Effective Treatment of Claw Horn Lesions in Dairy Cattle

by

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Thesis submitted to the University of Nottingham in accordance with the requirements for the degree of Doctor of Philosophy (PhD) in the School of Veterinary Medicine and Science

November 2016

Word count 78,047

Abstract

Lameness was described by the Farm Animal Welfare Council (2009) as one of the foremost health and welfare challenges facing dairy cattle in the UK. Studies suggest UK lameness prevalence has increased over the past 30 years peaking at 36.8% in 2006-2007. The first study in this thesis aimed to investigate current lameness prevalence and related management practices in the UK. Short, structured interviews were conducted with farmers on 43 randomly selected farms in central England during spring 2014 before mobility scoring the lactating herd. Mean herd lameness prevalence was 30.1% (range 7.3%-60.6%). This represents a drop in prevalence since 2007, suggesting a corner may have been turned in control of lameness. A large proportion of farmers reported conducting their own routine trimming and treatment of lame cows. It is therefore important to ensure correct training reaches these farmers if lameness prevalence is to continue to fall.

Lameness is often associated with claw horn lesions (sole ulceration and white line disease) however little information is available in the scientific literature on treatment protocols for these lesions. This second study in this thesis aims to begin to address this knowledge gap through a partially blinded, randomised, positively controlled clinical trial (RCT). Animals with an acute case of lameness (two non-lame scores followed by a lame score determined by fortnightly mobility scoring) resulting from claw horn lesions on a single, hind claw were enrolled and allocated at random one of four treatments: 1) Therapeutic trim (TRM) (positive control group), 2) therapeutic trim and foot-block (TB), 3) therapeutic trim and nonsteroidal anti-inflammatory drug (NSAID) (TN) and 4) therapeutic trim, foot-block and NSAID (TBN). One hundred and eighty-three cows were enrolled over a 13-month period. Based on a sound score (score 0) at 35 days post treatment, the number (and proportion) of successful treatments was 11 of 45 (24.4%) TRM, 14 of 39 (35.9%) TB, 12 of 42 (28.6%) TN and 23 of 41 (56.1%) TBN. A significant difference was seen between treatment groups (P=0.01). The results of this study suggest that recovery in animals treated for lameness due to claw horn lesions is maximised by treatment with a TBN. Smaller non-significant improvements were also seen in TB and TN compared with a TRM.

The lesions treated in this RCT were largely mild due to the early recognition and treatment protocol used. Studies have demonstrated delays in identification of lame cows on farms and so the lesions seen in this study may not represent those treated by farmers, foot trimmers and vets in the field. The third study in this thesis aimed to investigate the impact of chronicity of lameness on treatment outcomes. The prospective, partially blinded, positively controlled RCT followed a similar protocol to the previous RCT but enrolled cows lame on the same hind leg for at least two of the last three mobility scores. Animals were randomly allocated one of three treatments: 1) therapeutic trim only, 2) therapeutic trim and shoe or 3) therapeutic trim, shoe and NSAID. Three outcomes at 42 (±4) days post treatment were analysed: (i) non-lame (score 0 or 1 at outcome), (ii) improved (lower mobility score at outcome than enrolment) and (iii) apparent leg cure (non-lame on treated leg or lame on contralateral leg at outcome). Over a 13-month period, data was collected for 189 cases of lameness from 176 cows (13 cows received treatment on both hind limbs). No significant difference between treatment groups was seen for any of the outcomes analysed. A very low response rate to treatment of around 15% was seen across all treatment groups. Data for all animals treated in this chronic lameness RCT (CLRCT) was compared to a subset of data from the acute lameness RCT (ALRCT). Analysis showed a significant difference for outcomes (i), (ii) and (iii) in animals treated for acute compared to chronic lesions ($P<0.01$). In the ALRCT, 31 of 127 treated animals were lame at outcome (15 lame on the opposite hind leg to enrolment). In the CLRCT 132 of 156 treated animals were lame at outcome (60 lame on the opposite hind leg to enrolment). These findings support the need for both early and effective treatment and suggest that animals should receive appropriate treatment interventions in both hind limbs even if presenting with unilateral lameness.

To have an impact on lameness prevalence, it is essential that research findings are disseminated to farmers treating cows on farms. The final study in this thesis aimed to assess the efficacy of different methods of knowledge transfer (KT) in relation to this. A prospective, qualitative and quantitative study was conducted to assess three methods of cattle lameness KT; 1) paper based/online AHDB dairy resources (positive control group), 2) resources plus facilitated discussion

group, 3) resources plus on-farm visit by ‘expert’ veterinary surgeon. Prior to the KT session participants completed a semi-structured interview and observed video clips of lame and non-lame cows to select how quickly they would treat each case. Following the KT session the video exercise was repeated and a feedback form completed. Video clip responses were analysed pre-and post-session. Feedback forms were used to assess engagement and likelihood of behavioural change. Fifty-one individuals participated in the study. ‘Expert’ visits had a significant positive effect on the farmers’ awareness of the ‘correct’ maximum treatment interval advised for lame cows compared to resources alone. ‘Expert’ KT sessions were also felt to be significantly more enjoyable and useful. A narrow range of feedback scores suggest this method was also most accessible to a range of learners. The findings of this study suggest the role of the veterinary advisor remains central to the KT process.

The key messages derived from the research undertaken in this thesis are the need for early identification and prompt, effective treatment of claw horn lesions in dairy cows. As the body of research grows it is imperative that suitable knowledge transfer strategies are employed to best disseminate these findings to farm-level and maximise their impact on the health and welfare of affected animals.

Acknowledgements

This thesis is dedicated to my parents, Lesley and Alan, who have been a great support to me throughout my studies.

I would like to thank Nikki Bollard, Giuliana Miguel Pacheco and Sara Pederson for their assistance during on-farm data collection for this thesis. I would also like to thank Sue Horseman and Becky Whay for their help and support with the qualitative research study.

My sincerest thanks go to my supervisor, Jon Huxley for his guidance and encouragement during my time at the University of Nottingham.

I would like to acknowledge the financial support provided by AHDB Dairy and the BVA animal welfare fund that allowed me to carry out this thesis and thank the AHDB Dairy managers and regional extension officers who assisted with the KT study.

Finally, I would like to thank all the farmers who allowed me onto their farms to carry out my research and those that participated in KT activities, without them none of this would have been possible.

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List of abbreviations

AHDB	Agriculture and Horticulture Development Board
BT	British Telecom
CPD	Continuing Professional Development
DIM	Days In Milk
DVD	Digital Video Disk
FAWC	Farm Animal Welfare Council
GRP1-cont	Group 1 – control group
GRP2-disc	Group 2 – discussion group
GRP3-exp	Group 3 – expert group
ID	Identification
L	Litres
NACFT	National Association of Cattle Foot Trimmers
NSAID	Non-Steroidal Anti-Inflammatory Drug
KT	Knowledge Transfer
RCT	Randomised Clinical Trial
SH/U	Sole Haemorrhage and/or Ulceration
TB	Trim and Block
TBN	Trim, Block and NSAID
TRM	Trim
TN	Trim and NSAID
TS	Trim and Shoe
TSN	Trim, Shoe and NSAID
UK	United Kingdom
WLD	White Line Disease

Chapter 1. Introduction

1.1 Lameness in dairy cattle

Lameness in dairy cattle can be defined as the clinical presentation of impaired locomotion (Archer *et al*.,2010) resulting from pain or discomfort from hoof or leg injuries and disease (Flower and Weary., 2009). It is considered one of the primary disease conditions recorded in dairy cows (Leonard *et al*., 2001, Esslemont and Kossaibati, 1996) and was stated by the Farm Animal Welfare Council (2009) as being one of the foremost health and welfare challenges facing the United Kingdom (UK) dairy industry. Records collected by the Dairy Herd Health and Productivity Service in the UK between 1980 and 2002 (Whitaker *et al*., 2004) showed a substantial increase in lameness on many farms in the early 1990's before a gradual improvement started to occur. The level of lameness seen in dairy herds today however, still presents serious implications for both cow welfare and productivity.

Lameness is a symptom of a wide range of diseases rather than a single condition in itself. The exact cause and pathogenesis of many of these diseases are still relatively poorly understood, with research in the field of cattle lameness lagging behind that of other endemic diseases. A database search conducted September 14th 2012 of the United States Library of Medicine (PubMed: www.pubmed.com)by Bicalho (2013) using the keywords 'bovine lameness' produced 831 articles, however when the word 'lameness' was replaced with 'mastitis' the number of articles increased to 6510. It has been suggested that this may, in part, be due to control of lameness being associated with relatively few medicine sales and therefore funding available from pharmaceutical companies which has supported research into mastitis has not been forthcoming (Maxwell *et al*., 2015).

Most cases of lameness in dairy cows are associated with one of four predominant lesion types, sole ulcers, white line disease, interdigital necrobacillosis and digital dermatitis (Archer *et al*. 2010). Interdigital necrobacillosis and digital dermatitis result from infection by *fusobacterium necrophorum* and *Treponema spp.* respectively while sole ulcer and white line disease are associated with defects in the claw horn itself. Collation of records

provided to AHDB Dairy by Category 1 members of the National Association of Cattle Foot Trimmers between March and October 2010 showed that of 5109 cows from 90 farms across the UK, 56% had a least one foot lesion. Sole bruising was the most common, followed by digital dermatitis, white line disease and sole ulceration (Huxley *et al*., 2011).

While much research still needs to be undertaken to fully understand this disease, the link between high producing cows and increased risk of all production diseases, including lameness, is well established, while lameness has also been shown to exert an influence back on production. In a review of the English language peer reviewed literature, Huxley (2013) looked at the impact of lameness in cows on health and production. Very strong evidence was found from around the world that lameness has a negative impact on milk production (Bicalho *et al*, 2008; Green *et al*., 2002; Amory *et al*., 2008) with total losses throughout the lactation in the range of 270 to 574kg. Losses in production were also seen to begin before the case of lameness was identified and treated as well as continuing after the lameness event. In a study by Green *et al*. (2002) investigating the impact of lameness on milk yield, 900 cows in five farms in Gloucester, UK were followed for 18 months from 1997 to 1999. In clinically lame cows, milk yield was found to reduce from up to four months before lameness was diagnosed and treated to five months after. Over 70% of cows in this study became lame at least once during the study period. High yielding cows were also seen to be more likely to be lame than those that were not during the 18 month period. These cows produced a mean of 342 extra kilograms of milk over 305 days in milk. When compared to the production losses reported above, it indicates that these higher yielding cows return to more average production levels for the herd in the event of an incident of lameness occurring therefore reduction in milk production may not be immediately apparent. Analysis of herd size and production trends in the UK dairy industry suggest an increasing demand is being placed on dairy cows (Huxley and Green, 2010). With increasing world populations and subsequent consumption of dairy products, the push for even greater production is likely to increase both the risk of animals becoming lame and the number of animals suffering from disease. There is however, the potential for increased productivity leading to greater investment

in facilities and infrastructure. A greater emphasis on research into the causes, management and treatment of lameness is therefore needed to ensure this investment can be most effectively targeted.

1.1.1 Detection of lameness in dairy cattle

Visual detection of lame cows can be highly subjective and as such various methods have been developed to provide more structured analysis to ensure greater accuracy and repeatability in identifying affected individuals. Locomotion scoring evolved as a way of categorising the gait of a group of animals into subsets (Whay, 2002). The stoic nature of cattle means that even painful pathologies of the hoof or leg may result in little change in the animals' behaviour (Flower and Weary, 2009) and so many different systems have been developed to evaluate gait as a means of detecting lame animals.

Two main approaches to subjective assessment of lameness are seen in the scientific literature. Numerical rating scores typically rate individual cows on around a five-point scale for the presence or absence of behaviours and postures related to gait (Flower and Weary, 2009). Examples of such systems are shown in table 1. Interpretation of some of these numerical rating scores using terms such as 'mild' or 'slight' may be affected by the previous experience of the observer and so simpler systems using the presence or absence of a specific behaviour or posture have become more frequently used. To a lesser extent visual analogue scales are used to grade lameness. These were originally developed for use by human patients to rate pain and consist of a horizontal line with a description of the extremes at either end of the scale (Flower and Weary, 2009) This system may be more sensitive than numerical rating scores as lameness is measured on a continuous scale rather than restricting the score to discrete units, however numerical rating continues to be a more popular approach to measuring lameness both in research studies and for management purposes on farms.

Locomotion scoring systems used in research and in herd management may require different levels of complexity to serve their purpose. For some research studies it is necessary to have substantial discrimination between lameness levels in the scoring system to detect early stages of lameness while for non-research

purposes, such complicated and subtle scoring systems may be time consuming and discouraging to use (Whay, 2002). A number of visual scoring systems have been developed to allow observers to match their observations against an assessment framework and allocate each animal a 'score' according to the severity of lameness seen. This process of scoring is often carried out as cows are entering or leaving the milking parlour (Bell., 2015) although the main requirement is a firm, level surface on which to observe the animal walk.

1.1.1.1 Locomotion scoring systems

One of the earlier locomotion scoring systems seen in the scientific literature is that of Manson and Leaver, (1988), whose system was designed to assess the influence of concentrate amount on locomotion and clinical lameness in dairy cattle. This nine-point scoring system was not specifically designed to identify lame cows but as a sensitive scale to note subtle changes in locomotion that might lead to lameness. For this reason, the first half of the scale is dedicated to changes seen prior to overt lameness being observed. The system is commonly used by researchers however, while it is useful in identifying early signs of discomfort, it can be complicated to use (Whay, 2002).

Subsequent scoring systems were developed to specifically categorise the severity of lameness and as such concentrate less on the changes in gait seen prior to lameness. Table 1 shows a range of locomotion scoring systems used in the scientific literature.

Table 1. Locomotion scoring systems used in the scientific literature for assessment on lameness in cattle

Scoring system	Score	Observation
Manson and Lever (1988)	1.0	Minimal abduction/adduction, no unevenness of gait, no tenderness
	1.5	Slight abduction/adduction, no unevenness or tenderness
	2.0	Abduction/adduction present, uneven gait, perhaps tender
	2.5	Abduction/adduction present, uneven gait, tenderness of feet
	3.0	Slight lameness not affecting behaviour
	3.5	Obvious lameness, some difficulty in turning, behaviour pattern affected
	4.0	Obvious lameness, difficulty in turning, behaviour pattern affected
	4.5	Some difficulty rising, difficulty in walking, behaviour pattern affected
	5.0	Extreme difficulty in rising, difficulty walking, adverse effects on behaviour pattern
Wells *et al*., (1993)	0	None – gait abnormality not visible at walk; not reluctant to walk
	1	Mild – mild variation from normal gait at walk; includes intermittent gait asymmetry or mild bilateral or quadrilateral restriction in free movement
	2	Moderate – moderate and consistent fair asymmetry or symmetric gait abnormality, but able to walk without continuous stimulation
	3	Severe- marked gait asymmetry or severe symmetric abnormality
	4	Non-ambulatory - recumbent
Sprecher *et al* (1997)	1	The cow stands and walks with a level-back posture. Her gait is normal.
	2	The cow stands with level-back posture but develops an arched-back posture when walking. Her gait remains normal
	3	An arched-back posture is evident both when standing and while walking. Her gait is affected and is best described as short striding with one or more limbs
	4	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favours one or more limbs/feet
	5	The cow demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet
Whay *et al* (1997)	1	Sound
	2	Imperfect locomotion
	3	Mild lameness
	4	Moderate lameness
	5	Severe lameness
	6	As lame as possible while upright

Winkler and Willen (2001) (taken from Flower and Weary, 2009)	1	Normal gait
	2	Uneven gait (stiff/very careful/swinging of legs around the udder/swaying of trunk and/or hindquarters)
	3	Short striding gait with one limb (even if just noticeable)
	4	Short striding gait with more than one limb or strong reluctance to bear weight on one limb
	5	Does not support weight on one limb or strong reluctance to put weight on two or more limbs, holding a limb up whenever possible
Cook (2003)	1	No gait abnormality – walks rapidly and confidently, making long strides with a level back
	2	Mild lameness- walks more slowly making shorter strides with an arched back. Stands with a level back and does not appear to favour a limb
	3	Moderate lameness – often thin. Walks slowly making deliberate steps with an arched back, may favour a limb. Makes frequent stops. Encounters difficulty turning, stands with and arched back and frequently lifts affected foot
	4	Severe lameness – usually very thin, moves slowly making frequent stops to rest affected limb. Only partially weight bearing. Frequently salivates. Encounters extreme difficulty turning. Stands and walks with pronounced arched back
Whay (2003)	0	Sound
	1	Abnormal locomotion / perhaps tender
	2	Lame
	3	Severely lame
Rutherford *et al* (2009)	1	'Normal walking' Cow walks freely and evenly. Cow shows even stride lengths with good tracking, no adduction or abduction and an even walking rhythm
	2	'Mild deviation from normal walking' Cow walks with a small gait abnormality. Gait pattern is almost normal but cow shows slight but noticeable deviations from normal tracking or clear adduction or abduction
	3	'Gait abnormality' Cow is clearly walking abnormally, with clear deviations from normal tracking and abduction or adduction. Stride length can be reduced and stride rhythm may be irregular
	4	'Lame' Movement is clearly impaired and the cow is seen to limp or hobble as she moves. The cow shows uneven stride length and timing and appears reluctant to bear weight on one or more limbs
Barker *et al* (2010)	0	Sound, walks confidently with even weight on all four feet, tracks up (hind feet in prints of fore feet)
	1	Imperfect locomotion. May walk cautiously, possibly because of tenderness, OR does not track up, OR legs swing out or in, but no obvious limp
	2	Lame. Definite limp (foot fall uneven, dew claws on affected limb do not drop as far) OR arched

	3	spine. A favoured limb will move more quickly than the lame limb. Speed of walk not noticeably affected Severely lame. Cannot walk at brisk human pace, Animal shows obvious signs of limb pain (e.g. reluctance to bear weight, very obvious shifts in body posture)

1.1.1.2 The AHDB Mobility Scoring system

In 2007 concern was raised about the number of widely different 'locomotion scores' being used on UK dairy farms leading to confusion amongst farmers and the wider industry. A cross industry group of 50 veterinary surgeons, consultants, academics, foot trimmers, farmers, milk buyers and other industry representatives met to discuss the standardisation and nomenclature for scoring lameness on farms (Bell and Huxley, 2009). From this meeting it was decided that the term 'mobility scoring' would be used to avoid confusion with the locomotion score in use for assessment of conformation by Holstein UK. A smaller working group was then established to reach a consensus on appropriate descriptors broadly reflecting the typical actions that farmers take when assessing cows for lameness. In general, lameness scoring methods use the signs of pain such as reduced walking speed, shortened stride length, an arched back and decreased weight bearing on the affected limb (Bell, 2015). Bringing these systems together the 'AHDB Dairy Mobility Score' was developed as the UK standard method to grade lameness in dairy cattle (see figure 1) providing a clear and consistent message to the industry and allowing large quantities of comparable data to be collected to help better understand lameness in the UK.

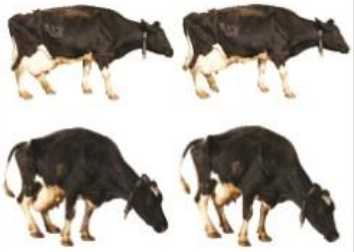
Category of score	Score	Description of cow behaviour	Suggested action
Good mobility 	0	Walks with even weight bearing and rhythm on all four feet, with a flat back. Long, fluid strides possible.	• No action needed • Routine (preventative) foot trimming when/if required • Record mobility at next scoring session.
Imperfect mobility 	1	Steps uneven (rhythm or weight bearing) or strides shortened; affected limb or limbs not immediately identifiable.	• Could benefit from routine (preventative) foot trimming when/if required • Further observation recommended.
Impaired mobility 	2	Uneven weight bearing on a limb that is immediately identifiable and/or obviously shortened strides (usually with an arch to the centre of the back).	• Lame and likely to benefit from treatment • Foot should be lifted to establish the cause of lameness before treatment • Should be attended to as soon as practically possible.
Severely impaired mobility 	3	Unable to walk as fast as a brisk human pace (cannot keep up with the healthy herd). Lame leg easy to identify – limping; may barely stand on lame leg/s; back arched when standing and walking. Very lame.	• This cow is very lame and requires urgent attention, nursing and further professional advice • Examine as soon as possible • Cow will benefit from treatment • Cow should not be made to walk far and kept on a straw yard or at grass • In the most severe cases, culling may be the only possible solution.

Figure 1. The AHDB Dairy Mobility Scoring System

At a farm level, routine locomotion scoring fulfils several functions, identifying individuals for treatment, providing information on lameness prevalence within the herd and identifying times of seasonal risk (Whay, 2002). While severely lame animals may be very apparent at the back of the herd at milking and thus become the focus of the herd manager (Bell., 2015), it is more difficult to detect cows that are mildly or moderately lame within the main herd. Mobility scoring encourages the observer to recognise more mildly affected animals and treat

these alongside the more severely affected individuals (Whay, 2002). Such subjective methods of lameness assessment are also well suited to on-farm use as they can be conducted quickly on-site, require no technical equipment and allow observers to assess gait in a large number of animals (Flower and Weary, 2009). However, the sensitivity of detection of lame cows may vary considerably between individual observers, with variability seen to be greatest in milder cases of lameness (Archer *et al*., 2010).

1.1.1.3 Inter- and intra-observer variability

Reliability of subjective assessments can be defined as the extent to which they are precise and consistent (Flower and Weary, 2009). Locomotion scoring systems may be affected by both poor inter- and intra-observer reliability, differences between observers may be affected for example by the level of experience of the observer while differences within the observer may be seen over time, known as 'observer drift' which can be quantified by re-scoring the same video tapes at different times. The level of detail in the descriptor may also affect reliability with some scoring systems such as that used by Whay (2003) allowing a large degree of interpretation by the observer while others such as Cook (2003) are much more specific. Errors affecting repeatability may also be seen due to sources of bias such as errors by omission (failing to score a behaviour which occurred) or errors of expectation (failing to score an animal as lame because the rest of the herd was healthy) (Flower and Weary, 2009).

Kappa is used as a measure of agreement for categorical variables and is often employed to assess agreement between two different observers assigning locomotion scores to the same group of animals. Kappa relates the actual agreement with that which would have been attained if the score had been given at random, i.e. it compares the actual agreement with chance agreement (Petrie and Watson., 2006). A value of zero indicates the agreement is the same as chance. Kappa values <0.2 indicate poor or slight agreement, 0.21-0.4 = fair agreement, 0.41-0.6=moderate agreement, 0.61-0.8 substantial agreement and >0.8 good or almost perfect agreement (Cramer *et al*., 2008).

Problems of subjective assessment of lame cows can be avoided using objective kinematic and kinetic methods to measure gait (Flower and Weary, 2009). While

the equipment used to collect these measures is often expensive and impractical for on-farm assessment currently, much research is being carried out in this area to discover ways of automating the process, reducing both time spent mobility scoring and inter and intra-observer variation in lameness assessment.

Whether subjective or objective systems of lameness detection are used on farms, it is important they are validated to show how the values recorded relate to the pain and discomfort caused by the presence of hoof and leg pathologies (Flower and Weary, 2009).

1.1.2 Incidence and prevalence of lameness in dairy cattle.

Over the past three decades, much work has been carried out to establish the level of lameness in cattle in many countries and across different management systems. Two main methods of collecting and presenting such data are employed. Measuring incidence of lameness, the number of new cases of a disease in a population over a period of time, is often achieved by collating data from records kept by farm managers, veterinary practitioners or cattle hoof trimmers on lameness cases treated. Lameness incidence is usually calculated on an annual basis (Whay, 2002), however it relies on accurate reporting of all lameness cases on farms, not only those requiring veterinary intervention, to provide accurate figures. Monitoring lameness through farm records provides information about types of lameness seen within the herd, indicates seasonal periods when the risk of specific conditions may be higher, provides information on severity and duration of lameness events and identifies individuals with repeated bouts of disease. Incidence rate has traditionally been the method used to record and monitor lameness however problems may occur from subjective opinions on whether the cow is lame, correct identification of the lesion and recurrence rates (Burnell and Reader., 2010).

More recently the industry has adopted the use of prevalence of cases to monitor lameness levels. Prevalence relates to the percentage of a population affected by lameness at a given time and may therefore be observed directly by trained operators providing a level of consistency in reporting (Whay, 2002). It is important to recognise however that many environmental and temporal factors may influence lameness which must be taken into consideration when

interpreting these figures. It is also important when prevalence scoring is performed that the same cows are seen, however dry cows are rarely scored as this can be inconvenient and cows in straw yards/under treatment groups may be missed (Burnell and Reader., 2010). As straw yards/treatment groups may contain the worst affected individuals this could lead to an underestimate of both the level and severity of lameness within the herd. While prevalence scoring provides an opportunity for the observer to look at all the lactating individuals in the herd, it gives no indication of the causes of lameness or of high-risk periods (Whay, 2002). A combination of incidence and prevalence data is therefore useful to gain a more accurate representation of lameness levels in dairy cattle. Guard (2008) notes a disconnect between observed prevalence and associated incidence data. From modelling data form real herds suggests that the management performance of most herds in finding and treating incident cases of lameness could be improved. It is therefore important to record and review both of these measures to gain a more complete picture of lameness on dairy farms

1.1.2.1 Incidence of lameness in UK dairy herds

In the UK, a range of studies have taken place to assess and monitor the incidence of lameness in dairy herds. A summary of these studies is shown in table 2.

Table 2. Incidence of lameness in cattle reported on United Kingdom dairy farms between 1974 and 1998

Number of cases	Period of study	Location of study	Case selection	Overall incidence	Incidence range	Reference
1005	August 1974 – July 1975	Somerset, United Kingdom	Cases presented to 6 person, 90% large animal practice	First visit incidence 7.33% Incidence of animals served by practice 4.72%	0-32% across farms	Eddy and Scott (1980)
	1977	United kingdom	Cases from 48 veterinary practices	Annual incidence 5.5%	1.8-11.8% for different veterinary practices	Russel *et al* (1982)
21048	April 1981 – March 1982	England and Wales, United Kingdom	Treatment of milking age cows by farm staff and veterinary surgeons	25%	2-55% across farms	Whitaker *et al* (1983)
	May 1989 – September 1991	Four regions of Britain (United Kingdom)	Recording forms from farmers, veterinary surgeons and foot trimmers	54.6 cases per 100 cows Summer mean 22.9 Winter mean 31.7	10.7-170.1 cases per 100 cows	Clarkson *et al* (1996)
	Summer 1990	Wirral, United Kingdom	8 farms, forms completed by farmers/stockment	11.6%		Clackson and Ward (1991)
13680	12 months 1992-1993	Southern England, United Kingdom	Dairy information system (DAISY) records from farmers, consultants and veterinary professionals	24 cases per 100 cows	4.7 per 100 cows in first quarter – 47.4 in highest quarter	Esslemont and Kossaibati (1996)
	1995-1998	England and Wales, United Kingdom	10 organic dairy farms, records from herdsmen/farmer and veterinary surgeon visits	20.2 cases per 100 cows	3.9-74.9 cases per 100 cows	Weller and Bowling (2000)

An initial lack of information in the literature on lameness in dairy cattle prompted Eddy and Scott (1980) to undertake a survey of all cases of lameness in their 6-person, 90% large animal practice in Somerset from August 1974 to July 1975. 1,005 cases were seen, giving a first visit lameness incidence of 7.33% of adult cattle on farms where lameness was recorded and 4.72% of the estimated number of adult cattle served by the practice (range 0% to 32% across farms). Similar figures were recorded in a survey undertaken during 1977 where information on lameness cases treated by 48 veterinary practices was gathered and an annual incidence of 5.5% lameness calculated, with an average range of

1.8% to 11.8% for different veterinary practices (Russell *et al*., 1982). While these early studies highlighted the importance of lameness treatment as part of veterinary practice, the use of veterinary practice records does not take into account lameness cases treated by farm staff or the policy of farmers for seeking veterinary attention for lame cows. For this reason, it may significantly underestimate the incidence of lameness on commercial dairy farms at the time. In order to provide further information on the incidence of lameness in dairy cows, a study was carried out between April 1981 and March 1982, examining data on lameness treatments from 21,048 cows in England and Wales. This study recorded each treatment for lameness in a cow of milking age carried out by both farm staff and veterinary surgeons. Incidence was recorded at 25% overall with a range on individual farms from 2% to 55%. 6.3% were treated by veterinary surgeons and 18.7% treated by farmers (Whitaker *et al*., 1983). In all of these studies, a case presented for treatment was used as the measure for an incident of lameness. The incidence of lameness treated by veterinary surgeons in this study (6.3%) is similar to that reported by Eddy and Scott (7.33%) and Russell *et al*., (5.5%) and so it is likely in these earlier studies that many cases were also treated by farmers and the actual incidence of lameness on dairy farms at this time was much higher.

A decade later, in a survey carried out between May 1989 and September 1991 in four regions of Britain, the annual incidence rate was calculated as a mean of 54.6 new lameness cases per 100 cows (range 10.7-170.1), comprising a mean incidence rate for the summer period of 22.9 and for the winter period of 31.7 (Clarkson *et al*., 1996). In this study, incidence was calculated using recording forms completed by farmers, veterinary surgeons or foot trimmers. In contrast, a study of eight farms on the Wirral during the summer of 1990 found a mean incidence of lameness of 11.6% (Clackson and Ward, 1991). Data for lameness incidence in this case was also obtained from forms completed by stockmen or veterinary surgeons whenever a foot was lifted for treatment. A study conducted over a 12 month period in 1992/1993 found an incidence of 24 cases per 100 cows ranging from 4.7 per 100 cows in the first quarter to 47.4 per 100 cows in the highest quarter (Esslemont and Kossaibati, 1996). Lameness incidence was calculated using computer records from farmers, consultants and veterinary

professionals using the Dairy Information System (DAISY). Data was used from 90 herds covering a total of 13,680 cows across southern England. On average, the survey showed 17% of the cows in the 90 herds were affected by lameness.

Slightly lower figures were recorded in a three year study from 1995 to 1998 on ten organic dairy farms in England and Wales where a mean incidence of lameness at 20.2 per 100 cows (range 3.9-74.9) was reported (Weller and Bowling, 2000). Again in this study the occurrence and treatment of health problems were recorded by the herdsman/farmer including visits by a veterinary surgeon. Many studies have demonstrated a higher incidence of lameness in winter than summer (Clarkson *et al*., 1996, Rowlands *et al*., 1983, Jubb and Malmo, 1991) however, in contrast, a study looking at veterinary treatments of lameness in the UK over an eight year period from January 1997 to December 2004 found no effect of season on total reports of lameness to the National Animal Disease Information Service, a network of 40 private veterinary practices and six UK veterinary schools with 48,720 reports of lameness over the period (Laven and Lawrence, 2006)

1.1.2.2 Prevalence of lameness in UK dairy herds

In more recent years, measuring the prevalence of lameness in British dairy cattle has gained more focus. In a study by Clarkson *et al.* (1996), locomotion scoring on a five-point scale, was carried out by trained observers on 37 farms between May 1989 and September 1991, where the mean number of cows at risk at any one time was 4230. The mean prevalence over the whole period of the study was 20.6% (range 2.0%-53.9%). A later study conducted during the winter housing period of 2002/2003 recorded lameness at a median point of 24.2%. The study was carried out on 15 organic dairy farms in the south-west of England with lameness assessed using a 4 point scoring system, (Huxley *et al*., 2004). It is important to recognise however that lameness prevalence is thought to be higher during the winter housing period which may account for the higher prevalence recorded in this study compared to that found by Clarkson *et al* (1996).

Work looking at organic and non-organic farms (Rutherford *et al*., 2009) found a mean herd lameness prevalence of 16.2%, 16.3% and 19.1% in the autumn

winter and spring respectively across all farms demonstrating this increase in lameness prevalence during the winter housing period. Due to the study design using matched pairs of organic and non-organic farms, the numbers of straw yard farms included were higher than representative of the UK dairy industry but taking figures for non-organic cubicle housed cattle only, prevalence's were 19.1%, 21.0% and 23.1% in autumn, winter and spring respectively, supporting the findings of other studies.

A higher lameness prevalence was found in a study carried out during 2006-2007 on 205 dairy farms across central and southern England and Wales where a mean prevalence of lameness of 36.8% (range 0-79.2%) was recorded (Barker *et al.*, 2010). Cows were locomotion scored on a four-point scale as they exited the parlour or in a loafing yard. This study clearly demonstrates the scale of the situation with regard to lameness in dairy cattle in the UK and the need for greater research and education of farmers in lameness prevention and treatment.

It should be noted that digital dermatitis, an infectious disease causing lameness in cattle was first recorded in the UK in 1987 (National Animal Disease Information Service, www.nadis.org.uk). While the lameness prevalence studies above were all conducted after this date, rising lameness levels may reflect the spread of digital dermatitis as well as any increase lameness caused by claw horn lesions.

1.1.2.3 Prevalence of lameness in dairy cattle outside the UK

Many studies have also been carried out in other western European, North American and Australasian countries to establish the incidence and prevalence of lameness in their respective dairy farming systems.

In Europe, a study of 4899 cattle in 101 Swedish dairy herds undergoing routine foot trimming from October 1996 to May 1997 and from September 1997 to June 1998 found a lameness prevalence of 5.1% (Manske *et al.*, 2002). A study in Denmark found a similar mean of 5% lameness in 55 herds containing 6240 cows during the winter of 2002/2003 (Capion *et al.*, 2008). A questionnaire based study to investigate animal welfare in the Republic of Ireland identified 9.5% of the 15,022 cows on 201 farms in 1996 as lame (Leonard *et al.*, 2001),

while in Greece, a cross-sectional evaluation of 3400 Holstein dairy cows during 2007 found an overall prevalence of lameness of 18.7% using a 5 point lameness scoring system (Katsoulos and Christodoulopoulos, 2009). Inspections on twenty-four Czech dairy farms in Central Bohemia identified between 6% and 42% of cows on individual farms to be at least moderately lame (median 22%) (Dembele *et al*., 2006), while work carried out in Turkey assessing 1190 cows on three zero-grazing farms reported lameness prevalence at 6.8% (Kilic, 2004) although no information was given on the scoring systems used.

In North America, a study carried out in the early 1990's investigating clinical lameness prevalence in seventeen herds in Minnesota and Wisconsin found 13.7% lameness in summer and 16.7% in spring (Wells *et al*., 1993) while in 2004, a cross-sectional evaluation of 5626 Holstein dairy cows in Minnesota found a herd lameness prevalence of 24.6% (range 3.3-57.3%) amongst cows in the high production groups on 50 farms (Espejo *et al*., 2006). The mean herd-level lameness prevalence was reported as 3.3% in tie-stalls and 7.5% in free-stall herds in a study of dairy cattle in Ontario (Cramer *et al*., 2008).

Further afield, a study in Iran on three differently sized dairy farms using a 5 point locomotion scoring system found 47.8% of 814 cows assessed to be lame in the autumn and 61.52% of 907 cows assessed on the same farms to be lame in the spring giving an average of 55.14% (Mohamadnia *et al*., 2008). Similar levels of lameness were reported in a Brazilian study where the cumulative prevalence of lameness caused by foot lesions in 1043 cows examined over an 18 month period was 50.2% (Cruz *et al*., 2001). In contrast a study in Australia utilising records from a 5-veterinary surgeon dairy practice over a four year period prior to 1987 found 2.5% of adult dairy cattle were treated for lameness per annum (Jubb and Malmo, 1991).

A number of factors may influence the different levels of lameness seen in dairy cows in these countries including management systems, breed differences and production intensity along with differences in the lameness scoring or other data collection procedures. It is clear however that lameness in dairy cattle exists as a concern throughout the world and research into risk factors, preventative

measures and effective treatment strategies are needed to reduce the impact of this disease.

1.1.3 Welfare and economic implications of lameness in dairy cattle

Lameness is considered to be one of the foremost welfare challenges affecting dairy cattle (FAWC., 2009) as a result of the combination of the level of discomfort caused and average duration of clinical episodes. Lameness represents a visible indicator of animal welfare with farm assurance schemes and media interest leading to and increased awareness of the problem amongst consumers (Archer *et al*., 2010).

Lameness may result as a consequence of pain from either infectious agents such as interdigital necrobacillosis or digital dermatitis initiating inflammatory pathways within limb or as a consequence of non-infectious lesions such as sole ulceration or white line disease. Studies have been conducted to demonstrate the association between pain and lameness, the results of which support the need for further research, especially into areas such as administration of pain-relieving drugs to lame animals. A case-control study conducted by Whay *et al*., (1998) used a nociceptive threshold test to determine the level of hyperalgesia shown in lame cows compared to non-lame cows. Hyperalgesia, an exaggerated sensitivity to pain, has been shown to be an effect of repeated constant intensity C-fibre stimulation which results in neurone responses increasing dramatically despite no change in stimulus intensity. Animals showing hyperalgesia therefore are experiencing a chronic pain stimulus, in this case from claw lesions leading to lameness. Whay *et al*., (1998) demonstrated that both unilaterally and bilaterally hind limb lame cows showed significant hyperalgesia compared with non-lame cows, matched on parity and stage of lactation. In some cattle in the unilateral lameness group, hyperalgesia remained significant at 28 days after treatment of the lameness causing lesion (the bilaterally lame group were not retested at 28 days).

As well as the welfare concerns, lameness also represents a significant economic loss to the dairy industry. The costs associated with lameness can be split into the direct costs such as the farmers time, cost of veterinary treatment and discarded milk which are apparent at the time of the event, and the indirect costs

that tend to be 'hidden' such as increased calving to conception intervals, increased risk of further lameness and reduced milk yield through the subclinical and recovery phases (Amory *et al*., 2008; Collick *et al*., 1989; Green *et al*., 2002). A study by Willshire and Bell., (2009) estimated costs in the UK, including treatment and detrimental effects on milk production and fertility, were around £76 for a case of digital dermatitis, £154 for a case of interdigital lameness, £514 for a case of sole ulceration and £300 for a case of white line disease.

1.2 Claw horn lesions in dairy cattle

Identification of the cause of lameness is important in the prevention and treatment of cases. The majority of lameness in dairy cattle appears to be associated with the foot. Studies in the 1980s and 1990s showed foot lesions to account for around 90% of all lesions with leg lesions above the pastern making up the remainder of cases (Rowlands *et al*., 1983; Russell *et al*., 1982; Jubb and Malmo., 1991). In a later study carried out by Clarkson *et al*., (1996), of the 6516 cows found to be lame, only 1% involved cows in which the lameness was associated with the leg rather than the foot. Studies have also reported a higher prevalence of lesions in the hind feet than the front feet (Russell *et al*., 1982; Cruz et.al., 2001; Sogstad *et al*., 2005a; Nguhiu-Mwangi *et al*., 2008; Olechnowicz *et al*., 2010). Manske *et al*. (2002) reported lesions approximately 2-4 times more prevalent in hind than front hooves. In contrast a post mortem study of 300 cattle in Iran showed no significant difference between the lesion prevalence in hindlimbs and forelimbs (Mohamadnia and Mohamadpour, 2003). The outer claws of the hind limbs are also more prone to lesions than the inner claws (Russell *et al*., 1982; Scott., 1980; Smits *et al*., 1992; Nguhiu-Mwangi *et al*., 2008). A study by Jubb and Malmo., (1991) of 653 mature female dairy cattle found 90.5% of lameness was caused by foot lesions, 69.2% of foot lameness was in the hind feet and 64.0% of hind foot lameness was in the lateral claw. Manske *et al*. (2002) also found that hoof lesions identified at routine claw trimming were more prevalent in lame than non-lame cattle demonstrating the link between macroscopic examination of lesions and their effect on locomotion.

In many areas of lameness, aetiology of individual diseases has surprisingly limited scientific understanding and is based on received wisdom unsubstantiated by experimental research (Huxley, 2012). In relation to claw horn lesions, an example of this is the theory that claw horn lesions result from an inflammation of the laminae and sinking of the distal phalanx, based on the model of laminitis in horses, which has been around for many years. This theory however has been difficult to reproduce experimentally with Tarlton *et al*., (2002) and(Knott *et al*., 2007) failing to identify signs of inflammation in the lamellae of claws with lesions. While the 'laminitis' aetiology has yet to be disproven claw lesions are no longer considered to be directly associated with

acidosis or inflammation of the laminae but rather an inflammation of the corium (Tarlton *et al*., 2002; Knott *et al*., 2007).

1.2.1 Anatomy and of the bovine foot

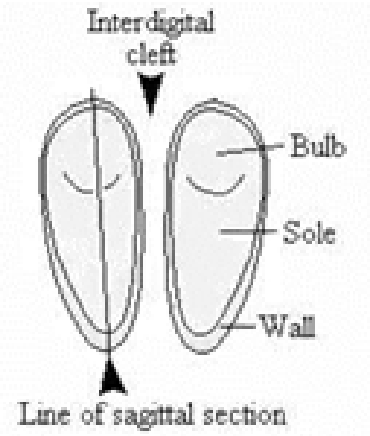


Figure 2. Palmar/plantar view of the medial and lateral claws of the bovine foot (University of Bristol, Department of Anatomy)

The bovine foot is divided into a medial and lateral 'claw' (see figure 2) in each of which the distal phalanx is suspended from the wall by the laminae and supported from beneath by the digital cushion (Lischer *et al*., 2002) (see figure 3). The forefeet carry 50-60% of the animals bodyweight and create lateral movement for flight while the hind feet generate forward propulsion (Hulsen., 2011). Weight is transferred to the distal phalanx via the middle phalanx with the force applied at the centre of rotation of the distal interphalangeal joint (Toussaint Raven., 1989). In the distal phalanx it may be resolved into a number of smaller forces applied to the corium. A ground reaction force is applied upward as the animal loads the claw and so the corium is under pressure between the distal phalanx and the horn of the sole. The distribution of weight over the two claws of one foot varies as the animal moves. Small lateral shifts in weight will cause a large relative increase in loading of the outer claw of the hindlimb (Toussaint Raven., 1989).

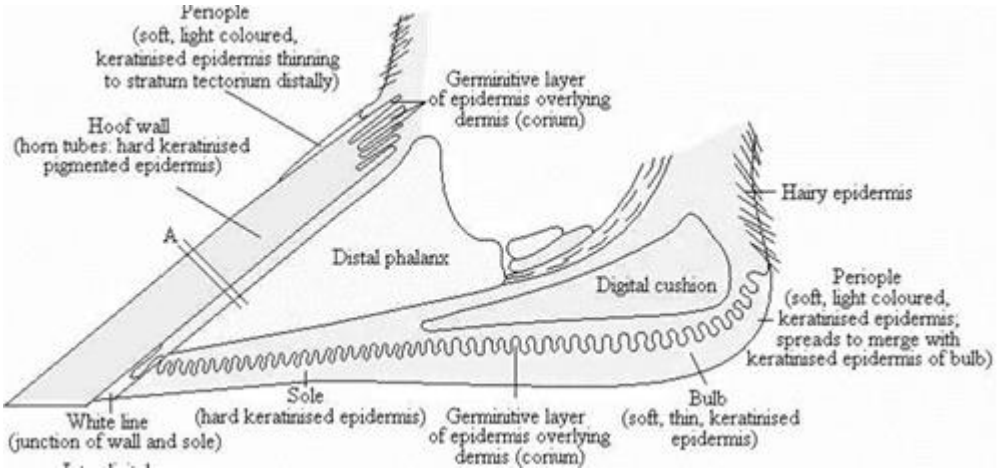


Figure 3. Lateral view of the bovine foot (University of Bristol, Department of Anatomy)

The claw capsule is composed of an inner layer of living cells and a thick layer of dead, cornified cells, the claw horn (Greenough, 2007). It forms at the coronary band (limbus or periople), a thin strip of soft tubular horn about 1.5cm wide between the skin of the pastern and the wall of the claw (see figure 3). The wall itself can be compared to the human nail (Toussaint Raven., 1989) with horn continuously formed at the coronary band by epidermal keratogenic cells (Greenough, 2007) and moving downwards until it is worn away on its weight-bearing border. Beneath the claw wall, the dermal laminae which are present exclusively in the wall region (Tomlinson *et al*. 2004), increase the surface area to which the suspensory apparatus of the digit is attached to provide nutritional supply via diffusion and good mechanical connection and stability (Greenough, 2007). Interdigitating dermal laminae and epidermal lamellae emerge at the ground surface as the white line (Greenough, 2007) (see figure 4.)

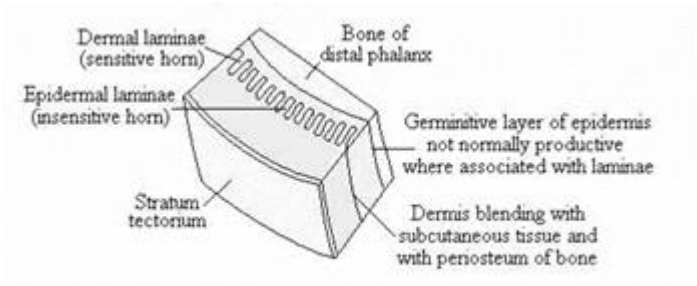


Figure 4. Dermal and epidermal laminae of the bovine claw wall (University of Bristol, Department of Anatomy)

The base of the claw is formed by the horn of the sole, which is softer than that of the walls (Toussaint Raven., 1989). The sole of the claw has a slightly hollow shape, its slope getting increasingly steeper toward the interdigital space. The average thickness of the sole in a normal, mature cow is approximately 5-7mm in the anterior region increasing to 15mm toward the heel (Greenough, 2007). This self-renewing layer is sufficient to withstand mechanical and chemical influences and protection against varying temperatures within certain limits (Toussaint Raven., 1989). To the rear of the sole lies a strip of thick horn referred to as the heel bulb or pad. This is the first structure to take concussive forces during locomotion (Greenough, 2007). The posterior and flexor aspects of the bulb are smooth and rounded and composed of soft and elastic rubber-like horn with papillae and small tubules distributed sparsely throughout the matrix (Greenough, 2007).

The dermis, also referred to as the corium, forms the supportive connective tissue layer for the epidermis, containing blood vessels and nerves (Tomlinson *et al*. 2004). From this layer, nutrients and hormones are provided to the stratum basal for the production of epithelial cells (Tomlinson *et al*. 2004).

Between the distal phalanx and the corium is a pad of fat and connective tissue, the digital cushion, that dissipates forces in the heel and under the distal phalanx during heel strike and limb loading (Raber *et al*. 2004). The digital cushion does not occur in every part of the claw and so in places the corium is immediately

adjacent to the distal phalanx (Toussaint Raven, 1989). The cushion consists of axial, middle and abaxial, roughly cylindrical pads, running parallel to the deep flexor tendon in the proximal heel segment. The digital pads are thick in the proximal non-weight bearing part of the heel segment but flatten out under the distal phalanx towards the toe (Raber *et al*. 2004). The middle pad continues apically to overlap the palmar/plantar edge of the distal phalanx approximately under the flexor process of the distal phalanx. It embeds in a thick, white oval capsule of densely woven connective tissue that merges with the insertion point of the deep flexor tendon so that the transition between the two is not discernible (Raber *et al*. 2004). The suspensory apparatus in cattle is much less well developed than in the horse where a large proportion of the body weight is carried by the suspensory apparatus attached to the hoof walls and only a small load rests on the sole and heel segment (Raber *et al*., 2004). As a result, the digital cushion must support a considerably greater proportion of body weight.

The average length of the dorsal surface of the claw of an adult female should be about 7.5cm (Greenough, 2007). For practical purposes, the claw grows at the rate of 0.5cm per month however this rate may increase during summer months and in young animals and in animals maintained on a higher plane of nutrition (Greenough, 2007). As the wall grows it is pushed towards the tip of the toe.

Horn quality and resistance against destructive environmental influences depends on the number of horn tubules and their medulla / cortex ratio (Greenough, 2007). In the wall the mechanical stimulus for increased proliferation and subsequent horn production is created by direct tensile force. On the sole of the claw, pressure is transferred via the epidermis to the basal cell layer, stimulating proliferation of cells and thereby accelerating the production of horn (Greenough, 2007).

The load on the inner hind claw is much more even. As a result of this greater stresses are likely to be placed on the outer claw irritating the corium and increasing tissue activity. Hypertrophy of the outer claw results in an even greater proportion of weight being borne on this claw and a cycle of hypertrophy and overloading, increasing the risk of lesions (Toussaint Raven.,1989).

1.2.2 Aetiology and pathogenesis of claw horn lesions

The aetiology and pathogenesis of claw horn lesions in dairy cows is not fully understood, however it is thought that many of the biological and management changes associated with their development occur concurrently at or around the time of calving (Tarlton *et al*., 2002; Raber *et al*., 2004; Knott *et al*., 2007). This transition period carries a particularly high risk due to increased stresses placed on the animal related to physiological changes, social factors and changes in housing. Mechanical load also has to be considered as a predisposing factor at this time, increasing disproportionately to the bearing surface of the claw due to rapid weight gain of the udder and foetus (Raber *et al*, 2006).

Due to the time taken for damaged horn to travel from the corium to the sole surface, lesions and the lameness they cause are not immediately obvious. Hernandez *et al*., (2005) found that 60% of lameness in dairy cattle occurred within the first eight weeks of lactation, Sogstad *et al*., (2007) identified claw lesions at two to three months postpartum and Knott *et al*., (2007) found evidence of sole haemorrhage at 12 weeks postpartum.

Work has also demonstrated that lameness in heifers leads to increased lameness events in future lactations. Deterioration in claw heath during the first lactation, cumulative effects of claw lesions between lactations and high recurrence of lameness makes prevention of lameness in heifers vital to maximise longevity of animals within the lactating herd (Manske *et al*., 2002). In a study by Maxwell *et al*., (2015), 95% of dairy heifers trimmed at 50-80 days postpartum had some pathology on at least one claw. Randell *et al*., (2016) reported that heifers with severe lesions in the first two to four months postpartum had an increased risk of future lameness.

1.2.2.1 Sole ulceration

Lesions seen in lame animals associated with sole ulceration vary from mild haemorrhage in the claw horn to large defects exposing the sole corium. Sole haemorrhage may occur following damage to the corium distal to the flexor tuberosity of the lateral distal phalanx. If the condition does not progress the area of horn produced during this event will grow toward the sole surface and be evident as red blood cells released from the corium incorporated in the horn

(Mahendran and Bell, 2015). Sole ulcers are a result of repeated or continuous injury to the germinal cells within the corium of the sole as a result of compression by the palmaro/plantaro-distal edge of the distal phalanx (Greenough., 2007). This injury results in chronic inflammation and disrupted horn growth leading ultimately to pathological exposure of the corium on the sole of the claw. This may take many weeks or months after the initial inciting factor. Sole ulceration classically appears several months after calving.

Several factors have been identified which may increase the risk of sole ulceration. A disruption of the suspensory apparatus, the structures of the corium linking the bone to the claw wall, may be seen around the time of calving linked to the release of the hormones. Release of oestrogen and relaxin at calving is thought to have systemic effects with oestrogen having anabolic effect on connective tissue metabolism while relaxin increases laxity of connective tissue (Tarlton *et al*, 2002). Enzyme matrix metalloproteinase-2, involved in homeostatic remodelling of elastin and collagen within the hoof, is also found in increased levels in period around calving leading to laxity in hoof support structures (Knott *et al*., 2007). The relaxation of ligaments within the claw capsule leads to movement or descent of the distal phalanx causing increased pressure on the germinal cells of the corium during weight bearing. The longer interdigital ligament supporting the axial side of distal phalanx is thought to allow greater depression of this aspect of the flexor tuberosity during loading than the shorter abaxial ligaments potentially leading to greater compression of the corium at the sole ulcer site (Lischer *et al*., 2002). Contusion is worsened by inflammation within the claw capsule and standing on concrete surfaces (Leonard *et al*., 1996).

Recent research has also suggested the digital cushion plays an important role in the pathogenesis of lameness (Raber *et al.*, 2004). It has been seen that the content of the fat pad changes with age, heifers having a digital cushion comprised largely of loose connective tissue which then fills in with monounsaturated fats in second and third parity cows. Alterations in the digital cushion due to metabolic stress may also be seen at calving and in early lactation with thickness decreasing from calving to four months postpartum (Bicalho *et al*., 2009). Negative energy balance around calving and early lactation leads to

mobilisation of body fat stores including those in the digital cushion. This reduction in fat content reduces its effectiveness in protecting the internal structures of the foot, claw lesion formation in thin cows. Randall *et al*., (2015) demonstrated a significant link between body condition score (BCS) and lameness with cows with a BCS < 2 at greatest risk of mild or severe lameness. Green *et al*., (2014) found that BCS < 2.5 was associated with increased risk for lameness treatment in the next 0-2 months and >2-4 months for sole ulceration and white line disease and increased risk in next 0-2 months for sole haemorrhage.

Changes in the shape of the distal phalanx around the flexor tuberosity are also thought to increase the risk of sole ulceration. Changes have been seen to occur with increasing age with new bone formation developing around the insertion of the flexor tendon (Blowey *et al*., 2000; Lischer *et al*., 2002; Newsome *et al*., 2016). This increased area of bone may exacerbate forces applied to the corium beneath the flexor tuberosity, increasing the risk of sole ulceration. Newsome *et al*., (2016) demonstrated that bone development on the caudal aspect of the distal phalanx at slaughter was specifically associated with the lifetime occurrence of chronic claw horn lesions.

Other factors affecting claw shape are recognised as risk factors for sole ulceration. Wear from concrete surfaces can lead to flattening of the sole surface, increasing the contact area with the floor and increasing pressure on the sole ulcer site. Loss of heel horn associated with standing in wet conditions on concrete or the lever action from overgrown toes can also lead to increased weight bearing through the caudal structures of the foot. Long toes can place greater strain on the flexor tendons leading to increased exostosis of the distal phalanx, further increasing the risk of damage to the sole corium (Telezhenko *et al*., 2008)

Management of sole ulceration is based around improving cow lying comfort and reducing the standing times on concrete in order to relieve the pressure exerted by the distal phalanx on the corium. Expert foot trimming on a routine basis to restore foot angle and reduce overloading at the sole ulcer site is also advised (Archer *et al*., 2010).

1.2.2.2 White line disease

The white line is a term used to describe the horn that joins the claw wall and the sole. The aetiology of white line disease is poorly understood but is thought to be caused by a breakdown of this junction allowing foreign material to track into the white line.

The mechanical strength and quality of hoof horn is directly related to the dimensions of the tubules, i.e. the diameter and proportion of medulla and cortex and therefore, the arrangement and spatial relationship of tubular, intertubular and laminar horn cells (Tomlinson *et al*. 2004). In the white line, large horn tubules with a wide medulla establish sites of predisposition for bacterial invasion (Tomlinson *et al*. 2004). Once the medullary horn has fallen out, microorganisms may invade the tubule, start horn cell destruction, and ascend within the tubule toward the inner living tissue layers. Once the bacterial invasion reaches the dermis, white line abscesses and wall separation can develop (Tomlinson *et al*. 2004). White line horn quality may be compromised by stresses that occur around the time of calving or by haemorrhage (bruising) in the white line itself (Barker *et al*., 2009). It is also thought that physical shearing forces associated with rapid acceleration or walking on uneven surfaces may also affect the quality of the horn in the white line. Soft horn may be at greater risk of damage due to shearing forces leading to haemorrhage within the white line. Cows that are out at pasture during the day and housed at night may be exposed to wet climatic conditions which soften the horn before exposure to uneven walking surfaces and loose stones and concrete floored housing, all of which my increase the risk of white line disease in these animals (Archer *et al*, 2010). Maintenance of good cow tracks, minimising standing times, ensuring smooth cow flow and not rushing cows is therefore vitally important in the prevention of white line disease.

1.2.3 Prevalence of claw lesions.

Claw lesions represent a concern in many dairy herds. In the first report of lesion prevalence across multiple herds and management systems in North America, Cramer *et al*. (2008) recorded the lesions found in 13,530 individual cows in 204 herds over a 15 month period. In tie-stall systems 88% of herds were found to

have infectious lesions and 92.3% horn hoof lesions. In free stall herds this increased to 92.1% with infectious lesions and 100% with hoof horn lesions, clearly demonstrating the scale of these conditions. A study of 383 dairy farms in the Netherlands between May 2002 and December 2003 looking at lesions on the hind claws of 22,454 cows found approximately 45% of herds had a within-herd prevalence of sole ulcers of between 1 and 5% (Holzhauer *et al*., 2008) while a study in the Netherlands identified 85% of the 385 herds examined to have individual cows with sole ulcers (Holzhauer *et al*., 2008). A summary of herd level lesion prevalence is shown in table 3.

Table 3. Herd level prevalence of foot lesions reported by two recent studies

Lesion	(Cramer *et al*., 2008)		(Capion *et al*., 2008)
	Tie-stall	Free-stall	
Infectious lesions	17.9%	32.9%	
Heel horn erosion	10.2%	12.1%	53%
Digital dermatitis	9.6%	24.4%	19%
Interdigital dermatitis			27%
Interdigital hyperplasia			5%
Foot rot	0.3%	0.0%	
All hoof horn lesions	13.1%	27.0%	
Haemorrhage	7.5%	11.2%	57%
Ulcers	5.1%	12.5%	6%
White line separation	1.0%	5.8%	6%
White line abscess	0.6	2.2	0.6%
Double sole			5%

At the individual cow level, a study in Ontario examined 13,530 cows and found 15.8% and 12.2% of cows in tie-stalls and 29.3% and 23.3% of cows in free-stalls to have infectious and hoof horn lesions respectively (Cramer *et al*., 2008). High levels of lesion prevalence were also identified in dairy cows undergoing annual foot trimming on three farms in Turkey. Of the 1190 cows examined, 89.8% had lesions, the majority of infectious aetiology but with sole ulcers accounting for 3.6% of lesions (Kilic, 2004). A post-mortem examination of 300 cattle in Iran found a lesion prevalence of 70.7% in Holstein cattle, 63.6% in cross breed cattle and 22.7% in native breeds. In Holsteins, 93.2% of lesions occurred in the sole region with under-run soles the most prevalent, significantly higher than the second most prevalent lesion of white line separation in this breed (Mohamadnia and Mohamadpour, 2003). It should be noted however that digital

dermatitis was grouped under lesions of the sole region in this study and therefore separating figures for lesions with infectious and non-infectious aetiology is not possible. Table 4 provides further breakdown of the percentage prevalence of different foot lesions found across a number of studies.

Table 4. Cow level prevalence of foot lesions reported in studies conducted worldwide between 1974 and 2003.

Number of cows	Number of herds/ farms	Date of study	Study / location	Persons treating	Cow level prevalence (%)												Reference
					Digital dermatitis	Interdigital dermatitis	Sole ulcer	Sole haemorrhage	White line disease	Heel horn erosion	Interdigital necrobacillosis	Interdigital hyperplasia	Under-run heel	Punctured / pricked sole	Under-run sole	Deep sepsis	
13,588	150	Aug 1974 – July 1975	Somerset, England, United Kingdom	6 person vet practice			11.4		separation 10.7; abscess 24.2		14.3	1.7	1.9	20.4			(Eddy and Scott, 1980)
136,800	1821	1977	England, Wales and Scotland, United Kingdom	146 vets, 48 practices			12.0		separation 4.2; abscess 13.8		14.7	4.2	7.7	9.2		3.1	(Russell *et al*., 1982)
5,854 foot and leg lesions		1977	England and Wales, United Kingdom	20 vet practices			12.0		separation 4.4; abscess 12.2		15.8	4.2	6.8	10.7		3.9	(Rowlands *et al*., 1983)

625		1981 - 2006	Nairobi, Kenya. Cases admitted to university hospital.	University Large Animal Hospital			2.3				36	12			11	5	(Nguhiu-Mwangi *et al*., 2008)
653		Feb 1987 to July 1988	Australia	2 vets in 5 vet dairy practice			4.0		7.2		13.0			2.9	14.6	6.4	(Jubb and Malmo, 1991)
	34	Mar/ Apr 1990	Eastern Netherlands. Zero grazing herds	routine claw trimming	17.6		5.5		widening 7.6			8.8			4.9		(Smits *et al*., 1992)
4899	101	Oct 1996 - May 1997 + Sept 1997 - June 1998	Sweden	trained technician or authors	2.3	27	8.6	30	haemorrhage 14; fissure 8.8	41		1.8			3.3		(Manske *et al*., 2002)
1,043	4		Brazil		29.9	17.8	18.3		5.3	4.5	2.4	10.4			10.7	0.7	(Cruz *et al*., 2001)
1,900 (1,547 cows, 403 heifers)	57	Jan 2002-summer let out	Norway. Norwegian Red dairy cattle in free stalls	13. professional claw trimmers	6.7 Hind claws only		3.0 Hind claws only	20.0 Hind claws only	haemorrhage 13.6; Fissures 9.4 Hind claws only	39.6 Hind claws only							(Sogstad *et al*., 2005a)

2665 (1118 tie-stalls, 1547 free-stalls)	112 (55 tie-stalls, 57 free-stalls)	1st Jan 2002 - 28th June 2002	Norway. Norwegian dairy cattle	14 professional claw trimmers	Tie-stall 4.2; Free-stall 5.7		Tie-stall 2.8; Free-stall 3.2	Tie-stall 11.7; Free-stall 20.4	haemorrhage Tie-stall 7.3; Free-stall 13.6 fissures Tie-stall 5.5; Free-stall 9.7	Tie-stall 7.9; Free-stall 38.0							(Sogstad *et al*., 2005b)
6,240	55	Winter 2002/3	Denmark. Primarily Danish Holstein cows loose housed	4 professional claw trimmers.	22	25	6	59	lesions 6; disease 1% (fissure with abcess/ multliple lesions)	54		6	6				(Capion *et al*., 2008)
13,530	204	Mar 2004-May 2005	Ontario, Canada Cross sectional study	5 professional hoof trimmers	Tie-stall: 9.3 Free-stall: 22.9		Tie-stall: 4.7 Free-stall: 9.3	Tie-stall: 7.1 Free-stall: 11.1	Tie-stall: separation 1.0 abscess 0.6 Free-stall: separation 5.2 abscess 2.0	Tie-stall: 8.3 Free-stall: 8.4	Tie-stall: 0.2 Free-stall 0.2					Tie-stall 0.0 Free-stall 0.2	(Cramer *et al*., 2008)

1,330	11	May 2003 - May 2004	Poland Polish Holstein-Fresian cattle	professional claw trimmers		6.7	11.8	6.9	3.5								(Olechnowicz *et al*., 2010)
22,454	383	May 2002-December 2003	Netherlands. Cross sectional study, Dutch dairy cattle	28 professional foot trimmers			5.6										(Holzhauer *et al*., 2008)

It should be noted that the inter-relationship of claw lesions and lameness prevalence is not clear-cut. In a study by Manske *et al* (2002), the prevalence of hoof lesions and lameness was recorded at hoof trimming in 4899 cows on 101 randomly selected Swedish dairy farms. The study found 72% of all animals (range 25-98% across farms) had at least one hoof lesion however the prevalence of lameness was only 5.1% (range 0-33%) suggesting that most hoof lesions did not cause lameness in this study. Equally it is possible that animals can show impaired locomotion as a result of other, non-painful factors such as conformation or factors associated with pregnancy and milking such as altered gait due to the presence of a full udder (Chapinal et al., 2008). Further research is needed to assess the threshold at which cows become lame with hoof lesions and the implications of this on early diagnosis and treatment of lesions.

1.3 Treatment of claw horn lesions in dairy cattle

Much of the work relating to veterinary management of claw horn lesions in dairy cattle has concentrated on future prevention through exploration of risk factors for lameness at individual cow and herd level. There is however very little information available in the literature regarding appropriate treatment of lesions once they have been diagnosed.

Potterton *et al*., (2012) undertook a review of the peer and non-peer reviewed literature on treatment and prevention of foot lameness in cattle between 2000 and 2011. Three reference databases (Ovid SP (Wolters Kluwer Health), PubMed (National Centre for Biotechnology Information) and Web of Science (Thomson Reuters)) were searched using previously published search terms for lameness in cattle plus (mobility and score) and (digital cushion) finding 284 relevant scientific papers. Two hundred and fifty-eight of these (91%) contained information on lameness prevention while only 31 were found on treatment. Of these 27 related to treatment of digital dermatitis, an infectious skin condition, three related to treatment of sole ulceration and none to treatment of while line disease. Further, a review of the non-peer reviewed literature (23 text books, 6 lameness control plans and 17 'other' sources such as information sheets and training manuals) showed some texts directly contradicting each other in relation to treatment of claw horn lesions with the only recommendation common to all being that of therapeutic trimming.

1.3.1 Therapeutic trimming for treatment of claw horn lesions

While the recommendation of therapeutic trimming for treatment of claw horn lesions was common to all texts reviewed by Potterton *et al*., (2012), even here implementation of the procedure may vary. In a study carried out by O'Callaghan Lowe *et al*., (2004), 156 veterinary surgeons and 68 cattle foot trimmers completed a questionnaire investigating their working practices when dealing with lame cows. While the majority of the foot trimmers (57 of 68, 89%) always used the 'Dutch' method of trimming less than half of veterinary surgeons (58 of 156, 47%) always used this method with 35 veterinary surgeons stating they were unfamiliar with this technique. Despite this, the 5-stage method of claw trimming described by Toussaint Raven (1989) is generally

accepted as the definitive intervention for lameness management in the UK (Mahendran and Bell., 2015).

Toussaint Raven's 5-stage claw trimming method, developed in the Netherlands and hence becoming known as the 'Dutch' method, describes the purpose of trimming as cutting and paring the claw in order to make them function as well as possible. An excessively long claw wall causes the claw to tilt axially and backwards placing more weight on the axial part of the heel bulb and less on the claw wall. A 16% increase in weight bearing on the lateral claw can be seen due to overgrowth which along with the caudal shift in weight distribution places more pressure on the site predisposed to sole ulcers. Functional claw trimming distributes the load evenly between both claws to avoid this pressure overload which can also lead to increased horn production and enlargement of a region resulting a vicious cycle (Greenough, 2007). The aim of correct trimming is therefore to create a better division of weight within the claw and a better distribution of weight over the two adjacent claws (Toussaint Raven. 1989). Artificially removing horn from the sole during routine trimming also increases pressure on keratogenic cells, stimulating the production of healthy horn (Greenough, 2007) and balancing wear (Vermunt., 1999). The five stages of the 'dutch' method of foot trimming are summarised in table 5.

Table 5. The 'Dutch' five step trimming method. (adapted from Mahendren and Bell., 2015)

Procedure	
1	Assess the dorsal wall length from where the hard horn wall begins (starting with the medial hind-claw or lateral fore-claw) and trim to correct length, typically 75-80mm for Holsteins. Reduce the sole depth at the toe to approximately 5-7mm until the continuity of the white line is restored. The heel and axial wall must not be trimmed unless pathologically overgrown
2	Correct the dorsal wall length and sole depth for the other claw (lateral hind- or medial fore-claw), judged using the correct length and levels of the first claw. Create balance at the toe and heel using the levels taken from the plane of the stable toe triangle on the first claw.
3	Model the foot at the sole ulcer predisposition site by dishing-out to create a concave area
4	Lower the heel of the painful claw and place a block on the sound claw to reduce weight bearing through the unhealthy claw
5	Remove any loose or underrun horn and hard ridges to reduce the risk of slurry and dirt becoming lodged. Loose and underrun horn associated with sole ulcers and white line disease can be removed at this stage using local anaesthesia where appropriate.

A study by Montgomery *et al*., (2012) investigated the efficacy of the five-stage method of claw trimming for treating lame cows. Three hundred and six new cases of lameness identified by stockmen in four Cheshire dairy herds and associated with claw horn disruption were treated by a para-professional claw trimmer. Where it was not possible to unload the affected claw through trimming, a wooden block was applied to the non-affected claw and removed six weeks later. Both claws of the contra-lateral limb were also treated. Cows were assigned a locomotion score prior to trimming and again seven days later by the principle investigator. It was found that trimming reduced the proportion of lame cows by 55% and those with poor gait by 49%. The results of this study suggest the theoretical science behind the 'Dutch' method of trimming is indeed effective both in cows presenting with lameness (in this study attributed to the presence of sole ulcers and white line disease) and those with poor gait (attributed to the presence of sole haemorrhage and bruising) with a significant improvement in lameness over a seven-day period. It should be noted however there was no control group in this study to compare locomotion score at day zero and day seven in cows that had not received a five-stage trim. In contrast a study in sheep (Kaler and Green., 2009) found that routine foot trimming was significantly associated with an increase in lameness prevalence. This may be a reflection of the different diseases affecting sheep and skill of the trimmers working with this species, but emphasises the need for further robust research into foot trimming for treatment of lame cows. While functional claw trimming has been reported to reduce both the prevalence of lameness and the duration of clinical cases however it has also been seen that incorrect trimming can actually create lameness problems (Vermunt, 1999). Over-trimming or an unbalanced trim due to poor technique may lead to pain and pressure points in the foot and actually result in the development of claw lesions. An abattoir survey of cadaver bovine feet (Burgi and Cook., 2008) demonstrated a high degree of imbalance in feet that had received routine trimming. The study also found inappropriate removal of weight bearing parts of the hoof wall and over-shortening of the dorsal wall in some feet which could reduce the protective function of the hoof structure and result in injury or disease.. Appropriate training of farmers and foot trimmers in the correct technique and timing of foot trimming is therefore essential to ensure greater damage is not produced.

1.3.2 Additional treatments for claw horn lesions

Advice given in the non-peer reviewed literature on additional treatment of claw horn lesions following a therapeutic trim varies widely (Potterton *et al*. 2012) with little scientific evidence to support clinical decision making. When carrying out a review of the peer-reviewed literature between 2000 and 2011, Potterton *et al*., (2012) found only three out of 284 relevant scientific papers related to treatment of claw horn lesions.

The first paper was a retrospective study in Kenya which examined the outcomes of treatments applied to 625 cows with foot conditions admitted to the University of Nairobi Faculty of Veterinary Medicine Large Animal Hospital between 1981 and 2006 (Nguhiu-Mwangi *et al*., 2008). Treatments applied depended on the nature of the foot condition although all treatments began with cleansing using soap and water and hoof trimming. Results showed that for the conditions which affected less than 5% of the 625 cases (including sole ulcers and double soles) all of the cows healed. For sole abscesses, 92.9% of cows affected were healed following treatment with 7.1% not healed. No time scales for recovery were given. As the cases reported in this study were only those admitted to the veterinary hospital and not those seen by the ambulatory service it is likely they represent more severe cases rather than a cross-section of the lesions seen in dairy herds. The full treatment protocols were also not described nor were the recovery periods making the information of limited use for clinical decision making.

The second paper reported on 42 cases of sole ulcers in Turkish dairy cattle (Durmus, 2005). All cattle were treated with a combination of foot trimming including paring of any under-run sole adjacent to the ulcer, a wet antiseptic dressing applied locally and a seven-day course of parenteral broad spectrum antibiotics. The study found that most cases recovered within 4 to 5 months though no exact figures were given. No control animals were used. As sole ulcers are a non-infectious condition it is difficult to understand the rational for treatment with both a wet antiseptic dressing and parenteral broad-spectrum antibiotics. The study also reported only three animals suffering from severe lesions where the corium was severely damaged and necrotic tissue seen. In the

remaining cases ulceration was only slight or moderate (11 and 28 cases respectively). No evidence of bacterial infection was reported which would suggest the use of antibiotics was for prophylactic purposes only. The lack of control animals makes it impossible to know whether the antibiotic use had any effect on healing rates and the results do not specify which of the lesions (mild, moderate or severe) had failed to heal at 4 to 5 months post treatment. It is therefore difficult to gain any useful information on the most effective treatment protocols from this report.

The final Swiss study looked at the effect of therapeutic dietary biotin on the healing of uncomplicated sole ulcers (Lischer *et al*., 2002). Twenty-four cows with mild pathological changes associated with sole ulcers were examined for clinical and histological changes in a double-blinded, placebo controlled clinical trial taking place over a 50-day period. Cows all received a functional foot trim followed by removal of all loose and defective horn to create a circular defect with a 2cm radius area around the lesion. A foot block was fitted to the non-affected claw and the cows bedded on straw. Twelve of the cows were supplemented with 40 mg of biotin per day. The biotin supplementation had no significant difference on the degree of lameness with almost all individuals free of lameness at the end of the study. Short term healing was assessed as being somewhat worse in the biotin-supplemented animals than the placebo however the microscopic structure of the horn at the end of the study was improved in the biotin-supplemented group. While this study provides some interesting findings in regard to nutritional supplementation for improvement of horn quality in a healing lesion, all the cows received the same treatment in regard to having a foot block fitted and being bedded on straw and so little can be drawn from this study in regard to further treatment options.

These three studies, all undertaken outside of the UK, fail to provide information which may be of use in clinical decision making on the treatment of claw lesions in dairy cattle. It is clear therefore from the Potterton *et al*., (2012) review that much of the clinical decision making when treating claw horn lesions must be based on anecdote and experience of those publishing non-peer reviewed literature. This information is not necessarily incorrect but has never been tested

in clinical trials for efficacy. Also where information between sources is contradictory there is no robust scientific research to guide the clinician.

A wider examination of the peer-reviewed literature using the same search terms but extending the publication period, revealed two further studies relating to treatment of claw horn lesions of a more clinical nature. The first, a clinical trial of treatments for foot lameness in dairy cows, was carried out between August and December 1994 at an Australian veterinary clinic (Pyman, 1997). 112 cows from 30 herds (78% Friesian, 21% Jersey) presented as part of the normal case load at the veterinary clinic were enrolled on the study, cows that had received previous treatment with a device applied to the affected foot or with lameness in more than one digit were excluded. Cows were considered eligible if diagnosed with axial wall cracks, sole ulcers, white line disease, under-run soles or punctured soles and were allocated at random one of three treatments, a cotton wool pad with copper sulphate crystals bandaged to the foot, a wooden block attached with methylmethacrylate adhesive or a commercially available rubber shoe. The data from the first 90 cows was analysed and the remaining 22 cows randomly allocated either a block or rubberised shoe as the results showed elevation of the claw to be a superior method of treatment to bandaging. Lameness was assessed by the herd manager on a scale of one to three at the time of treatment and days 1, 3, 7 and 14 after treatment. The study found a significant difference in lameness between blocks and rubber shoes compared to bandages at days 3 and 7 with the block and shoe providing a more rapid return to normal gait. At 14 days post treatment there were no significant differences between the three treatments. There were no statistically significant differences between recovery rates in cows treated with block and shoes although the shoes were significantly easier to apply and also significantly more likely to remain attached than the blocks.

A further clinical trial (Laven, 2008) saw 149 cows on nine dairy farms (two farms predominantly Jersey cows, the remainder predominantly Friesian) in New Zealand that were identified as lame by farm staff examined by one of four veterinary surgeons for claw lesions. Animals with infectious foot disease were excluded. Locomotion scores and nociceptive threshold measurements were made by one of two operators using a 5-point scale for locomotion and a

pneumatically actuated blunt pin, 2mm in diameter, applied to the dorsal metatarsus to measure the pressure applied before the animals produced a nociceptive response. Lesions were divided into three categories, white line lesions, sole lesions and other and treatment applied in the form of corrective hoof paring focusing on drainage of abscesses, removal of under-run horn and reduction of weight bearing on the primary lesion site. An assessment was then made to ascertain whether the affected claw could be trimmed sufficiently to reduce weight bearing on the lesions or if the animal required application of a plastic orthopaedic shoe to the non-affected claw to achieve this. Forty-four percent of cattle examined were considered to need a plastic shoe. Those that didn't require a shoe at examination were then randomly treated with a plastic shoe, a non-steroidal anti-inflammatory drug (NSAID) Tolfenamic acid, a combination of a plastic shoe and Tolfenamic acid or received no further treatment following the corrective trim. If the cow, because of the site and/or extent of the lesion required the application of a plastic shoe, it was then randomly allocated either an injection of Tolfenamic acid or no further treatment. Locomotion and nociceptive measurements were taken on days 3, 8, 28 and 100 after treatment.

The study found that at each time point there was a significant improvement in nociceptive threshold and locomotion score compared with the previous time point with the nociceptive threshold on day 100 significantly higher and the locomotion score significantly lower than on any other day. While all groups showed improvements over time though, there were no significant differences between the treatment groups in either nociceptive threshold or locomotion score over the 100-day outcome period.

While these two clinical trials provide some information with regard to efficacy of treatments, in the Australian study (Pyman, 1997) cases were only followed for 14 days post treatment with lameness assessment conducted by the herd manager who would not be blind to the treatment used. The results of this study must therefore be interpreted with caution. The New Zealand study, while more comprehensive, relied on the opinion of the treating veterinary surgeon as to whether the position and/or extent of the lesion required application of a foot block to the non-affected claw before further treatment was randomised which

may have led to bias in the results obtained. It also relied on the identification of lame animals by farm staff rather than by locomotion scoring the whole herd as part of the study so it is possible animals were missed or identified at a later stage of disease (see section 1.3.3) impacting the findings of the study.

The decision to test administration of a NSAID in the Australian study is interesting as a survey of cattle veterinary practitioners in the UK (Huxley and Whay, 2006) found that of 252 respondents only around a third (32.9%) stated that they would use NSAIDs in more than 50% of cases of sole ulcer they saw in clinical practice. In total 75.6% stated they would use analgesia with 22.3% stating they would use alpha-2 agonist drugs and 20.4% stating they would use local anaesthetic in more than half of the cases seen. This is despite a mode score of 7 (range 1-10) being given to sole ulcers when respondents were asked to rate the severity of pain associated with sole ulcers on a scale of one to ten, suggesting that they believed sole ulceration to be a painful condition. Laven *et al*., (2008) found no significant differences between treatments in either nociceptive threshold or locomotion score over the 100-day outcome period revealing no evidence that use of a tolfenamic acid, had a significant long-term benefit to nociceptive threshold above that of a therapeutic trim. This is in contrast to a study undertaken to investigate the role of ketoprofen in the modulation of hyperalgesia associated with lameness (Whay *et al*., 2005). Here forty lactating dairy cows with a unilateral hindlimb lameness detected using locomotion scoring were randomly allocated either a three-day course of the NSAID ketoprofen at a dose of 3mg/kg or administration of the same volume of 0.9% sterile saline. All cows mechanical nociceptive threshold was tested prior to administration of ketoprofen or sterile saline as a baseline and one hour later to assess the effect of the drug alone. Each cow then received conventional treatment for the lesion including foot paring plus antibiotic therapy or application of a foot block as necessary. The cows received the second and third doses of the drug or placebo at 24 hour intervals and their locomotion and nociceptive thresholds were measured on days 3, 8 and 28. As with the findings of Laven *et al*., (2008), Whay *et al*., (2005) found no effect of the drug on locomotion score however the nociceptive thresholds of the 20 cows that received ketoprofen had increased significantly on days 3, 8 and 28. Whay

suggests that locomotion scoring may not be sensitive enough to detect the modulation of hyperalgesia that was detected by the nociceptive threshold tests. It is also possible that the mechanism of action of these two NSAIDs differs in their effect on lame cows resulting in the differences seen between these studies. It is clear from these studies that the use of NSAIDs for modulation of hyperalgesia in lame cows and long-term pain relief is an area which requires further research to guide clinical decision making on appropriate treatment protocols.

In the study by Laven *et al*., (2008), raising of the affected claw was achieved through application of a plastic shoe (Cowslip, Dairystar Ltd, Auckland, NZ) while Pyman trialled both hardwood foot blocks attached with methylmethacrylate adhesive and cowslip shoes (referred to as rubber shoes in this instance). Pyman found that the rubber/plastic shoe was significantly easier to apply based on a three-point scale assigned by the operator at the time of treatment and was also significantly more persistent than the blocks with 88.1% of shoes remaining attached at day 14 compared with 51.3% of blocks and 57.1% of shoes remaining attached at day 30 compared with 30.8% of blocks. The persistence of these shoes is supported by Blowey *et al*., (1999) describing the fate of 90 cowslips applied to lame cows by one practitioner in general veterinary practice. Seventy-nine shoes (88%) were applied to hind feet with 53 of these (67%) applied to the medial claw. A total of 41 (45%) fell off naturally with a mean survival of 71.3 days with a further 39 (43%) taken off after a mean interval of 97.8 days. It is possible that different foot blocks have a different effect on claw health due to differences in weight transfer through the wall and sole of the hoof. The effect of raising the painful claw from the ground though applies to all blocks fitted to the non-affected claw and so while further investigation of weight distribution may be useful, the practicality of use my ultimately have most influence on the choice of design.

In the clinical trials described by Pyman, (1997) and Laven *et al*., (2008) animals received the same treatment protocols regardless of the lesion diagnosed. This seems to be normal practice in the treatment of claw horn lesions. In a survey of UK dairy farmers (Horseman. S, 2013), respondents rarely differentiated between sole ulcer and white line disease when describing their treatment

methods. Thirty-seven percent of farmers questioned discussed treatments for sole ulceration and white line disease together while 19% discussed them separately but ultimately described a process which was fundamentally the same in each case. A further 13% of farmers when prompted indicated that they performed the same procedures for both conditions. This finding is significant as these lesions have different aetiology and so may respond differently to individual treatments. Further investigation of the efficacy of treatment for different claw lesions is required to determine if this single approach is appropriate.

Despite these two trials, evidence to support the use of a foot block in treatment of claw horn lesions remains limited. While Pyman showed the elevation of the claw was more effective than a cotton wool pad with copper sulphate crystals bandaged to the foot, no control group was used in this study to determine whether the application of the foot block was any more effective than a minimal treatment intervention (corrective trim) or indeed no treatment at all. In the study by Laven *et al*., (2008) the benefit of elevation of the affected claw was assumed through application of a foot block to all cows where it was not felt the affected claw could be trimmed sufficiently to reduce pressure on the lesion. This additional treatment therefore reduces the impact of the randomisation of treatment to the remainder of the cases as the effect of not elevating the claw in these cases was not investigated. In a survey of UK veterinary surgeons and cattle foot trimmers conducted in 2001 by O'Callaghan Lowe *et al*., (2004), it was found that foot trimmers used foot blocks with greater frequency than veterinary surgeons although both groups encountered similar claw horn lesions. The use of footblocks therefore seems to be generally accepted as an effective treatment for claw lesions through there is no scientific evidence to support this. The findings of Laven *et al*., (2008) would suggest that this is an unnecessary cost yet the author assumed application was necessary in some cases as part of the study design. It is clear more research is required on the use of foot blocks in order to provide appropriate guidance on their use.

It is also worth noting that the more extensive management systems and associated claw lesion diseases in Australia and New Zealand may be very different to those seen in intensively managed herds in the UK and Europe.

Breed may also have an effect with the cows in these studies predominantly Jersey or Friesian whereas in the UK Holstein cattle are common in dairy herds. While the findings of these two studies are the only clinical evidence available at the current time it is clear that interpretation in the context of UK dairy herds must be made with caution. Further research is required to investigate treatment protocols for claw horn lesions in UK dairy herds.

1.3.3 Early detection and treatment of claw horn lesions

While the scientific literature provides limited evidence for the most appropriate treatment of claw horn lesions, recent studies have shown that early treatment of lesions is key to promoting recovery and reducing reoccurrence of lesions. Groenevelt *et al*., (2014) conducted a study on four dairy farms in the South-West of England where cows on each farm were pair matched by parity and stage of lactation and randomly allocated to treatment and control groups. Lactating cows were mobility scored fortnightly during the housing period and acutely lame cows (those with 2 non-lame scores followed by lame score on one or both hind limbs) in the treatment group received a therapeutic foot trim within 48 hours by the investigating veterinary surgeon. Cows in the control group were treated by the farmer following their normal lameness protocols with only 3.9% having had a treatment recorded within 2 weeks of becoming eligible and an average treatment delay of 37.7 days (range 7-126). The cows in the treatment group had significantly lower lameness prevalence in years 2 and 3 than those in the control group. In year 1, prevalence was lower but not significant. A large number of cows in the control group appeared to achieve clinical cure without individual treatment in the initial bout of lameness. However, many of these relapsed several weeks later and were more likely to stay chronically lame. A high rate of relapse was seen in both treatment and control groups. The differences between treatment and control groups were significant for two-week recovery rate and average score following treatment although the difference was small. Relapsed cases from the treatment group responded better to subsequent treatments creating a cumulative effect over time. The use of the control group in this study, not only allows comparison of cows treated early following detection of lameness through mobility scoring but also highlights the delay in treatment when cows are being identified as lame by farm staff without any

routine lameness detecting sessions. The study clearly shows that the early treatment of cows results in significantly better cure rates and lower levels of chronic lameness supporting the case for early and effective treatment of claw lesions.

In a study conducted on four dairy farms in Somerset, UK between June 2008 and April 2009, Leach *et al*., (2012) investigated the hypothesis that treatment of lameness within two days of the cow becoming lame would reduce its duration. Cows on each of the four farms were matched by parity and days in milk and allocated at random to treatment and control groups. The study investigators then mobility scored the herds at 14 day intervals as they exited the milking parlour. Cows which recorded two consecutive non-lame scores followed by a lame score in one or both hind limbs were enrolled on the study. Animals in the treatment group received a five stage foot trim and lesion specific treatment within two days while those in the control group were treated by the farmers at their discretion continuing existing farm procedures. During the course of the study 67 cows became eligible in the treatment group and 101 in the control group. All 67 cows in the treatment group were treated within 2 days, only 12 of the control cows were treated by farmer. Control cows were often lame for several weeks before treatment and 21% required re-treatment while in the treatment group only five percent required retreatment. No significant difference in mobility score was seen at 2 weeks after enrolment but by 4 weeks a significantly higher number of cows in the treatment group recorded a non-lame score. At six to ten weeks after enrolment no significant difference was seen between the groups though fewer cows in the treatment group had moved to a severe lameness score. The study concluded that farmers treated cows when they were more severely lame and had been lame for longer time. The cows treated within two days of recording a new lame score had less severe lesions and at four weeks after treatment had significantly lower lameness prevalence than those treated by the farmers under their existing farm procedures. There was also a suggestion of a longer term benefit in the treatment group in lower prevalence of severely lame cows although numbers were too small for statistical comparison.

From these studies it is clear that early identification and treatment of lame cows is important to successful lameness management however farmers are identifying and treating lame cows at a later stage in the disease process than researchers using locomotion scoring to identify acutely lame cows. This finding is supported by other surveys based on locomotion scoring that have shown the prevalence of clinical lameness is around three times higher than farmer estimates. In an assessment of welfare in dairy cattle (Whay *et al*., 2003), fifty three commercial dairy farms in the Midlands and South-West of England were visited once during the winter of 2000/2001 and each cow scored for lameness on a four point scale as they exited the milking parlour. When comparing these scores with the farmers estimates of lameness prevalence poor correlation was found. Farmers mean estimate of lameness prevalence at the time of the visit was 5.7% but the mean prevalence recorded by locomotion scoring was 22.1% suggesting that farmers were failing to identify three out of four cases. A similar finding was made in a study conducted in housed cows in Minnesota, USA (Espejo *et al*., 2006). In this cross-sectional study, 5,626 Holstein dairy cows on 50 free-stall dairy farms were visited between July and October 2004. Cows were locomotion scored on a five-point scale as they exited the milking parlour. At the time of the visit, prior to the locomotion score assessment, herd managers were asked how many cows they considered to be lame. The prevalence of lameness by locomotion scoring averaged 24.6% (range 3.3-57.3%) while the prevalence reported by herd managers had a mean estimate of 8.3% (range 0-30%) meaning the prevalence of lameness estimated by the study investigators was 3.1 times greater than that estimated by the herd managers. In a study investigating the barriers to lameness control on dairy farms (Leach *et al*., 2010a) a face-to-face questionnaire of 222 dairy farms in England and Wales was carried out by four researchers. As part of the survey, farmers were asked how many lame cows were in their herd on the day of the visit. The researchers then assessed the locomotion of the entire herd on a four-point scale as they exited the milking parlour. Across all the farms the prevalence of lameness stated by the farmer was skewed towards lower values with a mean of 6.9%, median of 5.4% and range of 0-49%. The locomotion scores recorded by the researchers had a normal distribution with a mean of 36%, median of 36% and range of 0-79%. The study also found a closer relationship

between the prevalence of lameness given by the farmer and the prevalence of severely lame cows recorded by the researchers than the total prevalence of lame cows reported by the researchers. This would support the theory that farmers are identifying cows as lame at a more severe level of disease and are not fully aware of the true numbers of lame cows in their herds.

In 2008 AHDB Dairy (formerly DairyCo), the UK dairy levy body, launched a mobility scoring system to help and encourage farmers to detect and treat a greater proportion of their lame cows (see section 1.1.1). A study quantifying transitions between levels of mobility score (Stoye *et al*., 2014) demonstrated that the progression from being sound to being lame happens over several weeks, with only 1.5% of the 19,587 mobility scores used in the study increasing by more than one score between two consecutive readings within 30 days of each other. This means that if mobility score is assessed fortnightly it should be possible to detect most cows as they first become lame before progression to a severely lame state. Putting this scoring system into regular practice on commercial farms though has met with barriers. A qualitative study conducted at the Bristol University (Horseman *et al*., 2014) aimed to use in-depth interviews to understand the process of treating lame dairy cows from the farmers' perspective. Twelve dairy farmers were interviewed for one to two hours, face-to-face whilst they carried out lameness treatment on their farms. Farmers felt that they were able to detect lameness adequately but rarely spoke of carrying out regular formal mobility scoring on a monthly basis as recommended by the industry standard. Despite this there was broad acknowledgement of the benefits of the AHDB Dairy mobility scoring system however 'having the right person to do it', 'finding time to be able to have a go', 'finding a place to do it' and 'needing to be the same person all the time' were cited as practical concerns for the ease of application of the system.

Another potential barrier to early detection and treatment of lameness highlighted by this study was the definition of lameness used by the farmers. Animals potentially lame under the scientific definition were described by farmers as 'not walking quite right', 'just a little bit impaired in how mobile they are', 'aren't walking correctly', 'walking a little light', or 'her mobility is suffering a bit'. Farmers avoided using the term 'lame' by using terms such as

'impaired mobility' for less severely lame cows and 'score three' (severely impaired mobility on the AHDB Dairy mobility score) to describe more severely lame cows. During the development of the AHDB Dairy mobility scoring system the terms 'imperfect mobility', 'impaired mobility' and 'severely impaired mobility' were coined to make the initiative more palatable and acceptable to farmers. It appeared from the interviews that this language had been adopted by the farmers and was influencing the way they talked about lameness. Horseman suggests that it may be the language used by the farmers causing the underestimation of lameness prevalence shown in the scientific literature and underestimation may have less to do with under-detection and more to do with misleading labelling of the severity of lameness as degrees of mobility impairment. Leach *et al*., (2010a) also considered the difference in definition of a lame cow to be a factor in the discrepancy between the prevalence of lameness reported by farmers and that found by researchers when locomotion scoring the herd. The study found a closer relationship between cows reported as lame by the farmer with those recorded as severely lame by the researcher than the total lameness prevalence. This could be either because the more mildly lame cows were not identified by the farm staff or that they used different terminology for these animals and only considered severely impaired animals as 'lame'. Another factor suggested by the author to explain this discrepancy was the fact that the researcher was concentrating on the specific task of assessing gait in every cow while farm staff have other tasks and responsibilities. This theory requires further investigation to ascertain whether it is indeed the farmers ability to identify lame cows that is leading to under-detection or whether other distractions mean that some lame cows are missed.

To understand how this delay in lameness recognition impacts on the subsequent treatment, a study was undertaken using weekly mobility scoring to identify the onset of lameness and measure the subsequent interval until presentation for treatment (Alawneh, 2012). A cohort study of 452 mixed age dairy cows in a New Zealand dairy herd locomotion scored all cows as they exited the milking parlour each week between July 2008 and April 2009. Farm staff were not given access to locomotion scoring records and cases continued to be identified and managed using the normal farm practices. Cows suspected of being lame were

referred for veterinary examination with veterinary treatment being undertaken weekly at no cost to the farmer except for pharmaceuticals and consumables. Farmers were shown to be better at detecting severe lameness than mild cases, however the delay between recognition of severe lameness by locomotion scoring and being presented for treatment by farm staff was significant with less than 25% of cows being presented the same week as the severe lameness score had been recorded. The median delay in treatment for severely lame cows was 21 days and for mild cases 70 days. Overall the estimated median interval length between lameness detection by locomotion score and presentation by the farmer for treatment was 28 days.

The design of this study provides minimal barriers to the prompt treatment of lame cows by offering weekly veterinary treatment at no cost suggesting the length of interval between recognition of severely lame animals by locomotion scoring and their presentation for treatment may be due to a delay by the farm staff in recognising that the animals required treatment. However during the in-depth interviews carried out to understand the process of treating lame cows from the farmers' perspective (Horseman *et al.*, 2014), comments made by farmers suggested that while the severity of lameness determined how quickly cows were treated, less severely lame cows were still being identified but the benefits of prompt treatment for these animals was not always recognised. Again it is suggested that this may be due to the terminology used in the AHDB Dairy mobility scoring system where cows with 'impaired mobility' (score 2, mildly lame) are described as 'likely to benefit from treatment' and 'should be attended to as soon as practically possible'. Only cows with 'severely impaired mobility' (score 3, severely lame) are said to 'benefit from treatment' stating that these cows require further treatment or nursing. The treatment strategies adopted by farmers therefore seem to reflect these recommendations resulting in a delay in the treatment of mildly lame animals with only severely lame animals requiring urgent attention.

Even once a lame cow is recognised, farmers report many barriers to prompt treatment. Leach *et al.*, (2010a) suggest that the farmers' perception of lameness in relation to other herd health issues is an important influence on the effort dedicated to lameness control. Lameness is also considered by farmers as having

a greater practical difficulty to control than other issues such as mastitis. Treatment was perceived to require control actions which were separate from the daily routine and therefore have time and labour implications which may restrict lameness control activities. The in-depth interviews by Horseman *et al*., (2014) suggest a wider range of priorities which farmers must balance against lameness control with farmers acknowledging their lameness treatment may be sub-optimal but that is an inevitable part of running a commercial dairy farm. Examples of other priorities included routine management tasks, crop and field management, other herd health and welfare concerns and lambing. A shortage of sufficient skilled labour at particular times of the week or times of the year creates problems when considered in combination with the farmers need to balance different priorities. Finally, factors such as farm layout, cow flow and cow handling facilities were identified by farmers as barriers to treatment. The use of all-purpose crushes rather than one specifically designed for foot trimming made treatment 'challenging', particularly for front feet. Where farmers reported having a well set up farm this was seen to increase the frequency and/or promptness of lameness treatment. Despite these barriers, Horseman *et al*., (2014) reported that many farmers enjoyed the process of treating lame cows. In general, their enjoyment was connected to the satisfaction they felt when they could identify the cause of lameness and when their treatment improved the cows mobility. A study looking at farmers' motivators to reduce cattle lameness (Leach *et al*., 2010b) also found 'pride in a healthy herd' and 'feeling sorry for lame cows' received higher ratings as motivators than the fact that 'lame cows lose money'. This suggests at both an individual cow and herd level farmers achieve personal satisfaction in the control of lameness in their herds. A survey conducted by Bennett *et al*., (2014) looked at barriers from an alternative perspective by gauging the farmers willingness to pay (WTP) to reduce lameness prevalence in their herds. Face to face interviews were conducted with 163 farmers in England and Wales which found that farmers strongly agreed that lameness caused pain in their animals and that they could reduce lameness on their farms. While a wide variation in WTP was seen between farmers, a substantial WTP to avoid the inconvenience of lameness control was seen, demonstrating this as a significant barrier. The relative sizes of the estimates for lameness reduction and reduction of inconvenience however, indicated that

farmers were generally prepared to incur inconvenience as long as it reduced lameness prevalence in their herd. These finding support those of Leach *et al* (2010a; 2010b) in suggesting that while there are significant time and labour implications of treating lame cows, farmers view the welfare of the cows as equally or more important than the economic implications.

Bringing together the literature available on treatment of claw horn lesions in dairy cows the principal messages which appear are the need for early recognition of lameness by farm staff and prompt, effective treatment of cases. If the barriers to early detection and prompt treatment can be overcome, the issue of effective treatment then comes to the fore. Review of the literature demonstrates a lack of peer-reviewed scientific evidence to support treatment choices. This is an area which requires further research on which to base clinical decision making and ensure treatment protocols employed are the most appropriate for the lesion found.

1.4 Farmer engagement in lameness detection and treatment

With the recent increase in research into the causes, detection and treatment of lame cows, it is vital to disseminate the key messages down to a farm level if improvements are to be made which benefit cattle health and welfare. This was highlighted by the Farm Animal Welfare Council (FAWC., 2009) in response to the information becoming available about risk factors stating that dissemination of existing knowledge about lameness to many farmers and stockmen is also needed. It is clear that the responsibility to detect and treat lame cows is heavily weighted towards the farmer and farm staff who are responsible for day to day management of the herd (Whay *et al*., 2012). However, there are many other 'influencers' within the agricultural industry such as veterinary surgeons, paraprofessionals, consultants and charities which support management change through provision of advice from personal experience and research.

In an early study looking at the effect of level of knowledge and training of farmers or stockmen on lameness prevalence (Mill and Ward, 1994), cows were locomotion scored on 15 dairy farms and the person who decided when lame cows needed treatment interviewed. The questionnaire used in the interview was designed to assess the participants knowledge of lameness by selecting the most common foot problems seen on the farm from a list then identifying foot lesions from photographs. The general agricultural education and specific training relating to lameness the participant had received was also recorded. The study found that the participants knowledge, degree of training and awareness of lameness were each highly significantly and inversely related to the proportion of cows independently observed to be lame.

The need for appropriate training in detection and treatment of lame cows is imperative to ensure welfare of affected animals is not compromised. There are currently a range of courses and qualifications offered in the UK and Europe available to farmers and those wishing to pursue a career as a professional foot trimmer. Bodies awarding foot trimming qualifications include the Dutch Diploma awarded by PTC and Friesland College, Holland, City and Guilds, NPTC certification of competency in cattle foot trimming awarded at level 2 (stockman / herdsman) and level 3 (professional foot trimmer), The National

Association of Cattle Foot Trimmers (NACFT) (endorsed by the British Cattle Veterinary Association) and Lantra who provide quality assured training courses with a certificate of attendance. It is not however legally necessary for a person trimming cows feet to have completed any of these courses or qualifications. In the UK, the lack of a single foot trimming organisation to oversee training and quality control has led to a wide range of abilities within the veterinary, para-veterinary and farming professions (Mahendran and Bell., 2015).

The traditional approach to disseminating information to farmers about lameness control has been through individual meetings with a veterinary surgeon or consultant specialising in this area. It is a simplistic expectation that raising awareness of a problem will lead to behavioural change however (Leach *et al*., 2013). A study of 61 UK farms in the South West, Midlands and Wales (Bell *et al*., 2006), found that significantly fewer control and corrective control measures were implemented for lameness than for mastitis despite a similar proportion of farmers believing they had a problem with these diseases (87% lameness, 89% mastitis). A further study on the development, implementation and testing of a lameness programme (Bell *et al*., 2009) found that even though valid advice on reducing lameness was provided, many farmers did not implement it when provided in a traditional advisory style. A similar study conducted by Barker *et al*., (2012) also found no significant reductions in prevalence following recommendations made by a veterinary surgeon to reduce lameness. Consideration of these findings alongside the increasing lameness prevalence in the UK over the past 20 years (see section 1.1.2.2) suggests that the delivery of key messages about lameness control are not having a substantial effect at a farm level.

The likelihood an individual will implement a change to reduce a problem is dependent on the severity of the problem, the benefits of change and the barriers to implementation of a solution (Leach *et al*., 2013). This relationship was explored in a study by Leach *et al*., (2013) as part of a lameness research programme at Bristol University between 2006 and 2010 known as the 'Healthy Feet Project' investigating a range of outcomes related to provision of supported lameness advisory programme on dairy farms. This intervention study, designed to encourage farmer uptake of lameness-related advice, was conducted on 140

intervention and 87 control farms recruited by direct contact or via relevant milk companies. A team of four researchers then undertook a four-year programme of visits, follow-up telephone contacts and group meetings on the intervention farms. (Main and Whay, 2012). Farms were visited and monitored annually with lameness prevalence measured on a four-point scale (Whay *et al*., 2012). They were divided into a 'monitored only' (MO) group and a 'monitored and supported' (MS) group which received different levels of support from the project team (Leach *et al*., 2013). In the first visit to the MS group, farms were provided with information about lameness prevalence and a summary of lameness risk factors on their farm. They were then offered an advisory meeting with a veterinary surgeon to formulate a 'lameness action plan'. At subsequent visits the action plan was further developed and social marketing tools used to support farmers in developing and implementing their plans. In the MO group, farmers were provided with lameness prevalence figures but received no further advice or support until the completion of the study.

In the study by Leach *et al*., (2013), data on lameness prevalence during the first visit in 2006-2007 and final visit in 2009-210 was collected for 128 farms (51 MO, 77 MS). In the initial visit farmers rated barriers to lameness in terms of their importance and were asked to state how many lame cows they believed they had in the herd on that day. They were also asked what proportion of lame cows they considered to be a problem (tolerance). During the course of the study the mean lameness prevalence fell across all farms. A key finding was that reduced prevalence of lameness was more widely associated with a reduction in tolerance than with improved detection alone. This suggests that while failure to recognise a disease clearly prevents positive action against it, detection alone does not necessarily initiate control measures. A change in perception of the severity of the problem is needed to drive behavioural change.

Traditional methods of knowledge transfer, while providing information, may not be effective at overcoming the barriers to create change. As part of the Healthy Feet Project, Whay *et al*, (2012) investigated two methods of delivery of existing lameness management knowledge, on 117 farms allocated to the MS group and 72 farms in the MO group. Over the three years of the study 692 action points were identified of which 330 (48%) were implemented fully. A

number of management changes were also made which were not included on action plans and changes were also seen on the control farms. Overall however, the 'supported' group made a greater percentage of changes likely to be of benefit and a lower percentage likely to increase risk of lameness than the control group. This study used several types of intervention, a traditional technical advice, facilitation techniques to encourage farmer participation and the application of social marketing principles to promote implementation of change (Main *et al*., 2012). It was seen in the facilitated discussions at the annual monitoring visits, farmers were generating substantial numbers of action points over and above those initially agreed with the veterinary surgeon. These facilitated discussions therefore enabled farmers to engage with the process over a longer period and may be at least as beneficial as a direct advisory approach in generating change to improve lameness levels on farms. The difference in proportion of changes made on 'supported' and control farms however, demonstrate that farmers needed support in starting and sustaining the process (Whay *et al*., 2012).

The Healthy Feet Project saw a decline in lameness prevalence on MS farms over the course of the study. An unexpected finding however was that lameness prevalence was also reduced in the MO group believed to be as a result of lameness-specific information received outside of the project (Main *et al*., 2012). An increased awareness of lameness due to the monitoring of these farms may also have contributed along with discussion of ideas between MS and MO farmers. More research is therefore needed to fully understand the impact of these different methods of knowledge transfer on lameness control in the UK. The results of the Healthy Feet Project were fed forward into the Healthy Feet Programme overseen by AHDB Dairy to form a structured programme facilitated by vets or foot trimmers trained as 'Mobility Mentors'. While this approach is underpinned by strong research, it requires farmers to be proactive in recognising they have a lameness problem on their farms and initiate and engage with the programme. With positive results also seen in the control group for this project, further research is needed to assess alternate ways of disseminating information to dairy farmers in order to encourage behavioural change.

1.5 Conclusion

Lameness in dairy cattle represents a significant health and welfare concern in the UK yet research into the causes and treatment of this condition lags behind that of similar endemic diseases such as mastitis and fertility. The majority of lameness occurs due to conditions affecting the foot, with claw horn lesions (sole ulceration and white line disease) accounting for a large proportion of cases.

In recent years the need for early detection and prompt treatment of claw lesions has become more widely understood yet there is little information available in the scientific literature to guide clinical decision making on the most effective treatments. Current practices are largely based on experience and anecdote which lack underpinning scientific evidence. Research is needed to better understand which treatment protocols will provide the best results. These findings along with current knowledge on control of lameness must then be disseminated to the farmers managing and treating lame cows if it is to have a substantial impact on prevalence of disease.

Chapter 2. Prevalence of lameness and mobility scoring and lameness treatment practices in UK dairy cattle

2. Abstract

Studies suggest a rising trend in lameness prevalence in UK dairy herds over the past 30 years, however with the most recent report conducted during 2006-2007 (Barker *et al*., 2010) the current situation is unclear. The following study aimed to investigate lameness prevalence and treatment practices in the central UK in 2014, hypothesising that current lameness prevalence and management practices would differ from those previously described.

Dairy farms within a two hour radius of the University of Nottingham, School of Veterinary Medicine and Science were selected at random and 434 farmers contacted by telephone for recruitment. Fifty eight farmers agreed to participate in the study. During April and May 2014, 43 farms were visited for data collection, six farmers withdrew prior to the visit and the remaining nine were not available within the study timeframe. Visits were conducted by a trained observer who carried out a short interview questionnaire with the farmer about mobility scoring and lameness treatment practices then mobility scored the cows in the lactating herd as they exited the milking parlour. Cows were scored on a six-point scale from 0 (sound) to 3b (non-weight bearing). Data from the questionnaire was grouped for analysis following consultation with the steering group overseeing the research.

Mean herd lameness prevalence was 30.1% (range 7.3% - 60.6%) across the 43 herds. No significant difference was found in herd lameness prevalence in relation to herd size, milk yield or management type. In response to the questionnaire, mobility scoring frequency on the 43 farms ranged from monthly (n=4) to none (n=26). Thirty one farms reported carrying out foot-bathing for control of digital dermatitis. Foot trimming and hoof lesion treatment was conducted by the farmer (n=30), farmer and hoof trimmer (n=11) hoof trimmer only (n=1) or farmer, hoof trimmer and vet (n=1). A wide variation was seen in frequency of routine foot trimming. Eleven farmers reported they carried out treatment on lame animals within 24 hours, with a further 13 treating in 1-2 days.

This study is the first to use a truly randomised method of farm selection to investigate lameness prevalence in UK dairy herds. Previous studies have suggested a year on year increase in lameness prevalence, peaking at 36.8% (range 0-79.2%) in the most recent study by Barker *et al* (2010) during 2006-2007. While it is possible the current study may represent an anomaly due to seasonal, geographic or sample size factors, a mean lameness prevalence of 30.1% (range 7.3-60.6%) would appear to suggest a corner has been turned in the control of lameness in dairy herds.

While improvements look to be being made in tackling lameness, the results of the questionnaire suggest that the efforts of the industry to promote detection of lame cows through mobility scoring is failing, with less than 10% of farms conducting mobility scores once a month. While farmers reported prompt treatment once animals had been identified as lame, this lack of routine detection may lead to a delay in recognition of affected individuals and therefore implementation of treatment. The questionnaire also revealed that a large proportion of farmers were carrying out their own routine trimming and treatment of lame cows. Ensuring appropriate training for farmers and ensuring the key messages on prompt and effective treatment gets to those managing and treating the animals is therefore imperative if lameness prevalence is to continue to fall.

2.1 Introduction

Lameness in dairy cattle is recognised as a painful condition which compromises animal welfare (Whay *et al*., 1997) and results in production losses such as reduced milk yield, lower fertility and increased risk of culling (Green *et al*., 2002; Collick *et al*., 1989; Whitaker *et al*., 2004). Cost estimates for lameness are thought to average around £334 per case (Willshire and Bell, 2009) meaning high incidence of lameness in the herd can represent a significant economic loss to the dairy farmer. A study published in 1996 by Clarkson *et al*., reported the mean prevalence of lameness across 37 British dairy farms at 20.6%, while a later study conducted in south-west England during the winter housing period 2002/2003 (Huxley *et al*., 2004) reported a median of 24.2%. A further study carried out during 2006-2007 on 227 dairy farms in central and southern England and Wales, reported a mean prevalence of 36.8% (Barker *et al*., 2010). These studies, all conducted by trained observers using a four or five-point locomotion scoring system, may suggest a rising trend in lameness prevalence over time, certainly records collected by the Dairy Herd Health and Productivity Service in the UK between 1980 and 2002 showed a substantial increase in lameness on many farms in the early 1990's before a gradual improvement started to occur (Whitaker *et al*., 2004). Lameness is recognised as a disease of high production (Green *et al*., 2002) and with the drive for ever greater productivity within the dairy industry, lameness levels in dairy herds have the potential to keep rising if treatment and prevention practices fail to keep pace.

The following study aimed to investigate lameness levels and treatment practices in the central UK in 2014. The hypothesis was that current lameness prevalence and management practices would differ from those previously described. Three objectives were identified for this study; to evaluate the practicalities of selecting farms for lameness prevalence studies using a randomised method, the scientific 'gold standard'; to assess current lameness prevalence on the randomly selected farms for comparison with previous reports and to investigate current on-farm practices for treating lameness in dairy cows for comparison with industry recommendations.

2.2 Materials and Methods

The data used in the following report was collected during initial information gathering visits for a matched paired, parallel group clinical trial conducted by the author, that was designed to test the impact and benefits at a herd level of implementing a treatment protocol for claw horn lesions in dairy cattle. The protocol was reviewed and approved by the University of Nottingham's school of Veterinary Medicine and Science, Ethical Review Committee prior to data collection commencing. This study was subsequently discontinued at the behest of the funder, however the lameness data collected provides a useful insight into lameness prevalence and on-farm lameness detection and treatment practices. The nature and quantity of data presented below therefore reflects the information available at the termination of the clinical trial.

2.2.1 Farm recruitment

Dairy farms within reasonable distance (maximum 2-hour drive) of the University of Nottingham, School of Veterinary Medicine and Science were selected for the study. One thousand, one hundred and fifty dairy farms were identified on a database of all known dairy farms in the counties of Derbyshire, Leicestershire, Northamptonshire, Nottinghamshire, and Staffordshire in the central UK. Farms were numbered in the order they appeared on the database and a computer randomisation programme (randomization.com) used to generate a random list from zero to 1150 to determine the order in which the farms would be contacted. Telephone numbers for each of the farms were identified via a search of three online resources in the following order; 1) BT find a person, 2) BT find a business, 3) yell.com. If no contact telephone number was found using these resources, then the farm was excluded.

Between July and September 2013, farmers were contacted by telephone to ask if they would be willing to participate. Each farmer was contacted a maximum of two times on different dates and at different times. The phone was allowed to ring 20 times or until an automated voice mail message cut in. If a voice mail message was reached, a short standard reply was left giving contact details for the researcher. If the farmer was contacted at the first or second attempt but the

time was not convenient for discussion of the study, a more suitable time to call back would be arranged.

A data collection form was completed to record relevant farm information, contact details to arrange further visits and identify the farm veterinary practice. For recruited farms, the senior veterinary surgeons at each of the veterinary practices were contacted by email to seek permission to conduct the study on their clients' farms. Where farms did not wish to participate in the study, a reason for this was recorded.

2.2.2 Mobility scoring

Mobility scoring was undertaken on each farm by one of three observers who had undergone a group training session as part of a separate RCT (see chapter 3) using a six-point scoring system adapted from the AHDB Dairy mobility scoring system (see table 6). All observers had prior experience with the AHDB Dairy mobility scoring system and scoring of cows on commercial farms as they exited the milking parlour. The training and standardisation exercise comprised of an explanation of the six-point system followed by observation and discussion of forty video clips of cows walking for at least three strides on a firm, level surface. Observation and discussion using the six-point system was then repeated on-farm at the University of Nottingham Dairy Centre. Following the training session, observers were once again shown the 40 video clips of cows and asked to provide a mobility score for each of the cows. This exercise was repeated with an interval of at least four hours between scorings to assess inter-observer and intra-observer variation.

Following recruitment, a visit was made to each farm to record lameness prevalence in the lactating herd and to collect further information on lameness management and treatment practices. The observer conducted a short structured interview with the farmer and responses recorded in a questionnaire (see appendix 1). Due to time implications, farmers were not required to support their responses with farm records or other data. Mobility scoring the herd was then undertaken as the animals exited the milking parlour. Each cow was mobility scored walking for a minimum of three strides in a straight line. Cows were not

identified individually by freezebrand number as only the overall prevalence of lameness in the herd was required. Dry cows and youngstock were not scored.

Table 6. Mobility scoring descriptors employed in a study to assess lameness prevalence on farms in the central region of the United Kingdom (adapted from the Agriculture and Horticulture Development Board (AHDB) Dairy Mobility Score system)

AHDB Dairy Mobility Score	AHDB Dairy Descriptor	Study Mobility Score	Study Descriptor
0	Walks with even weight bearing and rhythm on all four feet, with a flat back. Long fluid strides possible.	0	As AHDB Dairy descriptor. Even weight bearing and rhythm, flat back, long fluid strides
1	Steps uneven (rhythm or weight bearing or strides shortened; affected limb or limbs not immediately identifiable.	1	As AHDB Dairy descriptor. Uneven rhythm or weight bearing but affected limb not immediately identifiable, back may be raised. Walking velocity normal.
2	Uneven weight bearing on a limb that is immediately identifiable and/or obviously shortened strides (usually with an arch to the centre of the back).	2a	Mild asymmetry in hind-limb movement. Decreased stride length on affected limb and slightly decreased stance duration with a corresponding increase in limb flight velocity on the non-affected side. Walking velocity remains normal. Back may be raised.
		2b	Moderate asymmetry in hind-limb movement. Decreased stride length on affected limb and a distinct decrease in stance duration. Limb flight on the non-affected limb is correspondingly faster and the overall walking velocity is reduced. Back usually raised.
3	Unable to walk as fast as a brisk human pace (cannot keep up with the healthy herd) and signs of score 2.	3a	Severe asymmetry in hind-limb movement. Marked decrease in stride length on affected limb and very short stance duration. Limb flight on non-affected limb rapid and walking velocity reduced such that cannot keep up with healthy herd. Back raised.
		3b	Minimal or non-weight bearing on affected limb (hops). Back raised. Reluctant to walk without encouragement

2.2.3 Data management and statistical analysis

Data capture was achieved through the completion of data capture forms and transcribed and stored in a relational database (Access 2007, Microsoft Corporation) for analysis. Data analysis was conducted in Minitab 17.2.1 (Minitab Inc.). Data capture forms were retained and the database was checked for errors against written records prior to analysis. Data was grouped for analysis (lameness prevalence: low (<20%), moderate (20-40%), high (>40%); herd size: large (>250 cows), medium (120-250 cows) small (>120 cows); milk yield: high (>8500 litres), moderate (6000-8500 litres), low (<6000 litres); management type: housed (>8 months housed), standard (5-8 months housed), pasture (<5 months housed) following consultation with the steering group overseeing the study.

Lameness prevalence data was tested using the Anderson-Darling test of composite normality and found not to deviate significantly from normal. Analysis of lameness prevalence against other herd variables was carried out using a one-way analysis of variance (ANOVA) test with a significance level set at $P \leq 0.05$.

2.3 Results

2.3.1 Farms recruited to the study

Between July and September 2013, an internet search was conducted for 519 telephone numbers using addresses from the database. Four hundred and thirty-four numbers were successfully identified and called regarding participation in the study. Fourteen numbers were incorrect. One hundred and seventy-three farmers were unable to discuss the study, either due to not answering following the two call protocol or where contact was made the farmer was unable to talk at the time and subsequent contact was unsuccessful. Two hundred and forty-seven farmers were available to discuss the study, of these 46 were no longer milking cows, eight were stopping farming altogether, 26 stated they were too busy to participate, six had participated in an earlier study or worked with another vet school, four farmers said they had no lameness problem, 16 already had lameness or mobility scoring systems in place, four had health problems preventing participation, two farms had too few cows and two farmers didn't deal directly with the cows. Seventy-five farmers gave no specific reason for not participating. Fifty-eight farmers agreed to participate in the study.

2.3.2 Initial information gathering visits

Between the 3rd of April 2014 and the 13th of May 2014, 43 of the 58 farms recruited to the study during the initial telephone calls were visited. Of the remaining 15 farms, six withdrew from the study when contacted to arrange the visit. A suitable time for both the farmer and researcher was not able to be arranged at the remaining nine farms prior to the herd level study ceasing.

Farms were situated across the central region of the UK with 15 farms located in Derbyshire, ten farms in Leicestershire, two farms in Northamptonshire, two farms in Nottinghamshire and 14 farms in Staffordshire. Herd size ranged from 50 to 475 cows, 21 were small farms with less than 120 cows, 16 were medium sized farms with 120 to 250 cows and six were large farms with greater than 250 cows. The main breeds of cattle kept on the farm were Holstein (14 farms), Friesian (5 farms) or Holstein-Friesian crosses (14 farms). Four farms had Friesians crossed with other breeds such as Montbelliard, Jersey and beef cattle, three farms had Holsteins crossed with other breeds such as Jersey cattle, one

farm had Guernsey cattle, one farm Jersey cross cattle and one farm Montbeliarde and cross bred cattle. The majority of farms (33) had cattle which were turned out at pasture during the summer and housed for five to eight months over the winter. Six farms had predominantly pasture kept cattle housed for four months of the year or less, three farms had cattle predominantly housed cattle which were kept in for more than eight months of the year. Table 7 gives further information on the herds used in this study.

Table 7. Herd size and 305 day milk yield and lameness prevalence information for 43 herds in the central region of the UK.

Variable	Number of herds	Mean	SE mean	St dev	minimum	Q1	Median	Q3	maximum
Herd size	43	152.1	15.0	98.1	50.0	87.0	120.0	168.0	475
305d yield (litres)	43	7515	239	1564	3500	6500	7700	8700	11000
Lameness %	43	30.1	2.0	12.8	7.3	20.6	31.3	41.4	60.6

Herds used in this study showed a non-normal distribution in size ($P<0.005$) with herd size skewed toward smaller farms (see figure 2). 305 day milk yield across the 43 herds showed a normal distribution (see figure 5).

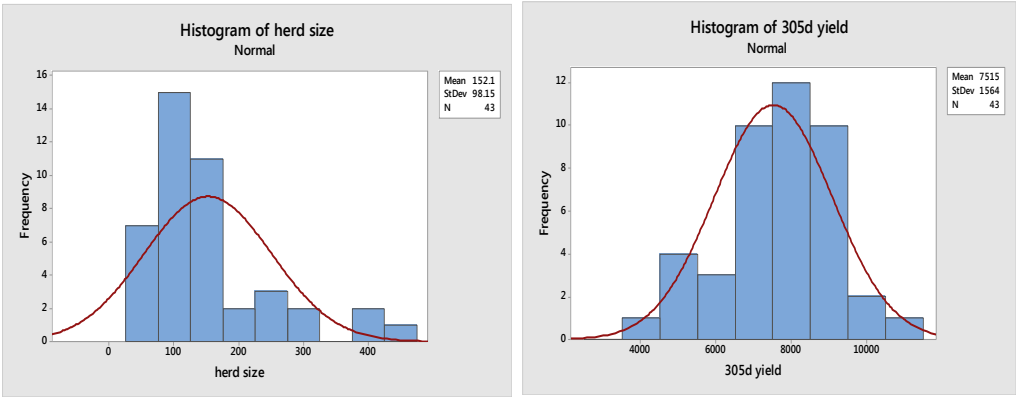


Figure 5. Frequency histograms showing distribution of herd size and 305 day milk yield across 43 randomly selected farms in the central region of the United Kingdom

2.3.3 Lameness prevalence

Five thousand six hundred and twenty cows were mobility scored across the 43 farms. Mean lameness prevalence was 30.1% (range 7.3% to 60.6%, median 31.3%) (see table 6). Ten farms were found to have a low lameness prevalence below 20%, 23 farms had a moderate lameness prevalence between 20% and 40% and ten farms had a high lameness prevalence above 40%. The number and percent prevalence across the whole study population for each lameness score is shown in table 8.

Table 8. Total number and prevalence of cows presenting as sound (score 0), mobility impaired (score 1), mildly lame (score 2a), moderately lame (score 2b), severely lame (score 3a) or non-weight bearing lame (score 3b) during mobility scoring of 43 herds in the central region of the UK.

Mobility score	0	1	2a	2b	3a	3b
Number	1241	2766	920	463	172	58
Prevalence	22.1%	49.2%	16.4%	(8.2%)	(3.1%)	(1.0%)

The prevalence of lame cows (score 2a and above) showed a normal distribution across the 43 farms (see figure 6).

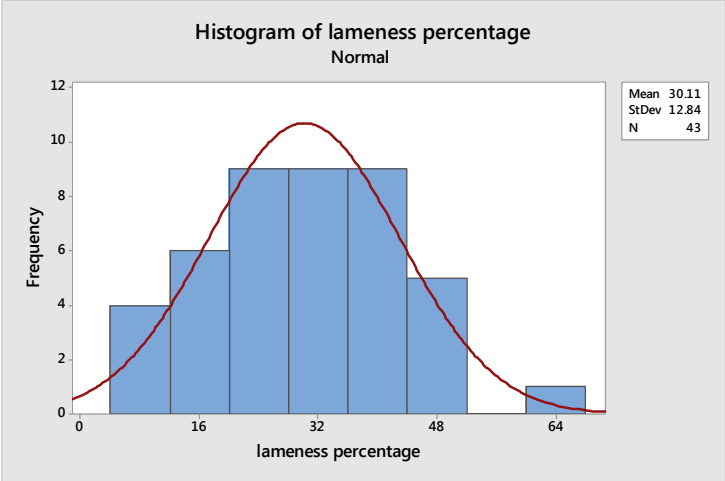
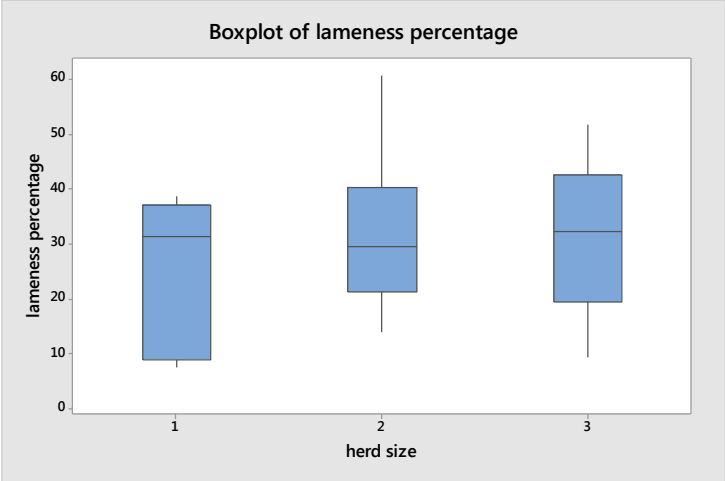


Figure 6. Frequency histogram showing distribution of lameness prevalence across 43 farms in the central region of the United Kingdom

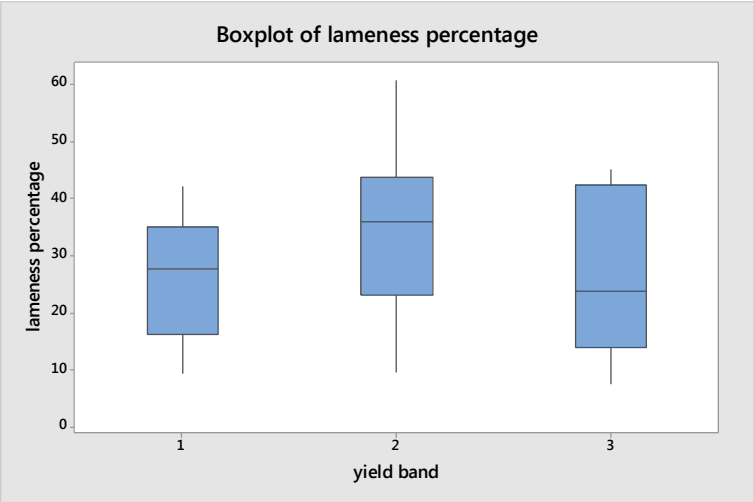
Analysis of lameness prevalence in relation to herd size was achieved by grouping farms into Group 1; large herds greater than 250 cows (n=6), Group 2; medium herds of 120-250 cows (n=16) and Group 3; small herds less than 120 cows (n=21). Mean lameness prevalence for Group 1 was 25.7% (SD 13.9, range 7.3-38.6%), mean lameness prevalence for Group 2 was 30.3% (SD 13.1, range 13.8-60.6%), mean lameness prevalence for Group 3 was 31.2% (SD 12.7, range 9.3-51.8%) (see figure 7). No significant difference was found in lameness prevalence across the different herd sizes.



*1 – herd size >250 cows, 2 – herd size 120-250 cows, 3 – herd size >120 cows

Figure 7. Box and whisker plot showing prevalence of lameness on 43 farms in the central UK in relation to herd size.

Analysis of lameness prevalence in relation to 305d milk yield was achieved by grouping farms into Group 1; high yield greater than 8500 litres (n=13), Group 2; moderate yield, 6000-8500 litres (n=23) and Group 3; low yield less than 6000 litres (n=7). Mean lameness prevalence for Group 1 was 26.2% (SD 10.4, range 9.3-42.1%), mean lameness prevalence for Group 2 was 33.8% (SD 13.1, range 9.4-60.6%), mean lameness prevalence for Group 3 was 25.4% (SD 14.3, range 7.3-45.0%) (see figure 8). No significant difference was found in lameness prevalence in the different 305 day milk yield bands.



*1 – 305 day milk yield >8500 litres, 2 – 305 day milk yield 6000-8500 litres, 3 – 305 day milk yield >6000 litres

Figure 8. Box and whisker plot showing prevalence of lameness on 43 farms in the central UK in relation to 305 day milk yield.

Analysis of lameness prevalence in relation to management type was achieved by grouping farms into Group 1; 'housed'- housed for greater than eight months of the year (n=8), Group 2; 'standard' -housed for five to eight months of the year (n=33) and Group 3; 'pasture'- housed for less than five months of the year (n=6). Mean lameness prevalence for Group 1 was 30.1% (SD 10.7, range 14.1-36.6%), mean lameness prevalence for Group 2 was 32.1% (SD 12.5, range 9.3-60.6%), mean lameness prevalence for Group 3 was 19.1% (SD 12.2, range 7.3-38.6%) (see figure 9). No significant difference was found in lameness prevalence in the different housing lengths.

*1 – >8 months, 2 – 5-8 months, 3 – <5 months

Figure 9. Box and whisker plot showing prevalence of lameness on 43 farms in the central UK in relation to housing length.

2.3.4 Mobility scoring and primary lesions

Of the 43 farms visited as part of this study 26 participants completing the questionnaire reported carrying out no mobility scoring as part of their lameness detection protocols. Four farms mobility scored the herd on a monthly basis, one farm every two months, eight farms carried out mobility scoring three to four times per year, and four farms irregularly.

Digital dermatitis was reported by participants as the primary lesion causing lameness on their farm in 19 cases, white line disease was reported as the primary lesion on two farms, sole ulceration on five farms, interdigital necrobacillosis on one farm, interdigital growths on one farm, overgrowth on two farms, stones on two farms and a combination of white line disease, sole ulceration and digital dermatitis were reported as the primary lesions on 11 farms.

2.3.5 Lameness treatments

Thirty-one of the 43 farms reported carrying out foot bathing for control of digital dermatitis. Frequency ranged from daily (4 farms) to every two months (1 farm) (see figure 10).

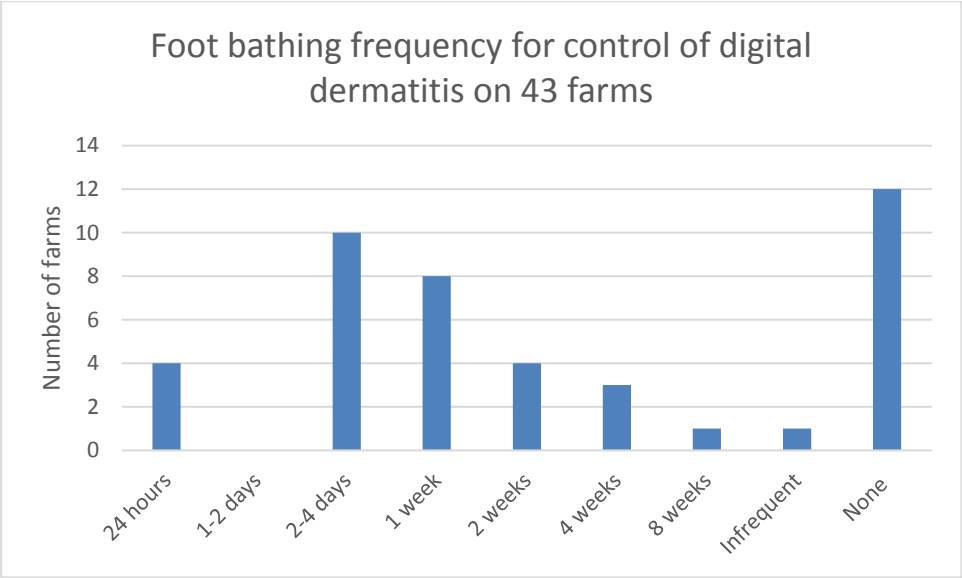


Figure 10. Frequency of foot bathing reported by farmers for control of digital dermatitis on 43 farms in the UK Midlands participating in a cattle lameness study

Foot trimming and treatment of lesions was primarily conducted by the farmer or member of farm staff (30 farms) or a combination of the farmer and hoof trimmer (11 farms). One farmer carried out treatments along with their vet and hoof trimmer and on one farm all trimming and treatment was carried out by a hoof trimmer. Frequency of routine trimming being carried out on farms is shown in figure 11. On 31 farms the person carrying out the foot trimming and treatment had received some training in the past, 12 farmers had received no training.

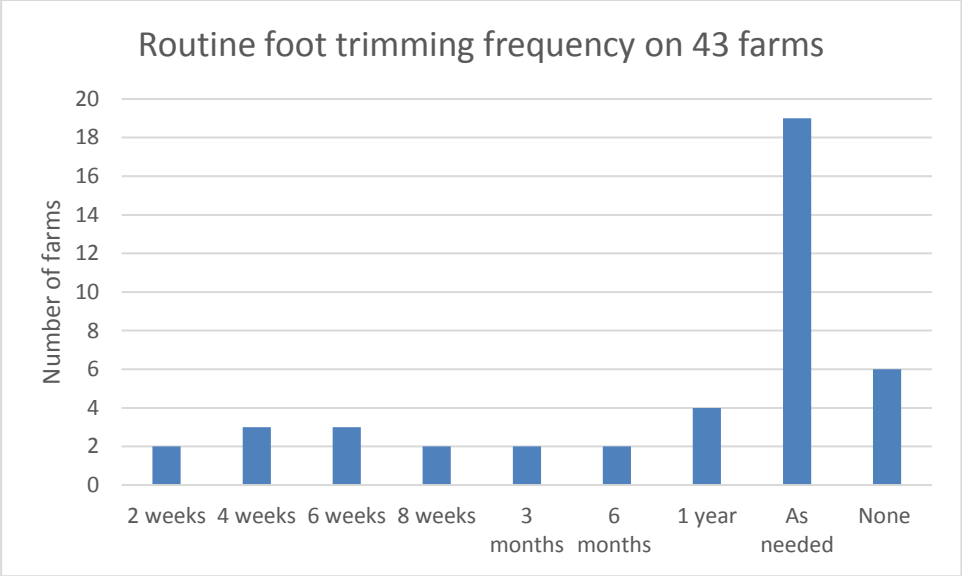


Figure 11. Frequency of routine foot trimming provision on 43 farms in the UK Midlands participating in a cattle lameness study

The time delay to treatment of cows identified as lame ranged from within 24 hours to one week. Further information is shown in figure 12.

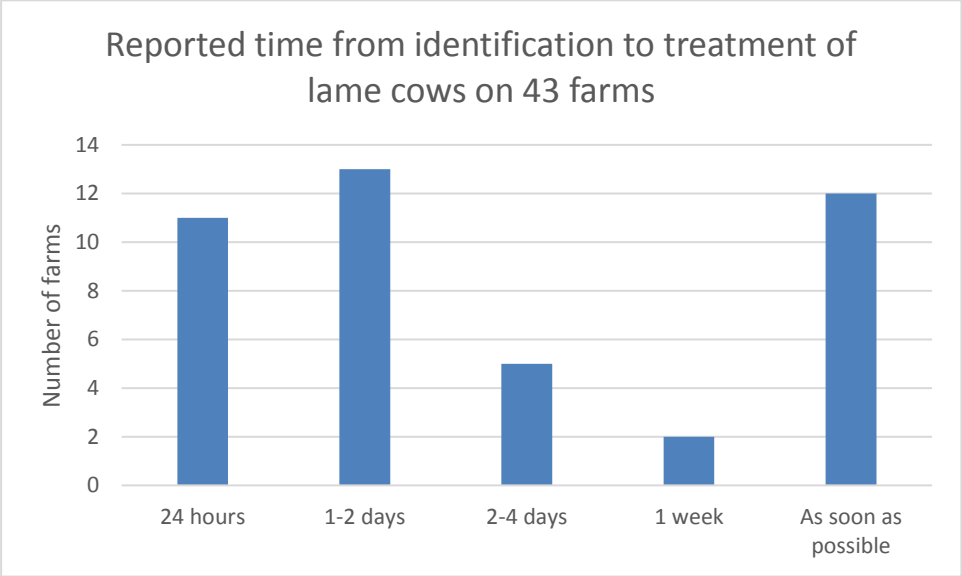


Figure 12. Reported time to treatment of cows identified as lame on 43 farms in the UK Midlands participating in a cattle lameness study

2.4 Discussion

2.4.1 Lameness prevalence

This study is the first to investigate lameness prevalence in UK dairy cows conducted using a true randomised selection of farms. Five thousand, six hundred and twenty cows were mobility scored across 43 farms in central England during April and May 2014 recording a mean lameness prevalence of 30.1% (range 7.3-60.6%). This prevalence is greater than that reported by Clarkson *et al*. (1996) (mean 20.6%, range 2.0-53.9%) and Huxley *et al*. (2004) with a median lameness of 24.2%, however it is lower than the 36.8% (range 0-79.2%) reported in a closely comparable study by Barker et.al. (2010) where lameness prevalence was assessed across 205 dairy farms in central and southern England and Wales during 2006-2007.

Direct comparison of results with that of Huxley *et al*. (2004) is not possible due to differences in farm selection however in the study is conducted by Clarkson *et al*. (1996) the number and type of farms visited was similar to that seen in the current report (37 farms in the west of England with a mean total number of cows at risk at any one time 4230). One notable difference is that farms locomotion scored by Clarkson et.al. (1996) were not selected at random but nominated by veterinary practices which may have some effect on results. Clarkson *et al*. (1996) also collected data over a two-and-a-half-year time period between May 1989 and September 1991, recording prevalence either monthly (Wirral, Cheshire and Wales) or twice during the winter and once during the summer (Somerset) and combining these to give a mean prevalence for the herd rather than the 'snapshot' seen in the current study. This method may give a more accurate reflection of prevalence taking into account seasonal variability.

In the study by Barker *et al*. (2010), although carried out on a greater scale and covering a wider geographic area, stronger similarities in methodology can be seen including the definition of lame and non-lame cows. Consequently, the reduction in mean lameness prevalence of over 6.5% may represent a true reflection of lameness prevalence. A point worth noting again however is the time period over which the study took place. Cows were locomotion scored once on each farm between October and May, which in many UK farming systems

would represent the winter housing period while the current study took place over a five-week period during April and May. Some aspects of the increase in lameness seen between these two studies may therefore be accounted for by seasonal variation in lameness prevalence. Barker *et al*. (2010) reported lameness prevalence to be significantly higher on farms where the milking cows had been housed for greater than 61 days compared to those housed for 0-60 days. Similar findings for increasing lameness prevalence during the winter housing period was seen by Rutherford *et al*. (2009), who reported a mean herd lameness prevalence of 19.1%, 21.0% and 23.1% in the autumn, winter and spring respectively in cubicle housed cows. In the current study, all visits were made at the end of the winter housing period and lameness prevalence reflects a residual effect of housing. The reduction in lameness prevalence between the 2006-2007 study and the current study in 2014 may therefore be more significant than the figures first suggest with Barker et.al (2010) reporting the mean prevalence of lameness in cows housed for 61-120 days at 39.9%, 121-180 days at 40.4% and >180 days 47.0%.

In the current study, it was seen that animals who were housed for less than five months had a lower mean prevalence (19.1%) than those housed for five to eight months (32.1%) or greater than eight months (30.1%). (Note, this is the total period cows were housed on farms, not the housing period prior to locomotion scoring). Though not significant (P=0.07), the lower prevalence in cows housed for less than five months is likely to be a reflection of the time of year the study took place. Cows housed for short periods were not only at lower risk of lameness but also already back out at pasture at the time of data collection thus having had time to recover from the effects of housing. In the study by Barker *et al*. (2010) cows that were not currently housed had a mean lameness prevalence of 20.2% and those never housed of 20% compared to 365 day housed animals with a mean lameness prevalence of 42%. It should be noted that the sample size of farms in the current study that housed their cattle for less than five months was small (n=8) which could have affected the result. Geographic location may also affect the length of winter housing due to the range of climatic conditions seen around the UK and therefore a larger scale study covering a wider area would be necessary to support these conclusions.

Breaking the figures down further, it was seen that of the 5620 cows mobility scored, 16.4% presented with a mild lameness (score 2a), 8.2% presented with a moderate lameness (score 2b), 3.1% presented with a severe lameness (score 3a) and 1% presented with a non-weight bearing lameness (score 3b). By amalgamating the 'a' and 'b' figures into score 2 (lame) and score 3 (severely lame), direct comparison can be made with the findings of Barker *et al*., (2010) score 2 and 3 cows. Barker et.al., (2010) reported the prevalence of score 2 cows at 31.5% and score 3 at 5.3%. The current study showed a prevalence of 24.6% score 2 and 4.1% score 3. These results demonstrate a drop of just over a fifth in both score 2 and score 3 cows, showing the reduction in lameness is across the whole range of lame animals, not just a reduction in the number of severely lame individuals or a lowering in the number of new, milder cases arising. The level of score three cows seen on farms is still of considerable welfare concern as these represent the most severely affected individuals likely to be experiencing considerable pain.

No significant difference was found in this study on lameness prevalence as a result of herd size. It should be noted however that herd size was skewed towards smaller farms with a minimum herd size of 50 cows, a median of 120 cows and a maximum of 475 cows (interquartile range 87-168). Only six out of the 43 farms in the study had a herd size of greater than 250 cows. In the study by Barker *et al*. (2010), herd size was found to be significant in univariable analysis however it was not significant in multivariable analysis suggesting that much of this difference was accounted for by other model variables. In this study average herd size was 163 cows (range 37-642).

In the current study, average 305 day milk yield across the 43 farms showed a normal distribution with a mean yield of 7515 litres (range 3500-11000 litres). No significant difference in lameness prevalence was seen in relation to yield. This contrasts with other studies where high milk yield has been shown to be a risk factor for lameness (Green *et al*., 2002). It may be in this case that as prevalence and yield were assessed at a herd level rather than an individual cow level some of the effect of this risk was lost. Milk records for individual lame cows would be required to examine this further. In a similar study, Barker *et al*., (2010) reported mean annual yields per cow at 7202 litres (range 2500-11200

litres). Modelling suggested that the effect of mean annual yield was linked to other factors on the farm such as management or the environment in which the animals were kept and it was therefore not possible to draw conclusions on the effect of production levels using this measurement.

Barker et.al. (2010), demonstrated an increased risk of lameness associated with breed. Having a herd consisting of a single breed other than Holstein-Friesian or a mixture of breeds and cross breeds was found to be associated with lower lameness prevalence. In this study the limited number of farms visited and range of breeds observed did not allow for further analysis of this factor. It should be noted in comparison of all of the above factors, differences between observers conducting mobility scoring may account for some or all of the differences seen. Inter-observer variability is well recognised (see section 5.4.1.1) however it is not possible to examine this effect between non-related studies.

While a lameness prevalence of 30.1% demonstrates a reduction compared to the earlier study by Baker et.al. (2010), this level of lameness still represents an area for concern. In the current study, only ten of the 43 farms were found to have a 'low' lameness prevalence of less than 20%. A further ten farms had a high lameness prevalence of over 40% with a maximum recorded prevalence of 60.6%. Whay *et al*. (1997) demonstrated that lame cows display increased sensitivity to pain, indicating that lameness is likely to cause affected individuals considerable discomfort. This finding is supported by surveys of farmers and veterinary surgeons who subjectively report lameness to be a painful condition (Huxley and Whay., 2006; Huxley and Whay., 2007). The proportion of cows seen to be lame in this study clearly shows that lameness in dairy cattle remains a major welfare concern in the UK dairy industry.

2.4.2 Farm practices in relation to lameness detection

Mobility scoring is the recommended method of lameness detection by AHDB Dairy, the UK levy-funded organisation which works on behalf of farmers to provide independent, evidence-based information. Despite the recommendations and resources provided by AHDB Dairy to UK milk producers, 60.5% of the 43 farms visited for this study carried out no mobility scoring as part of their lameness detection protocols. A study by Barker *et al*. (2010) also found that

less than half of farmers participating in a study assessing lameness prevalence and associated risk factors in dairy herds were actively engaged in proactive detection of lame cows during the winter of 2006-2007. It has been shown that farmers tend to underestimate lameness prevalence compared to surveys based on locomotion scoring (Whay *et al*., 2003, Espejo *et al*., 2006, Leach *et al*., 2010a), with farmer estimates more closely matching the number of cows scored as severely lame in these studies. This is likely to be due to farmers only observing the cattles' locomotion as they are handled for other purposes rather than as a specific lameness detection exercise. Less than 10% of farmers in this study conducted specific mobility assessment on a monthly basis. It is therefore likely that delays in detection and treatment of score 2 cows with milder levels of lameness is occurring on a substantial number of UK dairy farms. Early detection and treatment of lame cows is discussed further in section 4.1.

2.4.3 Primary lesions causing lameness and associated treatment

The primary lesion causing lameness on 19 of the 43 farms was reported to be digital dermatitis, an infectious condition caused by the *Treponema* species of spirochetes. A further 11 farms reported digital dermatitis as a primary cause of lameness alongside claw horn lesions. Research into the treatment of digital dermatitis is some way ahead of that on treatment of claw horn lesions, a review of the peer and non-peer reviewed literature on treatment and prevention of foot lameness in cattle between 2000 and 2011 (Potterton *et al*., 2012) found 31 treatment papers, of which 27 related to the treatment of digital dermatitis. This was also reflected in the level of treatment seen on farms with 31 of the 43 farms reporting that they carried out foot-bathing for control of digital dermatitis in their herds.

Claw horn lesions were the primary lesion causing lameness on only seven of the 43 farms although on a further 11 farms these were reported in combination with digital dermatitis. This lower level of incidence along with the more complicated aetiology may explain to some extent the focus of treatment research on infectious causes of lameness. Routine trimming was carried out on all but six of the farms questioned. Routine trimming has been shown to restore the correct angle of the foot reduce overloading of the corium at the site where

sole ulcers can form (Archer *et al*. 2010). The large proportion of farms conducting routine trimming in this study may therefore have an effect on the number reporting claw horn lesions as their primary cause of lameness.

All farms reported that they responded to incidents of lameness quickly, 24 of the farms treated their lame cows within 48 hours, a further seven within a week and the remainder as soon as possible. This is in contrast to a similar study by Barker *et al*. (2010) where 56 farms treated their cows within 48 hours while 132 took more than 48 hours to treat, in some cases up to six weeks. Increased lameness prevalence was seen to be associated with a lack of prompt treatment. Several other studies have demonstrated a delay in recognition and treatment of lame cows results in increased severity of disease and a delay in recovery.

While participants in this study reported rapid response to incidents of lameness, the lameness prevalence and severity seen on farms during data collection suggests that this may not be a true reflection of treatment on farms. A potential reason for this may be that participants reported the treatment interval they believed to be 'correct' (as given in industry guidelines) rather than the actual interval on the farm. Cross checking lameness treatment records to determine this was outside the scope of the study. Another potential reason for the disparity may be due to a delay in recognition of the animals as lame. In this case the participant may be correct in stating treatment was administered rapidly following identification of lame individuals, however these animals may have been lame for some time before it was detected. The low number of farms conducting regular mobility scoring in their herds as discussed above would support this possibility with mildly lame individuals at particular risk of remaining undetected. The importance of early recognition and effective treatment of lameness is discussed further in chapter 4.

Foot trimming and treatment of lesions was primarily conducted by the farmer or a member of farm staff on 30 of the farms questioned and by a combination of the farmer and hoof trimmer on a further 11 farms with 12 farmers stating they had received no training. The fact that farmers are trimming cows feet and treating lame animals with no training is of considerable concern, several describing themselves as 'self-taught'. Poor trimming may in itself be a cause

of lameness (Vermunt., 1999). It is clear that a considerable proportion of foot trimming and treatment of lame cows is carried out by non-professionals and so correct education and dissemination of up to date information on effective prevention and treatment protocols must be made down to a farm level to ensure best practice. Further discussion of this subject can be found in section 5.4.

2.4.4 Development of the six-point mobility scoring system

The method selected for recording herd lameness prevalence in this study was mobility scoring by direct observation of the herd as they exited the milking parlour. A numerical rating score based on six group descriptors was used to assess locomotion.

The specific six-point mobility scoring system used in this study was developed for a RCT to investigate the effectiveness of different treatments for claw horn lesions in lame cows (see chapter 3). In this RCT, emphasis was placed on using practical, on farm treatment protocols and so to this end, the AHDB Dairy mobility scoring system, the current UK standard, was used as the basis for lameness detection. While this system is very practical to use for identifying lame cows for treatment on commercial dairy farms, it lacks some discrimination between levels of lameness severity compared to other locomotion scoring systems for research purposes. In order to address this problem, the descriptors used in the AHDB Dairy mobility score system were compared to those used in other studies and an adapted system produced which is used throughout this thesis.

In all the studies reviewed, observation of the animals' gait was the main focus of the scoring system, however Sprecher *et al*., (1997) also introduced the concept of observing back posture to differentiate between different levels of lameness. This feature was also seen in the scoring system developed by Cook, (2003) and appears in the descriptors in the AHDB Dairy mobility scoring system. While other systems are centred purely on limb movement, Manson and Leaver, (1988) also considered behavioural changes and Cook, (2003) referred to the cows weight (often thin, usually very thin). Many of the systems used for research purposes involved observations while the cow is standing, walking and turning. This level of observation may be easier when assessing individual cows

than whole herds as they enter or leave the parlour. As the adapted scoring system developed for the RCT required fortnightly scoring of five herds to identify individual lame cows over a 15-month period, this level of observation was not possible and so the AHDB Dairy mobility score model of assessing the gait of animals at walk for a minimum of three strides was considered more practical for on farm use.

In all the locomotion scoring systems reviewed, the lowest score was allocated to cows with a 'sound' or 'normal' gait. The descriptors for these fit with those of the AHDB Dairy mobility score 0, where the cow is described as walking with even weight bearing and rhythm on all four feet, with a flat back. Long fluid strides possible. This score and descriptor was therefore maintained in the adapted system.

In all the locomotion scoring systems reviewed, except for Wells *et al*. (1993), a pre-lameness change in gait was recognised where locomotion was imperfect but a lame leg could not be selected. Cook (2003) considered this mild lameness whereas others identified it as uneven gait (Winkler and Willen, 2001), abnormal locomotion, perhaps tender (Whay *et al*., 2003), back arched but gait normal (Sprecher *et al*.,1997), lameness hardly noticeable (Tranter and Morris, 1991), imperfect locomotion (Whey *et al*., 1997) or imperfect locomotion, may walk cautiously or does not track up (Barker et.al., 2010). Manson and Lever (1988) concentrated their scoring system on this early stage of lameness for the purposes of their study allocating half of their scoring system to pre-lame symptoms. While this system may not be suitable for large scale use on farms, it does raise the question of whether these scores indicating the early stages of lameness should be classified as 'lame' and therefore included in lameness prevalence monitoring and in the selection of individuals for further treatment. Once again the AHDB Dairy mobility score 1 fits well with other descriptors of the phase it terms 'imperfect mobility' where steps are uneven (rhythm or weight bearing) or strides shortened but the affected limb or limbs is not immediately identifiable. This score and descriptor therefore remained unchanged in the adapted system used for this thesis.

Where the differences in discrimination between lameness levels in the AHDB Dairy mobility scoring system and other locomotion scoring systems began to be seen was in the classification of lame cows. In the AHDB Dairy system, cows are either deemed to have 'impaired mobility' (score 2 - uneven weight bearing on a limb that is immediately identifiable and/or obviously shortened strides, usually with an arch to the centre of the back), or 'severely impaired mobility' (score 3 - unable to walk as fast as a brisk human pace, (cannot keep up with the healthy herd) and signs of score 2). Using this system 'score 2' contains a wide variation in level of lameness that would be useful to subdivide for research purposes. Looking at other studies, this system is very similar to that used by Whay *et al*. (2003) in a study of welfare assessment where cows were given a score of 0-sound, 1-abnormal locomotion, 2-lame or 3-severely lame, and by Barker *et al*. (2010) in a study of lameness prevalence where cows were given a score of 0-sound, 1-imperfect locomotion, 2-lame or 3-severely lame. This is perhaps unsurprising as the AHDB Dairy mobility score system is based on the descriptions used by Whay *et al*., (2003) which has subsequently become the main UK mobility scoring system, however, in an early study by Whay *et al*., (1997) it was seen that intermediate categories for mild and moderate lameness were used to subdivide 'lame' and in addition a further category of 'as lame as possible while upright' was added above severely lame. The intermediate categories of mild and moderate lameness were also seen in other systems described by Wells *et al*. (1993) and Cook (2003) while the extra category for non-weight bearing lameness was seen in systems described by Tranter and Morris (1991), Wells *et al*. (1993) and Sprecher *et al*. (1997). To increase the level of discrimination in the AHDB Dairy mobility score system for the purposes of this thesis, it was decided to split the score 2, impaired mobility, category into a score 2a, mildly impaired and score 2b, moderately impaired, to reflect the intermediate categories described in the research studies above. Score 3 cows on the AHDB Dairy mobility score were re-named score 3a to represent severely mobility impaired cows and an additional category of 3b created for non-weight bearing lameness. By adapting the system in this way the mobility scoring system developed for this thesis was able to achieve similar levels of discrimination to lameness severity as other locomotion scores used in research and it was possible to amalgamate the 'a' and 'b' scores back into one category

as required for analysis and reporting to avoid confusion in the wider UK dairy industry and for clinical or on-farm use.

The descriptors used in the six-point system were given a more technical description than in some other studies. It was felt that the greater detail would allow more consistency between observers than systems where simple definitions such as that given in Whay *et al*. (2003) may result in a wider degree of individual interpretation. Three observers were used to undertake mobility scoring across the 43 farms in the study. To address the possibility of inter-observer variation in use of the six-point mobility scoring system, the observers underwent a group training session prior to commencement of data collection. Inter- and intra-observer variation using the six-point system developed by the author was assessed prior to its first use in a RCT investigating the recovery of lame cows following treatment (see chapter 3). The data was analysed in a separate, parallel study (Miguel-Pacheco *et al*., 2016) with overall inter-observer agreement fair for mobility scores 0-3 (K_W = 0.40 (95% CI: 0.33-0.61), range 0.39 to 0.55) and for lameness status (non-lame - score 0 or 1) or lame - score ≥2) (K_W = 0.37 (95% CI: 0.16-0.70), range 0.36 to 0.55). This is lower than a similar study by Barker *et al*. (2010) using a four-point scoring system where kappa values ranged from 0.67 (moderate) to 0.93 (good) and is likely to be a reflection of the more complicated scoring system used in the current study. In a study by Channon *et al*. (2009) using the Manson and Leaver locomotion scoring system, an increase in agreement was seen when fewer categories were used, only when the threshold was set to lame or non-lame did observers agree in over 80% of cases. While there may have been some difference between observers, the random selection of farms was designed to reduce the impact of this.

To reduce intra-observer variation, all mobility scoring took place over a five-week period to limit the effects of 'observer drift' over time. Resources and notes from the initial training session were available to observers throughout the data collection period to allow further self-assessment and reflection. In the study by Miguel-Pacheco *et al*. (2016), using the same six-point mobility scoring system, overall average intra-observer agreement for was substantial for mobility scores 0-3 (K_W = 0.70 (95% CI: 0.61-0.73), range 0.62 to 0.76) and for lameness status

(non-lame - score 0 or 1) or lame - score ≥2) (K_W = 0.74 (95% CI: 0.55-0.93), range 0.43 to 0.89). Inter- and intra-observer variation is discussed in greater detail in section 5.4.1.1.

2.4.5 Study design

The methodology used in the recruitment of farms through randomisation of the order of contact and standardisation of the telephone protocols allowed for recruitment of as representative a sample of farms as possible. It should be noted however that of the 246 farmers with whom initial contact was made, only 58 were prepared to participate in the study. This proportion may have increased if the study had initially been designed purely to assess lameness prevalence as the level of involvement by the farmers would have been less than in the proposed clinical trial the data was gathered for. However, it is also likely that the farmers who agreed to participate in a study treatment of lame cows are also the farmers who are more aware of lameness in their herds and interested in taking a proactive approach, therefore the data recorded may be biased by the willingness of farmers to participate. The majority of farmers contacted but not willing to participate gave no specific reason for this. For those who gave a reason, nearly half had stopped milking or were stopping in the very near future, a clear reflection of the current economic state of the UK dairy industry. Most of the other reasons around not participating were related to time pressures or current lameness control practices which may relate back to the original study proposal.

Random selection of farms for this study was also limited by the need for proximity to the University of Nottingham, School of Veterinary Medicine and Science in the initial research proposal. All the farms surveyed were located in the central region of England. Farms visited may not therefore be representative of the UK as a whole and lameness prevalence findings should be considered in this context.

Other lameness prevalence studies such as that carried out by Clarkson et. al. (1996) and Barker *et al*. (2010) recruited farms through veterinary practice recommendation or dairy companies respectively. In the current study, a database of all known UK dairy farms was used to identify potential participants, these were placed in a random order, then contact telephone numbers were found

through an internet search. This method resulted in significant time implications both in sourcing contact details and then trying to make contact with farmers. A two call protocol was put in place to reduce the overall time spent on farm recruitment however to enrol fifty-eight farmers on the study (the original study target was to enrol 60-70 farms) took ten weeks with 519 searches made on the internet search engines BT find a person, BT find a business and yell.com in order to identify and call 434 telephone numbers. While this method of randomisation to recruit a representative sample may have its strengths from a scientific point of view, the time and cost implications of implementing such a recruitment system should not be underestimated.

2.5 Conclusion

The prevalence of lameness found in this study raises considerable welfare concerns with around 30% of cows showing evidence of symptoms associated with painful locomotion. The prevalence however does show a reduction when compared to a similar study carried out seven years earlier. Whether this reduction shows a true downward trend in lameness prevalence in the UK remains to be seen.

Despite efforts by organisations such as AHDB Dairy to promote the detection and treatment of lame cows, a low level of routine mobility scoring was seen with less than ten percent of farms conducting monthly mobility scores. A large proportion of farmers were also carrying out their own routine trimming and treatment of lame cows. Disseminating new research on the most effective protocols and providing appropriate training to farm staff is therefore key in addressing the issue of lameness on UK farms.

Chapter 3. A randomised controlled clinical trial (RCT) for treatment of claw horn lesions in acutely lame cows

3. Abstract

Lameness is one of the most significant endemic disease problems facing the UK dairy industry. Claw horn lesions (sole haemorrhage/ ulceration (SH/U) and white line disease (WLD)) are some of the most prevalent conditions leading to lameness in affected animals. To achieve sustainable reduction in claw horn lesions, attention must be paid to implementing appropriate prevention strategies and ensuring new cases are identified quickly and treated effectively. Much of the research focus in recent years has been on prevention of lesions through identifying risk factors, however there is little scientific research to guide clinical decision making on the most appropriate treatment protocols when animals become lame. This study aims to begin the process of determining effective treatments for claw horn lesions by way of a partially blinded, randomised, positively controlled clinical trial (RCT).

Mobility scoring was conducted fortnightly on five farms in close proximity to the University of Nottingham, School of Veterinary Medicine and Science and animals identified with an acute case of lameness (two non-lame scores followed by a lame score) on one hind limb put forward for examination. Animals with claw horn lesions on a single claw and no evidence of active infectious disease were eligible for enrolment and allocated at random one of four treatments. The primary outcome measure was mobility score at 35 (±4) days post treatment conducted by an observer blind to the treatment group.

Treatments selected for the study were determined by a steering group comprised of veterinary experts and representatives of the funding body. Two preliminary studies were conducted to feed into this group and allow wider opinion to be considered. The first of these was conducted at the University of Bristol and surveyed farmers on their perception of efficacy and practicality of different treatment options. The second surveyed industry professionals on their current practices and which treatments they would like to see included in the trial. From these results the steering group selected four treatments to go forward into the RCT; 1) Therapeutic trim (TRM) (positive control group), 2) therapeutic trim

plus an orthopaedic foot block on the non-affected claw (TB), 3) therapeutic trim plus a three day course of the nonsteroidal anti-inflammatory drug (NSAID) Ketoprofen (TN) and 4) therapeutic trim plus orthopaedic foot block plus NSAID (TBN).

Between 10th January 2012 and 31st January 2013 a total of 512 cows were examined with 183 meeting all the inclusion criteria for the study. Forty seven cows were allocated in the treatment group TRM, 46 TB, 45 TN and 45 TBN. 16 cows were withdrawn before the primary outcome measure. Based on a sound score (score 0) at 35 days post treatment, the number (and proportion) of successful treatments was 11 of 45 (24.4%) TRM, 14 of 39 (35.9%) TB, 12 of 42 (28.6%) TN and 23 of 41 (56.1%) TBN. A significant difference was seen between treatment groups (P=0.01). To test for confounding imbalances between treatment groups, logistic regression models were built with two outcomes, sound (score 0) or non-lame (score 0 or 1) at 35 days post treatment. Compared with TRM, animals which received TBN were significantly more likely to recover to a sound outcome. Farm, treatment season, lesion diagnosis, limb affected, treatment operator and stage of lactation were included in the final model.

The results of this study suggest that recovery in animals treated for lameness due to claw horn lesions is maximised by treatment with a therapeutic trim plus the application of an orthopaedic foot block to the non-affected claw and a three day course of NSAID. Smaller non-significant improvements were also seen with the addition of a foot block or a three day course of NSAID in addition to a therapeutic trim when compared with a therapeutic trim alone.

3.1 Introduction

If sustainable reduction of lameness levels on dairy farms are to be achieved, the problem needs to be addressed both in terms of prevention and effective treatment. Primarily, the key to lameness control is to find ways to decrease the incidence of new cases and thus the associated economic and welfare implications. However completely eliminating lameness is unlikely to occur and so it is necessary to ensure the treatment protocols used are effective. Much of the emphasis of recent research has rightly focused on lameness prevention and identifying risk factors for disease however the treatment of animals once they become lame must not be neglected.

The majority of lameness in dairy cattle appears to be associated with the foot (Russell *et al*., 1982, Rowlands *et al*., 1983, Jubb and Malmo, 1991, Clarkson *et al*., 1996) with lesions divided between those of infectious aetiology and those affecting the claw horn as a result of pathological changes within the claw structure. Of the latter, sole ulcer, sole haemorrhage and white line disease are the most prevalent conditions causing lameness in dairy cows (Capion *et al*., 2008, Cramer *et al*., 2008). Recent work has suggested that early treatment is the key to promoting recovery and reducing recurrence of these lesions (Groenevelt, 2014, Leach, 2012) however there is little scientific research to guide us on the most effective treatment strategies. Potterton *et al* (2012), in a review of the peer-reviewed literature published between 2000 and 2011 on the treatment and prevention of foot lameness in cattle, identified 27 studies relating to the treatment of digital dermatitis, an infectious skin disorder of the foot but little on the treatment of lesions occurring in the claw itself, with only three papers on the treatment of sole ulcers and none on the treatment of white line disease. Of these three papers, two were non-experimental, a retrospective study of cases treated at the University of Nairobi Large Animal Hospital (Nguhiu-Mwangi *et al*., 2008), and a report of 42 cases of sole ulcers in Turkish dairy cattle where all cattle were treated using the same protocol and no control animals were used (Durmus, 2005). The third was a Swiss study looking at the effect of dietary biotin on the healing of uncomplicated sole ulcers (Lischer *et al*., 2002). A wider examination of the peer reviewed literature revealed only two other studies relating to treatment of claw lesions. The first, a clinical trial

conducted at an Australian veterinary clinic, randomly allocated a copper sulphate bandage, wooden foot block or commercially available rubber shoe to cases presented for treatment at a veterinary clinic (Pyman, 1997). The initial allocation of treatments was randomised in blocks of nine with three repetitions of each treatment in each block, however the final 22 cows on the study were only allocated either a wooden block or rubber shoe after preliminary analysis revealed these to be a superior treatment to bandaging. Lameness was assessed by the herd manager at the time of treatment and on days one, three, seven and 14. At days three and seven there was a significant difference in lameness between blocks and rubber shoes compared to bandages, with the block and shoe providing a more rapid improvement in gait however by 14 days this difference was no longer evident. In the second (Laven, 2008), animals identified as lame by farm staff were treated on nine dairy farms. Following a corrective trim, if the affected claw could be trimmed sufficiently to reduce weight bearing on the lesion, cows were randomly allocated the addition of a plastic shoe, non-steroidal anti-inflammatory drug (NSAID), a combination of a plastic shoe and NSAID or no further treatment. If the affected claw could not be trimmed sufficiently to reduce weight bearing, a foot block was fitted to the non-affected claw and cows randomly allocated a NSAID or no further treatment. Both locomotion score and nociceptive threshold were recorded but the authors found that while all treatment groups showed continuous improvement between day 0 and 100 there was no significant difference between the treatment groups. It is worth noting however these cows were managed on and suffered diseases associated with an extensive pasture-based system, very different from the intensively housed management systems more commonly seen in the UK.

With this deficit of experimental evidence for the efficacy of treatments, particularly in the UK, clinical decision making is often based on anecdote and experience of experts working in the field. This doesn't necessarily mean that the treatments are ineffective but it is clear that further, robust scientific investigation is required to elucidate which of the options available would lead to the highest cure rates in the shortest time.

This study aims to begin the process of determining appropriate and effective treatments for sole haemorrhage, sole ulceration and white line disease. The

hypothesis was that claw horn lesions would recover at different rates depending on the treatment administered. Two primary objectives were identified for this study; to identify treatments currently in common use and any barriers associated with their implementation (section 3.2) and to evaluate of the comparative efficacy of selected treatments by way of a partially blinded, randomised, positively controlled clinical trial (section 3.3).

3.2 Study 3a: Selection of treatments for use in a randomised controlled clinical trial (RCT) on treatment of claw horn lesions in dairy cattle

3.2.1 Introduction

A steering group was established to oversee a proposed RCT on treatment of claw horn lesions in dairy cattle. The steering group comprised veterinary experts from four UK Universities (the investigators on a wider programme of lameness research, which this thesis forms part of) and representatives of the body funding the clinical trial. Final decisions on the RCT protocol were based on consensus opinion by all members of the steering group. Two studies canvassing the opinions of end users, farmers, veterinary practitioners and cattle foot trimmers, were instigated to feed in to the steering group and allow wider opinion to be considered before the group decided the final treatments to be used in the RCT used in the RCT.

The first of these studies, undertaken at Bristol University School of Veterinary Sciences as part of a wider program of research, consisted of a survey of dairy farmers designed to gain insight into the barriers to on-farm treatment of individual lame cows (Horseman *et al*, 2013). One hundred and two farmers were contacted of whom 84 agreed to participate and were asked a combination of closed and short-answer, open ended questions during a ten-minute telephone interview. Questions related to current on-farm practices, the main issues the farmer saw as barriers to treatment and factors which may motivate treatment. They were also asked their thoughts on the potential effectiveness and practicality of four different treatment options for sole ulcer, sole haemorrhage and white line disease. The treatments suggested were trimming the affected claw, trimming the affected claw and applying an orthopaedic foot block to the unaffected claw, trimming the affected claw and giving the animal access to a straw bed and trimming the affected claw and administering antibiotics.

A second follow-on survey was undertaken by the author at the University of Nottingham to canvas the views from other industry professionals, gauge wider opinion and ensure all options had been considered by the steering group. The survey and its outcomes are described below.

3.2.2 Materials and Methods

A survey of industry professionals was conducted to assess treatments currently in use for claw horn lesions and to canvas the opinion of these professionals on which would be the most appropriate treatments to investigate in a proposed RCT. A convenience sample of experts identified by the steering group (n=29) were contacted during November 2011 and emailed a questionnaire to complete on the treatment of claw horn lesions. Those contacted were either veterinary surgeons recognised as experts in the field of cattle lameness (n=15), or Category 1 professional hoof trimmers / committee members of the National Association of Cattle Foot Trimmers (NACFT), the UK representative body for professional cattle hoof trimmers (n=14).

The questionnaire provided photographic examples of claw horn lesions and asked for a brief description of how the individual would currently treat the lesion, if they would ever treat the lesion differently and in what circumstances, and what different treatment procedures they would most like to see tested in the clinical trial (see Appendix 1).

The findings of this questionnaire were then considered by the steering group, alongside the results of the study conducted by the University of Bristol (Horseman *et al*., 2013), to identify treatments which were commonly used on farms, practical to implement for the purposes of a RCT and of interest to end users who would be treating lame dairy cows.

3.2.3 Results

3.2.3.1 Results of farmer survey conducted at University of Bristol by Horseman *et al.*, (2013)

Eighty four farmers completed the telephone survey. Table 9 shows the views of these farmers on the effectiveness and practicality of four potential treatments. The results consider sole ulcer, sole haemorrhage and white line disease together as survey respondents rarely distinguished between these lesions.

Table 9. Views of 84 farmers of the efficacy and practicality of four treatment options; trimming affected claw, trimming affected claw and applying an orthopaedic foot block on the healthy claw, trimming affected claw and placing the cow on a straw yard and trimming (adapted from Horseman *et al.*,2013)

Treatment	**Proportion that considered treatment effective in all cases of Sole ulceration and white line disease**	**Proportion that considered treatment was/was not effective in some cases with descriptions of criteria applied**	**Proportion that considered treatment was practical**	**Comments on practicality of treatment**
Trim* affected claw	24%	64% – if animal could take the weight off the affected claw via trimming alone	85%	For the remaining farmers this treatment was deemed impractical due to: • Lack of handling facilities • Having no-one on farm who could carry out trimming • Lack of confidence in trimming skills
Trim* affected claw and apply orthopaedic block on the healthy claw	70%	21% – applying a block not always necessary	68%	Problems mentioned: • Lack of handling facilities • Having no one on farm who could carry out trimming • Difficulties getting blocks to adhere to unaffected claw • Time taken to apply blocks • Expense of blocks/adhesive
Trim* affected claw and place cow on straw yard	54%	17% – would help/work in mild cases only	33%	Problems mentioned: • Lack of space • Problems associated with creating an additional group of cows • Increased risk of mastitis when housed on straw • Worries about separating cows from main herd • Cost of straw bedding
Trim* affected claw and give antibiotics	14%	37% – effective if evidence of infection	60%	Problems mentioned: • Development of antibiotic resistance • Milk withdrawal times

* 'Trim' was briefly described to the farmers as a therapeutic trim with a brief outline of the five-step Dutch method (National Association of Cattle Foot Trimmers, 2011).

24% of the respondents thought that trimming the affected claw was an effective treatment for mild sole ulcer/haemorrhage and white line disease lesions. A further 64% felt that it was an effective treatment if the weight could be adequately taken off the affected claw by trimming alone. 85% of farmers felt that trimming was a practical treatment for them to carry out. 70% of farmers felt that trimming the affected claw and then putting a block on the unaffected claw was effective in treating mild lesions however 21% felt that applying a block was not always necessary with mild lesions. While 54% of respondents considered placing cows in a straw yard after trimming to be effective, several practical constraints were highlighted including lack of accommodation space. Antibiotic use was seen as practical by 60% of farmers, however only 14% felt this was an effective treatment for all mild cases, 37% felt it was effective if there was evidence of infection and 4% felt it was effective for severe cases.

3.2.3.2 Results of industry professional survey conducted at University of Nottingham

Eleven of the 29 individuals contacted responded to the questionnaire on the treatment of claw horn lesions. Questionnaires were returned anonymously so the proportion of veterinary surgeons and NACFT members completing the survey is unknown. Figure 13 illustrates the results of the questionnaire with regard to the treatment of sole ulceration and sole haemorrhage (SH/U). Figure 14 illustrates the results with regard to the treatment of white line disease (WLD).

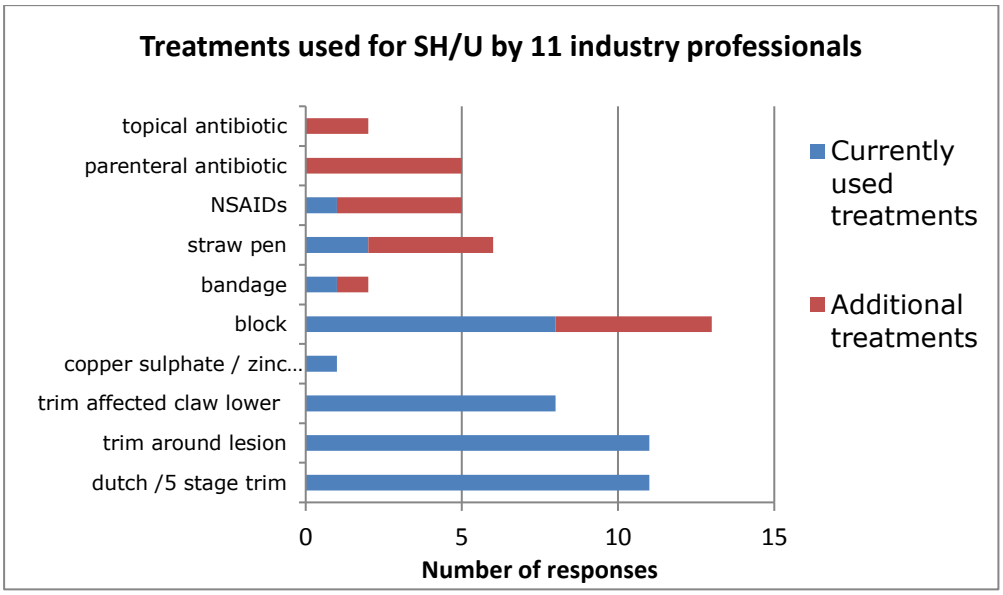


Figure 13. Treatment procedures described by 11 industry professionals in a questionnaire as those they currently use for cases of sole haemorrhage and sole ulceration and those they may use as an additional treatment in some circumstances

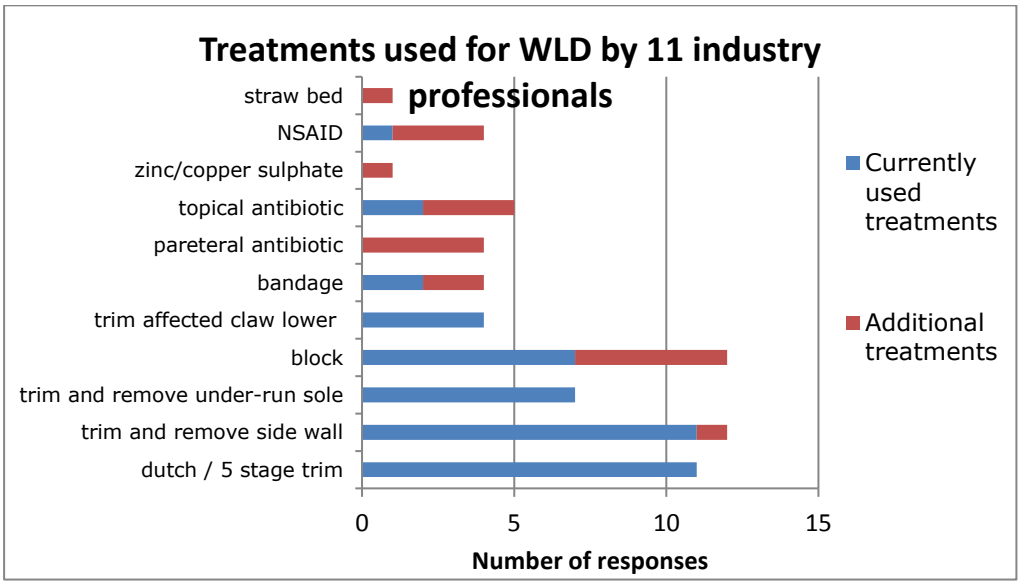


Figure 14. Treatment procedures described by 11 industry professionals in a questionnaire as those they currently use for cases of white line disease and as those they may use as an additional treatment in some circumstances

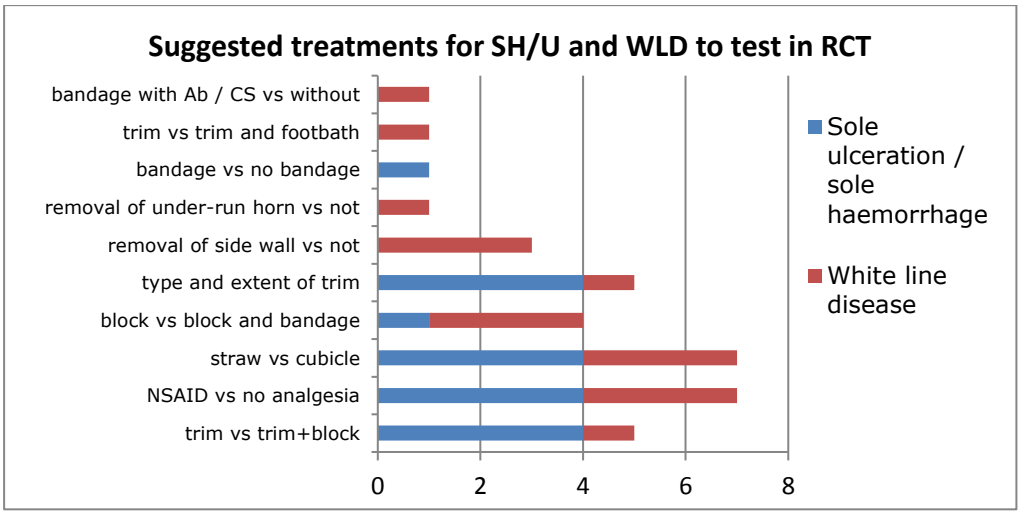
All of the respondents reported that they would trim the foot as a primary treatment for both SH/U and WLD. For SH/U all respondents also reported they would trim around the lesion and in WLD trim and remove the side wall.

Where respondents stated they would treat lesions differently in certain circumstances further information was given. Table 10 displays the additional comments made in the questionnaire in relation to secondary treatment options for SH/U and WLD.

Table 10. Reasons given by industry professionals in a questionnaire for using straw pens and antibiotics as additional treatments for sole ulcer and sole haemorrhage and for using bandages and antibiotics as additional treatments for white line disease

SOLE HAEMORRHAGE / SOLE ULCER		**WHITE LINE DISEASE**	
SECONDARY TREATMENT	REASON FOR USE	SECONDARY TREATMENT	REASON FOR USE
Straw pen	• For freshly calved cows or heifers • If unable to block other claw	Bandage	• With zinc/copper sulphate if corium exposed or digital dermatitis. • + topical antibiotics if digital dermatitis only
Antibiotics	• If evidence of infection • If corium infected • If digital dermatitis on exposed corium • If evidence/suspicion of synovial infection	Antibiotics	• If swelling • If develops wall ulcer • If evidence of digital dermatitis • If swelling/evidence of synovial infection

Respondents were also asked which three different treatment procedures they would be most interested seeing tested in the clinical trial. Figure 15 illustrates the different treatment procedures suggested for SH/U and WLD and the combined result for both claw lesions



*Ab – antibiotic, CS- copper sulphate, NSAID – non-steroidal anti-inflammatory drug

Figure 15. Treatment procedures suggested by 11 industry professionals as those they would be most interested in seeing tested in a randomised clinical trial.

The four most frequently suggested treatments to test for SH/U were the use of a trim compared to a trim and foot block, the use of non-steroidal anti-inflammatory analgesics (NSAID) compared to no analgesia, the use of a straw yard compared to the animals normal environment and the type and extent of trim. The four most frequently suggested treatments to test for WLD were the use of analgesia compared to no analgesia, the use of a straw yard compared to the animals normal environment, the use of a foot block compared to foot block and bandage and the removal of the side wall compared to leaving the wall intact. Combining the responses for both lesion types the four most popular combinations for testing were trim compared to trim and foot block, analgesia compared to no analgesia, use of a straw yard compared to the animals normal environment and investigating the type and extent of the trim.

3.2.3.3 Treatments selected for RCT

Following consideration of the results of the two surveys described above, the steering group reached a consensus that the treatment options shown in table 11 would be put forward to trial in the RCT.

Table 11. Final treatment combinations selected by a steering group for use in a randomised clinical trial on the treatment of claw horn lesions in dairy cows.

TREATMENT		**FOOT BLOCK**	
		NO	**YES**
NSAID	**NO**	**Treatment 1** Therapeutic trim only (TRM)	**Treatment 2** Therapeutic trim + foot block (TB)
	YES	**Treatment 3** Therapeutic trim + NSAID (TN)	**Treatment 4** Therapeutic trim + foot block + NSAID (TBN)

*NSAID- non-steroidal anti-inflammatory drug

3.2.4 Discussion

The results obtained from the questionnaire suggest that a five-stage foot trimming procedure and the application of foot blocks are the most common treatments used by veterinary surgeons and professional hoof trimmers, either as a primary or secondary treatment, for both SH/U and WLD. The standard five-stage foot trim includes three stages whereby the foot is trimmed and balanced for routine maintenance, followed by two 'therapeutic' stages when any lesions are explored and trimmed appropriately and the affected claw lowered to reduce weight bearing. This five stage or 'Dutch' trimming method described by Toussaint Raven (1989) is widely used in Europe with the theoretical science underpinning this technique supported to some extent by a study carried out in 2007 by Montgomery *et al* (2012) showing trimming using this method reduced the proportion of lame cows by 55% over a seven-day period (although no control group was used in this study and therefore results must be interpreted accordingly). From the results of the survey of industry professionals detailed above, the 'five-stage-trim', 'trimming around the lesion', 'trimming the affected claw lower', 'removing the side wall' and 'removing under-run sole' could all be considered part of the 'Dutch' trimming method and were therefore all grouped under the term 'therapeutic trim'. The application of a foot block to the non-affected claw was also commonly used by both veterinary surgeons and hoof trimmers to transfer weight to the non-affected claw reducing pressure on the lesion and reducing pain during locomotion. This treatment however should not be used where lesions are found on both claws as this would increase the pressure on lesions in the blocked claw.

When it came to the favoured options put forward by the respondents for testing in the RCT the use of foot blocks, analgesic NSAIDs, straw pens and investigating the type and extent of trim were the most frequently suggested. The comparison of a therapeutic trim with a therapeutic trim and application of an orthopaedic foot block fitted the clinical trial criteria of being commonly used in practice, considered practical and effective by farmers and of interest to the professionals for testing. Use of an orthopaedic foot block was therefore considered by the steering group as a suitable treatment to be fed forward into the RCT. The use of NSAIDs was an interesting result as while fewer than half

of the respondents were currently using these in the treatment of SH/U and WLD, it was the joint most frequently suggested treatment for inclusion in the study. This would suggest that there is a desire to know whether this particular treatment is effective which may impact on future clinical decision making. While the use of analgesics was not specifically discussed in the study by Horseman *et al*., 2013, the use of antibiotics which are administered in a similar way were considered practical by farmers (although not particularly effective). Based on this the steering group decided the use of analgesics would also be put forward for testing in the RCT. Investigation of the use of straw yards was of particular interest to industry professionals, however from the Bristol study it was also clear that this was an area where farmers had practical concerns over implementation, particularly in respect to the space required for such facilities. As the RCT aimed to identify the most effective treatment which can be practically carried out on the farm, investigating the use of straw yards was discounted as an option due to these practical concerns. Type and extent of foot trimming was a popular choice however standardising protocols to apply to lesions of different severity was felt to be outside the limits of this study and so this option was also discounted. For similar reasons investigating the removal of the side wall compared to non-removal in cases of white line disease was omitted due to the variation in lesions likely to be seen in a clinical setting. The final suggestion of comparing the use of a foot block to a foot block and bandage was felt to be of little value until the efficacy of the foot block itself had been established.

Drawing together all these factors, along with the experience of members of the steering group and the requirements of the body funding the RCT, the use of a therapeutic trim, foot block and NSAIDs were identified as the three treatment options for investigation. Following further discussion, it was decided that all animals examined on the clinical trials would receive a standard, three-stage trim to balance the foot and identify the foot lesion present and the minimum treatment of a therapeutic trim to meet the requirements of the Veterinary Surgeons Act under which the clinical trial was to take place (full description in section 3.3). Enrolled cows would then be allocated to one of four treatment

groups in a two by two design incorporating a combination of the three treatment options chosen (see table 11).

Due to time constraints, the number of respondents to the survey on treatment of SH/U and WLD was limited which may have a bearing on the results obtained. Had time allowed, a subsequent telephone call would have been made to elicit greater response, however it was imperative for the RCT to commence at the time stated in the research proposal to allow completion within the required time frame and the responses received were considered sufficient to inform the steering group. The initial convenience sample of industry professionals was also neither systematic or random which may have led to bias in the result. While a relatively small group of individuals were contacted they were believed by the steering group to be representative of the industry. Alternative qualitative methods of collecting information on current practices such as focus groups and one to one interviews were felt to be too time consuming and expensive for the basic data required and were logistically problematic due to the geographical locations and work loads of those asked to participate. While a greater range and depth of information may have been gathered on currently used treatment protocols for claw horn lesions using these alternative methods, this type of information gathering exercise would have constituted a separate study in itself and along with the cost implications was not deemed necessary in order to select the treatment options for the proposed RCT. As responses were anonymised, the proportion of veterinary surgeons and professional hoof trimmers who responded was unclear however ultimately the purpose of the survey was to ensure that the opinions of the steering group were not out of step with the views of other professionals working within the industry and this objective was satisfactorily achieved. It is recognised therefore, that the treatments put forward for the RCT did not allow for a comprehensive study of all treatment options but would provide evidence of efficacy for the four individual treatment protocols tested on which clinicians and hoof trimmers could base their treatment choices.

3.3 Study 3b: A randomised controlled clinical trial (RCT) for treatment of claw horn lesions in acutely lame cows

3.3.1 Materials and Methods

3.3.1.1 Study design

A positively controlled RCT with blind outcome observation was planned to investigate the cause-effect relationship between four commonly used treatments for claw horn lesions and their outcome. The primary outcome measure was a mobility score at 35 days ±4 days post treatment conducted by an independent observer. Based on a binary measure of lame or not lame at outcome, a power calculation suggested that treatment group sizes of 58 would detect a 25% difference in recovery rate between treatments (power value of 0.8, $P \leq 0.05$). A difference of 25% was selected as it was considered clinically meaningful and likely to be large enough to warrant the additional cost of treatment should they prove superior.

The RCT was conducted under the Veterinary Surgeons Act 1966 which regulates acts of veterinary surgery in the UK. As such no animal was left untreated and a positive control group was used involving a baseline treatment intervention (therapeutic trim). Farms involved in the study were instructed to continue their normal practices for treatment of lame cows between visits by the researchers. The protocol was reviewed and approved by the University of Nottingham's School of Veterinary Medicine and Science Ethical Review Committee prior to the study commencing. The research was over by a steering group comprising veterinary experts from four UK Universities (the investigators on a wider programme of lameness research, which this thesis forms part of) and representatives of the body funding the clinical trial. Decisions regarding the timeframes covered in the study protocol were determined by the steering group based on experience of clinical practice and the practicalities of implementing the protocol.

3.3.1.2 Treatment selection

Treatments to be tested in the RCT were identified using social science techniques to assess suitability and acceptability to the dairy industry (see section 3.2) and four treatment groups were decided upon; treatment 1:

therapeutic trim only (TRM), treatment 2: therapeutic foot trim and application of an orthopaedic foot block (TB), treatment 3: therapeutic foot trim and administration of a NSAID (TN) and treatment 4: therapeutic foot trim, application of an orthopaedic foot block and administration of a NSAID (TBN).

The choice of products to use for each of the treatments was arrived at following further consultation within the steering group. In order for the RCT not to favour particular designs of orthopaedic shoe available commercially, it was decided to use a simple wooden foot block to raise the affected claw from the ground. The preferred adhesive for longevity of the foot blocks was felt to be Demotec 95 (Siegfried Demel, Germany. Methylcrylic acid methyl ester or methyl methylcrylate, containing an activator). Although other adhesives were available, no experimental evidence supported the use of a particular type and so the decision was made based on the experience of the experts in the steering group.

The NSAID chosen for the trial was a three-day course of ketoprofen (Ketodale 100mg/ml solution for injection for horses, cattle and swine, Richter Pharma AG) administered by deep intramuscular injection at 3mg ketoprofen/Kg bodyweight, equivalent to 3ml per 100Kg bodyweight. The choice of Ketodale was made based on the Veterinary Medical Directorate prescribing cascade with Ketodale being the only drug licenced specifically for treatment of lameness in cows, at that time (December 2011). The dose administered was based on an estimation of weight. The first injection was administered by the treatment operator at the time of examination, subsequent injections were prepared and labelled by the treatment operator and administered by a member of farm staff.

3.3.1.3 Farm recruitment

A convenience sample of five dairy farms were recruited for participation in the RCT within close proximity of the University of Nottingham School of Veterinary Medicine and Science. To be eligible for participation, farms were required to be conducting routine milk recording, have a lameness prevalence of above 20% at the start of the study, be undertaking routine measures to control digital dermatitis at the herd level (e.g. foot bathing) and be willing to participate and comply with the study requirements for the duration of the study (see form

A, appendix 2). Farms were recruited either through their veterinary surgeons' who were asked to nominate clients they considered met the criteria and would be willing to participate or were previously known to the trial coordinators. A short list of suggested farms were approached and visited to discuss the trial and assess their lameness prevalence. Following an introductory telephone call one farm elected not to participate as they considered the trial would interfere with their day to day farm management.

Information on farm management, housing and lameness protocols were gathered for each of the farms through farm records, milk recording databases or direct observation by the author during the course of the study. The farms recruited to the study were between 187 and 353 (median 241) cows in size with 305 day adjusted milk yields ranging from 7,394 to 11,579L (median 10,381L). Two farms (farms 2 and 4) milked cows in an automatic milking system, the remaining farms milked cows in conventional parlours twice daily (see table 12).

Table 12. Management information on five herds used in a randomised clinical trial on treatment of claw horn lesions in dairy cattle.

Farm ID	Herd size (2012)	Cows in milk (2012) [1]	Feeding system	Milking system	Milking regime	Average 305d milk yield (litres)	Lameness prevalence at start of study [2]
1	270	209	Mixed ration twice daily	Herring-bone parlour	Twice daily	7394 L	43.3%
2	192	175	Mixed ration once daily plus AMS	Automatic milking system (4)	Free access (max 5x day)	11579 L	55.9%
3	187	172	Mixed ration twice daily	Herring-bone parlour	Twice daily	10381 L	57.1%
4	241	207	Mixed ration once daily plus AMS	Automatic milking system (4)	Free access (max 5x day)	11138 L	29.6%
5	353	304	Mixed ration twice daily	Rotary parlour	Twice daily	9893 L	22.6%

AMS – Automatic Milking System

[1]Number of cows with milk records for 2012

[2]Lameness prevalence in the lactating herd, not including dry cows and young-stock

Three of the farms (farms 2, 4 and 5) housed lactating cows continuously throughout the year, the other two farms managed cows at pasture during the summer (~ March-October) and housed over winter. On all farms lactating cows were accommodated in cubicles (see table 13). All walkways and standing areas

were concrete except farm 2 which had rubber matting throughout and farm 3 which had rubber matting at the feed face of the high yielding group.

Table 13. Description of housing management on five farms used in a randomised clinical trial on treatment of claw horn lesions in dairy cattle.

Farm ID	Average Housing Period	Lactating Cow Groups	Sick cow accommodation	Cubicle bedding	Passageways	Automatic scraper
1	October to March	High yield Low yield	Straw pen for 4 - 5 cows	Rubber mattress	Concrete	No Tractor scraped twice daily while cows in parlour
2	365days	None	Individual straw pens	Rubber mattress with sawdust	Rubber matting	Yes Every hour
3	October to March	High yield Low yield Heifers	Straw pen for 4 - 5 cows	Rubber mattress	Concrete with rubber matting at high yield cows feed face	Yes Twice per hour
4	365days	None	Straw pen for 4 - 5 cows	Water beds with ash lime and Envirobed paper	Parallel grooved concrete	Yes Every hour
5	365days	None	Large straw pen	Rubber mattress	Concrete	No Tractor scraped twice daily while cows in parlour

All farms undertook routine foot trimming although scheduling ranged from ‘as required’ to weekly sessions (see table 14). Two farms (farms 1 and 2) used an external professional foot trimmer, on the other farms trimming was conducted by farm staff. The reported interval to treatment of lame cows varied from as soon as they were identified for severely lame cows to fortnightly with routine foot trimming sessions. Treatment intervals depended on disease severity and staff availability.

Table 14. Lameness protocols employed on five farms enrolled in a randomised clinical trial on treatment of claw horn lesions in dairy cattle

Farm ID	Foot bathing protocols	Routine foot trimming protocols	Identity of foot trimmer	Lame cow treatment frequency
1	Formalin 5% Daily	Fortnightly	External foot trimmer	Fortnightly with routines
2	Copper sulphate 5% Once per week	5 monthly	External foot trimmer	At routine trimming, additional for severely lame cows as required
3	Formalin 5% 3 times per week	Weekly	Stockman	Weekly with routines. Severely lame same day
4	Formalin 5% As required	4 monthly	Farm manager	At routine trimming, additional for severely lame as required
5	Formalin 5% Daily	As required	Farmer	As required

3.3.1.4 Mobility Scoring

Mobility scoring of all cows in the lactating herd was undertaken at fortnightly intervals on each of the five farms. Mobility scoring was carried out by the author and two trained technicians who provided vacation cover with quarterly revalidation sessions to maximise agreement between the observers. These sessions comprised observation of forty video clips of cows walking slowly for at least three strides with each of the scorers completing a mobility score sheet. The results of the revalidation session were then compared and discussed within the group. Mobility scoring was undertaken as the cows exited the parlour after milking (Farms 1, 3 and 5) or in a passageway with a firm, level surface (farms 2 and 4) and results recorded on a data collection form (see form B, appendix 2). All animals in the herd were uniquely identified by freezebrand numbers which were used to identify individual cows. Dry cows and youngstock were not scored. Cows were scored on a 6-point scale adapted from the AHDB Dairy mobility scoring system (see section 2.2.2). Each cow was mobility scored walking for a minimum of 3 strides in a straight line. For cows with a mobility score of 2a or above, the lame leg was identified and recorded.

3.3.1.5 Study protocol

To be considered for inclusion in the clinical trial, animals were required to present with a 'new' or acute case of lameness in a single hind limb. For a case of lameness to be considered acute, the cow must have recorded two successive non-lame scores (score 0 or 1) followed by a lame score (score 2a, 2b, 3a or 3b) during the last three fortnightly mobility scoring process. Cows entering the herd post-calving must have recorded at least one non-lame score followed by a lame score.

The records of animals meeting the inclusion criteria were checked to determine if they had received any previous treatment for lameness, either by the farmer or on the RCT, within the previous 120 days if the lameness was in the same foot or 90 days if the lameness was in another foot. Records were also checked to see if animals had completed a course of parenteral antibiotics or NSAIDs within the previous 14 days. If either of these had occurred, the animal was excluded from the study. Animals which had previously been enrolled on the study, either on the same or a different leg, were also excluded (see form C, appendix 2).

Full examination of the foot identified as lame was undertaken within 48 hours of the mobility score. A repeat mobility score on a firm surface was carried out by the treating clinician to confirm the mobility score and lame leg immediately before the animal was restrained in a crush for examination. Administration of treatment was mainly undertaken by the author with vacation cover from one of four other operators.

Each animal was examined for the infectious lesions interdigital necrobacillosis and active digital dermatitis and excluded if these were found. Animals with a substantial interdigital growth or significant hock lesion which may cause discomfort and therefore affect their locomotion were also excluded at this stage. Identification of the affected claw was attempted using a 'tweak test', (lateral rotation of the claw resulting in a withdrawal reflex if pain was elicited) and application of hoof testers. Pressure was applied with the hoof testers at three sites on the sole and two sites across the hoof wall (see figure 16). A consistent withdrawal reaction to the tweak test or pressure from the hoof testers was considered indicative of pain in the claw.

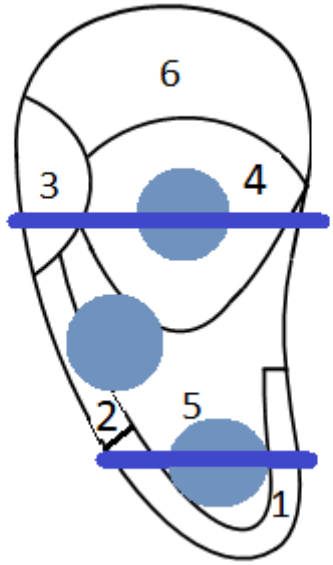


Figure 16. Foot map (adapted from Greenhough (2007)) showing claw zones (1-6) and position of hoof tester application (circles, pressure applied to sole, lines pressure applied across walls) during the enrolment examination of animals on a randomised clinical trial of treatment of claw horn lesions in dairy cattle.

Each animal received a five-stage, therapeutic trim of the affected foot (both claws) consisting of removal of excess horn growth, investigation and trimming out of any lesions present, removal of diseased and under-run horn and, as far as possible, rebalancing the claw height to reduce weight bearing on the diseased claw (Toussaint Raven, 1989). A written and pictorial description of the lesion was recorded (see figure 17) and photographic records of the lesions with a cow identification number and date were collected (see form C, appendix 2).

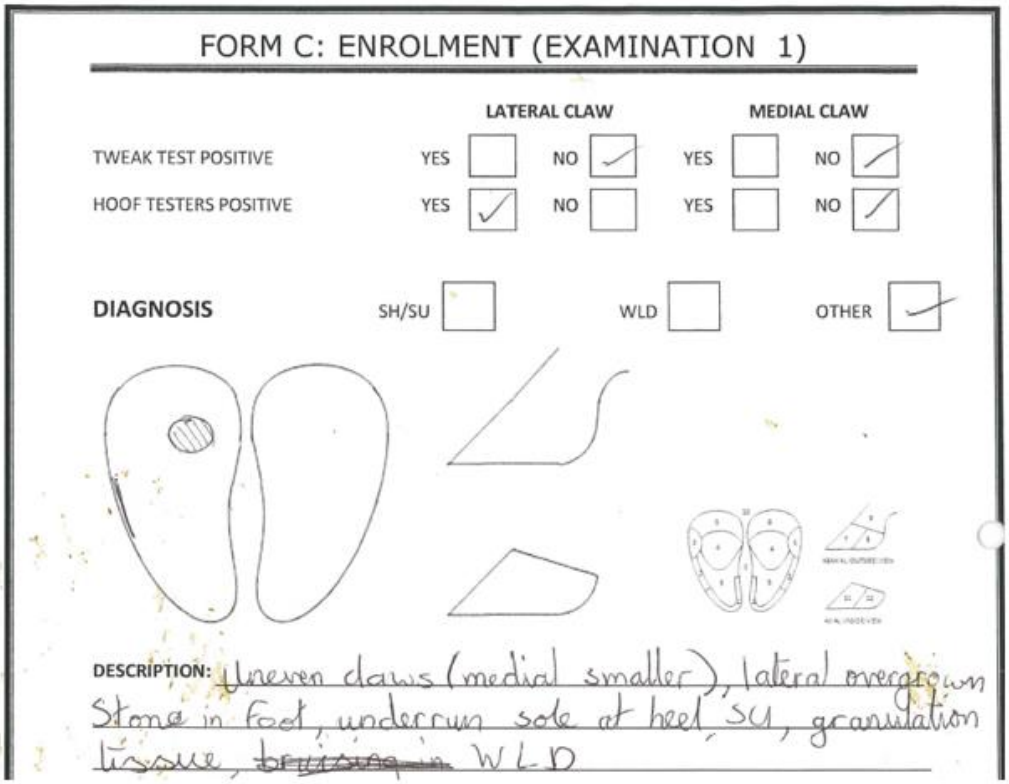


Figure 17. Pictoral representation of lesions seen in the lame foot during the enrolment and outcome examinations during a randomised clinical trial on treatment of claw horn lesions in dairy cattle as recorded on data collection sheets.

Animals were excluded from the study if they were diagnosed with two or more substantial claw lesions where one or more of the lesions occured in both claws. Animals were also excluded if they failed to comply with the study protocol including taking more than 15 minutes to load into the crush, becoming unduly stressed by the procedure or going down in the crush and failing to rise immediately more than once during administration of the protocol. Animals who did not meet the enrolment criteria were treated but not enrolled. They took no further part in the study but could be considered again in the future providing the minimum lag periods since treatment had elapsed.

Claw lesions identified during examination of the foot were classified into three groups, 'sole haemorrhage / sole ulceration (SH/U)', 'white line disease (WLD)' and 'other' (see figure 18). Following the therapeutic trim, affected animals were blocked by diagnosis in one of these three subdivisions.

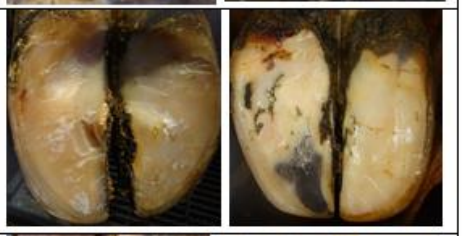
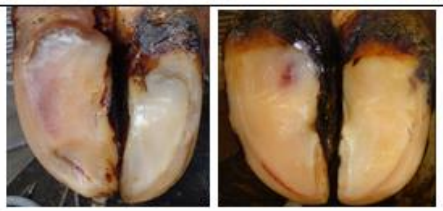
Claw lesion	Description	Examples
Sole haemorrhage / sole ulceration (SH/U)	A lesion composed of haemorrhage or ulceration of the sole	
White line disease (WLD)	A lesion of any severity (haemorrhage to complete separation) at any location on the white line.	
Other	Any other claw lesion which cannot be categorised as SH/U or WLD Two or more claw horn lesions on a single claw	

Figure 18. Classification of claw horn lesions in a randomised clinical trial on treatment of claw horn lesions in dairy cattle.

Four treatment groups were tested (see table 15). The therapeutic trim only (TRM) group was considered the positive control group. Enrolled animals were randomly allocated to one of these groups once the therapeutic trim was complete. Computer generated randomisation plans (random number generator, www.randomization.com) were created in blocks of four, with one repetition of each treatment in each block. Randomisation was further blocked by diagnosis and farm to ensure approximate temporal matching of equal numbers of cows with each diagnosis within each farm. The randomised sequence was transferred to consecutively numbered cards in a card index holder. Each farm had its own index card holder and cards in each box grouped by lesion type. Treatment allocation was written on the reverse of the card so it would only be apparent to the researcher once the card had been drawn. Once a card had been allocated, the cow ID number and date were written on the reverse to allow cross checking with data-capture forms and ensure no re-allocation of the same card.

Table 15. Descriptors of treatments tested in a randomised clinical trial on treatment of claw horn lesions in dairy cattle

Treatment	**Description**
Therapeutic trim only (TRM)	Therapeutic trim applicable to the lesion
Therapeutic trim and foot block (TB)	Therapeutic trim applicable to the lesion Application of Demotec 95 foot block to the unaffected claw
Therapeutic trim and NSAID (TN)	Therapeutic trim applicable to the lesion Administration of a three day course of ketoprofen (Ketodale 100mg/ml solution for injection for horses, cattle and swine, Richter Pharma AG) administered by deep intramuscular injection at 3mg ketoprofen / Kg bodyweight (equivalent to 3mg/100Kg bodyweight)
Therapeutic trim and foot block and NSAID (TBN)	Therapeutic trim applicable to the lesion Application of Demotec 95 foot block to the unaffected claw Administration of a three day course of ketoprofen (Ketodale 100mg/ml solution for injection for horses, cattle and swine, Richter Pharma AG) administered by deep intramuscular injection at 3mg ketoprofen / Kg bodyweight (equivalent to 3mg/100Kg bodyweight)

Animals which had been enrolled were identified with a band applied to both hind limbs. Farmers were asked to continue managing them in accordance with normal farm management practices but not to treat them for lameness and notify the author if they felt intervention was necessary. All enrolled animals were re-examined at 8 days (±3 days) after treatment by the author (see form D, appendix 2) and re-treated if the foot had become visibly swollen or inflamed or if the animal had failed to respond to treatment (i.e. if the mobility score of the animal had deteriorated since the time of enrolment). If a foot block was applied as part of the treatment protocol (TB and TBN) and was not present, then it was re-applied. If a foot block was part of the treatment protocol (TB and TBN), animals were further checked by the author at 28 days (±3 days) post enrolment (see form E, appendix 2) and the foot block manually removed using trimming pincers and

careful leverage if still in place. No further treatment was undertaken at this time point. Animals were withdrawn from the study if they would not comply with the study protocol following treatment allocation or at any subsequent visit up to and including the outcome assessment visit. Animals which were sold, culled or died before the primary outcome measure was assessed were also withdrawn (see form G, appendix 2).

The primary outcome measure for the comparison of treatments was a mobility score at 35 days (±4 days) post enrolment. The outcome mobility score was conducted by an independent observer blind to the treatment administered. Three independent observers were each trained to use the six-point scoring system prior to commencement of the trial and attended quarterly revalidation sessions to ensure good agreement between observers. At outcome the cows were observed walking in isolation on a firm, level surface.

The animals' body condition score was recorded by the author at enrolment, re-examination and outcome measurement visits according to Edmonson *et al* (1989) using a scale of 1-5 with increments of 0.5. Following the outcome mobility score, the cows were once again restrained in a cattle crush and the foot identified as lame at enrolment examined. A three stage foot trim was carried out to clean the surface of the claws and written, pictorial and photographic records of the lesions with a cow identification number and date taken as at the enrolment examination (see form F, appendix 2). Milk recording data was collected monthly on all farms to assess data on parity, monthly milk yield and calving date of enrolled cows.

3.3.1.6 Data management and statistical analysis

Data capture was achieved through the completion of data capture forms (see appendix 3) which were then transcribed and stored in a relational database (Access 2007, Microsoft Corporation) for analysis. Data capture forms were retained to allow further consideration of pictorial lesion maps completed at enrolment and outcome alongside photographic records taken at the time of examination. Data for milk yield, parity and calving date was obtained directly as data files from the milk recording companies and managed using relevant software. Data analysis was conducted in Minitab 16 (Minitab Inc.). Data was checked for errors against written records prior to analysis. Spurious records were identified by manually scanning for outlying data within each category. Differences between treatment groups at time of enrolment were assessed by a $\chi 2$ test (mobility score at enrolment) analysis of variance (days in milk and last recorded monthly yield) and using the Kruskal-Wallis test (body condition score at enrolment and parity).

Analysis of the data was based on successful treatment at the 35 day (±4 day) outcome examination. Successful treatment was defined as either a sound locomotion score (Score 0) versus non-sound score (score 1, 2a, 2b, 3a or 3b) or a non-lame score (Score 0 or 1) versus a lame score (score 2a, 2b, 3a or 3b). The proportions of successful treatments in animals which received treatments TB, TN and TSN were compared to the proportion of successful treatments in the positive control group TRM. Comparison was completed using a $\chi 2$ test with significance set at $P \leq 0.05$.

To test for confounding effects in the results, a multivariable analysis was conducted. Logistic regression models were built in MLwiN (Version 2.1, Centre for Multilevel Modelling, University of Bristol), with the same outcomes described above of a sound locomotion score (Score 0) or non-lame score (score 0 or 1) at 35 days (±4 days) after treatment. Farm and treatment were forced into the models as categorical fixed effects. Other variables and plausible interactions were investigated by forwards selection, for inclusion stepwise. Variables were eliminated from the model based on the Wald test if $P \leq 0.05$. Variables tested included parity (1, 2, 3, ≥4), days in milk, calving season (winter, spring,

summer, autumn), season of treatment, locomotion score at treatment, lame leg at treatment, body condition score at treatment and outcome, lesion classification (SH/U, WLD, Other), active digital dermatitis at outcome (Yes/No), retreatment required at 8 day recheck visit (Yes/No), reapplication of block required at 8 day recheck visit (Yes/No), treatment operator (author or 'other' operators) and milk yield at the last two monthly recordings. Days in milk was tested as a linear mean centred variable, a categorical variable in 30 d increments, and as a non-linear variable; e(-0.065 * DIM) (Silvestre *et al*., 2006). To assess fit, model predictions were compared to the observed data in groups stratified by categorical variables in the model, such as treatment group. Predictions were generated by simulation (MCMC). The models were deemed adequate if observed values were within 95% confidence intervals of production.

3.3.2 Results

Mobility scoring of cows commenced on the 22nd of December 2011 to allow collection of three mobility scores for the identification of acutely lame animals prior to the first enrolments on 10th January 2012. Enrolment of cows on Farm 3 was suspended on the 24th of April 2012 due to the very low numbers of animals which were becoming eligible for enrolment (i.e. the number of new cases of lameness had dropped substantially from the start of the study). Farm 5 was recruited to the study as a replacement. Following three preliminary mobility scoring sessions, enrolment began on the 17th of July 2012 and continued to the end of the study. Selection of cows on Farm 3 recommenced on the 16th of November 2012 and continued to the end of the study.

Between the 10th of January 2012 and the 31st January 2013 a total of 512 cows met the initial selection criteria and were examined. Of the selected and examined cows, 183 met all of the inclusion criteria and were enrolled into the RCT. The remaining 329 animals were not enrolled for the following reasons: 227 (68.9%) had a lesion on both claws; 27 (8.2%) had no visible lesion on either claw and no painful claw could be identified; 2 (0.6%) were no longer lame, 41 (12.5%) had active digital dermatitis, 3 (0.9%) had interdigital necrobacillosis, 1 (0.3%) had an inter-digital hyperplasia, 6 (1.8%) had a hock lesion, 14 (4.3%) had been treated by farm staff in the previous 14 days and 8 (2.4%) were not compliant with the study protocol.

Of the enrolled cows, 151 (82.5%) presented with a locomotion score of 2a, 20 (10.9%) with a score of 2b, 9 (4.9%) with a score of 3a and 3 (1.6%) with a score of 3b at the enrolment examination.

The number of cows allocated to each of the treatment groups by lesion diagnosis and farm is outlined in Table 16. In total 47 cows were allocated the treatment TRM, 46 TB, 45 TN and 45 TBN.

Table 16. Number of cows allocated to each of 4 treatment groups by lesion diagnosis and farm in a randomised clinical trial designed to test the recovery of dairy cows from claw horn lesions

Farm ID	Lesion Diagnosis												Total
	Sole Haemorrhage / Ulcer				White Line Disease				'Other' Lesion				
	TRM	TB	TN	TBN	TRM	TB	TN	TBN	TRM	TB	TN	TBN	
1	6	6	5	5	1	1	1	1	3	4	3	3	39
2	4	5	5	5	4	4	3	4	3	2	3	3	45
3	1	1	1	1	2	2	1	2	2	2	2	2	19
4	8	7	8	8	2	2	2	1	4	4	4	4	54
5	2	2	2	1	1	0	1	1	4	4	4	4	26
Total	21	21	21	20	10	9	8	9	16	16	16	16	
Grand Total	83				36				64				183

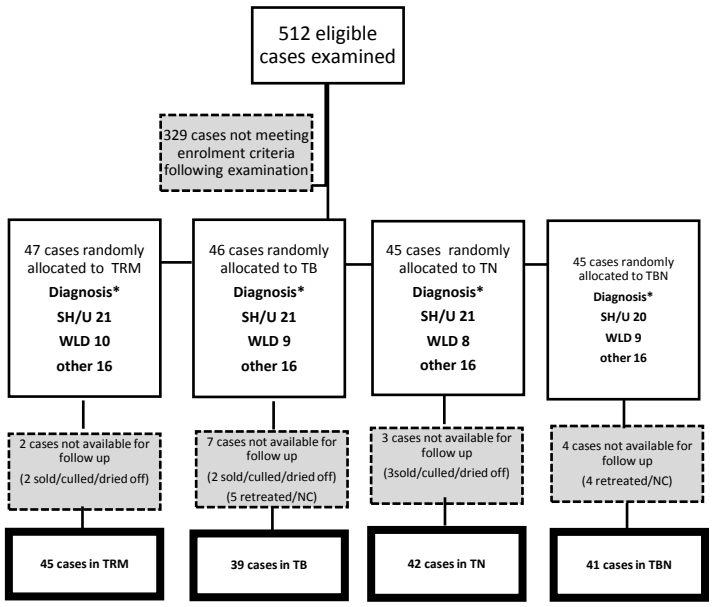
TRM trim only, TB Trim and Block, TN Trim and NSAID, TBN Trim, Block and NSAID

Sixteen enrolled cows were withdrawn before the primary outcome was assessed at 35 days (±4 days) post enrolment as shown in table 17. Of the remaining 167 enrolled animals, six animals (Farm 1, TRM and TB; Farm 2, TB and TN; Farm 4, TB and TBN) required retreatment at the day eight recheck visit. Two received additional trimming, two had their foot block removed and repositioned, one was treated for digital dermatitis with topical oxytetracyline spray (Alamycin aerosol 3.58% w/w cutaneous spray solution, Norbrook) and one received treatment for a hock lesion by cleaning and the application of topical oxytetracyline spray. Seven animals that received TB, and ten animals which received TBN required the reapplication of a foot block at the day eight recheck visit because it was no longer present. A summary of the number of animals examined, randomly allocated to treatment groups and completing the study protocol is shown in figure 19.

Table 17. Cows withdrawn from a randomised clinical trial on treatment of acutely lame cows after enrolment but prior to primary outcome assessment at 35 (±4 days)

Reason for withdrawal	**Treatment group and farm number**
Culled	TN farm 1
Non-compliance with the study protocol after enrolment (e.g. becoming unduly stressed or repeated collapsing in the crush)	TB farm 2 (x2) TB farm 5 TBN farm 4 TBN farm 5
Re-treated by the farmer without informing the researcher	TB farm 2 TB farm 4 TBN farm 2 TBN farm 4
Lost to the study or unavailable for reassessment for other reasons (e.g. moved to a distant location or incorrectly identified)	TRM farm 4 TRM farm 5 TB farm 1 TB farm 2 TN farm 1 TN farm 4

TRM – trim only, TB – trim and block, TN – trim and NSAID, TBN – trim, block and NSAID



TRM – trim only, TB – trim and block, TN – trim and NSAD, TBN- trim, block and NSAID

SH/U – sole haemorrhage/ulceration, WLD – white line disease

Figure 19. Diagram showing the number of animals examined, randomly allocated to treatment groups and completing the study protocol, in a randomised controlled trial investigating the treatment of acute claw horn lesions.

The parity, days in milk, last recorded milk yield and body condition score and lameness score at treatment of enrolled cows by treatment group are outlined in Table 18. Differences in these parameters between the treatment groups were not significant.

Table 18. Descriptive statistics relating to parity, milk yield, body condition score and lameness score of animals in each of 4 treatment groups in a randomised clinical trial investigating the recovery of cows with acute claw lesions post treatment.

	Treatment Group			
	TRM	TB	TN	TBN
Parity (Median (Interquartile range))	3 (2-4)	3 (2-4)	3 (2-3)	2.5 (2-3)
Days in milk (Mean (SE))	205 (126)	180 (111)	168 (100)	182 (102)
Last recorded milk yield (Mean (SE))	36.2 (10.8)	37.4 (10.8)	43.1 (9.1)	37.6 (9.4)
Body condition score at treatment (Median (Interquartile range))	3 (2.5-3)	3 (2.5-3)	2.5 (2.5 – 3.375)	2.5 (2.5 – 3.5)
Lameness Score at treatment (Median (Interquartile range))	2a (2a-2a)	2a (2a-2a)	2a (2a-2a)	2a (2a-2a)

TRM trim only, TB Trim and Block, TN Trim and NSAID, TBN Trim, Block and NSAID

The locomotion scores of enrolled cows at outcome, 35 (±4) days after treatment, are outlined in Table 19. Based on a sound score (Score 0) the number (and proportion) of successful treatments was 11 of 45 (24.4%) for TRM, 14 of 39 (35.9%) for TB, 12 of 42 (28.6%) TN and 23 of 41 (56.1%) for TBN. A significant difference was found between treatment groups (P=0.01)

Based on a non-lame score (Score 0 or 1), the number (and proportion) of successful treatment was 31 of 45 (68.8%) TRM, 28 of 39 (71.8%) for TB, 32 of 42 (76.2%) for TN and 35 of 41 (85.3%) for TBN. No significant differences were found between treatment groups.

Table 19. Locomotion score 35 days after treatment in dairy cows recruited to a randomised clinical trial designed to test recovery from claw horn lesions

	Locomotion score 35 days after treatment					
	0	1	2a	2b	3a	3b
TRM (n=45)	11 (24.4%)	20 (44.4%)	14 (31.1%)	0	0	0
TB (n= 39)	14 (35.9%)	14 (35.9%)	8 (20.5%)	2 (5.1%)	1 (2.6%)	0
TN (n=42)	12 (28.6%)	20 (47.6%)	9 (21.4%)	1 (2.4%)	0	0
TBN (n=41)	23 (56.1%)	12 (29.3%)	6 (14.6%)	0	0	0

Score 0 = Sound; Scores 0 & 1 = Non-lame

TRM trim only, TB Trim and Block, TN Trim and NSAID, TBN Trim, Block and NSAID

Of the animals with a mobility score of 2a or above (lame) at 35 (±4) days after treatment, the number (and proportion) of animals lame on the leg that was treated at enrolment was 8 of 14 (57.1%) for TRM, 4 of 11 (36.4%) for TB, 5 of 10 (50%) for TN and 5 of 6 (83.3%) for TBN. The remainder of the animals were lame on a different leg.

One hundred and forty-four cows were treated by the author and 23 cows were treated by one of four other operators.

Results of the logistic regression models are outlined in Table 20. Of the enrolled cows, 85 had missing milk records in the previous month to outcome and 66 in the previous two months. Milk recording records in the two months preceding treatment were tested in the models based on the subsets of the dataset with no missing records. Eight animals had missing records for days in milk and were discarded.

In the first model testing recovery to outcome (i) sound (Score 0), animals in TBN were significantly more likely to recover compared to cows in TRM ($P \leq 0.05$). Cows treated on Farm 5, compared to other study farms, and treatments in Spring and Autumn, compared to treatments in winter, were less likely to recover.

In the second model testing recovery to outcome (ii) non-lame (Score 0 or 1), treatment group was not significant, however there was a trend for animals in TBN to be more likely to recover compared to cows in TRM. Cows with ‘Other’

lesions were less likely to recover compared to cows treated for SH/U and animals treated by ‘Other’ operators were less likely to recover than those treated by the author.

In both models, animals treated for lameness on the left hind limb were more likely to recover compared to those treated for lameness on the right hind limb and cows were more likely to recover from lameness when treated in early lactation with exponential decay in the relationship with time after calving.

Table 20. Outcomes from logistic regression models in a randomised clinical trial designed to test the recovery of dairy cows from claw horn lesions (odds ratio scale unless shown otherwise)

	Outcome (i) Sound locomotion score (Score 0) 35 days after treatment			Outcome (ii) Non-lame locomotion score (Score 0 or 1) 35 days after treatment		
		95% CI			95% CI	
Model term	Odds ratio	2.5%	97.5%	Odds ratio	2.5%	97.5%
Intercept	-1.08	-2.14	-0.05	3.28	0.82	13.1
TRM[1]	Reference			Reference		
TB[1]	2.1	0.8	5.8	1.2	0.4	3.8
TN[1]	1.2	0.4	3.2	1.3	0.4	4.3
TBN[1]	6.4*	2.4	18.0	3.2	0.9	11.3
Farm 1	Reference			Reference		
Farm 2	0.6	0.2	1.8	0.7	0.2	2.5
Farm 3	1.3	0.4	4.3	3.6	0.6	21.9
Farm 4	1.2	0.5	3.5	1.1	0.3	4.0
Farm 5	0.1*	0.0	0.4	0.7	0.2	2.8
Right hind limb	Reference			Reference		
Left hind limb	4.8*	2.3	10.5	2.3*	1.0	5.5
$e^{-0.065 * DIM}$ (logit scale)	8.5*	3.5	13.9	7.8*	2.3	13.3
Winter treated[2]	Reference					
Spring treated[2]	0.2*	0.1	0.4			
Summer treated[2]	0.4	0.1	1.1			
Autumn treated[2]	0.1*	0.0	0.3			
Sole ulcer / haemorrhage				Reference		
White line disease				0.8	0.2	2.6
'Other' lesion(s)				0.3*	0.1	0.9
Principal Treatment Operator				Reference		
'Other' Treatment Operators				0.3*	0.1	0.8

*$P \leq 0.05$

[1]TRM – Therapeutic trim only; TB – Therapeutic trim plus block on the sound claw; TN – Therapeutic trim plus 3d course of NSAID; TBN – Therapeutic trim plus block plus NSAID

[2]Spring – March, April and May; Summer – June, July and August; Autumn – September, October and November; Winter – December, January and February

Photographic and pictorial records taken during data collection to assess lesion severity were fed forward to a study out-with this thesis.

Data collection over the 15 months of this study occupied 2554 hours or 49 person hours per week on farms. This figure does not include travel time. A breakdown of this figure is shown in table 21.

Table 21. Personnel hours spent conducting a RCT on treatment of acutely lame cows over a 15 month period

Activity	**Person hours occupied**
Mobility scoring	360
Examination and treatment visits (operator and research assistant)	1664
Independent outcome observation	104
Administration for case selection	416
	Total 2554

3.4 Discussion

3.4.1 Results of the randomised clinical trial (RCT)

This study set out to investigate the hypothesis that claw horn lesions recover at different rates depending on the treatment administered. Four treatments were tested, TRM (positive control), TB, TN and TBN. The results support the hypothesis with cows treated with TBN found to be significantly more likely to recover to soundness (mobility score 0) than those treated with TRM. (P=0.01). Smaller, non-significant improvements were also seen with TB and TN compared to TRM.

3.4.1.1 Treatment with a therapeutic trim and foot block (TB)

The recovery of cows treated for claw horn lesions with a foot block applied to the non-affected claw in addition to a therapeutic trim compared to use of a therapeutic trim alone was surprising when considered alongside current practice. The use of a foot block when treating claw horn lesion is common in the UK, a recent review of text books and grey literature (e.g. reports and control plans) (Potterton *et al*., 2012) found that 85% of sources advocated the use of foot blocks for claw horn lesions and foot blocks were the second most common treatment option described after use of the therapeutic 5-stage foot trim. Similarly, in a survey of UK dairy farmers (Horseman *et al*., 2013), 92% of respondents reported using foot blocks and 70% considered a therapeutic trim and application of a foot block to the non-affected claw an effective treatment for claw horn lesions. Despite this widespread use, the findings from this study show only a small, non-significant difference in success between treatment with a therapeutic trim and foot block compared to the positive control group. Similar results were found in a New Zealand study by Laven *et al*. (2008), where locomotion scores and nociceptive threshold were measured on days three, eight, 28 and 100 following administration of four randomised treatments similar to those used in this current study. While the authors found a significant improvement at each time point with all treatments, no significant differences were found between recovery in cows fitted with foot blocks and those without. While these are only two studies investigating very specific groups of cows, they raise questions as to the efficacy of the widespread use of foot blocks on their

own in treating claw horn lesions. The aetiology of claw horn lesions in dairy cows is still not fully understood but is a topic receiving more attention in recent research. Sole ulcer aetiology is liked with disrupted production of sole horn. It is thought that compression of the germinal cells within the corium between the third phalanx and the sole horn leads to chronic inflammation (Greenough., 2007). Vascular compromise, ischaemia and local haemorrhage result in the interruption of keratogenesis and ultimately pathological exposure of the corium. Lesions formed by this process appear first as sole haemorrhage which with repeated or continuous injury can develop into sole ulceration. The aetiology of white line disease is even less well understood. It is thought that breakdown of the horn joining the sole and hoof wall (white line) results from shearing forces applied during locomotion. Foreign material can then track up into the white line (Barker *et al*., 2009). Shearing forces can also cause haemorrhage into this potential space at the pinch point between the wall and sole, weakening the horn structure. Progression of the lesion may result in abscess formation. The application of a foot block to the non-affected claw is thought to reduce load bearing on the lesion, reducing the compressive forces on the corium and the shearing forces on the white line in the diseased claw, allowing the compromised tissues to heal. The lack of evidence to support the use of foot blocks as a means to improving recovery from claw horn lesions however raises many questions on their widespread use in addition to therapeutic trimming. Further research is clearly required in order to appropriately inform veterinary practitioners, foot trimmers and farmers on use of foot blocks within treatment protocols.

3.4.1.2 Treatment with a therapeutic trim and non-steroidal anti-inflammatory drug (NSAID) (TN)

It is an interesting finding that the use of a NSAID in addition to a therapeutic trim also produced marginal, non-significant differences in recovery to soundness compared to a therapeutic trim alone. NSAIDs in contrast to foot blocks do not form a standard part of the treatment protocol for claw horn lesions in the UK. A survey of cattle practitioners (Huxley and Whay., 2006) found that only around a third of respondents stated they would use NSAIDs in more than 50% of cases of sole ulcers they saw in clinical practice, while the study by Horseman *et al*., (2013) reported only 17% of farmers used injectable pain relief

for treatment of claw horn lesions. Laven *et al*., (2008) also investigated the use of NSAIDs, in this case Tolfenamic acid, on recovery of claw horn lesions finding no evidence of a significant benefit to either nociceptive threshold or locomotion score above that of a therapeutic trim alone. In contrast Whay *et al*., (2005) found a significant increase in nociceptive threshold in cows with unilateral hind limb lameness at days three, eight and 28 following administration of a three-day course of ketoprofen, the same NSAID used in this current study. Locomotion score however was not affected leading the author to suggest that this method of scoring may not be sensitive enough to fully detect the modulation of hyperalgesia by this drug. As nociceptive threshold tests were not carried out in this current study it cannot be determined if the marginal and non-significant improvement in recovery to soundness is a true indicator of the effect on hyperalgesia or if the effects were larger but the method of measurement not sufficiently sensitive to detect them. The effects of NSAIDs may however be multifactorial. It is thought that the damage to the germinal cells of the corium in the pathogenesis of sole ulcers results in chronic inflammation (Greenough., 2007). This may not only cause increased stimulation of nerve endings and the sensation of pain, but may also cause increased pressure in region between the distal phalanx and the corium resulting in further damage to the germinal cells. The marginal effect of NSAIDs in improving recovery compared to therapeutic trimming may therefore be linked to reduction in the inflammatory process and prevention of further damage occurring. It is also possible that the different response to NSAIDs seen in the current study and that of Laven *et al*., (2008) is a result of the different NSAID used. It is unclear whether the different actions of these drugs may affect the inflammation associated with claw horn lesions and/or the level of discomfort experienced by the animals. More research is needed to better understand the effects of different NSAIDs on claw lesions in order to determine if this is a factor in the findings of these two studies.

3.4.1.3 Treatment with a therapeutic trim, foot block and NSAID (TBN)

To produce a significant difference in the recovery from lameness due to claw horn lesions following treatment, both an orthopaedic foot block applied to the non-affected claw and the administration of a three-day course of NSAID were required. This suggests there is a synergistic effect of using a foot block and NSAID simultaneously resulting in an improved recovery compared with the use of either treatment alone. Based on the suggested pathogenesis of claw lesions, the combined effect of the foot block and NSAID could be impacting tissue directly at the corium, the NSAID reducing inflammation in the compromised area and the application of a foot block to the non-affected claw reducing loading. As well as providing pain relief by unloading the affected area and inhibiting inflammatory pathways, the reduction in pressure from both internal and external factors may reduce any further damage to the corium. Combined use of both of these techniques may therefore prevent further damage, allow more rapid healing of the lesion and lead to the significant improvement in recovery to soundness with this dual treatment.

Alternatively, it is possible that foot blocks may cause some discomfort following application due to loading of all the animals weight onto one claw or as a result of the elongation of the limb. This may in turn modify the animals behaviour (e.g. changing lying or feeding time) and affect the recovery of the diseased claw. Administration of a NSAID in combination with a foot block may lessen this discomfort and allow normal behaviour allowing the improvement in recovery seen with the combined treatment. The results of this study provide some circumstantial evidence in support of this theory. At outcome (35 (±4) days after treatment), six cows were lame on the contralateral hind leg in the TRM group, seven cows in the TB group and five cows in the TN group. This compares to just one cow in the TBN group. As many of the factors which predispose an animal to claw horn lesions occur at the cow level, for example relaxation of the ligaments within the claw at the time of parturition, and changes in body condition (Tarlton *et al*., 2002; Randall *et al*., 2015), it is reasonable to assume that the changes occur in both hind limbs even if the lesion which leads to lameness is more substantial in one. Lame cows in the TRM, TB and TN groups may have increased loading on the contralateral hind limb as a result of

discomfort from application of a foot block to the lame foot. This in turn may predispose the already compromised structures in the contralateral limb to further damage and result in lameness in this contralateral leg. If cows in the TBN group were comfortable enough to bear weight evenly on the lame and non-lame limbs, this would reduce the risk of exacerbating any changes in the non-lame leg. At the same time the foot block would provide a reduction in weight bearing on the affected claw allowing the lesion to heal. A parallel study on a smaller subset of the animals (44 cows on 2 farms) treated in this RCT investigated the effect of the lameness treatments on lying behaviour (Miguel Pacheco *et al*., 2016). Thirty-four non-lame cows matched by parity, days in milk and farm acted as controls. Behaviour data collected using accelerometers for five days following treatment showed no difference in lying behaviour in cows treated with TRM, TN and TBN. Cows treated with TB however recorded higher lying times than control cows leading to the hypothesis that the foot blocks caused discomfort which was alleviated by the addition of a NSAID. Further work is required to better understand the effects of the different treatment options on the biomechanics and behaviour of cows with claw horn lesions however this parallel study supports the treatment of lame cows with a NSAID in addition to a foot block. In this study animals were administered a three day course of Ketoprofen. Routine use of this drug in cases of lameness come with financial implications. Alternative NSAIDs are available which require only a single dose and may therefore be more cost effective. At the time of this RCT however, Ketodale (Ketoprofen) was the only drug licenced for the treatment of lameness in the UK. Further research is needed to establish the efficacy of alternate NSAIDs and to analyse the cost/benefit of this treatment to limit financial barriers to the uptake by farmers of this treatment protocol.

3.4.1.4 Comparison of primary outcome results to previous RCTs

While the results of this study show a significant difference in recovery to soundness between cows treated with a foot block and NSAID and the control group, the results reported by Laven *et al*., (2008) disagree with these findings. Laven *et al*., (2008) found no significant difference in locomotion score and nociceptive threshold between lame cows with claw horn lesions treated with foot blocks and the NSAID, Tolfenamic acid in addition to a therapeutic trim

compared to those that received a therapeutic trim alone. While these studies are sufficiently similar to allow comparison, some of the differences in the treatment outcomes observed may be due to differences in methodology.

When considering case selection, the current study identified acutely lame cows by means of an external observer conducting routine mobility scoring. In contrast, Laven *et al*., (2008) selected cases based on identification of lame cows by farm staff. Studies have shown detection of lame cows by farm staff often occurs at a later stage in the disease process than when carried out by researchers using routine locomotion scoring and therefore more chronic and severe cases may have been presented for treatment. Further discussion relating to this contrast in detection of lameness by farmers and researchers can be found in chapter 4. The study by Laven *et al*., (2008) also does not state whether treatment was given free of charge which may have affected the point at which a cow was presented by the farm staff. Even where treatment is administered without charge however, it can be seen that farmers present cows at a later stage than identification by researchers. Alawneh *et al*., (2012) reported a median delay in presentation of severely lame cows for treatment of 21 days and mild cases of 70 days even when there was no cost to the farmer other than pharmaceuticals and consumables. It is therefore possible that the differences seen in recovery by the cows receiving treatment in the current study and those receiving treatment by Laven *et al*., (2008) may have been a result of the chronicity of lesions despite both being described as "acutely lame". Indeed, Laven *et al*., (2008) saw greater than 25% of animals presenting with abscesses which had developed from the original lesion which suggest much more chronic and severe conditions than that seen in the current study where the majority of cows (82.5%) presented with a mobility score of 2a (mild lameness) and were seen to have early lesions such as haemorrhage in the sole or white line.

In the current study, the period of time which could have elapsed between animals first becoming lame and being treated ranged between 2 and 16 days taking into account the fortnightly mobility scoring plus the lag time to the treatment visit. This population was selected firstly because it was considered ethically questionable to identify and then knowingly leave lame animals for a number of weeks before they were treated and secondly because the steering

group who set up the study believed that these were the animals which the industry should be targeting for treatment. The delay in presentation for treatment when cows are identified by farmers however suggests this study population, and consequently the results of this RCT, may not reflect the cases that are currently being treated on farms. At this stage it is not possible to say whether the results are generalisable to more severe and / or chronic cases managed in different farm systems. The impact of chronicity of lameness on effectiveness of treatment therefore requires much greater investigation and may explain the differences in outcome between the current study and that conducted by Laven *et al*., (2008).

Differences in the management systems in the UK and New Zealand may also affect the outcomes of the current study and that of Laven *et al*., (2008) and potentially explain the differences in recovery from treatment seen. In the current study cows were housed for at least half of the year as is common in the UK. On three of the farms cows were housed in indoor cubicle yards all year around while on the remaining two they were housed in cubicle yards during the winter and kept at pasture during the summer. Post treatment cows were returned to the herd and received no preferential treatment. The management of farms in New Zealand is much more extensive with cows living at pasture for all or most of the year. In the study by Laven *et al*., (2008) none of the cows were housed after treatment with most kept for varying periods in paddocks near the milking parlour. Hernandez-Mendo *et al*., (2007) found that keeping mildly lame cattle at pasture rather than in cubicle yards with concrete passageways significantly improved their gait. The effect of the combined treatment of TBN compared to TRM may therefore have been diminished somewhat by the effect of keeping the cows at pasture where the impact of housing on the healing lesions would be reduced and potentially lead to a more similar recovery rate across the treatment groups.

Differences in management may also have a considerable impact on the type of lesions seen in the two studies. The extensive management of cattle in New Zealand predisposes animals to white line lesions due to the movement of cows along farm tracks sometimes considerable distances to and from the milking parlour. In contrast the increased standing times on hard concrete surfaces in

housed cows predisposes them to pressure lesions such as sole haemorrhage and ulcers. While treatment protocols administered to animals with claw horn lesions do not appear to vary significantly with the type of lesion diagnosed (Pyman., 1997; Laven *et al*., 2008; Horseman *et al*., 2013), the predominant lesions seen may impact on the recovery times of affected animals and so differences in outcome may be seen despite similar treatment protocols being trialled.

Finally, the type of cows used for each of the studies may have affected the outcome of these two clinical trials. Lameness has been shown to be a disease of high production (Green *et al*., 2002) and so the predominantly high yielding Holstein cattle seen in intensively housed UK dairy herds may respond differently to treatment than the predominantly lower yielding Friesian and Jersey cattle seen in the extensive New Zealand systems. Many other unidentified factors in dairy systems in the UK and New Zealand could also impact the results of these studies and so while comparison of the results of this study with those of Laven *et al*., (2008) is valid, the context in which the studies were undertaken must be acknowledged

3.4.1.5 Other variables impacting on recovery

A range of other variables were found to have a significant impact on recovery to soundness in the final models. These variables included farm, days in milk, limb treated, season of treatment, diagnosis and operator.

One finding of note was the recovery to soundness (score 0) on Farm 5. On this farm recovery was significantly worse across all treatment groups than on the other study farms despite identical case selection criteria. The factor or factors which affected the outcome on this farm could not be identified at the time of the study and further investigation into farm practices in this case is required. This finding demonstrates that while significant improvements in outcome were seen in the RCT, applying these protocols on commercial farms in practice requires a much more holistic approach than simply changing lameness detection and treatment protocols.

Another significant difference seen in the model for recovery to soundness (score 0) was an effect of season of treatment. Animals treated in the Spring and Autumn were less likely to recover than those treated in the winter. The reason for this is not entirely clear. Three of the five farms on this study were housed all year around with only two farms managing cows at pasture during the summer. Enrolments on one of these farms was suspended in the early spring due to low levels of recruitment and so the majority of data was collected from year around housed farms. Risk of lameness has been shown to increase with increasing length of housing and so the reduction in recovery in the spring may have been a residual effect of housing on the farm where cows were kept at pasture in summer but this would not affect the remaining farms. Treatments were also blocked by farm to allow for management differences. Other factors may have had a seasonal influence on the farms in this study. High temperatures in animal housing during the summer months has been shown to impact animal behaviour which in turn can lead to increased risk of claw horn lesions. Equally cold conditions may lead to slippery floor surfaces, increasing shearing forces on the foot and risk of damage to internal structures. Further investigation is needed to fully understand the seasonal effects in seen on recovery in the current study.

The lesion with which the cow was diagnosed was seen to affect the recovery to 'non-lame' (score 0 or 1). Cows with 'Other' lesions had a reduced level of recovery compared to cows treated for sole ulceration/haemorrhage. The lesion classification of 'other' encompassed animals showing both sole haemorrhage/ulceration and white line disease in the same claw. This combination of lesions may be suggestive of a greater level of trauma to the claw horn and a consequent effect on recovery.

A significant effect of the treatment operator on recovery to non-lame (score 0 or 1) was also seen in the final analysis. Animals treated by the author were more likely to recover that those treated by other operators. As the study protocol used was consistent across all operators and all were qualified veterinary surgeons this finding is likely to reflect the relative number of cases the author was treating during the course of the study allowing greater skill acquisition in the treatment protocol than those treating lame cows intermittently. This finding may be of

relevance to veterinary surgeons in practice where treatment of claw horn lesions is only one of many tasks they carry out in their day to day work. In contrast professional hoof trimmers concentrate on this one area and so may develop greater skills. It is also possible that differences in technique could have affected the outcome. While the basic protocol for conducting a five-stage therapeutic trim and application of foot blocks is universal, there may be some individual interpretation of these protocols in both the extent of trimming and correct positioning of blocks. The need for continuing professional development in both of these skilled groups is clear, to both maintain skill level and ensure procedures to not drift from the standardised protocols over a period of time.

In both models of recovery to soundness (score 0) and non-lame (score 0 or 1) seen that cows on the study were more likely to recover from lameness when treated in early lactation. This relationship showed an exponential decay with time after calving. As it is thought the events which predispose to claw horn lesions occur around the time of parturition (Tarlton *et al*., 2002; Raber *et al*., 2004; Knott *et al*., 2007), this finding suggests early detection and intervention is key to achieving the best outcome in these cases. It is possible that animals detected as newly lame and given treatment later in lactation may also have experienced an episode of lameness earlier in that lactation but were unsuitable for enrolment at that time. As animals were not enrolled until at least 120 days had elapsed since any previous treatment on the same limb, the reduction in treatment success later in lactation could reflect more chronic lesions from previous lameness events.

A difference in recovery rates in both models was also seen between left and right hind limbs. The reason for this is unclear but it may be a reflection of an operator bias based on the relative ease of trimming left and right feet, depending on the dominant hand of the worker. Previous studies have shown that increased loading on one hind limb due to farm design, for example a sharp left exit from the milking parlour, may predispose that limb to claw horn lesions however no obvious similarities could be identified in this study and so the cause of this difference in recovery rate requires further investigation.

3.4.2 Complexities of undertaking an on-farm RCT

Implementing on-farm protocols to provide a robust RCT to investigate the recovery from lameness in dairy cattle following treatment reveals many complexities. These may, in part, explain why very few such studies have been conducted previously.

The 'gold standard' for clinical trials is the double blind, randomised, negatively controlled clinical trial, considered the most rigorous way of determining whether there is a cause-effect relationship between a treatment and an outcome (Sibbald and Roland, 1998)

Double blinding means that neither the patient nor the person measuring the outcome is aware of the treatment given until the trial has ended. In the case of veterinary clinical trials this also applies to the owner/manager of the animals. Double blinding ensures that any preconceived ideas of the persons involved in the study do not bias the result. This is of particular importance where the outcome assessment is subjective. In the case of the owner/manager, subtle differences in the way the animal is cared for could also influence the result.

The study carried out to compare treatment of claw lesions in dairy cattle was only a partially blinded RCT due to the nature of the treatments being assessed. It was not possible to blind the owner/manager of the animals to the treatments as foot blocks are directly observable and there is a legal requirement to record administration of NSAIDs. In this study farmers were also required to administer a pre-prepared NSAID injection to some animals on days two and three post enrolment. Farm managers were requested to otherwise manage the animals following treatment in the same manner as was applied to the rest of the herd. To ensure there was no bias in the final outcome measure, an independent observer 'blind' to the treatment used conducted the mobility scoring assessment. Foot blocks were removed one week prior to outcome measurement to ensure there were no visible markers of treatment. By ensuring the primary outcome measure was 'blind', bias in the result was limited as far as practicable in the on-farm RCT. For logistical reasons, all other mobility scores were recorded by the treating clinician, either at the recheck examination or at the fortnightly herd mobility scoring sessions. While an observer blind to the

treatment may have been preferable, for four weeks following enrolment 50% of the enrolled cows were fitted with foot blocks which would have been directly observable to any mobility scorer and therefore the independent observation was limited to the primary outcome score at 35 (±4) days.

The randomised nature of the study was designed to ensure that no third factor, known or unknown, could influence the outcome of the trial. The treatment allocation order was computer generated to give a random sequence for each farm participating in the study. Furthermore, the treatment allocations were compiled in advance and a card index system used to prevent the treating clinician observing the upcoming treatment order. Treatments for enrolled cows were not revealed until the full therapeutic trim, the minimum treatment for all cases, had been completed thus ensuring that no differences in therapeutic trim were consciously or subconsciously made depending on the treatment allocation. The treatments were randomised in blocks of four with one repetition of each treatment in each block. This ensured approximate temporal matching allowing for variation in external factors through different seasons. Treatments were also blocked by farm to allow for variation in external factors between farms. The aim of both randomisation blocks was to achieve approximately equal numbers of each treatment, on each farm at each time of the year. It is possible however, that through this blocking, the operator may have gained some knowledge of the next treatment. With only four treatments in each block, if one treatment were drawn twice in succession on one farm the operator would be aware it could not reappear for at least three more treatments. While it was uncommon to enrol several cows on one farm visit and thus enable the operator to see a pattern, it is possible that this could happen and subconscious changes made to the therapeutic trimming procedure as a result. Even in this scenario however, the randomised nature of the trial would mean that such occurrences would be distributed amongst the four treatment groups and therefore the effect would be minimised in the final outcome.

Conducting an RCT on farms is not only limited by practical considerations but also ethical factors. Negative control groups in a trial allow direct comparison of the effects of a treatment intervention with that of no intervention. This can be achieved either by having two parallel, matched groups of animals, one group

receiving the treatment intervention and the other not, or by subjecting the same animal to treatment and non-treatment, for the same condition, in two separate periods of time. In the case of the study carried out, it would not be possible to compare treatment and non-treatment in the same animal as it would not be possible to replicate the lesions and external variables in two different time periods. While a matched parallel control group would provide useful information, for ethical reasons it is difficult to justify not treating animals with foot lesions and would only be possible under the experimental animals legislation. It has been shown in the literature that these lesions cause pain to the animals affected (Whay et.al.,1997) and therefore issues relating to the animals welfare arise if allocated into a non-treatment group. Practical difficulties also arise in that it is necessary to perform the first three stages of the therapeutic trim in order to identify the lesion and hence enrol the animal on the study. This means that in attaining the diagnosis that the lameness is indeed caused by a claw horn lesion, the initial stages of treatment have already been performed, thus a negative control group receiving no treatment is not possible. Matching animals with the same type and extent of lesions, along with other factors such as farm, parity, milk yield, time of year etc. could also prove problematic. There is much evidence in the literature to show that these external factors have an effect on claw lesions (Green *et al*., 2002; Newsome *et al*., 2016; Randall *et al*., 2016) and so this level of matching would be required to allow direct comparison. As lesions are not consistent in their type and extent however, enrolling sufficient numbers to make these matches relevant would be very difficult given the enrolment criteria in this particular trial.

The RCT in this case was conducted under the Veterinary Surgeons Act and so it was necessary to carry out some form of treatment for animals diagnosed with a claw lesion causing lameness. For this reason and the reasons outlined above, a negative control group was therefore not used and instead the therapeutic trim used as a minimum intervention (positive control group) to assess the effect of further interventions beyond this. The lack of a negative control group however meant it was not possible to assess how the animals would have responded if no treatment had been given and therefore the results of this study are not able to establish if minimal intervention (therapeutic trim) is superior or inferior to no

intervention. This is of particular importance as poor quality trimming or over-trimming may actually slow recovery or make the animal more lame and so in some cases animals that recovered with treatment may indeed have responded as well or better with no treatment at all.

The population chosen for the study were selected on the basis of proximity to the University of Nottingham, School of Veterinary Medicine and Science and willingness of farm managers to participate in the trial. Minimum requirements for lameness prevalence, milk recording and digital dermatitis control were also specified. Due to this, farms were not selected at random and the variance in the population as a whole may not be fully reflected by the farms included in the study. Environmental similarities resulting from the narrow geographical location, the level of management given in herds that routinely milk record and control digital dermatitis over those that do not and the attitudes of farm managers who are willing to participate in a clinical trial could all influence the final result. The management of the herds in the study also may not reflect the national population with three out of five of the herds 365 day housed and two of the five herds using robotic milking systems. The logistics of running such a trial where all herds required fortnightly mobility scoring, an enrolment visit, recheck visit, block removal visit and outcome visit however precluded farms more than an hours drive from the University. The willingness of farmers to participate in the study was also vital as while the research provided mobility scoring and treatment free of charge, the weekly visits by the author and research assistant and use of the crush for over a year, no doubt caused some inconvenience to the normal working practices of the farm.

Case selection was also of particular importance in this study. A wide range of disease can be seen on farms from early onset through to chronic, necrotic lesions. While ethically it would be ideal to treat all lame cows on farms, this may have resulted in large numbers of chronically lame cows being treated at the commencement of the study and mostly newly lame cows being treated towards the end. To ensure this didn't complicate the result and similar cases were treated throughout the study period, it was decided that only acutely lame cows with a duration of lameness of less than two weeks would be eligible for enrolment. Chronic cases were flagged to the farmer for treatment under normal

farm procedures ensuring that no animal identified as lame was left without treatment. The treatment of these early lesions however raised issues around their relevance to the lesions normally treated on farms and whether more chronic lesions would respond to treatment in the same way. It was decided however that acute cases needed to be investigated in the first instance with follow on studies to investigate treatment of more chronic and potentially severe disease. To reduce bias, animals could only be enrolled once on the study.

The primary outcome measure chosen for the study was mobility score. This was achieved through direct observation by a trained technician giving a subjective assessment of the outcome. More objective assessment may have been achieved through the use of kinematic and kinetic data, for example the use of video-analysis of gait to determine the degree of asymmetry or the use of force plates to measure differences in weight bearing in the affected and non-affected limbs. The use of video-analysis of gait was considered in the study, however the logistics of performing this to a standard suitable for analysis, within the confines of the facilities available on the commercial dairy farms was not possible. Equally the measurement of kinetic variables would be costly and impractical in the existing environment. A full description of the six-point mobility scoring scale is given in section 2.4.3. Understanding of the subjective descriptors and variation in inter-observer mobility scoring was minimised by initial training of all observers participating in the study and by quarterly revalidation sessions. Inter- and intra-observer variation was assessed prior to the commencement of the study and found to be fair and moderate respectively (see section 2.4.3). The scale used for the scoring gave a categorical/discrete variable based on six group descriptors rather than a continuous variable across the full range from completely sound to non-weight bearing lame. The most variation in mobility score allocation was therefore likely to occur in those animals on the border-line between descriptors. The use of these categorical/discrete variables is also important to take into consideration when evaluating the results of this study. The mobility scores are independent of each other and the range of lameness covered within each group different therefore a score of 2 cannot be considered twice as lame as a score of 1 and equally a score of score of 2a may cover a wider range of lameness than a score of 3a.

Comparison of recovery rates based on mobility score at enrolment must therefore be interpreted in this context.

Logistically, this was a complex, expensive and time consuming study protocol to conduct. The low proportion of cows which met all the selection criteria was particularly challenging, over 500 animals had to be examined and trimmed to enrol 183 cows. The principal reason, making up nearly 70% of exclusion, were animals with lesions on both claws. Even if the claw causing the lameness was obvious, large numbers of animals had mild lesions on the contralateral claw. Whilst in practice, therapeutic blocks are often applied to claws with visible but mild lesions it was felt to be important that this was not the case in a RCT as the effect of increased loading on such lesions could not be fully elucidated. The use of blocks as part of treatment also necessitated an additional crush restraint intervention to remove blocks from the treatment groups which had received them. This was considered necessary firstly to blind the treatment group from the outcome observer and secondly because it was believed that some cows may alter their gait whilst walking on blocks.

When looking at personnel hours alone, it can be seen that this study required a great deal of time commitment to fulfil. All practical elements of the RCT (mobility scoring, case selection, examination, treatment and follow up visits/examinations) were conducted for the duration of the study by the author. A research assistant attended all examination and treatment visits to assist in the handling of cattle and complete data collection forms as directed by the author. Two further assistants were trained in the six-point mobility scoring system and four farm animal veterinary clinicians familiarised with the study protocol to assist during short vacation periods over the 15 months of data collection. Mobility scoring at fortnightly intervals across the five farms amounted to some 360 hours in total. Examination and treatment visits, recheck, block removal and outcome visits by the author and research assistant came to another 1664 person hours. The independent observer performing the outcome mobility scoring required 104 hours to assess all the animals individually. A further 416 hours were spent by the author in the administration of mobility scoring data and identification and selection of eligible animals for treatment the following day. In total this amounts to 2554 hours or 49 person hours/week dedicated to the

collection of data alone. It should also be noted that these hours are those spent dealing directly with the cattle and do not include travelling time for mobility scoring and other farm visits.

While the complexities discussed above negatively influenced the current RCT, they provide useful insights in to the logistical problems of such on farm studies that may be taken into account when considering selection criteria, case definitions and methodology of similar studies in the future.

3.5 Conclusion

Little information is available in the peer-reviewed scientific literature to support clinical decision making in the treatment of claw horn lesions in dairy cattle. This study investigated the use of four treatment protocols for use in acutely and predominantly mildly lame dairy cattle on commercial farms in the UK. It was found that cows treated with a combination of a therapeutic trim, application of an orthopaedic foot block to the non-affected claw and administration of a three-day course of NSAID were significantly more likely to recover to soundness 35 days after treatment that cows treated with a therapeutic trim alone. Cows treated in this study were those identified with a lameness in a single hind leg of two to 16 days duration based on fortnightly mobility scoring, with an identifiable lesion in a single claw.

In attempting to determine the most effective on-farm treatment protocol for treatment of claw lesions in dairy cattle the double blind, randomised negatively controlled clinical trial represents the most rigorous method of analysis. Conducting this style of clinical study on a commercial dairy farm however presents both ethical and practical difficulties. This RCT utilised as many of the qualities of the double blind, randomised negatively controlled clinical trials as was possible, while being aware of the constraints that the limitations in the study protocol imposed on the interpretation of results.

Further research is required to fully understand the effect of other treatments not trialled in this study and also to appreciate the impact of chronicity of lameness on the protocols tested.

Chapter 4: Recovery of lame cows following treatment for acute and chronic lameness

4. Abstract

A randomised clinical trial (RCT) conducted on acutely lame cows diagnosed with claw horn lesions concluded that, compared to a minimum treatment intervention of a therapeutic trim, treatment with a therapeutic trim plus an orthopaedic footblock on the unaffected claw and a three day course of the NSAID Ketoprofen had a significant effect on recovery to soundness at 35 days post treatment (chapter 3). While recent work suggests early treatment of lame cows is fundamental in promoting recovery and reducing recurrence (Groenevelt *et al*., 2014; Leach *et al*., 2012) the early and predominantly mild lesions seen in this study may not necessarily be representative of lesions treated by farmers, foot trimmers and vets in the field. A further RCT was therefore designed to investigate the impact of chronicity of lameness on outcome following treatment.

A prospective, partially blinded, positively controlled RCT was conducted based on the protocol for the acute lameness RCT described in chapter 3 with some amendments to take into account the complexities identified in this study. To be eligible for enrolment animals must have had at least two of the last three consecutive mobility scores at 2a or above (lame) on the same hind leg with at least one of the scores 2b or above. Enrolled animals were randomly allocated one of three treatments: 1) therapeutic trim only (TRM), 2) therapeutic trim plus orthopaedic shoe on the unaffected claw (TS) or 3) therapeutic trim plus orthopaedic shoe plus three day course of NSAID (TSN). The primary outcome measure was mobility score at 42 days post treatment. Three outcomes were analysed: (i) non-lame (score 0 or 1 at outcome), (ii) improved (lower mobility score at outcome than enrolment) and (iii) apparent leg cure (non-lame on treated leg or lame on contralateral leg at outcome). A subset of data from the acute lameness RCT was further analysed to these outcomes for comparison.

Between December 2013 and January 2015, 648 cows were examined and 189 cases of lameness from 176 cows enrolled on the study (13 cows received treatment on both hind limbs). Sixty three cases were allocated to TRM, 64 to

TS and 62 to TSN. No significant difference between treatment groups was seen for any of the outcomes analysed. Combining the results of all treatment groups and comparing these to the combined results from the acute lameness RCT showed a significant difference for all outcomes ($P<0.01$). In the acute lameness RCT 31 of cases of lameness from 127 treated animals were seen at outcome with 15 of these lame on the opposite hind leg to enrolment. In the chronic lameness RCT 132 cases of lameness from 156 treated animals were seen at outcome with 60 of these identified as lame on the opposite hind leg to enrolment.

While differences in methodology mean these results should be interpreted with some caution, the findings support the need for both early and effective treatment of lameness in order to improve recovery. When treated in the acute stage of lameness, treatment with a TSN significantly improved recovery to sound compared with TRM at 35 days. This effect was lost when treatment was delayed. In chronically lame cows a very low response rate to treatment of around 15% was seen across all treatment groups. An unexpected finding of these RCTs was that over 45% of animals treated for a unilateral, hind limb lameness caused by claw horn lesions in both acute and chronic cases, were lame on the contralateral leg at outcome. Lameness on the contralateral limb was substantially less however in cows treated with TBN than other treatment groups. It is thought that aetiopathogenesis of claw lesions is linked to events which occur around the time of calving and so, while lameness may only present in one hind limb, it is likely pre-lameness changes have also occurred in all feet. While this finding requires greater research, a recommendation that both hind limbs should receive an appropriate treatment intervention can be made.

4.1 Introduction

The findings of a RCT carried out to investigate the effect of commonly used treatments for claw horn lesions in acutely lame dairy cows concluded that, compared to a minimum treatment intervention of a therapeutic foot trim, the addition of an orthopaedic foot block in combination with a three-day course of non-steroidal anti-inflammatory drug (NSAID) had a significant effect on recovery to soundness over a 35-day period (see chapter 3). In contrast two RCTs conducted in Australia and New Zealand (Pyman, 1997, Laven *et al*., 2008) investigating the use of common treatments for claw horn lesions found no significant difference between treatments at their 14 day and 100 day outcomes respectively (see section 3.1). One notable difference between these studies is the method used to identify lame cows. In the first study, identification was made by the primary researcher using fortnightly locomotion scoring while in the latter two studies, identification of lame cows was made by farm staff. This is of significance as studies have shown that farmers identify and treat lame cows later in the disease process. Surveys based on locomotion scoring show prevalence of lameness is around three times higher than farmer estimates. Whay *et al*., (2003) found poor correlation between lameness prevalence recorded by researchers and that estimated by farmers, with farmers failing to identify three out of four cases of lameness. A similar finding was reported by Espejo *et al*., (2006) with the prevalence of lameness estimated by study investigators 3.1 times greater than that estimated by herd managers. Leach *et al*., (2010a) found a closer relationship between the prevalence of cows identified as lame by farmers and those scored severely lame by researchers than the total prevalence of lame cows reported by researchers. These studies suggest that farmers detect cows as lame at a later stage in the disease which may influence the interval between cows going lame and receiving treatment. A further complication may be that many farmers do not identify or refer to milder cases as 'lame'. It appears they reserve the term 'lame' for more severe cases (Horseman *et al*., 2014) using terms such as *'not walking quite right'* or *'just a little bit impaired in how mobile they are'* for milder lameness cases. Consequently, if farmers do not consider that milder cases are 'lame' it stands to reason that they would not necessarily be considered for treatment. In a study

by Alawneh *et al*., (2012) farmers were again shown to be better at detecting severe lameness than milder cases although even with severe cases fewer than 25% were presented for veterinary treatment the same week as a severe lameness score had been recorded by the researcher. The study found a median delay in treatment of 21 days for severely lame cows and 70 days for milder cases. Similar findings were made by Groenevelt *et al*., (2014) with an average treatment delay of lame cows by farmers of 37.7 days (range 7-126) and Leach *et al*., (2012) where only twelve of the 101 eligible cows in the control group were treated by the farmer and had often been lame for several weeks before treatment.

While recent work suggests early treatment of lame cows is fundamental in promoting recovery and reducing recurrence of cases (Groenevelt, 2014, Leach *et al.,* 2012), the early and predominantly mild lesions seen in the RCT on acutely lame cows (see chapter 3) may not necessarily be representative of those lame cows treated by farmers, foot trimmers and vets in the field. Due to the delay in treatment when lameness is identified by farm staff it may be difficult to apply the findings from this trial to cases presented for treatment.

The aim of this study was to investigate the impact of chronicity of lameness on outcome following treatment. The hypotheses were that cows would recover from chronic claw horn lesions at different rates depending on the treatment administered and that that cows would recover from claw horn lesions at different rates with the same treatment depending on the severity and chronicity of the lameness. Two primary objectives were identified for this study; to evaluate the response to treatment in cows suffering from more severe and chronic lameness conditions using a similar protocol to that seen in the RCT on acutely lame cows and to compare this data with additional data from the RCT on acutely lame cows to gain further insight into the effects of severity and chronicity of lameness on response to treatment.

4.2 Materials and methods

As part of this study, data from an RCT on acutely lame cows (see chapter 3) was utilised for analysis that had not previously been undertaken. The methods used for collection of this data are described in section 3.3.1. Data from the enrolment and outcome examinations of cows treated with TRM, TB and TBN underwent further analysis as described in section 4.2.9. The following methods relate to the collection of data for a follow-on RCT on treatment of chronically and more severely lame cows.

4.2.1 Study design for RCT on chronically lame cows

A prospective, partially-blinded, positively controlled RCT was designed based on the protocol developed for the RCT on treatment of claw lesions in acutely lame cows (see section 3.3.1) with some amendments to take into account the complexities identified in this study (see section 3.4.2). The current study aimed to build on knowledge from this previous RCT to determine the best treatments for claw horn lesions in dairy cattle that have resulted in a chronic lameness of greater than two weeks duration and to fill the knowledge deficit in treatment of claw horn lesions for cows suffering more chronic and possibly severe lesions. The authors role is this study included revising the protocol from the previous study and overseeing the data collection and collating raw data. Day to day implementation of the study protocol was undertaken by a research assistant with experience of the study design. Mobility scoring was undertaken by trained technicians and the results forwarded to the author for case selection. Cows meeting the inclusion criteria underwent examination and treatment by a fully licenced member of the National Association of Cattle Foot Trimmers (NACFT) or a qualified veterinary surgeon.

Based on the findings of the previous RCT on acutely lame cows where a 32% difference in cure rate to soundness was demonstrated between the four treatment groups, a power calculation (power value of 0.8, $P \leq 0.05$) suggested the minimum size of treatment groups to find a 30% difference in cure rate between treatment groups in this RCT was 41 animals per group. Minimum treatment group sizes were planned for 50 animals to allow for withdrawals with

target group sizes of 60 to allow for differences in treatment response rates in this study population.

The RCT was carried out under the Veterinary Surgeons Act 1966 which regulates acts of veterinary surgery in the UK. Positive control groups were used and farmers remained free to treat any of their animals at any time as per the RCT on acutely lame cows (see section 3.3.1). No animals were left untreated. All treatments used were considered 'normal' and 'accepted' UK practice by the industry and/or profession at the time of the trial and treatments were overseen by the study leader working in collaboration with the study farms' own vets. The study protocol was reviewed and granted approval by the University of Nottingham's School of Veterinary Medicine and Science Ethical Review Committee.

4.2.2 Farm recruitment

A convenience sample of five commercial dairy farms within close proximity to the University of Nottingham, School of Veterinary Medicine and Science were recruited to the study. Farm recruitment criteria were unchanged from the RCT on acutely lame cows (see section 3.3.1). Two farms (farms 1 and 5) elected to leave the study prior to completion and were replaced with farms 6 and 7.

The farms recruited to the study had herd sizes ranging from 87 to 392 cows (median 147) with 305 day adjusted milk yields from 6826L to 10607L (median 9062L). On six of the farms (farms 1, 2, 3, 4, 5 and 7) lactating cows were cubicle housed over the winter (~October-March) and kept at pasture during the summer. Cows on these farms were milked twice daily in herringbone or swing over parlours. On one farm (farm 6) cows were continuously housed during the period of the study and milked on an automatic (robotic) milking system. Initial herd lameness prevalence ranged from 22% to 59% (median 30%).

All farms taking part in the study undertook routine foot bathing for control of digital dermatitis and were visited either fortnightly (farm 7), monthly (farms 1, 2, 3, 4) or three times a year (farm 6, whole herd) by a professional hoof trimmer for routine hoof trimming. Farm 5 was visited three times a month by a professional hoof trimmer for treatments only. Additional lameness treatments

were undertaken by the farmers or farm veterinary surgeon as required (see Table 22).

Table 22. Management, housing and lameness protocols employed on seven herds at the start of a randomised clinical trial on treatment of chronic claw horn lesions in dairy cattle

Farm Number	Herd size at start of study	Cows in milk at start of study	Approx. duration winter housing	Lactating cow groups	Management of sick cows	Passageways	Scraper	Milking system	Milking regime	Average 305d milk yield	Foot bathing frequency	Foot bath chemical	Foot bath chemical dilution	Frequency of routine foot trimming visits	Identity of foot trimmer	Lame cow treatment frequency	Initial herd lameness prevalence
1	143	133	7 months	One	With drys in loose housing	Concrete with grooving	Automatic every 2 hours	11/22 Herringbone parlour	Twice daily	9062	2x week	Formalin	5%	Monthly	External foot trimmer	Monthly with routine trims	22.2%
2	103	90	6 months	First calvers, old cows, main group	None	Concrete	Tractor scraped twice a day	Herringbone parlour	Twice daily	10270	6x week	Copper sulphate and healthy hooves	~	Monthly	Farmer and external hoof trimmer	Farmer treatment as required	23.1%
3	87	81	6 months	One	Straw pen	50% rubber matting, 50% concrete	Tractor and hand scraped 3x daily	14/14 Herringbone parlour	Twice daily	8160	2x week	Formalin	5%	Monthly	Farmer and external hoof trimmer	Farmer treatment as required	24.7%

(Table 22. continued)

Farm Number	Herd size at start of study	Cows in milk at start of study	Approx. duration winter housing	Lactating cow groups	Management of sick cows	Passageways	Scraper	Milking system	Milking regime	Average 305d milk yield	Foot bathing frequency	Chemical	Dilution	Frequency of routine foot trimming visits	Foot trimmer	Treatment frequency	Initial herd lameness prevalence
4	147	138	5 months	One	Straw bedded loose yard		Tractor scraped 3x daily	12/24 swingover parlour	Twice daily	9765	2-4x week	Copper sulphate	12.5%	Monthly	Farmer and external foot trimmer	Monthly with routines, farmer as required for severely lame	58.9%
5	392	332	High yielding 12 months, low yielding 6 months	High, mid, low yield groups and heifers	Straw pens	concrete	One shed automatic, others tractor scraped twice daily	Herringbone	Twice daily	8866	3-5x week	formalin	6%	No routine trimming	External foot trimmer	Visits three times per month by foot trimmer	32.7%
6	201	177	12 months	One	Straw pens	Rubber matting	automatic	Automatic (robotic) milking machine	Average three visits daily	10670	1x week	Copper sulphate	12.5%	Whole herd 4-5 months	External foot trimmer	As required by farmer or foot trimmer	33.1%
7	323	267	6 months	High and low yield	Straw pen	Concrete	Tractor scraped twice a day	Herringbone parlour	Twice daily	6826	daily	Formaldehyde	5%	Whole herd 5 months	External foot trimmer	Fortnightly by foot trimmer	29.7%

4.2.3 Mobility scoring

Mobility scoring of all lactating cows on the seven farms was undertaken fortnightly by trained technicians using the protocol described in section 3.3.1. Mobility scoring was conducted as cows exited the parlour (farms 1, 2, 3, 4, 5 and 7) or in a passageway with a firm, level surface (farm 6). Each farm was allocated a trained technician for the duration of the study.

Mobility scoring data was transferred from data capture forms to a relational database (Access 2007, Microsoft Corporation) by the technician then forwarded to the author to select cows for treatment. Animals were eligible for enrolment if they had at least two out of the last three consecutive mobility scores at score 2a, 2b, 3a or 3b (lame) on the same hind leg with at least one of the scores a 2b, 3a or 3b. Where the first two mobility scores were lame on the same leg but the most recent mobility score was a '1', animals were included. Animals were excluded if at the most recent mobility score the cow was lame on a different leg to the previous two scores, the first two mobility scores were lame on the same leg but the most recent score was a '0' or if the cow did not have a mobility score recorded at the most recent visit. Cows were also excluded if they had received treatment on the study or by the farmer in the previous six weeks. If cows had been enrolled on the study previously, they were not eligible for re-enrolment on the same leg, however they could be selected for treatment on the opposite leg provided a minimum of six weeks had elapsed since the last treatment. Animals which had reached the end of a course of parenteral antibiotics or anti-inflammatory treatment within the previous 14 days were excluded.

4.2.4 Enrolment examination

Animals meeting the inclusion criteria were presented for examination by the treatment operator within 2 (±2) days of mobility scoring following the protocol described in section 3.3.1. Examinations and treatments were undertaken on three of the farms (Farms 5, 6 and 7) every two weeks throughout the study period. On the remaining four farms (Farms 1, 2, 3 and 4) treatments were undertaken every four weeks. On farms 6 and 7 treatments were carried out by veterinary surgeons whilst on the other five farms (Farms 1, 2, 3, 4 and 5) cows were treated by a professional hoof trimmer. The exclusion criteria at

examination, identification of the affected claw and therapeutic trimming followed the protocol described in section 3.3.1. Animals which failed to meet the enrolment criteria during the enrolment examination still received the baseline treatment of a five-stage therapeutic trim but were not enrolled. They took no further part in the study at this stage but could be considered again if found to be lame on the same or opposite leg providing a minimum of six weeks had elapsed since examination.

4.2.5 Lesion classification and treatment allocation

Claw lesions were identified by the treatment operator following the 5-stage therapeutic trim and animals were placed into one of three diagnosis categories, sole haemorrhage/sole ulceration (SH/U), white line disease (WLD) and 'other' as described in section 3.3.1. Three different treatment protocols were then tested (see table 23).

Table 23. Treatments administered in a randomised controlled trial to test the recovery of cows with chronic claw horn lesions following different treatments

Treatment group	**Treatment definition**
1 (TRM) Therapeutic foot trim only	1. Remove excess horn growth Investigate and trim out any lesions present Remove diseased and under-run horn As far as possible, rebalance claw height to reduce weight bearing on diseased claw (Toussaint Raven, 1985).
2 (TS) Therapeutic trim and plastic shoe	1. Therapeutic foot trim as in treatment 1 2. Application of an orthopaedic plastic shoe[1] (Demotec. Nidderau, Germany) to the unaffected claw
3 (TSN) Therapeutic trim, plastic shoe and NSAID	1. Therapeutic foot trim as in treatment 1 2. Application of an orthopaedic plastic shoe[1] (Demotec. Nidderau, Germany) to the unaffected claw 3. Administration of a three-day course of ketoprofen (Ketofen 10% solution for injection at 3mg/kg IM, Merial Animal Health, Woking, UK)

[1]Plastic shoe with weight bearing surface approximately 110 mm long, 55 mm wide and 18 mm deep. The shoe was positioned and fixed in place following the manufacturers instructions in an attempt to replicate normal claw placement and weight distribution.

Treatments were blocked, randomised and assigned to the enrolled cows following the same protocol as described in section 3.3.1 (allowing for three treatment groups rather than four). Farmers were requested to manage enrolled cows following their normal practices and inform the researchers if they had any concerns between visits.

4.2.6 Treatment follow up and outcome observations

Animals were re-examined at 14(±3) days after treatment by the allocated trained technician during the routine fortnightly mobility scoring session with re-treatment eligibility as per the RCT on acutely lame cows (see section 3.3.1). Animals which were re-treated were subsequently withdrawn from the study. If the plastic shoe had remained attached (treatment groups TS and TSN) at 28 (±3) days, it was manually removed using trimming pincers and careful leverage. Withdrawal and exclusion criteria prior to the primary outcome measure followed that of the earlier RCT (see section 3.3.1)

The primary outcome measure was a mobility score at 42 (±4) days after treatment and was undertaken by the trained technician with responsibility for scoring that farm at their fortnightly visit. Technicians were not informed of which treatment the animal had received.

4.2.7 Additional data collected

Body condition score and milk recording data were collected as described in section 3.3.1.

4.2.8 Outcomes

Three primary outcomes were investigated separately for the RCT on acutely lame cows (see chapter 3) and the RCT on chronically lame cows detailed above.

Outcome (i) ‘non-lame’, compared the recovery following treatment of cows in each of the treatment groups at the outcome measure (35±4 days in the acute RCT, 42±4 days in the chronic RCT). Recovery was based on a binary measure of having a ‘non-lame’ score (score 0 or 1) as opposed to a ‘lame’ score (score 2a, 2b, 3a or 3b) at outcome for each of the treatment groups.

Outcome (ii) ‘improved’, investigated whether cows in each of the treatment groups showed an improvement in their mobility score at the outcome measure, i.e., the mobility score at outcome was lower than the mobility score at enrolment

Outcome (iii) ‘apparent leg-cure’ examined whether cows were ‘non-lame’ (score 0 or 1) on the treated leg or ‘lame’ (score 2a, 2b, 3a or 3b) on the contralateral, untreated hind leg at outcome.

4.2.9 Data management and statistical analysis

Data capture was achieved through the completion of data capture forms and then transcribed and stored in a relational database (Access 2007, Microsoft Corporation) for analysis. Data for milk yield was obtained directly as data files from the milk recording companies and managed using relevant software. Data analysis was conducted in Minitab 17 (Minitab Inc.). Data was checked for errors against written records prior to analysis. Differences between treatment groups at time of enrolment were assessed by a $\chi 2$ test (mobility score at enrolment) analysis of variance (days in milk and last recorded monthly yield) and using the Kruskal-Wallis test (body condition score at enrolment and parity).

For analysis of Outcome (i) 'non-lame' in the chronic lameness RCT, the proportion of successful treatments in the TS group and TSN group were compared to the successful treatments in the positive control group TRM(chronic). In the acute lameness RCT the proportion of successful treatments in the TB group, TN group and TBN group were compared to the successful treatments in the positive control group TRM(acute).

Multivariable logistic regression analysis was carried out to account for confounding factors or clustering at the cow or farm level. A description of the multivariable analysis completed for the acute lameness RCT is given in section 3.3.1.6. Regression modelling for the chronic lameness RCT was carried out in MLwiN version 2.1 using stepwise forward selection, with $P \leq 0.05$ considered significant. Single-level and two level random effects models (case level and cow level) were fitted with treatment group forced in to the model. Farm, parity, diagnosis, days in milk, body condition score at enrolment, body condition score four weeks after treatment, identity of technician conducting mobility score treatment operator, test day milk yield one and two months before and one, two and three months after treatment were all tested as explanatory variables.

4.3 Results

4.3.1.1. Enrolments and exclusions for RCT on acute lameness

A full description of enrolments and exclusions of cows in the acute lameness RCT is given in section 3.3.2. A subset of data for 127 cows from the TRM, TB and TBN treatment groups was obtained for additional analysis in this study. The parity, days in milk, last recorded milk yield, body condition score and lameness score at enrolment were not significantly different between the cows in the three groups.

4.3.1.2 Enrolments and exclusions for RCT on chronic lameness

During the course of the RCT, two farms elected to leave the study. Enrolment of cows on farm 5 was suspended on April 16th 2014 at the request of the farmer due to time constraints. Enrolment of cows on farm 1 was suspended on July 1st 2014 as the protocol did not meet the expectations of the farmer. Two further farms were recruited to the study on February 6th 2014 and July 4th 2014 (farms 6 and 7 respectively) to replace farms 5 and 1. Enrolment of cows continued on these farms until the end of the study.

Between December 1st 2013 and January 16th 2015, 648 cows were examined after meeting the initial selection criteria. Four hundred and fifty-nine cows were excluded prior to enrolment. One hundred and forty-nine were found to have active digital dermatitis, 17 had been treated with an NSAID or antibiotic in the past 14 days, four were found to have interdigital necrobacillois, 12 had a large interdigital growth and 231 were excluded for other reasons such as still having a block in place from a previous treatment (41), no visible lesions being found (90), lesions in both claws (4), necrotic toe diagnosed (20), and non-compliance with the study protocol (13).

The remaining 189 cases of lameness from 176 cows were enrolled on to the trial, 13 cows having received treatment on both hind limbs in accordance with the enrolment criteria. The number of cows allocated to each of the treatment groups by lesion diagnosis and farm is outlined in Table 24.

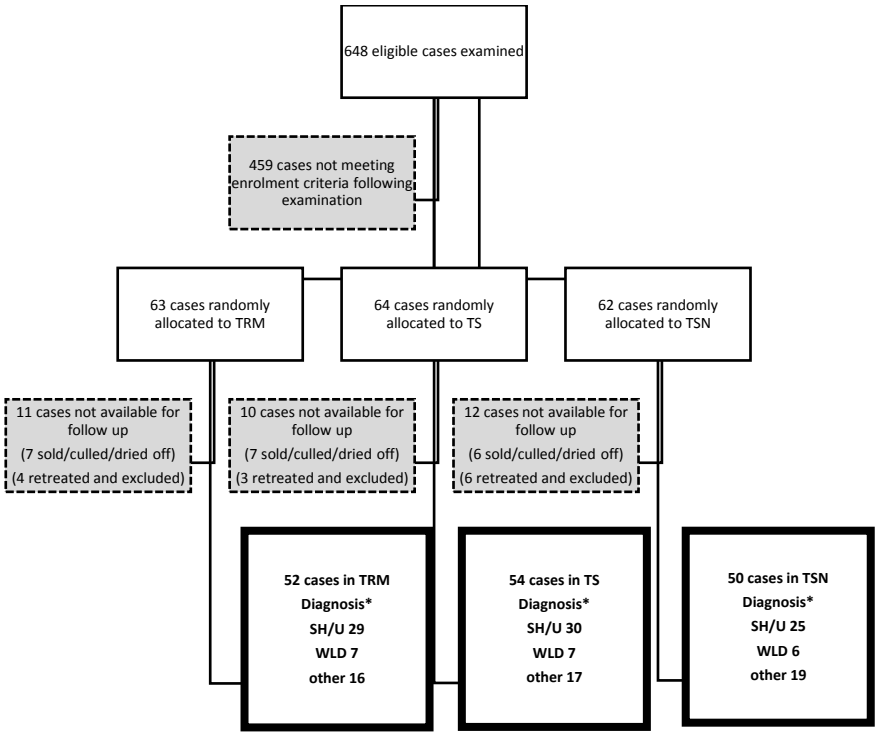
Table 24. Number of cows allocated to each of 3 treatment groups by lesion diagnosis and farm in a randomised clinical trial designed to test the recovery of chronically lame dairy cows with claw horn lesions

Farm ID	Lesion Diagnosis									Total
	Sole Haemorrhage / Ulcer			White Line Disease			'Other' Lesion			
	TRM	TS	TSN	TRM	TS	TSN	TRM	TS	TSN	
1	3	2	3	0	1	0	1	1	1	12
2	3	5	3	1	1	1	3	1	3	21
3	2	1	4	2	1	0	0	2	1	13
4	10	11	12	3	3	1	5	5	4	54
5	3	4	2	3	3	4	1	0	2	22
6	8	7	7	1	1	3	2	1	0	30
7	8	7	3	0	0	1	4	6	8	37
Total	37	37	34	10	10	10	16	16	19	
Grand Total	108			30			51			189

TRM trim only, TS Trim and Shoe, TSN Trim, Shoe and NSAID
Missing lesion diagnosis, farm 3 (n=2), farm 7 (n=1)

In total 33 cases were not available for mobility scoring at the outcome assessment. Twenty cases were sold, culled or dried off across the three treatment groups (see figure 20), one cow (farm 6) had undergone abdominal surgery and received NSAIDs prior to outcome score, ten cows (farms 2 (x2), 3 (x2), 4 (x3), 5 (x1) and 6 (x2)) had received additional treatment at the four-week check, one cow (farm 6) had been administered NSAIDs not related to lameness and one cow (farm 10) was found to have a foot block partially present at outcome.

Of the 156 cows included in the final analysis, ten cows in the TS or TSN groups had lost their foot blocks by the four week recheck visit (6 in TS, 4 in TSN).



TRM – trim only, TS – trim and shoe, TSN- trim shoe and NSAID

SH/U – sole haemorrhage/ulceration, WLD – white line disease

Figure 20. Diagram showing the number of animals examined, randomly allocated to treatment groups and completing the study protocol, in a randomised controlled trial investigating the treatment of chronic claw horn lesions.

*Lesions ranged from mild to severe but did not include any lesions with an infectious component (e.g. lesions with secondary digital dermatitis infection)

The parity, days in milk, last recorded milk yield and body condition score and lameness score at treatment of enrolled cows in the chronic lameness RCT are outlined in Table 25 by treatment group. Differences in these parameters between the treatment groups were not significant.

Table 25. Descriptive statistics relating to parity, milk yield, body condition score and lameness score of animals in each of 3 treatment groups in a randomised clinical trial investigating the recovery of cows with chronic claw lesions post treatment.

	Treatment Group		
	TRM	TS	TSN
Parity (Median (Interquartile range))	3 (2-5)	3 (2-5)	4 (3-5)
Days in milk (Mean (SE))	200 (15.5)	196 (15.4)	190 (14.4)
Last recorded milk yield (Mean (SE))	32.5 (1.63)	31.7 (1.45)	32.6 (1.46)
Body condition score at treatment (Median (Interquartile range))	2.5 (2-2.5)	2.5 (2-2.5)	2.5 (2-3)
Lameness score at treatment (Median (Interquartile range))	2b (2a-2b)	2b (2a-2b)	2b (2a-2b)

TRM – trim only, TS – trim and shoe, TSN – trim, shoe and NSAID

Data collection exceeded the minimum sample size of 41 cows per group set with a power value of 0.8 and a significance of $P \leq 0.05$ to find a 30% difference in cure rate. A retrospective power calculation using final trial data demonstrated that the study was sufficiently powered to detect a 27% difference in recovery between treatment groups.

4.3.3 Mobility scores

Mobility scores were recorded on a six-point scale at enrolment and outcome for both the acute lameness RCT and chronic lameness RCT. The number and proportion of each mobility score for enrolled cows is shown in table 26. Across the 127 cows included in the additional analysis of data from the RCT on acutely lame cows, both the mode and median score at enrolment was 2a. Across the 156 cows included in the final analysis for the RCT on chronically lame cows, both the mode and median score at enrolment was 2b.

Across the 127 cows in the acute lameness RCT, the mode at outcome, 35(±4) days post treatment was score 0 and median score 1. Across the 156 cows in the chronic lameness RCT, both the mode and median score at outcome 42 (±4) days post treatment was 2a.

Table 26. Proportion (and number) of mobility scores on a six-point scale seen in cows enrolled on a randomised clinical trial (RCT) for acute lameness and those enrolled on a RCT on chronic lameness on the day they were treated for lameness (enrolment) and at outcome at 35(±4) days (acute) and 42(±4) days (chronic) post treatment.

Mobility score	Enrolment		Outcome	
	Acute RCT	Chronic RCT	Acute RCT	Chronic RCT
0	0% (0)	0% (0)	39.4% (50)	0% (0)
1	0% (0)	4.5%* (7)	36.2% (46)	15.4% (24)
2a	83.5% (106)	28.2% (44)	22.0% (28)	41.6% (65)
2b	11.0 % (14)	47.4% (74)	1.6% (2)	31.4% (49)
3a	5.5 % (7)	13.5% (21)	0.8% (1)	9.6% (15)
3b	0% (0)	6.4% (10)	0 % (0)	1.9% (3)
Total	(127)	(156)	(127)	(156)

* Animals were eligible for enrolment if they had at least two out of the last three consecutive mobility scores at score 2a, 2b, 3a or 3b (lame) on the same hind leg with at least one of the scores a 2b, 3a or 3b. Where the first two mobility scores were lame on the same leg but the most recent mobility score was a '1', animals were included.

4.3.4 Primary outcome analysis

Data used for the analysis of the primary outcome is summarised in table 27 for both acutely and chronically lame cows. It is shown as a binary measure of recovery defined as non-lame, (score 0 or 1) or lame, (score ≥2a). Recovery to sound (score 0) versus non-sound (score ≥1) was not tested due to the low numbers of score 0 cows at outcome in the chronic RCT. Results for outcome to sound for the acute RCT are shown in section 3.3.2.

The number of cases in each of the three recovery outcomes, (i) non-lame, (ii) improved and (iii) apparent leg-cure is shown for each treatment group. For the purposes of comparison cows treated with a wooden orthopaedic foot block (B) in the acute lameness RCT will be considered equivalent to those treated with a plastic orthopaedic shoe (S) in the chronic lameness RCT, with S being used to signify both treatments henceforth. It should also be noted that there was a one-week difference in time to outcome score with outcome recorded in the acute RCT at 35(±4) days and outcome recorded in the chronic RCT at 42 (±4). Further explanation and discussion of these differences can be found in section 4.4.1.

Table 27. Number of cows recovering in each treatment group in two randomised controlled trials (RCT) testing the recovery of dairy cows from acute and chronic claw horn lesions

Treatment Group	N (acute RCT)	N (chronic RCT)	Proportion (and number) of cases recovered at 35 day (acute lameness) and 42 day (chronic lameness) outcome score respectively.					
			Acute RCT Outcome (i) non-lame[1]	Chronic RCT Outcome (i) non-lame[1]	Acute RCT Outcome (ii) improved[2]	Chronic RCT Outcome (ii) improved[2]	Acute RCT Outcome (iii)Apparent Leg-cure[3]	Chronic RCT Outcome (iii) Apparent Leg-cure[3]
1 (TRM)	45	52	68.9% (31)	15.4% (8)	80.0% (36)	44.2% (23)	82.2% (37)	51.9% (27)
2 (TS)	39	54	71.8% (28)	14.8% (8)	79.5% (31)	48.1% (26)	92.3% (36)	51.9% (28)
3 (TSN)	43	50	86.0% (37)	16.0% (8)	88.4% (38)	48.0% (24)	88.4% (38)	58.0% (29)
Total	127	156	75.5% (96)	15.4% (24)	82.7% (105)	46.8% (73)	87.4% (111)	53.8% (84)

TRM – trim only, TS – trim and shoe, TSN – trim, shoe and NSAID
[1]non-lame: Cows that were score 0 or 1 at outcome
[2]improved: Cows where the score at outcome was lower than the score at enrolment
[3]apparent leg-cure: Cows which were "non-lame" or identified as lame on the contralateral leg at outcome

Within each RCT, no significant differences between treatment groups for each of the recovery definitions ((i) Non-lame, (ii) Improved, (iii) Apparent Leg-cure) were seen in either the acute lameness RCT or chronic lameness RCT.

When combining the results of all the treatments on each trial and comparing the acute lameness RCT results to the chronic lameness RCT, univariable analysis using each of the recovery definitions ((i) Non-lame, (ii) Improved, (iii) Apparent Leg-cure) for total number of cows receiving treatment identified a significant difference between cows treated for acute lesions and cows treated for chronic lesions ((i) $P<0.01$, (ii) $P<0.01$, (iii) $P<0.01$) (see figure 21).

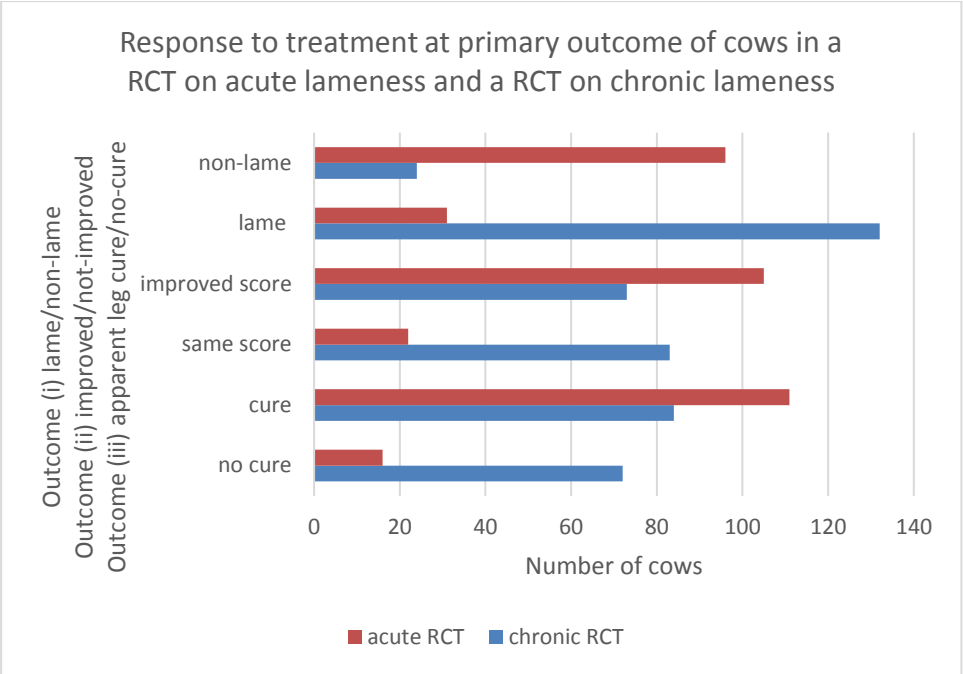


Figure 21. Response to treatment of 127 cows on an RCT for acute lameness and 156 cows on a RCT for chronic lameness to one of three outcomes, outcome (i) non-lame, outcome (ii) improved mobility score and outcome (iii) apparent leg cure (non-lame or lame on untreated leg) at 35 (±4) days (acute RCT) or 42 (±4) days (chronic RCT) post treatment

In the acute lameness study 31 cases of lameness (mobility score ≥2a) were seen at outcome 35 (±4) days after treatment across the four treatment groups. Fifteen of these cases (48.4%) were identified as lame on the opposite hind leg to the lame leg at enrolment.

In the chronic lameness study 132 cases of lameness were seen at outcome 42 (±4) days after treatment across the three treatment groups. Sixty of these cases (45.5%) were identified as lame on the opposite hind leg to that at enrolment.

In the chronic lameness RCT, a significant effect of 'farm' was found in outcome (i) non-lame ($P<0.01$) and a significant effect of 'operator' ($P=0.05$) in outcome (iii) apparent leg cure

4.3.5 Additional analysis

Results of logistical regression modelling in the acute lameness study are described in section 3.3.2.

In the chronic lameness study, no statistically significant effect of treatment group was detected for any of the three outcomes. Parity and month of lactation

were found to be significant in recovery to outcome (i) non-lame with heifers were more likely to be non-lame after treatment. Farm and mobility score at enrolment were found to be significant in recovery to outcome (ii) improved with greatest improvement seen in the most severely affected cows.

Photographic and pictorial records taken during data collection to assess lesion severity were fed forward to a study out-with this thesis.

4.4 Discussion

Comparing the recovery of all cows treated for claw horn lesions in an RCT for animals with acute lameness of less than two weeks duration and an RCT for animals with a chronic lameness of greater than two weeks duration (often considerably greater), the results support the hypothesis that cows would recovery at different rates depending on the chronicity of lameness. Recovery was significantly improved in all outcomes for cows that received treatment at the acute stage of lameness compared to those treated for more chronic lesions.

While the direct comparison of data between these two studies should be interpreted with some caution due to differences in methodology, the two studies are sufficiently similar to justify some evaluation of the results against one another. These differences however do reduce the amount of analysis that can be made. For example, it was not possible to directly examine differences in mobility score at enrolment on these two RCTs as the result was biased by the enrolment criteria. To be eligible for enrolment on the acute lameness RCT, cows had to present with two non-lame scores (score 0 or 1) followed by a lame score (score ≥2a). For this reason, no cows were treated with a non-lame score at enrolment. To be eligible for enrolment on the chronic lameness RCT, cows had to present with at least two out of the last three consecutive mobility scores as lame (score ≥2a) with at least one of the scores at 2b, 3a or 3b. It was therefore possible for some cows to be non-lame (score 0 or 1) at enrolment if the preceding two scores had been lame (score ≥2a). The greater severity of lameness at enrolment is also likely to be a reflection of the requirement for at least one score to be at 2b, 3a or 3b rather than being attributable purely to chronicity of lameness. The recovery of cows given different treatments in the chronic RCT discussed below may therefore also be a consequence of the severity of the lameness treated as well as its duration.

The hypothesis that cows would recover from claw horn lesions at different rates depending on the treatment administered was analysed for each of the primary outcomes. Analysis of recovery to outcome (i) non-lame, found no significant difference in recovery at the primary outcome measure in the cows treated with TS or TSN compared to TRM in either the acute lameness RCT or the chronic

lameness RCT. Interestingly, in the chronic lameness RCT, only 15% of cows were non-lame at outcome meaning response rate to treatment was very low, and response was seen to be almost identical between groups (TRM 15.4%, TS 14.8%, TSN 16.0%). Contrast this with a range of 68.9% (TRM) to 86.0% (TSN) in the acute lameness RCT and it is evident that delaying the time to administration of treatment has a profound effect on outcome. Recent studies have shown that early treatment of lesions is key to promoting recovery to non-lame. Groenevelt *et al*., (2014) and Leach *et al*., (2012) conducted studies on acutely lame cows using the same mobility scoring frequency and acute lameness definition as in RCTs presented here. Cows in the treatment groups received treatment within 48 hours while those in the control group were treated by the farmer following their normal lameness protocols. In the study by Groenevelt *et al*., (2014) only 3.9% of control group cows had a treatment recorded within 2 weeks of becoming lame while in the study by Leach *et al*., (2012) only 11.9% of eligible lame cows in the control group were treated in the whole duration of the study. The differences between treatment and control groups in Groenevelt *et al*., (2014) were significant for two-week recovery while Leach *et al*., (2012) found no significant difference in mobility score at 2 weeks but by 4 weeks a significantly higher number of cows in the treatment group recorded a non-lame score. In this study, the response rates to treatment in the acute lameness RCT are substantially higher across all treatment groups than the response in the equivalent treatment groups in the chronic lameness RCT, and the effect of individual treatments was lost in chronic and more severe cases. This provides more evidence that early identification and treatment is key to successful recovery regardless of the treatment administered. Once lameness caused by claw horn lesions becomes chronic, it is much more difficult to treat successfully.

While no significant difference was seen in recovery to non-lame across the three treatment groups for data from the acute lameness RCT, a similar trend to that found in chapter 3 to the outcome ‘sound’ was evident. The results of chapter 3 found that cows treated with TBN were significantly more likely to recover to soundness (score 0) than those treated with TRM. (P=0.01). Smaller, non-significant improvements were also seen with TB and TN compared to TRM. In

this study further analysis of the data showed that the proportion of cows recovering to non-lame in the TSN group (86.0%) was also larger than the other groups with a smaller improvement in TS (71.8%) compared to TRM (68.9%). While these differences were not significant the trend is certainly in the same direction as that seen to the outcome 'sound' and it may be that the study was underpowered to demonstrate a significant difference to the outcome non-lame. The possible synergistic effect of a foot block and NSAID on recovery is discussed further in section 3.4.1.3.

No significant difference in recovery was seen between treatment groups to outcome (ii) improved in either the acute lameness RCT or the chronic lameness RCT. Similar to outcome (i) however, the proportion of cows showing improved mobility scores in the acute lameness RCT was much greater than those in the chronic lameness RCT, in this case around double the amount (acute TRM 80%, TS 79.5%, TSN 88.4% vs chronic TRM 44.2%, TS 48.1%, TSN 48.0%). The improvement in mobility score at outcome following treatment shows that while only around 15% of cows on the chronic lameness study were non-lame at outcome, around half had shown some improvement and so treatment had some effect on the level of lameness. It is clear once again from these results that early intervention is key however when treating lame cows for claw horn lesions.

Analysis of the data to outcome (iii) apparent leg cure showed no significant differences between treatment groups in either the acute lameness RCT or the chronic lameness RCT. This outcome measured the number of cows that were either non-lame or lame on the contralateral, untreated limb, suggesting that the treated limb had responded to treatment and was no longer painful. In the acute lameness RCT there was a suggestion that cows treated with a therapeutic trim alone were less likely to cure on the treated leg than those treated with additional treatments (TRM 82.2%, TS 92.3%, and TSN 88.4%). In contrast, in the chronic lameness study, treatment with an orthopaedic shoe appeared to provide no increase in recovery over a therapeutic trim (TRM 51.9%, TS 51.9%) while there was a suggestion of improvement in recovery when treated with the combination of a shoe and NSAID (TSN 58.0%) over a therapeutic trim alone. While there may not be a significant difference between treatment groups in each trial, again it is striking the much greater proportion of animals recovering to this outcome

on the acute lameness RCT compared to the chronic lameness with over 30% more animals achieving apparent leg cure in each treatment group. This finding further supports the need for early treatment of lesions in the acute stages of lameness to improve recovery.

Discounting the cows that were non-lame from this outcome, it can be seen that of the 31 cows that were still lame at the primary outcome measure in the acute lameness RCT, 15 (48.4%) of these were lame on the opposite hind limb to that treated at enrolment and in the chronic lameness RCT, of the 132 cows that were lame at outcome, 60 (45.5%) were lame on the untreated leg. These findings are significant as they demonstrate that lameness is often not a unilateral condition. There are two possible explanations for the findings seen here. Firstly, as many of the proposed factors leading to claw horn lesions occur at a cow level, it is reasonable to expect that changes occur in both hind limbs following a period of high risk such as calving. Lameness is likely to show first in the more severely affected limb though pain may be experienced to some degree in the other. By reducing the pain through treatment in the more severely affected leg, the animal is able to bear more weight on this limb and the pre-existing lameness becomes apparent in the contralateral limb. An alternative hypothesis is that the increase in loading on the contralateral limb during a lameness event could precipitate or exacerbate the development of more severe lesions in this previously non-painful limb and thus a new case of lameness in the untreated leg is seen at outcome.

Breaking the data down further by treatment group, it can be seen that of the 15 cows lame on the contralateral, untreated leg at outcome in the acute lameness RCT, six (40%) were in the TRM group, eight (53.3%) in the TS group and one (6.7%) in the TSN group. In the chronic lameness RCT of the 60 cows lame on the opposite hind limb at outcome, 19 (31.7%) were in the TRM group, 20 (33.3%) in the TS group and 21 (35%) in the TSN group. In the acute lameness RCT the effect of treatment with a trim, foot block and NSAID appears to substantially reduce the number of animals lame on the contralateral limb at outcome. This effect is discussed further in section 3.4.1. The effect of this treatment combination is lost however in the chronic RCT suggesting that the pre-existing bilateral lesions or changes as a result of increased loading on the

non-lame leg are too far advanced in these chronic cases to benefit from the treatment.

From these results it would be fair to suggest that in cases of lameness treated on farms, both hind limbs should be treated at the initial examination even if lameness is only evident in one limb. This intervention may in turn reduce the likelihood of a contralateral lameness occurring in the following weeks. Further research is required to fully understand the pathogenesis of lesions in the contralateral limb however it is reasonable to expect that the intervention of a therapeutic trim on the non-affected limb would relieve pressure on critical structures within the foot and reduce the risk of a further lameness event. While such advice may seem logical from the results of this study, in a clinical situation there may be situations where treatment of both hind limbs is not possible. Where an animal is demonstrating a severe lameness, ethical concerns may be raised in requiring the cow to bear all its weight on the lame leg while the other leg is treated. Treatment should clearly be administered to the lame leg first and in cases where total weight bearing on this limb is not deemed appropriate, an initial treatment of the lame claw only should be conducted with a repeat examination and treatment of both hind limbs as soon as possible. This situation may be avoided by detecting lameness in the more acute stages where lameness has been shown to be less severe and so weight bearing on the affected limb is less of a concern. Alternatively, the use of crushes which remove weight bearing from both hind limbs during treatment may be preferable providing they do not compromise the animals welfare. Provision of pain relief, for example by intravenous regional anaesthesia could also be considered, both for the initial treatment of the affected claw in severely lame animals and to improve comfort to allow trimming of the contralateral foot. It is clear more studies are needed to fully investigate the development of bilateral lameness in cattle and determine the most successful and practical on-farm strategies for its treatment.

Other factors seen to affect recovery outcome (i) non-lame in the chronic lameness RCT were month of lactation and parity. The effect of month of lactation on recovery to non-lame was also seen in the acute lameness RCT (see section 3.4.1.5) with cows more likely to recover from lameness when treated in early lactation with the relationship showing an exponential decay with time

after calving. This finding in both RCTs has two possible explanations. It is thought the events which predispose cows to claw horn lesions occur around the time of parturition and so identification and treatment earlier in lactation may suggest that these lesions are less chronic than those treated in later lactation. This theory is supported by the findings of this study which show that acute lesions respond better to treatment than chronic lesions and so the effect of month of lactation may be linked to chronicity of disease. Another possible explanation for the effect of month of lactation relates to the study design. In the acute lameness RCT animals detected as acutely lame and given treatment later in lactation may also have experienced an episode of lameness earlier in that lactation but were unsuitable for enrolment at that time. Animals could not be enrolled until at least 120 days had elapsed since any previous treatment on the same limb and so the lower recovery rate later in lactation could reflect more chronic lesions from previous lameness events. Again this theory is supported by the results of this study which show an improved rate of recovery in animals treated in the acute stages of disease. In the chronic lameness RCT, this effect may also be evident and compounded by an amendment to the protocol from the acute lameness RCT which meant in this subsequent RCT animals could be enrolled separately for both hind limbs provided a minimum period of six weeks had elapsed between enrolment on the primary hind limb and the contralateral limb. As the events leading to claw horn lesions occur at a cow level, it is possible that both feet were affected at the same time and the second limb the animal was enrolled on represented a more chronic lesions than that seen at the primary enrolment. Thirteen cows were enrolled on both hind limbs in the chronic lameness RCT.

No effect of parity was seen on recovery in the acute lameness RCT however in the chronic lameness RCT it was seen that heifers were more likely to be non-lame at outcome than multiparous cows. This may be an effect of changes which occur within the foot as a result of repeated lameness episodes, predisposing the individual to further lesions (Blowey *et al*. 2000; Lischer *et al*., 2002; Newsome *et al*., 2016). Further research is needed to establish whether these changes not only influence risk of lameness but also response to treatment though it is very likely that the two are interlinked.

4.4.1 Comparison of study designs for acute and chronic lameness RCTs

One of the major complexities of the acute lameness RCT was the time and cost implications of conducting the study (see section 3.4.2). For the chronic RCT, the protocol was streamlined and duties placed into three groups. The author oversaw the study and managed the case selection data and analysis. All mobility scoring was carried out by separate trained technicians who were each allocated a farm to observe for duration of study. Scoring included the fortnightly herd mobility scores, recheck at two weeks and the outcome mobility score at six weeks. Treatments were then conducted by a qualified foot trimmer.

In the initial study design a single foot trimmer conducted treatments on all farms, however two of these farms withdrew from the study prior to completion and were replaced. Due to the private workload of the hoof trimmer, treatments on the two replacement farms were conducted by one of two vets who were each allocated one farm for the remainder of the study. Farm, mobility scoring technician and treatment operator were correlated and therefore could not be tested together to account for differences between individuals. As the final model showed no significant differences between the farms participating in the study it can be supposed there was no significant effect of operator or observer variability.

Treatment interval differed both between the acute and chronic RCTs and within the chronic RCT. In the acute lameness RCT treatments were carried out every two weeks while in the chronic lameness RCT treatments were carried out every two weeks on three farms and every four weeks on the remaining five farms. The impact of this difference in treatment interval is unclear as treatment intervals were linked to both farm and operator and so it was not possible to account for these in final models. The amendment to four week treatments was a result of cost as well as the availability of the professional hoof trimmer conducting the treatments. As the chronic RCT was designed to treat cows with chronic and potentially more severe lesions, the delay in treatment should not have impacted the result as the criteria was lameness of greater than two weeks duration, a maximum duration was not specified.

The protocols used for treatment of lame cows, randomisation of treatments and blocking of farms was largely similar for both RCTs although there were small differences. In the acute lameness RCT cows allocated treatment to raise the affected claw from the ground were fitted with a wooden foot block. In the chronic lameness RCT the same effect was achieved with a plastic shoe at the request of the professional hoof trimmer. While the initial application of these orthopaedic devices would have the same effect, it is possible that the distribution of weight across the sole and wall of the non-affected claw may differ between the two methods and the wear of the wooden block compared to the plastic shoe over the four-week period they were fitted could affect recovery. There was also no recheck on day seven by the treatment operator in the chronic lameness RCT and so shoes were not reapplied if they were not present one week after application compared to the protocol to refit the wooden foot block if it had been lost in the first seven days on the acute lameness RCT. The number of shoes missing at seven days was unknown on the chronic lameness RCT as the recheck examination was at 2 weeks by the mobility scoring technician and animals put forward for re-treatment if needed at this time. It is therefore not possible to determine any effect of lost foot blocks / shoes on recovery between the acute and chronic RCTs. The final notable change in protocol for the chronic RCT centred around the enrolment eligibility. In both RCTs, cows could only be enrolled once on a single hind limb. In the acute lameness RCT enrolled cows were then not eligible for re-enrolment for the remainder of the study while in the chronic lameness RCT cows could be enrolled on other hind leg provided a minimum of six weeks had passed since the first enrolment. This amendment was made to increase enrolment and in total, 13 cows were enrolled on each hind leg on separate occasions. As the study was looking at chronic lameness, this amendment should not have affected the primary outcome as even if the event causing the lameness had affected both hind limbs simultaneously, the lesion in the second limb to be treated, whilst being more chronic than the first, would still fit the criteria of lameness greater than two weeks duration.

One of the most significant changes in the study protocol for the chronic lameness RCT was the primary outcome measure at 42 days post treatment by the mobility scoring technician at the fortnightly mobility score rather than

observation by an independent observer at 35 days post treatment as seen in the acute lameness RCT. In theory both outcome scores were made blind to the treatment administered as the mobility scoring technicians were not informed of the treatment given to individual cows. The nature of treating with orthopaedic shoes however meant the presence or absence of this treatment was visible and as mobility scorers had been required to identify cows for the two week recheck it is possible they may have had some memory of treatment group which could lead to bias in the results. The decision not to appoint an independent observer for this study was based on the time and cost implications of conducting this procedure experienced in the acute RCT. This change however does reduce the strength of the study design in the latter RCT.

While these factors individually may be small, their effects could be additive and so comparison of results from the two studies should be interpreted with caution. Although it would be considered unlikely, it remains possible that the differences in results observed between the recovery from treatment in the acute and chronic RCTs were, in whole or in part, due to these small differences in methodology.

4.5 Conclusion

In these RCTs investigating the treatment of acute and chronic lameness caused by claw horn lesions in dairy cows there were no differences in recovery of lame cows between treatment groups to each of the outcomes analysed. Response to treatment in the chronic RCT was poor regardless of the treatment administered, however, while there were no significant differences between treatment groups in the acute lameness RCT, the effect of each treatment compared to the equivalent treatment in chronically lame cows was substantially improved. When comparing the response to treatment overall it could be seen that cows were very significantly more likely to recover when treated in the acute stages of lameness than when treated for more chronic lesions. Clinically, this finding suggests that any delay in the time to treatment of claw horn lesions, regardless of the treatment administered, is likely to reduce the rate of recovery. Early identification of lame cows and prompt, effective treatment of claw horn lesions is therefore key to their successful management. In both the acute and chronic lameness RCTs it was also seen that nearly half of the animals still lame at the primary outcome measure were lame on the contralateral, untreated leg. While the pathogenesis underlying this requires further investigation, for clinical purposes it would be fair to suggest that when treating lame cows with claw horn lesions, they should be considered to have lesions on both hind legs regardless of which leg is identified as lame.

Chapter 5. Knowledge transfer

5. Abstract

For research findings to have a significant impact on lameness levels on farms, appropriate dissemination of knowledge is required to those managing and treating lame cows. A study investigating lameness practices (see chapter 2) showed that the majority of foot trimming and treatment is carried out by farmers yet there is little research to support the most effective ways of transmitting research findings to farm staff. The following study aimed to assess the impact of different methods of knowledge transfer (KT) sessions on acquisition of knowledge and behavioural change in dairy farmers.

A prospective, qualitative and quantitative study was conducted to assess three methods of KT determined by the steering group based on existing practices within the industry. Group 1, the control group, acted as a positive control group and received a range of paper based AHDB dairy resources relating to lameness recognition in cattle. Group 2, the discussion group, received the AHDB Dairy resources and also participated in a facilitated discussion group on cattle lameness. Group 3, the expert group, received the AHDB Dairy resources and received an individual on-farm visit by a veterinary surgeon specialising in cattle lameness. Participants were recruited in existing discussion group or with the assistance of AHDB Dairy regional extension officers and blocked by region around the existing groups. Prior to the KT session, participants completed a short semi-structured interview with the researcher and then observed 40 video clips and selected whether the cow required treatment in the next 48 hours, week, 2-3 weeks or no treatment. Following the KT session the video exercise was repeated and a form completed using visual analogue scales to record feedback on the session. Responses to the video clips were analysed pre and post session. Feedback forms were used to assess engagement of participants and likelihood of behavioural change.

Between March and May 2015, 51 individuals participated in the study. Individual on-farm advisory sessions were seen to have a significant effect on the farmers awareness of the correct maximum treatment interval advised for lame cows. No significant difference was seen in the control or discussion

groups. The expert KT sessions were also felt to be significantly more enjoyable and useful than the control session. All respondents in this group gave similar feedback scores on the visual analogue scale, the narrow range suggesting this method of KT was accessible to a range of learners. A narrow range of responses was also seen for the discussion group. The control group gave a much wider range of responses suggesting this method of KT was more accessible to some individuals than others. From this study it can be seen that the traditional, on-farm veterinary advisory session is the most effective for communicating the message of prompt treatment of lame cows. While other KT methods may support dissemination of research findings the role of the veterinary advisor remains central to this process.

5.1 Introduction

The body of scientific evidence to support the importance of early detection and prompt, effective treatment of claw horn lesions in dairy has grown rapidly over recent years. In order to create a significant impact on lameness reduction at a farm level, dissemination of this existing knowledge about lameness to farmers and stockmen is needed (FAWC, 2009). It is clear that the responsibility for detection and treatment is heavily weighted towards the farmer and farm staff (Whay *et al*., 2012), however mechanisms to communicate the latest research findings to support best practice are less clear.

A variety of approaches are available to disseminate knowledge, each with strengths and weaknesses in regard to practicality, accessibility, impact and cost. Traditionally knowledge has been imparted by veterinary surgeons providing advice directly to the farmer. Studies have shown however that such approaches do not always result in the advice being followed (Bell *et al*., 2009; Barker *et al*. 2012). During a lameness research programme at the University of Bristol between 2006 and 2010, researchers conducted an intervention study designed to encourage farmer uptake of lameness related advice on 140 intervention and 87 control farms. Farms in the intervention group farms were provided with information about lameness prevalence and a summary of risk factors on their farm then attended an advisory meeting with a veterinary surgeon to formulate a lameness action plan. At subsequent annual visits, farmers were given support in further developing and implementing these action plans. The control group were provided with lameness prevalence figures but no further advice or support. Several interesting outcomes resulted from this study. In this project annual visits to the intervention group involved facilitated discussions, enabling farmers to engage further with the process. It was seen at these visits that farmers were generating substantial numbers of action points over and above those agreed with the veterinary surgeon (Whay *et al*., 2012). Almost half of the action points identified were implemented fully in the intervention group while changes were also made in the control group. Overall however, the intervention group made a greater proportion of changes likely to be of benefit and fewer likely to increase the risk of lameness than the control group. As expected, lameness prevalence fell during the course of the study in the intervention group. An unexpected

finding however was that lameness prevalence also decreased in the control group. A number of explanations for this were proposed including participants receiving lameness specific information outside of the project, an increased awareness of lameness in the herd due to the monitoring process and the discussion of ideas between intervention group and control group farmers (Main *et al*., 2012). It is clear therefore that while the facilitated intervention in this study was effective at encouraging uptake of advice and improving lameness measures, other routes may also offer opportunities to transfer knowledge in a less structured format.

In recent years, methods of knowledge transfer have evolved as greater understanding of motivators of behavioural change has developed. AHDB Dairy, the levy-funded organisation responsible for providing independent, evidence based information to dairy farmers have established a number of regional farmer discussion groups based on the model of Danish stable schools and farmer field schools developed in East Asia and Africa. These groups are formed by farmers in similar situations to develop common learning and development of farming systems suitable for their local conditions (Vaarst *et al*., 2007). Farmer field schools are widely used in developing countries to alleviate poverty and empower poor farmers through education and common learning. This concept was further developed by Vaarst *et al*., (2007) to create 'stable schools' in Denmark, so called as they contained a stable cohort of participants who could develop a relationship of trust and feel comfortable to talk about their farm practices. Farmers met once a month in groups of five or six and over the course of a year met twice on each group members farm with approximately six months between the two meetings. This allowed participants to observe farm practices at first hand and view the changes and improvements made by the host as a result of the previous visit. In the UK discussion groups (termed AHDB Dairy Business groups) are formed from members with a common link, for example they supply milk to the same processor or have common farming systems. Each group is facilitated by an AHDB extension officer with specialist training to help farmers get the most out of the meetings (AHDB Dairy., dairy.ahdb.org.uk). Farmers meet four to eight times a year to discuss a range of topics and compare best practice. Research into the effectiveness of these groups

with regard to control of specific cattle health and welfare issues however has not been undertaken in the UK.

The following study aimed to assess the impact of different methods of KT sessions on acquisition of knowledge and behavioural change in dairy farmers. The hypothesis was that the method of KT would influence the knowledge and skills gained by the farmer and their likelihood of making positive changes to reduce lameness on their farms. Two primary objectives were identified for this study; to identify current practices for prevention, detection and treatment of lameness in dairy herds and to evaluate the comparative efficacy of three currently used methods of knowledge transfer in disseminating key messages about lameness control and treatment on dairy farms.

5.2 Materials and Methods

5.2.1 Study design

A prospective, quantitative and qualitative study was designed to identify the most appropriate method of knowledge transfer (KT) to meet the specific needs of dairy farmers in relation to the early detection and treatment of lame cows.

Four study questions were identified for investigation.

1. What are the current practices for prevention and early detection of lameness used by dairy farmers in the UK?
2. Did the KT session affect the farmers' ability to recognise cows that require early treatment for lameness?
3. Did the farmer engage with the KT session and would they be likely to attend another of the same format?
4. Did the KT session encourage the farmer to adopt new practices on the farm?

Following consultation with industry professionals and representatives of the body funding the study, three methods of knowledge transfer were identified for investigation based on existing practices within the industry (see table 28).

Table 28. Description of the three methods of knowledge transfer investigated in a quantitative and qualitative study to assess their efficacy in relation to controlling lameness in dairy cattle

Group	**Knowledge transfer method**	**Description**
Group 1 – Control (GRP1– cont)	Resources only	Positive control group Participants provided with a range of AHDB Dairy resources relating to lameness detection and treatment
Group 2 – Discussion (GRP2- disc)	Facilitated discussion group + resources	Non-structured group discussion with no technical input from facilitator AHDB Dairy resources provided to each participant as per group 1
Group 3 – Expert (GRP3- exp)	Individual KT session with expert advisor + resources	Individual on-farm session to farmer/farm team provided by a veterinary surgeon. Farm specific with one-to-one discussion. AHDB Dairy resources provided to each participant as per group 1

Throughout the study KT facilitators and advisors were kept blind to the outcome data collection methods to avoid the session becoming structured around providing the 'right' answers.

5.2.2 Participant recruitment

Participants were recruited to the study with the assistance of AHDB Dairy regional extension officers. In order to replicate the current practice, recruitment was based around existing UK discussion groups consisting of around eight to ten farmers who meet regularly to discuss areas such as current challenges in dairy farming, on-farm practice, and business planning. These discussion groups could not be artificially created for the purposes of this study as they are dependent on the long term relationships between members. Meetings are facilitated by AHDB Dairy extension officers and designed to provide peer support in the farming community as well as provide a route for knowledge transfer. In general, the farmers in the discussion group decide on the subjects they wish to discuss and how often they want to meet.

Extension officers running existing discussion groups were identified and contacted to provide details of the study and request their participation. Four extension officers expressed an initial interest with three agreeing to participate once additional information had been provided. Recruitment of participants for

GRP1-cont and GRP3-exp was then targeted at other farmers in the same AHDB Dairy region. Leaflets were handed out and an article placed in AHDB Dairy and veterinary practice newsletters. Farmers recruited were allocated at random into GRP1-cont and GRP3-exp.

KT groups were blocked by region to minimise travelling time to meetings and minimise geographical differences in attitude amongst the farming community. Blocking followed the distribution of the existing discussion groups. The three regions used in the study were therefore 'Devon', 'Yorkshire and Lancashire' and 'Derbyshire and Staffordshire'. The AHDB Dairy extension officer who facilitated the discussion meetings also served as a point of contact for the farmers in the other two KT groups.

5.2.3 Resource development

To address the study questions, three methods of data collection were chosen for use.

A questionnaire was used to collect background data on the participants farms (see Appendix 2). Questionnaires were designed to investigate three themes, 1) current practices in lameness detection and treatment, 2) previous training received and preferred training methods and 3) changes already made to reduce lameness on farms. The questionnaire consisted largely of closed questions with specific responses to allow grouping and the option of 'other' where appropriate. Semi-structured interviews were held with three test farmers prior to construction of the questionnaire to help identify probable answers. Questions were developed around the three themes above and grouped accordingly to aid progression. The questionnaire was piloted with two further farmers prior to commencing the study to identify any areas of ambiguity.

To assess the second study question on whether KT method affected the farmers' ability to recognise cows that require early treatment for lameness, two video films were produced to be shown before and after the KT session. Forty video clips of lame and non-lame cows were recorded in three different locations with each cow walking a minimum of three strides in a straight line. Clips were numbered in order of filming then compiled into a short video in a sequence

determined using a random sequence generator (random.org). Each clip was repeated twice with a short break between each animal. The video was shown to nine specialist cattle veterinary clinicians with experience of mobility scoring, at the University of Nottingham School of Veterinary Medicine and Science who scored the degree of lameness in each cow on a four-point scale (AHDB Dairy Mobility Score, see section 1.1.1.2). From these results, sixteen of the forty clips were selected for use in the KT study film, four of which would be repeated within the sequence shown to the farmers to assess variability in response.

Two random number sequences were generated to determine the order of the 20 clips (16 clips plus 4 repeated clips) in the final films for use in the KT study. A different sequence generated for use before the KT session and after the KT session to prevent any bias as a result of 'learned responses' (a minimum of one hour elapsed between videos while the KT session took place). In the final film, each video clip was shown twice with a short break between animals.

Feedback forms were provided to each participant at the end of the KT session (see Appendix 3). The form comprised of four questions; 'How useful did you find this session?', 'How enjoyable did you find this session?', 'How likely are you to attend another session of this type?' and 'How likely are you to make changes on your farm as a result of this session?'. These measurements for efficacy of the KT session were chosen in consultation with the steering group to best meet the requirements of the funding body for planning future KT strategies. Participants were asked to mark their responses on a visual analogue scale of zero to ten along a 100mm line. Zero on the scale represented 'not at all' and ten represented 'very'. The response to each question was measured in millimetres to compare feedback between KT groups.

5.2.4 Pre-KT session protocol

Participants were met individually once by the author to complete the questionnaire prior to the KT session commencing. These meetings and subsequent KT sessions took place at the participants farm for GRP1-cont and GRP3-exp, and at a central meeting point for GRP2-disc (see section 5.2.5, 5.2.6 and 5.2.7 below).

Participants were then asked to watch the pre-KT session film (see section 5.2.3). For each video clip, participants were asked to select whether the cow required a) no treatment for lameness, b) treatment in the next 48 hours, c) treatment in the next week or d) treatment in the next two to three weeks. The film was shown on a laptop computer (GRP1-cont and GRP3-exp) or on a projector screen (GRP2-disc) and participants completed data collection forms provided. Video clips on the film were clearly numbered to ensure the response matched the clip number on the data collection form.. Participants could ask for the film to be paused or clips re-shown as required.

5.2.5 Control group (GRP1-cont) session protocol

Participants in GRP1-cont, were met individually by the author at the participants' home or place of work. Each was interviewed to complete the questionnaire, shown the pre-KT session film on a laptop computer and provided with a the currently available AHDB Dairy resources as shown in figure 22. These included an AHDB Dairy mobility scoring chart, mobility scoring record sheets and Hoof care guide along with general resources on other aspects of controlling lameness in cattle and links to online resources. The resources selected were freely available to all farmers through AHDB Dairy. The farmer was given a period of two to three weeks to read through the resource pack before a follow up visit was made. This group acted as a positive control group against which the other two groups could be compared.

Figure 22. AHDB Dairy resources provided to participants in a study evaluating three methods of knowledge transfer

5.2.6 Discussion group (GRP2-disc) session protocol

Participants in GRP2-disc were met at a central venue in their AHDB region by the author 30 minutes prior to the discussion session starting. They were provided with refreshments and an AHDB Dairy resource pack (see section 5.2.5) to read through while the author conducted short individual interviews with each participant to complete the questionnaire. The pre-KT session video was shown to the group on a projector screen however participants were asked not to discuss their answers prior to completing the data collection form.

Discussion sessions took place over a period of one to two hours facilitated by an AHDB Dairy regional extension officer. Facilitators were asked to focus the discussion around prevention and treatment of lameness however no other input was made by the author. Facilitators were blind to the data collection methods asked to leave the room during the pre-KT session video so content could not bias the session.

5.2.7 Expert group (GRP3-exp) session protocol

Participants in GRP3-exp were met individually on their farms by the author and a veterinary surgeon specialising in cattle lameness (the 'expert'). The expert was blind to the data collection methods and remained outside the room while the author conducted the questionnaire interview, the pre-KT session video and provided an AHDB Dairy resource pack. KT sessions took place over a period of one to one and a half hours whilst walking around the farm. The expert and participant discussed issues relating to lameness on the premises. No input was made to the KT session by the author.

5.2.8 Post-KT session protocol

Immediately following the KT session, (or at the follow-up visit for participants in GRP1-cont), participants were shown the post-KT session video and completed a data collection form as per the pre-session film along with a feedback form.

5.2.9 Outcomes

Three outcomes were identified for investigation in the study.

Outcome (i) Knowledge and skill acquisition. This outcome investigated the effect of different KT methods on farmers understanding of when to treat lame cows. Data collected from the pre and post KT study videos were used to analyse this affect.

Outcome (ii) Engagement. Data collected from feedback forms was used to analyse the engagement of participants with the different KT methods.

Outcome (iii) Likelihood of behavioural change. Data from the pre-KT session questionnaire and post KT session feedback form were used to assess current practices and whether KT session encouraged the participant to adopt new practices with regard to lameness on their farms.

5.2.10 Data management and analysis

Data was recorded on data collection forms and transcribed and stored in a relational database (Access 2007, Microsoft Corporation). Data capture forms were retained and the database was checked for errors against written records prior to analysis. Data analysis was conducted in Minitab 17.2.1 (Minitab Inc.).

Differences between KT groups at time of recruitment were assessed using the Kruskal-Wallis test (number of adult cows and 305 day milk yield) and $\chi 2$ test (perceived prevalence)

Comparison of video assessment results for outcome (i) was completed using a $\chi 2$ test with significance set at $P \leq 0.05$ and agreement between observers using Kappa. Feedback data for outcomes (ii) and (iii) were tested using the Anderson-Darling test of normality and found to deviate from normal distribution. Analysis was therefore completed using a Kruskal Wallis test with a significance set at $P \leq 0.05$.

5.3. Results

5.3.1 Participation

Between 16th March 2015 and 18th May 2015, fifty-one individuals participated in the KT study. The locations and farm roles of participants in each study group are shown in tables 29 and 30. All participants completed the pre-session exercises (questionnaire and video). Post-session results (video and feedback form) were collected for all participants in GRP2-disc and GRP3-exp. Nine participants in GRP1-cont were re-visited to complete the post-session exercises. A suitable time for a re-visit was not able to be arranged with the remaining six participants in this group. A DVD and YouTube link to the post-session video along with post-session data collection forms were sent by post to these six participants with a stamped, addressed envelope for return, however these responses were not received.

Table 29. Participant numbers in a study looking at the effectiveness of three methods of knowledge transfer (KT) to dairy farmers

KT group	Location of participants			Total number of participants
	Derbyshire	Devon	Yorkshire	
Group 1 - Control	6	5	4	15
Group 2 - Discussion	3	8	8	19
Group 3 - Expert	5	4	8	17

Table 30. Farm roles of participants in a study looking at the effectiveness of three methods of knowledge transfer (KT) to dairy farmers

Knowledge transfer group	Role of participant							Total
	Director	Owner	Partner	Farmer / farmers son	Tenant	Herdsman	No role given	
Group 1-Control	-	5	-	6	1	3		15
Group 2 Discussion	3	6	6	1	1	1	1	19
Group 3 Expert	-	3	-	7	1	1	5	17

The farms recruited to the study had herd sizes ranging from 45 to 900 cows with average 305 day milk yields from 4000L to 12000L. The number of adult cows in the farms recruited to GRP1-cont ranged from 70 to 600 (median 235) with 305 day milk yields from 5720L to 1200L (median 7800L). The number of adult

cows in the farms recruited to GRP2-disc ranged from 80 to 900 (median 230) with 305 day milk yields from 4000L to 10600L (median 7800L). The number of adult cows in the farms recruited to GRP3-exp ranged from 43 to 413 (median 137) with 305 day milk yields from 6200L to 10500L (median 8900L). The farmers perception of lameness prevalence for each of the KT groups is shown in table 31. The majority of participants considered lameness to be a mild or moderate problem on their farms across the three KT groups.

Table 31. Perceived lameness levels on 51 farms at the time of recruitment to a study investigating the efficacy of three methods of knowledge transfer.

	Not a problem	Mild	Moderate	Severe	Total
Group 1 - control	2	6	7	-	15
Group 2 - discussion	1	12	4	2	19
Group 3 – expert	-	5	10	2	17
Total	3	23	21	4	51

The main types of lesion causing lameness on each of the recruited farms is shown in table 32. The predominant cause(s) of lameness varied both within and between groups.

Table 32. Main types of lesion leading to lameness on 51 farms at the time of recruitment to a study investigating the efficacy of three methods of knowledge transfer.

	Digital dermatitis (DD)	Sole ulceration (SU)	White line disease (WLD)	More than one of DD, SU or WLD	Other	Total
Group 1 - control	2	4	2	7	-	15
Group 2 - discussion	4	1	4	8	2	19
Group 3 – expert	6	6	1	4	-	17
Total	12	11	7	19	2	51

Holstein cattle were the main breed on 22 farms (GRP1-cont n=9, GRP2-disc n=4 and GRP3=exp n=9). Holstein-Friesian cattle were the main breed on 16 farms (GRP1-cont n=4, GRP2-disc n=7 and GRP3-exp n=5). Friesian cattle were the main breed three of the GRP2-disc farms. The remaining farms had a mixture of other breeds (GRP1-cont n=2, GRP2-disc n=5 and GRP3-exp n=3) including Ayrshire, Jersey and cross breed cattle. Six farms housed cattle for zero to four months of the year (GRP1-cont n=0, GRP2-disc n=3 and GRP3-exp

n=3). Twenty-seven farms housed cows for greater than four months to eight months of the year (GRP1-cont n=10, GRP2-disc n=9 and GRP3-exp n=8). Seventeen farms housed cows for greater than eight months of the year (GRP1-cont n=5, GRP2-disc n=6 and GRP3-exp n=6). Housing length was not recorded for one farm in GRP2-disc.

There was no significant difference in the number of adult cows on farms, average 305 day milk yield or perceived lameness prevalence between the three KT groups.

5.3.2 Pre-KT session questionnaire results

5.3.2.1 Lameness detection and treatment

Fifty-one participants completed a questionnaire prior to their allocated KT session. Methods and frequency of lameness detection for each of the study groups are shown in table 33. Twenty-seven participants did not state a lameness detection frequency however these all stated they detected lameness through general observation at milking or in housing.

Twenty-five participants carried out routine foot trimming on their farms (GRP1-cont n= 12, GRP2-disc n=6, GRP3-exp n=7) while twenty-six did not (GRP1-cont n=3, GRP2-disc n=13, GRP3-exp n=10). Three of these participants (GRP2-disc n=1 and GRP3-exp n=2) stated while they did not carry out routine trimming, they trimmed cows as needed. Further information on trimming routines is shown in table 34.

The person reported as responsible for treating lame cows on farms is shown in table 35. Three participants did not give an answer to this question.

Table 33. Practices reported for the detetction of lameness in dairy cattle in a survey of farmers in the UK taking part in a knowledge transfer study

Knowledge transfer method	Lameness detection method – number of participants							Lameness detection frequency – number of participants							
	Mobility scoring (MS)	MS + observation at milking	Observation at milking	Observation at milking and in housing	Observation in housing	MS + observation in housing	Other	Daily	Fortnightly	Monthly	6 weekly	2 monthly	3 monthly	6 monthly	Annual
Group 1-Control	4	1	6	3	1	-	-	-	2	3	-	-	-	-	-
Group 2 -Discussion	1	3	9	-	2	1	3	6	-	1	2	1	-	2	-
Group 3 -Expert	1	1	15	-	-	-	-	-	-	1	1	-	1	-	4
Total	6	5	30	3	3	1	3	6	2	5	3	1	1	2	4

Table 34. Trimming routines for dairy cattle reported in a survey of farmers in the UK taking part in a knowledge transfer study

Knowledge transfer group	Protocol for routine foot trimming – number of participants												
	8 weeks before calving	1 month before drying off	At drying off	60 days lactation	1 month before drying off and 60 days lactation	Drying off and 60 days lactation	Drying off and 90 days lactation	Drying off and 100 days lactation	80 days before and 80 days after calving	1-2 times per year	2 times per year	Annual whole herd	No routine trimming
Group 1 – Control	-	1	8	-	-	2	-	1	-	-	-	-	3
Group 2 -Discussion	2	-	-	-	1	-	-	-	1	1	1	-	13
Group 3 – Expert	-	-	3	1	-	-	1	-	-	-	-	1	10
Total	2	1	11	1	1	2	1	1	1	1	1	1	26

Table 35. Persons responsible for treatment of lame cows reported in a survey of farmers in the UK taking part in a knowledge transfer study

Knowledge transfer group	Person responsible for treatment of lame cows					
	Farmer	Farmer and foot trimmer	Farmer and vet	Farmer, foot trimmer and vet	Foot trimmer	Trained staff
Group 1 - Control	8	4	1	1	1	-
Group 2 - Discussion	8	6	1	-	-	1
Group 3 - Expert	7	7	-	2	1	-
Total	23	17	2	3	2	1

5.3.2.2 Training in lameness detection and treatment

Forty-two participants had completed previous training sessions on detection and treatment of lameness (GRP1-cont n= 15, GRP2-disc n= 15, GRP3-exp n=12). Nine participants had had no previous training (GRP1-cont n= 0, GRP2-disc n= 4, GRP3-exp n= 5). Further information on training experience is given in table 36. All participants in the GRP1-cont found the training useful. Thirteen participants in the GRP2-disc and 12 participants in GRP3-exp found the training useful. The remaining participants (GRP2-disc n=6, GRP3-exp n=5) did not provide an answer to this question.

Table 36. Previous training in detection and treatment of lame cows reported in a survey of farmers in the UK taking part in a knowledge transfer study

Knowledge transfer group	Time since previous training session				Training session type			
	3 months	6 months	1 year	> 1 year	Discussion group	Talk by vet / other expert	On-farm with own vet	Other
Group 1 – Control	0	1	0	14	0	4	2	9
Group 2 - Discussion	2	1	1	7	2	4	2	5
Group 3 - Expert	0	1	1	10	1	4	0	7
Total	2	3	2	31	3	12	4	21

Seven participants in GRP2-disc and five participants in group three, GRP3-exp didn't state the time since they last received training. One participant in GRP2-disc stated their training was 'ongoing'. Six of the seven participants in GRP2-disc and all five participants in GRP3-exp who didn't state the time since their last training also didn't state the type of their last training session.

Table 37 shows the types of training participants would prefer to attend at future sessions. The preferred types of training varied both within and between groups.

Table 37. Types of training participants would prefer to attend in relation to detection and treatment of lameness in dairy cows

KT group participant	Discussion group	Talk by vet / other expert	On-farm with own vet	More than one of previous	Other	None
Group 1 - Control	4	0	5	6	0	0
Group 2 - Discussion	3	2	2	7	3	1
Group 3 - Expert	1	3	6	6	0	1
Total	8	5	13	19	3	2

5.3.2.3. Previous changes to reduce lameness

Thirty-nine participants had made changes on their farms in the past two years to reduce lameness levels (GRP1-cont n= 14, GRP2-disc n= 13, GRP3-exp n= 12). Twelve participants had made no changes (GRP1=cont n= 1, GRP2-disc n= 6, GRP3-exp n= 5). Changes made are shown in table 38.

Table 38. Recent changes made on the farms of 51 participants in a KT study to improve lameness levels on farms

KT group participant	Trimming	Foot-bathing	Housing	Parlour	Tracks	Record keeping
Group 1 - Control	2	6	1	2	2	0
Group 2 - Discussion	1	3	5	1	2	1
Group 3 - Expert	0	2	6	4	0	0
Total	3	11	12	7	4	1

Nineteen participants reported the changes they had made on their farms were as a result of training (GRP1-cont n= 6, GRP2-disc n= 5, GRP3-exp n= 8). Thirteen participants had made changes for other reasons (GRP1-cont n= 5, GRP2-disc n= 6, GRP3-exp n= 2). Nineteen participants did not answer this question (GRP1-cont n= 4, GRP2-disc n= 8, GRP3-exp n= 7). All of the participants who answered in the GRP1-cont and GRP2-disc felt that the changes made had improved lameness levels on the farm. Two participants in GRP3-exp felt changes had not made a difference, the remaining ten participants in this group

that answered the question felt changes made had improved their lameness levels.

5.3.3 Pre- and Post-KT session video results

5.3.3.1 Video clip selection by expert group

Of the 40 video clips shown to the nine specialist veterinary clinicians to select clips for use in the study, eight were felt to be 'clear' by all clinicians in the quality of video and level of lameness shown. Seven clips were felt to be 'unclear' by more than 50% of the respondents and were excluded from selection.

Variation in scores allocated to the cows in the video clips were seen amongst clinicians. Agreement across the nine clinicians was tested for 35 of the 40 clips (four clips contained missing data and were excluded from analysis). Agreement for score 0 and score 1 was poor (K=0.11, (95% CI: 0.05-0.17) and K=0.19, (95% CI: 0.13-0.25) respectively). Agreement for score 2 was fair (K=0.22, (95% CI: 0.16-0.28)) and for score 3 was substantial (K=0.73, (95% CI: 0.67-0.79)). Overall agreement in mobility score between observers for the 35 video clips was fair (K=0.32, (95% CI: 0.28 -0.36)).

Five video clips were given the same mobility score by all clinicians, (4x mobility score 3, severely mobility impaired and 1x mobility score 2, mobility impaired). A further four clips were given a 'lame score' (score 2 or 3) by all respondents. These nine clips were selected to represent 'lame' cows in the assessment video for the KT study. There was no unanimous agreement for score 0 or score 1 cows. In one clip all clinicians however agreed the cow was 'non-lame' (score 0 or 1), in three clips, eight out of nine clinicians gave the cow a non-lame score and in 3 further clips seven out of nine clinicians gave the cow a non-lame score. These seven video clips were selected to best represent 'non-lame' cows in the assessment video for the KT study. A full breakdown of scores allocated to the 16 video clips selected for the assessment are shown in table 39.

Table 39. Mobility scores given by nine veterinary clinicians to cows in 16 video clips selected for use in a study on different methods of knowledge transfer relating to lameness in dairy cows

	Video number	Number of clinicians allocating score			
		Score 0	Score 1	Score 2	Score 3
Selected as 'lame'	12				9
	20			9	
	28				9
	31				9
	33				9
	4			2	7
	21			5	4
	25			1	8
	35			7	2
Selected as 'non-lame'	30	4	5		
	19	3	5	1	
	40	1	7	1	
	3	1	7	1	
	1	5	2	2	
	10	1	6	2	
	14		7	2	

Four clips were selected for repetition within the final sequence, based on score agreement and clarity, to assess intra-observer variability. The clips represented 'score 0', 'score 1', 'score 2' and 'score 3' cows.

5.3.3.2 Pre- and post-KT session video results

Forty-five of the 51 participants in the study completed both the pre-KT session post-KT session video assessment. Six participants in GRP1-cont did not complete the post-KT session video assessment and so their pre-KT session data was excluded from this analysis. The number of participants in GRP1-cont, GRP2-disc and GRP3-exp providing each of the four responses to the pre- and post-KT session videos are shown in table 40. Where a video clip was repeated only the response to the first time the clip was shown is given.

Table 40. Frequency of responses to an assessment before and after a KT session questionning the time participants would leave until treatment for lameness of cows in 20 video clips.

Video clip number	AHDB Dairy Mobility score	Frequency of 'Time to treatment' responses																					
		Pre-KT session												**Post-KT session**									
		No treatment			**48 hours**			**1 week**			**2-3 weeks**			**No treatment**			**48hours**			**1 week**			**2-3 weeks**		
		GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp	GRP1-cont	GRP2-disc	GRP3-exp
12	**3**	0	3	0	8	11	6	1	2	11	0	3	0	1	1	1	6	14	11	2	4	5	0	0	0
28	**3**	2	8	4	3	5	2	3	5	8	1	1	3	3	5	2	3	4	9	2	7	3	1	3	3
31*	**3**	4	5	1	1	2	4	0	5	6	3	7	6	1	2	1	5	6	7	2	5	6	1	6	3
33*	**3**	1	7	3	4	3	2	1	5	4	3	4	8	1	5	2	5	2	1	1	5	7	2	7	6
4	**3**	0	1	0	6	13	17	3	4	0	0	1	0	1	0	0	6	15	16	1	4	1	1	0	0
25	**3**	1	1	0	3	12	15	2	6	2	2	0	0	2	0	0	5	15	17	2	2	1	0	0	1
21*	**2**	6	12	10	0	2	0	0	3	2	3	2	5	6	15	12	1	0	1	0	1	3	2	2	1
20	**2**	5	10	7	2	4	4	0	3	4	2	2	2	6	10	5	1	2	5	2	3	4	0	4	3
35	**2**	8	12	11	1	1	1	0	3	4	0	3	1	4	10	3	1	4	2	1	3	6	3	2	6
30	**1**	0	1	0	7	7	7	1	9	8	1	2	2	1	2	0	5	8	9	1	9	6	2	0	2
19	**1**	6	13	3	1	3	4	0	2	5	2	1	5	4	12	6	2	2	3	0	1	3	3	4	5
40	**1**	0	1	2	5	6	4	4	8	7	0	4	4	2	6	2	3	4	9	3	4	4	1	5	2
3	**1**	9	14	15	0	1	0	0	3	0	0	1	2	9	16	12	0	0	1	0	2	3	0	1	1
10	**1**	1	0	0	8	17	16	0	2	1	0	0	0	1	0	0	7	12	16	1	6	1	0	0	0
14	**1**	4	7	6	2	2	1	0	5	3	3	4	7	3	13	5	2	0	3	0	4	5	4	2	4
1	**0**	7	12	11	0	1	1	1	3	0	1	2	4	6	16	9	3	0	0	0	1	6	0	2	2

*1 missing result for clip31, GRP1-cont in pre-KT session assessment, 1 missing result for clip 21, GRP2-disc and clip 33, GRP3-exp in post-KT session assessment

Analysis of the responses pre- and post-KT session was made against the AHDB Dairy mobility score descriptors (see section 1.1.1.2) for the score allocated to each video by the specialist veterinary clinicians. The proportion of respondents considered to give the 'correct' answer for each mobility score is shown in tables 41 to 43 for each mobility score.

For mobility score three cows, the AHDB Dairy mobility score recommends, 'This cow is very lame and requires urgent attention, nursing and further professional advice. Examine as soon as possible. Cow will benefit from treatment'. The 'correct' answer for time to treatment for these cows was therefore considered '48 hours'.

Table 41. Frequency (and proportion) of participants in a video assessment recognising AHDB Dairy mobility score 3 cows required treatment in the following 48hours

Video clip number	AHDB Dairy Mobility score	GRP1-cont			GRP2-disc			GRP3-exp		
		Pre-KT session	**Post-KT session**	**Significance**	**Pre-KT session**	**Post-KT session**	**Significance**	**Pre-KT session**	**Post-KT session**	**Significance**
12	**3**	**88.8%** (8 of 9)	**66.7%** (6 of 9)	NS*	**57.9%** (11 of 19)	**73.7%** (14 of 19)	NS	**35.3%** (6 of 17)	**64.7%** (11 of 17)	NS
28	**3**	**33.3%** (3 of 9)	**33.3%** (3 of 9)	NS	**26.3%** (5 of 19)	**21.1%** (4 of 19)	NS	**11.8%** (2 of 17)	**52.9%** (9 of 17)	0.01
31 *	**3**	**12.5%** (1 of 8)	**55.6%** (5 of 9)	NS	**10.5%** (2 of 19)	**31.6%** (6 of 19)	NS	**23.5%** (4 of 17)	**41.2%** (7 of 17)	NS
33 *	**3**	**44.4%** (4 of 9)	**55.6%** (5 of 9)	NS	**15.8%** (3 of 19)	**10.5%** (2 of 19)	NS	**11.8%** (2 of 17)	**6.3%** (1 of 16)	NS
4	**3**	**66.7%** (6 of 9)	**66.7%** (6 of 9)	NS	**68.4%** (13 of 19)	**78.9%** (15 of 19)	NS	**100%** (17 of 17)	**94.1%** (16 of 17)	NS
25	**3**	**33.3%** (3 of 9)	**55.6%** (5 of 9)	NS	**63.2%** (12 of 19)	**78.9%** (15 of 19)	NS	**88.2%** (15 of 17)	**100%** (17 of 17)	NS

NS - No significant difference
GRP1-cont n=9, GRP2-disc n=19 GRP3-exp n=17
*1 missing result for clip31, GRP1-cont in pre-KT session therefore proportion of n=14
1 missing result for clip 33, GRP3-exp in post-KT session therefore proportion of n=16

A significant difference in the frequency of 'correct' answers given by the participants for all 'severely mobility impaired' (score 3) cows before and after

the KT session was seen for GRP3-exp (pre 46 of 102, post 61 of 101, P<0.01). There was no significant difference for GRP1-cont (pre 25of 54, post 30 of 54) or GRP2-disc (pre 46 of 114, post 56 of 114).

For mobility score two cows, the AHDB Dairy mobility score recommends, 'Lame and likely to benefit from treatment. Foot should be lifted to establish the cause of lameness before treatment. Should be attended to as soon as practically possible. The 'correct' answer for time to treatment for these cows was therefore considered '48 hours' or '1 week'. (N.B. current research recommendations are that all animals identified as lame should be treated in 48 hours however due to the difference in wording for treatment of score 2 and 3 cows on the AHDB Dairy mobility scoring system, responses of '48 hours' or '1 week' were considered acceptable in this study).

Table 42. Frequency (and proportion) of participants in a video assessment recognising AHDB Dairy mobility score 2 cows required treatment in the following 48hours to 1 week

Video clip number	AHDB Dairy Mobility score	GRP1-cont			GRP2-disc			GRP3-exp		
		Pre-KT session	**Post-KT session**	**Significance**	**Pre-KT session**	**Post-KT session**	**Significance**	**Pre-KT session**	**Post-KT session**	**Significance**
21 *	**2**	**0%** (0 of 9)	**11.1%** (1 of 9)	NS	**26.3%** (5 of 19)	**5.6%** (1 of 18)	NS	**11.8%** (2 of 17)	**23.5%** (4 of 17)	NS
20	**2**	**22.2%** (2 of 9)	**33.3%** (3 of 9)	NS	**36.8%** (7 of 19)	**26.3%** (5 of 19)	NS	**47.1%** (8 of 17)	**52.9%** (9 of 17)	NS
35	**2**	**11.1%** (1 of 9)	**22.2%** (2 of 9)	NS	**21.1%** (4 of 19)	**36.8%** (7 of 19)	NS	**29.4%** (5 of 17)	**47.1%** (8 of 17)	NS

NS – No significant difference
GRP1-cont n=9, GRP2-disc n=19 GRP3-exp n=17
*1 missing result for clip 21, GRP2-DISC in post-KT session therefore proportion of n=18

A significant difference in the frequency of 'correct' answers given by the participants for all 'mobility impaired' (score 2) cows before and after the KT session was seen for GRP3-exp (pre 15 of 51, post 26 of 51, P=0.03). There was no significant difference for GRP1-cont (pre 3 of 27, post 6 of 27) or GRP2-disc (pre 16 of 57, post 13 of 56).

For mobility score one cows, the AHDB Dairy mobility score recommends, 'could benefit from routine (preventative) foot trimming when/if required. Further observation recommended'. For mobility score zero cows, the AHDB Dairy mobility score recommends, 'No action needed. Routine (preventative) foot trimming when/if required'. No treatment is specifically recommended for these cows therefore the 'correct' answer for time to treatment for both scores was considered 'no treatment'

Table 43. Frequency (and proportion) of participants in a video assessment recognising AHDB Dairy mobility score 1 and 0 cows required no treatment

Video clip number	AHDB Dairy Mobility score	GRP1-cont			GRP2-disc			GRP3-exp		
		Pre-KT session	**Post-KT session**	**Significance**	**Pre-KT session**	**Post-KT session**	**Significance**	**Pre-KT session**	**Post-KT session**	**Significance**
30	**1**	**0%** (0 of 9)	**11.1%** (1 of 9)	NS	**5.3%** (1 of 19)	**10.5%** (2 of 19)	NS	**0%** (0 of 17)	**0%** (0 of 17)	NS
19	**1**	**66.7%** (6 of 9)	**44.4%** (4 of 9)	NS	**68.4%** (13 of 19)	**63.2%** (12 of 19)	NS	**17.6%** (3 of 17)	**35.3%** (6 of 17)	NS
40	**1**	**0%** (0 of 9)	**22.2%** (2 of 9)	NS	**5.3%** (1 of 19)	**31.6%** (6 of 19)	0.04	**11.8%** (2 of 17)	**11.8%** (2 of 17)	NS
3	**1**	**100%** (9 of 9)	**100%** (9 of 9)	NS	**73.7%** (14 of 19)	**84.2%** (16 of 19)	NS	**88.2%** (15 of 17)	**70.6%** (12 of 17)	NS
10	**1**	**11.1%** (1 of 9)	**11.1%** (1 of 9)	NS	**0%** (0 of 19)	**0%** (0 of 19)	NS	**0%** (0 of 17)	**0%** (0 of 17)	NS
14	**1**	**44.4%** (4 of 9)	**33.3%** (3 of 9)	NS	**36.8%** (7 of 19)	**68.4%** (13 of 19)	0.04	**35.3%** (6 of 17)	**29.4%** (5 of 17)	NS
1	**0**	**77.8%** (7 of 9)	**66.7%** (6 of 9)	NS	**63.2%** (12 of 19)	**84.2%** (16 of 19)	NS	**64.7%** (11 of 17)	**52.9%** (9 of 17)	NS

NS - No significant difference

There was no significant difference in the frequency of 'correct' answers given by the participants for all 'non lame' (score 1 + score 0) cows before and after the KT session for GRP1-cont (pre- 27 of 63, post 26 of 63) and GRP3-exp (pre 37 of 119, post 34 of 119). A significant difference was seen in GRP2-disc (pre 48 of 133, post 65 of 133, P=0.04).

5.3.3.3. Observer variability within pre and post sessions

Four video clips were repeated twice in the randomised 20 video clip sequence in the pre- and post-KT session videos. Fifty participants were included in the pre-KT session video analysis. Intra-observer agreement was fair (median K= 0.33 (95% CI: 0-0.72). One participant (2%) failed to give the same response twice for any of the four repeated clips, nine participants (18%) gave the same response for both viewings of one video clip, 16 (32%) for two video clips, 19 (38%) for three video clips and five (10%) for all four clips. Inter-observer agreement was poor (K= 0.19 (95% CI: 0.18-0.19). A response was not given for the second appearance of clip 35 in by one participant and so was excluded from the analysis.

Forty-four participants were included in the post-KT session video analysis. Intra-observer agreement was moderate (median K= 0.5 (95% CI: 0-1). Two participants (4.5%) failed to give the same response twice for any of the four repeated clips, two participants (4.5%) gave the same response for both viewings of one video clip, 12 (27.3%) for two video clips, 23 (52.3%) for three video clips and five (11.4%) for all four clips. Inter-observer agreement was poor (K= 0.16, (95% CI: 0.15-0.17)). A response was not given for the first appearance of clip 3 in by one participant and so was excluded from the analysis.

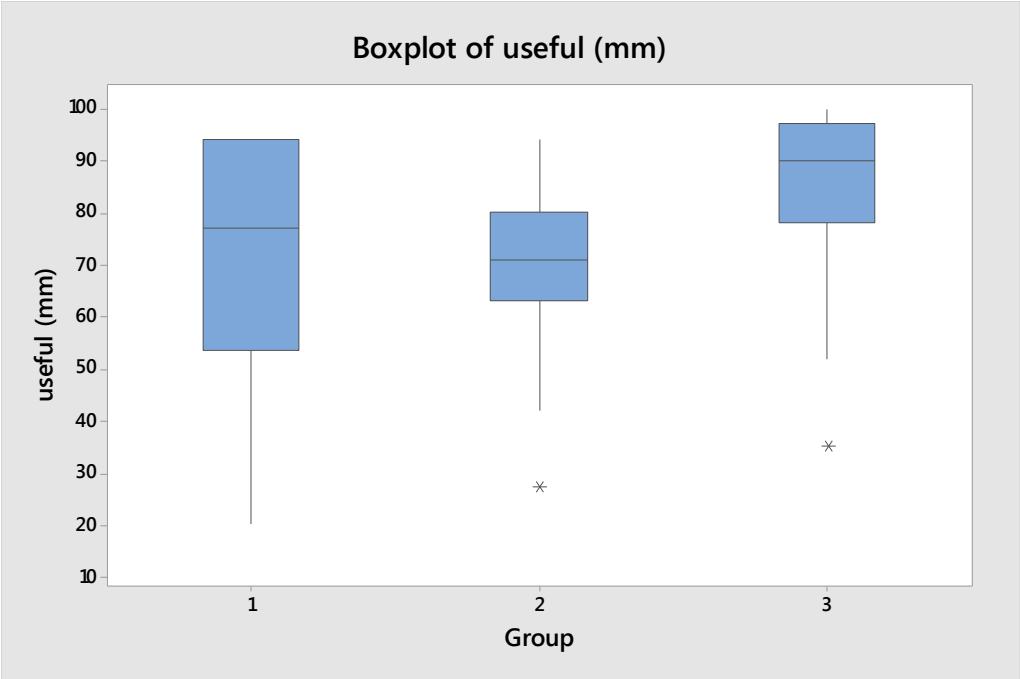
5.3.4 Post KT-session feedback form results

Of the fifty-one individuals who participated in the KT study, 45 completed a post session feedback form (see section 5.2.3). Six participants from GRP1-cont, did not complete forms. Responses were recorded in millimetres on a visual analogue scale with a line length of 100mm. Results are therefore given as a figure out of 100.

5.3.4.1 Feedback - How useful did you find this session?

The median value given to ‘useful’ in GRP1-cont (n=9) was 77mm (range 20-94mm). The median value in GRP2-disc (n=19) was 71mm (range 27-94mm). The median value in GRP3-exp (n=17) was 90mm (range 35-100mm). A significant difference was seen across the three groups (P=0.02). A notable difference was the range of responses seen in GRP1-cont (interquartile range

53.5-94) compared to GRP2-disc and GRP3-exp (interquartile range 63-80 and 78-97 respectively) (see figure 23).



Group 1- control group, Group 2 – discussion group, Group 3 – expert group

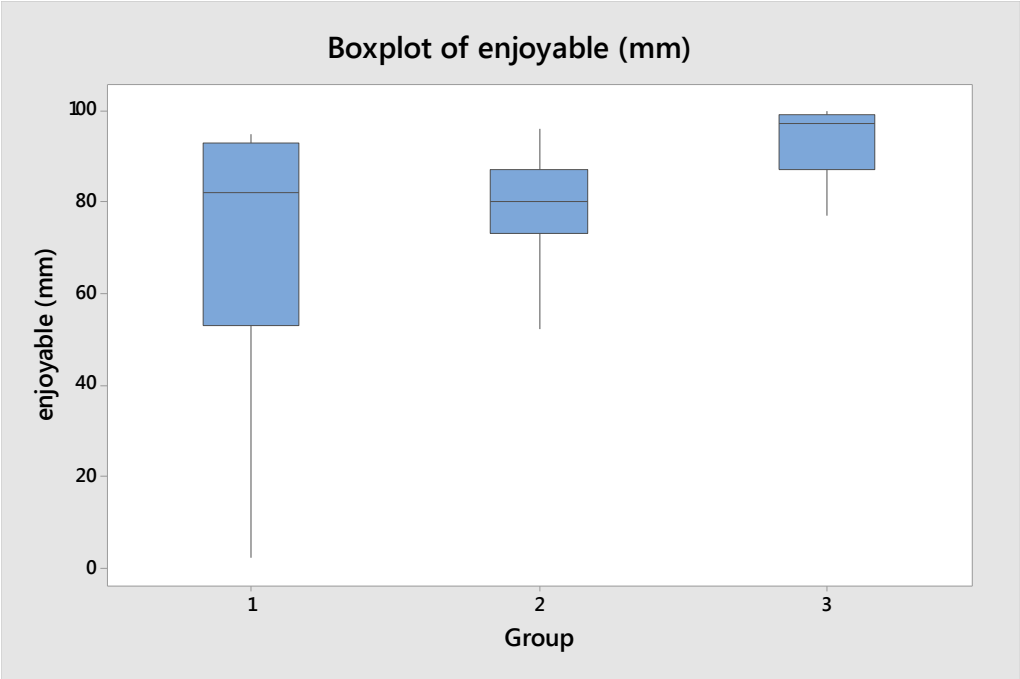
Figure 23. Boxplot showing feedback given on the usefulness of three methods of knowledge transfer sessions in relation to lameness in dairy cattle. Participants were asked to rate how useful they found the session on a visual analogue scale of zero to ten along a 100mm line. Zero on the scale represented 'not at all' and ten represented 'very'.

Feedback comments from GRP1-cont were; 'watched same clips five years ago' and 'always good to refresh your memory'. Feedback comments from GRP2-disc were; 'good', 'already have foot care programme' and 'not anything new for me personally this time'. No feedback comments were received from GRP3-exp in response to this question.

5.3.4.2 Feedback - How enjoyable did you find this session?

The median value given to 'enjoyable' in GRP1-cont (n=9) was 82mm (range 2-95mm). The median value in GRP2-disc (n=19) was 80mm (range 52-96mm). The median value in GRP3-exp (n=17) was 97mm (range 77-100mm). A significant difference was seen across the three groups ($P<0.01$). Notably, responses were much less varied in GRP3-exp and GRP2-disc (interquartile

range 87-99 and 73-87 respectively) than those seen in GRP1-cont (interquartile range 53-93) (see figure 24).



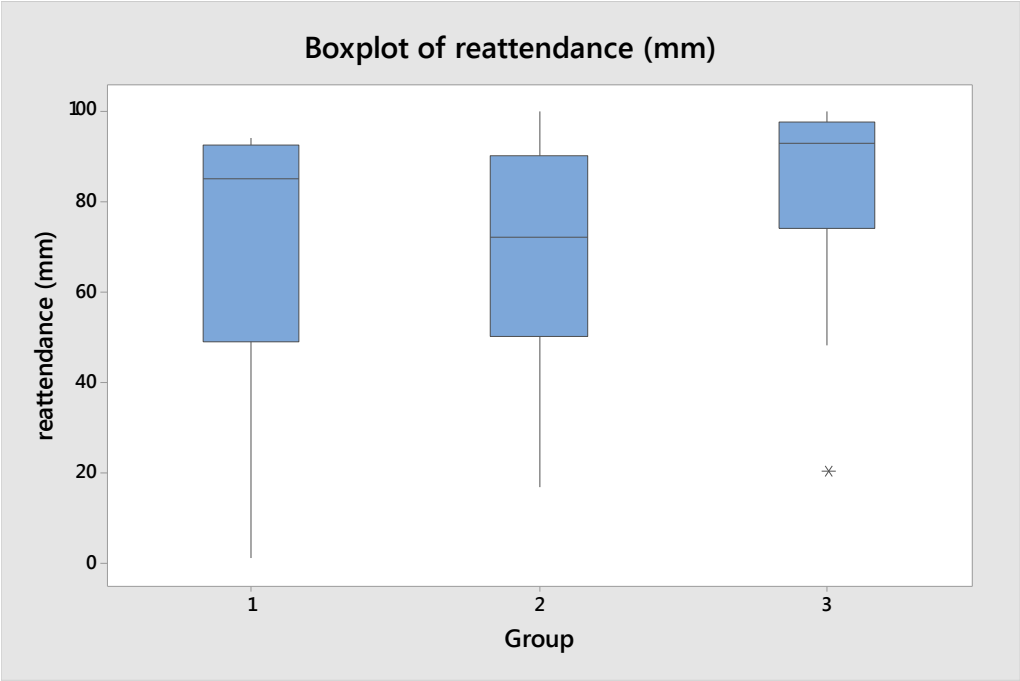
Group 1- control group, Group 2 – discussion group, Group 3 – expert group

Figure 24. Boxplot showing feedback given on the enjoyability of three methods of knowledge transfer session in relation to lameness in dairy cattle. Participants were asked to rate how enjoyable they found the session on a visual analogue scale of zero to ten along a 100mm line. Zero on the scale represented 'not at all' and ten represented 'very'.

No feedback comments were received to this question from participants in GRP1-cont or GRP3-exp. One participant in GRP2-disc responded; 'always good to talk to other farmers about what they do'.

5.3.4.3 Feedback - How likely are you to attend another session of this type?

The median value given to 're-attendance' in GRP1-cont (n=9) was 85mm (range 1-94mm). The median value in GRP2-disc (n=19) was 72mm (range 17-100mm). The median value in GRP3-exp (n=17) was 93mm (range 20-100mm). No significant difference was seen across the three groups (P=0.055). Interquartile ranges in GRP1-cont (49-92.5) and GRP2-disc (50-90) were notably wider than GRP3-exp (74-97.5) (see figure 25).



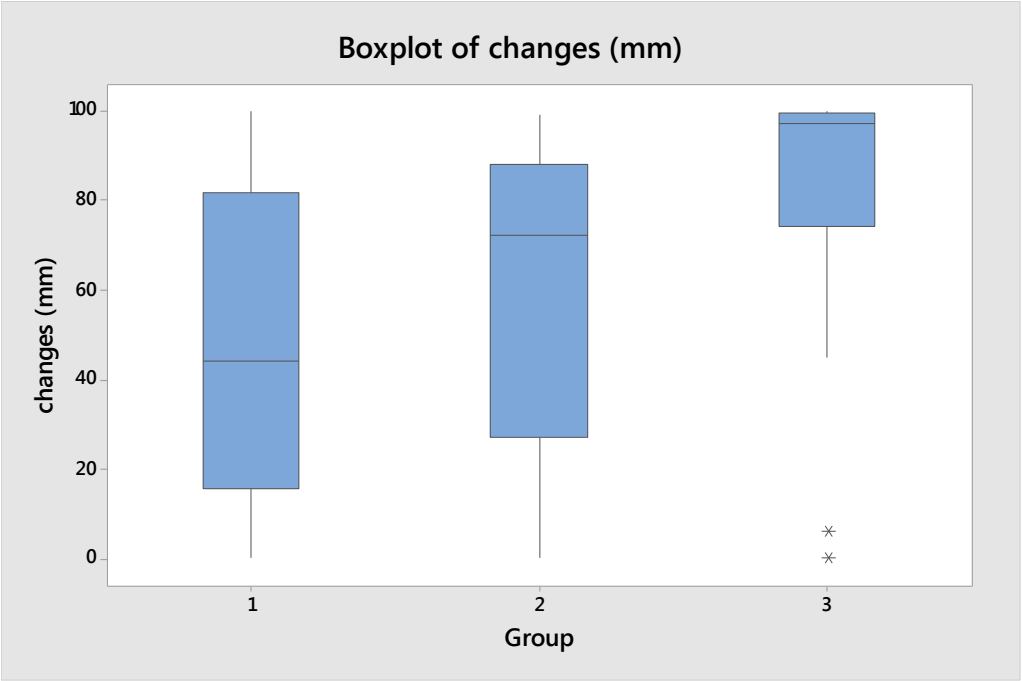
Group 1- control group, Group 2 – discussion group, Group 3 – expert group

Figure 25. Boxplot showing feedback given on the likelyhood of reattending one of three methods of knowledge transfer session in relation to lameness in dairy cattle. Participants were asked to rate how likely they were to attend another session of this type on a visual analogue scale of zero to ten along a 100mm line. Zero on the scale represented 'not at all' and ten represented 'very'.

Feedback comments to this question from GRP1-cont were; 'if you stop attending learning sessions you go backwards' and 'continuing need to train staff'. No feedback comments were received from participants in the other two groups.

5.3.4.4 Feedback - How likely are you to make changes on your farm as a result of this session?

The median value given to 'changes' in GRP1-cont (n=9) was 44mm (range 0-100mm). The median value in GRP2-disc (n=19) was 72mm (range 0-99mm). The median value in GRP3-exp (n=17) was 97mm (range 0-100mm). A significant difference was seen across the three groups (P=0.02). Notably, responses were much less varied in GRP3-exp (interquartile range 74-99.5) than those in GRP2-disc and GRP1-cont (interquartile range 27-88 and 15.5-81.5 respectively) (see figure 26).



Group 1- control group, Group 2 – discussion group, Group 3 – expert group

Figure 26. Boxplot showing feedback given on the likelyhood of making changes on farm as a result of three methods of knowledge transfer session in relation to lameness in dairy cattle

Feedback comments in relation to this question from GRP1-cont were; ‘protocols have been in place for the past five years’ and ‘already made use of resource’. Feedback comments from GRP2-disc were; ‘where possible’, ‘happy with efforts undertaken on farm’ and ‘already implementing. Feedback comments from GRP3-exp were; ‘thank you!’, ‘very helpful’ and ‘attended similar session before hence feedback’

5.4 Discussion

The results of this study showed that farmers strongly favoured traditional advisory sessions as a method of knowledge transfer and that these one to one, on-farm sessions with a veterinary surgeon had a significant effect on the farmers awareness of the need for prompt treatment of lame cows. Feedback following the KT sessions saw a significant difference across the three groups for how useful and enjoyable the session was felt to be with GRP3-exp providing the most positive feedback and GRP1-control the least. Feedback comments from GRP1-cont were fairly neutral; '*protocols have been in place for the past five years'* and *'already made use of resource'*, as were those from GRP2-disc; *'happy with efforts undertaken on farm'* and *'already implementing'*. In contrast, feedback from GRP3-exp was very positive; *'thank you!'* and *'very helpful'*.

Awareness of the need to treat lame animals in the 'correct' time frame as stated by current, evidence-based industry recommendations was also seen to significantly change as a result of GRP3-exp KT sessions with a greater frequency of 'correct' responses to video clips of lame cows after the KT session than before. No significant improvement in the 'correct' response to treatment of lame cows was seen in either GRP2-disc or GRP1-cont.

While these advisory sessions were seen to be most effective in this study, it is a simplistic expectation that raising awareness of a problem will lead to behavioural change (Leach *et al*.,2013). Participants in this study were asked to rate how likely they were to make changes on their farms as a result of the KT session on a visual analogue scale where zero was 'not at all' and ten was 'very'. A significant difference was seen in this response across the KT groups with GRP3-exp providing the most positive response recording a median of 9.7/10. Whether this intention will translate into actual changes being made on farms is unknown. Follow-up studies would be needed once sufficient time had elapsed for farmers to implement change to investigate this. Other studies which have investigated the response to veterinary advisory sessions (Bell *et al*., 2006; Bell *et al*., 2009; Barker *et al*., 2012) however, have found implementation of suggested control measures were not undertaken in many cases. There are many

reasons why such advice may not be acted upon by farmers. In a study by Bell *et al*., (2006) comparing the implementation of control measures for mastitis and lameness, significantly fewer interventions were made for lameness control despite a similar proportion of farmers believing they had a problem with each disease. This may be due to the relative ease of implementation of control measures for these two diseases. Farmers have a wide range of priorities to balance on their farms (Horseman *et al*., 2014) and control measures for lame cows are perceived to require actions which are separate from the daily routine, creating a barrier to implementation from the additional time and labour implications (Leach *et al*., 2010a). It seems then, that while a failure to recognise lame animals will clearly prevent positive action against it, awareness alone will not necessarily initiate intervention (Leach *et al*., 2012). For an action to occur the farmer must perceive the lameness in the animal to be of sufficient significance to overcome barriers to treatment. Although farmers in GRP3-exp appeared to have greater awareness of cows requiring prompt treatment following the technical advisory session, this does not necessarily mean they would prioritise treatment on their farms. Leach *et al*., (2010a; 2010b) demonstrated that farmers perception of lameness in relation to other health and welfare conditions had an important influence on the effort dedicated to lameness control and primary motivators for change were more likely to be 'pride in a healthy herd' rather than economic benefits. Communication with peers in facilitated discussion groups, while not in themselves as effective as advisory sessions in disseminating knowledge, may have greater impact on motivation drive change, investigation of which was outside the scope of this study. The ongoing nature of facilitated discussion groups may also support change, particularly where peers are visiting their premises on several occasions each year.

In the UK, a programme known as Healthy Feet, overseen by AHDB Dairy has been developed as a way to provide structured, ongoing advisory sessions with vets or hoof trimmers trained as 'mobility mentors'. This programme is based on a large intervention study conducted at the University of Bristol, designed to encourage farmer uptake of lameness related advice. The project underpinning the Healthy Feet Programme used a combination of interventions, an initial

veterinary advisory session to formulate an action plan for lameness control then facilitated annual meetings to provide support in developing and implementing the plan (Main *et al*., 2012; Whay *et al*., 2012; Leach *et al*., 2013). These facilitated meetings allowed farmers to engage with and take ownership of the plan after the initial advisory session, shown by farmers generating substantial numbers of action points over and above those initially agreed with the veterinary surgeon. Whay *et al*., (2012) concluded that the difference in proportion of changes made on farms that had undergone the programme and control farms who had not, demonstrated that farmers required support in both initiating and sustaining the process of change.

While the Healthy Feet Programme has a strong evidence base to support its structure, engagement with the programme requires a proactive approach from farmers suggesting that they already have some perception of lameness being a problem in their herds. A further benefit of farmer discussion groups is that farmers who have not previously considered seeking lameness advice may have their awareness heightened by observation of animals and management practices on other farms, as well as highlighting of their own situation when others visit their premises. Feedback from the discussion groups included *'always good to talk to other farmers about what they do'*. By raising awareness of lameness as a problem, farmers may then be motivated to seek more structured advice through their veterinary practice or industry schemes. More research is needed to understand the impact of farmer discussion groups and their role in farmer education. A particular advantage of these groups over technical advisory sessions from the perspective of provision is the substantially lower cost of discussion groups. If evidence is found to support the role of these groups in motivating change, a combined approach of knowledge transfer through one to one advisory sessions or group presentations may result in a greater impact on lameness control than either method alone.

An interesting finding in this study was the range of responses given to the feedback questions using the visual analogue scales. In GRP3-exp a relatively narrow range of responses to all the questions suggested that participants in this group found the experience similarly helpful. A narrow range of responses was also seen for GRP2-disc in relation to usefulness and enjoyment of the session

but a greater range was seen in how likely they were to attend another session or implement changes on their farms as a result. In GRP1-cont a wide variation in response was seen between participants for all questions. These responses give us some insight into the nature of knowledge transfer using these different KT methods. It is likely that all study groups contained individuals with a variety of educational backgrounds and preferred learning styles. While researchers disagree on the value of education constructed around individual learning styles, it is recognised that the dominant ways people learn can be grouped into visual, auditory, kinaesthetic, logical, social and solitary. Using a range of learning styles is therefore likely to be accessible to a wider group of learners. The narrow range of responses from GRP2-disc and GRP3-exp for usefulness and enjoyment suggest that both farmer discussions and technical advisory sessions are accessible to a wide variety of individuals. As the conversation is led by the participants in discussion groups, it can be assumed farmers are able to shape the conversation to meet their individual needs. The practical on-farm nature of technical advisory sessions means these can also be tailored to suit the participant. In contrast, the resources provided to the control group received a much more varied response in usefulness and enjoyability. Such a method of KT clearly suits some individuals learning styles better than others. The narrow range of responses to the likelihood of attending another similar session and likelihood to implement change as a result of the technical advisory session also shows that participants were equally and highly motivated by the session while the participants in GRP2-disc and GRP1-control were much more varied in their responses. The individual, targeted nature of the technical advisory sessions was therefore seen to suit all participants while the remaining methods may suit different individuals in driving change on their farms.

5.4.1 Current management practices on farms

A large variety of management practices in relation to control of lameness were seen across the farms involved in this study. Widely differing practices in lameness detection and routine foot trimming (or lack thereof) suggest that consistent messages are not being disseminated to farmers. Less than a quarter of participants were conducting mobility scoring sessions to identify lame cows, with the remainder relying on general observations in housing or at milking

times. Many studies however have shown the advantages of treating lame cows in the early stages of disease with routine mobility scoring important in the detection of newly affected animals (Groenevelt *et al*., 2014; Leach *et al*., 2012; Whay *et al*., 2003). This is of particular concern when considered against the finding that lameness treatment was undertaken by the farmer or farm staff on almost half of the farms participating in the study. If key messages are not reaching farmers on the control of lameness on farms, animal welfare may suffer.

Also of concern is the lack of training some farmers had received for treating lame cows. Nine participants had had no previous training and of the 42 who had, 31 of these had received it more than a year previously (training in this context including discussion groups, talks, veterinary advisory sessions or formal courses). An early study looking at the effect of knowledge and training on lameness prevalence (Mill and Ward, 1994) found that the participants knowledge, degree of training and awareness of lameness were each highly significantly and inversely related to the proportion of cows independently observed to be lame on their farms. Ongoing KT programmes are therefore key to ensure those treating lame cows are able to access the latest information on lameness control. Where farmers had made changes on their farms to control lameness, 48% reported they had done so as a result of training they had been received. A further 33% had made changes for other reasons. The vast majority of these participants felt that the changes had made a difference to lameness levels on their farms. These figures demonstrate that training can have a substantial impact on implementing changes on farms reinforcing the need for accessible KT sessions to provide incentive and guidance for farmers.

5.4.2 Study design

The design of this study was broken down into three elements, a questionnaire to gather information on current lameness control practices, a video assessment conducted before and after the KT session to assess knowledge acquisition and a feedback questionnaire to gather information on engagement with the KT session itself.

The first element of the study involved a questionnaire comprising of mainly closed questions developed through pre-pilot semi-structured interviews with

three farmers. This approach ensured questions were phrased in an appropriate manner and allowed a greater depth of discussion to ensure clarity than may have been possible using a focus group approach. As the breadth of response was potentially more limited in this approach, the questionnaire was piloted with two further farmers to identify any areas of ambiguity. These semi-structured interviews also allowed identification of probable answers that could then be grouped for closed questioning and analysis. While this approach allowed clearer comparison between participants, it reduced the range and depth of information that may have been gathered using open questioning.

The questionnaire was conducted as a short interview by the author who completed the data collection form. This helped to ensure questions were correctly understood and to prevent any issues around literacy of participants arising, questions were also asked to participants in a one to one setting to avoid bias from peer pressure to give the 'correct' answer which may have occurred in a group setting.

The second element of this study was a video assessment conducted before and after the KT session. This section of the study was structured to assess the application of knowledge acquired during the KT session rather than assessing the knowledge itself. In this way bias from variation in different KT methods could be reduced by placing the emphasis on recognising lame and non-lame animals and understanding their requirements for treatment rather than memorising mobility scoring descriptors. Each cow had a predetermined mobility score established by a panel of veterinary surgeons and the 'correct' answer for time to treatment was derived from the treatment advice given for the relevant score using the UK industry standard AHDB Dairy mobility scoring system (see figure 1). Participants were not however asked to use the AHDB mobility scoring system directly. 40 video clips were initially produced for this assessment however to reduce ambiguity arising from unclear recording or inconsistent gait, these were reduced to 16 clips for the final assessment. Even within the panel of nine farm animal veterinary clinicians who assisted with selecting lame and non lame videos for use in the study however there was not consistent agreement on the assigned mobility score. Across the full range of videos originally recorded agreement was greatest for score three, severely

mobility impared cows with substantial (K=0.73, (95% CI: 0.67-0.79)) agreement between observers. Agreement for score 2, mobility impaired cows was fair (K=0.22, (95% CI: 0.16-0.28)) and for score 0 and score 1 was poor (K=0.11, (95% CI: 0.05-0.17) and K=0.19, (95% CI: 0.13-0.25)) respectively. Overall agreement in mobility score between observers for all the video clips was fair (K=0.32, (95% CI: 0.28 -0.36)). As the panel was made up of experienced cattle veterinary clinicians, it is likely that this variation in agreement is more of a reflection of quality of video clips rather than the use of the scoring system itself. To decrease ambiguity in the final assessment, video clips were chosen that were considered clear by the panel and received the most consistent responses across the group. The use of videos in this assessment rather than live animals may have impacted the farmers ability to recognise lameness however videos were infinitely more practical and consistent for comparison between the different KT groups and the randomised nature of the study means that the effect of video observations would have been equal across the groups.

Another feature developed in this video assessment was the repeat of four clips within the sequence to assess variation in farmer response. An interesting finding was the low intra-observer agreement considering the same clips were shown within a few minutes of each other within the sequence. Median agreement was only fair pre study (K=0.33) and moderate post study (K=0.5) with only 10% of respondents giving the same response for the first and second showing of all four clips in the pre session video and 11.4% in the post session video. Inter-observer agreement was poor both pre and post session (K=0.19 and K=0.16 respectively). This finding raises questions with regard to how farmers were assessing cows in each of these clips to decide on what level of treatment they required. It was also seen that the number of ‘correct’ answers decreased following the KT session for some clips again leading to concerns over how farmers are making decisions on treatment requirements. Indeed in the discussion group, the number of correct responses for score 2 cows went down for two of the three clips following the KT session raising the question whether this was a result of individual variability or is a result of incorrect interpretation of treatment recommendations in these facilitated sessions. Further research is

needed to determine how farmers arise at these decisions and whether similar results are seen in observation of live animals.

It should be noted that analysis of the pre and post-KT video assessments involved multiple comparisons. With significance set at P=0.05 this means that one in twenty of the comparisons undertaken would be expected to be significant by chance. A post-hoc test e.g. Bonferroni correction could be used which would reduce the p-value by multiplying it by number of tests (eg. 0.05 x 6 (number of score 3 clips)) to account for the multiple comparisons however such a test would make all results non-significant. For the purposes of this study, post-hoc analysis had not been undertaken in order to show trends across the large fields of data.

The final element of this study used visual analogue scales to record feedback on the KT session itself. Visual analogue scales were developed to assess pain in humans and allow measurement of subjective characteristics. Visual analogue scales utilise a continuous scale allowing greater sensitivity in response than discrete scales and allow for a greater range of analysis. By using this simple system of gathering feedback, a quantitative response could be gathered for statistical analysis to a qualitative question, thus allowing simple comparisons of results. Other methods such as interviews or feedback forms with open questions may have provided a greater breadth and depth of information to be gathered on the participants perceptions of the KT session. Due to time restraints this was not possible in this study however follow up interviews of participants would add to the interpretation of these results to feed forward into future KT provision.

While the techniques selected to gather data for this study have their limitations, it is not felt that they significantly impacted the findings and all fulfilled their requirements to address the required outcomes.

5.5 Conclusion

Lameness often occurs as a culmination of several events over the lifetime of the affected individual therefore applying effective control measures on farms is essential. Increasing understanding of the causes, detection and treatment of lameness must be fed down to farmers in such a way as to encourage implementation of effective control and treatment strategies on farms.

The results of this study demonstrate that of the KT methods tested, the traditional, veterinary advisory session is the most effective for raising awareness of lameness and providing motivation for change. Other KT methods however may be of value to support this approach to ensure advice received during these sessions is implemented on farms.

More research is needed to fully understand how different KT methods can be used together to raise awareness, disseminate information to farmers and initiate and support behavioural change. The role of the veterinary advisor however remains central to this process.

Chapter 6. General discussion

Cattle lameness represents one of the foremost health and welfare challenges in the UK dairy industry (FAWC, 2009) yet research in this field has lagged behind similar endemic diseases such as mastitis and infertility (Huxley., 2012). A study conducted on 43 farms in the UK Midlands (see chapter 2) showed a mean lameness prevalence of 30.1% (range 7.3-60.6%) in the late spring of 2014. In this, the first true randomised study of lameness prevalence in the UK, it could be seen that around three in ten cows were showing some degree of lameness, with double that number on some farms. Not only does this constitute a significant welfare concern it also has considerable economic consequences as a result of treatment costs, reduced milk production and fertility and increased culling (Willshire and Bell., 2009). While this lameness prevalence is clearly beyond acceptable levels, recent research shows a corner may have been turned in tackling lameness levels in the UK. Records collected by the Dairy Herd Health and Productivity Service between 1980 and 2002 showed a substantial increase in lameness on farms in the early 1990's before a gradual improvement (Whitaker *et al*., 2004) while a study by Barker *et al*., (2010) found mean lameness prevalence in central and southern England and Wales during 2006-2007 to be 36.8% (range 0-79.2%). The mean prevalence of 30.1% found in the 2014 study therefore represents a change in the right direction, albeit small, though one that requires further evidence to validate.

The reasons for the apparent delay in tackling the issue of cattle lameness compared to other production diseases such as mastitis are multifactorial. Risk factors for development of lameness often relate to environmental factors such as poor surfaces in walkways (Barker *et al*., 2010) and cow comfort (Cook and Nordlund., 2009), improvement of which may require large infrastructure changes on farms. In fact, strategies already put in place to reduce the risk of mastitis such as a move away from straw bedded yards, may have inadvertently increased the risk of claw lesions due to a less comfortable lying area and hence an increase in standing time. A lack of understanding of the full pathogenesis of claw horn disease complicates control and management of the disease. Recent research has changed its focus from theories relating to inflammation of the laminae towards the effect of body condition on the digital cushion (Green *et al*.,

2014; Randall *et al*., 2015) and changes within the bones of the foot themselves (Blowey *et al*. 2000; Lischer *et al*., 2002). Anatomical changes and repeated lameness episodes associated with bone development on the caudal aspect of the distal phalanx due to lifetime occurrence of chronic claw horn lesions. (Newsome *et al*., 2016) complicates the control of lameness further. Management and environmental changes made on farms are likely to benefit only heifers in the immediate period after implementation while animals which already have structural changes in their feet associated with previous episodes of lameness may continue to suffer repeat cases. In the short-term this could prove demoralising for producers and create barriers to future improvements. Until the full pathogenesis of claw horn disease is understood, effective control and targeted treatment strategies are much more difficult to implement than for a bacterial disease such as mastitis.

One of the key differences between the treatment of mastitis and foot lesions is the time and skill level required for effective treatment. While most farm staff are capable of administering appropriate treatment for mastitis quickly and effectively during routine milking, treatment of lame cows requires specific time allocation, identification and separation from the herd of affected individuals, appropriate treatment areas and equipment such as foot trimming crushes and the presence of a skilled operator to carry out appropriate treatment. Time and labour implications were cited by farmers as significant barriers to treatment of lame cows (Leach *et al*., 2010a) with farmers acknowledging their lameness treatment may be sub-optimal but the need to balance lameness control against other priorities such as crop and field management would seem to form an inevitable part of running a commercial dairy farm (Horseman *et al*., 2014).

Data gathered during April and May 2014 for a study on 43 farms in the UK Midlands (see chapter 2) found that on nearly 70%, foot trimming and treatment of lame cows was carried out by the farmer or farm staff. Five percent of farms also included treatment by a vet or treatment only by the hoof trimmer while the remainder procedures were carried out by a combination of the farmer and a hoof trimmer. Similar proportions were found on a study conducted between March and July 2015 in three further regions of the UK (Devon, Derbyshire and Staffordshire and Yorkshire and Lancashire) (see chapter 5). Of the 51

participants in this study, nearly half reported treatment of lame cows on their farms was undertaken by the farmer or farm staff and a further third by a combination of the farmer and foot trimmer.

With no single professional group carrying out treatments on lame cows, ensuring appropriate standards are met is problematic. Current UK legislation means that of the above, the only individuals required to complete formal training are veterinary surgeons and yet these results suggest that vets are treating only a minority of cases on commercial farms. A much larger proportion of treatments (95.4% in chapter 2 and 80.4% in chapter 5) were carried out by farmers and foot trimmers. The lack of a single UK foot trimming organisation to oversee training and quality control has led to a wide range of abilities within the veterinary, para-veterinary and farming professions (Mahendran and Bell., 2015). Much of the treatment carried out on the farms in these two studies was conducted by farmers or farm staff who fall outside any professional regulations. The study in 2014 (see chapter 2) found that on over a quarter of farms, farmers had undergone no previous training in foot trimming, several describing themselves as 'self -taught'. The study in 2015 (see chapter 5) found that although over 80% of participants had received some training, three quarters of this training took place greater than a year previously. Training in this context for half the participants comprised 'other' training such as specific training days or as part of a college/university course while the remainder had attended either a discussion group, a talk from a veterinary surgeon or other expert or a one to one discussion on their farm with their own vet. The lack of regulation of farmers treating their own cows and a lack of current training is of concern when considering the welfare of these animals. While much of this treatment *may* be correct and effective, there is no way to monitor this and structured dissemination of new research into treatment of lame cows may be difficult. A study on treatment of acutely lame cows (see chapter 3) highlighted the effects of treatment operator on the effectiveness of treatment. All treatment operators in this study were cattle veterinary surgeons, however analysis showed that cows were significantly more likely to recover when treated by the author than 'other' operators. The reasons for this may be many, however the finding highlights the importance of correct training and regular updating and scrutiny of personal skill

sets. Ensuring appropriate evidence-based training reaches all parties involved in treatment of lame cows will be imperative if the lameness situation in the UK is to be tackled effectively.

6.1. Early detection and treatment of lame cows

Key to effective treatment of lame cows is identifying lameness in the early stages and providing prompt interventions appropriate to the condition. Research has demonstrated that farmers detecting lame cows through general observation as opposed to routine mobility scoring are likely to underestimate the number of lame cows on their farms (Whay *et al*., 2003, Espejo *et al*., 2006, Leach *et al*., 2010, Groenevelt *et al*., 2014) leading to a delay in treatment. The terminology surrounding lameness in the UK dairy industry may also impact the early recognition of disease with Horseman *et al*., (2014) reporting farmers avoided the word 'lame' and instead described animals as '*just a little impaired in how mobile they are'. 'aren't walking correctly'* or *'her mobility is suffering a bit'*. This terminology appears to be very similar to the AHDB Dairy mobility scoring system where cows scored on a four-point scale are described as having 'good mobility', 'imperfect mobility' impaired mobility' and 'severely impaired mobility'. Whether the terminology has arisen from the scoring system or the scoring system incorporated common terminology at the time of its development is unclear but this avoidance of the word 'lame' may potentially be leading to the delay in treatment rather than the farmers not identifying cases. The AHDB Dairy mobility score also states that 'impaired mobility' (score 2) cows are 'likely to benefit from treatment and should be attended to as soon as practicably possible' while 'severely impaired' (score 3) cows are 'very lame and require urgent attention, will benefit from treatment' reinforcing the idea that more mildly lame cows can be left longer before treatment. With the growing scientific evidence supporting early recognition and prompt treatment of milder cases, it is not unreasonable to suggest that the wording on the AHDB Dairy mobility score needs to be changed to avoid this potential barrier to lameness treatment. Leach *et al*., (2010a) found that farmers' perception of lameness in relation to other herd health issues had an important influence on the effort dedicated to lameness control and so if farmers are underestimating the significance of impaired mobility it stands to reason they will not prioritise treatment of affected

individuals. Even if farmers are aware of individual lame cows, that in itself may not be enough to drive change in control and treatment practices. Only by understanding the full implications of disease and the severity of the problem will the desire to implement change outweigh the costs and inconvenience of doing so.

Identification and treatment of animals in the early stages of lameness has been shown in several studies to improve recovery (Groenevelt *et al*., 2014, Leach *et al*., 2012), findings which are strongly supported by the results of the acute and chronic lameness RCTs presented here (see chapter 4). Despite this however, over 60% of farms in a lameness study in 2014 (see chapter 2) conducted no mobility scoring and less than 10% mobility scored their herds a minimum of once per month. A further study conducted in 2015 (see chapter 5) revealed that less than a quarter conducted some mobility scoring while the remaining farms identified lame cows through general observation in housing or at milking. This low level of proactive detection of lameness is of concern as education provided by bodies such as AHDB Dairy have focussed on this area for some time. Indeed, many of the participants who reported that they undertook mobility scoring, did so at only three or six month intervals to meet the requirements of farm assurance schemes, rather than as a proactive method of lameness detection. It is clear that the messages being disseminated on early identification of lame cows through mobility scoring have failed to create a substantial behavioural change on most farms. Horseman *et al*., (2014) found that although there was broad acknowledgement of the benefits of undertaking mobility scoring, having somebody to do it, finding the time and having a suitable place to do it were all perceived as practical barriers to implementation. As research continues to strengthen the argument for the benefits of early treatment of lame cows and thus the advantages of routine mobility scoring, these messages must be conveyed more clearly to farmers to show the importance of overcoming such barriers. With many farmers reporting they only undertook scoring for farm assurance schemes, penalties and premiums associated with these may be the most effective ways to drive change in the recognition of lame cows in the short term.

Once lameness has been identified, rapid intervention even in mild cases is key to successful recovery. When comparing the results of the acute and chronic lameness RCTs conducted here (see chapter 4), regardless of the treatment used, cows were significantly more likely to recover if treated for lameness of less than two-weeks duration (75% non-lame at outcome) than those treated for lameness of greater than two-weeks duration (15% non-lame at outcome). All cows on the acute lameness study received treatment within 2 days of first recording a 'lame' mobility score (score ≥2a). A delay in treatment also affected the efficacy of individual treatments. Acutely lame cows treated using a foot block and NSAID in addition to a therapeutic trim were significantly more likely to recover to sound (score 0) than those treated with a therapeutic trim alone (see chapter 3) with a similar, though non-significant trend in recovery to non-lame (score 0 or 1; trim, block and NSAID 86.0%, trim only 68.9%) (see chapter 4). This differential effect of treatment on recovery however was completely lost in the chronic lameness study where recovery of around 15% was seen at outcome for all treatment groups. The message of early intervention is reinforced further by the finding that acutely lame cows treated early in lactation were more likely to recover. It is thought that the changes leading to claw horn lesions happen around the time of calving (Knott *et al*., 2007; Tarlton *et al*., 2002; Bicalho *et al*., 2009) and therefore the earlier in lactation the cows were treated, the more acute the lesions were likely to be. Heifers were also seen to be more likely to recover suggesting effective early treatment in life, as well as in the lameness episode may affect recovery. This may be due to changes in the pedal structures as a result of repeated chronic lameness events which then predispose to further episodes (Blowey *et al*. 2000; Lischer *et al*., 2002; Newsome *et al*., 2016). Randell *et al*., 2016 reported that heifers with severe lesions in the first two to four months postpartum had an increased risk of future lameness reinforcing the importance of early treatment to reduce the impact of lameness on lifetime productivity.

The message of ensuring early detection of lame cows must therefore be followed by that of prompt treatment. Data collected on a cattle lameness study in 2014 (see chapter 2) found that just over half of farmers reported that they treated cows within 48 hours of first identifying them as lame rising to over 70%

treated within a week. On a similar study by Barker *et al*., (2010) just over quarter of farmers treated lame cows within 48 hours of identification. Time and labour requirements outside of the daily routine are often cited as reasons for delays in treatment (Leach *et al*., 2010a) while having a good farm layout, cow flow and handling facilities are seen to increase frequency and promptness of treatment (Horseman *et al*., 2014). The severity of lameness is also seen to impact the time between identification and treatment with the benefits of prompt treatment in less severely affected individuals not always recognised (Horseman *et al*., 2014). In a study by Alawneh., (2012) where barriers to treatment were reduced by offering weekly veterinary treatment at no cost, a delay to presentation of lame cows for treatment was still seen, with severely lame cows presented on average 21 days after researchers first recorded a lame mobility score and milder cases experiencing a delay of around 70 days. These figures suggest that while farmers are aware of the need for early intervention, the importance of prompt treatment in the acute stages of lameness are not necessarily being recognised. Cows that are only mildly lame are potentially being allowed to progress to a more chronic state that will then respond considerably less well to treatment. Prioritising milder cases in theory will not only improve response to treatment but also reduce the risk of recurrence (Groenevelt *et al*., 2014), however more chronic and severe cases cannot be neglected from a welfare point of view. Finding ways to overcome barriers to treatment and ensure treatment in the early stages of disease is therefore not a straightforward task. It requires substantial commitment from farmers to treat both acute and chronic cases initially so that they can reach the point where chronic cases are managed or culled and the main focus can be turned to acutely lame cows.

6.2 Effective treatment of lame cows

Continuing from the message of early identification and prompt treatment of lame cows, it is clear that treatments administered should be the most effective for the condition, to maximise recovery and improve welfare. Limited research has been conducted into the most effective treatments for claw horn lesions in dairy cows, a study by Potterton *et al*., (2012) finding only three peer reviewed publications on the treatment of sole ulceration in the scientific literature

between 2000 and 2011 and none on white line disease. A wider examination of the literature revealed two further studies, both RCTs, conducted by Pyman., (1997) in Australia and Laven *et al*., (2008) in New Zealand. These studies were all conducted outside the UK and failed to provide any evidence on which clinical decision making for on-farm treatment of sole ulcers might be based.

In contrast, the findings of the acute lameness (less than two-weeks duration) RCT (see chapter 3) found that when a foot block and NSAID were administered in addition to a therapeutic trim, cows were significantly more likely to recover to sound (mobility score 0) than if treated with a therapeutic trim alone. A similar, though non-significant trend was seen in cows recovering to non-lame (mobility score 0 or 1). Smaller, non-significant improvements were seen in cows treated either with a foot block or a NSAID in addition to a therapeutic trim compared with a therapeutic trim alone. The reasons for the synergistic effect of treating claw horn lesions with a foot block and NSAID are unclear. They may relate to behavioural changes where the addition of a NSAID improves comfort when weight bearing on a foot block (Miguel-Pacheco *et al*., 2016), or to physiological changes within the claw itself related to the anti-inflammatory effects of the NSAID when pressure has been removed by elevating the affected claw. Further investigation of the effects of NSAIDs on claw horn lesions are required to fully understand this finding but from a welfare view alone, the addition of an analgesic medication to an animal with a foot lesion sufficiently painful for the animal to alter its gait, can be strongly recommended. This RCT investigated the efficacy of three treatments against a control treatment of a therapeutic trim and so the efficacy of the trim over no treatment cannot be established from this research. Further investigation on this, and if significant, the most effective type and extent of trim are required to create a clearer picture on the most effective treatment protocols. The finding in both RCTs presented here and of Laven *et al*., (2008) that the addition of a foot block provides no significant difference in recovery compared to a therapeutic trim alone is of particular interest as this treatment is widely used across the world for claw horn lesions. Further investigation of this finding is therefore necessary to inform the industry of appropriate use. Other treatments, types of foot block and varieties of NSAID which were not examined in the RCTs presented here

may also affect recovery and so there is much more work to be carried out in this area before evidence-based, gold standard protocols can be designed and disseminated to farm level.

One message clearly highlighted from the acute and chronic lameness RCTs (see chapter 4) is the importance of trimming both hind feet even if lameness only presents in one limb. With unilateral trimming and treatment, over 45% of cows were still lame at outcome in both the acute lameness study and chronic lameness study, were seen to be lame on the opposite, untreated hind limb. It stands to reason that if many of the changes leading to claw horn lesions occur at a cow level, both hind feet will be affected and so, unless there is strong justification for not doing so, both hind feet should receive an appropriate treatment intervention as soon as lameness is detected. The risk of lameness on the contralateral leg may also be reduced to some extent by the treatment used on the affected leg. The acute lameness RCT showed that six cows treated with a therapeutic trim and eight cows treated with a trim and foot block were lame on the contralateral leg at outcome. This contrasts with just one cow in the trim, foot block and NSAID group. It may be that this more effective treatment combination improves the comfort of the cow and allows more even distribution of weight, reducing the risk of overloading the opposite leg, however this effect requires more research to understand fully.

While research may identify the most effective treatment protocols for claw horn lesions, it must be recognised that in isolation, these protocols will not give a complete answer to treatment on farms. Farm differences in response to treatment were seen in both the acute and chronic lameness RCTs conducted here (see chapter 4). It is well recognised that environmental and management factors on individual farms affect risk of lameness in the herd (Cook and Nordlund., 2009) but the findings here also suggest that such factors may also affect the efficacy of treatment. Treatment of lame cows therefore must be considered as part of a more holistic approach to cattle lameness.

6.3 Dissemination of research findings

The findings from this research clearly identify three main recommendations; early detection, prompt treatment and effective treatment, in order to improve

the recovery of cows affected by claw horn lesions. The mechanisms by which these recommendations can be disseminated to the people managing and treating lame cows at farm level however are less straight forward.

In the veterinary profession, knowledge transfer pathways through courses, seminars, conferences and the scientific literature are well established and with the re-structuring of the hoof trimming profession there is the potential for similar pathways may be formed. The findings presented here (chapter 2 and chapter 5) however, show that the majority of lameness treatments are being conducted by individual farmers, placing an emphasis on these professionals and other industry bodies to ensure this knowledge is further disseminated to a farm level.

A study investigating the efficacy of different methods of knowledge transfer to farmers in relation to lameness in their herds (see chapter 5), showed that one to one, on-farm visits by a veterinary surgeon were the most effective method in terms of acquisition of knowledge, enjoyment and likelihood to cause behavioural change on farms compared to farmer discussion groups or provision of lameness related reading material. Such methods of knowledge transfer however are costly and time consuming to operate. Schemes such as the Healthy Feet Programme, overseen by AHDB Dairy are based on such principals where 'mobility mentors', either vets or professional foot trimmers facilitate structured programmes to help farms identify and apply the correct management techniques to reduce lameness on farms. These schemes however are likely to target only those farmers who already have a good awareness of lameness within their herds and are proactive about tackling it. An interesting finding of the research underpinning the Healthy Feet Programme (Main *et al*., 2012) was that the control group who received no support for their lameness management other than the provision of an annual herd mobility score, also saw a reduction in lameness on their farms. It was proposed that lameness information received outside of this study from lameness specific events, an increased awareness through monitoring by researchers and discussion between farmers on supported and control farms may have led to this effect. These alternative methods of knowledge transfer require further investigation to understand their efficacy in dissemination of lameness information. Local farmer discussion groups run

either by industry bodies or veterinary practice offer a less costly method that may provide some of the effects outlined above to increase awareness of lameness and allow peer discussion and support in control strategies. In the study presented here, discussion groups alone were not shown to make a significant difference in transferring knowledge in relation to the prompt treatment of lame cows however they may prove useful as part of a wider knowledge transfer programme. Discussion groups have the advantage that farmers who are not proactively looking to address lameness on their farms may be easier to target using this method, by disseminating lameness prevention and treatment messages as part of a much wider package of topics. While primarily designed to encourage interaction and peer-support with other farmers, they may also provide a route for veterinary surgeons and hoof trimmers to further disseminate the latest research findings they have learned by arranging to attend groups for one-off presentations and discussions.

Ultimately a range of techniques will be required to ensure the key messages coming from research into treatment of claw horn lesions reach those on farms who are at the forefront of managing lame cows. It is the responsibility of all stakeholders to ensure knowledge transfer pathways are available and utilised effectively if current research finding are to have a significant impact on lameness levels in UK dairy cattle.

6.4 Complexities of conducting on-farm research studies

The work conducted in this thesis revealed many complexities in conducting lameness research on farms.

A study to assess the prevalence of lameness on UK dairy farms (see chapter 2) was the first of its kind to collect data using a truly randomised selection of farms. In order to achieve this 519 telephone numbers were searched on the internet from a database of farm addresses and contact made with 247 on the first or second attempt. Of these only 58 farmers agreed to participate in the study. These figures demonstrate the time implications of selecting farms for a study in a randomised manner. Recruitment of farmers occupied on average two to three hours per day, three days per week over a ten week period. While this method of farm selection is scientifically robust, the benefit of using true

randomisation over the more common methodology of recruiting through veterinary practices must be balanced against the cost of implementation.

Conducting randomised clinical trials on farms also proved to be highly complex and may explain to some extent why very few of these studies have been conducted previously. In the acute lameness RCT (see chapter 3), 'double blinding' the trials was not possible due to the nature of the treatments administered which were distinct, visible and had a legal requirement to record administration of NSAIDs. While partial blinding was possible by using an independent observer to assess the primary outcome, this required an additional farm visit by the observer with both cost implications for the study and practical implications on farm. In the chronic lameness study (see chapter 4) it was necessary to streamline this procedure by incorporating the observation of outcome in to the fortnightly mobility scoring sessions. While this reduced cost and was substantially more practical, the possibility of bias was increased. Though the observer was not informed of treatments administered, in scoring the herd on a regular basis they may have been aware of which cows had been treated with a foot block.

Ethical considerations around negative control groups also limited the scope of the studies as once an animal had been identified as lame and therefore experiencing discomfort, it was necessary to provide treatment. A minimum treatment intervention was therefore selected as a positive control. It was therefore not possible to determine whether this minimum treatment was more effective than no treatment at all. When designing the study on chronic lameness (see chapter 4), it was also necessary to allow farmers to continue their normal treatment practices so that animals were not left in unnecessary discomfort. Once treated by the farmer these animals were excluded from the study and so, while few cows were excluded on this basis, some bias may have been seen in the sample.

The substantial time implications of conducting these RCTs over a 15 month period restricted the recruitment of farms as they were required to be within a reasonable distance of personnel at the University of Nottingham, School of Veterinary Medicine and Surgery and also prepared to participate in the trial

fully over this period. The farms selected may therefore not have accurately represented the variance in the population as a whole due to geographical location, management practices and available facilities for treating animals.

Logistically these RCTs were complex, expensive and time consuming, the acute lameness RCT (see chapter 3) occupying 49 person hours per week dedicated to data collection alone. This necessitated the subdivision and streamlining of tasks in the later RCT on chronic lameness (see chapter 4) which resulted in further limitations in interpretation of results and comparison between the two studies. However despite this it was still possible to gain useful data in the latter study with clinically relevant findings which will benefit future treatment protocols in lame cows. By understanding the complexities and limitations of conducting such studies, future studies may be planned which balance scientific vigour with practical implications in order to produce useful outcomes for the industry.

6.5 Conclusion

The key message coming from the research detailed in this thesis is the need for early identification and prompt, effective treatment of lameness caused by claw horn lesions in dairy cattle. More research is needed to fully understand the pathogenesis of these lesions which may allow us to further appreciate the interaction of different treatments with the structures of the foot and develop evidence based treatment strategies for these lesions.

Conducting randomised clinical trials on the treatment of lameness on commercial dairy farms has many complexities which place limitations on study design. This should be recognised however it should not prevent further research being conducted in this field. The lessons learned during this thesis provide a solid foundation for future research planning in order to maximise the validity of results.

As the body of research grows and knowledge into the most effective treatment protocols becomes more comprehensive, it is essential to get this information out to those persons treating lame cows at the farm level. In the veterinary profession, established methods of research dissemination through CPD and peer reviewed, scientific literature give a clear pathway for knowledge transfer. The

growing infrastructure for hoof trimmers may in future also allow similar mechanisms for disseminating the latest research. Where knowledge transfer strategies are lacking are in the most effective ways to get these messages to farmers who are responsible for majority of treatment of lame cows. It is vital that industry, veterinary surgeons and research institutions work together to ensure the latest research findings can be implemented at farm level to achieve greatest impact on lameness in dairy cattle caused by claw horn lesions and improve cattle welfare and productivity in the UK.

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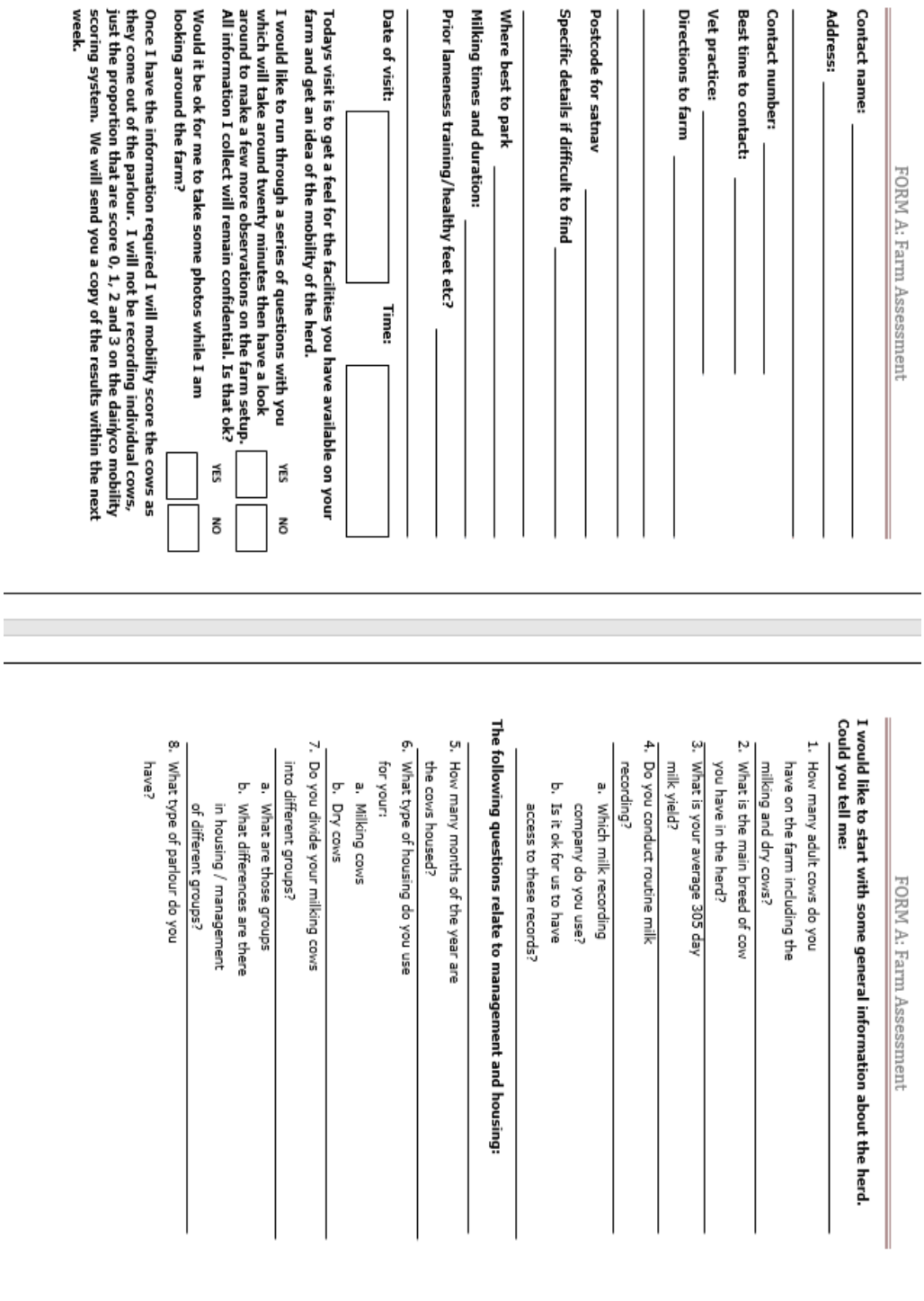
Appendices.

Appendix 1. Lameness prevalence study interview questionnaire



FORM A: Farm Assessment

Contact name: _____

Address: _____

_____

Contact number: _____

Best time to contact: _____

Vet practice: _____

Directions to farm _____

_____

Postcode for satnav _____

Specific details if difficult to find _____

_____

Where best to park _____

Milking times and duration: _____

Prior lameness training/healthy feet etc? _____

_____

Date of visit: _____ **Time:** _____

Todays visit is to get a feel for the facilities you have available on your farm and get an idea of the mobility of the herd.

I would like to run through a series of questions with you which will take around twenty minutes then have a look around to make a few more observations on the farm setup. All information I collect will remain confidential. Is that ok? YES ☐ NO ☐

Would it be ok for me to take some photos while I am looking around the farm? YES ☐ NO ☐

Once I have the information required I will mobility score the cows as they come out of the parlour. I will not be recording individual cows, just the proportion that are score 0, 1, 2 and 3 on the dairyco mobility scoring system. We will send you a copy of the results within the next week.

FORM A: Farm Assessment

I would like to start with some general information about the herd. Could you tell me:

1. How many adult cows do you have on the farm including the milking and dry cows?
2. What is the main breed of cow you have in the herd?
3. What is your average 305 day milk yield?
4. Do you conduct routine milk recording?
   a. Which milk recording company do you use?
   b. Is it ok for us to have access to these records?

The following questions relate to management and housing:

5. How many months of the year are the cows housed?
6. What type of housing do you use for your:
   a. Milking cows
   b. Dry cows
7. Do you divide your milking cows into different groups?
   a. What are those groups
   b. What differences are there in housing / management of different groups?
8. What type of parlour do you have?

9. Do you use a footbath?
   a. How often are the cows foot bathed?
   b. What chemical do you use at what dilution?
   c. Do you footbath dry cows and heifers as well as milking cows?

This rest of the questions I am going to ask relate to lameness detection and treatment on your farm

10. What are the main types of lameness you see on your farm?
11. Would you say lameness is a mild, moderate or major problem on your farm?
12. How do you detect lame cows on your farm?
    a. How do you identify if it is a new case or one that has been going on for a while?
13. Do you carry out any form of mobility scoring on the farm?
    a. Who carries this out?
    b. How often is it done?
    c. Has the person received any training in mobility scoring?
14. What foot trimming equipment do you have available on the farm?
    a. Is the crush easy to use
    b. Do you use a grinder or knives?

FORM A: Farm Assessment

    c. Do you carry out routine foot trimming or just if the cow needs treatment?
    d. What is your trimming routine? (Stage of lactation etc)
15. Who would usually treat the lame cows on your farm?
    a. Has the person received any training in foot trimming?
    b. How long on average after a lame cow is detected will she be treated? (WHY?- i.e., ask if timescale suggests something like regular foot trimmer/ vet visit)
    c. Do you use any treatments other than trimming (bandages / blocks / injections etc)?

Thankyou. That's all the questions I have. Would it be ok if I have a walk around the farm and make a few more notes?

Record of observations:

Cubicles and bedding

Flooring (cubicle and feeding areas)

Hygiene

FORM A: Farm Assessment

Collecting yard (backing gates, flooring, space)

Parlour (flooring, layout, pinch points)

Footbath (position etc)

Foot trimming area (condition of crush, position, lighting

General condition of cows

Other observations

Appendix 2. Expert Questionnaire on the Treatments for Claw Horn Lesions

We will shortly be undertaking a clinical trial funded by DairyCo to investigate protocols for the treatment of sole haemorrhage / ulcers and white line disease (haemorrhage and separation). The results of the trials will be used to promote early identification and treatment of lame cows by appropriately trained farm staff to help control lameness on farm. We are seeking the opinions of foot trimmers and vets with expertise and an interest in this field. We would really value your input and opinions on the treatments we test

.

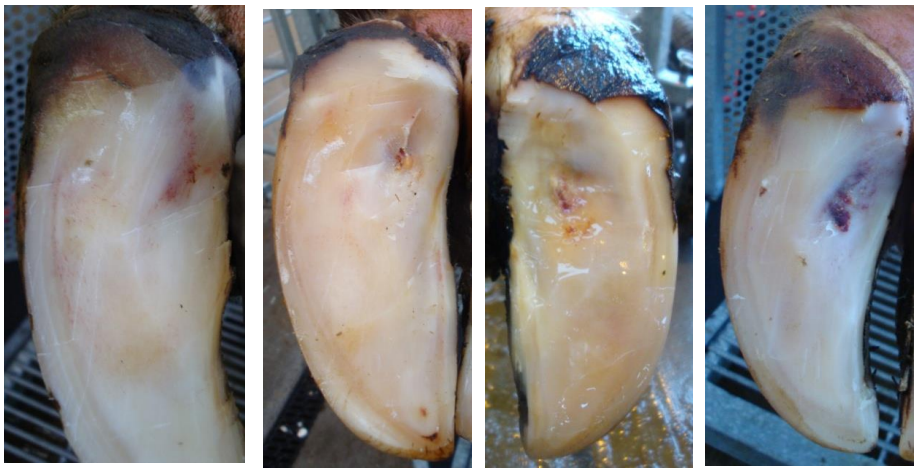
Importantly, the study will be aimed at *early* treatment i.e. cows that have *recently* become lame. Therefore the lesions we will be treating will tend to be early stage and relatively mild; we believe this is justified as there is now good evidence that early treatment leads to better outcomes and we wish to promote this approach on farm.

The questionnaire should take no more than 10-15 minutes of your time.

Please note we have deliberately left all the questions as free text responses as we do not wish to influence your thoughts in any way. Many thanks for your time; we really appreciate your help.

Sole Haemorrhage / Ulcers

This section is all about sole haemorrhage / ulcers. The types and range of lesions we would like you to consider are illustrated in the pictures below. Please answer the following questions with these sorts of lesion in mind.



Please briefly describe how you would currently treat the types of sole haemorrhages / ulcers illustrated in the pictures above. Please describe all aspects of the treatment protocol you would administer, particularly please describe the detail of how you would trim the claw.

Would you ever treat these types of lesions differently? If so, what aspects would you change / what additional treatment would you add and in what circumstances would you change your procedure?

We will test three different treatment procedures for these types of sole haemorrhage / ulcers. The differences between procedures could be small or large. What differences would you be most interested in us testing?

White Line Disease (Haemorrhage and Separation)

This section is all about white line disease. The types of lesions we would like you to consider are illustrated in the pictures below, some of these lesions may have developed small abscesses under the sole. Please answer the following questions with these sorts of lesion in mind.




Please briefly describe how you would currently treat the types of white line disease illustrated in the pictures above. Please describe all aspects of the treatment protocol you would administer, particularly please describe the detail of how you would trim the claw.

Would you ever treat these types of lesions differently? If so, what aspects would you change / what additional treatment would you add and in what circumstances would you change your procedure?

We will test three different treatment procedures for these types of white line disease. The differences between procedures could be small or large. What differences would you be most interested in us testing?

Any other comments

Please feel free to add any other comments you may have for us here.

Thank you, we really appreciate your time

Appendix 3. Acute lameness RCT data collection forms

FORM A: FARM ENROLMENT

NAME

ADDRESS

POSTCODE

NUMBER OF COWS

MANAGEMENT STYLE (Housing / feeding etc), Please describe:

- CONDUCTING ROUTINE MILK RECORDING YES ☐ NO ☐
- LAMENESS PREVALENCE GREATER THAN 20% YES ☐ NO ☐

ROUTINE MEASURES TO PREVENT DIGITAL DERMATITIS (e.g. regular foot bathing), Please describe:

OTHER INFORMATION OF RELEVANCE:

Page 1

FORM A: FARM ENROLMENT

- **OWNER / MANAGER CONSENT:**

I, the undersigned owner/manager of the farm, have read and understood the following. Any aspects that I did not understand were explained to me:

1. Animals in my care will be taking part in a clinical study on the treatment of claw horn lesions.
2. Animals will be identified as lame through a mobility assessment based on the Dairy-Co mobility scoring system. Assessment will take place approximately every 2 weeks.
3. Animals will be selected for treatment if they meet the following criteria:
   a. They have a new case of lameness (animals must have recorded non-lame scores in the previous two mobility assessments).
   b. They have not been treated with antibiotics or anti-inflammatories within the last 14 days.
   c. They have not been treated in the study for lameness in the same foot in the past 120 days or lameness in another foot in the past 90 days.
   d. They have not been treated on the farm (outside of the study) for lameness in the same foot in the past 120 days or lameness in another foot in the past 90 days.
   e. They do not have active digital dermatitis, foul-in-the-foot or large interdigital growths.
   f. They do not have lesions in more than one claw.
4. On some occasions, not all of animals which meet the criteria will be included in the study.
5. Following the mobility assessment, I will be notified of:
   a. Any animals which have been identified as lame but do not meet the above criteria.
   b. Any animals which meet the above criteria but are not selected for inclusion in the study
   c. The animals which have been selected for inclusion in the study, (these animals will then be treated the following day).
   d. Any animals which are required for re-examination following a previous treatment.
6. If any of the cows undergoing treatment in the study are given any veterinary medical product or any additional treatment to their feet, I will notify the study investigator.

I undertake to participate in the study for its entire duration. I agree to separate out and present selected cows for examination or treatment as requested by the study investigator. I agree to assist the investigator with all reasonable requests, e.g. access to relevant farm records etc.

Comments

Signed _____ _____

Owner / manager Investigator

Date _____

Page 2

FORM B: MOBILITY SCORING

DATE | FARM ID | OPERATOR

COMMENTS:

COW NUMBER	MOBILITY SCORE	LEFT HIND	RIGHT HIND	BOTH HIND	LEFT FORE	RIGHT FORE	BOTH FORE	TX BAND	BLOCK

FORM B: MOBILITY SCORING

COW NUMBER	MOBILITY SCORE	LEFT HIND	RIGHT HIND	BOTH HIND	LEFT FORE	RIGHT FORE	BOTH FORE	TX BAND	BLOCK

FORM C: ENROLMENT (EXAMINATION 1)

DATE: **FARM ID:** **COW ID:** **SHEET NO:**

MOBILITY ASSESSMENT

OPERATOR

	SCORE	LH	RH	OPERATOR
PREVIOUS DAY MOBILITY SCORE				

FOOT TREATED IN STUDY WITHIN 120 DAYS	NO	YES/EXCLUDED
ANOTHER FOOT TREATED IN STUDY WITHIN 90 DAYS	NO	YES/EXCLUDED
FARMER TREATED SAME FOOT WITHIN 120 DAYS	NO	YES/EXCLUDED
FARMER TREATED ANOTHER LIMB WITHIN 90 DAYS	NO	YES /EXCLUDED
ANTIBIOTICS OR ANTI-INFLAMMATORIES WITHIN 14 DAYS	NO	YES/EXCLUDED

EXAMINATION

TIME STARTED

	SCORE	LH	RH
MOBILITY SCORE IMMEDIATELY PRIOR TO TX			

BODY CONDITION SCORE

ACTIVE DIGITAL DERMATITIS	NO	YES/EXCLUDED
FOUL IN THE FOOT	NO	YES/EXCLUDED
LARGE INTERDIGITAL GROWTH	NO	YES/EXCLUDED

OTHER REASONS FOR EXCLUSION: NO YES/EXCLUDED

COMMENTS

Page 1

FORM C: ENROLMENT (EXAMINATION 1)

	LATERAL CLAW		MEDIAL CLAW	
TWEAK TEST POSITIVE	YES	NO	YES	NO
HOOF TESTERS POSITIVE	YES	NO	YES	NO

DIAGNOSIS SH/SU WLD OTHER

DESCRIPTION:

MORE THAN ONE CLAW AFFECTED NO YES/EXCLUDED

PHOTOGRAPH TAKEN

TREATMENT ADMINISTERED

TREATMENT 1	TREATMENT 2	TREATMENT 3	TREATMENT4
TRIM	**TRIM + BLOCK**	**TRIM + NSAID**	**TRIM+BLOCK+NSAID**

TERRAMYCIN SPRAY LEG BAND FITTED

OTHER COMMENTS:

TIME COMPLETED SIGNED

Page 2

FORM D: RE-CHECK (EXAMINATION 2)

DATE: ☐ **FARM ID:** ☐ **COW ID:** ☐ **SHEET NO:** ☐

MOBILITY ASSESSMENT

OPERATOR ☐

COW ENROLMENT DATE ☐ OPERATOR AT ENROLMENT ☐

	SCORE	LH	RH
MOBILITY SCORE ON DAY 8	☐	☐	☐
PREVIOUS MOBILITY SCORE	☐	☐	☐

FOOT BLOCK PRESENT YES ☐ NO ☐

BODY CONDITION SCORE ☐

RETREATMENT

TREATMENT ALLOCATION AT ENROLMENT:

TREATMENT 1	TREATMENT 2	TREATMENT 3	TREATMENT4
TRIM	**TRIM + BLOCK**	**TRIM + NSAID**	**TRIM+BLOCK+NSAID**
☐	☐	☐	☐

RETREATMENT REQUIRED: **NO** ☐

YES: SWELLING ☐ SCORE DETERIORATION ☐

RE-APPLICATION OF FOOT BLOCK ☐ OTHER ☐

COMMENTS: _____

_____

_____

_____

FORM E: BLOCK REMOVAL (EXAMINATION 3)

DATE: ☐ **FARM ID:** ☐ **COW ID:** ☐ **SHEET NO:** ☐

OPERATOR ☐

COW ENROLMENT DATE ☐ OPERATOR AT ENROLMENT ☐

BODY CONDITION SCORE DAY 28 ☐

TREATMENT ALLOCATION AT ENROLMENT:

TREATMENT 1	TREATMENT 2	TREATMENT 3	TREATMENT 4
TRIM	**TRIM + BLOCK**	**TRIM + NSAID**	**TRIM+BLOCK+NSAID**
☐	☐	☐	☐

BLOCK REMOVAL ASSESSMENT

FOOT BLOCK PRESENT YES ☐ NO ☐

FOOT BLOCK REMOVED YES ☐ NO ☐ n/a ☐

COMMENTS: _____

_____

_____

OTHER COMMENTS: _____

_____

_____

_____

FORM F: OUTCOMES (EXAMINATION 4)

DATE: ____ **FARM ID:** ____ **COW ID:** ____ **SHEET NO:** ____

	SCORE	LH	RH	OPERATOR
MOBILITY SCORE IMMEDIATELY				
PRIOR TO EXAMINATION:				

EXAMINATION

TIME STARTED ____

BODY CONDITION SCORE ____

ACTIVE DIGITAL DERMATITIS	NO ☐	YES/WITHDRAWN ☐
FOUL IN THE FOOT	NO ☐	YES/WITHDRAWN ☐
LARGE INTERDIGITAL GROWTH	NO ☐	YES/WITHDRAWN ☐

OTHER REASONS FOR WITHDRAWL: _____ NO ☐ YES/WITHDRAWN ☐

_____

COMMENTS _____

_____

_____

_____

	LATERAL CLAW		MEDIAL CLAW	
TWEAK TEST POSITIVE	YES ☐	NO ☐	YES ☐	NO ☐
HOOF TESTERS POSITIVE	YES ☐	NO ☐	YES ☐	NO ☐

FORM F: OUTCOMES (EXAMINATION 4)

DESCRIPTION: _____

_____

_____

_____

PHOTOGRAPH TAKEN ☐

LEG BANDS REMOVED ☐

OTHER COMMENTS: _____

_____

_____

_____

_____

_____

TIME COMPLETED ____ SIGNED ____

FORM H: COW WITHDRAWL

DATE: _____ **SHEET NO:** _____

FARM ID: _____ **COW ID:** _____

OPERATOR: _____

REASON FOR WITHDRAWL:

FAILURE TO COMPLY WITH STUDY PROTOCOL ☐

SOLD ☐ CULLED ☐ DIED ☐ OTHER ☐

FURTHER DETAILS: _____

_____

_____

_____

_____

COMMENTS: _____

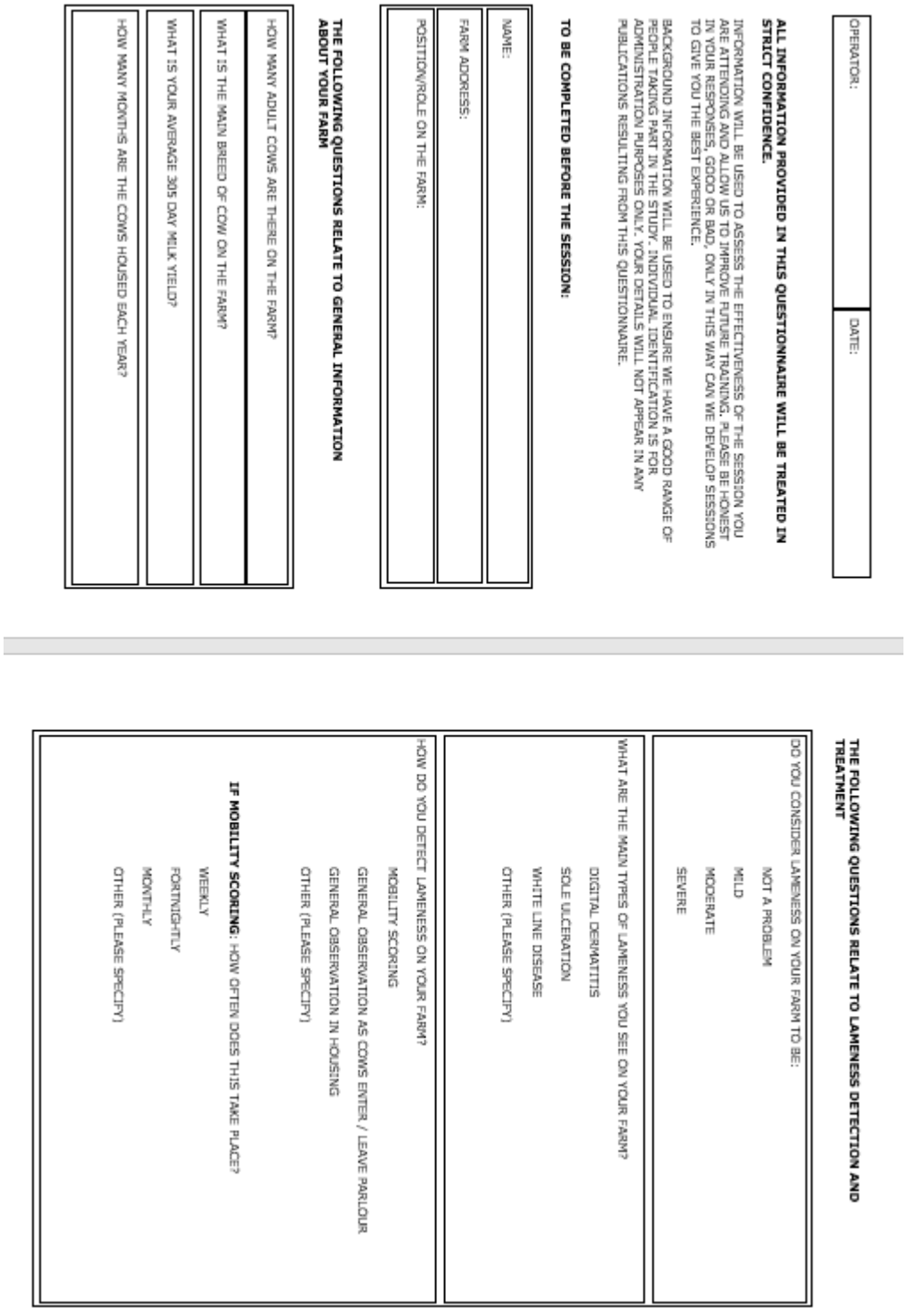
_____

_____

_____

_____

Appendix 4. KT study questionnaire



OPERATOR: | DATE:

ALL INFORMATION PROVIDED IN THIS QUESTIONNAIRE WILL BE TREATED IN STRICT CONFIDENCE.

INFORMATION WILL BE USED TO ASSESS THE EFFECTIVENESS OF THE SESSION YOU ARE ATTENDING AND ALLOW US TO IMPROVE FUTURE TRAINING. PLEASE BE HONEST IN YOUR RESPONSES, GOOD OR BAD, ONLY IN THIS WAY CAN WE DEVELOP SESSIONS TO GIVE YOU THE BEST EXPERIENCE.

BACKGROUND INFORMATION WILL BE USED TO ENSURE WE HAVE A GOOD RANGE OF PEOPLE TAKING PART IN THE STUDY. INDIVIDUAL IDENTIFICATION IS FOR ADMINISTRATION PURPOSES ONLY. YOUR DETAILS WILL NOT APPEAR IN ANY PUBLICATIONS RESULTING FROM THIS QUESTIONNAIRE.

TO BE COMPLETED BEFORE THE SESSION:

NAME:

FARM ADDRESS:

POSITION/ROLE ON THE FARM:

THE FOLLOWING QUESTIONS RELATE TO GENERAL INFORMATION ABOUT YOUR FARM

HOW MANY ADULT COWS ARE THERE ON THE FARM?

WHAT IS THE MAIN BREED OF COW ON THE FARM?

WHAT IS YOUR AVERAGE 305 DAY MILK YIELD?

HOW MANY MONTHS ARE THE COWS HOUSED EACH YEAR?

THE FOLLOWING QUESTIONS RELATE TO LAMENESS DETECTION AND TREATMENT

DO YOU CONSIDER LAMENESS ON YOUR FARM TO BE:

NOT A PROBLEM

MILD

MODERATE

SEVERE

WHAT ARE THE MAIN TYPES OF LAMENESS YOU SEE ON YOUR FARM?

DIGITAL DERMATITIS

SOLE ULCERATION

WHITE LINE DISEASE

OTHER (PLEASE SPECIFY)

HOW DO YOU DETECT LAMENESS ON YOUR FARM?

MOBILITY SCORING

GENERAL OBSERVATION AS COWS ENTER / LEAVE PARLOUR

GENERAL OBSERVATION IN HOUSING

OTHER (PLEASE SPECIFY)

IF MOBILITY SCORING: HOW OFTEN DOES THIS TAKE PLACE?

WEEKLY

FORTNIGHTLY

MONTHLY

OTHER (PLEASE SPECIFY)

WHO IS RESPONSIBLE FOR TREATING LAME COWS ON YOUR FARM?

FARMER

FOOT TRIMMER

VET

OTHER (PLEASE SPECIFY)

DO YOU CONDUCT ROUTINE FOOT TRIMMING

YES / NO

IF YES: HOW OFTEN/AT WHICH STAGE IN LACTATION?

HAVE YOU HAD SPECIFIC SESSIONS ON DETECTION AND TREATMENT OF LAMENESS IN DAIRY COWS BEFORE?

YES / NO

IF YES:

HOW LONG AGO DID THE SESSION TAKE PLACE?

IN THE LAST: 3 MONTHS

6 MONTHS

1 YEAR

MORE THAN 1 YEAR

WHAT TYPE OF SESSION WAS IT?

DISCUSSION GROUP

TALK BY VET/OTHER EXPERT

INDIVIDIAL ON-FARM SESSION WITH OWN VET

OTHER (PLEASE SPECIFY)

DID YOU FIND THE SESSION USEFUL?

YES / NO

COMMENTS:

HAVE YOU MADE ANY CHANGES ON YOUR FARM IN THE PAST TWO YEARS TO REDUCE LAMENESS LEVELS?

YES / NO

IF YES:

PLEASE BREIFLY DESCRIBE CHANGES:

WERE THESE CHANGES AS A RESULT OF TRAINING YOU RECIEVED?

YES / NO

IF NO: WHAT INSPIRED THE CHANGES?

DO YOU FEEL THE CHANGES HAVE MADE A DIFFERENCE TO LAMENESS LEVELS ON THE FARM?

YES / NO

COMMENTS:

WHAT TYPE OF TRAINING SESSION WOULD YOU BE MOST LIKELY TO ATTEND IN THE FUTURE?

DISCUSSION GROUP

TALK BY VET/OTHER EXPERT

INDIVIDIAL ON-FARM SESSION WITH OWN VET

OTHER (PLEASE SPECIFY)

Appendix 5. KT study feedback form

DairyCo KT Study feedback form

Name	**Date**

On a scale of 0-10 where 0 is 'not at all' and 10 is 'very', please draw a line to indicate:

How useful did you find this session?

not at all 0 ——— 10 very

Comments:

How enjoyable did you find this session?

not at all 0 ——— 10 very

Comments:

How likely are you to attend another session of this type?

not at all 0 ——— 10 very

Comments:

How likely are you to make changes on your farm as a result of this session?

not at all 0 ——— 10 very

Comments: