Van Der Ploeg, H.P. and Bauman, A.E. (2010) 'Physical activity promotion in the physical therapy setting: perspectives from practitioners and students', *Physical therapy*, 90(9), pp. 1311–1322. Available at: <https://doi.org/10.2522/PTJ.20090383>.

Showery, J.E. *et al.* (2016) 'The rising incidence of degenerative and posttraumatic osteoarthritis of the knee in the United States military', *The Journal of arthroplasty*, 31(10), pp. 2108–2114.

Shull, Pete B. *et al.* (2013) 'Six-week gait retraining program reduces knee adduction moment, reduces pain, and improves function for individuals with medial compartment knee osteoarthritis', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 31(7), pp. 1020–1025. Available at: <https://doi.org/10.1002/jor.22340>.

Shull, Pete B *et al.* (2013) 'Toe-in gait reduces the first peak knee adduction moment in patients with medial compartment knee osteoarthritis', *Journal of biomechanics*, 46(1), pp. 122–128.

Shumnalieva, R., Kotov, G. and Monov, S. (2023) 'Obesity-Related Knee Osteoarthritis—Current Concepts', *Life (Basel, Switzerland)*, 13(8), p. 1650. Available at: <https://doi.org/10.3390/life13081650>.

Shumway-Cook, A. and Woollacott, M.H. (2007) *Motor control: translating research into clinical practice*. Lippincott Williams & Wilkins.

Sidani, S. *et al.* (2009) 'Assessment of preferences for treatment: validation of a measure', *Research in nursing & health*, 32(4), pp. 419–431. Available at: <https://doi.org/10.1002/NUR.20329>.

Silva, M. *et al.* (2002) 'Average patient walking activity approaches 2 million cycles per year', *The Journal of arthroplasty*, 17(6), pp. 693–697. Available at: <https://doi.org/10.1054/arth.2002.32699>.

Silva, M.D.C. *et al.* (2022) 'Effects of neuromuscular gait modification strategies on indicators of knee joint load in people with medial knee osteoarthritis: A systematic review and meta-analysis', *Plos one*, 17(9), p. e0274874.

Silverwood, V. *et al.* (2015) 'Current evidence on risk factors for knee osteoarthritis in older adults: a systematic review and meta-analysis', *Osteoarthritis and cartilage*, 23(4), pp. 507–515.

Sim, J. (1998) 'Collecting and analysing qualitative data: issues raised by the focus group', *Journal of Advanced Nursing*, 28(2), pp. 345–352. Available at: <https://doi.org/10.1046/J.1365-2648.1998.00692.X>.

Sim, J. (2019) 'Should treatment effects be estimated in pilot and feasibility studies?', *Pilot and Feasibility Studies*, 5(1), p. 107. Available at: <https://doi.org/10.1186/s40814-019-0493-7>.

Simic, M. *et al.* (2011) 'Gait modification strategies for altering medial knee joint load: A systematic review', *Arthritis Care and Research*, pp. 405–426. Available at: <https://doi.org/10.1002/acr.20380>.

Simic, M. *et al.* (2012) 'Trunk lean gait modification and knee joint load in people with medial knee osteoarthritis: The effect of varying trunk lean angles', *ARTHRITIS CARE & RESEARCH*, 64(10), pp. 1545–1553. Available at: <https://doi.org/10.1002/acr.21724>.

Sims, E.L. (2012) 'The Relationship Between Gait Mechanics and Radiographic Disease Severity in Knee Osteoarthritis', in. IntechOpen. Available at: <https://doi.org/10.5772/28651>.

Singer, J.C. and Lamontagne, M. (2008) 'The effect of functional knee brace design and hinge misalignment on lower limb joint mechanics', *Clinical biomechanics*, 23(1), pp. 52–59.

Singh, J.A. and Lewallen, D. (2010) 'Predictors of pain and use of pain medications following primary Total Hip Arthroplasty (THA): 5,707 THAs at 2-years and 3,289 THAs at 5-years', *BMC musculoskeletal disorders*, 11(1), pp. 1–8.

Sivan, M., Smith, M. and Al-khayer, A. (2011) 'Opportunities and challenges in musculoskeletal medicine training. A survey of British rehabilitation medicine trainees', *International Musculoskeletal Medicine*, 33, pp. 94–99. Available at: <https://api.semanticscholar.org/CorpusID:72145230>.

Skivington, K. *et al.* (2021) 'A new framework for developing and evaluating complex interventions: Update of Medical Research Council guidance', *The BMJ*, 374(2018), pp. 1–11. Available at: <https://doi.org/10.1136/bmj.n2061>.

Skou, S.T. and Roos, E.M. (2017) 'Good Life with osteoArthritis in Denmark (GLA:D™): evidence-based education and supervised neuromuscular exercise delivered by certified physiotherapists nationwide', *BMC musculoskeletal disorders*, 18(1), pp. 1–13. Available at: <https://doi.org/10.1186/s12891-017-1439-y>.

Sled, E.A. *et al.* (2010) 'Effect of a Home Program of Hip Abductor Exercises on Knee Joint Loading, Strength, Function, and Pain in People With Knee Osteoarthritis: A Clinical Trial', *PHYSICAL THERAPY*, 90(6), pp. 895–904. Available at: <https://doi.org/10.2522/ptj.20090294>.

- Smink, A.J. *et al.* (2011) “Beating osteoARThritis”: development of a stepped care strategy to optimize utilization and timing of non-surgical treatment modalities for patients with hip or knee osteoarthritis’, *Clinical rheumatology*, 30(12), pp. 1623–1629.
- Smith, J. and Firth, J. (2011) ‘Qualitative data analysis: the framework approach’, *Nurse researcher*, 18(2), pp. 52–62. Available at: <https://doi.org/10.7748/nr2011.01.18.2.52.c8284>.
- Smith, S.L., Woodburn, J. and Steultjens, M.P.M. (2019) ‘155 Sex-related differences in muscle co-activation in individuals with knee osteoarthritis’, *Rheumatology* [Preprint]. Available at: <https://api.semanticscholar.org/CorpusID:146099237>.
- Smith, T., Kirby, E. and Davies, L. (2014) ‘A systematic review to determine the optimal type and dosage of land-based exercises for treating knee osteoarthritis’, *Physical Therapy Reviews*, 19(2), pp. 105–113.
- Sokolove, J. and Lepus, C.M. (2013) ‘Role of inflammation in the pathogenesis of osteoarthritis: latest findings and interpretations’, *Therapeutic advances in musculoskeletal disease*, 5(2), pp. 77–94.
- Somaiya, K.J., Samal, S. and Boob, M.A. (2024) ‘Physiotherapeutic Intervention Techniques for Knee Osteoarthritis: A Systematic Review’, *Curēus (Palo Alto, CA)*, 16(3), pp. e56817–e56817. Available at: <https://doi.org/10.7759/cureus.56817>.
- Sowers, M. *et al.* (2003) ‘Magnetic resonance-detected subchondral bone marrow and cartilage defect characteristics associated with pain and X-ray-defined knee osteoarthritis’, *Osteoarthritis and cartilage*, 11(6), pp. 387–393. Available at: [https://doi.org/10.1016/S1063-4584\(03\)00080-3](https://doi.org/10.1016/S1063-4584(03)00080-3).
- Sowers, M.R. and Karvonen-Gutierrez, C.A. (2010) ‘The evolving role of obesity in knee osteoarthritis’, *Current opinion in rheumatology*, 22(5), p. 533.
- Spector, T.D. *et al.* (1996) ‘Genetic influences on osteoarthritis in women: a twin study’, *Bmj*, 312(7036), pp. 940–943.
- Spencer, J., Wolf, S.L. and Kesar, T.M. (2021) ‘Biofeedback for Post-stroke Gait Retraining: A Review of Current Evidence and Future Research Directions in the Context of Emerging Technologies’, *Frontiers in neurology*, 12, pp. 637199–637199. Available at: <https://doi.org/10.3389/fneur.2021.637199>.
- Spieth, P.M. *et al.* (2016) ‘Randomized controlled trials – A matter of design’, *Neuropsychiatric disease and treatment*, 12(Issue 1), pp. 1341–1349. Available at: <https://doi.org/10.2147/NDT.S101938>.
- Squires, A. (2009) ‘Methodological challenges in cross-language qualitative research: A research review’, *International Journal of Nursing Studies*, 46(2), pp. 277–287. Available at: <https://doi.org/10.1016/J.IJNURSTU.2008.08.006>.
- Srikanth, V.K. *et al.* (2005) ‘A meta-analysis of sex differences prevalence, incidence and severity of osteoarthritis’, *Osteoarthritis and cartilage*, 13(9), pp. 769–781.
- Sritharan, P. *et al.* (2017) ‘Musculoskeletal loading in the symptomatic and asymptomatic knees of middle-aged osteoarthritis patients’, *JOURNAL OF ORTHOPAEDIC RESEARCH*, 35(2), pp. 321–330. Available at: <https://doi.org/10.1002/jor.23264>.
- Staniszewska, S. *et al.* (2010) ‘The PRIME project: developing a patient evidence-base’, *Health expectations: an international journal of public participation in health care and health policy*, 13(3), pp. 312–322. Available at: <https://doi.org/10.1111/J.1369-7625.2010.00590.X>.

- Stanley, I.H. *et al.* (2016) 'Improved Clinical Functioning for Patients Receiving Fee Discounts That Reward Treatment Engagement.', *Journal of clinical psychology*, 72 1, pp. 15–21. Available at: <https://api.semanticscholar.org/CorpusID:206045092>.
- Stansfield, B.W. *et al.* (2001) 'Normalized Speed, Not Age, Characterizes Ground Reaction Force Patterns in 5-to 12-Year-Old Children Walking at Self-Selected Speeds', *Journal of pediatric orthopaedics*, 21(3), pp. 395–402. Available at: <https://doi.org/10.1097/00004694-200105000-00026>.
- Steckler, A.B., Linnan, L. and Israel, B. (2002) *Process evaluation for public health interventions and research*. Jossey-Bass San Francisco.
- Steenkamp, W. *et al.* (2022) 'The correlation between clinical and radiological severity of osteoarthritis of the knee.', *SICOT-J*, 8, p. 14. Available at: <https://doi.org/10.1051/sicotj/2022014>.
- Steingrebe, H. *et al.* (2018) 'Biomechanical analysis of the knee joint load during a unilateral sit-to-stand movement', *The open sports sciences journal*, 11(1).
- Stensgaard Stoltze, J., Rasmussen, J. and Skipper Andersen, M. (2018) 'On the biomechanical relationship between applied hip, knee and ankle joint moments and the internal knee compressive forces', *International Biomechanics*, 5(1), pp. 63–74.
- Stevens, K.N. *et al.* (2008) 'Epidemiology of balance and dizziness in a national population: findings from the English Longitudinal Study of Ageing', *Age and ageing*, 37(3), pp. 300–305. Available at: <https://doi.org/10.1093/ageing/afn019>.
- Stewart, D.W. (2015) *Focus groups: theory and practice*. 3rd ed. Edited by P.N. Shamdassani. Los Angeles, Calif. ; London: SAGE (Applied social research methods series ; 20).
- Stone, R.C. and Baker, J. (2017) 'Painful Choices: A Qualitative Exploration of Facilitators and Barriers to Active Lifestyles Among Adults With Osteoarthritis', *Journal of applied gerontology*, 36(9), pp. 1091–1116. Available at: <https://doi.org/10.1177/0733464815602114>.
- Stoquart, G., Detrembleur, C. and Lejeune, T. (2008) 'Effect of speed on kinematic, kinetic, electromyographic and energetic reference values during treadmill walking', *Neurophysiologie clinique*, 38(2), pp. 105–116. Available at: <https://doi.org/10.1016/j.neucli.2008.02.002>.
- Stratford, P.W.W. *et al.* (2007) 'Measurement properties of the WOMAC LK 3.1 pain scale', *OSTEOARTHRITIS AND CARTILAGE*, 15(3), pp. 266–272. Available at: <https://doi.org/10.1016/j.joca.2006.09.005>.
- Street, R.L. *et al.* (2009) 'How does communication heal? Pathways linking clinician–patient communication to health outcomes', *Patient education and counseling*, 74(3), pp. 295–301. Available at: <https://doi.org/10.1016/j.pec.2008.11.015>.
- Stuart, E.A., Ackerman, B. and Westreich, D.J. (2018) 'Generalizability of Randomized Trial Results to Target Populations', *Research on Social Work Practice*, 28, pp. 532–537. Available at: <https://api.semanticscholar.org/CorpusID:51706758>.
- Sturnieks, D.L. (2021) 'Biomechanics of Balance and Falling', in *Falls in Older People*. Cambridge University Press, pp. 105–118. Available at: <https://doi.org/10.1017/9781108594455.006>.
- Subahi, M. *et al.* (2020) 'Stakeholder opinion of care pathways to increase physical activity in individuals with knee osteoarthritis in Saudi Arabia', *Osteoarthritis and Cartilage*, 28, pp. S159–S160.

- Sullivan, G.M. and Artino, A.R. (2013) 'Analyzing and Interpreting Data From Likert-Type Scales', *Analyzing and interpreting data from likert-type scales, J Grad Med Educ*, 5(4), pp. 541–542. Available at: <https://doi.org/10.4300/JGME-5-4-18>.
- Sullivan, G.M. and Artino Jr, A.R. (2013) 'Analyzing and interpreting data from Likert-type scales', *Journal of graduate medical education*, 5(4), pp. 541–542.
- Sun, J., Freeman, B.D. and Natanson, C. (2018) 'Meta-analysis of Clinical Trials', *Principles and Practice of Clinical Research*, pp. 317–327. Available at: <https://doi.org/10.1016/B978-0-12-849905-4.00022-8>.
- Svinøy, O.-E. *et al.* (2020) 'Timed up and go reference values for older adults with and without noncommunicable diseases and arthritis', *Osteoarthritis and Cartilage*, 28, pp. S361–S362.
- Szoeke, C. *et al.* (2006) 'The relationship between prospectively assessed body weight and physical activity and prevalence of radiological knee osteoarthritis in postmenopausal women.', *The Journal of rheumatology*, 33(9), pp. 1835–1840.
- Taherdoost, H. (2019) 'What is the best response scale for survey and questionnaire design; review of different lengths of rating scale/attitude scale/Likert scale', *Hamed Taherdoost*, pp. 1–10.
- Takacs, J. *et al.* (2014) 'Lateral trunk lean gait modification increases the energy cost of treadmill walking in those with knee osteoarthritis', *Osteoarthritis and Cartilage*, 22(2), pp. 203–209.
- Tamura, H. *et al.* (2023) 'Clinically significant effects of gait modification on knee pain: A systematic review and meta-analysis', *Journal of Back and Musculoskeletal Rehabilitation*, (Preprint), pp. 1–10.
- Tanaka, K. *et al.* (2008) 'Characteristics of trunk lean motion during walking in patients with symptomatic knee osteoarthritis'. Available at: <https://doi.org/10.1016/j.knee.2007.12.009>.
- Tarrier, N., Liversidge, T. and Gregg, L. (2006) 'The acceptability and preference for the psychological treatment of PTSD', *Behaviour research and therapy*, 44(11), pp. 1643–1656. Available at: <https://doi.org/10.1016/J.BRAT.2005.11.012>.
- Tausch, A.P. and Menold, N. (2016) 'Methodological Aspects of Focus Groups in Health Research: Results of Qualitative Interviews With Focus Group Moderators', *Global qualitative nursing research*, 3, pp. 2333393616630466–2333393616630466. Available at: <https://doi.org/10.1177/2333393616630466>.
- Taylor, B. (2005) 'The experiences of overseas nurses working in the NHS: results of a qualitative study', *Diversity and Equality in Health and Care*, 2(1).
- Taylor, S.J., Bogdan, R. and DeVault, M. (2015) *Introduction to Qualitative Research Methods: A Guidebook and Resource*. Wiley. Available at: <https://books.google.co.uk/books?id=pONoCgAAQBAJ>.
- Teddlie, C. (2009) *Foundations of mixed methods research : integrating quantitative and qualitative approaches in the social and behavioral sciences*. Edited by A. Tashakkori. Thousand Oaks ; London: Sage.
- Teherani, A. *et al.* (2015) 'Choosing a Qualitative Research Approach', *Journal of Graduate Medical Education*, 7(4), p. 669. Available at: <https://doi.org/10.4300/JGME-D-15-00414.1>.
- Telfer, S., Lange, M.J. and Sudduth, A.S.M. (2017) 'Factors influencing knee

adduction moment measurement: A systematic review and meta-regression analysis', *Gait & posture*, 58, pp. 333–339. Available at: <https://doi.org/10.1016/J.GAITPOST.2017.08.025>.

Teo, P.L. *et al.* (2020) 'Physiotherapists may improve management of knee osteoarthritis through greater psychosocial focus, being proactive with advice, and offering longer-term reviews: a qualitative study', *Journal of Physiotherapy*, 66(4), pp. 256–265.

Teoh, J.C. *et al.* (2013) 'Investigation of the biomechanical effect of variable stiffness shoe on external knee adduction moment in various dynamic exercises', *JOURNAL OF FOOT AND ANKLE RESEARCH*, 6. Available at: <https://doi.org/10.1186/1757-1146-6-39>.

Teresi, J.A. *et al.* (2022) 'Guidelines for Designing and Evaluating Feasibility Pilot Studies', *Medical care*, 60(1), pp. 95–103. Available at: <https://doi.org/10.1097/MLR.0000000000001664>.

Terkawi, M.A. *et al.* (2022) 'Low-Grade Inflammation in the Pathogenesis of Osteoarthritis: Cellular and Molecular Mechanisms and Strategies for Future Therapeutic Intervention.', *Biomedicines*, 10(5). Available at: <https://doi.org/10.3390/biomedicines10051109>.

Terwee, C.B. *et al.* (2006) 'Self-reported physical functioning was more influenced by pain than performance-based physical functioning in knee-osteoarthritis patients.', *Journal of clinical epidemiology*, 59 7, pp. 724–731. Available at: <https://api.semanticscholar.org/CorpusID:14884283>.

Thabane, L. *et al.* (2010) 'A tutorial on pilot studies: The what, why and how', *BMC medical research methodology*, 10(1), pp. 1–1. Available at: <https://doi.org/10.1186/1471-2288-10-1>.

Thom, J.M. *et al.* (2023) 'Knee osteoarthritis patient perspectives of their care in an australian private physiotherapy setting: a qualitative exploratory interview study', *BMC musculoskeletal disorders*, 24(1), pp. 564–564. Available at: <https://doi.org/10.1186/s12891-023-06692-4>.

Thomas, D.R. (2006) 'A General Inductive Approach for Analyzing Qualitative Evaluation Data', *American Journal of Evaluation*, 27, pp. 237–246.

Thomas, L. *et al.* (1995) 'Comparison of focus group and individual interview methodology in examining patient satisfaction with nursing care', *Social Sciences in Health*, 1(4), pp. 206–220.

Thompson, R. *et al.* (2020) 'Lower-limb joint reaction forces and moments during modified cycling in healthy controls and individuals with knee osteoarthritis', *Clinical Biomechanics*, 71, pp. 167–175.

Thorlund, J.B. *et al.* (2015) 'Arthroscopic surgery for degenerative knee: systematic review and meta-analysis of benefits and harms', *bmj*, 350(jun16 3), pp. h2747–h2747. Available at: <https://doi.org/10.1136/bmj.h2747>.

Thorp, L.E. *et al.* (2006a) 'Knee joint loading differs in individuals with mild compared with moderate medial knee osteoarthritis', *Arthritis & Rheumatism*, 54(12), pp. 3842–3849. Available at: <https://doi.org/10.1002/ART.22247>.

Thorp, L.E. *et al.* (2006b) 'Knee joint loading differs in individuals with mild compared with moderate medial knee osteoarthritis', *ARTHRITIS AND RHEUMATISM*, 54(12), pp. 3842–3849. Available at: <https://doi.org/10.1002/art.22247>.

- Thorp, L.E. *et al.* (2007) 'Relationship between pain and medial knee joint loading in mild radiographic knee osteoarthritis', *Arthritis Care and Research*, 57(7), pp. 1254–1260. Available at: <https://doi.org/10.1002/art.22991>.
- Thorp, L.E.E. *et al.* (2006) 'Bone mineral density in the proximal tibia varies as a function of static alignment and knee adduction angular momentum in individuals with medial knee osteoarthritis', *Bone*, 39(5), pp. 1116–1122.
- Thorpe, K.E. *et al.* (2009) 'A pragmatic-explanatory continuum indicator summary (PRECIS): a tool to help trial designers', *Journal of clinical epidemiology*, 62(5), pp. 464–475. Available at: <https://doi.org/10.1016/J.JCLINEPI.2008.12.011>.
- Thorstensson, C.A. *et al.* (2004) 'Reduced functional performance in the lower extremity predicted radiographic knee osteoarthritis five years later', *Annals of the rheumatic diseases*, 63(4), pp. 402–407.
- Thorstensson, C.A. *et al.* (2005) 'Six-week high-intensity exercise program for middle-aged patients with knee osteoarthritis: a randomized controlled trial [ISRCTN20244858]', *BMC Musculoskeletal Disorders*, 6(1), pp. 1–10.
- Thorstensson, C.A. *et al.* (2006) 'How do middle-aged patients conceive exercise as a form of treatment for knee osteoarthritis?', *Disability and rehabilitation*, 28(1), pp. 51–59. Available at: <https://doi.org/10.1080/09638280500163927>.
- Tidmarsh, L. V *et al.* (2022) 'The Influence of Adverse Childhood Experiences in Pain Management: Mechanisms, Processes, and Trauma-Informed Care.', *Frontiers in pain research (Lausanne, Switzerland)*, 3, p. 923866. Available at: <https://doi.org/10.3389/fpain.2022.923866>.
- Tilley, S.A. (2003) "Challenging" Research Practices: Turning a Critical Lens on the Work of Transcription', *Qualitative Inquiry*, 9(5), pp. 750–773. Available at: <https://doi.org/10.1177/1077800403255296>.
- Titscher, S. *et al.* (2000) *Methods of Text and Discourse Analysis*. London: SAGE Publications, Limited.
- Toda, Y. and Tsukimura, N. (2004) 'A six-month followup of a randomized trial comparing the efficacy of a lateral-wedge insole with subtalar strapping and an in-shoe lateral-wedge insole in patients with varus deformity osteoarthritis of the knee', *Arthritis and rheumatism*, 50(10), p. 3129-3136. Available at: <https://doi.org/10.1002/art.20569>.
- Toda, Y. and Tsukimura, N. (2008) 'Influence of concomitant heeled footwear when wearing a lateral wedged insole for medial compartment osteoarthritis of the knee', *Osteoarthritis and Cartilage*, 16(2), pp. 244–253.
- Toda, Y., Tsukimura, N. and Segal, N. (2005) 'An optimal duration of daily wear for an insole with subtalar strapping in patients with varus deformity osteoarthritis of the knee', *Osteoarthritis and cartilage*, 13(4 CC-Musculoskeletal), p. 353-360. Available at: <https://doi.org/10.1016/j.joca.2004.12.012>.
- Tokuda, K. *et al.* (2018) 'Biomechanical mechanism of lateral trunk lean gait for knee osteoarthritis patients', *JOURNAL OF BIOMECHANICS*, 66, pp. 10–17. Available at: <https://doi.org/10.1016/j.jbiomech.2017.10.016>.
- Torgerson, D., Ryan, M. and Donaldson, C. (1995) 'Effective Health Care bulletins: are they efficient?', *Quality in Health Care*, 4(1), p. 48. Available at: <https://doi.org/10.1136/QSHC.4.1.48>.
- Toriyama, M. *et al.* (2011) 'Effects of unloading bracing on knee and hip joints for

patients with medial compartment knee osteoarthritis', *Clinical Biomechanics*, 26(5), pp. 497–503.

Torres, L. *et al.* (2006) 'The relationship between specific tissue lesions and pain severity in persons with knee osteoarthritis', *Osteoarthritis and cartilage*, 14(10), pp. 1033–1040. Available at: <https://doi.org/10.1016/j.joca.2006.03.015>.

Torzilli, P.A. *et al.* (1999) 'Effect of impact load on articular cartilage: cell metabolism and viability, and matrix water content'.

Treweek, S. *et al.* (2013) 'Methods to improve recruitment to randomised controlled trials: Cochrane systematic review and meta-analysis', *BMJ open*, 3(2), p. e002360. Available at: <https://doi.org/10.1136/bmjopen-2012-002360>.

Trombini-Souza, F *et al.* (2012) 'Effectiveness of a long-term use of a minimalist footwear versus habitual shoe on pain, function and mechanical loads in knee osteoarthritis: a randomized controlled trial', *BMC musculoskeletal disorders*, 13, p. 121. Available at: <https://doi.org/10.1186/1471-2474-13-121>.

Trombini-Souza, Francis *et al.* (2012) 'Effectiveness of a long-term use of a minimalist footwear versus habitual shoe on pain, function and mechanical loads in knee osteoarthritis: A randomized controlled trial', *BMC Musculoskeletal Disorders*, 13. Available at: <https://doi.org/10.1186/1471-2474-13-121>.

Trombini-Souza, F. *et al.* (2015) 'Long-term use of minimal footwear on pain, self-reported function, analgesic intake, and joint loading in elderly women with knee osteoarthritis: a randomized controlled trial', *Clinical biomechanics (Bristol, Avon)*, 30(10), p. 1194-1201. Available at: <https://doi.org/10.1016/j.clinbiomech.2015.08.004>.

Tröster, M. *et al.* (2020) 'Biomechanical model-based development of an active occupational upper-limb exoskeleton to support healthcare workers in the surgery waiting room', *International Journal of Environmental Research and Public Health*, 17(14), pp. 1–16. Available at: <https://doi.org/10.3390/ijerph17145140>.

Trouvin, A.-P. and Perrot, S. (2018) 'Pain in osteoarthritis. Implications for optimal management', *Joint, bone, spine: revue du rhumatisme*, 85(4), pp. 429–434. Available at: <https://doi.org/10.1016/j.jbspin.2017.08.002>.

Tsai, L.-C., Scher, I.S. and Powers, C.M. (2013) 'Quantification of Tibiofemoral Shear and Compressive Loads Using an MRI-Based EMG-Driven Knee Model', *JOURNAL OF APPLIED BIOMECHANICS*, 29(2), pp. 229–234. Available at: <https://doi.org/10.1123/jab.29.2.229>.

Tucker, M.G. *et al.* (2008) 'Age-related differences in postural reaction time and coordination during voluntary sway movements', *Human movement science*, 27(5), pp. 728–737. Available at: <https://doi.org/10.1016/j.humov.2008.03.002>.

van Tulder, M. *et al.* (2003) 'Updated Method Guidelines for Systematic Reviews in the Cochrane Collaboration Back Review Group', *Spine*, 28(12), pp. 1290–1299. Available at: <https://doi.org/10.1097/01.BRS.0000065484.95996.AF>.

van Tunen, J.A.C. *et al.* (2018) 'Association of malalignment, muscular dysfunction, proprioception, laxity and abnormal joint loading with tibiofemoral knee osteoarthritis - a systematic review and meta-analysis.', *BMC musculoskeletal disorders*, 19(1), p. 273. Available at: <https://doi.org/10.1186/s12891-018-2202-8>.

Van Tunen, J.A.C. *et al.* (2016) 'Biomechanical factors associated with the development of tibiofemoral knee osteoarthritis: protocol for a systematic review and meta-analysis', *BMJ open*, 6(6), p. e011066.

Tuohy, D. *et al.* (2013) 'An overview of interpretive phenomenology as a research methodology', *Nurse researcher*, 20(6), pp. 17–20. Available at: <https://doi.org/10.7748/NR2013.07.20.6.17.E315>.

Turpin, K.M. *et al.* (2012) 'Biomechanical and Clinical Outcomes With Shock-Absorbing Insoles in Patients With Knee Osteoarthritis: Immediate Effects and Changes After 1 Month of Wear', *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION*, 93(3), pp. 503–508. Available at: <https://doi.org/10.1016/j.apmr.2011.09.019>.

Uhlrich, S.D. *et al.* (2019) 'Six weeks of personalized gait retraining to offload the medial compartment of the knee reduces pain more than sham gait retraining', *Osteoarthritis and cartilage*, 27, p. S28-. Available at: <https://doi.org/10.1016/j.joca.2019.02.043>.

Uivaraseanu, B. *et al.* (2022) 'Therapeutic approaches in the management of knee osteoarthritis (Review)', *Experimental and therapeutic medicine*, 23(5). Available at: <https://doi.org/10.3892/etm.2022.11257>.

Ulrich, B. *et al.* (2023) 'Diverse parameters of ambulatory knee moments differ with medial knee osteoarthritis severity and are combinable into a severity index', *Frontiers In Bioengineering And Biotechnology*, 11, p. 1176471.

Vanover, C., Mihas, P. and Saldaña, J. (2021) *Analyzing and interpreting qualitative research: After the interview*. SAGE Publications.

Veenhof, C. *et al.* (2006) 'Active involvement and long-term goals influence long-term adherence to behavioural graded activity in patients with osteoarthritis: a qualitative study', *Australian Journal of Physiotherapy*, 52(4), pp. 273–278. Available at: [https://doi.org/https://doi.org/10.1016/S0004-9514\(06\)70007-1](https://doi.org/https://doi.org/10.1016/S0004-9514(06)70007-1).

Verma, S.K. *et al.* (2016) 'Falls and fall-related injuries among community-dwelling adults in the United States', *PloS one*, 11(3), pp. e0150939–e0150939. Available at: <https://doi.org/10.1371/journal.pone.0150939>.

Vignon, É. *et al.* (2006) 'Osteoarthritis of the knee and hip and activity: a systematic international review and synthesis (OASIS)', *Joint Bone Spine*, 73(4), pp. 442–455.

Villemure, C., Slotnick, B.M. and Bushnell, M.C. (2003) 'Effects of odors on pain perception: deciphering the roles of emotion and attention', *Pain (Amsterdam)*, 106(1), pp. 101–108. Available at: [https://doi.org/10.1016/S0304-3959\(03\)00297-5](https://doi.org/10.1016/S0304-3959(03)00297-5).

Vincent, T. (2004) 'Osteoarthritis, 2nd edition. Kenneth Brandt, Michael Doherty, L. Stefan Lohmander. £125. Oxford University Press, Oxford. 512 pages. ISBN 0-19-850967-7', *Rheumatology*, 43(5), pp. 685–685. Available at: <https://doi.org/10.1093/rheumatology/keh144>.

Vincent, T.L. (2020) 'Peripheral pain mechanisms in osteoarthritis', *PAIN*, 161. Available at: https://journals.lww.com/pain/fulltext/2020/09001/peripheral_pain_mechanisms_in_oosteoarthritis.15.aspx.

Visser, A.W. *et al.* (2015) 'The relative contribution of mechanical stress and systemic processes in different types of osteoarthritis: the NEO study', *Annals of the rheumatic diseases*, 74(10), pp. 1842–1847.

Vos, T. *et al.* (2012) 'Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010', *The Lancet*, 380(9859), pp. 2163–2196. Available at:

[https://doi.org/https://doi.org/10.1016/S0140-6736\(12\)61729-2](https://doi.org/https://doi.org/10.1016/S0140-6736(12)61729-2).

Vos, T. *et al.* (2016) *Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015*. Available at: [https://doi.org/10.1016/S0140-6736\(16\)31678-6](https://doi.org/10.1016/S0140-6736(16)31678-6).

Wager, T.D. (2005) 'Expectations and anxiety as mediators of placebo effects in pain', *Pain (Amsterdam)*, 115(3), pp. 225–226. Available at: <https://doi.org/10.1016/j.pain.2005.03.018>.

Walker, L.S. *et al.* (1995) 'Long-Term Health Outcomes in Patients with Recurrent Abdominal Pain', *Journal of pediatric psychology*, 20(2), pp. 233–245. Available at: <https://doi.org/10.1093/jpepsy/20.2.233>.

Wallis, J.A. *et al.* (2019) 'Experience of living with knee osteoarthritis: a systematic review of qualitative studies', *BMJ Open*, 9(9), p. e030060. Available at: <https://doi.org/10.1136/bmjopen-2019-030060>.

Walston, S., Al-Harbi, Y. and Al-Omar, B. (2008) 'The changing face of healthcare in Saudi Arabia', *Annals of Saudi medicine*, 28(4), pp. 243–250.

Walter, J.P. *et al.* (2010) 'Decreased knee adduction moment does not guarantee decreased medial contact force during gait', *Journal of Orthopaedic Research*, 28(10), pp. 1348–1354. Available at: <https://doi.org/10.1002/jor.21142>.

Walter, J.P. *et al.* (2015) 'Contribution of tibiofemoral joint contact to net loads at the knee in gait', *JOURNAL OF ORTHOPAEDIC RESEARCH*, 33(7), pp. 1054–1060. Available at: <https://doi.org/10.1002/jor.22845>.

Walter, S.D. and Yao, X. (2007) 'Effect sizes can be calculated for studies reporting ranges for outcome variables in systematic reviews', *Journal of clinical epidemiology*, 60(8), pp. 849–852.

Walters, S.J. *et al.* (2019) 'Sample size estimation for randomised controlled trials with repeated assessment of patient-reported outcomes: what correlation between baseline and follow-up outcomes should we assume?', *Trials*, 20(1), pp. 1–16.

Wang, H. *et al.* (2016) 'Osteoarthritis and the risk of cardiovascular disease: A meta-analysis of observational studies', *Scientific Reports*, 6. Available at: <https://doi.org/10.1038/srep39672>.

Wang, J., Chen, X., Sun, X., *et al.* (2021) 'The application of 'Timed up and go'test in fall screening of Elderly people in Shanghai: a cross-sectional study', *Iranian journal of public health*, 50(12), p. 2567.

Wang, Q., Runhaar, J., Kloppenburg, M., *et al.* (2021) 'Diagnosis of early stage knee osteoarthritis based on early clinical course: data from the CHECK cohort', *Arthritis Research & Therapy*, 23, pp. 1–10.

Wang, S., Mo, S., *et al.* (2021) 'How foot progression angle affects knee adduction moment and angular impulse in people with and without medial knee osteoarthritis: a meta-analysis', *Arthritis Care & Research*, 73(12), pp. 1763–1776. Available at: <https://doi.org/10.1002/acr.24420>.

Wang, S., Chan, P.P.K., *et al.* (2021) 'Sensor-Based Gait Retraining Lowers Knee Adduction Moment and Improves Symptoms in Patients with Knee Osteoarthritis: A Randomized Controlled Trial', *Sensors (Basel, Switzerland)*, 21(16), p. 5596. Available at: <https://doi.org/10.3390/s21165596>.

- Wang, T. and He, C. (2018) 'Pro-inflammatory cytokines: The link between obesity and osteoarthritis', *Cytokine & Growth Factor Reviews*, 44, pp. 38–50. Available at: <https://doi.org/https://doi.org/10.1016/j.cytogfr.2018.10.002>.
- Wang, X. *et al.* (2015) 'Metabolic triggered inflammation in osteoarthritis', *Osteoarthritis and cartilage*, 23(1), pp. 22–30. Available at: <https://doi.org/10.1016/j.joca.2014.10.002>.
- Wang, Y. *et al.* (2018) 'Knee pain as a predictor of structural progression over 4 years: data from the Osteoarthritis Initiative, a prospective cohort study', *Arthritis Research & Therapy*, 20. Available at: <https://api.semanticscholar.org/CorpusID:53233144>.
- Ward, D.J. *et al.* (2013) 'Using Framework Analysis in nursing research: a worked example', *Journal of advanced nursing*. Ward D.J., Furber..., 69(11), pp. 2423–2431. Available at: <https://doi.org/10.1111/jan.12127>.
- Ware, J.E.J. and Gandek, B. (1998) 'Overview of the SF-36 Health Survey and the International Quality of Life Assessment (IQOLA) Project.', *Journal of clinical epidemiology*, 51(11), pp. 903–912. Available at: [https://doi.org/10.1016/s0895-4356\(98\)00081-x](https://doi.org/10.1016/s0895-4356(98)00081-x).
- Warmink, K. *et al.* (2020) 'High-fat feeding primes the mouse knee joint to develop osteoarthritis and pathologic infrapatellar fat pad changes after surgically induced injury', *Osteoarthritis and Cartilage*, 28(5), pp. 593–602.
- Wegener, L., Kisner, C. and Nichols, D. (1997) 'Static and dynamic balance responses in persons with bilateral knee osteoarthritis', *The journal of orthopaedic and sports physical therapy*, 25(1), pp. 13–18. Available at: <https://doi.org/10.2519/jospt.1997.25.1.13>.
- Wei, J. *et al.* (2019) 'Risk factor heterogeneity for medial and lateral compartment knee osteoarthritis: analysis of two prospective cohorts'.
- Weidenhielm, L. *et al.* (1994) 'Adduction moment of the knee compared to radiological and clinical parameters in moderate medical osteoarthrosis of the knee.', in *Annales chirurgiae et Gynaecologiae*, pp. 236–242.
- Weidow, J., Mars, I. and Kärrholm, J. (2005) 'Medial and lateral osteoarthritis of the knee is related to variations of hip and pelvic anatomy.', *Osteoarthritis and cartilage*, 13 6, pp. 471–477. Available at: <https://api.semanticscholar.org/CorpusID:31542291>.
- Wengraf, T. (2001) *Qualitative research interviewing: Biographic narrative and semi-structured methods*. sage.
- Wheeler, J.W., Shull, P.B. and Besier, T.F. (2011) 'Real-Time Knee Adduction Moment Feedback for Gait Retraining Through Visual and Tactile Displays', *JOURNAL OF BIOMECHANICAL ENGINEERING-TRANSACTIONS OF THE ASME*, 133(4). Available at: <https://doi.org/10.1115/1.4003621>.
- Whitehouse, S.L. *et al.* (2005) 'The Oxford Knee Score; problems and pitfalls', *The knee*, 12(4), pp. 287–291. Available at: <https://doi.org/10.1016/j.knee.2004.11.005>.
- Widhalm, K., Durstberger, S. and Putz, P. (2021) 'Effects of real-time feedback during decline walking on kinematic and kinetic gait parameters in a healthy population: study protocol for a randomized trial - up and down', *Current controlled trials in cardiovascular medicine*, 22(1), pp. 477–477. Available at: <https://doi.org/10.1186/s13063-021-05422-2>.
- Wilkie, R. *et al.* (2007) 'Factors associated with restricted mobility outside the home in community-dwelling adults ages fifty years and older with knee pain: An example

of use of the international classification of functioning to investigate participation restriction', *ARTHRITIS & RHEUMATISM-ARTHRITIS CARE & RESEARCH*, 57(8), pp. 1381–1389. Available at: <https://doi.org/10.1002/art.23083>.

Wilson, J.L.A. *et al.* (2011) 'The association between knee joint biomechanics and neuromuscular control and moderate knee osteoarthritis radiographic and pain severity', *Osteoarthritis and Cartilage*, 19(2), pp. 186–193.

Wilson, J.L.A. and Kobsar, D. (2021) 'Osteoarthritis year in review 2020: Mechanics', *Osteoarthritis and Cartilage* [Preprint].

Wluka, A.E. *et al.* (2002) 'Supplementary vitamin E does not affect the loss of cartilage volume in knee osteoarthritis: a 2 year double blind randomized placebo controlled study.', *The Journal of Rheumatology*, 29(12), pp. 2585 LP – 2591. Available at: <http://www.jrheum.org/content/29/12/2585.abstract>.

Woolf, C.J. (2010) 'What is this thing called pain?', *The Journal of clinical investigation*, 120(11), pp. 3742–3744. Available at: <https://doi.org/10.1172/JCI45178>.

Woolf, C.J. (2011) 'Central sensitization: Implications for the diagnosis and treatment of pain', *Pain (Amsterdam)*, 152(3), pp. S2–S15. Available at: <https://doi.org/10.1016/j.pain.2010.09.030>.

Van Der Woude, J.A.D. *et al.* (2017) 'Knee joint distraction compared with total knee arthroplasty: a randomised controlled trial', *The bone & joint journal*, 99(1), pp. 51–58.

Wylde, V. *et al.* (2011) 'Persistent pain after joint replacement: prevalence, sensory qualities, and postoperative determinants', *PAIN®*, 152(3), pp. 566–572.

Xia, H. *et al.* (2019) 'Preliminary test of a smart shoe for training foot progression angle during walking', *Osteoarthritis and cartilage*, 27, pp. S64–S65. Available at: <https://doi.org/10.1016/j.joca.2019.02.091>.

Xie, F. *et al.* (2010) 'Use of a Disease-Specific Instrument in Economic Evaluations: Mapping WOMAC onto the EQ-5D Utility Index', *Value in health*, 13(8), pp. 873–878. Available at: <https://doi.org/10.1111/j.1524-4733.2010.00770.x>.

Xing, F. *et al.* (2017) 'A systematic review and meta-analysis into the effect of lateral wedge arch support insoles for reducing knee joint load in patients with medial knee osteoarthritis', *Medicine (United States)*, 96(24), pp. 1–10. Available at: <https://doi.org/10.1097/MD.00000000000007168>.

Xu, Q. *et al.* (2017) 'The Effectiveness of Manual Therapy for Relieving Pain, Stiffness, and Dysfunction in Knee Osteoarthritis: A Systematic Review and Meta-Analysis', *Pain Physician*, 20(4), pp. 229–243. Available at: <http://nottingham.idm.oclc.org/login?url=https://www.proquest.com/scholarly-journals/effectiveness-manual-therapy-relieving-pain/docview/2655998320/se-2?accountid=8018>.

Yamamoto, Y. *et al.* (2022) 'Mobile application for home exercise adherence in patients with knee osteoarthritis: A pilot study', *Medicine (United States)*, 101(42), p. E31181. Available at: <https://doi.org/10.1097/MD.00000000000031181>.

Yang, Y.-R. *et al.* (2005) 'Gait outcomes after additional backward walking training in patients with stroke: a randomized controlled trial', *Clinical rehabilitation*, 19(3), pp. 264–273. Available at: <https://doi.org/10.1191/0269215505cr860oa>.

Yilmaz, B. *et al.* (2016) 'Effects of two different degrees of lateral-wedge insoles on unilateral lower extremity load-bearing line in patients with medial knee osteoarthritis', *ACTA ORTHOPAEDICA ET TRAUMATOLOGICA TURCICA*, 50(4), pp. 405–408.

Available at: <https://doi.org/10.1016/j.aott.2016.06.004>.

Yonclas, P.P. *et al.* (2006) 'Orthotics and assistive devices in the treatment of upper and lower limb osteoarthritis: An update', *American Journal of Physical Medicine and Rehabilitation*, 85(11 SUPPL.). Available at: <https://doi.org/10.1097/01.PHM.0000247790.71487.80>.

Young, C., Oliver, M.L. and Gordon, K.D. (2021) 'Design and validation of a novel 3D-printed wearable device for monitoring knee joint kinematics.', *Medical engineering & physics*, 94, pp. 1–7. Available at: <https://api.semanticscholar.org/CorpusID:236243295>.

Yu, L. *et al.* (2021) 'Effects of orthopaedic insoles on patients with knee osteoarthritis: A Meta-analysis and systematic review', *Journal of rehabilitation medicine*, 53(5), pp. jrm00191–jrm00191. Available at: <https://doi.org/10.2340/16501977-2836>.

Yucesoy, B. *et al.* (2015) 'Occupational and genetic risk factors for osteoarthritis: a review', *Work*, 50(2), pp. 261–273.

Zafar, A.Q. *et al.* (2020) 'The effectiveness of foot orthoses in the treatment of medial knee osteoarthritis: A systematic review', *Gait & posture*, 76, pp. 238–251. Available at: <https://doi.org/10.1016/J.GAITPOST.2019.12.016>.

Zafar, A.Q., Zamani, R. and Akrami, M. (2020) 'The effectiveness of foot orthoses in the treatment of medial knee osteoarthritis: A systematic review', *Gait & posture*, 76, pp. 238–251.

Zamawe, F.C. (2015) 'The implication of using NVivo software in qualitative data analysis: Evidence-based reflections', *Malawi medical journal*, 27(1), pp. 13–15. Available at: <https://doi.org/10.4314/mmj.v27i1.4>.

Zeng, C.-Y. *et al.* (2021) 'Benefits and Mechanisms of Exercise Training for Knee Osteoarthritis', *Frontiers in physiology*, 12, pp. 794062–794062. Available at: <https://doi.org/10.3389/fphys.2021.794062>.

Zeni, J.A. and Higginson, J.S. (2009) 'Differences in gait parameters between healthy subjects and persons with moderate and severe knee osteoarthritis: A result of altered walking speed?', *Clinical biomechanics (Bristol)*, 24(4), pp. 372–378. Available at: <https://doi.org/10.1016/j.clinbiomech.2009.02.001>.

Zeni, J.A., Rudolph, K. and Higginson, J.S. (2010) 'Alterations in quadriceps and hamstrings coordination in persons with medial compartment knee osteoarthritis', *Journal of Electromyography and Kinesiology*, 20(1), pp. 148–154.

Zhang, B. *et al.* (2018) 'Is the Wedged Insole an Effective Treatment Option When Compared with a Flat (Placebo) Insole: A Systematic Review and Meta-Analysis', *Evidence-based complementary and alternative medicine*, 2018, pp. 8654107–13. Available at: <https://doi.org/10.1155/2018/8654107>.

Zhang, J., Wang, Q. and Zhang, C. (2018) 'Ineffectiveness of lateral-wedge insoles on the improvement of pain and function for medial knee osteoarthritis: a meta-analysis of controlled randomized trials', *ARCHIVES OF ORTHOPAEDIC AND TRAUMA SURGERY*, 138(10), pp. 1453–1462. Available at: <https://doi.org/10.1007/s00402-018-3004-z>.

Zhang, M. *et al.* (2015) 'The biomechanical effects of backward walking on the knee: A new method for releasing the joint loading', *Osteoarthritis and cartilage*, 23, pp. A121–A122. Available at: <https://doi.org/10.1016/j.joca.2015.02.845>.

Zhang, Weibo *et al.* (2010) 'EULAR evidence-based recommendations for the

diagnosis of knee osteoarthritis', *Annals of the rheumatic diseases*, 69(3), pp. 483–489. Available at: <https://doi.org/10.1136/ard.2009.113100>.

Zhang, W *et al.* (2010) 'OARSI recommendations for the management of hip and knee osteoarthritis Part III: changes in evidence following systematic cumulative update of research published through January 2009', *Osteoarthritis and cartilage*, 18(4), pp. 476–499. Available at: <https://doi.org/10.1016/j.joca.2010.01.013>.

Zhang, Y. *et al.* (2001) 'Chinese have a much lower prevalence of radiographic osteoarthritis (ROA) of the hand than Caucasians in the US', *Arthritis & Rheumatism*, 44(9).

Zhang, Y. and Jordan, J.M. (2010) 'Epidemiology of osteoarthritis', *Clinics in Geriatric Medicine*. Elsevier, pp. 355–369. Available at: <https://doi.org/10.1016/j.cger.2010.03.001>.

Zhao, Dong *et al.* (2007) 'Correlation between the Knee Adduction Torque and Medial Contact Force for a Variety of Gait Patterns', *Journal of Orthopaedic Research*, 25(6), pp. 787–789. Available at: <https://doi.org/10.1002/jor.20379>.

Zhao, D *et al.* (2007) 'Correlation between the Knee Adduction Torque and Medial Contact Force for a Variety of Gait Patterns', *Journal of Orthopaedic Research*, 25(6), pp. 787–789.

Zheng, L. *et al.* (2021) 'The role of metabolism in chondrocyte dysfunction and the progression of osteoarthritis', *Ageing Research Reviews*, 66, p. 101249. Available at: <https://doi.org/https://doi.org/10.1016/j.arr.2020.101249>.

Zuhur, S. (2011) *Saudi Arabia*. Edited by ProQuest (Firm). Santa Barbara, Calif.: ABC-CLIO (Middle East in focus series).

APPENDEIXES:

Appendix 1: Databases search strategy

Medline, Embase and AMED (Ovid):

P	("exp *osteoarthritis, knee"/ or osteochondritis/ or cartilage/ or arthritis/ or bursitis/ or "*knee joint*" or menisci, tibial/ or "*tibiofemoral or femorotibial".mp.) or ((Knee joint* adj4 Osteoarthritis) or (Knee adj4 Degenerat* Chang*) or ((Medial or Lateral) adj4 "knee osteoarthritis") or ("Knee adj3 OA" or KOA)).mp. not ("Anterior Cruciate Ligament*" or ACL or Posterior or "Patellofemoral joint*" or "Total Knee Arthroplasty" or Replace* or TKA or TKR).mp.
I	exp *gait/ or *gait analysis/ or walk*.mp. or ("Gait Modification*" or "Strid* Length*" or SL or ("Gait Stance*" or Phase*) or ("Gait Train*" or Chang* or Alter* or Variat* or Therap*) or "Re-train*" or "Re-gait").ti,ab. or (((Lateral or Medial) adj3 Wedge*) or ((Medial* or Lateral*) adj3 (Insole* or Arch*))).ti,ab. or *Torso/ or *Pelvis/ or exp *Trunk/ or (Lateral Trunk* adj3 Lean*).ti. or (Lateral* adj3 (Switch* or Sway*).ti,ab. or (Step* or (Step adj3 Width*) or (Walk* adj3 Speed*) or Speed* or SW).ti,ab. or exp *Ankle/ or exp *foot/ or heel/ or *Orthotic Devices/ or Orthosis.ti,ab. or AFO.mp. or FO.mp. or ((Foot* adj4 Angle*) or FA or FAP).ti,ab. or *toes/ or ("Toe-in" or "Toe In" or "Toe-out" or "Toe Out").ti,ab. or Shoe*.ti. or ("Foot* wear*" or "Footwear*" or "Foot-wear").ti. or (Cane* or Brace or Support*).m_titl.
O	*Weight-Bearing/ or ("Knee Kinetic*" or Pressure or Stress).mp. or "Knee dynamic* Load".mp. or "Knee Contact".mp. or ((External adj3 Knee* Adduct* Moment*) or (Knee* adj3 Adduction moment*) or KAM or AKM or EKAM or "Knee Alignment*" or ((Knee adj3 Thrust*) or Varus* or Valgus*) or "Knee Flex* angle" or KFA or AFK or (Knee* adj3 Rotat*).ti,ab. or pain/ or exp *arthralgia/ or exp *musculoskeletal pain/ or ("Self Report* or VAS" or NPRS).mp. or exp *range of motion/ or musculoskeletal physiological phenomena/ or movement/ or locomotion/ or exp *walking/ or (Knee* adj3 (Function* or Disab* or Mobil*).mp. or exp *activities of daily living/ or exp human activities/ or rehabilitation/ or *functional status/ or ADLS.mp. or ADLY.ti,ab. or ("Motion Analy?* System*" or "3D Analy\$*" or "Three-dimension*" or "Video record").mp.

CINAHL:

P	((Osteoarthritis* OR (MH "Osteoarthritis, Knee")) OR (Osteochondritis or Cartilage or Arthritis or Bursitis or Menisci or Tibiofemoral or Femorotibial) OR ("Knee joint* N4 Osteoarthritis*" or "Knee N4 Degenerat* Chang*") OR ("Medial or Lateral" N4 "knee osteoarthritis") OR ("Knee N3 OA" or KOA)) NOT (((MM "Arthroplasty, Replacement, Knee") OR (MM "Anterior Cruciate Ligament") OR (MM "Posterior Cruciate Ligament")) OR (MM "Patellofemoral Pain Syndrome") OR ("ACL or PCL or TKA or TKR"))
I	(((MM "Gait*") OR (MH "Gait Analysis") OR (MH "Gait* Modification")) OR ((MM "Biomechanics+") or (MH "Mechanics+") or) OR ("Gait Modification*" or "Strid* Length*" or SL or "Gait Stance*" or ("Gait Train*" or Chang* or Alter* or Variat* or Therap*) or "Gait N3 Re-train*" or "Re-gait* N3 Train*") or Walk*) OR ((Ankle or Foot or Heel) OR (("Lateral or Medial" N3 Wedge*) or ("Medial or Lateral" N3 Insole* or Arch*)) OR TI ("Orthotic Devices" or Orthosis) OR TI "Ankle foot orthoses" OR (AFO or FO) OR ("Foot* N3 Angle*" or FA or FAP) OR ("Toe*" OR "Toe-in" or "Toe In" or "Toe-out" or "Toe Out") OR (Step* or "Step N3 Width*" or "Walk* N3 Speed*" or SW or (Gait* or Stride* N3 Length*)) OR (TI "Shoe*") or (MW "Foot* wear*" or "Footwear*" or "Foot-wear*")) OR ((MW "Torso" or "Pelvis" or "Trunk")) OR "Lateral Trunk*" N3 Lean* OR TI (Cane* or Brace* or support*))
O	(((MH "Biomechanic* Load*") OR (MH "Kinematics") OR (MH "Kinetics") OR ") OR "Weight OR Load* OR Bear*" OR "Stress, Mechanical" OR "Ground Reaction Force" OR GRF OR "Weight* N3 Shift*" OR ("Knee Dynamic*" N3 Load*) OR "Knee N3 Contact*") OR (("External N3 Knee* Adduct* Moment*") or ("Knee* N3 Adduction moment*") or KAM or AKM or EKAM) OR ("Knee N3 Thrust*" or Varus* or Valgus*) OR "Knee Alignment*" OR ("Knee Flex*" N3 angle) OR (KFA or AFK)) OR (((MH "Arthralgia+") OR (MH "Knee Pain+")) OR "Musculoskeletal pain" OR ("Self Report*" or VAS or NPRS)) OR (((MH "Movement") OR (MH "Locomotion") OR (MH "Range of Motion")) OR MW (Walking or Gait or Ambulation) OR TI ((Knee* N3 (Function* OR Disab* OR Mobil*)) or "Activity of daily living") OR (ADL's or ADL or ADLY)) OR ((MH "Imaging, Three-Dimensional") OR ("Image Process*" OR "Computer Assist*" OR "3D analy?*"))

Cochrane Library:

P	[Osteoarthritis, Knee] explode all tree OR (osteocondritis or cartilage or arthritis):ti,ab,kw OR (Tibiofemoral or Femorotibial):ti,ab,kw OR ((Knee joint* near/4 Osteoarthritis*) OR (Knee near/4 Degenerat* Chang*)):ti,ab,kw OR (((Medial or Lateral) near/4 knee osteoarthritis*)):ti,ab,kw OR (Knee near/3 OA) or KOA OR ("Anterior Cruciate Ligament*" OR ACL OR "Patellofemoral joint*" OR "Total Knee Arthroplasty" or Replace* or TKA or TKR):ti,ab,kw
I	[Gait] explode all trees OR ("Gait Modification*" or "Strid* Length*" or SL or "Gait Stance*" or "Re-train*" or "Re-gait*"):ti,ab,kw OR (("Gait Chang*" or Alter* or Variat*)):ti,ab,kw OR (((Lateral or Medial) near/3 Wedge*) or ((Medial or Lateral) near/3 (Insole* or Arch*)):ti OR (Torso or Pelvi* or Trunk):ab OR (("Lateral Trunk*" near/4 Lean*)):ti,ab,kw OR (Step* or (Step near/3 Width*) or (Walk* near/3 Speed*) or SW):ti OR (Ankle or foot or heel or "Orthotic Devices" or Orthosis or AFO or FO):ti Or ("Foot* near/4 Angle*" or FA or FAP):ti OR (toes or ("Toe-in" or "Toe In" or "Toe-out" or "Toe Out")):ti,ab,kw OR (Shoe* or ("Foot* wear*" or "Footwear*" or "Foot-wear*)):ti,ab,kw OR (Cane* or Brace or Support*):ti
O	[Weight-Bearing] explode all trees OR ("Knee Dynamic*Load*" or "Knee Contact*"):ti,ab,kw OR ((External near/3 "Knee* Adduct* Moment*" or (Knee* near/3 "Adduction moment*") or KAM or AKM or EKAM):ti,ab,kw Or ("Knee Alignment*" or ("Knee near/3 Thrust*" or Varus* or Valgus*) or "Knee Flex* angle" or KFA or AFK):ti,ab,kw Or [Pain] this term only OR (Arthralgia or "Musculoskeletal pain"):ti,ab,kw Or ("Self Report*" or VAS or NPRS):kw OR [Range of Motion, Articular] explode all trees OR (movement or locomotion or walk*):kw OR ((Knee* near/3 (Function* or Disab* or Mobil*)):kw OR ("activities of daily living" or ADL or ADLS or ADLY):kw Or (("Motion Analy?* System*" or "3D Analy?*" or "Three-dimension*" or "Video record*"):ti,ab,kw

Clinical Trails:

P	(EXPAND[Concept] "Knee Osteoarthritis" OR Tibiofemoral OR EXPAND[Concept] "Knee Degenerative" OR Osteochondritis OR Cartilage OR Tibiofemoral OR Femorotibial OR EXPAND[Concept] "Medial knee osteoarthritis") AND NOT (EXPAND[Concept] "Knee Arthroplasty" OR Replacement OR EXPAND[Concept] "Anterior Cruciate Ligament" OR EXPAND[Concept] "Posterior Cruciate Ligament" OR EXPAND[Concept] "Patellofemoral Pain Syndrome")
I	(Gait OR EXPAND[Concept] "Gait Modification" OR Biomechanics OR Mechanics OR EXPAND[Concept] "Gait Training" OR Change OR EXPAND[Concept] "Re-gait training" OR EXPAND[Concept] "Strid Length" OR EXPAND[Concept] "Gait Stance" OR Anke OR Foot OR Heel OR Wedge OR Insole OR Arch OR Orthosis OR EXPAND[Concept] "Ankle foot orthoses" OR EXPAND[Concept] "Foot Angle" OR Toe OR EXPAND[Concept] "Toe-in" OR EXPAND[Concept] "Toe In" OR EXPAND[Concept] "Toe-out" OR EXPAND[Concept] "Toe Out" OR Step OR EXPAND[Concept] "Step Width" OR Walk OR EXPAND[Concept] "Walk Speed" OR EXPAND[Concept] "Gait OR Stride Length" OR Shoe OR EXPAND[Concept] "Foot wear" OR EXPAND[Concept] "Footwear" OR EXPAND[Concept] "Foot-wear" OR Trunk OR EXPAND[Concept] "Lateral Trunk Lean" OR Cane OR Brace OR support)
O	(EXPAND[Concept] "Biomechanic Load" OR Weight OR Kinematics OR Kinetics OR EXPAND[Concept] "Ground Reaction Force" OR EXPAND[Concept] "Knee Dynamic Load" OR EXPAND[Concept] "Knee Contact" OR EXPAND[Concept] "Stress, Mechanical" OR EXPAND[Concept] "Knee Alignment*" OR EXPAND[Concept] "External Knee Adduction Moment" OR EXPAND[Concept] "Knee Adduction moment" OR EXPAND[Concept] "Knee Thrust" OR Varus OR Valgus OR EXPAND[Concept] "Knee Flexion angle" OR Arthralgia OR EXPAND[Concept] "Musculoskeletal pain" OR EXPAND[Concept] "Knee Pain" OR EXPAND[Concept] "Range of Motion" OR EXPAND[Concept] "Knee Function" OR Activity OR Movement OR Locomotion OR EXPAND[Concept] "Self Report" OR Imaging OR EXPAND[Concept] "Three-Dimensional" OR EXPAND[Concept] "3D analysis")

Applied Filters: With Results Adult (18–64) Older Adult (65+), INTERVENTIONAL STUDIES, COMLELTED WITH RESULTS.

Web of Science:

P	TS=((Osteoarthrit* OR "Osteoarthritis, Knee" OR Tibiofemoral* OR "Cartilage, Articular" OR Arthrit* OR Osteochondrit*) NOT "Patellofemoraljoint" OR "AnteriorCruciateLigament" OR ACL OR "TotalkneeArthroplasty" OR TKR OR "Totalknee" OR "RheumatoidArthritis" OR RT OR Hip OR Patella OR Exercise*) OR TS= (Osteoarthrit* near/3 (Knee* Joint*)) OR TI= (Osteoarthrit* near/3 (Medial* OR Lateral* OR Knee*)) OR TS= (Knee near/3 (Degenerat* Chang*)) OR TS= ("Knee OA" OR KOA)
I	TS= (*Gait* OR "Gait Analy?*" OR "Gait Training" OR "ReTraining" OR Walk* OR "Gait* Modification*" OR Biomechanic* OR Mechanic*) OR TI= ("Gait *Chang*" OR Vari* OR Alter*) OR TI= (Ankle* OR "Foot Orthoses" OR Foot* OR Heel*) OR TS= (Train* near/3 Re-gait*) OR TI= (Foot* near/3 Angle*) OR TS= (FAP) OR TI= ("Foot* wear*" OR "Footwear*" OR "Foot*-Wear*" OR Shoes* OR Toe* OR "Toe-In" OR "Toe-out") OR TI= (Length* near/3 (Gait* OR Stride*)) OR TS= (Gait* near/3 (Stance OR Phase* OR Peak*)) OR TI= ((Lateral or Medial) near/3 Wedge* OR Insole* OR Arch) OR TI= (Walk* near/3 Speed* OR Step* near/3 Width) OR TI= (Step* OR SW) OR TI= (Lateral* near/3 (Switch* or Sway*)) OR TI= ("Pelvic Tilt" OR Trunk*) OR TI= (Trunk* near/3 Lean*) OR TI= (Cane* or Brace* or support*)
O	(Weight OR Load* OR Bear* OR "Ground Reaction Force" OR Kinematics OR Kinetics OR "Weight* Shift*" OR "Dynamic* Load*" OR "Contact* Force*" OR "Q-Angle" OR QA) OR TS= ((External adj3 Knee* Adduct* Moment*) or (Knee* adj3 Adduction moment*) or KAM or AKM or EKAM) OR TI= ("Knee Alignment*") OR TI= (Knee near/3 (Thrust* OR Varus* OR Valgus*)) OR TI= (Knee* near/3 (Flex* OR Angle*) OR KFA) OR TI= (Knee* near/3 Rotat*) OR TI= (Arthralgia OR "Knee Pain") OR TI= ("Pain Measur*" OR "Pain Assess*" OR "Pain Scal*" OR VAS OR NPRS) OR TI= (Move* OR "Range of Motion" OR ROM OR AROM) OR TI= (Knee* near/3 (Function* OR Disab* OR Mobil*)) OR TI= (Activ* near/3 (Daily* or Living* or Life*)) OR TS= (ADL or ADLS or ADLY) OR TI= ("Motion Analy?* System*" or "3D Analy\$*" or "Three-dimension*" or "Video record*")

Web of Science:

P	TS=((Osteoarthrit* OR "Osteoarthritis, Knee" OR Tibiofemoral* OR "Cartilage, Articular" OR Arthrit* OR Osteochondrit*) NOT "Patellofemoraljoint" OR "AnteriorCruciateLigament" OR ACL OR "TotalkneeArthroplasty" OR TKR OR "Totalknee" OR "RheumatoidArthritis" OR RT OR Hip OR Patella OR Exercise*) OR TS= (Osteoarthrit* near/3 (Knee* Joint*)) OR TI= (Osteoarthrit* near/3 (Medial* OR Lateral* OR Knee*)) OR TS= (Knee near/3 (Degenerat* Chang*)) OR TS= ("Knee OA" OR KOA)
I	TS= (*Gait* OR "Gait Analy?*" OR "Gait Training" OR "ReTraining" OR Walk* OR "Gait* Modification*" OR Biomechanic* OR Mechanic*) OR TI= ("Gait *Chang*" OR Vari* OR Alter*) OR TI= (Ankle* OR "Foot Orthoses" OR Foot* OR Heel*) OR TS= (Train* near/3 Re-gait*) OR TI= (Foot* near/3 Angle*) OR TS= (FAP) OR TI= ("Foot* wear*" OR "Footwear*" OR "Foot*-Wear*" OR Shoes* OR Toe* OR "Toe-In" OR "Toe-out") OR TI= (Length* near/3 (Gait* OR Stride*)) OR TS= (Gait* near/3 (Stance OR Phase* OR Peak*)) OR TI= ((Lateral or Medial) near/3 Wedge* OR Insole* OR Arch) OR TI= (Walk* near/3 Speed* OR Step* near/3 Width) OR TI= (Step* OR SW) OR TI= (Lateral* near/3 (Switch* or Sway*)) OR TI= ("Pelvic Tilt" OR Trunk*) OR TI= (Trunk* near/3 Lean*) OR TI= (Cane* or Brace* or support*)
O	(Weight OR Load* OR Bear* OR "Ground Reaction Force" OR Kinematics OR Kinetics OR "Weight* Shift*" OR "Dynamic* Load*" OR "Contact* Force*" OR "Q-Angle" OR QA) OR TS= ((External adj3 Knee* Adduct* Moment*) or (Knee* adj3 Adduction moment*) or KAM or AKM or EKAM) OR TI= ("Knee Alignment*") OR TI= (Knee near/3 (Thrust* OR Varus* OR Valgus*)) OR TI= (Knee* near/3 (Flex* OR Angle*) OR KFA) OR TI= (Knee* near/3 Rotat*) OR TI= (Arthralgia OR "Knee Pain") OR TI= ("Pain Measur*" OR "Pain Assess*" OR "Pain Scal*" OR VAS OR NPRS) OR TI= (Move* OR "Range of Motion" OR ROM OR AROM) OR TI= (Knee* near/3 (Function* OR Disab* OR Mobil*)) OR TI= (Activ* near/3 (Daily* or Living* or Life*)) OR TS= (ADL or ADLS or ADLY) OR TI= ("Motion Analy?* System*" or "3D Analy\$*" or "Three-dimension*" or "Video record*")

Appendix 2: GRADE evidence profile

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Gait modification approach	Another gait modification approach, or Combined form or Controls	Relative (95% CI)	Absolute (95% CI)		
KAM- 1st peak (follow-up: range 1 days to 12 months)												
15	randomised trials	serious ^a	not serious	not serious	serious ^b	none	696	526	-	SMD 0.09 SD lower (0.23 lower to 0.05 higher)	⊕⊕○○ Low	CRITICAL
KAM- 2nd peak (follow-up: range 1 days to 6 months)												
5	randomised trials	serious ^a	serious ^{a,b}	serious ^a	very serious ^b	none	273	269	-	SMD 0.08 SD lower (0.22 lower to 0.05 higher)	⊕○○○ Very low	IMPORTANT
KAAI (follow-up: range 1 days to 12 months)												
9	randomised trials	serious ^a	serious ^c	not serious	serious ^b	none	337	316	-	SMD 0.18 SD lower (0.35 lower to 0.08 lower)	⊕○○○ Very low	IMPORTANT
Pain level (follow-up: range 1 days to 6 months; assessed with: scale)												
7	randomised trials	serious ^a	not serious ^d	not serious	serious ^a	none	380	375	-	SMD 0.06 SD lower (0.26 lower to 0.16 higher)	⊕⊕○○ Low	CRITICAL
Knee ROM (follow-up: range 2 weeks to 12 weeks)												
4	randomised trials	serious ^a	serious ^f	not serious	serious ^b	none	75	63	-	SMD 0.93 SD higher (0.57 higher to 1.3 higher)	⊕○○○ Very low	IMPORTANT

Certainty assessment							No of patients		Effect		Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Gait modification approach	Another gait modification approach, or Combined form or Controls	Relative (95% CI)	Absolute (95% CI)		

Gait speed (follow-up: range 1 days to 5 months)

7	randomised trials	serious ^a	serious ^f	not serious	serious ^b	none	312	308	-	SMD 0.01 SD higher (0.24 lower to 0.26 higher)	⊕○○○ Very low	IMPORTANT

Stride length (follow-up: mean 4 weeks; assessed with: meters)

3	randomised trials	serious ^a	serious ^f	not serious	serious ^b	none	51	51	-	SMD 0.97 SD higher (0.6 higher to 1.4 higher)	⊕○○○ Very low	NOT IMPORTANT

Cadence (follow-up: range 2 weeks to 6 weeks)

2	randomised trials	serious ^a	not serious ^b	not serious	serious ^b	none	39	39	-	SMD 0.47 SD higher (0.05 lower to 0.99 higher)	⊕⊕○○ Low	NOT IMPORTANT

Functional Activity Tests (follow-up: mean 11 weeks)

4	randomised trials	serious ^a	not serious	not serious	serious ^b	none	143	130	-	SMD 0.05 SD higher (0.19 lower to 0.3 higher)	⊕⊕○○ Low	NOT IMPORTANT

CI: confidence interval; SMD: standardised mean difference

Explanations

- The forest plot with the 2 RCTs directly answers the question about the effect of lateral wedge insoles on KAM 2nd peak. The additional three RCTs include some studies directly comparing footwear interventions, but others involve different types of interventions (e.g., gait training, knee braces), which may introduce indirectness.
- The majority of the studies had small or insignificant effect sizes with a lack of statistical significance.
- variation among the studies in terms of the size and direction of the effects, as well as the level of statistical significance
- There was moderate heterogeneity
- The CI is not much wider
- The heterogeneity within the main forest plot, consisting of 2 RCTs, is negligible, indicating consistency in those studies.

Appendix 3: Topic guide for KOA participants

Prompts

- General Prompts for KOA Subjects:

1. Knowledge of gait modification with KOA (*Behavioral change wheel: BCW Capability [physical & psychological]*)

- 1.2 During your rehabilitation program, have you ever heard of the use of gait modification? Do you know anyone who has been encouraged to use it in their rehabilitation? Has anyone mentioned it to you?
- 1.3 Have you ever been encouraged to use gait modification techniques (e.g., toe-in and out, trunk lean, shoes insoles, knee brace or sleeves and cane support)? Do you know anyone who has used this type of approach in their rehabilitation (or has mentioned using it)?
- 1.4 Could you tell me more about gait modification?
 - 1.4.1 What does gait modification mean to you? or might mean to you?
 - 1.4.2 What exactly modified gait do you perform? or would perform?
 - 1.4.3 How would gait modifying technique help you? In which way?
- 1.5 How would you feel if your therapist encouraged you to change your gait during your exercise sessions in clinic or at home during your rehabilitation program?
 - 1.5.1 Would you prefer to do modifying gait at home before coming to the exercise session? When would you use it? Might want to use it?
 - 1.5.2 Would you prefer to do modifying gait before, after the session or during the exercise sessions in clinic?

2. Prospect (*BCW motivation [automatic and reflective]*)

2.1. Enable acceptability and implementation

- 2.1.1 How would you encourage yourself to use gait modification more frequently during your KOA rehabilitation program?
- 2.1.2 During walking, whether you are trying to alter your gait by (toe-out or in, trunk lean, decreased footstep or step width), or using comfort shoes, insoles, a cane/poles, or wearing knee sleeves or braces. In your opinion, which is the most suitable and comfortable one for you?
- 2.1.3 Which one helping you to perform a modified gait pattern? Is it watching videos or yourself in the mirror while performing modified gait, listening to a therapist's, or following oral instructions? (Feedback)
- 2.1.4 In your opinion, would modify gait therapy at rehabilitation clinics be most useful? What about outside of rehabilitation clinics (at home)?
- 2.1.5 When would it be more helpful or acceptable to perform the modified gait? Is it before, during, or after the physiotherapy session?
- 2.1.6 Do you prefer to have pre-training course before applying gait modification approach?

Appendix 4: Topic guid for the therapists' participation

Prompts

KOA patients often participate in different rehabilitation programmes to improve their symptoms, activities of daily living (ADLs), and quality of life (QOLs); however, incorporating a gait modification technique into their rehabilitation plans can contribute to improved progress.

General Prompts for KOA Therapists:

1- Knowledge of gait modification with KOA (*Behavioral change wheel: BCW Capability [physical & psychological]*)

1.1 *Do you know what gait modification is? Do you have any knowledge of what it is? Are you familiar with anyone who has used it?*

1.1.1 *Can you please elaborate further if yes? Specifically, how? Could you please explain what gait modification means to you in more detail?*

1.2 *Were you able to use it? Do you plan to use it?*

1.3 *Did you ever modify the gait of KOA individuals? In what way do you prefer to apply gait modification to KOA patients (for example, as an alternative to a treatment plan, combined with a treatment plan, or an addition to a treatment plan)? Could you explain why?*

1.4 *Can you explain how you would use it in general? What other considerations would you have while using it? (For example, timing of apply, duration and where?)*

1.4.1 *Is your method of gait modification based upon a theory, model, or protocol that you are familiar with?*

1.4.2 *How did you become aware of gait modification? Have you ever encountered articles discussing gait modification, attending workshops or conferences? Could you share any examples from your own experience?*

2- Prospect (*BCW motivation [automatic and reflective]*)

2.1 Enable implementation

2.1.1 *What inspired you to begin practising gait modification?*

2.1.1.1 *How would you be motivated to utilise it more frequently? Do you think attending workshops or receiving additional training would be advantageous?*

2.1.2 *Do you employ gait modification at the rehabilitation clinic or at the patient's residence? According to the severity of the KOA patients, where would be the most appropriate location for this? Could you explain why?*

2.1.3 *Can places provide an example of what type of gait modification you prefer with KOA patients?*

2.1.4 *Your reasons for using it?*

2.1.5 *When would you use it?*

Appendix 5: Ethical approval from University of Nottingham

	University of Nottingham UK | CHINA | MALAYSIA	Faculty of Medicine & Health Sciences Research Ethics Committee Faculty Hub Room E41, E Floor, Medical School Queen's Medical Centre Campus Nottingham University Hospitals Nottingham, NG7 2UH Email: FMHS-ResearchEthics@nottingham.ac.uk

28 February 2022

Abdullah Al Assiri
PhD Student, Rehabilitation and Ageing
Injury, Recovery & Inflammation Sciences
School of Medicine
B109, Medical School
QMC Campus, Nottingham University Hospitals
Nottingham, NG7 2UH

Dear Mr Al Assiri

Ethics Reference No: FMHS 448-0122 – please always quote	
Study Title: What are patient's and physiotherapists' perception and acceptability regarding applying gait modification as part of treatment of knee osteoarthritis in Saudi Arabia? - A Mixed methods study approach.	
Chief Investigator/Supervisor: Pip Logan, Professor of Rehabilitation Research and Occupational Therapist, Injury, Recovery & Inflammation, School of Medicine	
Lead Investigators/student: Abdullah Al Assiri, PhD student, School of Medicine	
Other Key investigators: Ana Valdes, Professor of Molecular and Genetic Epidemiology, Rheumatology, Benjamin Smith, Assistant Professor, Rehabilitation & Ageing, Injury, Recovery & Inflammation, School of Medicine	
Proposed Start Date: 10/01/2022	Proposed End Date: 30/09/2022

Thank you for submitting the above application which was considered at a sub-committee meeting on 11/02/2022. The following documents were received:

- FMHS REC Application form and supporting documents version 1.0: 27/01/2022

These have been reviewed and are satisfactory and the project is given a favourable ethics opinion.

Please submit copies of letters of approval from the King Faisal Specialist and Research Centre Hospital IRB/REC when these are available so they can be noted to file. This must be completed before recruitment of human participants commences.

Please note that this favourable ethics opinion has been given on the understanding that:

1. All appropriate ethical requirements and regulatory permissions are respected and followed in accordance with all local laws of the country in which the study is being conducted and those required by the host organisation/s involved.
2. The research project will adhere to [ICH E6 \(R2\)](#) Good Clinical Practice (GCP) which is the international ethical, scientific, and practical standard to which all clinical research is conducted.
3. The protocol agreed is followed and the Committee is informed of any changes using a notice of amendment form (please request a form).
4. The Chair is informed of any serious or unexpected event.
5. An End of Project Progress Report is completed and returned when the study has finished (Please request a form).

Yours sincerely



Dr John Williams, Associate Professor in Anaesthesia and Pain Medicine
Chair, Faculty of Medicine & Health Sciences Research Ethics Committee

Appendix 6: Ethical Approval from Aseer Central Hospital

Kingdom of Saudi Arabia Ministry of Health Directorate health Affairs-Aseer Region		المملكة العربية السعودية وزارة الصحة المديرية العامة للشؤون الصحية بـبصر	
اللجنة المحلية لأخلاقيات البحوث Asser Institutional Review Board			
National Registration Number with NCBE-KACST, KSA: (H-06-B-091)			
<u>Approval letter</u>			
Date: 5/16/2022 IRB Log No: REC -18-05-2022 Category of Approval: Full Board			
Dear, Mr. Abdullah Al Assiri			
The Aseer IRB is pleased to inform you that your study mentioned below has been reviewed and approved. This letter gives you an ethical clearance to implement your study according to the approved documents and you still need to obtain administrative approval from the site/s where the study will be conducted.			
Protocol Title	What are patient's and physiotherapist perception and acceptability regarding applying gait modification as part of treatment of knee osteoarthritis in Saudi Arabia? A mixed methods study approach		
PI Name	Mr. Abdullah Al Assiri	PI ID	1029120829
PI Affiliation	MOH	PI E-mail	assiri.1991@gmail.com
IRB Approved Documents (attached)	☒ Research proposal ☒ Consent form ☒ Data collection tool ☐ Others, _____		
Co-Investigators	#	Name	ID
	1-	Pip Logan	
Study Site and Sample	#	Site	Sample size
	1-	Rehabilitation centre, Abha	45
Total sample = 45			
Approval Conditions:			
1. The approval is valid for one year from the date of this letter.			
IRB E-mail: Rec-aseer@moh.gov.sa			

Appendix 7 Participants information sheets:

 University of Nottingham UK CHINA MALAYSIA Faculty of Medicine & Health Sciences School of Medicine 109 Room, B Floor, Queen Medical Centre Derby Rd, Lenton, Nottingham NG7 2UH Supervisors: Professor Pip Logan pip.logan@nottingham.ac.uk Professor Ana Valdes Ana.Valdes@nottingham.ac.uk Dr. Benjamin Smith msabs5@exmail.nottingham.ac.uk Lead researcher: Abdullah Al Assiri PhD student in Aging & Rehabilitation, University of Nottingham Email: mzxaa19@nottingham.ac.uk Study Title: What are the possibilities and acceptability of patients and physiotherapists' perception regards applying lateral wedge insole as part of the treatment of knee osteoarthritis in Saudi Arabia? A Mixed methods study approach. PARTICIPANT INFORMATION SHEET Research Ethics Reference: [FMHS 448-0122] Version 1.0 Date: 30/01/2022 We would like to invite you to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. One of our team will go through the information sheet with you and answer any questions you have. Please take time to read this carefully and discuss it with others if you wish. Ask us anything that is not clear. What is the purpose of the research? The main study's aim is to understand the possibilities and acceptability for the implementation of gait modification approach with knee osteoarthritic patients in Saudi Arabia, which are necessary for designing various techniques in the physiotherapy department to improve patient outcomes and rehabilitation programs. Why have I been invited to take part? We invite you to participate in the interviews/ experimental trail since you have knee osteoarthritis (KOA) and can share your KOA experience with possibilities and acceptability to use gait modification as part of a physiotherapy program. Our goal to invite 10 to 15 KOA subjects like you to participate with this study. Do I have to take part? No. It is up to you to decide if you want to take part in this research. We will describe the study and go through this information sheet with you to answer any questions you may have. If you agree to participate, we will ask you to sign a consent form and will give you a copy to <td> keep. However, you would still be free to withdraw from the study at any time, without giving a reason and without any negative consequences, by letting the research know. 1. What will happen to me if I take part? If you accept to participate in the study, you will be contacted by phone. Then we will schedule a convenient time, and you will receive a confirmation message. The interview should last between 30 and 45 minutes and will take place in a confidential, quiet area inside your clinical setting. The interview will include questions about KOA knowledge, the importance of gait modification engagement and its impact on the KOA rehabilitation process and identifying possibilities and implications of practising gait modification to improve KOA subject engagement with the gait modification approach. If not impossible to interview at the hospital according to the COVID19 circumstance, you will be called by phone to organise the appointment, and we will agree to a videoconferencing program (e.g. MS teams, skype or zoom) to perform the interview. If you are still interested in participating, you will be required to sign a permission form. 2. Are there any risks in taking part? We consider there will be no risks in participating in this study. The interviews will be conducted privately, and we do not think there are any risks associated with disclosing the personal information of the involved participants. As for the group discussion between clinicians, the researcher would inform participants of the need to respect others' opinions or reveal what was discussed in the focus group to keep the study effective. 3. Are there any benefits in taking part? Taking part in this study will have no direct advantage for you. However, it might improve the existing practise of KOA rehabilitation in Saudi Arabia by giving additional techniques (gait modification) to increase participation in the rehabilitation process. 4. Will my time/travel costs be reimbursed? Participants will not receive an inconvenience allowance to participate in the study. 5. What happens to the data provided? All your personal information will be treated with strict confidentiality and following ethical and legal practices regulations. If you participate in the study, the researchers at the University of Nottingham will access certain aspects of the data you provide. To ensure that the study is being carried out appropriately, authorised individuals may also inspect the study. To the best of our ability, we will ensure that all study subjects are held to the highest standards of confidentiality. All information gathered throughout the research will be held in a secured office and on a password-protected database to protect your privacy. Your name and address will be removed (anonymised) from any information that leaves the institution, and a code number will be assigned to prevent you from being identified. For up to 6 to 12 months after the end of the study, your personal data (address and phone number) will be maintained to notify you about the findings and any follow-up studies (unless you advise us that you do not wish to be contacted). After this period, your personal information will be safely discarded. Research data will be archived for 7 years at a minimum. Page 2 Short Title/Acronym, Participant Information Sheet, version X.X: DD.MM.YYYY </td>	keep. However, you would still be free to withdraw from the study at any time, without giving a reason and without any negative consequences, by letting the research know. 1. What will happen to me if I take part? If you accept to participate in the study, you will be contacted by phone. Then we will schedule a convenient time, and you will receive a confirmation message. The interview should last between 30 and 45 minutes and will take place in a confidential, quiet area inside your clinical setting. The interview will include questions about KOA knowledge, the importance of gait modification engagement and its impact on the KOA rehabilitation process and identifying possibilities and implications of practising gait modification to improve KOA subject engagement with the gait modification approach. If not impossible to interview at the hospital according to the COVID19 circumstance, you will be called by phone to organise the appointment, and we will agree to a videoconferencing program (e.g. MS teams, skype or zoom) to perform the interview. If you are still interested in participating, you will be required to sign a permission form. 2. Are there any risks in taking part? We consider there will be no risks in participating in this study. The interviews will be conducted privately, and we do not think there are any risks associated with disclosing the personal information of the involved participants. As for the group discussion between clinicians, the researcher would inform participants of the need to respect others' opinions or reveal what was discussed in the focus group to keep the study effective. 3. Are there any benefits in taking part? Taking part in this study will have no direct advantage for you. However, it might improve the existing practise of KOA rehabilitation in Saudi Arabia by giving additional techniques (gait modification) to increase participation in the rehabilitation process. 4. Will my time/travel costs be reimbursed? Participants will not receive an inconvenience allowance to participate in the study. 5. What happens to the data provided? All your personal information will be treated with strict confidentiality and following ethical and legal practices regulations. If you participate in the study, the researchers at the University of Nottingham will access certain aspects of the data you provide. To ensure that the study is being carried out appropriately, authorised individuals may also inspect the study. To the best of our ability, we will ensure that all study subjects are held to the highest standards of confidentiality. All information gathered throughout the research will be held in a secured office and on a password-protected database to protect your privacy. Your name and address will be removed (anonymised) from any information that leaves the institution, and a code number will be assigned to prevent you from being identified. For up to 6 to 12 months after the end of the study, your personal data (address and phone number) will be maintained to notify you about the findings and any follow-up studies (unless you advise us that you do not wish to be contacted). After this period, your personal information will be safely discarded. Research data will be archived for 7 years at a minimum. Page 2 Short Title/Acronym, Participant Information Sheet, version X.X: DD.MM.YYYY

Only members of the study team will have access to your personal information during the study period, as everyone engaged will make every effort to keep your information confidential.

In addition, we would like to ask for your permission to preserve and utilise your data for prospective future study during and after the 7 years. This is entirely voluntary (please indicate you agree to this on the consent form).

6. What will happen if I don't want to carry on with the study?

You are free to leave at any time without giving any explanation, and your legal rights will not be affected by your participation in this project. However, even if you drop out of the research, the data you've already gathered can still be included in the project's analysis.

7. Who will know that I am taking part in this research?

Data will be used for research purposes only and in accordance with the General Data Protection Regulations. Any audio digital recordings and electronic data will be anonymised with a code as detailed above. Electronic storage devices will be encrypted while transferring and saving of all sensitive data generated in the course of the research. All such data are kept on password-protected databases sitting on a restricted access computer system and any paper information (such as your consent form, contact details and any research questionnaires) would be stored safely in lockable cabinets in a swipe-card secured building and would only be accessed by the research team.

Under UK Data Protection laws the University is the Data Controller (legally responsible for the data security) and the Chief Investigator of this study (named above) is the Data Custodian (manages access to the data). This means we are responsible for looking after your information and using it properly. Your rights to access, change or move your information are limited as we need to manage your information in specific ways to comply with certain laws and for the research to be reliable and accurate.

You can find out more about how we use your information and to read our privacy notice at: <https://www.nottingham.ac.uk/utilities/privacy.aspx/>

Designated individuals of the University of Nottingham may be given access to data for monitoring and/or audit of the study to ensure we are complying with guidelines. With your consent, we will keep your personal information on a secure database to contact you for future studies. [please indicate you agree to this on the consent form]

Anything you say during an interview will be kept confidential, unless you reveal something of concern that may put yourself or anyone else at risk. It will then be necessary to report to the appropriate persons.

8. What will happen to the results of the research?

These findings will be used to design another research, which will also be published as a dissertation and submitted to the University of Nottingham for the degree of Doctor of Philosophy in Rehabilitation and ageing Research. Additionally, the study's findings will be published to ensure that other healthcare professionals' benefit from the research. It should be noted that you would not be identifiable in any such analysis or publishing.

9. Who has reviewed this study?

All research at the University of Nottingham is approved by independent experts, known as the Research Ethics Committee, to protect your interest. The Faculty of Medicine and Health Sciences (FMHS) Research Ethics Committee evaluated and approved this study.

10. Who is organising and funding the research?

This study is being organised by Nottingham University, while funding is provided by King Khalid University (KKU).

11. What if there is a problem?

If you have any questions or concerns regarding this project, please contact the Chief Investigator, Mr Abdullah Al Assiri, at mzxaa19@nottingham.ac.uk, or the primary supervisor, Professor Pip Logan, at pip.logan@nottingham.ac.uk. The study team's complete contact information is provided at the conclusion of this information sheet. If you are still dissatisfied and wish to make a formal complaint, please write to the FMHS Research Ethics Committee Administrator, c/o The University of Nottingham, School of Medicine Education Centre, B Floor, Medical School, Queen's Medical Centre Campus, Nottingham University Hospitals, Nottingham, NG7 2UH. Contact Louise Sabir at louise.sabir@nottingham.ac.uk.

12. Contact Details:

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

Abdullah Al Assiri
Injury, Recovery & Inflammation Sciences
109, B Floor, Queen medical Centre Derby Rd, Lenton.
Nottingham NG7 2UH
Tel: 00966554900314
Email: mzxaa19@nottingham.ac.uk.

Appendix 8 Case report forms:

 The University of Nottingham UNITED KINGDOM • CHINA • MALAYSIA  KING KHALID UNIVERSITY CASE REPORT FORM The possibilities and acceptability of applying gait modification to the treatment of knee osteoarthritis in Saudi Arabia based on the perceptions of patients and physiotherapists. A Mixed-methods study approach Ethics Reference: FMHS 448-0122 Study Sponsor: King Khalid University & University of Nottingham Study Site King Faisal Specialist Hospital & Research Centre – Jeddah, Saudi Arabia Principal Investigator Abdullah Al Assiri <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">Participant Initials</td> <td style="width: 10%;"></td> <td style="width: 10%;"></td> <td style="width: 10%;"></td> <td style="width: 10%;"></td> <td style="width: 10%;"></td> </tr> <tr> <td>Participant ID</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table> Please check only one box ☐ Baseline assessment ☐ 4 Weeks assessment ☐ 6 Weeks assessment <i>It is my belief that the information provided in this case record form is accurate and complete. My confirmation is that the study was conducted according to the protocol and any protocol amendments, and that written informed consent was obtained before the study began.</i> Investigator's Signature: Date: / / 2022.	Participant Initials						Participant ID						Participant ID Date: / / 2022 INFORMED CONSENT: Please note: any study-specific procedures must be preceded by written informed consent. Has the individual given written informed consent in a free and voluntary manner? Yes ☐ No ☐ Date consent form signed: ____ / ____ / ____ Study master file contains original consent, participant receives a copy. Yes ☐ No ☐ Assessment: Assessor Name/ Date: / / 2022 • Demographic and Background Information Date of Birth: ____ / ____ / ____ Age: ____ Gender: Male ☐ Female ☐ Affected Knee: Right ☐ Left ☐ Both ☐ Height - (cms) Weight - (kgs) BMI- (kg/m²) • Relevant medical history: Primary knee osteoarthritis diagnosis: Yes ☐ No ☐ Time since diagnosis MM/YYYY - ____ / ____ / ____ Have you had a radiology finding? Yes ☐ No ☐ In the case of yes, is it: X-ray ☐ CT ☐ Ultrasound ☐ MRI ☐ Most recent radiology date MM/YYYY - ____ / ____ / ____ • Severity of knee osteoarthritis: (Kellgren–Lawrence KL OA Grading System) 0 (normal) ☐ 1 (Doubtful) ☐ 2 (Minimal) ☐ 3 (Moderate) ☐ 4 (Severe) ☐ • Current Mobility: <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Walk Distance</th> <th style="text-align: center;">Stairs</th> <th style="text-align: center;">Assistive device</th> </tr> </thead> <tbody> <tr> <td>☐ Unlimited</td> <td>☐ Normal (Reciprocal way)</td> <td>☐ None</td> </tr> <tr> <td>☐ 500m-1km</td> <td>☐ Step by step</td> <td>☐ Stick/Cane outdoors</td> </tr> <tr> <td>☐ 100-500m</td> <td>☐ Using rails, down</td> <td>☐ Stick/Cane always</td> </tr> <tr> <td>☐ <100m</td> <td>☐ Using rails, up & down</td> <td>☐ 2 sticks/canes</td> </tr> <tr> <td>☐ Housebound</td> <td>☐ Unable down or up</td> <td>☐ 2 Crutches</td> </tr> <tr> <td>☐ Unable</td> <td>☐ Unable</td> <td>☐ Walker frame</td> </tr> </tbody> </table>	Walk Distance	Stairs	Assistive device	☐ Unlimited	☐ Normal (Reciprocal way)	☐ None	☐ 500m-1km	☐ Step by step	☐ Stick/Cane outdoors	☐ 100-500m	☐ Using rails, down	☐ Stick/Cane always	☐ <100m	☐ Using rails, up & down	☐ 2 sticks/canes	☐ Housebound	☐ Unable down or up	☐ 2 Crutches	☐ Unable	☐ Unable	☐ Walker frame
Participant Initials																																		
Participant ID																																		
Walk Distance	Stairs	Assistive device																																
☐ Unlimited	☐ Normal (Reciprocal way)	☐ None																																
☐ 500m-1km	☐ Step by step	☐ Stick/Cane outdoors																																
☐ 100-500m	☐ Using rails, down	☐ Stick/Cane always																																
☐ <100m	☐ Using rails, up & down	☐ 2 sticks/canes																																
☐ Housebound	☐ Unable down or up	☐ 2 Crutches																																
☐ Unable	☐ Unable	☐ Walker frame																																

1

2

Appendix 9 Participants Consent form

 University of Nottingham UK CHINA MALAYSIA Faculty of Medicine & Health Sciences School of Medicine 109 Room, B Floor, Queen Medical Centre Derby Rd, Lenton, Nottingham NG7 2UH Participants Consent Form Version 1.0: 10.10.2022 Title of Study: The possibilities and acceptability of applying lateral wedge insole to the treatment of knee osteoarthritis in Saudi Arabia based on the perceptions of patients and physiotherapists. A Mixed-methods study approach. REC ref: (FMHS 448-0122) Name of Researchers: Abdullah Al Assiri, PhD student in the Rehabilitation and Ageing at the University of Nottingham. Email: mzxaa19@nottingham.ac.uk Supervisors: Professor Pip Logan pip.logan@nottingham.ac.uk Professor Ana Valdes Ana.Valdes@nottingham.ac.uk Dr. Benjamin Smith msabs5@exmail.nottingham.ac.uk Name of Participant: _____ Please initial box 1. I confirm that I have read and understand the information sheet version number 1 dated 13.12.2021 for the above study which is attached and have had the opportunity to ask questions. ☐ 2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without disadvantage. ☐ 3. I understand that relevant sections of my data collected in the study may be looked at by the research group and by other responsible individuals for monitoring and audit purposes. I give permission for these individuals to have access to these records and to collect, store, analyse and publish information obtained from my participation in this study. I understand that my personal details will be kept confidential. ☐ 4. I understand that the interview, focus group discussion and survey sheet will be audio recorded using a digital device and that anonymous direct quotes from the interview and discussion may be used in the study reports. ☐ 5. I understand that information about me recorded during the study will be made anonymous before it is stored. It will be uploaded into a secure database on a computer kept in a secure place. Data will be kept for 7 years after the study has ended and then deleted. ☐ 6. I agree that my anonymous research data will be stored and used to support other research in the future and shared with other researchers including those working outside the University. ☐ 7. I understand that what I say during the interview or focus group discussion will be kept confidential unless I reveal something of concern that may put myself or someone else at any risk. It will then be necessary to report this to the appropriate persons. ☐ 8. I understand that the information discussed in the Focus Group Discussion may be sensitive and is confidential. I agree to respect other participant's privacy and will not disclose what others have said in the Focus group. ☐ 9. I agree to take part in the above study. ☐ 2 copies: 1 for participant, 1 for the project notes.	 University of Nottingham UK CHINA MALAYSIA Faculty of Medicine & Health Sciences School of Medicine 109 Room, B Floor, Queen Medical Centre Derby Rd, Lenton, Nottingham NG7 2UH <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; border-bottom: 1px solid black;">Name of Participant</td> <td style="width: 33%; border-bottom: 1px solid black;">Date</td> <td style="width: 33%; border-bottom: 1px solid black;">Signature</td> </tr> <tr> <td style="border-bottom: 1px solid black;">Name of Person taking consent</td> <td style="border-bottom: 1px solid black;">Date</td> <td style="border-bottom: 1px solid black;">Signature</td> </tr> </table> 2 copies: 1 for participant, 1 for the project notes.	Name of Participant	Date	Signature	Name of Person taking consent	Date	Signature
Name of Participant	Date	Signature					
Name of Person taking consent	Date	Signature					

Appendix 10 Withdrawal study form:

• **OFF Study Form:**

Off Study Date: ____ / ____ / ____
(DD/MM/YYYY)

Last Assessment Date: ____ / ____ / ____

Number of intervention sessions/days: ____

Select one of the following if a participant has withdrawn before completing the study (early withdrawal):

☐ Participant withdrawn – by Subject PRIOR to enrollment**

☐ Participant withdrawn – by Subject AFTER enrollment**

☐ Participant withdrawn – by PI PRIOR to enrollment**

☐ Participant withdrawn – by PI AFTER enrollment**

☐ Other**

Specify the reason(s) for withdrawal (*mark only the primary reason. Other responses must be explained*).

☐ Participants lost to follow-up.....

☐ Participants refused follow-up / Non-compliant.....

☐ Due to adverse events or complications.....

☐ Medical contraindication.....

☐ Other**.....

**An additional explanation is needed:

.....

.....

.....

.....

Completed by:..... Signature:.....

Re-gait acceptability study case report form

23

Appendix 11 Numeric Rating Pain Scale (NRPS) form:

Numeric Rating Pain Scale (NRPS)

[In the last 24 hours], pain at rest and during movement:

Pain location

At Rest

0

1

2

3

4

5

6

7

8

9

10

No pain

Moderate pain

Worst possible pain

During Movement

0

1

2

3

4

5

6

7

8

9

10

No pain

Moderate pain

Worst possible pain

Has a NRPS test been performed?

Yes ☐

No ☐ (please give reason/s):

Completed by:

Signature:

Re-gait acceptability study case report form

13

Appendix 12 Western Ontario and McMaster Universities Osteoarthritis (WOMAC) Index

Participant ID: Date: / /2022

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Osteoarthritis Index

Instructions: There will be questions about your knee pain in sections A, B, and C. You will need to select each response. In cases where you are unsure how to answer a question, please give your best answer.

Section A: PAIN
(Think about the pain you felt during the last 48 hours caused by the arthritis in your knee).
Select the number that best describes your pain:

Question: How much pain have you had:

	None	Mild	Moderate	Severe	Extreme
1- When walking in a flat surface?	0	1	2	3	4
2- When going up or down stairs?	0	1	2	3	4
3- At night while in bed? (Pain that disturbs your sleep)	0	1	2	3	4
4- While sitting or lying down?	0	1	2	3	4
5- While standing?	0	1	2	3	4
Total Pain Score (Max 20)					

Section B: STIFFNESS
(Think about the stiffness (not pain) you felt during the last 48 hours caused by the arthritis in your knee. Stiffness is a sensation of decreased ease in moving your joint).
Select the number that best describes your stiffness:

	None	Mild	Moderate	Severe	Extreme
6- How severe has your stiffness been after you first woke up in the morning?	0	1	2	3	4
7- How severe has your stiffness been after sitting or lying down or while resting later in the day?	0	1	2	3	4
Total Stiffness Score (Max 8)					

14

Re-gait acceptability study case report form

Participant ID: Date: / /2022

Section C: DIFFICULTY PERFORMING DAILY ACTIVITIES
(Think about the difficulty you had in doing the following daily physical activities during the last 48 hours caused by the arthritis in your knee. By this we mean your ability to move around and take care of yourself).
Select the number that best describes your difficulty:

Question: What degree of difficulty do you have?

	None	Mild	Moderate	Severe	Extreme
8- When going down the stairs?	0	1	2	3	4
9- When going up the stairs?	0	1	2	3	4
10- When getting up from a sitting position?	0	1	2	3	4
11- While standing?	0	1	2	3	4
12- When bending to the floor?	0	1	2	3	4
13- When walking on a flat surface?	0	1	2	3	4
14- Getting in or out of a car, or getting on or off a bus?	0	1	2	3	4
15- While going shopping?	0	1	2	3	4
16- When putting on your socks or panty hose or stockings?	0	1	2	3	4
17- When getting out of bed?	0	1	2	3	4
18- When taking off your socks or panty hose or stockings?	0	1	2	3	4
19- When lying in bed?	0	1	2	3	4
20- When getting in or out of the bathtub?	0	1	2	3	4
21- While sitting?	0	1	2	3	4
22- When getting on or off the toilet?	0	1	2	3	4
23- While doing heavy household chores?	0	1	2	3	4
24- While doing light household chores?	0	1	2	3	4
Total Difficulty Score (Max 68)					
Total WOMAC Score (Max 96)					

Scoring

- All items on each scale are classified as none, mild, moderate, severe, or extreme. The ordinal scale ranges from 0 to 4.
- In each subscale, the scores are added up, with ranges of pain 0-20, stiffness 0-8, and physical function 0-68. Summarizing the items for all three subscales creates the WOMAC score (scale of 0-96).
- Interpretation of Scores: In the WOMAC, higher scores indicate greater pain, stiffness, and functional limitations.

Source: Bellamy N. WOMAC Osteoarthritis Index User Guide. Version V. Brisbane, Australia 2002.

Has a WOMAC test been performed? Yes ☐ No ☐ (please give reason/s):
.....

Completed by: Signature:

15

Re-gait acceptability study case report form

Appendix 13 Likert Scale forms for both KOA and therapists' participants:

Survey form for the knee osteoarthritis participants	▲ Survey form for the physiotherapists participants										
Name: _____ Date: ____/____/____	Name: _____ Date: ____/____/____										
INSTRUCTIONS:											
This survey asks for your opinion regarding how the re-gait training program has impacted your knowledge and skills. By recording this information, we will be able to monitor your attitudes towards the re-gait training intervention and how you will be able to accept and motivate this type of program. This survey consists of 8 points and will take about 10 minutes. Please check the appropriate box for each question. If you are unsure about how to answer a question, please provide your best judgment. I would like to get your permission to collect this form after you answered. I will present this study's findings in a report that will be submitted for academic publication. Although your participation in the study will remain confidential, your identity will not be included in any published study documents or materials.											
Satisfaction Questions: What is your satisfaction level with the knee symptoms improvement in the following areas?											
1- For the relief of knee pain: <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
2- Enhance your ability to perform daily activities (walking, sitting, standing, and climbing). <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
3- Your easy application of re-gait interventions <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
4- For your commitment to the re-gait application throughout the day <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
5- For clarification of re-gait application during the session <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
6- The time allocated for application sessions <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
7- Have any side effects been experienced during or after the re-gait process? <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
8- In general, have your knee symptoms improved due to applying the gait modification approach? <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
INSTRUCTIONS: This survey asks for your opinion regarding how the re-gait training program has impacted your knowledge and skills. By recording this information, we will be able to monitor your attitudes towards the re-gait training intervention and how you will be able to implement and deliver this type of intervention to the targeted subjects. This survey consists of 5 points and will take about 10 minutes. Please check the appropriate box for each question. If you are unsure about how to answer a question, please provide your best judgment. I would like to get your permission to collect this form after you answered the related points. I will present this study's findings in a report that will be submitted for academic publication. Although your participation in the study will remain confidential, your identity will not be included in any published study documents or materials.											
Satisfaction Questions: What is your satisfaction level with the gait modification intervention in the following areas?											
1- The LWI enhanced my knowledge of gait modification in the context of KOA <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
2- The LWI has increased my practical skills in applying gait modification techniques <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
3- The LWI is easy to understand and apply assistive gait modification in practice <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Not at all satisfied</td> <td style="text-align: center;">Somewhat satisfied</td> <td style="text-align: center;">Satisfied</td> <td style="text-align: center;">Very satisfied</td> <td style="text-align: center;">Extremely satisfied</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied	☐	☐	☐	☐	☐
Not at all satisfied	Somewhat satisfied	Satisfied	Very satisfied	Extremely satisfied							
☐	☐	☐	☐	☐							
Implementation Questions: Introduce gait modification as a component of the KOA treatment plan by answering the following questions.											
1- I agree that specific requirements must be met to implement the LWI in the KOA treatment plan effectively. (lab gait, orthosis, tools, etc.) <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Strongly disagree</td> <td style="text-align: center;">Disagree</td> <td style="text-align: center;">Neither agree nor disagree</td> <td style="text-align: center;">Agree</td> <td style="text-align: center;">Strongly agree</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	☐	☐	☐	☐	☐
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree							
☐	☐	☐	☐	☐							
2- I agree that clear guidelines are necessary to properly apply the LWI in the KOA treatment plan. <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Strongly disagree</td> <td style="text-align: center;">Disagree</td> <td style="text-align: center;">Neither agree nor disagree</td> <td style="text-align: center;">Agree</td> <td style="text-align: center;">Strongly agree</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	☐	☐	☐	☐	☐
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree							
☐	☐	☐	☐	☐							
3- I support the inclusion of the LWI as a part of the overall KOA treatment plan. <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Strongly disagree</td> <td style="text-align: center;">Disagree</td> <td style="text-align: center;">Neither agree nor disagree</td> <td style="text-align: center;">Agree</td> <td style="text-align: center;">Strongly agree</td> </tr> <tr> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> <td style="text-align: center;">☐</td> </tr> </table>		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	☐	☐	☐	☐	☐
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree							
☐	☐	☐	☐	☐							

Appendix 14 Patients' Daily Record form:

[illegible]

Appendix 15 KOA patient's follow-up sheet:

Participant ID Date: / /2022

• **Assigned Intervention:**

Knee side: Right ☒ Left ☒

Intervention/ Insole conducting date: 24 / 10 /2022.

Insole size: 42

Describe the insole's usage to participants: Yes ☒ No ☐ (please give reason/s):

Participant is willing to be contacted for an assessment either by phone or in person:

Yes ☒ No ☐ (please give reason/s):

Has the participant been advised to wear the insole for at least 7 hours every day when walking?

Yes ☒ No ☐

• The following table summarises insole applications:

	Week	Weekly follow-up	Hours per day
1 st	23 / 10 /2022	☒ 1 st ☐ 2 nd ☐ 3 rd	8 hours/day 8
2 nd	30 / 10 /2022	☒ 1 st ☒ 2 nd ☐ 3 rd	hours/day —
3 rd	6 / 11 /2022	☒ 1 st ☒ 2 nd ☐ 3 rd	6 hours/day 6,6
4 th	13 / 11 /2022	☒ 1 st ☒ 2 nd ☐ 3 rd	6 hours/day 6
5 th	20 / 11 /2022	☒ 1 st ☒ 2 nd ☐ 3 rd	hours/day
6 th	27 / 11 /2022	☒ 1 st ☒ 2 nd ☐ 3 rd	4 hours/day 4,4
Total weeks & days		 weeks. days	

• Note: $12 + 12 = \frac{24}{4} = 6 \text{ hours/day}$

Completed by: Qauri Khan Signature: Qauri Khan

Appendix 16 Arabic version of Western Ontario and McMaster Universities Osteoarthritis (WOAMC) Index:

Participant ID: Date: / / 2022

**مؤشر احتكاك المفصل في جامعة ويسترن أونتاريو ومكاملستر
(رومانك) مؤشر خشونة الركبة**

التعليمات: ستكون هناك أسئلة حول ألم الركبة في الأقسام (أ) و (ب) و (ج). ستحتاج إلى تحديد إجابة لكل سؤال. في الحالات التي تكون فيها غير متأكد من كيفية الإجابة على سؤال ، يرجى تقديم أفضل إجابة ممكنة.

القسم (أ): الألم

انقر في الألم الذي شعرت به خلال الـ 48 ساعة الماضية الناجم عن احتكاك مفصل الركبة

حدد الرقم الذي يصف ألمك بشكل أفضل:

لا شيء	قليلة	متوسطة	شديدة	شديدة جداً	السؤال: ماهي شدة الألم الذي عانيت منه؟
0	1	2	3	4	1- عندما تمشي على أرض مستوية؟
0	1	2	3	4	2- عند صعود أو نزول الدرج؟
0	1	2	3	4	3- في الليل أثناء وجوئك على السرير؟ (الألم الذي يزعج نومك)
0	1	2	3	4	4- عند الجلوس والاستلقاء؟
0	1	2	3	4	5- عند الوقوف؟

مجموع نقاط الألم (بعد أقصى 20)

القسم (ب): التيبس أو تصلب المفصل

انقر في التصلب وليس الألم الذي شعرت به خلال الـ 48 ساعة الماضية الناجم عن احتكاك مفصل الركبة. التصلب هو إحساس بالخففت السهولة في تحريك المفصل

حدد الرقم الذي يصف صلابة المفصل لديك بشكل أفضل:

ماهي شدة تيبس أو تصلب مفصل الركبة لديك؟

لا شيء	قليلة	متوسطة	شديدة	شديدة جداً	
0	1	2	3	4	6- بعد استيقاظك لأول مرة في الصباح؟
0	1	2	3	4	7- بعد الجلوس أو الاستلقاء أو أثناء الراحة في وقت لاحق من اليوم؟

مجموع نقاط التيبس أو التصلب (بعد أقصى 8)

[illegible]

Appendix 17 King Faisal Specialist Hospital Ethical Approval form:

مستشفى الملك فيصل التخصصي ومركز الأبحاث (مؤسسة عامة) - جدة KING FAISAL SPECIALIST HOSPITAL AND RESEARCH CENTRE (General Organization) - Jeddah	
Title of Research: The possibilities and acceptability of applying gait modification to the treatment of knee osteoarthritis in Saudi Arabia based on the perceptions of patients and physiotherapists.	عنوان البحث: إمكانات ومقبولية تطبيق تعديل المشي على علاج خشونة الركبة في المملكة العربية السعودية بناءً على تصورات المرضى وأخصائيي العلاج الطبيعي
A. Purpose of the Research: Explore clinicians' perceptions, awareness, and understanding of gait modification interventions. Explore knee osteoarthritis patients' how they tolerate, gait modifications and consider the most relevant outcome measures.	أ. الغرض من البحث: من أجل تقديم معرفة ممارسي العلاج الطبيعي بشأن مفهوم تعديل المشي، وتقييم وعلاجه وكيفية تقديمه. كذلك تقديم مرضى خشونة الركبة ما إذا كان المرضى يقبلون عليه وكيفية الالتزام ببرامج تعديل المشي؟ والنظر بالنتائج ذات العلاقة.
B. Description of the Research: Phase (2) consists of a feasibility study (single intervention), followed by phase (3) as a descriptive study.	ب. وصف البحث: تتكون المرحلة (2) من دراسة جدوى (تدخل واحد)، تليها المرحلة (3) كدراسة وصفية.
C. Potential Benefits: Increasing therapists' knowledge of gait modification (insole) interventions, their delivery, and patient acceptance. The results will also help clinicians deliver foot insole interventions that patients will use, reducing health system financial waste.	ج. الفوائد المحتملة: زيادة المعرفة العلمية للمعالجين بتدخلات تعديل المشي (النعل الداخلي)، وطريقة تقديمه، ومدى قابلية المرضى له. ومساعد النتائج أيضاً الممارسين على تقديم التدخل العلاجي الخاص ببطانة القدم الذي سيستخدمه المرضى، مما يقلل من الهدر المالي للنظام الصحي.
D. Potential Risks and Discomforts: During this research study, no risks will arise.	د. المخاطر والأزعاجات المحتملة: خلال عمل هذه الدراسة لا يوجد هناك مخاطر تتكرر
E. Voluntary Participation: Participation in this study is voluntary. You will not suffer penalty nor loss of any benefits to which you are entitled for, if you decide not to participate.	هـ. المشاركة الطوعية: المشاركة في هذه الدراسة طوعية وإذا قررت عدم المشاركة فإنك لن تتعرض لأيّة مضايقات أو لفقدان حقاك المشروع في المعالجة.
Significant new findings developed during the course of the study, which might be expected to affect your willingness to continue to participate in the study, will be provided to you. A signed copy of consent form will be given to you.	سيتم إبلاغك بآلية نتائج جديدة هامة تظهر خلال سير الدراسة والتي قد تؤثر في رغبتك في الاستمرار بالمشاركة في هذه الدراسة سيتم تزويدك بنسخة موقعة من هذا الإقرار.
F. Alternative to Participation and Withdrawal (if applicable): Withdrawal from or not participating in this research study will not affect your ability to obtain alternative methods of medical care available at King Faisal and Research Centre (General Organization) - Jeddah	و. البدائل عن المشاركة والانسحاب من المشاركة (إن وجد): إن قرارك بعدم الإشتراك أو بالانسحاب من الدراسة لن يؤثر على تلقائك لخدمات علاجية بديلة متوفرة في مستشفى الملك فيصل التخصصي ومركز الأبحاث بجدة (مؤسسة عامة).
This Informed Consent Form (ICF) is approved by the Institutional Review Board at KFSH&RC(Gen.Org.)-Jeddah Branch ICF Version No.: 1.2 Date: 20-10-2022 IRB #: 2022-80 The Informed Consent Approved By IRB Approval Dated: 19 September 2022 From: 19 September 2022 To: 19 March 2023	

مستشفى الملك فيصل التخصصي ومركز الأبحاث (مؤسسة عامة) - جدة KING FAISAL SPECIALIST HOSPITAL AND RESEARCH CENTRE (General Organization) - Jeddah	
G. Confidentiality: Your identity and medical record, as a participant in this research study, will remain confidential with respect to any publications of the results of this study. However, your medical record may be reviewed by the principal investigator/ delegate involved in this research, the Institutional Review Board, or the agency sponsoring this research in accordance with applicable laws and regulations.	ز. السرية: كشراك في هذه الدراسة ستكون هويتك ومحتويات ملفك الطبي سرية في جميع المنشورات المتعلقة بنتائج الدراسة. إلا إنه يمكن لكل من الباحث الرئيسي/ناقيه، أو المجلس التقييمي للبحوث، أو الجهة الداعمة للدراسة الإطلاع على ملفك الطبي وذلك في حدود النظم والقوانين المطبقة بهذا الخصوص.
H. Compensation: In the event of injury resulting from participation in this research study, KFSH&RC-J will make available to you, including admission, if required, its hospital facilities and professional attention. Financial compensation from KFSH&RC-J, however, is not available.	ح. التعويضات: في حالة حدوث أي ضرر لا قدر الله من جراء مشاركتك بهذه الدراسة؛ سيكتفل مستشفى الملك فيصل التخصصي ومركز الأبحاث بجدة بتقديم العناية الطبية اللازمة أو التنويم في المستشفى إن لزم الأمر، ولكنه لا يوجد أي تعويضات مالية.
I. Reimbursements: KFSH&RC-J will not reimburse the participant for participation in the study.	ط. التعويض المالي: لا يلتزم مستشفى الملك فيصل التخصصي ومركز الأبحاث بجدة (مؤسسة عامة) بدفع أي تعويض مالي مقابل المشاركة في البحث.
J. Contact Person(s): For any specific questions regarding this study or in the event of a research-related injury, please contact the principal investigator/delegate, Waleed Bakallah, telephone No. 0507505515.	ي. الأشخاص الذين يمكن الاتصال بهم: في حالة وجود أسئلة محددة تتعلق بهذا البحث، أو في حالة حدوث أي إصابات تتعلق بالدراسة، نرجو الاتصال على الباحث الرئيسي وليد باكالا هاتف رقم 0507505515
For general questions concerning research at KFSH&RC-Jeddah, you may call the research coordinator telephone # 012687-7777 Ext. or the Institutional Review Board telephone#012687-7777 Ext. 62984.	لأسئلة العامة المتعلقة بالبحوث بمستشفى الملك فيصل التخصصي ومركز الأبحاث بجدة يرجى الاتصال على منسقة الأبحاث على هاتف رقم ٠١٢٦٦٧٧٧٧٧ تحويله رقم أو الاتصال على رئيس مجلس تقييم الأبحاث/ناقيه على هاتف رقم ٠١٢٦٦٧٧٧٧٧ تحويله رقم ٦٢٩٨٤.
K. I, the principal investigator/ Waleed Bakallah	ك. أقر أنا الباحث الرئيسي/ وليد باكالا
This Informed Consent Form (ICF) is approved by the Institutional Review Board at KFSH&RC(Gen.Org.)-Jeddah Branch ICF Version No.: 1.2 Date: 20-10-2022 IRB #: 2022-80 The Informed Consent Approved By IRB Approval Dated: 19 September 2022 From: 19 September 2022 To: 19 March 2023	

Appendix 18 The calculation of MCIDs for the WOMAC and NRPS scores:

Participant ID	Baseline NRPS (Rest)	Post 6-weeks (Rest)	Change in NRPS Score	MCID Rest NRPS Achieved? (≥2 point reduction)	Baseline NRPS (Walk)	Post 6-weeks NRPS (Walk)	Change in NRPS Score	MCID NRPS Achieved? (≥2 point reduction)	Baseline WOMAC total score	Post 6-weeks WOMAC total Score	% Change in WOMAC Score	17-22% MCID WOMAC Achieved?
1-AB 329	3.0	0.0	-3.0	Yes	6.0	3.0	-3.0	Yes	28.0	3.0	-97%	Yes
2-AM 128	5.0	4.0	-1.0	No	8.0	2.0	-6.0	Yes	66.0	9.0	-91%	Yes
3-AR 006	3.0	0.0	-3.0	Yes	6.0	1.0	-5.0	Yes	36.0	5.0	-95%	Yes
4-AR 041	3.0	2.0	-1.0	No	5.0	5.0	-0.0	No	59.0	26.0	-74%	Yes
6-FA 281	0.0	0.0	-0.0	No	2.0	0.0	-2.0	Yes	5.0	1.0	-99%	Yes
7-FM 255	4.0	0.0	-4.0	Yes	2.0	5.0	-3.0	No	26.0	25.0	-75%	Yes
8-HA 721	5.0	5.0	-0.0	No	6.0	5.0	-1.0	No	65.0	53.0	-47%	Yes
10-MM 103	2.0	1.0	-1.0	No	6.0	2.0	-4.0	Yes	44.0	27.0	-73%	Yes
11-MR 430	5.0	1.0	-4.0	Yes	5.0	1.0	-4.0	Yes	28.0	11.0	-89%	Yes
14-RM 134	5.0	5.0	-0.0	No	7.0	4.0	-3.0	Yes	58.0	27.0	-73%	Yes
15-RR 656	3.0	1.0	-2.0	Yes	6.0	2.0	-4.0	Yes	60.0	22.0	-78%	Yes
16-JA 302	2.0	0.0	-2.0	Yes	7.0	3.0	-4.0	Yes	54.0	21.0	-79%	Yes
17-SM 631	0.0	0.0	-0.0	No	4.0	0.0	-4.0	Yes	67.0	33.0	-67%	Yes
18-SO 417	1.0	1.0	-0.0	No	5.0	1.0	-4.0	Yes	20.0	6.0	-94%	Yes
19-TA 029	5.0	1.0	-4.0	Yes	8.0	1.0	-7.0	Yes	48.0	12.0	-88%	Yes
20-AM 248	3.0	1.0	-2.0	Yes	7.0	1.0	-6.0	Yes	51.0	36.0	-64%	Yes
21-TA 307	3.0	2.0	-1.0	No	6.0	4.0	-2.0	Yes	55.0	43.0	-57%	Yes
Average			1.647		Average		3.29		Average		-78.82%	

Appendix 19 Copy from patient's adverse event:

• Adverse Events:

Does the patient have any Adverse Events since signing the Informed Consent?

Yes ☒

No ☐

Log and describe any adverse events using the reporting table below:

1 st Adverse Event (AE.)	Details
Date: 8 / 11 / 2022	Right Some knee pain with walking (on/off), not always.
AE. Description: Right inner knee pain	Severity: 1= Mild 2= Moderate 3= Severe
Action Taken: No action	
Result: 1= Resolved 2= Recovery with sequelae 3= Continued	
Withdrawn from study due to AE? 1= No 2= Yes, existing data can be used 3= Yes, the data has been deleted.	

2 nd Adverse Event (AE.)	Details
Date: / / 2022	
AE. Description:	Severity: 1= Mild 2= Moderate 3= Severe
Action Taken:	
Result: 1= Resolved 2= Recovery with sequelae 3= Continued	
Withdrawn from study due to AE? 1= No 2= Yes, existing data can be used 3= Yes, the data has been deleted.	

• If there are more than 2 adverse events, add more pages.

Completed by: Nour Abduljawad Signature: [Signature]