Lameness in Beef Cattle: Establishing a Knowledge Base

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

by

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November 2020

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List of abbreviations

Abbreviation	Expanded form
ADLG	Average daily live weight gain
AC	Agreement coefficient
AHDB	Agriculture and Horticulture Development Board
ANOVA	Analysis of variance
BCS	Body condition score
CAD	Canadian dollar
CHeCS	Cattle Health Certification Standards
CI	Confidence interval
Defra	Department for Environment Food and Rural Affairs
EMA	European Medicines Agency
GB	Great Britain
g	Gram
Kg	Kilogram
NHF	Norman Hayward Fund
NSAID	Non-steroidal anti-inflammatory drug
NSG	Dutch Guilder
OR	Odds ratio
SD	Standard deviation
TMR	Total mixed ration
UK	United Kingdom
US / USA	United States of America
USD	US dollar
VITAL	Virtual Teaching at Liverpool

Acknowledgements

This work would not have been possible without the assistance and support of a number of people. First of all, my thanks go to my supervisors at the University of Liverpool: Karin Mueller, Helen Higgins, Dai Grove White and Jo Oultram, who had the unenviable task of guiding me through this research project. Undoubtedly their encouragement and more importantly patience has been required. Additionally, my thanks go to numerous others at the university, both staff and students, who have provided guidance in various different forms.

My thanks also go to the funders of this research, the Animal Welfare Foundation (Norman Hayward Fund) and the team, as this research could not have taken place without their continued support. I would particularly like to thank them for being so supportive of my two periods of suspension to enable me to fulfil other roles during the project.

The farmers, researchers, clinicians and students that have engaged in the research in various ways, from participating to assisting with recruitment, all have been essential - without these individuals, there would be no research, and so I am extremely grateful. Additionally, the industry bodies and veterinary practices that have supported this research and showed ongoing enthusiasm for the project have my appreciation.

Finally, I thank my family and friends. Although my return to study may not have been part of any career plan, and certain not expected by any, I'm grateful for the support and encouragement I've received.

Abstract

Lameness in Beef Cattle: Establishing a Knowledge Base

Cattle lameness is a considerable welfare concern in the United Kingdom (UK). However, there is a paucity of published literature regarding lameness in UK beef cattle. The aim of this study was to establish a baseline of information on lameness in UK beef cattle.

A four point locomotion scoring system was developed and 40 video clips of beef cattle produced, along with a short training package. These were shown to eight livestock researchers, eight livestock veterinary clinicians and eight veterinary students and the locomotion scoring results from these participants were studied for intra- and inter-observer agreement. Results for both intra- and inter-observer agreement were acceptable, and this scoring system is recommended for use.

A cross sectional study of 18 finishing units and 12 suckler farms estimated a mean farm level lameness prevalence of 8.3% (range 2.0 – 21.2%) for finishing cattle and 14.2% (range 0 – 43.2%) for suckler cows. White line disease and claw overgrowth were the two most prevalent lesions positively associated with lameness for finishing cattle and white line disease and under run sole were the two most prevalent lesions positively associated with lameness for suckler cows. For finishing cattle; poor pen ventilation, high grip flooring and a large pen area provided per animal, and for suckler cows; increasing age and poor pen ventilation were all suggested as risk factors for lameness, and are worthy of further investigation.

Finishing cattle were repeatedly weighed and locomotion scored, and slaughter data collected during a longitudinal study of three farms. Finishing cattle that were lame once or more were estimated to have a 240g reduction in average daily live weight gain. The impact of lameness increased as the proportion of sessions in which an animal was scored as lame increased.

Beef farmers underestimated lameness on their farms, with a mean underestimation of 7 % (95% CI 5 – 9%), when compared to researcher locomotion scoring. Interviews of these 21 farmers identified i) perception of lameness prevalence, ii) technical knowledge and skills, iii) perception of the impact of lameness and iv) barriers to the control of lameness as important themes regarding their approaches to treatment and control of lameness. Important behaviours, such as contraindicated lameness treatment methods, the absence of treatment and confusion regarding transportation of lame animals were identified.

A large scale questionnaire, with 532 eligible responses, found that farmers estimated a low prevalence of lameness on their farms, with a mean farm level prevalence of 0.6% for finishing units, and 2% for suckler herds. Most farmers lacked suitable, safe facilities for examining all four feet of cattle, and some declared that they waited a while before treating lame cattle, whereas others reported that they did not treat lame cattle at all. Conflicting opinions regarding dealing with chronically lame animals was clear, with some farmers feeling that they could transport lame animals to slaughter, and others feeling that they could not. Reported barriers to both treatment and prevention of lameness largely mirrored the themes identified during interviews of the 21 farmers, being i) facilities and location, ii) staff, time and knowledge and iii) concerns over drug use.

These results provide a baseline for further research into lameness in beef cattle, but also from which to further support the UK beef industry with farmer engagement and knowledge exchange, aiming to prompt and support behaviour change.

1 Introduction

1.1 The UK beef industry

There were approximately 1,558,000 suckler cows in the United Kingdom (UK) in June 2018 (1), showing a steady decline from 1,626,000 in June 2009 (2) and 1,596,000 in 2016 (3). The number of holdings keeping beef cattle also fell over a similar period, from 66,279 in 2009 to 57,710 in 2017 (4). The average number of suckler cows per holding has increased from 25 to 27 (4). A larger herd size may partially explain the relatively small drop in cow numbers despite a notable drop in holdings.

The performance outputs of a suckler herd can be measured in a number of ways, most commonly by either comparing the number of calves weaned per 100 cows (or heifers) put to the bull per year, or by using a ‘cow efficiency’ measure: averaging weaning weight of calves (at 200 days old) per weight of cows (or heifers) bred (5). The latter may be a more useful measure of year round performance of a farm, as it considers the growth of a foetus and calf, rather than just conception and survival. A target of over 94 calves weaned per 100 cows has been suggested (5), with the top third of Scottish study herds achieving 89 - 93, and the bottom third achieving 84 - 87 calves weaned per 100 cows, depending upon land type (6). Cow efficiency is a relatively new performance indicator, with a suggested target of 50% (5), meaning that if all cows put to the bull had one calf per year, that calf’s weaning weight would, on average, be half that of its dam if the target were to be met. It has been suggested that many farms are below 40% (7).

Cattle in the months before slaughter (the finishing or fattening period), having been reared solely for beef production, and having never bred, can be termed finishing cattle, fattening cattle or prime cattle. Many are fed a particular ‘finishing ration’ for the duration of the finishing period. At a farm level, finishing cattle are perhaps best considered in terms of either number of animals, or even total weight of animals produced per year, as this shows a better representation of the industry because of the seasonality and variation between lengths of finishing period. The total number of prime cattle slaughtered in the UK in 2016 was 1.994 million (4). In 2009, this number was very similar, at 1.98 million, but in 2000 it was higher, at 2.275 million(2). Despite less animals slaughtered, when measured by red meat production, an increase can be shown, from 707,000 tonnes of beef and veal production in 2000, to 833,000 tonnes in 2009 (2) and to 922,500 tonnes in 2018 (4). This indicates a trend of increasing weight per prime animal since 2000. However, 2017 figures show carcase weights for male cattle are declining, the result of a number of meat processors requesting animals finished earlier, and as such, at a lower weight (8).

This highlights that the numbers of UK beef cattle are decreasing, despite an increasing demand for red meat internationally. This is likely to lead to farmers attempting to optimise performance and farm efficiency to provide a consistent, predictable product, which meets consumers' requirements (9).

1.2 Cattle lameness

The term lame can typically be defined as:

'Incapable of normal locomotion; deviation from the normal gait. The commonest cause of lameness in animals is pain in a limb or its supporting structures, but contractures of joints, and deformities and shortness of limbs are also causes' (10)

and various descriptions may use terminology such as asymmetry, incoordination and inefficient (11), suggesting that defining what is normal and what is not, requires interpretation. This interpretation provides an opportunity for disagreement, as well as difficulty in understanding and comparing true lameness prevalence between system types, breeds and countries. Scoring systems have been utilised to reduce this disagreement, however there are a number in use.

1.2.1 Lameness detection

Lameness can typically only be assessed when an animal walks (or attempts to walk) unless it is severe, when inability to bear weight is detectable, even at rest (11). The majority of scoring systems take no account of chronicity, prognosis or pain, but concentrate on descriptive terms for how an animal walks between two points (12–14). Furthermore, they do not differentiate between hoof lesions and other limb lesions or injuries. This makes lameness scoring practically applicable, and allows it to be carried out at one point in time to determine a prevalence. Lameness scoring is also known as ‘locomotion scoring’ or ‘mobility scoring’.

Scoring systems have been used for many years to perform locomotion scoring in cattle (12), and more latterly they have been used to locomotion score sheep (15). Different systems tend to vary in two main aspects. The first variation is the emphasis given to observed factors, including posture / back arching, speed of leg movement, head movement and foot placement. The second variation is the number of grades. More grades allow more detail, and more specific division of severity. However, less grades makes it quicker to use, and easier to train ‘scorers’ to conduct the process. A simpler system is sometimes chosen in order to reduce the inter-observer variability between scorers (16). The usefulness of these different systems is likely to vary depending on their purpose, for example whether the system is used to score the severity and clinical progression of individual lame animals, or to establish a herd prevalence. Although there is no rule as such regarding the environment in which to perform scoring, most studies looking at dairy cattle scoring systems agree that they should be performed with cows walking on a firm, even surface with sufficient grip (17).

For determining farm level lameness prevalence, some studies have utilised farm records of lameness (18), requiring farm staff to perform lameness detection before recording it. This method of data collection depends upon different observers across different farms, with different knowledge and training, and likely to be using different lameness detection systems. Intra-observer reliability could be a weakness of this method. Crucially it also requires any lame animal to be recorded, which may lead to under reporting of lameness (13,19). Where this recording is in a medicine book, it could lead to lame animals treated with medicines to be more likely to be recorded than those not treated with medicines (20).

1.2.2 The use of locomotion scoring systems for beef cattle

There is limited evidence of broad use of lameness scoring systems in beef cattle. However, Fjeldaas *et al*. (21) conducted a study where different foot trimmers scored cows in different Norwegian beef herds. They graded cows as 0 for ‘absent (no lameness)’, 1 for ‘asymmetric gait, bearing weight on all limbs’ and 2 for ‘avoiding weight-bearing on one or more limbs’. Simon *et al*. (22) also used a three point scoring system, but looked at whether an affected limb is identifiable, speed of walking, length of stride and ability to place weight on an affected limb.

Lameness scoring in finishing or feedlot systems has been conducted a little more frequently than in beef cows. Terrell *et al.* (23) used a 0 to 3 system developed by veterinarians and welfare experts at Kansas State University which monitored stride length, head bob, how identifiable an affected limb was, willingness to bear weight and a general willingness to move to score an animal 0 to 4. The Zinpro Corporation Step-Up locomotion scoring system (24) was created in conjunction with the work of Terrell *et al*. This involves a 0 to 3 scoring system, concentrating on head movement, stride length, an identifiable limp and weight bearing. The North American Meat Institute Animal Welfare Committee has produced an online teaching resource for cattle handlers (25), which uses a 1 to 4 scale, plus a fifth score of ‘downer’ for immobile animals. This system is similar to others above, but includes identifiable stiffness, discomfort and relative speed when compared to normal cattle in its criteria. This scoring system was designed for use in the packaging industry, where large numbers of finished cattle are unloaded from vehicles, and moved around for processing and slaughter. Cattle are typically moved in groups, with little opportunity to observe individuals. This makes relative speed an important observation criteria. Edwards-Callaway *et al*. (16) have described how evident it is in these packaging plants that some animals exhibit signs of lameness yet still keep up with the rest of the group, whereas other animals were ‘so impaired they lagged behind most cattle in their group’.

There is a lack of published information regarding the use of any of these systems in the UK beef cattle industry. Some of these systems, or alternative ones may be in use on a small scale, for example within a group of farms or abattoirs. However, to the author’s knowledge, the use of a scoring system is not common within the UK beef industry, nor has any system been assessed for reliability in beef cattle.

1.2.3 The use of locomotion scoring systems for dairy cattle

A number of locomotion scoring systems have been used in dairy cattle (26). By 2007 in the UK, concerns were raised that the large number of scoring systems was leading to confusion, both to farmers and the farming industry (27) and was making comparison of research findings difficult (18). Following discussion forums and farmer consultation, DairyCo (now Agriculture and Horticulture Development Board, AHDB) promoted a 4 point mobility score (27,28). This 0 to 3 scale concentrates on weight bearing, stride length, whether a lame limb is identifiable and whether an animal can keep up with the healthy herd. This system has been promoted by a number of major UK milk buyers and supermarkets (29) since its introduction, and, based on literature citations, it is now the second most frequently used system for researching lameness in British dairy cattle since 1975 (18).

Internationally, however, there are still a large number of scoring systems in use for dairy cattle, both for research and commercial use. Many recent scoring systems have taken some guidance from the system introduced by Sprecher *et al*. (12). This 1 to 5 system concentrates on back posture and normal gait for the low scores, and notes differences in stride length and weight bearing along with back posture at the higher scores. It was used by 27.9% of 244 locomotion scoring research articles examined by Schlageter-Tello *et al*. (17), notably more than any of the other 24 observer based system.

1.2.4 Automated lameness detection systems

Automated lameness detection systems have been introduced. They have the potential to reduce bias, in particular bias due to intra and inter observer reliability. Schlageter-Tello (17) identified 15 different automatic scoring systems used for dairy cows, and described them as either kinetic (involving measuring forces), kinematic (measuring time and distance relating to limbs or posture variable), or indirect approaches (measuring behaviour or production in various ways, for example incorporating milk production or rumination into a calculation, to indicate level of locomotion (30)). A number of these automatic methods used manual, human observation scoring systems as a reference for calibration and also for initial validity assessment.

1.3 Lameness prevalence in the UK

1.3.1 Lameness prevalence in beef cattle

The prevalence of lameness in the UK beef herd is unreported. A 2007 study of Norwegian suckler cows estimated a lameness prevalence of 1.1% of cows across 12 herds, based on locomotion scoring by several trained foot trimmers as animals walked to the trimming facility (21). An incidence rate of 1% was estimated for 6 large feedlots in Kansas and Nebraska in 2017, scored by trained farm staff (23), and a rate of 2% was determined by analysing farm records across 5 feedlots in the western United States (US) in 1993 (31). A mean of farmer, veterinarian and nutritionist estimates of feedlot lameness incidence was 3.8% in a US study from 2014 (32). In Alberta, Canada, researchers used health records over a 10 year period from 2005 to estimate a lameness prevalence of 4.5% across 28 feedlots. Research has also been conducted at US livestock markets, observing cull cows and bulls presented, with 15.1% of beef cows and 15.4% of beef bulls judged to be lame (33).

1.3.2 Lameness prevalence in UK dairy cattle

Two recent studies have estimated the mean farm level prevalence of lameness of UK dairy cattle to be 31.6% (34) and 30.1% (35) using data from 61 farms in 2015 - 2016 and from 43 farms in 2014 respectively. Both used the AHDB 4 point mobility scoring system. Clarkson *et al* (36) reported a mean farm level lameness prevalence of 20.6% across 37 dairy farms in England and Wales in 1989 - 1991, as determined by trained observers, using a 1 - 5 system (37). A number of studies have investigated lameness in UK dairy cattle between the dates of these studies, estimating prevalence's of 22.1% (13), 15% for grazing cattle and 39% for zero-grazing cattle (38), and 36.8% (39), suggesting that the prevalence has remained consistently high for the last two decades.

1.4 Effects of lameness on production outcomes

1.4.1 Effects of lameness on beef cattle production

In beef systems rearing cattle for slaughter, production performance parameters such as daily live weight gain, days on farm (or days in a particular stage of rearing, e.g. finishing period), or carcass classification grading at slaughter are monitored.

Financial parameters, such as price per Kg, may also be used, but these can be difficult to interpret with fluctuating markets.

Lame beef bulls at slaughter were found to have a lower weight than their non-lame counterparts, possibly due to earlier culling combined with a reduced feed intake (40). Salvaged lame feedlot cattle were shown to only reach 53% of their purchase price in a US study (31), and in Canadian feedlots some cattle showed negative returns of -CAD[1] 701, compared to +CAD 690 for non-lame healthy cattle (41). Both beef cows and beef bulls realised reduced prices (per Kg) when sold at US livestock auctions, with more severe lameness grades realising a greater reduction (33).

Lameness is an important factor affecting semen quality in breeding beef bulls (42), and joint lesions in particular can lead to reproductive failure, even when bulls show no obvious clinical lameness (43). It is likely that this is due to pain affecting luteinising hormone (LH) secretion and thereby reducing testosterone secretion, which is required for spermatogenesis (44,45).

Lameness has been estimated to cost USD[2] 121 per lame feedlot animal (USD 2.54 per animal purchased), and USD 18 million in Nebraska (1993 prices).

1.4.2 Effects of lameness in dairy cattle production

Compared with the UK beef sector, the effects of lameness on the dairy industry and dairy cattle productivity have been well reported. Reduced milk yield has been associated with lameness (46–48), with some studies identifying a reduction preceding clinically detectable lameness (49), either suggesting detection (via locomotion scoring in this case) is not adequately sensitive, or a shared cause, as a result of which milk yield changes first. This reduction in milk yield can be difficult to identify in some cases, as lame cows were more likely to have had higher milk

[1] CAD: Canadian dollar
[2] USD: United States dollar

yields earlier in their lactation, compared to cows that do not become lame (50,51). In effect, higher yielding cows are more likely to become lame therefore the reduction in milk yield may leave lame cows within a normal range for their given farm, despite their potential.

Reproductive performance is negatively affected by lameness. Lameness is associated with reduced maximum progesterone concentration for several days before oestrus, and a subsequent reduction in the frequency of sexual behaviour expression when in oestrus (52,53) leading to longer calving to first service intervals (54). Lameness also reduces the likelihood of a cow ovulating (55), leading to longer calving to conception intervals (54,56), increased calving intervals (57), and lame animals are likely to require more services per conception than their non-lame counterparts (12).

Studies into the effect of lameness on the likelihood of an animal being culled show some ambiguity. Most publications suggest that lameness leads to a greater likelihood of an animal being culled (12,58–60), but some suggest no effect of lameness on culling likelihood (61), and one study even suggests that lameness reduced the likelihood of an animal being culled (62). The relationship between culling and lameness is likely to be complex, as it involves a decision making process that may vary by farmer or farm. For example, lameness may make it difficult to get much financial return on a cull animal because of fitness to transport aspects (63), so a farmer may choose to wait, hoping it becomes non-lame. Alternatively, an animal destined to be culled may become lame because of less favourable management (for example, sub-standard housing or exclusion from routine preventative foot trimming). A farmer may also wish to retain lame animals that continue to yield well (50).

At slaughter, an animal with a lameness history is likely to have a reduced live weight, and an inferior carcass grading (59,64,65), compared to a non-lame counterpart, although some lameness causing lesions have been associated with different effects. For example, corkscrew claws, heel horn erosion and tarsus lesions were associated with inferior carcass qualities at slaughter, compared to white line lesions, which were associated with positive slaughter characteristics and sole ulcers, which were associated with some positive and some negative slaughter characteristics (59). This may be due to risk factors for particular lesions also leading to positive slaughter characteristics, and so a confounding effect is seen.

The suggested increased likelihood of having a reduction in milk yield, poorer reproductive performance, and being culled early, is further worsened by a lameness event increasing the likelihood of an animal becoming lame again (66,67).

These production factors have an economic impact of lameness, which is difficult to fully estimate, but includes the milk yield loss, decreased reproductive performance costs, costs associated with culling (including loss of genetic potential), costs of additional management, treatment costs, costs of milk discarded during treatment and costs related to the risk of spread for contagious causes of lameness (68). Cost estimates range from £425, as an average cost per cow with a sole ulcer (based on 1995 prices) (69), to clinical cases of lameness costing NLG[3] 50 (approx. £15 in 1997) per cow in the herd (65). Subclinical cases have been suggested to cost €13 per case (£11 in 2010) (70). Lameness has been estimated to cost the typical UK dairy herd £7,499 per year (71), and two studies have estimated varied costs of £53.5 million (72) to the GB dairy industry and £127.8 million (71) to the UK dairy industry.

1.4.3 Effects of lameness on sheep production

Some parts of the UK beef industry are more comparable to the sheep industry than to the dairy industry, with cattle spending all, or most of their lives grazing,

[3] NLG: Dutch guilder

sometimes a long way from the main farm, making it difficult to monitor, examine and treat animals. As such, the effects of lameness on sheep production may offer useful guidance for researching effects of lameness on the UK beef sector.

Wethers (male castrated sheep (10)) in a group with a footrot infection had 7.3Kg (11.6%) lower mean bodyweight, and a 0.4Kg (8%) lower mean fleece weight over a 2 year period (73). A more recent study also identified weight loss in lame sheep compared to non-lame sheep over 11 months (74). More virulent strains of the footrot causative agent (*Dichelobacter nodosus* (75)) will cause a greater weight loss than less virulent strains (76). Lameness in a dairy ewes reduced milk yield by approximately 24% per lactation (77). The lamb crop from lame ewes with footrot is expected to be lower than that of non-lame ewes, and their offspring are also likely to have a reduced birthweight (78). The cost of footrot to the GB sheep industry is estimated to be £24 million, with approximately half arising from preventative measures, and half arising from a combination of treatment costs, and production losses (78).

1.5 Welfare implications of lameness

Cattle lameness is considered one of the priority welfare topics for the dairy industry (79). A true understanding of the welfare cost to an animal is not possible, as its own experience is not understood by humans (80). There are a number of proposed frameworks which could be utilised to assess welfare, for example the ‘three spheres’ framework (biological functioning, natural behaviour and affective states (81)), the ‘Vienna’ framework (frequency, duration, arousal, context, previous experience, individual differences, sense of agency and long term benefit (82)), ‘a life worth living’ framework (a life not worth living, a life worth living or a good life) (83) the five domains (84,85) or even a qualitative assessment of positive welfare behaviours (86). However the five freedoms framework (87), has been utilised here to gain insight into the welfare implications of lameness in cattle:

1. Freedom from hunger and thirst
2. Freedom from discomfort
3. Freedom from pain, injury or disease
4. Freedom to express normal behaviour
5. Freedom from fear and distress

1.5.1 Freedom from hunger and thirst

Lameness has been associated with changes in lying and feeding behaviour, with lame animals showing increased lying bout duration (88), increased total lying duration (89) and reduced time walking (89,90). It has been suggested that lame cows have a lower bite rate whilst grazing compared to non-lame cows (90), and have reduced daily feeding duration, a reduced number of feeding bouts and an increased feeding rate (kilograms of fresh matter eaten per minute) (91). This altered feeding behaviour is likely to compromise an animal's freedom from hunger (and possibly thirst).

1.5.2 Freedom from discomfort

Lame cattle spend more time lying down (89), it is likely that this, in part is due to difficulty lying and rising (80). In addition, the lying time of lame cows varies depending on lying surfaces, with those on sand or deep littler bedding lying for longer (92,93). This suggests that some are more comfortable, an important consideration for recovery. These findings indicate that lame animals experience discomfort.

1.5.3 Freedom from pain, injury or disease

Although some definitions of lameness mention that it is not always a painful condition, most highlight that it normally is (10). Exceptions can be due to malformations, particularly malformations of the upper limb, and fused joints, however most cases of lameness in dairy cows are known to be associated with foot lesions (20,94). Pain is an interaction between a physiological effect and an emotive response, and as such there is no current method to truly assess this in animals. However, it would be acceptable to regard lameness to be painful (95,96). This is supported by findings of prolonged hyperaesthesia and lowered pain threshold in lame cattle (95), and improved locomotion scores in animals administered Non-Steroidal Anti Inflammatory (NSAID) (96,97). Additionally, as most cases of lameness are associated with foot lesions (20,94), disease is present in all of these cases. Consequently, we can expect this freedom to be compromised in most cases of lameness.

1.5.4 Freedom to express normal behaviour

The normal behaviour of cattle would usually include feeding, drinking, resting, ruminating and social interactions (80,98). Lameness is associated with changes in time budgets in a number of these behaviours, for example, feeding behaviour, where lameness leads to reduced feeding duration (90), and changes in social reproductive behaviours (53). Furthermore, lying time is increased (89), suggesting that lame cattle are not expressing their normal behaviour.

1.5.5 Freedom from fear and distress

There is limited research regarding the association between lameness and fear and distress (80). However, it should be considered that lame animals may separate themselves from the herd and feel vulnerable to predators (99), and the process of being examined and treated for lameness is likely to induce a fear response in cattle.

All five freedoms probably are at risk of compromise in any given case of lameness. Although most research is derived from lame dairy cattle, there is some international attention to welfare in beef cattle, including transport and slaughter (22,32,100,101), and some recent attention in the UK, where authors postulated the possibility that some beef cattle remain lame for longer periods of time than dairy cattle, due to facilities and housing location constraints (102).

1.6 Perceptions of lameness

Evidence regarding the effects of lameness on production parameters has been discussed, and the impact on welfare highlighted. The prevalence of lameness in UK dairy cattle, and in a small number of international beef cattle studies has been presented. However, it is crucial that farmers and farm staff act in order to effect change. These key stake holders are likely to be the person who has the first opportunity to identify a lame animal, decide whether to treat it, perform or pay for that treatment and monitor any improvement. They are also likely to be responsible for implementing and financing any preventative measures. This suggests that without buy-in from farmers and farm staff, a transition from evidence to improvement will be limited.

In order to engage farmers and farm staff with cattle lameness awareness, as well as treatment and prevention, it will help to understand the current situation. UK dairy farmers have been shown to typically underestimate lameness on their farms (19,103). Assuming lameness is recognised and evidence presented that action will lead to improvement, some farmers may not act upon this advice (104). Reasons for this may include a wish to maintain simplicity, or current habits, or even self-confidence in own knowledge of required actions. Farmers' motivations for deciding whether or not to deal with lameness are likely to vary, but probably fall into categories of economic reasons, wishing to avoid penalties / receive premiums, or a desire to have an efficient farm that meets regulations (105).

Veterinarians have been identified as an important source of information for a farmer (106), although findings suggest that foot trimmers and feed advisors may be important sources for some farmers (107), and some farmers may even feel that their veterinarian has insufficient knowledge to help with certain topics (108). It is also important to acknowledge that within the veterinary or other professions there will be differences in opinion regarding whether, or how, to treat or prevent lameness on farms (99,109).

The literature suggests that perceptions of lameness vary across the cattle industry, but little information is available regarding UK beef farmers perceptions of lameness. The ability to locomotion score, the motivation to act regarding treatment and prevention, and the knowledge of how to treat or prevent lameness are all potential barriers to lameness control within the UK beef industry.

1.7 Diseases of the foot

Cattle lameness causes are commonly categorised into either foot or non-foot lesions. Foot lesions are generally sub-categorised into claw horn (non-infectious) or infectious diseases conditions, or a mixture of these two (110,111). Lesions are then further categorised by specific lesions nomenclature. Claw horn lesions include white line disease, sole haemorrhage, sole ulcers, double sole (also known as under-run sole), and axial fissure. Infectious lesions include digital dermatitis, interdigital dermatitis, interdigital phlegmon (also known as foul, foul in the foot or cattle foot rot) and heel horn erosion (110,112,113). Combined claw horn and infectious lesions are sometimes termed 'non-healing' lesions, and can be due to a claw horn lesion later becoming infected (114,115). An example of a lesion likely to be a combined lesion is Toe Necrosis (114).

1.8 Non-foot diseases

Reports of non-foot related lameness lesions are less frequent than reports of foot lesions. This could be due to a true lower prevalence, or due to difficulties in identifying and diagnosing some upper limb lameness lesions, possibly requiring imaging equipment, or post mortem. Findings of a retrospective study of records of beef cattle presented to a veterinary teaching hospital in Canada (116) found that approximately 16% of lame animals had non-foot related lesions, with stifle, tarsus and pastern lesions respectively being most prevalent. Joint disorders such as osteochondrosis have been reported in growing beef cattle (117,118), and muscular lesions have been identified, especially in well-muscled animals (119). A study of both dairy and beef cattle at a Canadian veterinary teaching hospital (120) identified subchondral bone cysts, joint instability and degenerative joint disease as the most frequently presented stifle lesions. However, nerve injuries, fractures, septic arthritis and tendon lesions should be considered possible causes of non-foot lesions (121).

1.9 Risk factors for lameness

There is a paucity of information regarding lameness in UK beef cattle. Studies from other countries have shown that stocking density of finishing cattle can affect lameness prevalence (40), although some found that stocking density only affected the recovery of those that did become lame (122). The flooring type that finishing cattle are kept on can affect lameness risk, with slatted flooring leading to animals being at greater risk (40,123,124). Animal factors are also important, with male or Charolais finishing cattle showing a higher predisposition to lameness than females or other breeds (123). UK studies have identified a possible shared aetiopathogenesis for digital dermatitis between beef cattle, dairy cattle and sheep (125), and the GI system as a possible reservoir for causal treponemes (126), suggesting that co-grazing or shared facilities or equipment may be a risk factor for transmission.

Risk factors for lameness have been investigated for UK dairy cattle (14,34,39,46,67,127–129). The bedding type, frequency of foot trimming, foot bathing protocols, floor grooving characteristics and the amount of concentrate cattle are fed all impact upon farm lameness prevalence (34). The presence of damaged concrete and sharp turns near the parlour entrance or exit and the duration of housing also influence lameness prevalence (39). Older cows, and those more intensively managed are also more likely to be lame (46), as are cows with a low body condition score (BCS) (67). Although these factors should not be extrapolated directly to the UK beef sector due to the different living environment and daily routine of beef cattle, they provide some insight into potential risk factors for lameness in beef cattle.

1.10 Treatment and control of lameness

A number of text books and other non-peer reviewed literature provide suggestions for lameness treatment with moderate agreement between protocols (130–139). Few peer reviewed publications investigate how to treat lameness related lesions, and those that do often do not include treatments for all common lesion types (130). A recent publication regarding claw horn lesions does investigate the use of therapeutic trimming of lame dairy cows plus one of therapeutic blocking of a sound claw, NSAID drug administration, and therapeutic blocking plus NSAID use, finding that blocking of the sound claw with NSAID administration was significantly more likely to lead to a sound outcome (97). Similar findings support the notion that analgesics are beneficial for the relief of lameness (95,96,140). A survey of on-farm treatment of sole ulcers (141) highlighted that dairy farmers often treated sole ulcers and white line disease the same. Trimming, with or without blocking the unaffected claw was the most frequently reported treatment used by dairy farmers, with some farmers using antibiotics, analgesics and / or moving lame animals to straw pens as part of their protocol. Foot-trimming has been found to reduce the risk of digital dermatitis on dairy farms (142), as well as spraying feet with a mixed copper and zinc based product on a regular basis. Crucially, early treatment has been identified as a key factor for resolution of lameness (143). Foot bathing of cattle has been recommended for the control of infectious lameness causing pathogens, as well as suggesting that some products may harden the hoof, protecting from claw horn lesions (144). Although limited research has been conducted regarding foot bath products, both formalin and copper based products have the potential to be effective for prevention and treatment of digital dermatitis (145,146), but foot baths at a reduced frequency may not have a positive effect, and may even increase the prevalence of digital dermatitis (146). Historically, antibiotic footbaths have been considered an option in the UK as a treatment for digital dermatitis, however there is industry concern regarding antibiotic foot bathing (147) due to antibiotic use and concerns regarding statutory milk and meat withdrawal periods (147). The Responsible Use of Medicines in Agriculture Alliance guidelines (148) state that improved building design, foot cleaning and routine foot bathing, with non-antimicrobial products, should be utilised, in order to prevent and control digital dermatitis, reducing the requirement for antibiotics.

1.11 Conclusions

There is very little published information regarding lameness in UK beef cattle, including the prevalence of lameness, the lesion types associated with lameness, the risk factors or effects of lameness, or perceptions of lameness in beef cattle. There is notably more evidence regarding lameness in UK dairy cattle and sheep, and this evidence suggests that lameness in beef cattle can be considered a welfare issue, and is likely to have an impact upon productivity. This highlights the need for a baseline of evidence regarding lameness in beef cattle.

1.12 Objectives

The objectives of this thesis research were designed to form a baseline of information regarding lameness in beef cattle, in order for this to be further built upon.

Objective 1: To investigate the reliability of a locomotion scoring system for use in clinical practice

Objective 2: To estimate the prevalence of lameness in UK finishing cattle and suckler cows, as these represent two distinct sectors of the UK beef industry.

Objective 3: To identify lameness associated lesion types and frequencies present on beef units, and estimate their prevalence, and association with lameness.

Objective 4: To explore potential risk factors for lameness in UK finishing units and suckler farms.

Objective 5: To identify production impacts of lameness on UK finishing units.

Objective 6: To identify UK beef farmer perceptions of lameness by means of in depth interviews.

Objective 7: To investigate UK beef farmer perceptions of lameness by means of an online and postal questionnaire, developed and informed by in depth interviews.

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Chapter 2

Reliability of a Beef Cattle Locomotion Scoring System for use in Clinical Practice

Tunstall J, Mueller K, Sinfield O, Higgins HM. Reliability of a beef cattle locomotion scoring system for use in clinical practice. Vet Rec. 2020;187(8).

2 Reliability of a Beef Cattle Locomotion Scoring System for use in Clinical Practice

2.1 Abstract

Locomotion (lameness) scoring has been used and studied in the dairy industry, however to the author's knowledge, there are no studies assessing the reliability of locomotion scoring systems when used with beef cattle.

A four point scoring system was developed and beef cattle filmed walking on a firm surface. Eight veterinary researchers, eight clinicians and eight veterinary students were shown written descriptors of the scoring system and four video clips for training purposes, before being asked to score 40 video clips in a random order. Participants repeated this task four days later.

The intra-observer agreement (the same person scoring on different days) was acceptable with weighted mean Kappa values of 0.84, 0.81 and 0.84 respectively for researchers, clinicians and students. The inter-observer agreement (different people scoring the same animal) was acceptable with weighted Gwet's Agreement Coefficient values of 0.70, 0.69 and 0.64 for researchers, clinicians and students respectively. Most disagreement occurred over scores one (not lame but imperfect locomotion) and two (lame, but not severe).

This scoring system has the potential to reliably score lameness in beef cattle and help facilitate lameness treatment and control, however some disagreements will occur especially over scores one and two.

2.2 Introduction

Lameness in cattle is considered to be a critical welfare issue (79,149), with lame beef cattle being a specific issue due to the risks of being left untreated for a long period of time (102). Identification of lame animals is considered to be an important step in dealing with individual animals, but also in acknowledging and understanding the scale of the problem. As such, the United Kingdom (UK) dairy industry is encouraging farmers to locomotion score cattle (28,149), and a sheep locomotion scoring tool is available (15). Locomotion scoring also allows benchmarking, meaning that farmers can understand how they compare to others, and allows improvements or deteriorations to be measured over time. However, this requires scorers to be able to give an animal with any given locomotion the same score on any given day. Furthermore, it requires different scorers to also give an animal with any given locomotion the same score, in order for the results to be consistent. In particular, a practical and easy to use scoring system is needed that can be used by veterinary surgeons in clinical practice. This is different to scoring systems designed specifically for research purposes with typically considerable detail and a large number of possible scores. While necessary for research reasons, it makes them more complex and hence less practical for use by clinicians and is not essential for the routine monitoring and control of lameness in clinical practice.

Any locomotion scoring system would ideally have been proven to be *valid* in the sense that it accurately measures lameness, and also *reliable* which encapsulates the extent to which there is consistency (repeatability) in scores when independent measurements are performed. Although assessing validity of a locomotion scoring system can be challenging, reliability can be assessed in two regards. Inter-observer reliability relates to multiple people scoring the same animal and asks the question: how consistent are the scores they assign? In other words, do different people agree with each other over the same animal? Intra-observer reliability relates to the same person scoring the same animal on different occasions (with degree of lameness unchanged), and asks the question: to what extent does a person agree with themselves?

In dairy cattle, several scoring systems have been developed and reported in the literature, typically based on a combination of subjective visual observations such as back arching, stride length, weight bearing and so forth (12,28,36). However, to the author's knowledge none of these have been assessed for reliability when scoring beef cattle.

The aim of this study was to assess the inter- and intra-observer reliability of a locomotion scoring system for use with beef cattle in clinical practice by veterinary surgeons.

2.3 Methods

2.3.1 Locomotion scoring system

A four point locomotion scoring system was developed following consultation between JT and the research team (DGW, HMH, JO, KM) based around two current dairy cattle scoring systems, but with due consideration for the practicalities and specific attributes of beef cattle (12,28). Of these two dairy cattle scoring systems utilised to develop the new one, the AHDB system is one commonly used in practice the UK, and the Sprecher system is well publicised and cited internationally. The descriptors are given in **Table 2.1**.

Table 2.1 The proposed locomotion scoring system designed for use in beef cattle (adapted from Sprecher (12) and AHDB (28) scoring systems.

Locomotion Score		
0	Normal	Even weight-bearing and rhythm on all four feet. The back is level.
1	Imperfect	Uneven steps or shortened strides, but affected limb not identifiable. The back may show minimal arching while walking.
2	Impaired	Uneven weight-bearing or shortened strides. Affected limb is identifiable (unless multiple limbs affected). The back may show arching while walking
3	Severely impaired	Slower pace - unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected). An arched back may be noted while standing and walking.

2.3.2 Video clips and on-line completion

Video clips were created by filming both suckler cows and finishing cattle walking on a firm surface, either from the rear, the side or a transition from side to rear. Where necessary, the animal intended as the focus of the video was identified with an arrow to avoid confusion and any audio was removed. These clips were examined by three experienced researchers to ensure a sufficient range of scores were present (approximately ten of each score, zero, one, two and three) and yielded a total of 40 video clips for assessment by participants. The researchers' also selected four additional video clips to be used for training purposes (one clip for each score) that they agreed were typical of each score.

The 40 assessment video clips and 4 training clips were uploaded onto the University of Liverpool's virtual learning environment (VITAL – Virtual Interactive Teaching at Liverpool), which uses Blackboard 2018 (Blackboard Inc. Washington, USA). This platform enabled participants to view the training videos alongside the descriptors for each score at the start. They could re-play the training clips as many times as they wanted. Thereafter, they were asked to watch each of the 40 assessment videos and assign a score to each. Videos lasted between 1 and 18 seconds. Each assessment video could also be re-played as many times as the observer wanted. The order of the assessment videos was randomised for each participant. After four days, the observers were asked to repeat the entire task i.e. to watch the training videos and read the descriptors again and re-score the 40 assessment videos, which were presented again in a randomised order.

2.3.3 Observers

Observers were a convenience (non-random) sample of eight private practice veterinary surgeons ("clinicians" or "C") involved with livestock work and undertaking postgraduate livestock courses alongside their clinical role, eight veterinary researchers / lecturers involved with livestock research / teaching ("researchers" or "R") and eight veterinary students, in years three to five of a five year course ("students" or "S"). Observers were coded 1-8 for each group ordered by their intra-observer exact agreement percentage.

2.3.4 Data Analysis

The data was exported from VITAL into Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington, USA). Statistical tests were conducted in

Minitab 18.1 (Minitab Statistical Software, State College, Pennsylvania, USA), and R (R Core Team, 2019), including Computing Chance-Corrected Agreement Coefficients R Package (irrCAC, Gwet 2019). P values are reported as continuous values and without setting any arbitrary threshold (150,151). Quadratic weightings were used to produce weighted Kappa values and AC2 values.

2.3.5 Intra-observer agreement

Percent exact agreement (and +/- 1 and +/- 2 scores) was calculated for each observer across the 40 videos and mean values for the three different groups (i.e. the researchers clinicians and students) were compared with paired t-tests. Differences between the same observer at the first and second scoring (intra-observer agreement) were examined using weighted Cohen's Kappa values (152), and the difference between mean values for researchers, clinicians and for students was compared using paired t-tests. Systematic bias between attempts for each scorer was investigated by subtracting each observer's second score from their first, and performing a one sample t-test on the resulting value (null hypothesis: the mean value equals zero, alternative hypothesis: the mean value is not equal to zero).

2.3.6 Inter-observer agreement

Inter-observer scores were investigated using each observer's first attempt at scoring the videos.

The percentage of video clips that an observer agreed on with each individual observer in their group (i.e. the researchers, clinicians and students) was calculated to produce seven scores. The mean of these scores produced the mean exact agreement for that observer. This was repeated for each of the twenty four observers to initially assess the agreement within groups. Agreement was formally analysed using quadratic weighted Gwet's Agreement Coefficient 2 (AC2). An AC2 value was produced for each group of observers (researcher, clinician or student), and overall for all observers. AC2 values were adjusted using Critical Values provided by Gwet 2010 (153,154).

For each video, the mode score was determined, and considered to be the correct score. One video was bimodal, and the mean score was utilised to determine which mode to consider correct. All videos of each score were then grouped and an AC2 value generated for each score to show the agreement of observers for each individual locomotion score. This was performed for each group of observers, and overall.

Ethical approval was granted by the University of Liverpool Ethics committee (VREC533a). It is reported in accordance with the guidelines for reporting reliability and agreement studies (GRAAS) (155).

2.4 Results

The distribution of scores, as determined by the mode score for each video, were: score 0: 12 clips, score 1: 10 clips, score 2: 9 clips, and score 3: 9 clips. The results for one video were bimodal, therefore the mean score was utilised to determine which mode to consider the correct score.

2.4.1 Intra-observer agreement

Three observers did not provide a score for one clip on their second scoring session (all differed on the clips not scored). The individual's scoring for that clip were not included in the analysis for intra-observer agreement.

For all 24 observers, the mean exact agreement between first and second observation was 66.0% with a 95% confidence interval of 61.9% - 70.1%, it was 68.0% (61.7% – 74.3%) for researchers, 63.3% (51.7% - 74.9%) for clinicians and 66.8% (60.9% - 71.7%) for students (**Table 2.2**). Agreement within one score (with 95% confidence in brackets) was achieved as follows for researchers, clinicians and students: 98.4% (96.8% - 100%), 97.5% (95.0% - 100%) and 98.7% (97.1% - 100%). The clinicians achieved 99.7% agreement within two scores, the researchers and students achieved 100% agreement within two scores. The clinicians achieved 100% agreement within three scores.

The mean weighted Kappa value for agreement between first and second observation was 0.84 with a 95% confidence interval of 0.78 - 0.89 for researchers, 0.81 (0.73 - 0.89) for clinicians and 0.84 (0.82 - 0.86) for students (see also **Table 2.3**). As shown in **Table 2.4**, there may be some systematic bias between observations for some observers (examples could include researchers 1 and 2, clinician 6 and students 3, 6 and 7).

Table 2.2 Percent exact agreement between locomotion scores given during sessions 1 and 2 (and within 1 and 2 points) for each observer. Means and standard deviation (SD) presented. Difference in means between two groups presented with 95% confidence Intervals.

Observer	Intra observer agreement (%)		
	Exact agreement	+/- 1 score agreement	+/- 2 score agreement
Researcher 1	56.4	94.9	100.0
Researcher 2	60.0	97.5	100.0
Researcher 3	65.0	100.0	100.0
Researcher 4	67.5	100.0	100.0
Researcher 5	67.5	97.5	100.0
Researcher 6	75.0	100.0	100.0
Researcher 7	77.5	97.5	100.0
Researcher 8	77.5	97.5	100.0
Mean (SD)	68.0 (7.5)	98.4 (1.9)	
Clinician 1	40.0	92.5	100.0
Clinician 2	45.0	95.0	97.5
Clinician 3	64.1	100.0	100.0
Clinician 4	65.0	95.0	100.0
Clinician 5	67.5	100.0	100.0
Clinician 6	70.0	100.0	100.0
Clinician 7	75.0	97.5	100.0
Clinician 8	80.0	100.0	100.0
Mean (SD)	63.3 (13.9)	97.5 (3.0)	99.7 (0.9)
Student 1	57.5	100.0	100.0
Student 2	60.0	100.0	100.0
Student 3	61.5	94.9	100.0
Student 4	62.5	100.0	100.0
Student 5	70.0	100.0	100.0
Student 6	72.5	100.0	100.0
Student 7	75.0	97.5	100.0
Student 8	75.0	97.5	100.0
Mean (SD)	66.8 (7.1)	98.7 (1.9)	
Mean of all observers (SD)	66.0 (9.8)	98.2 (2.3)	99.9 (0.5)
Difference in means between two groups (95% CI)			
Researcher – Clinician	4.7 (-11.8, 21.1)	0.9 (-2.4, 4.3)	0.3 (-0.4, 1.1)
Researcher – Student	1.2 (-10.4, 12.9)	-0.3 (-2.1, 1.5)	
Clinician – Student	-3.4 (-13.6, 6.7)	-1.23 (-4.0, 1.5)	-0.3 (-1.1, 0.4)

Table 2.3 Weighted Kappa values for each observer's agreement between sessions 1 and 2. Means of each group compared with paired t-tests. Classification based on Landis and Koch (156).

Observer	Intra Observer Weighted Kappa (95% CI)	Classification
Researcher 1	0.75 (0.61-0.90)	Substantial
Researcher 2	0.78 (0.66-0.91)	Substantial
Researcher 3	0.77 (0.66-0.88)	Substantial
Researcher 4	0.87 (0.80-0.95)	Almost Perfect
Researcher 5	0.83 (0.72-0.94)	Almost Perfect
Researcher 6	0.90 (0.83-0.97)	Almost Perfect
Researcher 7	0.91 (0.83-0.98)	Almost Perfect
Researcher 8	0.90 (0.84-0.97)	Almost Perfect
Mean (SD)	0.84 (0.07)	Almost Perfect
Clinician 1	0.63 (0.46-0.80)	Substantial
Clinician 2	0.69 (0.50-0.88)	Substantial
Clinician 3	0.83 (0.74-0.93)	Almost Perfect
Clinician 4	0.80 (0.68-0.93)	Almost Perfect
Clinician 5	0.85 (0.77-0.94)	Almost Perfect
Clinician 6	0.88 (0.82-0.95)	Almost Perfect
Clinician 7	0.88 (0.79-0.97)	Almost Perfect
Clinician 8	0.90 (0.83-0.98)	Almost Perfect
Mean (SD)	0.81 (0.10)	Almost Perfect
Student 1	0.83 (0.74-0.92)	Almost Perfect
Student 2	0.82 (0.74-0.91)	Almost Perfect
Student 3	0.81 (0.69-0.92)	Almost Perfect
Student 4	0.83 (0.74-0.92)	Almost Perfect
Student 5	0.85 (0.77-0.93)	Almost Perfect
Student 6	0.88 (0.81-0.96)	Almost Perfect
Student 7	0.86 (0.76-0.97)	Almost Perfect
Student 8	0.84 (0.71-0.96)	Almost Perfect
Mean (SD)	0.84 (0.02)	Almost Perfect
Difference in group means of weighted kappa between two groups (95% confidence interval)		
Researcher – Clinician		0.03 (-0.02, 0.08)
Researcher – Student		-0.00 (-0.04, 0.004)
Clinician – Student		-0.03 (-0.11, 0.04)

Table 2.4 Mean difference between locomotion scores given during first and second session and results of one sample t tests.

Observer	Intra observer difference	
	Mean difference between first and second observation	p value of one sample t-test of mean difference between observations and zero
Researcher 1	-0.28	0.02
Researcher 2	-0.28	0.01
Researcher 3	0.15	0.11
Researcher 4	-0.08	0.41
Researcher 5	0.00	1.00
Researcher 6	-0.05	0.53
Researcher 7	0.10	0.25
Researcher 8	0.05	0.53
Mean (SD)	-0.05 (0.16)	
Clinician 1	-0.13	0.39
Clinician 2	-0.08	0.61
Clinician 3	0.05	0.60
Clinician 4	0.00	1.00
Clinician 5	-0.13	0.17
Clinician 6	0.20	0.02
Clinician 7	0.03	0.79
Clinician 8	-0.10	0.16
Mean (SD)	-0.02 (0.11)	
Student 1	-0.03	0.81
Student 2	0.10	0.32
Student 3	0.33	0.00
Student 4	-0.03	0.80
Student 5	0.10	0.25
Student 6	-0.18	0.03
Student 7	-0.18	0.05
Student 8	-0.08	0.41
Mean (SD)	0.00 (0.17)	

2.4.2 Inter-observer agreement

The mean exact agreement percent was 61.6 (95% CI 59.5 – 63.7) for researchers, 57.6 (95% CI 50.3 – 64.9) for clinicians and 54.6 (95%CI 51.6 – 57.7) for students (see also Table 2.5). The AC2 values were 0.70 (unadjusted 0.81 95% CI 0.76 – 0.86), 0.69 (unadjusted 0.80 95% CI 0.77 – 0.84) and 0.64 (unadjusted 0.75 95% CI 0.69 – 0.81) for researchers, clinicians and students respectively (Table 2.5). The overall adjusted AC2 value for all observers was 0.72 (unadjusted 0.75 95% CI 0.69 – 0.81).

The adjusted AC2 values created for each locomotion score are displayed in Table 2.6. They show almost perfect or substantial agreement for videos scoring either zero or three (as determined by the mode score). There was substantial or moderate agreement for videos scoring two, and substantial agreement for videos scoring one according to the interpretations determined by Landis and Koch (156): <0.00 = Poor, 0.00 – 0.20 = Slight, 0.21 – 0.40 = Fair, 0.41 – 0.60 = Moderate, 0.61 – 0.80 = Substantial, 0.81 – 1.00 = Almost Perfect.

Table 2.5 Mean exact agreement and Gwet's AC2 for each group of observers (Researchers, Clinicians and Students) and for all observers combined. AC2 values adjusted for critical values*. Difference in means between two groups presented with 95% confidence Intervals. Classification based on Landis and Koch (156).

Observer	Inter observer	
	Mean % exact agreement	Gwet's AC2 / classification
Researcher 1	61.1	
Researcher 2	65.0	
Researcher 3	58.2	
Researcher 4	62.1	
Researcher 5	58.2	
Researcher 6	61.4	
Researcher 7	62.5	
Researcher 8	64.3	
Mean[1] (SD or 95% CI)	61.6 (2.5)	0.81 (0.76-0.86)
Adjusted AC2		0.70 / Substantial
Clinician 1	38.6	
Clinician 2	55.0	
Clinician 3	61.8	
Clinician 4	53.6	
Clinician 5	60.4	
Clinician 6	63.9	
Clinician 7	65.4	
Clinician 8	62.1	
Mean[2] (SD or 95% CI)	57.6 (8.7)	0.80 (0.77-0.84)
Adjusted AC2		0.69 / Substantial
Student 1	56.8	
Student 2	60.0	
Student 3	47.1	
Student 4	54.3	
Student 5	56.4	
Student 6	53.6	
Student 7	54.3	
Student 8	54.6	
Mean[3] (SD or 95% CI)	54.6 (3.7)	0.75 (0.69-0.81)
Adjusted AC2		0.64 Substantial
All observers mean (95% CI)		0.79 (0.75-0.82)
Adjusted AC2		0.72 / Substantial
Difference in means between two groups with 95% CI in brackets		
Researcher[1] – Clinician[2]	4.0 (-3.7 – 11.7)	
Researcher[1] – Student[3]	7.0 (4.4 – 9.5)	
Clinician[2] – Student[3]	3.0 (-6.0 – 11.9)	

*Critical value for all twenty four observers = 0.07, critical value for eight observers = 0.11 (10).

Table 2.6 Inter observer agreement coefficient (Gwet's AC2) for researchers, clinicians, students and all 24 observers combined. AC2 values adjusted with critical values*. Classification of adjusted values based on Landis and Koch (156).

Locomotion score	AC2 for all observers combined		AC2 for Researchers		AC2 for Clinicians		AC2 for Students	
0 (95% CI)	0.81 (0.86,0.94)	Almost perfect	0.73 (0.84,0.97)	Substantial	0.73 (0.87,0.95)	Substantial	0.71 (0.84,0.94)	Substantial
1 (95% CI)	0.72 (0.75,0.88)	Substantial	0.61 (0.67,0.91)	Substantial	0.66 (0.79,0.90)	Substantial	0.62 (0.66,0.95)	Substantial
2 (95% CI)	0.76 (0.78,0.93)	Substantial	0.73 (0.86,0.97)	Substantial	0.71 (0.81,0.98)	Substantial	0.53 (0.56,0.86)	Moderate
3 (95% CI)	0.88 (0.99,1)	Almost perfect	0.80 (0.94,1)	Substantial	0.78 (0.92,0.99)	Substantial	0.78 (0.91,1)	Substantial

*Critical value for all twenty four observers = 0.09, critical value for eight observers = 0.18 (10).

2.5 Discussion

Locomotion scoring is currently relied upon in the livestock sector, both to identify lame animals and to determine a herd level prevalence, including enabling benchmarking. Although locomotion scoring is criticised for being subjective, this subjectivity can be reduced by using a scoring system with good reliability, both by the same scorer when scoring on different occasions, and by different scorers scoring the same cattle. Lack of knowledge of the reliability of a scoring system makes it difficult to fully acknowledge its subjectivity.

This study has assessed the reliability of the proposed beef locomotion scoring system i.e. its consistency. However, it should be emphasised that it has not assessed the validity of the scoring system, which still needs testing. Neither inter- or intra-reliability addresses the issue of accuracy because observers can consistently agree with each other, and themselves on different occasions, and still be wrong.

When using this locomotion scoring system, researchers, clinicians and students achieved at least substantial agreement in both the intra- and inter- observer assessments with all results greater than 0.61 (classed as ‘substantial’ according to Landis and Koch (156)). This suggests that if the same observer scores the clips on different occasions, or if different observers score the clips, over the 40 clips they could expect to achieve substantial agreement. However, at the level of each score (Table 2.6), scores zero and three show almost perfect or substantial agreement, with score one showing substantial agreement and score two showing moderate or substantial agreement. This indicates that there is less agreement between observers over the actual locomotion score categories. This also shows that most disagreement is likely to be around score one and two, and as such care should be given when scoring animals believed to be in these categories. In veterinary practice, it is generally considered important to lift the feet of animals equivalent to the score two and three descriptors and treat them appropriately. Therefore, on an individual animal basis, where an observer is unsure if an animal is a score one or score two, we suggest that it may be worthwhile to take one of two options, with an aim to reduce the risk of missing lame animals: 1. Score these unsure animals as a two, ensuring that they have their feet lifted and are treated if appropriate, or 2. Create a new category of 'unsure', requiring a timely re-score.

Intra-observer agreement for this system (weighted kappa range 0.63 to 0.91) compares similarly to a 5-point system studied by Schlageter-Tello *et al.* (157) where observers weighed kappa values ranged from 0.63 to 0.86, and compares favourably to a 5-point system used by Thomsen *et al.* (158), where weighed kappa values ranged from 0.38 to 0.78. Schlageter-Tello and Thomsen used similar groups of observers to the present study, but Garcia *et al.* (159), included a greater range of observers, including farmers, non-livestock professionals and junior veterinary students, achieving a weighted kappa rage of 0.46 to 0.97, suggesting greater variability in within observer agreement to the present study.

Inter-observer agreement has been estimated to have a weighted kappa value of 0.52 after training using the 5-point system by Thomsen *et al.* (158), and values of 0.50, 0.57 and 0.55 for farmers, veterinarians and livestock drivers by Dahl-Pederson *et al.* (160).

To the author's knowledge, inter-observer agreement for cattle locomotion scoring systems has not previously been assessed using Gwets Agreement Coefficients. However, Vanhoudt *et al.* used Gwet's AC1 to assess inter-score agreement for 11 observers using a 6-point digital dermatitis scoring system. Their Gwet AC1 scores ranged from 0.48 to 0.99, whereas the Gwet AC2 values for the present 4-point locomotion scoring system ranged from 0.53 for students observing score 2 animals, to 0.8 for researchers observing score 3 animals.

The observers were all provided with training before watching the scoring videos. Although some evidence suggests that training can improve agreement for on farm scoring systems (161), there is also some evidence to suggest that training may not lead to much improvement in intra or inter-observer agreement for locomotion scores (158,159), but more scoring sessions, i.e. more experience, may lead to improvements in inter-observer agreement (162). If further experience of using the system, for example a number of practice clips that could be scored (with answers being shown afterwards) had been provided, it may have led to improved inter-observer agreement. This is also demonstrated by evidence indicating that experienced observers perform better than inexperienced observers (163).

This scoring system has not been studied with farmer observers. This would be worthwhile future work. The observers used for this study were not a random sample, and this may be a limitation of the study. Due caution should therefore be taken when extrapolating results to the wider population. In particular, the clinicians selected where all experienced veterinary surgeons undertaking further qualifications. It may be that less experienced clinicians (for example new graduate clinicians) may not be as reliable. However, the veterinary students studied showed almost perfect intra-observer agreement, and only slightly lower inter-observer agreement than the researcher group (AC2: researcher value of 0.70 compared to a student value of 0.64), yet still substantial agreement with each other. However, when looking at the level of individual locomotion scores (**Table 2.6**), there was a slight trend towards lower AC2 values than the researchers and clinicians suggesting that experience may lead to improved agreement on each specific locomotion score category.

The exact agreement between sessions was generally high (mean = 66.0% (SD 9.8) for all observers). However, the range is quite wide (40.0 to 80.0%) as there were a number of outliers that are likely to have skewed the results (e.g. clinicians 1 and 2). This suggests that some observers are not as good as others, and perhaps before individuals use this scoring system in practice, they should test their own agreement (precision). The videos utilised in this study can be made into a package for this use, and if individuals find that their intra observer agreement is poor, they may want to practice and train before reattempting the package with the aim of increasing their intra-observer agreement. Systematic bias between attempts could also be identified and controlled. Inter-observer agreement could also be assessed in the same way in clinicians working across the same farms to ensure that they are scoring similarly.

On the second scoring session, there was some evidence to support the notion that some observers had systemic bias in how they scored. However, these were in different directions (some increased their mean scores, and some decreased their mean scores), and only small mean changes were made. This suggests some bias in terms of systematically increasing or decreasing the scores between sessions one and two. In the author's opinion, this bias is small and unlikely to have a detrimental impact on the assessment of the scoring system.

The video clips used were variable in length. The author felt that this reflected on farm locomotion scoring, where on occasions, scorers will need to score quickly. As all observers scored the same clips, and as it was possible to watch the clips as many times as required, the author does not believe that this negatively affects the assessment of the scoring system.

The author has now used the system for research purposes and added a fifth point (164) to enable differentiation of severely lame animals from those who have non-weight bearing limbs. However, this was considered not clinically relevant, as a score 3 and a score 4 would both constitute severe lameness, warranting examination and suitable treatment. For practical use, the author would recommend utilising the zero to three system described in this study.

There is some disagreement regarding the categories from Landis and Koch (156). Some suggest higher scores should be achieved before agreement is considered 'substantial' or 'almost perfect'. For this reason, all values have been provided so that readers can interpret as required. However, in the author's opinion, the intra and inter-observer agreement across the 40 video clips is considered acceptable when compared to similar studies in the literature (15,158,165–167).

2.6 Funding and acknowledgements

This study was funded by the Animal Welfare Foundation (AWF; grant reference Norman Hayward Fund NHF 2016 05 KM). AWF is a fundraising and grant giving charity (charity number 287118) directed by veterinary and animal welfare professions which uses veterinary knowledge to improve the welfare of animals through science, education and debate. More information can be found at www.animalwelfarefoundation.org.uk. The author would like to thank the funders, along with the farmers who allowed their cattle to be filmed, the clinicians, researchers and students who took part in this study, as well as Denis Duret and Bob Read at The University of Liverpool who provided assistance with the online platform.

Chapter 3

A Cross-Sectional Study to Investigate the Prevalence of Lameness in UK Beef Cattle, Lameness Lesion Frequencies and Associated Risk Factors

3 A Cross-Sectional Study to Investigate the Prevalence of Lameness in UK Beef Cattle, Lameness Lesion Frequencies and Associated Risk Factors

3.1 Abstract

Lameness is an important welfare problem for cattle, and has negative effects on production. Despite this, lameness in beef cattle has received little attention in the United Kingdom (UK), with a paucity of knowledge regarding lameness prevalence, lesion frequencies and risk factors for lameness. The aims of this study were to: (i) Investigate the prevalence of lameness in UK finishing units and suckler herds, (ii) Investigate foot and distal limb lesion frequencies, and explore their relationship with lameness, and (iii) Investigate risk factors for lameness on both finishing and suckler cow units.

A convenience sample of 18 finishing units and 12 suckler farms were recruited from across England and Wales. Farms were visited and eligible cattle were locomotion scored on a five point scale by the author. Lame animals and a sample of non-lame animals underwent an examination of all four feet and legs. Lesions were identified, with investigative trimming where required. Where treatment was deemed necessary, it was carried out at the cost of the study. Data regarding possible risk factors for lameness were gathered by discussion with the farmer and via observation and measurement, using the same checklist for each farm.

The farm level lameness prevalence for finishing units was 8.3% (range 2.0 - 21.2%). The most frequent lesions at the animal level which increased the odds of lameness in finishing cattle were white line disease and overgrown claws.

Multivariable logistic regression suggested that increased pen area provide per animal, poor pen ventilation and a high pen grip score all increase the odds of animals within those pens being lame.

The mean farm level lameness prevalence for suckler cows was 14.2% (range 0 – 43.2%). The most frequent lesions at the animal level which increased the odds of lameness in suckler cows were also white line disease and overgrown claws. Multivariable logistic regression suggested that older cows were more likely to be lame, and that animals housed in a pen with poor ventilation were at a greater odds of being lame.

This study provides estimates for lameness prevalence in two major groups of UK beef cattle, as well as providing estimates of lesion frequencies. The farm level lameness prevalence, although lower than that in UK dairy cattle, suggests room for improvement. Lesion frequencies, and their association with lameness highlight the importance of claw horn diseases in both finishing cattle and suckler cows. Multivariable models of lameness risk factors suggest that aspects within control of farmers could be altered to reduce lameness on their farms. This study indicates that lameness within UK beef cattle is present at a level likely to be causing a welfare issue for UK beef cattle.

3.2 Introduction

3.2.1 The prevalence of lameness in United Kingdom (UK) beef cattle

Lameness is considered one of the most important causes of reduced welfare in cattle (80,102,149), and is a priority topic of The GB Dairy Cattle Welfare Strategy 2018-2020 (168). It is also acknowledged to be an important constraint on animal production. The two main production effects of lameness in dairy cattle are reported to be reduced milk yield and fertility (68) and a recent report has identified negative effects on weight gain in finishing cattle (41). There is, however, a limited amount of published information regarding lameness in beef cattle.

A recent estimate of the within herd prevalence of lameness on UK dairy farms is 31.6% (34). However, the prevalence of lameness within the UK beef herd is unreported. International studies give variable results ranging from a 1.1% prevalence in Norwegian suckler cows across 12 herds (21) to an estimated prevalence of 4.5% in a Canadian feedlot study (169). Incidence rates have been reported as 2% over the finishing period across five United States (US) farms (31), and 1% (23) and 3.8% (mean of farmer, veterinarian, or nutritionist estimate) (32) in two US feedlot studies (Western US and Kansas/Nebraska respectively). However two of these studies (31,169) gathered data from farm records, which required lame animals to be identified, treated (where medicine records were the source) and recorded for it to contribute to the figure. It has been suggested that some dairy farmers underestimate lameness problems on their farms (19,170) and beef farmers may do the same (164), so it may be the same in US feedlots. Aside from the possible underestimating, differences in beef management mean that extrapolation of these international prevalence estimates to derive at estimates for the UK beef industry may not be appropriate. A survey conducted at ten US livestock markets (located in California, Idaho or Utah) examined both dairy and beef animals presented, and suggested a lower prevalence of lameness in beef cattle, with 15.1%

and 15.4% of beef cows and bulls respectively described as lame by researchers, compared to 44.7% and 26.1% of dairy cows and bulls respectively, though this apparent difference may reflect both farmer perception and culling decision differences between the beef and dairy industries (33). Although the prevalence of lameness in the UK beef herd is unknown, it has been acknowledged by the Farm Animal Welfare Committee that lameness is not as commonly identified in beef cattle as it is in dairy cattle (102), possibly owing to the reduced opportunity to identify lameness in beef settings, or due to a true lower prevalence.

3.2.2 Lesions associated with lameness in beef cattle

Lameness lesions are usually categorised into either foot or non-foot related lesions. Foot related lameness cases are generally attributed to either claw horn (non-infectious) or infectious disease conditions, or a mixture of these two (110,111), and further categorised by specific lesion type such as Sole Ulcers, White Line Disease, Digital Dermatitis and Interdigital Phlegmon (also known as Foul, Foul in the foot or Cattle foot rot) (112). The frequency of lesion types in the UK beef sector is unknown. A Canadian study (116), recording findings of beef cattle presented to the Auburn University Large Animal Teaching Hospital, attributed almost 85% of the 745 cases to lesions in the foot, of which 79.5% were non-infectious, with corkscrew claw the most common lesion. The generally biased nature of hospital cases limits extrapolation of these findings to the UK beef industry, in particular because UK beef farmers may not present many cases for veterinary attention (164). A later Canadian study using farm records from 28 feedlots found 74.5% of lameness cases were due to foot rot (interdigital phlegmon), followed by joint injury at 16.1% (169). An Italian post mortem abattoir study of finishing beef cattle showed sole haemorrhage to be the most prevalent lesion type, present in almost all batches of cattle, with white line abscesses being the next most prevalent lesion type (171). However, visible lesions may not all be associated with clinical lameness, as suggested by a Norwegian study (21), where 29.6% of animals had lesions, whilst only 1.1% of animals were identified as lame. Digital Dermatitis has been identified in UK beef cattle, and is believed to have the same or similar aetiology as that in dairy cattle (172).

Non-foot related lameness lesions are less frequently reported than foot lesions, possibly due to difficulty in diagnosis, and the likely lack of diagnostic imaging equipment on-farm. Newcomer *et al* (116) identified that, of beef animals presented to a veterinary teaching hospital for lameness, 16% had non-foot lameness lesions. Osteochondrosis lesions have been reported in UK finishing cattle (117–119), in both lame and non-lame cattle (173). Occasional muscular lesions have been reported in literature (119), often in heavily muscled animals following exercise, or in cattle following periods of recumbency. Pelvic and stifle injuries have been described, including fractures, luxation of the coxo-femoral joint and lesions of the cranial cruciate ligament (174,175). Stifle lesions of both dairy and beef cattle were reported on by two Canadian veterinary teaching hospitals (120), with subchondral bone cysts, joint instability and degenerative joint disease being the most common reported conditions. Of 34 breeding beef bulls, culled for poor fertility reasons and examined at post mortem, 30 presented with lesions of at least one joint (43), with the stifle being the most prevalent location. Cases of metabolic bone disease are periodically reported in two UK farms, for example a recent report associated with insufficient dietary formulation firstly in five dairy heifers, and secondly in two finishing bulls (176). Nerve injury, septic arthritis, tendon lesions and other fractures should also be considered as possible causes of non-foot lameness (177,178). However, the true prevalence of non-foot related lameness lesions in UK beef cattle is unknown.

3.2.3 Risk factors for lameness in beef cattle

When exploring the cause of lameness, most studies have been cross sectional in nature, and as such causality cannot be determined. However, they do provide some insight and understanding of potential lameness causes. Griffiths *et al*. (34) in a cross sectional study of UK dairy cattle showed that bedding type, claw trimming, foot bathing frequency, floor grooving characteristics, and increased concentrate feeding were all associated with herd level lameness prevalence in dairy cattle. However, the environment in which a beef animal is kept and its daily routine can be quite different to that of a dairy cow, and as such, the way in which it responds to its environment may be different, leading to different risk factors for beef cattle. Three recent studies investigated lameness in Italian finishing units. Cortese *et al*. (122) suggested that an increase of up to 25% in stocking density appeared to have no effect on lameness prevalence in finishing bulls kept on slatted floors, although it did affect the number of lameness treatments required to recover from any lameness suggesting an increase in lesion severity. In contrast, Magrin *et al*. (40) identified that a reduction in space allowance in slatted pens increased the risk of lameness. They also showed that the prevalence of severe lameness (defined as leading to early culling) was higher in animals on fully slatted concrete flooring compared to deep litter, and suggested that these severe lameness effects occurred during the later stages of finishing. Compiani *et al*. (123) observed lameness more frequently in animals on slatted flooring compared to those in litter pens. They found males to be at higher risk of lameness than females, with an increased risk in Charolais cattle compared to other breeds, though the larger size and weight of Charolais may at least be part of this risk. Lameness incidence was higher in spring, but lower in summer, leading to the suggestion that this variation may be related to the type of cattle available for purchase (and therefore on farm at certain times of year) rather than environmental conditions *per se* such as higher temperatures. In Indiana, US, Elmore *et al*. (124) identified that castrated males on rubber covered slats had improved gait scores and less joint swelling compared to those housed on concrete slats or solid rubber matting. In contrast, Murphy *et al*. (179) identified no significant difference in locomotion scores between bulls housed during the growing and finishing period on concrete slats, rubber covered slats, or initially concrete slats followed by either straw litter bedding or rubber covered slats for the finishing period. However, they did identify reduced sole bruising in bulls housed on rubber covered slats for both the growing and finishing period. It is unknown if these risk factors apply to UK beef systems.

3.2.4 Aims and objectives of study

Knowledge of the prevalence of lameness in UK beef systems, and the frequency of lesion types, would assist in predicting problems and designing targeted control and prevention programmes. Awareness of risk factors for lameness in beef cattle would provide farmers and their veterinarians / advisors with the ability to more effectively investigate lameness on their own farms, and develop lower risk beef systems. The aims of the present study were to: (i) Investigate the prevalence of lameness in UK finishing units and suckler herds, (ii) Investigate foot and distal limb lesion frequencies, and explore their relationship with lameness, and (iii) Investigate risk factors for lameness on both finishing and suckler cow units.

3.3 Methods

This study was approved by the University of Liverpool Research Ethics Committee (VREC 533). Participants received written and verbal information and completed a consent form.

3.3.1 Identification and recruitment of farms

A convenience sample (including snowball sampling, n=1) of 18 finishing units and 12 suckler farms were recruited from a pool of potential participants that were either known to the researcher or suggested by other farmers or by veterinary practices and industry bodies asked to assist with recruiting potential participants. The author approached 150 farms directly or on occasion by telephone. Eligible animals were defined as i) finishing cattle - animals reared for beef production, and on their final finishing ration before slaughter and within four months of anticipated slaughter, and ii) suckler cows - adult female breeding cattle, intended to produce and rear calves for beef production, and in-calf heifers housed in the same environment as older cows on the farm. The inclusion criteria for finishing units were having at least 60 eligible cattle housed at the time of the study (June – October 2017) and due to be sent to slaughter directly from the farm. The inclusion criteria for suckler farms were having at least 60 eligible cows housed at the time of the study (January – April 2018).

3.3.2 Data collection

All data collection and animal examination was carried out by the same researcher (JT), a veterinarian with experience in locomotion scoring, lameness lesion identification and herd health assessments.

3.3.2.1 Locomotion scoring

Locomotion scoring was carried out using each farm's own facilities. Animals were identified by ear tag or uniquely identifying management tag, then released individually from a handling system or holding pen and allowed to walk on a firm surface, usually concrete. If a second passing was required to ascertain the score, animals were either returned to the handling system or released from the holding area they were in.

On some farms not all eligible animals were locomotion scored due to time and other logistical factors on farm. When this was the case, a pragmatic decision was made to score as many animals as reasonably possible. All farms recruited remained in the study, even if the actual number scored fell below the initial inclusion criterion of 60 cattle.

A five point locomotion scoring system was used (**Table 3.1**). A simplified four point version was previously investigated in chapter 2 (180). Any animal scoring two or above was considered clinically lame. Lameness was recorded at the animal level, and as such, no differentiation was made between any particular feet or limbs perceived to be causing lameness.

Table 3.1 Five point locomotion scoring system used. Adapted from Tunstall *et al*. (180)

Score	Category	Description
0	Normal	Even weight bearing and rhythm on all four feet. The back is level.
1	Imperfect locomotion	Uneven steps or shortened strides, but affected limb not identifiable. The back may show minimal arching while walking.
2	Impaired locomotion	Uneven weight bearing or shortened strides. Affected limb is identifiable (unless multiple limbs affected). The back may show arching while walking.
3	Severely impaired locomotion	Slower pace - unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected), but whole foot placed to floor. An arched back may be noted while standing and walking.
4	Severely impaired locomotion with non-weight bearing limb(s)	Slower pace - unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected). An arched back may be noted while standing and walking. One or more limb(s) non-weight bearing or toe touching.

3.3.2.2 Lesion Identification

Following locomotion scoring, clinically lame animals and a sample of non-lame animals (controls) underwent examination of all four feet and distal limbs (femorotibial (stifle) or humeroradioulnar (elbow) joints proximad to metacarpo-phalangeal or metatarso-phalangeal (fetlock) joints distad) with the animal restrained in a hydraulic lay over foot trimming facility (Northern Engineering Ltd, County Tyrone, Northern Ireland). The number of non-lame control animals undergoing a foot examination was determined pragmatically (Gail *et al*. (181) and Grimes *et al*. (182)) and was dependent upon the prevalence of lameness found on farm, with consideration of the time and facilities available. The target ratio of non-lame animals to lame animals examined was 4:1, 3:1, 2:1 and 1:1 for a farm lameness prevalence of ≤ 5%, ≤ 15%, ≤ 25% or > 25% respectively. The control animals were generally selected as the next non-lame animals to be locomotion scored, i.e. from the same management group. Where holding pen capacities or farm logistics did not allow this, a pragmatic selection of an animal closely representative of the lame animal in terms of production stage and management was made. Animals that were considered to be anxious or dangerous to handle were excluded from foot examination.

The distal limb was examined for skin lesions or soft tissue or joint swelling. For claw examination, claws were cleaned with a brush and / or water where required, and a superficial layer of sole horn removed where necessary to enable visualisation of possible lesions, using hoof knives and / or an angle grinder. All aspects of the claw including the interdigital space, accessory digits, wall and sole horn, and the length of the dorsal wall were assessed. Lesions were recorded as either present or absent at the claw level, with investigative trimming where required. Lesions were recorded according to descriptors at **appendix 1**, produced with reference to the International Committee for Animal Recording Claw Health Atlas (113), Agriculture and Horticulture Development Board Lesion Recognition Card / Trouble shooter (110,111) and Archer *et al.* (20). It has been suggested that digital dermatitis and interdigital dermatitis may be different manifestations of the same condition (20,131,183). They were recorded and reported both separately and combined as one variable, 'dermatitis'. Weight bearing claws were defined as the lateral claws of hind feet, and the medial claws of front feet, and non-weight bearing claws as the medial claws of hind feet and lateral claws of front feet, according to a study of dairy cattle (184). Where treatment was deemed necessary, it was carried out at the cost of the study.

3.3.2.3 Risk Factor Assessment

Data regarding possible risk factors for lameness were gathered during the farm visit, or during a return visit within seven days by discussion with the farmer and via observation and measurement, using the same checklist for each farm. Risk factors and coding descriptors for finishing cattle and suckler cows are in **Table 3.2** and **Table 3.3,** respectively.

3.3.2.3.1 Farm Management Factors

Factors that may impact farm biosecurity, such as sourcing of animals, bedding or feed and any co-grazing were recorded. Information regarding other species on farm and whether they share the same equipment or environment was recorded.

3.3.2.3.2 Animal Housing Factors

Pen type was recorded and pen sizes were measured. Flooring surfaces and any concrete grooving was noted. The frequency of scraping any concrete areas was determined. Type of bedding materials, and the frequencies of fresh bedding material being applied and the pens being mucked out was gathered. A faecal consistency score was determined for each pen by walking across the internal feed face of the pen and stopping at six equidistant points. The nearest fresh faecal pat to each stop was scored using the boot test with 1 = liquid faeces to 5 = dry, stiff faecal 'balls' (185) and a mean of these six scores was recorded. Pen flooring grip was determined using a 0 (no grip = slippery) to 4 (not possible to spin = abrasive) scoring method (186) by standing with knees bent and attempting to spin whilst keeping part of each foot on the floor. This was repeated at six equidistant points across the feed face of the pen, and a mean score recorded.

Ventilation aspects such as roof design and height, the presence of cobwebs, odours or draughts, as well as a subjective ventilation score were recorded. The ventilation of each pen was scored either 1 = good (considered to be sufficient), or 2 = poor (considered to be insufficient) based on the researcher's impression of airflow (taking into account inlets, outlets, odours, and current weather) when walking in the pen.

3.3.2.3.3 Feeding

Type, number and size of water and feed troughs were determined. Farmers were asked about feed constituents and amounts, as well as feeding and pushing up frequencies. Farmers were also asked about how long the animals scored had been on the described diet, and how they were transitioned onto the diet. Feed space (either open horizontal barrier space, or diagonally / vertically divided barrier spaces) was recorded, and determined to be either adequate or inadequate for the number of animals in the pen at the time of scoring, assuming a minimum forage feed space requirement of 550mm for finishing cattle, and 600mm for suckler cows, or one vertically / horizontally divided space per animal (187).

3.3.2.3.4 Lameness prevention / management

Farmers were asked about any foot bathing that the cattle of interest may have received, and asked to explain when and how they choose to do it. They were also asked if the cattle of interest ever had their feet examined and / or trimmed. If they did so, the reason (treatment or preventative), who did it and how often it was undertaken for each animal was noted.

3.3.2.3.5 Animal factors

The breed, sex and age of all cattle locomotion scored was recorded. Finishing cattle breeds were divided into beef and dairy breeds, and then subdivided into cross breed or not cross breed. Suckler cows were categorised by traditional British breeds, or continental breeds (including Stabiliser cattle). Cross breed suckler cows were grouped with the breed they were recorded as a cross of. All animals that received a leg examination were body condition scored (BCS, scale of 1 = spinous processes sharp and easily distinguish to 5 = bone structure no longer visible (188)). They received two cleanliness scores (adapted from Cook (189) and AHDB (190)): a ventral abdomen score and a foot score based on the area between the sole and the proximal fetlock, with the left hind limb used as a proxy for all four limbs.

3.3.3 Data Analysis

The data was recorded in Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington USA). Statistical analysis was performed using STATA/MP 16.1 (Statacorp, College Station, Texas, USA) for Windows. Data was exported to Minitab statistical software (Minitab 18, PA, USA) for the purposes of graphical representation. Data regarding finishing units and suckler farms were analysed separately, with separate regression models produced for each of the two farm types.

Data was analysed at different levels:

Lameness prevalence was analysed with farm as the experimental unit. A binary (lame / non-lame) variable "Lame" was derived from the locomotion scores, with scores ≥ 2 classified as lame and scores < 2 being non-lame.

Lesion frequency was recorded at claw level, and analysed at three levels, namely claw, foot and animal, as a binary (present or absent) variable. In addition to analysing lesions individually, lesions were categorised as follows:

- "Claw horn lesions" included any white line disease, sole haemorrhage, sole ulcer, overgrown sole, double sole, overgrown claw or axial fissure lesions.
- "Infectious lesions" included any lesion of digital dermatitis, interdigital dermatitis, interdigital phlegmon (foul), or heel horn erosion.
  "Infectious lesions" also had a sub-grouping of "Dermatitis" that included a lesion of either digital dermatitis or interdigital dermatitis.

Claws having toe necrosis lesions were not included in any of the above grouping as they are claw horn lesions strongly associated with infectious causes (114), but were investigated individually.

Potential associations between lesion presence for lame and non-lame cattle were compared using the Pearson's χ^2 test statistic, whilst associations between presence of a lesion and plausible risk factors (e.g. specific other lesion types) were analysed using Fisher's exact test due to smaller sample sizes.

The association between lameness and each of i) lesion presence, ii) body condition score or iii) animal cleanliness score was analysed with animal as the experimental unit. Farm and animal group were included in each analysis as random effects.

The association between lameness and risk factors was examined with animal as the experimental unit. Farm and animal group were included in each analysis as random effects. Following random effects univariable logistic regression modelling, all variables with $p \leq 0.1$ were eligible to be offered to a multivariable logistic regression model with the outcome variable being the binary variable "Lame". Where collinearity existed between some variables, the author considered biological plausibility to determine which variables were offered to the final model. Selection of variables for the final multivariable models was by backwards stepwise removal taking a p value < 0.1 for retention of a variable. Likelihood ratio testing was then performed, testing the model with and without each variable to maximise model fit. Biologically plausible interaction terms with a $p < 0.1$ at univariable level were offered to the final models, and were retained if they improved model fit.

Some recorded variables were not analysed due to missing data or due to the data lacking in variability. Some animals had partial missing data if the farmer could not provide answers, or factors were not able to be measured. **Table 3.2** and **Table 3.3** contain the number of animals which contributed to the analysis for finishing cattle and suckler cows respectively.

Table 3.2 Farm level risk factors for lameness in finishing cattle: description, coding and summary statistics. The missing values column indicates variables where less animals contributed than were locomotion scored.

Variable	Type[1]	Coding & description of variable	Missing values (n)	n	Mean +/-SD (Range)
Total herd size	Cont	Herd size, including all cattle types / ages	No	1686	474 +/- 264 (100-1100)
No. in pen	Cont	Number of animals sharing the pen	No	1686	34 +/-17 (3-85)
Breed type	Cat	1 = Beef cross breed	Yes (585)	737	
		2 = Beef breed		177	
		3 = Dairy cross breed		24	
		4 = Dairy breed		163	
Sex	Cat	0 = Castrated male	Yes (486)	626	
		1 = Entire male		285	
		2 = Female		289	
Age	Cont	Age in months at scoring	Yes (585)	1100	21 +/-5.6 (8-40)
Silage type	Binary	1 = Grass	Yes (650)	926	
		2 = Maize		110	
Ration type	Cat	1 = Total mixed ration (TMR)	No	929	
		2 = Various separate components fed		440	
		3 = *Ad libitum* concentrates		317	
Pen type	Cat	1 = Deep litter with concrete area	Yes (42)	792	
		2 = Mainly slatted flooring		219	
		3 = Complete deep litter pen		495	
		4 = Cubicles		138	
Bedding top-up frequency	Cat	1 = Daily	Yes (356)	946	
		2 = Every 2 to 3 days		154	
		3 = Twice a week		104	
		4 = Weekly or fortnightly		126	
Pen scraping frequency	Cat	1 = Daily	Yes (920)	162	
		2 = Every 2 to 4 days		420	
		3 = From every 5 days to monthly		184	
Pen muck out frequency	Cat	1 = More frequently than 3 monthly	Yes (399)	453	
		2 = Between 3 months and 6 months		420	
		3 = From 6 monthly to annually		414	
Bedding score[2]	Cat	1 = Good	Yes (42)	740	
		2 = Acceptable		609	
		3 = Poor		295	

Table 3.2 (continued)

Variable	Type	Coding and description of variable	Missing values (n)	n	Mean +/-SD (Range)
Straw condition[3]	Cat	1 = Clean	Yes (42)	438	
		2 = Slightly damp / dirty		771	
		3 = Damp / dirty		157	
		4 = Thick manure / considerably wet		278	
Feed space provision	Binary	Open horizontal barrier (m / animal)[4]			0.77 +/-0.37 (0-1.7)
Robertson et al (187)		Diagonal / vertical barrier (spaces / animal)[4]			2 +/-2.1 (0.7-8)
		1 = Inadequate	No	732	
		2 = Adequate		954	
Pen area per animal	Cont	Total area provided per head, in m^2 (log_e transformed)	Yes (53)	1633	7.7 +/-5.2 (1.7-64)
Pen ventilation[5]	Binary	1 = Good	Yes (1)	1422	
		2 = Poor		263	
Grip score	Cat	1 = Slippery	Yes (342)	0	
Dippel et al (186)		2 = Slightly slippery		138	
		3 = Medium		913	
		4 = Slightly abrasive		293	
		5 = Abrasive		0	
Faecal score	Cat	1 = Liquid consistency	Yes (342)	0	
Noordhuizen et al (185)		2 = Flat, thinly spread		44	
		3 = Circumscribed, moist raised pat		790	
		4 = Dry stiff pats		510	
		5 = Dry, stiff, faecal 'balls'		0	
Footbath ever provided	Binary	0 = No	No	1400	
		1 = Yes		286	
Does farmer ever trim feet	Binary	0 = No	No	1108	
		1 = Yes		578	

[1] Cont = continuous, Cat = categorical
[2] A subjective score of depth, spread and comfort of bedding surface / material
[3] A subjective score of cleanliness
[4] Six pens with both open horizontal feed barriers, and diagonal / vertical barriers were not included in these summary statistics, but were included in inadequate or adequate feed space provision analysis.
[5] A subjective score

Table 3.3 Farm level risk factors for lameness in suckler cows: description, coding and summary statistics. The missing values column indicates variables where less animals contributed than were locomotion scored.

Variable	Type[1]	Coding and description of variable	Missing values (n)	n	Mean +/-SD (Range)
Total herd size	Cont	Herd size, including all cattle types / ages	No	1050	328 +/-192 (111-800)
No. in pen	Cont	Number of animals sharing the pen	Yes (75)	975	47 +/-33 (1-110)
Breed type	Binary	1 = Traditional British breed	Yes (89)	85	
		2 = Continental or Stabiliser breed		876	
Age	Cont	Age in months at scoring ($\log_e$ transformed)	Yes (90)	960	70 +/-37 (16-226)
Pen type	Cat	1 = Deep litter with concrete area	Yes (95)	585	
		2 = Cubicles		309	
		3 = Complete concrete pen		61	
Bedding top-up frequency	Cat	1 = Daily	Yes (378)	176	
		2 = Every 2 to 3 days		427	
		3 = Twice a week		0	
		4 = Weekly or fortnightly		69	
Pen scraping frequency	Cat	1 = Daily	Yes (231)	209	
		2 = Every 2 to 4 days		443	
		3 = From every 5 days to monthly		167	
Pen muck out frequency	Cat	1 = More frequently than 3 monthly	Yes (176)	371	
		2 = Between 3 months and 6 months		206	
		3 = From 6 monthly to annually		297	
Bedding score[2]	Cat	1 = Good	Yes (95)	0	
		2 = Acceptable		302	
		3 = Poor		653	
Straw condition[3]	Cat	1 = Clean	Yes (95)	89	
		2 = Slightly damp / dirty		213	
		3 = Damp / dirty		231	
		4 = Thick manure / considerably wet		422	
Feed space provision	Binary	Open horizontal barrier (m / animal)			1.28 +/-0.77 (0.28-2.9)
Robertson et al (187)		Diagonal / vertical barrier (spaces / animal)			2.1 +/-1.4 (0.8-8)
		1 = Inadequate	Yes (210)	197	
		2 = Adequate		643	
Pen area per animal	Cont	Total area provided per head, in m^2 ($\log_e$ transformed)	Yes (96)	954	17.2 +/-16.8 (2.4-61.3)
Pen ventilation[4]	Binary	1 = Good	Yes (95)	603	
		2 = Poor		352	

Table 3.3 (continued)

Variable	Type[1]	Coding and description of variable	Missing values (n)	n	Mean +/-SD (Range)
Grip score	Cat	1 = Slippery	Yes (95)	67	
Dippel et al (186)		2 = Slightly slippery		190	
		3 = Medium		440	
		4 = Slightly abrasive		258	
		5 = Abrasive		0	
Faecal score	Cat	1 = Liquid consistency	Yes (95)	0	
Noordhuizen et al (185)		2 = Flat, thinly spread		67	
		3 = Circumscribed, moist raised pat		614	
		4 = Dry stiff pats		274	
		5 = Dry, stiff, faecal 'balls'		0	
Footbath ever provided	Binary	0 = No	No	969	
		1 = Yes		81	
Does farmer ever trim feet	Binary	0 = No	No	915	
		1 = Yes		135	
Does professional ever examine lame animals	Binary	0 = No	No	375	
		1 = Yes		675	
Any routine preventative trimming	Binary	0 = No	No	969	
		1 = Yes		81	

[1] Cont = continuous, Cat = categorical
[2] A subjective score of depth, spread and comfort of bedding surface / material
[3] A subjective score of cleanliness
[4] A subjective score

3.4 Results

3.4.1 Finishing cattle

3.4.1.1 Characteristics of farms and animals

The 18 finishing units were recruited from North Wales (n=4), Mid Wales (n=1), North West England (n=6), the West Midlands (n=5) and the East Midlands (n=2). The median herd size for farms with finishing cattle was 395, ranging from 70 to 1100. The median number of eligible finishing cattle on these farms was 240 (range 65 – 900), and a total of 1686 finishing cattle were locomotion scored with a median number of finishing cattle scored per farm of 100 (range 49 - 121).

Cattle were housed in one of four pen types: entirely deep litter, deep litter with a concrete area (generally a feed passage or loafing area), cubicle housing or slatted housing. It was common for farms (n=6) to employ a number of different pen types for similar production groups.

3.4.1.2 Farm lameness prevalence

One hundred and thirty two lame finishing animals were identified (7.8% of all finishing cattle locomotion scored). The mean within farm level prevalence of lameness of finishing cattle was 8.3% (median 5.8%, range 2.0 – 21.2%). Individual finishing unit lameness prevalences are displayed in **Figure 3.1**.

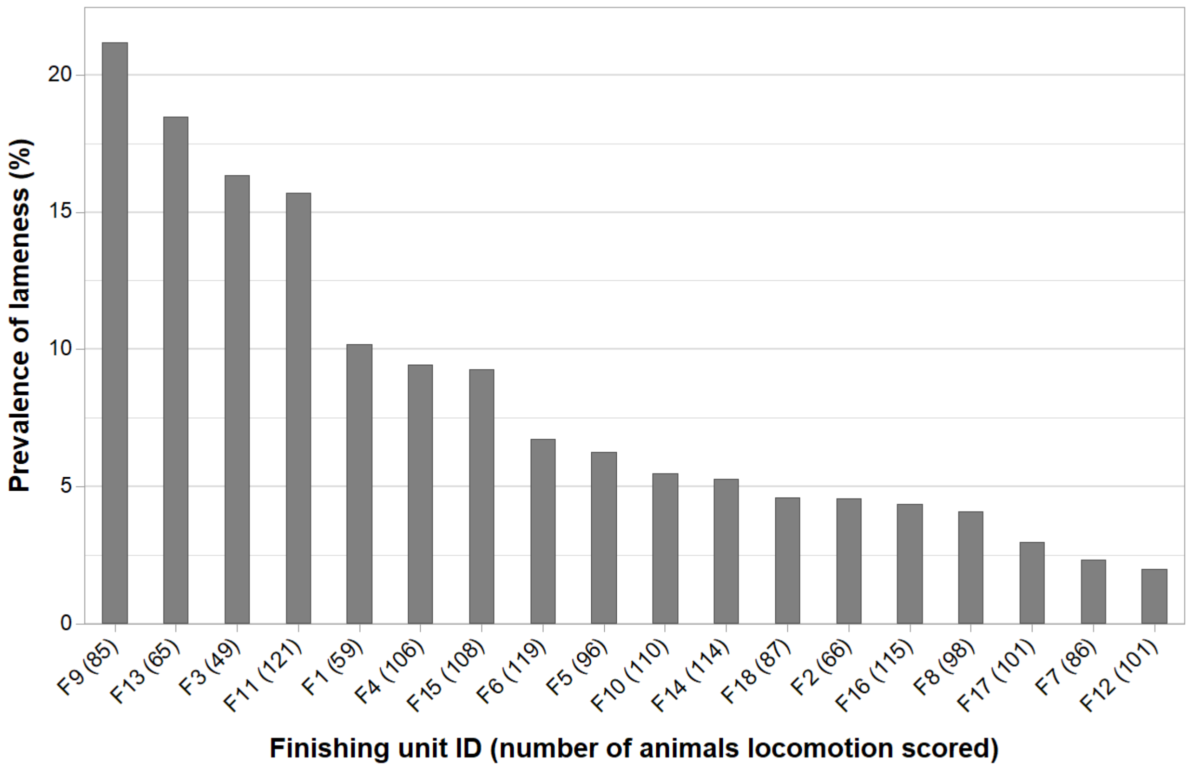


Figure 3.1 Lameness prevalence for 18 finishing units.

3.4.1.3 Lesion frequencies

Lesion frequencies for both non-lame and lame finishing cattle are presented in **Table 3.4**. Four lame animals were deemed too fractious to undergo foot inspection and were excluded from further analysis. In non-lame animals 72% of animals and 51% of claws had at least one lesion. In lame finishing cattle, significantly more animals (95%) and claws (69%) had a lesion than in non-lame animals (Pearson χ^2 $p < 0.001$ and $p < 0.001$ respectively). Of lame animals, 78% had a claw horn lesion, compared to 27% of non-lame animals (Pearson χ^2 $p < 0.001$). Digital dermatitis was present on 8 finishing units, and interdigital dermatitis was present on 7 units (4 of those finishing units having both present). Although neither lesion was highly prevalent, there was a positive association between the presence of digital dermatitis and interdigital dermatitis, with 6 finishing cattle having both lesions (Fisher's exact test $p \leq 0.001$). There was also a positive association between the presence of claw horn lesions and dermatitis lesions (Fisher's exact test $p = 0.030$), but no association between the presence of claw horn lesions and infectious lesions in general (Fisher's exact test p = 0.420). The group 'other lesions' consisted of lesions with a low prevalence, including suspected muscular injury, a deformed hoof or leg, and joint disorders. No non-foot lesions were diagnosed at sufficient frequency to enable further analysis.

Table 3.4 Lesion prevalence at animal, foot and claw level for non-lame and lame finishing cattle (non-lame = 176 animals, 704 feet, 1408 claws; lame = 128 animals, 512 feet, 1024 claws).

Lesion	**Number (%) in Non-lame**			**Number (%) in Lame**		
	Animals	**Feet**	**Claws**	**Animals**	**Feet**	**Claws**
Any lesion	126 (71.6)	389 (55.3)	725 (51.5)	122 (95.3)	397 (77.5)	703 (68.7)
Claw horn lesion	48 (27.3)	122 (17.3)	210 (14.9)	100 (78.1)	286 (55.9)	457 (44.6)
White line disease	9 (5.1)	11 (1.6)	12 (0.85)	67 (52.3)	124 (24.2)	137 (13.4)
Sole haemorrhage	1 (0.6)	1 (0.1)	1 (0.1)	7 (5.5)	9 (1.8)	11 (1.1)
Sole ulcer	0 (0)	0 (0)	0 (0)	10 (7.8)	11 (2.2)	11 (1.1)
Overgrown sole	1 (0.6)	1 (0.1)	1 (0.1)	6 (4.7)	15 (2.9)	27 (2.6)
Double sole	16 (9.1)	32 (4.6)	39 (2.8)	22 (17.2)	67 (13.1)	111 (10.8)
Overgrown claws	29 (16.5)	83 (11.8)	160 (11.4)	36 (28.1)	127 (24.8)	249 (24.3)
Axial fissure	3 (1.7)	6 (0.9)	8 (0.57)	13 (10.2)	28 (5.5)	39 (3.8)
Infectious lesion	101 (57.4)	309 (43.9)	581 (41.3)	67 (52.3)	194 (37.9)	364 (35.6)
I/d phlegmon	0 (0)	0 (0)	0 (0)	2 (1.6)	3 (0.6)	6 (0.6)
Dermatitis	8 (4.6)	12 (1.7)	24 (1.7)	21 (16.4)	35 (6.8)	67 (6.5)
Digital dermatitis	6 (3.4)	9 (1.3)	18 (1.3)	14 (10.9)	16 (3.1)	29 (2.8)
I/d dermatitis	4 (2.3)	5 (0.7)	10 (0.7)	11 (8.6)	23 (4.5)	46 (4.5)
Heel horn erosion	94 (53.4)	298 (42.3)	559 (39.7)	53 (41.4)	166 (32.4)	309 (30.2)
Toe necrosis	1 (0.6)	1 (0.1)	1 (0.07)	10 (7.8)	12 (2.3)	12 (1.2)
Other lesion	5 (2.8)	8 (1.1)	11 (0.8)	20 (15.6)	34 (6.6)	59 (5.8)
I/d = interdigital						

3.4.1.3.1 Lesion frequencies by claw types

Lesion frequencies in finishing cattle by type of claw are presented in **Table 3.5** (front versus hind claws), Table 3.6 (lateral versus medial claws) and **Table 3.7** (non-weight bearing versus weight bearing claws, according to Van Der Tol *et al*. (184)) for both non-lame and lame animals.

Table 3.5 Recorded lesion types on front and hind claws of finishing cattle, grouped by non-lame and lame status.

Lesion	Number (%) in Non-lame		Number (%) in Lame	
	Front claws	**Hind claws**	**Front claws**	**Hind claws**
Any lesion	363 (51.6)	362 (51.4)	362 (70.7)	341 (66.6)
Claw horn lesion	125 (17.8)	85 (12.0)	237 (46.3)	220 (43.0)
White line disease	8 (1.1)	4 (0.6)	79 (15.4)	58 (11.3)
Sole haemorrhage	1 (0.1)	0 (0)	4 (0.8)	7 (1.4)
Sole ulcer	0 (0)	0 (0)	4 (0.8)	7 (1.4)
Overgrown sole	1 (0.1)	0 (0)	15 (2.9)	12 (2.3)
Double sole	27 (3.8)	12 (1.7)	57 (11.1)	54 (10.6)
Overgrown claws	90 (12.8)	70 (9.9)	127 (24.8)	122 (23.8)
Axial fissure	7 (1.0)	1 (0.1)	18 (3.5)	21 (4.1)
Infectious lesion	273 (38.8)	308 (43.8)	190 (37.1)	174 (34.0)
I/d phlegmon	0 (0)	0 (0)	2 (0.4)	4 (0.8)
Dermatitis	4 (0.6)	20 (2.8)	24 (4.7)	43 (8.4)
Digital dermatitis	2 (0.3)	16 (2.3)	6 (1.2)	23 (4.5)
I/d dermatitis	2 (0.3)	8 (1.1)	18 (3.5)	28 (5.5)
Heel horn erosion	269 (38.2)	290 (41.2)	164 (32.0)	145 (28.3)
Toe necrosis	0 (0)	1 (0.1)	4 (0.8)	8 (1.6)
Other lesion	4 (0.6)	7 (1.0)	34 (6.6)	25 (4.9)
I/d = interdigital				

The odds ratio for the likelihood of both non-lame and lame finishing cattle having lesions on their hind versus front claws, medial versus lateral claws and non-weight bearing versus weight bearing claws derived from univariable logistic regression models are displayed in **appendix 2**, **tables A2.1, A2.2 and A2.3**. For non-lame finishing cattle, compared to hind claws, front claws were more likely to have a claw horn lesion in general (OR 1.57, 95% CI 1.17 – 2.12, p = 0.003), and were more likely to present with a double sole (OR 2.30, 95% CI 1.16 – 4.58, p = 0.018). For lame animals, there was no significant difference between front and hind claws in the likelihood of having either a claw horn lesion in general or a double sole ($p \geq 0.05$). However, hind claws of both lame and non-lame finishing cattle were more likely to present with digital dermatitis compared to front claws (lame animals OR 3.97, 95% CI 1.60 – 9.83, p = 0.003, non-lame animals OR 8.16, 95% CI 1.86 – 35.6, p = 0.005). There was no significant difference in the likelihood of occurrence of any other lesion type for either hind versus front claws, lateral versus medial claws, or non-weight bearing versus weight bearing claws ($p < 0.05$).

Table 3.6 Recorded lesion types on lateral and medial claws of finishing cattle, grouped by non-lame and lame status.

Lesion	Number (%) in Non-lame		Number (%) in Lame	
	Lateral claws	**Medial claws**	**Lateral claws**	**Medial claws**
Any lesion	358 (50.9)	367 (52.1)	359 (70.1)	344 (67.2)
Claw horn lesion	101 (14.4)	109 (15.5)	243 (47.5)	214 (41.8)
White line disease	7 (1.0)	5 (0.7)	77 (15.0)	60 (11.7)
Sole haemorrhage	1 (0.1)	0 (0)	5 (1.0)	6 (1.2)
Sole ulcer	0 (0)	0 (0)	9 (1.8)	2 (0.4)
Overgrown sole	0 (0)	1 (0.1)	14 (2.7)	13 (2.5)
Double sole	15 (2.1)	24 (3.4)	60 (11.7)	51 (10.0)
Overgrown claws	77 (10.9)	83 (11.8)	127 (24.8)	122 (23.8)
Axial fissure	5 (0.7)	3 (0.4)	18 (3.5)	21 (4.1)
Infectious lesion	288 (40.9)	293 (41.6)	176 (34.4)	188 (36.7)
I/d phlegmon	0 (0)	0 (0)	3 (0.6)	3 (0.6)
Dermatitis	12 (1.7)	12 (1.7)	33 (6.5)	34 (6.6)
Digital dermatitis	9 (1.3)	9 (1.3)	14 (2.7)	15 (2.9)
I/d dermatitis	5 (0.7)	5 (0.7)	23 (4.5)	23 (4.5)
Heel horn erosion	277 (39.5)	282 (40.1)	149 (29.1)	160 (31.3)
Toe necrosis	0 (0)	1 (0.1)	4 (0.8)	8 (1.6)
Other lesion	5 (0.7)	6 (0.9)	31 (6.1)	28 (5.5)
I/d = interdigital				

3.4.1.4 Lesion association with lameness

Overall, having a lesion led to an 8-fold increase in odds of an animal being lame (OR 8.07, 95% CI 3.34 – 19.5, $p < 0.001$). An increase in the odds of being lame was found for all but one lesion type (

Table 3.8), with white line disease showing the highest odds (OR 20.38, 95% CI 9.58 – 43.37, $p < 0.001$). The exception was heel horn erosion, with an animal having this lesion showing a decreased odds of being lame (OR 0.62, 95% CI 0.39 – 0.98, $p = 0.039$).

Table 3.7 Recorded lesion types on non-weight bearing and weight bearing claws of finishing cattle, grouped by non-lame and lame status.

Lesion	Number (%) in Non-lame		Number (%) in Lame	
	Non-weight bearing claws	Weight bearing claws	Non-weight bearing claws	Weight bearing claws
Any lesion	362 (51.4)	363 (51.6)	354 (69.1)	349 (68.2)
Claw horn lesion	102 (14.5)	108 (15.3)	223 (43.5)	234 (45.7)
White line disease	7 (1)	5 (0.7)	59 (11.5)	78 (15.2)
Sole haemorrhage	1 (0.1)	0 (0)	4 (0.8)	7 (1.4)
Sole ulcer	0 (0)	0 (0)	2 (0.4)	9 (1.8)
Overgrown sole	0 (0)	1 (0.1)	14 (2.7)	13 (2.5)
Double sole	15 (1.0)	24 (3.4)	58 (11.3)	53 (10.4)
Overgrown claws	79 (11.2)	81 (11.5)	125 (24.4)	124 (24.2)
Axial fissure	4 (0.6)	4 (0.6)	21 (4.1)	18 (3.5)
Infectious lesion	292 (41.5)	289 (41.1)	184 (35.9)	180 (35.2)
I/d phlegmon	0 (0)	0 (0)	3 (0.6)	3 (0.6)
Dermatitis	12 (1.7)	12 (1.7)	34 (6.6)	33 (6.5)
Digital dermatitis	9 (1.3)	9 (1.3)	15 (2.9)	14 (2.7)
I/d dermatitis	5 (0.7)	5 (0.7)	23 (4.5)	23 (4.5)
Heel horn erosion	281 (39.9)	278 (39.5)	156 (30.5)	153 (29.9)
Toe necrosis	1 (0.1)	0 (0)	6 (1.2)	6 (1.2)
Other lesion	4 (0.6)	7 (1.0)	30 (5.9)	29 (5.7)
I/d = interdigital				

Table 3.8 The likelihood of a finishing animal being lame by recorded lesion: Odds ratios[1] (95% CI) derived from univariable logistic regression models.

Lesion	No. animals with lesion (lame / non-lame)	Odds Ratio	95% CI[2]	p value
Any lesion	122 / 126	8.07	3.34 - 19.5	<0.001
Claw horn lesion	100 / 48	9.52	5.58 - 16.25	<0.001
White line disease	67 / 9	20.38	9.58 - 43.37	<0.001
Sole haemorrhage	7 / 1	10.12	1.23 - 83.34	0.031
Overgrown sole	6 / 1	8.61	1.02 - 72.39	0.048
Double sole	22 / 16	2.08	1.04 - 4.13	0.038
Overgrown claws	36 / 29	1.98	1.14 - 3.45	0.015
Axial fissure	13 / 3	6.52	1.82 - 23.38	0.004
Infectious lesion	67 / 101	0.82	0.52 - 1.29	0.383
Dermatitis	21 / 8	4.12	1.76 - 9.64	0.001
Digital dermatitis	14 / 6	3.48	1.3 - 9.32	0.013
Interdigital dermatitis	11 / 4	4.04	1.26 - 13	0.019
Heel horn erosion	53 / 94	0.62	0.39 - 0.98	0.039
Toe necrosis	10 / 1	14.83	1.87 - 117.39	0.011
Other lesion	20 / 5	6.33	2.31 - 17.37	<0.001

[1] Baseline odds provided in **appendix 3** [2] CI = confidence interval Sole ulcer and interdigital phlegmon only recorded in lame animals

Table 3.9 Association between body condition score and animal cleanliness and the likelihood of a finishing animal being lame: Univariable random effects logistic regression analyses.

Explanatory variable	Level	Number of animals	Odds Ratio	95% CI[3]	p value
Body Condition score[1]	Referent = combined 1.5 - 2.5	21			
	3	279	0.33	0.12 - 0.91	0.032
	4	4	0.12	0.01 - 1.64	0.111
	baseline odds		1.88	0.71 - 5.03	0.207
Foot cleanliness score[2]	Referent = 1	24			
	2	79	0.9	0.34 - 2.4	0.834
	3	201	0.86	0.33 - 2.29	0.767
	baseline odds		0.77	0.31 - 1.86	0.556
Abdomen cleanliness score[2]	Referent = 1	37			
	2	70	0.86	0.37 - 2.01	0.726
	3	197	1.03	0.46 - 2.29	0.942
	baseline odds		0.69	0.34 - 1.42	0.317

[1] Body condition score from 1 (spinous processes sharp and easily distinguished) to 5 (bone structure no longer visible(188)
[2] Cleanliness score from 1 (clean or minor dirt) to 3 (dirty); adapted from AHDB (28) and Cook (191)
[3] CI = confidence interval

3.4.1.5 Risk factors for lameness

Logistic regression analysis describing association between BCS, foot cleanliness, abdomen cleanliness and lameness is shown in **Table 3.9**. Neither cleanliness score showed a significant effect on the likelihood of a finishing animal being lame ($p < 0.05$). A finishing animal with a BCS of 3 out of 5 had a reduced likelihood of being lame, when compared to animals scoring 1.5 to 2.5 (OR 0.33, 95% CI 0.12 – 0.91 p = 0.032). Having a BCS of 4 apparently had no significant influence on lameness likelihood, but the number of animals scoring 4 was small. No animals were recorded with a BCS of 5.

Summary statistics for putative risk factors for lameness in finishing cattle are presented in **Table 3.2Error! Reference source not found.**. Results from univariable logistic regression analyses of associations between these putative risk factors and an animal being lame are displayed in **Table 3.10**. Variables where $p \leq 0.1$ in the univariable analysis were offered to a multivariable model. Variables with biologically plausible collinearity were examined. The variable ‘Straw condition’ was not offered to a multivariable model because it showed high collinearity (>60%) with ‘Bedding score’. No other instances of collinearity were identified. Following univariable analysis (**Table 3.10**), the following variables were offered to the initial multivariable model; ‘Ration type’, ‘Pen muck out frequency’, ‘Bedding score’, ‘Pen area per animal’, ‘Pen ventilation’, ‘Grip score’ and ‘Does the farmer ever trim feet’.

Animals on an *ad libitum* concentrate ration were more likely to be lame, than those on a total mixed ration (TMR) (OR 2.18, 95% CI 0.96 – 4.97, $p = 0.064$). The following factors were all associated with a reduced likelihood of an animal being lame ($p < 0.1$) for finishing cattle: being housed in pens mucked out more frequently (every 3 to 6 months compared to 6 months to annually), having a ‘good’ bedding score (compared to an ‘acceptable’ bedding score), being in a smaller sized pen, having ‘good’ ventilation (compared to ‘poor’), having a grip score of 2 (compared to a grip score of 3 or 4) and the farmer not trimming feet.

Following a backwards stepwise removal of variables where $p > 0.1$, the following variables were retained in the final multivariable model: ‘Pen area per animal’, ‘Pen ventilation’, and ‘Grip score’. Finishing cattle in pens with ‘poor’ ventilation score, an increased area (m^2) provided per animal or a higher grip score (increasing from 2-4) were associated with an increased odds of being lame (**Table 3.11**). Biologically plausible interaction terms were offered to the final multivariable model, but none were found to improve model fit.

Table 3.10 Association between putative farm level risk factors and the likelihood of a finishing animal being lame: Univariable random effects logistic regression analyses.

Explanatory variable	Level	Number of animals	Odds Ratio	95% CI[1]	p value
Total herd size	Herd size, including all cattle types / ages	1686	1	1 - 1	0.226
	baseline odds		0.1	0.05 - 0.21	<0.001
No. in pen	Number of animals sharing the pen	1686	0.98	0.96 - 1	0.11
	baseline odds		0.11	0.05 - 0.21	<0.001
Breed type	Referent = 1 = Beef cross breed	737			
	2 = Beef breed	177	1.08	0.56 - 2.08	0.815
	3 = Dairy cross breed	24	0.97	0.2 - 4.7	0.966
	4 = Dairy breed	163	1.3	0.64 - 2.66	0.468
	baseline odds		0.08	0.05 - 0.13	<0.001
Sex	Referent = 0 = Castrated male	289			
	1 = Entire male	626	1.03	0.5 - 2.11	0.942
	2 = Female	285	1.2	0.56 - 2.57	0.636
	baseline odds		0.08	0.05 - 0.15	<0.001
Age	Age in months at scoring	1100	1	0.95 - 1.06	0.867
	baseline odds		0.08	0.02 - 0.26	<0.001
Silage type	Referent = 1 = Grass	926			
	2 = Maize	110	0.9	0.24 - 3.38	0.873
	baseline odds		0.06	0.03 - 0.09	<0.001
Ration type	Referent = 1 = Total mixed ration	929			
	2 = Various separate components fed	440	1.77	0.83 - 3.79	0.139
	3 = *Ad libitum* concentrates	317	2.18	0.96 - 4.97	0.064
	baseline odds		0.05	0.03 - 0.08	<0.001
Pen type	Referent = 1 = Deep litter with concrete area	792			
	2 = Mainly slatted flooring	219	1.28	0.43 - 3.83	0.655
	3 = Complete deep litter pen	495	1.77	0.73 - 4.3	0.208
	4 = Cubicles	138	1.98	0.51 - 7.71	0.323
	baseline odds		0.05	0.03 - 0.09	<0.001
Bedding top-up frequency	Referent = 1 = Daily	946			
	2 = Every 2 to 3 days	154	0.55	0.13 - 2.33	0.417
	3 = Twice a week	104	1.64	0.4 - 6.78	0.494
	4 = Weekly or fortnightly	126	2.32	0.62 - 8.66	0.211
	baseline odds		0.06	0.03 - 0.1	<0.001
Pen scraping frequency	Referent = 1 = Daily	162			
	2 = Every 2 to 4 days	420	0.81	0.18 - 3.71	0.784

	3 = From every 5 days to monthly	184	1.75	0.31 - 9.9	0.528
	baseline odds		0.07	0.02 - 0.28	<0.001

Table 3.10 (continued)

Explanatory variable	Level	Number of animals	Odds Ratio	95% CI[1]	p value
Pen muck out frequency	Referent = 3 = From 6 monthly to annually	414			
	1 = More frequently than 3 monthly	453	0.49	0.2 - 1.21	0.123
	2 = Between 3 months and 6 months	420	0.36	0.14 - 0.93	0.035
	baseline odds		0.1	0.06 - 0.19	<0.001
Bedding score	Referent = 1 = Good	740			
	2 = Acceptable	609	2.41	1.18 - 4.93	0.016
	3 = Poor	295	1.77	0.73 - 4.3	0.207
	baseline odds		0.04	0.02 - 0.07	<0.001
Straw condition	Referent = 1 = Clean	438			
	2 = Slightly damp / dirty	771	1.29	0.59 - 2.81	0.53
	3 = Damp / dirty	157	2.99	1.06 - 8.44	0.038
	4 = Thick manure / considerably wet	278	1.36	0.49 - 3.8	0.554
	baseline odds		0.05	0.03 - 0.09	<0.001
Feed space provision	Referent = 1 = Inadequate	732			
	2 = Adequate	954	0.98	0.5 - 1.95	0.964
	baseline odds		0.07	0.04 - 0.12	<0.001
Pen area per animal	Total area provided per head, in m^2 (log_e transformed)	1633	2.33	1.21 - 4.49	0.011
	baseline odds		0.01	0 - 0.05	<0.001
Pen ventilation	Referent = 1 = Good	466			
	2 = Poor	1219	2.04	0.92 - 4.51	0.08
	baseline odds		0.04	0.02 - 0.08	<0.001
Grip score	Referent = 2 = Slightly slippery	138			
	3 = Medium	913	7.25	1.11 - 47.32	0.039
	4 = Slightly abrasive	293	8.78	1.21 - 63.9	0.032
	baseline odds		0.01	0 - 0.06	<0.001
Faecal score	Referent = 2 = Flat, thinly spread	44			
	3 = Circumscribed, moist raised pat	790	0.24	0.03 - 1.91	0.179
	4 = Dry stiff pats	510	0.29	0.04 - 2.36	0.248
	baseline odds		0.21	0.03 - 1.57	0.129
Footbath ever provided	Referent = 0 = No	1400			
	1 = Yes	286	1.07	0.4 - 2.85	0.896
	baseline odds		0.06	0.04 - 0.1	<0.001
Does farmer ever trim feet	Referent = 0 = No	1108			

	1 = Yes	578	2.12	1.1 - 4.08	0.024
	baseline odds		0.05	0.03 - 0.08	<0.001
[1]CI = Confidence interval					

Table 3.11 Association between putative farm level risk factors and the likelihood of a finishing animal being lame: Multivariable random effects logistic regression analyses.

Explanatory variable	**Level**	**Odds Ratio**	**95% CI[1]**	**p value**
Pen area per animal	Total area provided per head, in m^2 (log_e transformed)	1.8	1.03 - 3.15	0.039
Pen ventilation	Referent = 1 = Good			
	2 = Poor	2.16	1.02 - 4.6	0.045
Grip score	Referent = 2 = Slightly slippery			
	3 = Medium	7.37	1.37 - 39.58	0.02
	4 = Slightly abrasive	8.39	1.47 - 47.84	0.017
	baseline odds	0	0 - 0.01	<0.001
[1]CI = Confidence interval				

3.4.2 Suckler cows

3.4.2.1 Characteristics of farms and animals

The 12 suckler herds were recruited from North Wales (n=11) and North West England (n=1). The median herd size for farms with suckler cows was 238, ranging from 111 to 800. The median number of eligible suckler cows was 77 (range 61 – 150), and a total of 1050 suckler cows were locomotion scored, with a median number of cattle scored per farm of 79 (range 61 – 133). The median age of cows scored was 60.5 months (range 15.7 – 226.2 months).

Cows were housed in one of five pen types: entirely deep litter, deep litter with a concrete area (generally a feed passage or loafing area), entirely concrete flooring, cubicle housing or slatted housing. Some farms (n=3) employed a number of different pen types for similar production groups.

3.4.2.2 Farm lameness prevalence

One hundred and forty one lame suckler cows were identified (13.4% of all suckler cows locomotion scored). The mean within farm level prevalence of lameness of suckler cows was 14.2% (median 14.0%, range 0 – 43.2%). Individual suckler farm lameness prevalences are displayed in **Figure 3.2**.

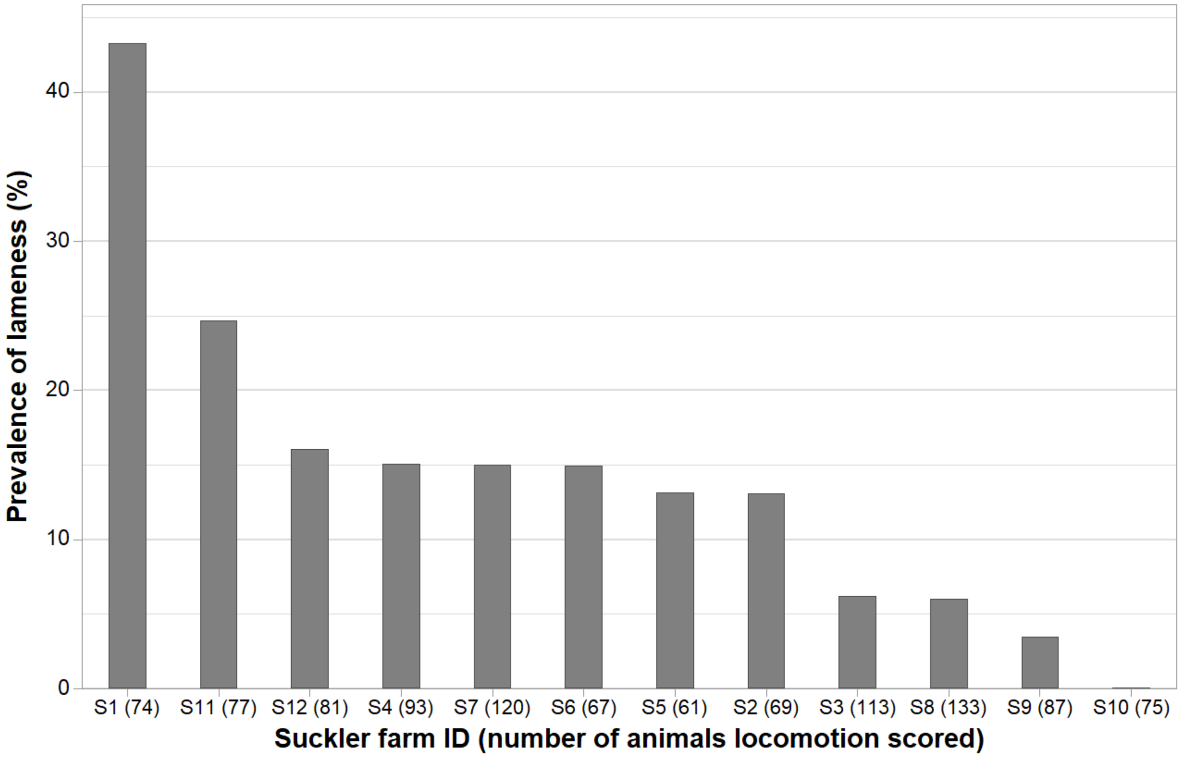


Figure 3.2 Lameness prevalence for 12 suckler farms.

3.4.2.3 Lesion frequencies

Lesion frequencies for both non-lame and lame suckler cows are presented in **Table 3.12**. In non-lame cows, 74% of animals and 61% of claws had at least one lesion. In lame cows, significantly more animals (96%) and claws (72%) had at least one lesion than non-lame cows (Pearson χ^2 $p < 0.001$ and $p < 0.001$ respectively). Digital dermatitis was present on four suckler farms, and interdigital dermatitis was present on two farms, one of which had both lesions (but not present on the same animals). There was no association between the presence of digital dermatitis and interdigital dermatitis in suckler cows (Fisher's exact test p = 1.000). There was a positive association between the presence of claw horn lesions and infectious lesions (Fisher's exact test p = 0.050), but no association between claw horn lesions and dermatitis lesions (Fisher's exact test p = 0.749). The group 'other lesions' consisted of lesions with a low prevalence, including suspected pelvic injury, a deformed hoof or leg, or joint disorders. No non-foot lesions were diagnosed at sufficient frequency to enable further analysis.

Table 3.12 Lesion prevalence at animal, foot and claw level for non-lame and lame suckler cows (non-lame = 129 animals, 516 feet, 1032 claws; lame = 111 animals, 444 feet, 888 claws).

Lesion	Number (%) in Non-lame			Number (%) in Lame		
	Animals	**Feet**	**Claws**	**Animals**	**Feet**	**Claws**
Any lesion	96 (74.4)	327 (63.4)	631 (61.1)	107 (96.4)	348 (78.4)	643 (72.4)
Claw horn lesion	32 (24.8)	76 (14.7)	117 (11.3)	91 (82.0)	221 (49.8)	309 (34.8)
White line disease	18 (14.0)	47 (9.1)	52 (5.0)	78 (70.3)	171 (38.5)	204 (23.0)
Sole haemorrhage	3 (2.3)	10 (1.9)	18 (1.7)	2 (1.8)	3 (0.7)	6 (0.7)
Sole ulcer	1 (0.8)	1 (0.2)	1 (0.1)	8 (7.2)	8 (1.8)	8 (0.9)
Overgrown sole	1 (0.8)	1 (0.2)	1 (0.1)	2 (1.8)	3 (0.7)	3 (0.3)
Double sole	1 (0.8)	1 (0.2)	1 (0.1)	13 (11.7)	20 (4.5)	22 (2.5)
Overgrown claws	20 (15.5)	36 (7.0)	66 (6.4)	25 (22.5)	58 (13.1)	107 (12.1)
Axial fissure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Infectious lesion	74 (57.4)	273 (52.9)	546 (52.9)	66 (59.5)	249 (56.1)	495 (55.7)
I/d phlegmon	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Dermatitis	1 (0.8)	1 (0.2)	2 (0.2)	9 (8.1)	9 (2.0)	14 (1.6)
Digital dermatitis	0 (0)	0 (0)	0 (0)	7 (6.3)	7 (1.6)	10 (1.1)
I/d dermatitis	1 (0.8)	1 (0.2)	2 (0.2)	2 (1.8)	2 (0.5)	4 (0.5)
Heel horn erosion	73 (56.6)	272 (52.7)	544 (52.7)	62 (55.9)	245 (55.2)	490 (55.2)
Toe necrosis	0 (0)	0 (0)	0 (0)	7 (6.3)	7 (1.6)	7 (0.8)
Other lesion	2 (1.6)	2 (0.4)	2 (0.2)	12 (10.8)	16 (3.6)	27 (3.0)
I/d = interdigital						

3.4.2.3.1 Lesion frequencies by claw types

Lesion frequencies in suckler cows by type of claw are presented in **Table 3.13** (front versus hind claws), **Table 3.14** (lateral versus medial claws) and

Table 3.15 (non-weight bearing versus weight bearing claws) for both lame and non-lame animals.

Table 3.13 Recorded lesion types on front and hind claws of suckler cows, grouped by non-lame and lame status.

Lesion	Number (%) in Non-lame		Number (%) in Lame	
	Front claws	**Hind claws**	**Front claws**	**Hind claws**
Any lesion	322 (62.4)	309 (59.9)	325 (73.2)	318 (71.6)
Claw horn lesion	62 (12.0)	55 (10.7)	156 (35.1)	153 (34.5)
White line disease	27 (5.2)	25 (4.8)	104 (23.4)	100 (22.5)
Sole haemorrhage	8 (1.6)	10 (1.9)	0 (0)	6 (1.4)
Sole ulcer	1 (0.2)	0 (0)	3 (0.7)	5 (1.1)
Overgrown sole	0 (0)	1 (0.2)	0 (0)	3 (0.7)
Double sole	1 (0.2)	0 (0)	15 (3.4)	7 (1.6)
Overgrown claws	34 (6.6)	32 (6.2)	53 (11.9)	54 (12.2)
Infectious lesion	272 (52.7)	274 (53.1)	250 (56.3)	245 (55.2)
Dermatitis	0 (0)	2 (0.4)	3 (0.7)	11 (2.5)
Digital dermatitis	0 (0)	0 (0)	3 (0.7)	7 (1.6)
I/d dermatitis	0 (0)	2 (0.4)	0 (0)	4 (0.9)
Heel horn erosion	272 (52.7)	272 (52.7)	248 (55.9)	242 (54.5)
Toe necrosis	0 (0)	0 (0)	5 (1.1)	2 (0.5)
Other lesion	1 (0.2)	1 (0.2)	14 (3.2)	13 (2.9)
I/d = interdigital				

Table 3.14 Recorded lesion types on lateral and medial claws of suckler cows, grouped by non-lame and lame status.

Lesion	Number (%) in Non-lame		Number (%) in Lame	
	Lateral claws	**Medial claws**	**Lateral claws**	**Medial claws**
Any lesion	320 (62.0)	311 (60.3)	335 (75.5)	308 (69.4)
Claw horn lesion	65 (12.6)	52 (10.1)	186 (41.9)	123 (27.7)
White line disease	35 (6.8)	17 (3.3)	135 (30.4)	69 (15.5)
Sole haemorrhage	10 (1.9)	8 (1.6)	3 (0.7)	3 (0.7)
Sole ulcer	1 (0.2)	0 (0)	6 (1.4)	2 (0.5)
Overgrown sole	1 (0.2)	0 (0)	3 (0.7)	0 (0)
Double sole	0 (0)	1 (0.2)	13 (2.9)	9 (2.0)
Overgrown claws	35 (6.8)	31 (6.0)	55 (12.4)	52 (11.7)
Infectious lesion	273 (52.9)	273 (52.9)	248 (55.9)	247 (55.6)
Dermatitis	1 (0.2)	1 (0.2)	7 (1.6)	7 (1.6)
Digital dermatitis	0 (0)	0 (0)	5 (1.1)	5 (1.1)
I/d dermatitis	1 (0.2)	1 (0.2)	2 (0.5)	2 (0.5)
Heel horn erosion	272 (52.7)	272 (52.7)	245 (55.2)	245 (55.2)
Toe necrosis	0 (0)	0 (0)	3 (0.7)	4 (0.9)
Other lesion	2 (0.4)	0 (0)	14 (3.2)	13 (2.9)
I/d = interdigital Axial fissure and interdigital phlegmon not recorded. Digital dermatitis toe necrosis only recorded in lame animals				

Table 3.15 Recorded lesion types on non-weight bearing and weight bearing claws of suckler cows, grouped by non-lame and lame status.

Lesion	Number (%) in Non-lame		Number (%) in Lame	
	Non-weight bearing claws	Weight bearing claws	Non-weight bearing claws	Weight bearing claws
Any lesion	313 (60.7)	318 (61.6)	315 (71.0)	328 (73.9)
Claw horn lesion	54 (10.5)	63 (12.2)	133 (30.0)	176 (39.6)
White line disease	20 (3.9)	32 (6.2)	81 (18.2)	123 (27.7)
Sole haemorrhage	8 (1.6)	10 (1.9)	3 (0.7)	3 (0.7)
Sole ulcer	1 (0.2)	0 (0)	1 (0.2)	7 (1.6)
Overgrown sole	0 (0)	1 (0.2)	0 (0)	3 (0.7)
Double sole	0 (0)	1 (0.2)	6 (1.4)	16 (3.6)
Overgrown claws	31 (6.0)	35 (6.8)	51 (11.5)	56 (12.6)
Infectious lesion	273 (52.9)	273 (52.9)	249 (56.1)	246 (55.4)
Dermatitis	1 (0.2)	1 (0.2)	8 (1.8)	6 (1.4)
Digital dermatitis	0 (0)	0 (0)	6 (1.4)	4 (0.9)
I/d dermatitis	1 (0.2)	1 (0.2)	2 (0.5)	2 (0.5)
Heel horn erosion	272 (52.7)	272 (52.7)	245 (55.2)	245 (55.2)
Toe necrosis	0 (0)	0 (0)	1 (0.2)	6 (1.4)
Other lesion	1 (0.2)	1 (0.2)	11 (2.5)	16 (3.6)
I/d = interdigital				

The odds ratio for the likelihood of both non-lame and lame suckler cows having lesions on their hind versus front claws, medial versus lateral claws and non-weight bearing versus weight bearing claws are displayed in **appendix 2**, **tables A2.4, A2.5 and A2.6**. Lame animals were more likely to have lesions of dermatitis in the hind claws compared to front claws (OR 3.73, 95% CI 1.03 – 13.48, p = 0.044), whilst in non-lame animals, dermatitis was only observed on hind claws (n = 2). Overall, lateral claws of lame suckler cows were more likely to present with a lesion of any type compared to medial claws (OR 1.36, 95% CI 1.01 – 1.82, p = 0.043). In the case of claw horn lesions in lame cattle, the odds ratio for lesion occurrence on the lateral claws compared to the medial claw was 1.88 (95% CI 1.42 – 2.49, p ≤ 0.001). For white line disease more specifically, the lateral claws of both lame and non-lame cows were more likely to have a lesion than medial claws (lame OR 2.37, 95% CI 1.71 – 3.29, p ≤ 0.001, non-lame OR 2.14, 95% CI 1.18 – 3.86, p = 0.012).

For lame animals, compared to non-weight bearing claws, the weight bearing claws (front medial and hind lateral) were more likely to have a claw horn lesion in general (OR 1.54, 95% CI 1.16 – 2.03, $p = 0.003$). In particular, white line disease (OR 1.71, 95% CI 1.25 – 2.36, $p = 0.001$), and a double sole was more likely to occur on a weight bearing claw than a non-weight bearing claw of lame suckler cows (OR 2.73, 95% CI 1.06 – 7.04, $p = 0.038$). There was no significant difference for any other lesion type for either hind versus front claws, lateral versus medial claws or non-weight bearing versus weight bearing claws (at $p \leq 0.05$).

3.4.2.4 Lesion association with lameness

Table 3.16 displays the odds ratios for associations between various lesion types and lameness for suckler cows.

Having any lesion was associated with a nine-fold increase in the odds of being lame (OR 9.2, 95% CI 3.14 – 26.91, $p < 0.001$). The presence of white line disease showed a 14.6-fold increase in the likelihood of being lame. Several other specific lesions (sole ulcer, double sole, dermatitis, and other lesion) were associated with an increased odds of being lame too, but with a wide 95% confidence interval. Digital dermatitis was not present on non-lame cows.

Table 3.16 The likelihood of a suckler cow being lame by recorded lesion: Odds ratios[1] (95% CI) derived from univariable logistic regression models.

Lesion	**No. animals with lesion (lame / non-lame)**	**Odds Ratio**	**95% CI[2]**	**p value**
Any lesion	107/96	9.20	3.14 - 26.91	<0.001
Claw horn lesion	91/32	13.79	7.36 - 25.84	<0.001
White line disease	78/18	14.58	7.66 - 27.73	<0.001
Sole haemorrhage	2/3	0.77	0.13 - 4.7	0.778
Sole ulcer	8/1	9.94	1.22 - 80.78	0.032
Overgrown sole	2/1	2.35	0.21 - 26.25	0.488
Double sole	13/1	16.98	2.18 - 132.01	0.007
Overgrown claws	25/20	1.58	0.83 - 3.04	0.167
Infectious lesion	66/74	1.09	0.65 - 1.82	0.743
Dermatitis	9/1	11.29	1.41 - 90.61	0.022
Interdigital dermatitis	2/1	2.35	0.21 - 26.25	0.488
Heel horn erosion	62/73	0.97	0.58 - 1.62	0.909
Other lesion	21/2	7.70	1.68 - 35.19	0.008

[1] baseline odds provided in **appendix 3**
[2] CI = confidence interval

3.4.2.5 Risk factors for lameness

Logistic regression analysis showed no significant association between either BCS, foot cleanliness or abdomen cleanliness with the likelihood of a suckler cow being lame (at $p \leq 0.05$, **Table 3.17**).

Table 3.17 Association between body condition score and animal cleanliness and the likelihood of a suckler cow being lame: Univariable random effects logistic regression analyses.

Explanatory variable	Level	Number of animals	Odds Ratio	95% CI[3]	p value
Body Condition score[1]	Referent = 2	5			
	2.5	34	1.24	0.18 - 8.67	0.829
	3	189	1.41	0.22 - 9.01	0.714
	3.5	12	1.62	0.19 - 14.18	0.661
	baseline odds		0.62	0.1 - 3.86	0.607
Foot cleanliness score[2]	Referent = 2	9			
	3	141	0.6	0.15 - 2.43	0.477
	4	90	0.75	0.18 - 3.13	0.693
	baseline odds		1.29	0.33 - 5.03	0.718
Abdomen cleanliness score[2]	Referent = combined 1 and 2	10			
	3	140	0.47	0.12 - 1.81	0.272
	4	90	0.65	0.16 - 2.58	0.537
	baseline odds		1.57	0.42 - 5.85	0.503

[1] Body condition score from 1 (spinous processes sharp and easily distinguished) to 5 (bone structure no longer visible) (188)
[2] Cleanliness score from 1 (clean or minor dirt) to 3 (dirty); adapted from AHDB (28) and Cook (191)
[3] CI = confidence interval

Summary statistics for putative risk factors for lameness in suckler cows are presented in **Table 3.3**. Results from univariable logistic regression analyses of associations between these putative risk factors and an animal being lame are displayed in **Table 3.18**. Variables where $p \leq 0.1$ in the univariable analysis were offered to a multivariable model. Variables with biologically plausible collinearity were examined, but none showed notable collinearity (>60%). Following univariable analysis (**Table 3.18**), the following variables were offered to the initial multivariable model: 'Age', 'Breed', 'Pen scraping frequency', 'Does the farmer ever trim feet', and 'Pen ventilation'. Continental breeds (including Stabilisers) and younger cows showed a reduced likelihood of being lame, whereas suckler cows in pens scraped more frequently or with 'poor' ventilation (compared to 'good' ventilation) or if the farmer ever trimmed any cows feet (compared to never trimming any feet) showed an increased likelihood of being lame ($p \leq 0.1$).

Following a backwards stepwise removal of variables where $p > 0.1$, the following variables were retained in the final multivariable model: ‘Age’ and ‘Pen ventilation’ (**Table 3.19**). Biologically plausible interaction terms were offered to the final multivariable model, but none were found to improve model fit.

Table 3.18 Association between putative farm level risk factors and the likelihood of a suckler cow being lame: Univariable random effects logistic regression analyses.

Explanatory variable	Level	Number of animals	Odds Ratio	95% CI[1]	p value
Total herd size	Herd size, including all cattle types / ages	1050	1	1 - 1	0.332
	baseline odds		0.08	0.03 - 0.23	<0.001
No. animals in pen	Number of animals sharing the pen	975	1	0.99 - 1.01	0.859
	baseline odds		0.16	0.08 - 0.32	<0.001
Breed	Referent = 1 = Traditional British breed	876			
	2 = Continental or Stabiliser breed	85	0.49	0.21 - 1.11	0.088
	baseline odds		0.45	0.08 - 2.38	0.345
Age	Age in months at scoring ($\log_e$ transformed)	960	3.17	2.02 - 4.96	<0.001
	baseline odds		0	0 - 0.01	<0.001
Pen type	Referent = 1 = Deep litter with concrete area	585			
	2 = Cubicles	309	1.33	0.65 - 2.74	0.436
	3 = Complete concrete pen	61	0.99	0.19 - 5.13	0.993
	baseline odds		0.14	0.08 - 0.24	<0.001
Bedding top-up frequency	Referent = 1 = Daily	176			
	3 = Twice a week	427	0.7	0.25 - 1.94	0.493
	4 = Weekly or fortnightly	69	0.7	0.11 - 4.59	0.708
	baseline odds		0.2	0.08 - 0.5	0.001
Pen scraping frequency	Referent = 1 = Daily	209			
	2 = Every 2 to 4 days	443	0.43	0.18 - 1.03	0.058
	3 = From every 5 days to monthly	167	0.68	0.25 - 1.84	0.452
	baseline odds		0.26	0.13 - 0.53	<0.001
Pen muck out frequency	Referent = 1 = More frequently than 3 monthly	371			
	2 = Between 3 months and 6 months	206	0.63	0.18 - 2.26	0.479
	3 = From 6 monthly to annually	297	1.15	0.4 - 3.3	0.798
	baseline odds		0.16	0.08 - 0.33	<0.001
Bedding score	Referent = 2 = Acceptable	302			
	3 = Poor	653	1.52	0.58 - 3.99	0.396
	baseline odds		0.11	0.05 - 0.26	<0.001
Straw condition	Referent = 1 = Clean	89			
	2 = Slightly damp / dirty	213	1.14	0.34 - 3.86	0.837
	3 = Damp / dirty	231	1.87	0.43 - 8.2	0.407
	4 = Thick manure / considerably wet	422	1.54	0.39 - 6.08	0.539
	baseline odds		0.1	0.03 - 0.35	<0.001

Table 3.18 (continued)

Explanatory variable	Level	Number of animals	Odds Ratio	95% CI[1]	p value
Feed space provision	Referent = 1 = Inadequate	197			
	2 = Adequate	643	1.17	0.50 - 2.77	0.718
	baseline odds		0.13	0.05 - 031	<0.001
Pen area per animal	Total area provided per head, in m^2 ($\log_e$ transformed)	954	0.71	0.43 - 1.15	0.159
	baseline odds		0.36	0.1 - 1.29	0.116
Pen ventilation	Referent = 1 = Good	271			
	2 = Poor	684	3.02	1.34 - 6.83	0.008
	baseline odds		0.02	0 - 0.1	<0.001
Grip score	Referent = 1 = Slippery	67			
	2 = Slightly slippery	190	1.04	0.16 - 6.67	0.964
	3 = Medium	440	0.96	0.19 - 4.87	0.96
	4 = Slightly abrasive	258	1.02	0.19 - 5.43	0.98
	baseline odds		0.15	0.03 - 0.7	0.016
Faecal score	Referent = 2 = Flat, thinly spread	67			
	3 = Circumscribed, moist raised pat	614	1.03	0.2 - 5.17	0.976
	4 = Dry stiff pats	274	0.91	0.15 - 5.37	0.919
	baseline odds		0.16	0.03 - 0.71	0.016
Footbath ever provided	Referent = 0 = No	969			
	1 = Yes	81	1.57	0.2 - 12.13	0.667
	baseline odds		0.12	0.07 - 0.22	<0.001
Does the farmer ever trim feet	Referent = 0 = No	915			
	1 = Yes	135	3.33	0.97 - 11.44	0.056
	baseline odds		0.1	0.06 - 0.18	<0.001
Does a professional ever examine lame animals	Referent = 0 = No	375			
	1 = Yes	675	1.14	0.36 - 3.61	0.821
	baseline odds		0.11	0.05 - 0.28	<0.001
Any routine preventative trimming	Referent = 0 = No	969			
	1 = Yes	81	1.57	0.2 - 12.13	0.667
	baseline odds		0.12	0.07 - 0.22	<0.001

[1]CI = Confidence interval

Table 3.19 Association between putative farm level risk factors and the likelihood of a suckler cow being lame: Multivariable random effects logistic regression analyses.

Explanatory variable	Level	Odds Ratio	95% CI[1]	p value
Age	Age in months ($\log_e$ transformed)	3.13	2 - 4.88	<0.001
Pen ventilation	Referent = 1 = Good			
	2 = Poor	2.97	1.36 - 6.5	0.006
	baseline odds	0	0 - 0	<0.001

3.5 Discussion

3.5.1 Farm lameness prevalence

The mean farm prevalence of lameness of 8.3% for finishing cattle and 14.2% for suckler cows are within the wide range of beef cattle lameness prevalence reports internationally (21,23,31,32,41), but are generally lower than the UK dairy prevalence estimates (34). The convenience sampling, and number and geographical location of farms in this study may limit the ability to extrapolate these figures across the wider UK beef industry. However, the results give an important and novel indication that may serve as a base for further studies. They also give an interesting insight into the range of lameness prevalence that exists across the industry, with nine farms showing low levels (less than 1 in 20 animals lame) rising to a maximum of approximately 1 in 5 animals lame on finishing units, and 2 in 5 in suckler herds. It should be borne in mind that lameness prevalence was established while cattle were housed and over a period of a few months only, therefore the prevalence in animals at pasture or at other times of year may differ.

The highest farm level lameness prevalence appears to be due to a general combination of risk factors, as farms with the highest prevalence did not consistently perform worst when looking at the presence and severity of risk factors. However, for suckler cows, the two highest lameness prevalence farms also had the two highest mean age of cows. This is likely to have contributed to their lameness risk, and should be considered during culling and replacement decisions.

There are concerns over agreement and reliability with locomotion scoring (17). However, the study used a scoring system based on one that was considered acceptable for intra and inter-observer agreement (chapter 2 (180)), and the observer was experienced in locomotion scoring in general, and practiced in the specific scoring system utilised. Binary analysis (i.e. lame versus non-lame) was found to be most suitable, and therefore adding scores to better discriminate severity of lameness was ultimately not required. Notwithstanding that the 16 animals (nine finishing cattle, seven suckler cows) demonstrating non-weight bearing (i.e. score 4) posed a particular welfare concern.

3.5.2 Lesion frequencies

The lesion types identified were similar in both finishing cattle and suckler cows. Claw horn lesions were more frequently seen than dermatitis lesions, which is consistent with findings in finishing cattle in Italy (171) and beef cattle in general in Canada (116). However, it contrasts with two Canadian studies in dairy cattle, where digital dermatitis was the most common foot lesion present across 156 herds (192) and the herd level prevalence of digital dermatitis was higher than that of any claw horn lesion across 142 tie-stall and 38 free-stall herds (94).

Heel horn erosion was frequently seen in both lame and non-lame cattle. In finishing cattle, heel horn erosion appeared to be associated with a reduced odds of being lame. Whilst heel horn erosion is a common finding in non-lame cattle, a protective effect has not previously been reported, thus this finding is worthy of further investigation.

An observation consistent across both finishing cattle and suckler cows was the importance of white line disease. It was the most common lesion in both lame finishing cattle and suckler cows (at the animal level), and its presence significantly increased the likelihood of an animal being lame; by approximately 20 times for finishing cattle, and 14 times for suckler cows. This confirms white line disease to be a clinically important condition. Claw horn disease in general increased the likelihood of an animal being lame by 9.5 times for finishing cattle and 13.8 times for suckler cows.

Digital dermatitis was identified amongst both finishing cattle and suckler cows. Until recently, this lesion had not been reported in UK beef cattle (125,172). Digital dermatitis is being increasingly identified amongst cattle populations internationally (193), which, if representative of a true increase in prevalence, is a cause for concern.

The presence of digital dermatitis was associated with the presence of interdigital dermatitis lesions in finishing cattle. This may support the body of opinion that they are different manifestations of the same condition (131,183). Alternatively, the association could be a coincidence, with both conditions having similar risk factors and these being present on those farms. Likely because of the small number of digital dermatitis and interdigital dermatitis lesions identified, no such association was seen in suckler cows.

There were relatively few non-foot lesions identified for both finishing cattle and suckler cows, and these included swollen joints, abscesses or deformities. Due to the small number of lesions identified, the association of individual lesions with lameness was not investigated. The method for non-foot lameness diagnosis is likely to have led to under reporting of upper limb lesions. For example, cartilage and other joint related lesions, including osteoarthritis and osteodystrophies, would have been better diagnosed with imaging, or upper limb palpation and flexion testing, neither of which were performed. As identified in this study, some foot lesions were found on non-lame animals, highlighting the importance of a thorough clinical assessment to avoid lameness being incorrectly attributed to a non-pathogenic foot lesion, when a non-foot lesion is the true cause.

3.5.2.1 Lesion frequencies by claw types

Dermatitis (either digital or interdigital) appears to show a predilection for hind claws of both non-lame and lame finishing cattle and lame suckler cows. However, that dermatitis was not observed in non-lame suckler cows is similar to findings by

Fjeldaas *et al.* in Norwegian suckler cows (21). In contrast, claw horn lesions were more likely to be found on front claws of non-lame finishing cattle, with no claw predilection shown on lame finishing cattle.

In finishing cattle, lesions showed no predilection for medial claws versus lateral claws, or weight bearing claws versus non-weight bearing claws. The absence of a predilection for lateral claws contrasts with an Italian post-mortem study of finishing cattle (171). Lame suckler cows, however, were more likely to have lesions on lateral claws than medial claws, and for white line disease this predilection applied to both lame and non-lame cattle. Lame suckler cows also had an increased likelihood of having a claw horn lesion on weight bearing claws versus non-weight bearing claws. This appeared to be a genuine difference, and not indirectly caused by a higher lesion frequency in either front or hind feet. In dairy cows, hind limbs possibly distribute as much as 80% of the weight through the lateral claws, and 20% through the medial claws. In the front limbs, the medial claw is considered to carry more weight than the lateral claw, however with a lesser difference in weight bearing than in the hind limbs (132,184). It has been suggested that weight bearing asymmetry increases as an animal ages (132), which may explain the lack of lesion frequency difference between lateral and medial claws in the finishing cattle, compared to the suckler cows.

3.5.3 Risk factors for lameness

Missing data is likely to have influenced the analysis of risk factors for lameness, particularly when performing multivariable analysis and considering that some data was missing not at random (e.g. some farmers unable to provide breed data, or some pens unmeasurable). The large number of missing values recorded, often at farm or pen level, may have resulted in both the non-inclusion of potentially important risk factors in the final multivariable model and in the production of biased estimates for included variables, thus the multivariable modelling results must be interpreted with caution. Similarly it must be accepted that the univariable results do not account for confounding by the other measured variables.

3.5.3.1 Housing environment factors

Both multivariable and univariable modelling identified that the pen area provided per animal, pen ventilation and the grip score of their pen were risk factors for lameness in finishing cattle and pen ventilation was an important risk factors in suckler cows.

Both finishing cattle and suckler cows kept in pens with poor ventilation were more likely to be lame than equivalent animals kept in pens with good ventilation. Poor ventilation is considered to have negative welfare implications, and has been identified as an important area for investment within the UK beef industry (102), and regulations stipulate the provision of ventilation (194). However the relationship with lameness is not likely to be simple. The general purpose of ventilation is to remove heat, moisture, gases and infectious agents from the housing environment. Pens with poor ventilation are likely to have increased humidity, resulting from impaired moisture removal. There is evidence that softer claw horn is associated with a greater claw moisture content, which is influenced by the environmental conditions (195), and this would leave animals more susceptible to white line disease and lameness. Increased moisture may have an effect on bed quality, and as such an effect on general cow comfort and standing / lying times, which are known to relate to lameness risk (196). Therefore, one might expect a poorer bedding score variable to show an increased lameness likelihood, but despite a positive trend for both finishing cattle and suckler cows, it was not statistically significant ($p < 0.05$). Ventilation score, however, as a subjective score may have inadvertently been a proxy for overall building quality, and this cannot be ruled out. Therefore, farms with buildings or environmental conditions that appear beneficial may have been given a ‘good’ score, and the true relationship may be between ‘good’ buildings and reduced lameness likelihood.

As the pen area (m^2) provided per finishing animal increased, there was an increase in likelihood of that animal becoming lame. For both finishing cattle and suckler cows, the recommended total loose housing space allowance for either a 500Kg or 600Kg animal is 5.85m^2 or 6.8m^2 respectively (197). Of finishing cattle, 633 animals (of 1689 records) failed to meet this requirement. Despite these notable numbers of animals with insufficient space allowance, increased space was detrimentally associated with lameness. This appears counterintuitive. However, increased space may lead to more activity, including rough play. Furthermore, a number of animals were observed to be housed in non-purpose built accommodation – such buildings (like machinery or storage sheds) may offer more space, but their design may inadvertently increase lameness risk factors. Therefore, the true cause of lameness may not be associated with the size of the pen or space allowance *per se*, but rather a combination of other underlying factors. The association between increasing pen area and increasing lameness contrasts with evidence from the dairy sector, where increased stocking density is known to reduce lying times (198) and so can increase the risk of lameness (199). In the present study of suckler cows, 159 cows (of 957 records) had less space allowance than recommended, however there was no association between lameness and housing area provided for suckler cows.

Grip score was associated with lameness likelihood in finishing animals, but not in suckler cows. Only scores of 2 (slightly slippery), 3 (medium) and 4 (slightly abrasive) were found across finishing units, and as the score increased from 2 to 3 and to 4, the likelihood of animals in pens scoring 3 or 4 being lame increased. The abrasiveness of flooring surface is known to be a risk factor for lameness in dairy cattle (200–202) due to altered wear leading to foot imbalance, thin soles and an increase in sole weight bearing (203).

Other putative risk factors identified in the univariable modelling, but not present in the final multivariable model are worthy of consideration. Both a good bedding score and clean straw were associated with a reduced likelihood of finishing cattle being lame, and the two show collinearity. Damp bedding is likely to affect horn quality as discussed earlier, and dirty bedding material is likely to expose cattle to lameness causing infectious agents (142,204–206).

An increased frequency of pen mucking out was associated with a reduced likelihood of finishing cattle being lame, but no consistent trend was identified for suckler cows. The importance of hygiene to promote a low lameness prevalence has been studied (205,206). However, these studies focused on the prevention of infectious agents, and the findings of this cross-sectional study suggest that, although infectious lesions are present, claw horn lesions may be a greater concern for beef cattle. In a deep litter system, a reduced frequency of mucking out may ensure a deeper, more comfortable bedding, and reduced contact with any floor surface underneath, and as such protect from lameness. Any advantage of reduced mucking out protocol may only be successful if the bedding remains dry. However, the frequency of a pen being mucked out is likely to be influenced by environmental conditions, and it may be that pens that are exposed to worsened environmental conditions, and getting wet / soiled quicker, may consequently get mucked out more frequently. Cattle within such pens mucked out more frequently may still be exposed to worsened hygiene overall, despite more frequent mucking out. The same consideration may apply to the suckler herds studied, where a reduction in pen scraping frequency, from daily to between two and four days showed a trend for a reduction in the odds of a cow within that pen being lame ($p = 0.058$). Mirroring the muck out frequency for finishing cattle, this could be due to a greater demand for scraping, and as such cattle within these pens generally being exposed to worsened hygiene, and wetter conditions than those in pens that require scraping out less frequently.

3.5.3.2 Animal factors

Increasing age resulted in suckler cows being more likely to be lame. This mirrors other studies of suckler cows, where claw lesions were more prevalent in older cows (21) and studies of dairy cattle, where older or higher parity cows had a greater occurrence of white line disease (207). Altered weight bearing (132) and greater abduction and asymmetry (208) in older cattle may have a role in the aetiology, along with the accumulation of foot pathology leading to scarring of the corium (209).

A putative animal-based risk factor identified in the univariable modelling, but not present in the final multivariable model was BCS. A finishing animal with a higher BCS, in this case a score 3 out of 5, was less likely to be lame (compared to scoring 1.5 – 2.5). This has parallels in studies of dairy cattle, where cows scoring < 2 out of 5 were at greatest risk of becoming lame in the future, and a score ≥ 2.5 reduced the risk (67). It should be borne in mind, however, that this cross sectional study cannot determine if these finishing animals became lame following a low body condition, or lost body condition due to reduced intakes associated with lameness (40), or if both weight loss and lameness were caused by a common factor. No effect of BCS on lameness likelihood was seen in suckler cows.

3.5.3.3 General management factors

Other univariable factors worth discussion are management factors. Whether a farmer ever trimmed their animals' feet (a farm level factor) was associated with increased odds of an animal being lame, in both finishing cattle and suckler cows. All finishing and suckler unit farmers that trimmed feet themselves (n=5 and n=2), only trimmed cattle as part of lameness treatment, rather than prevention. The direction of causality cannot be determined, and it is likely that farmers with a high incidence of lameness were more likely to trim, although poor techniques cannot be discounted.

The diet fed to finishing cattle showed an association trend with lameness likelihood at the univariable level (p = 0.064), with those fed an *ad libitum* concentrate ration seeming twice as likely to be lame as their counter parts fed a TMR. This would align with evidence from the dairy sector, where cattle fed higher concentrate rations, or higher crude protein per Kg dry matter, were more likely to be lame (34,46,210), and is equally suggested to be a risk factor for lameness of finishing cattle (211).

Inter or intra farm biosecurity was not analysed due to lack of variation. There were generally no notable biosecurity measures taken when introducing animals onto farms, other than some farms vaccinating cattle on or around the time of movement. Most farms were dual cattle and sheep farms (n = 16 out of 18 finishing units, 12 out of 12 suckler farms). Most either grazed cattle on the same land as sheep, or cattle shared the same yards as sheep. This suggests a risk of spread of infectious causes of lameness (125), but also suggests either a lack of awareness, or a disregard for the importance of biosecurity between species on farm. One farm was enrolled onto a disease control accreditation scheme (CHeCS).

3.6 Conclusions

This study has provided an important insight into the prevalence of lameness on UK beef farms, as well as the foot lesion types and frequencies found on those cattle. This is information that was previously unknown. The high lesion prevalence in non-lame animals is noteworthy, and highlights the need for a greater understanding of lameness aetiology and pathophysiology, especially in beef cattle. It also suggests that a complete examination of lame animals is important, ensuring all lesions present are identified and weighted, and the assumption that the first lesion identified is the causal lesion is avoided. The importance of white line disease, due to its frequency and large positive association with lameness is an important finding. This is particularly relevant considering that some beef farmers focus on infectious causes of lameness and do not have facilities to lift up cattle feet (164), which is an important requirement for diagnosing and treating white line disease along with other claw horn diseases (97). It also suggests that presumptions regarding the lameness cause combined with impaired diagnosis may lead to unnecessary antibiotic use (164), i.e. those farmers focussing on infectious causes potentially giving antibiotics without full examination. This knowledge could improve treatment interventions, improving both welfare and performance.

The risk factors identified provide a base for further research to more fully understand how to improve lameness in the UK beef herd, both for improved productivity and for improved welfare. Due to the combination of various farm and animal factors within the recruited farms and the sample size, confidence intervals are large on occasions. Therefore the findings of this study should be interpreted with appropriate caution. Future work should focus on identifying the impact and mechanisms of pen factors, including space allowance, on lameness prevalence in finishing cattle, as well as identifying any seasonal effects on lameness and lesion frequencies. International reports identifying handling methods for beef cattle as a risk factor for lameness (212) mean that this, along with large scale farmer perception studies would also be important to identify intervention points that could reduce the prevalence of lameness.

3.7 Funding and acknowledgements

This study was funded by the Animal Welfare Foundation (AWF; grant reference Norman Hayward Fund NHF 2016 05 KM). AWF is a fundraising and grant giving charity (charity number 287118) directed by veterinary and animal welfare professions which uses veterinary knowledge to improve the welfare of animals through science, education and debate. More information can be found at www.animalwelfarefoundation.org.uk. The author would like to thank the funders, along with the veterinary practices and industry bodies that supported the research, and the farmers and their teams, who gave up their time to make this research achievable.

Chapter 4

The Impact of Lameness on UK Finishing Cattle: A Longitudinal Study

4 The Impact of Lameness on UK Finishing Cattle: A Longitudinal Study

4.1 Abstract

Cattle lameness is a major health and welfare concern in the cattle industry, with an estimated mean farm level prevalence of 8.3% in United Kingdom (UK) beef finishing cattle. Negative effects of lameness on UK dairy industry production parameters have been reported, and equivalent effects have been identified in beef cattle internationally. Body weight at slaughter and price paid per Kg at slaughter have both been reported to be negatively impacted by lameness in beef cattle. However, the effects of lameness in UK finishing systems is unknown, therefore the aim of this study was to identify the impact of lameness during the finishing period on ADLG.

Three farms were visited every three to four weeks over the course of 12 months, weighing and locomotion scoring all finishing cattle present on each occasion. Slaughter records were collected once the animal left the farm. Records of those animals that were never identified as lame were compared to those that were and together with the proportion of sessions during which an animal was scored as lame were analysed against the animal's age at slaughter and the ADLG.

An animal ever identified as lame was more likely to have a reduced ADLG. The greater the proportion of sessions that it was identified as lame, the greater the effect on ADLG. An animal's sex was also related to lameness likelihood. Carcass classification showed little variation between those animals which were lame, and those that were not.

Lameness negatively affects ADLG, with prolonged, or repeated cases having a greater effect. Farmers are likely to be keeping lame animals on farm, rather than

slaughter them early. The two main likely reasons for these animals to stay on farm are i) ensuring they are fit for slaughter under the Welfare of Animals (Slaughter) and (Transport) orders, and ii) ensuring they are in optimal condition for slaughter in terms of bodyweight and conformation. The latter may explain the minimal effects of lameness on carcass classification.

An understanding of the direct and indirect costs of lameness on finishing cattle can help farmers make decisions regarding lame cattle. This understanding will also help farmers justify investment in preventative measures.

4.2 Introduction

Cattle lameness is widely regarded as a major health and welfare concern (79,102,149), and a reduction in the prevalence of lameness is an important component in maintaining and improving United Kingdom (UK) welfare standards (168). The prevalence of lameness in UK beef cattle may be lower than that of UK dairy cattle, based on the mean farm level prevalence in finishing units of 8.3% and suckler herds of 14.2% across England and Wales compared to English and Welsh dairy herds as identified in Chapter 3 (34,35). However, it is possible that some beef cattle remain lame for longer periods of time, both until lameness resolution or until examination and treatment, due to difficulties relating to the facilities and location kept (102,164). In addition to the welfare concerns, lameness is widely reported to have productivity effects in dairy cattle. Lameness had a negative impact on milk yield (47,48), reproduction traits (52,53,55), and is associated with earlier risks of culling and inferior carcass characteristics in cull cows (59), all of which are particularly important in the dairy sector, leading to economic losses for the industry (68,70).

On a farm level, the distinct management and husbandry of beef cattle may result in different lameness risk factors or prevalence compared to dairy units. Furthermore, animal factors such as breed, age and proportion of each sex are different between the dairy and the beef industries. These, along with the different production outputs, mean that the production parameters used to monitor performance within the dairy sector are not suitable for extrapolating to all parts of the beef sector. Finishing units, for example, may find it more helpful to monitor average daily live weight gain (ADLG), days to slaughter (from arrival on farm or from entering finishing group), or carcass quality at slaughter. Financial parameters, for example price achieved per animal at sale, or price per Kg at slaughter may be of interest, but can be difficult to interpret with fluctuating markets.

A number of international studies identify some lameness related productivity deficits in the beef sector. A study by Magrin *et al.* suggested a reduction of body weight at slaughter for lame beef bulls in Italy, postulated to be due to early culling of lame animals as well as a reduction in feed and water consumption (40). Griffin *et al.* (31) identified that salvaged lame animals (determined by health records) only realised 53% of their original purchase price on feedlots in Nebraska, and Davis-Unger *et al.* (41) estimated returns ranging from minus CAD[4] 701 (for lame animals with no visible swelling) to no perceivable loss (for heavy cattle with foot rot) compared to a mean positive return of CAD 690 for healthy cattle across feedlots in Alberta by using health records, representing a potential net loss of up to CAD 1391 per lame animal. Ahola *et al.* (33) studied cows and bulls sold in a number of livestock auctions across the Western US during 2008, and identified that both lame beef cows and beef bulls received reduced prices per Kg, with higher grade lame animals seeing a greater reduction in price.

In 2007, Persson *et al*. (43) suggested that joint lesions might contribute to reproductive failure in beef bulls, although the authors highlighted that affected bulls may be difficult to detect without a thorough lameness exam, especially where lesions are bilateral.

An effect of lameness on carcass characteristics in beef cattle is plausible based on findings in dairy cull cows. Two Dutch studies have identified lame dairy cull cows as having reduced carcass values due to a combination of reduced live weight and carcass grading (64,65). Sogstad *et al.* (59) showed that lame dairy cows were culled earlier and that lameness in general was associated with lower conformation class, lower carcass weight and lower economic value (with the effect varying between lactations). Different lameness related lesion types had different effects on slaughter characteristics, with heel horn erosion relating to lower fat cover, whereas

[4] CAD = Canadian dollar

sole ulcers were associated with a higher conformation class. The differences seen may relate to confounding factors like feeding system rather than a cause and effect. Having a corkscrew claw was associated with lower carcass weights.

UK abattoirs use the EUROP carcass classification system, following universal guidelines (213,214). This system grades cattle on both conformation (S – Superior, E – Excellent, U – Very good, R – Good, O – Fair, P – Poor) and fat cover (1 – Low, 2 – Slight, 3 – Average, 4 – High, 5 – Very high). This grade is then used to determine a price paid to the farmer (per Kg deadweight), generally applying a penalty deduction to the base price for undesirable fat or conformation grades. Two further sub classifications systems are used by some abattoirs: one where conformation is subdivided into upper (+) or lower (-) for U, O and P classes, and fat class is subdivided into leaner (L) and fatter (H) for both 4 and 5; or a second more detailed 15 point scale where all conformation and fat classes have a low (-), medium (mid, or no additional denotation) or high (+) subdivision. Price paid per Kg deadweight can be further increased or decreased based on these subdivisions. Although abattoir pricing points differ, conformation classes E and U and fat classes 2 to 4, attract the highest demand and price (214,215).

The effect of lameness on UK beef cattle, in the various sectors such as suckler farms or finishing units, is not reported in the literature. This information may help to economically justify intervention and treatment, and increase awareness of lameness as a challenge that is beneficial to be tackled within the industry. In order to gain an insight into the effects of lameness in UK finishing cattle, the aim of this study was to identify the impact of lameness during the finishing period on ADLG.

4.3 Methods

This study was approved by the University of Liverpool Research Ethics Committee (VREC 533). Participants received written and verbal information and completed a consent form.

4.3.1 Identification and Recruitment of Farms

A convenience sample of three finishing units were recruited. Veterinary practices and industry bodies were asked to suggest potential participants, who were then approached by the researcher. The inclusion criteria were farms expecting to finish 300 or more cattle during a 12 month period (July 2018 – July 2019), and sending finished animals directly to slaughter from the farm.

4.3.2 Data Collection

4.3.2.1 Weighing

Cattle weighing was performed at approximately three to four weekly intervals, timed to fit the farms normal husbandry practices. Each farm's own weigh scales were used, but scales were calibrated before each session using the same standard weights (four gym weights totalling 45Kg) provided by the researcher. All animals currently in the finishing group (i.e. on the finishing ration) were weighed at each visit. ADLG was estimated using the weight at first and last recorded weighing, and the number of days between weighing visits.

4.3.2.2 Locomotion scoring

Locomotion scoring of all animals in the finishing group was carried out following each weighing by the researcher using the farm's own handling equipment. Animals were observed walking on a concrete surface, and if a second passing was required, animals were identified and a second opportunity to observe them walking was provided. A locomotion score was assigned using a five point scoring system

(**Table 4.1**), a simplified version of which was investigated in chapter 2 (180). Animals given a score of two or above were classified as clinically lame.

4.3.2.3 Slaughter data

Slaughter data was collected and evaluated for all animals that left the farm during the study period. This included slaughter date, and carcass classification given at slaughter. The three farms sent cattle to different abattoirs, but each sent the majority of their cattle to one main abattoir. If a farm sent animals to an abattoir that was not their normal one, it was done for reasons not relating to lameness (for example, an abattoir being unable to accept animals at the point of farmer deciding they were ready for slaughter). Breed data was obtained from either slaughter records, or farm management records. A binary variable of breed type was developed, with conventional dairy breed or conventional beef breed options.

Table 4.1 Five point locomotion scoring system used. Adapted from Tunstall *et al*. (180).

Score	Category	Description
0	Normal	Even weight bearing and rhythm on all four feet. The back is level.
1	Imperfect locomotion	Uneven steps or shortened strides, but affected limb not identifiable. The back may show minimal arching while walking.
2	Impaired locomotion	Uneven weight bearing or shortened strides. Affected limb is identifiable (unless multiple limbs affected). The back may show arching while walking.
3	Severely impaired locomotion	Slower pace - unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected), but whole foot placed to floor. An arched back may be noted while standing and walking.
4	Severely impaired locomotion with non-weight bearing limb(s)	Slower pace - unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected). An arched back may be noted while standing and walking. One or more limb(s) non-weight bearing or toe touching.

4.3.2.4 Lameness prevention / management

Farmers were asked to record any lameness related treatments or prevention interventions that occurred during the study period, and the researcher prompted for any relevant information on each visit.

4.3.3 Data Analysis

The data was recorded in Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington USA). Statistical analysis was performed using STATA/MP 16.1 (Statacorp, College Station, Texas, USA) for Windows. Data was graphically represented in using both of the above.

Univariable associations between explanatory variables and farm, sex and breed type were investigated using one way ANOVA and Student's t-tests. Associations between lameness and slaughter factors were examined with animal as the experimental unit, and farm offered as a fixed effect in each analysis. Outcome variables were age at slaughter and ADLG. Primary explanatory variables considered were 'was an animal ever lame' (binary variable) and the categorical variable of 'proportion of visits when an animal was recorded as being lame'. To create this variable, the proportion of scoring sessions for which an animal was scored as lame was determined, with those never scoring lame as the first category, then four categories, one for each quartile of proportion of scoring sessions recorded as lame.

Possible confounders of 'breed type', 'sex' and 'farm' were offered as explanatory variables. Explanatory variables were added to the initial multivariable model. Selection of variables for the final multivariable models was by backwards stepwise removal taking a p value < 0.05 for retention of a variable. Likelihood ratio testing was then performed, testing the model with and without each variable to maximise model fit. Biologically plausible interaction terms with a $p < 0.05$ at univariable level were offered to the final models, and were retained if they improved model fit. Predicted marginal means (95% CI) derived from final regression models are presented where appropriate.

Some recorded animals had partial missing data because occasionally farmers could not provide data for some animals, or due to paperwork omissions, for example date of birth or sex for particular animals. There was little variation in carcass classification between animals that were lame and animas that were not lame. Due to the wide range of possible classifications, and this lack of variability, statistical analysis of differences between these groups was not performed.

4.4 Results

Three farms were recruited from the North of England. Across three farms, 1124 animals were weighed and locomotion scored. However, 319 did not receive a second scoring event, leaving 804 animals with two or more weighing events. Of these, slaughter data was unavailable for 154 animals. Therefore, data for 650 animals was available for analysis.

The numbers of females, castrated males and entire males recorded per farm, alongside variables of interest, are presented in **Table 4.2** (sorted by farm) and **Table 4.3** (sorted by sex). The mean age at slaughter was significantly different between farms ($p < 0.001$): farm 2 had the oldest mean age at slaughter at 28 months, and farm 1 had the youngest, with a mean of 13 months. Dairy breeds had a significantly reduced age at slaughter, compared to beef breeds ($p < 0.001$) and entire males also had a significantly reduced age at slaughter (13 months) compared to both females (22 months) and castrated males (23 months) ($p < 0.001$). It is important to note that whilst farms 2 and 3 finished both females and castrated males, farm 1 was primarily a bull beef unit, with over 95% of animals finished being dairy or dairy-cross entire males, and therefore aiming for a younger finishing age (typically 12 – 14 months). Such animals are finished at earlier ages (12-14 months). For further analysis of sex differences, and by extension, production system, a binary sex variable was produced (coded 1 “bull beef”, 0 “females and castrated males”). Entire males were significantly more likely to be lame at least once, with 33% of entire males, and 25% of females or castrated males likely to be scored as lame during the finishing period ($p = 0.040$). With farm identity included as a fixed effect, logistic regression estimates demonstrated that entire males were 1.4 times more likely to be lame during the finishing period compared to females or castrated males (OR 1.41 95% CI 0.57 – 2.25 $p = 0.001$).

Age at slaughter was significantly associated with ADLG ($p < 0.001$), with a decrease in ADLG leading to an increase in age at slaughter. Mean ADLG was significantly different between farms ($p < 0.001$), with the highest ADLG observed in farm 2, at 1.5Kg per day (SD 0.7) for farm 2, compared to farm 1 (1.35Kg / day, SD 0.4) and farm 3 (1.29Kg / day (SD 0.47) ($p < 0.001$). Mean ADLG was greatest in castrated males ($p < 0.001$) compared to both females and entire males. ADLG was also greater for dairy breeds than conventional beef breeds ($p = 0.001$). However, there was considerable variation in ADLG within all the afore-mentioned categories (**Table 4.2** and **Table 4.3**).

Table 4.2 Explanatory and outcome variables by farm.

Variable / Factor	Level / Descriptor	Farm 1	Farm 2	Farm 3	p value[1]
Sex	Female	5 (2.5)	39 (25.32)	97 (36.47)	<0.001
(n, (%))	Castrated male	6 (3)	115 (74.68)	169 (63.53)	
	Entire male	189 (94.5)	0	0	
Breed type	Dairy	61 (83.56)	21 (13.38)	0	<0.001
(n, (%))	Beef	12 (16.44)	136[3] (86.62)	240[4] (100)	
Age at slaughter (months)	Observations	213	83	241	<0.001
	Mean (SD)	13.34 (1.22)	28.32 (1.82)	21.17 (1.75)	
	Median (range)	13.23 (10.77 - 17.2)	28.2 (25 - 40.8)	21.17 (17.33 - 30)	
Average daily live weight gain (Kg)	Observations	213	170	267	<0.001
	Mean (SD)	1.35 (0.4)	1.5 (0.7)	1.29 (0.47)	
	Median (range)	1.36 (0.09 - 3.01)	1.46 (0 - 3.810	1.28 (-0.95 - 3)	
Number of scoring sessions per animal	Observations	213	170	267	<0.001
	Mean (SD)	3.25 (0.96)	2.55 (0.81)	4.51 (1.92)	
	Median (range)	3 (2 - 5)	2 (2 - 5)	4 (2 - 10)	
Animals ever scored as lame	Observations	213	170	267	0.169
	n (%)	65 (30.5)	38 (22.4)	78 (29.2)	
	95% CI[2]	24.4 – 37.2	16.3 – 29.4	23.8 – 35.1	
Proportion of sessions scored as lame	None	148 (69.48)	132 (77.65)	189 (70.79)	0.361
	1st quartile	22 (10.33)	5 (2.94)	37 (13.86)	
	2nd quartile	13 (6.1)	4 (2.35)	15 (5.62)	
	3rd quartile	13 (6.1)	27 (15.88)	16 (5.99)	
	4th quartile	17 (7.98)	2 (1.18)	10 (3.75)	

[1] ANOVA [2] CI = Confidence Interval [3] 66.9% were British Blue, Limousine or Hereford (pure or cross-bred) [4] 99.6% were Aberdeen Angus (pure or cross-bred)

Although **Table 4.4** suggests farm 2 had the lowest percentage of animals that were ever scored as lame, the farm an animal was on was not significantly associated with whether it was ever scored as lame ($p = 0.17$). Equally, the breed type was not associated with whether an animal was ever scored as lame ($p = 0.685$). However, the sex of an animal was associated with both whether an animal was ever lame ($p = 0.029$), and the proportion of scoring visits that an animal was lame for ($p = 0.003$) with highest levels of lameness observed in entire males.

The median number of weighing and scoring sessions per animal was three (range 2 – 10), with six animals receiving nine scores, and two receiving ten scores. Of these eight animals, seven were lame on at least one occasion. There were ten (1.5%) animals that were identified as lame at every scoring session (median number of scoring sessions for these ten animals was 4.5, range 2 - 10). Of 181 animals that were scored as lame at least once, 59 animals were lame on two or more visits, and 22 animals were scored as intermittently lame (i.e. scored non-lame between other visits where they were lame).

Table 4.3 Explanatory and outcome variables by sex.

Variable / Factor	Level / Descriptor	Female	Castrated male	Entire male	p value[1]
Farm (n, (%))	1	5 (3.55)	6 (2.07)	189 (100)	<0.001
	2	39 (27.66)	115 (39.66)	0	
	3	97 (68.79)	169 (58.28)	0	
Breed type (n, (%))	Dairy	1 (0.79)	18 (6.74)	53 (98.15)	<0.001
	Beef	125 (99.21)	249 (93.26)	1 (1.85)	
Age at slaughter (months)	Observations	111	218	189	<0.001
	Mean (SD)	22.3 (3.36)	22.87 (3/64)	13.18 (0.97)	
	Median (range)	21.82 (16.43 - 29.9)	13.23 (16.13 - 30.83)	12.97 (10.77 - 15.33)	
Average daily live weight gain (Kg)	Observations	141	290	189	<0.001
	Mean (SD)	1.2 (0.53)	1.46 (0.58)	1.36 (0.41)	
	Median (range)	1.19 (-0.34 - 2.95)	1.41 (-0.95 - 3.81)	1.36 (0.09 - 3.01)	
Number of scoring sessions per animal	Observations	141	290	189	<0.001
	Mean (SD)	3.46 (1.54)	3.91 (1.97)	3.33 (0.93)	
	Median (range)	3 (2 - 9)	3 (2 - 10)	3 (2 - 5)	
Number of animals ever scored as lame	Observations	141	290	189	0.029
	n (%)	43 (30.5)	66 (22.76)	63 (33.33)	
	95% CI[2]	23.0 - 38.8	18.1 - 28.0	26.7 - 40.5	
Proportion of sessions scored as lame	None	98 (69.5)	224 (77.24)	126 (66.67)	0.003
	1st quartile	11 (7.8)	30 (10.34)	22 (11.64)	
	2nd quartile	9 (6.38)	10 (3.45)	12 (6.35)	
	3rd quartile	16 (11.35)	22 (7.59)	13 (6.88)	
	4th quartile	7 (4.96)	4 (1.38)	16 (8.47)	

[1] ANOVA [2] CI = Confidence Interval

Age at slaughter was not significantly associated with whether an animal was ever lame or not (p = 0.97), but a reduced mean ADLG was observed in animals recorded as being lame on at least one occasion compared to animals not observed lame (1.17Kg (0.56) and 1.44 Kg (SD 0.5) respectively, p < 0.0001).

Table 4.4 Explanatory and outcome variables by whether an animal was ever scored as lame or not.

Variable / Factor	Level / Descriptor	Never scored lame	Scored as lame	p value[1]
Farm (n, (%))	1	148 (31.56)	65 (35.91)	0.835
	2	132 (28.14)	38 (20.99)	
	3	189 (40.30)	78 (43.09)	
Sex (n, (%))	Female	98 (21.88)	43 (25)	0.409
	Castrated male	224 (50)	66 (38.37)	
	Entire male	126 (28.13)	63 (36.63)	
Breed type (n, (%))	Dairy	58 (17.01)	24 (18.60)	0.685
	Beef	283 (82.99)	105 (81.40)	
Age at slaughter (months)	Observations	384	153	0.975
	Mean (SD)	19.16 (5.55)	19.18 (5.55)	
	Median (range)	19.68 (10.77 - 30.83)	20.43 (11.47 - 40.8)	
Average daily live weight gain (Kg)	Observations	469	181	<0.001
	Mean (SD)	1.44 (0.5)	1.17 (0.56)	
	Median (range)	1.4 (0 - 3.05)	1.15 (-0.95 - 3.81)	
Number of scoring sessions per animal	Observations	469	181	<0.001
	Mean (SD)	3.32 (1.41)	4.27 (1.93)	
	Median (range)	3 (2 - 9)	4 (2 - 10)	
Proportion of sessions scored as lame	None	469 (100)		<0.001
	1st quartile		64 (35.36)	
	2nd quartile		32 (17.68)	
	3rd quartile		56 (30.94)	
	4th quartile		29 16.02	

[1] t-test

The explanatory variables farm and sex were offered to two initial multivariable linear regression models. Age at slaughter was not offered since there was no statistically significant association with lameness on univariable analysis, and furthermore any association was likely to be in a reverse direction of causality thus age at slaughter cannot influence ADLG. Breed was not offered as an explanatory variable because of almost total confounding by farm and animal type, with almost all dairy type animals being entire bulls on farm 1 (**Table 4.3**). Model 1 investigated the impact of whether an animal was ever scored as lame on ADLG, and Model 2 investigated the impact of the proportion of sessions, in quartiles, for which an animal was scored as lame on ADLG.

Model 1 (**Table 4.5**) showed that if an animal was ever recorded as lame, and all other variables remain the same, its ADLG would have decreased by 0.24Kg (95% CI 0.15 – 0.33); mean ADLG for non-lame animals was 1.44Kg. There was no association between farm identity and ADLG after adjusting for sex of animal. As in the univariable analyses performed earlier, there was an association between sex of animal and ADLG with castrated males ($p < 0.0001$) and entire males ($p = 0.13$) both having higher ADLG than females, although the estimate for entire males was not statistically significant at the $p < 0.05$ level. **Figure 4.1** displays the predicted marginal means (95% CI) ADLG for animals that were ever scored as lame, and those that were not for Model 1.

Table 4.5 Model 1 –Impact of an animal ever being lame on the average daily live weight gain of finishing cattle: Multivariable linear regression analysis

Explanatory variable	Level	Coefficient	95% CI[1]	p value
Ever scored lame		-0.24	-0.33 - -0.15	<0.001
Farm	Referent = 1			
	2	0.23	-0.08 - 0.54	0.152
	3	0.03	-0.28 - 0.34	0.845
Sex	Referent = Female			
	Castrated male	0.21	0.11 - 0.31	<0.001
	Entire male	0.24	-0.07 - 0.56	0.129
intercept		1.19	0.89 - 1.5	<0.001

[1]CI = Confidence Interval

Model 2 (Table 4.6) showed how an increase in the proportion of scoring sessions that an animal was scored as lame decreased the ADLG (quartile 3 not significant, p=0.35). If an animal was in quartile 1 (was scored lame, but for a low proportion of scoring sessions), its ADLG would be 280g lower than an animal that was never lame. Those that were lame for a large proportion of their scoring sessions (quartile 4), their ADLG would be 480g lower than those that were never lame. As with Model 1, castrated males were likely to have a higher ADLG than females.

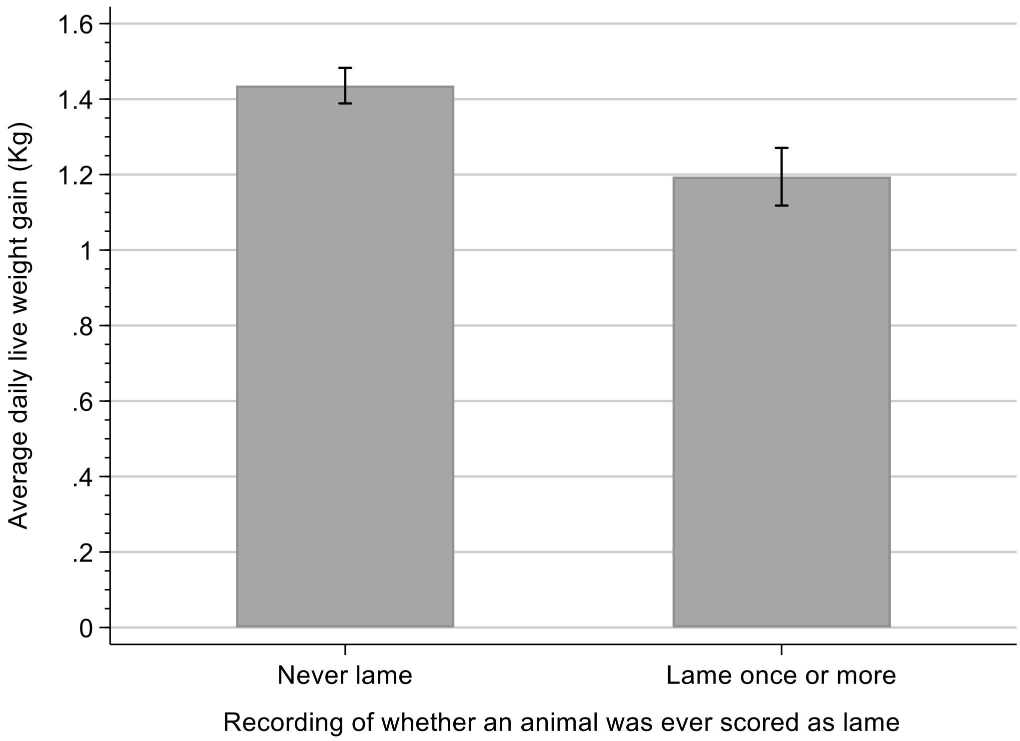


Figure 4.1 Impact of an animal ever being lame on average daily live weight gain (Kg). Predicted marginal means (95% CI) from Model 1.

Table 4.6 Model 2 –Impact of the proportion of scoring sessions (in quartiles) during which an animal was scored as lame on the average daily live weight gain of finishing cattle: Multivariable linear regression analysis

Explanatory variable	Level	Coefficient	95% CI[1]	p value
Proportion of scoring sessions scored as lame	Referent = never lame			
	Quartile 1	-0.28	-0.42 - -0.15	<0.001
	Quartile 2	-0.24	-0.43 - -0.06	0.009
	Quartile 3	-0.07	-0.22 - 0.08	0.35
	Quartile 4	-0.48	-0.68 - -0.28	<0.001
Farm	Referent = 1			
	2	0.21	-0.1 - 0.51	0.193
	3	0.04	-0.27 - 0.34	0.821
Sex	Referent = female			
	Castrated male	0.21	0.11 - 0.32	<0.001
	Entire male	0.26	-0.05 - 0.57	0.105
intercept		1.19	0.89 - 1.49	<0.001

[1]CI = Confidence Interval

Figure 4.2 displays the predicted marginal means (95% CI) ADLG for the proportion of scoring sessions that animals were scored as lame for, from none, through the four quartiles of proportions for Model 2.

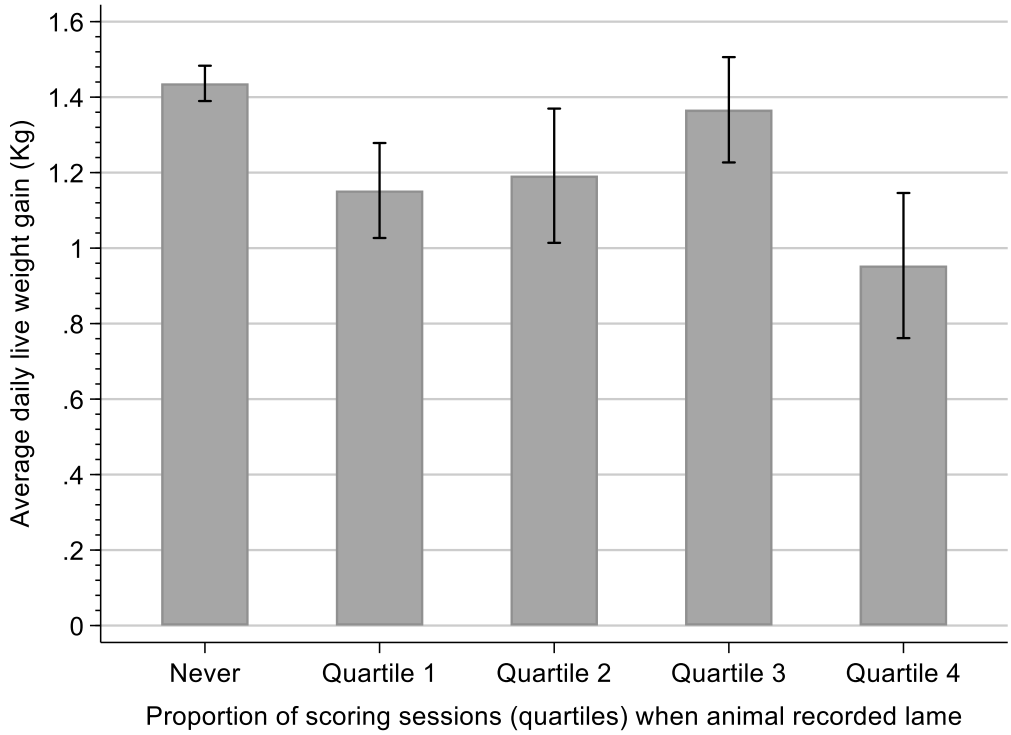
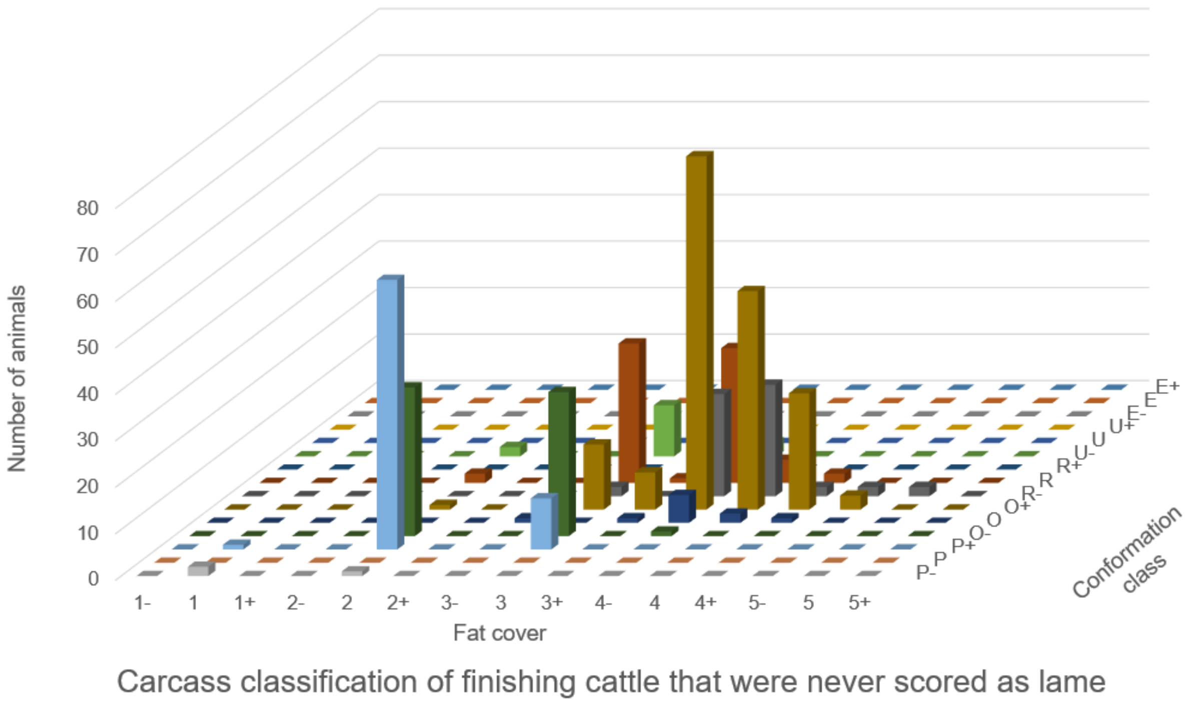


Figure 4.2 Impact of proportion of scoring sessions lame on average daily live weight gain (Kg). Predicted marginal means (95% CI) from Model 2.

Carcass classification for animals that were never scored as lame, and those that were scored lame once or more are displayed in **Figure 4.3**. For animals that were never scored as lame, the most frequent classifications were O+4- (n=76 (16%)), followed by P+2 (n=58 (13%)). For animals that were scored as lame, the most frequent classifications were P+2 (n=23 (13%)), O+4- (n=21 (12%)) and O+4 (n=21 (12%)).



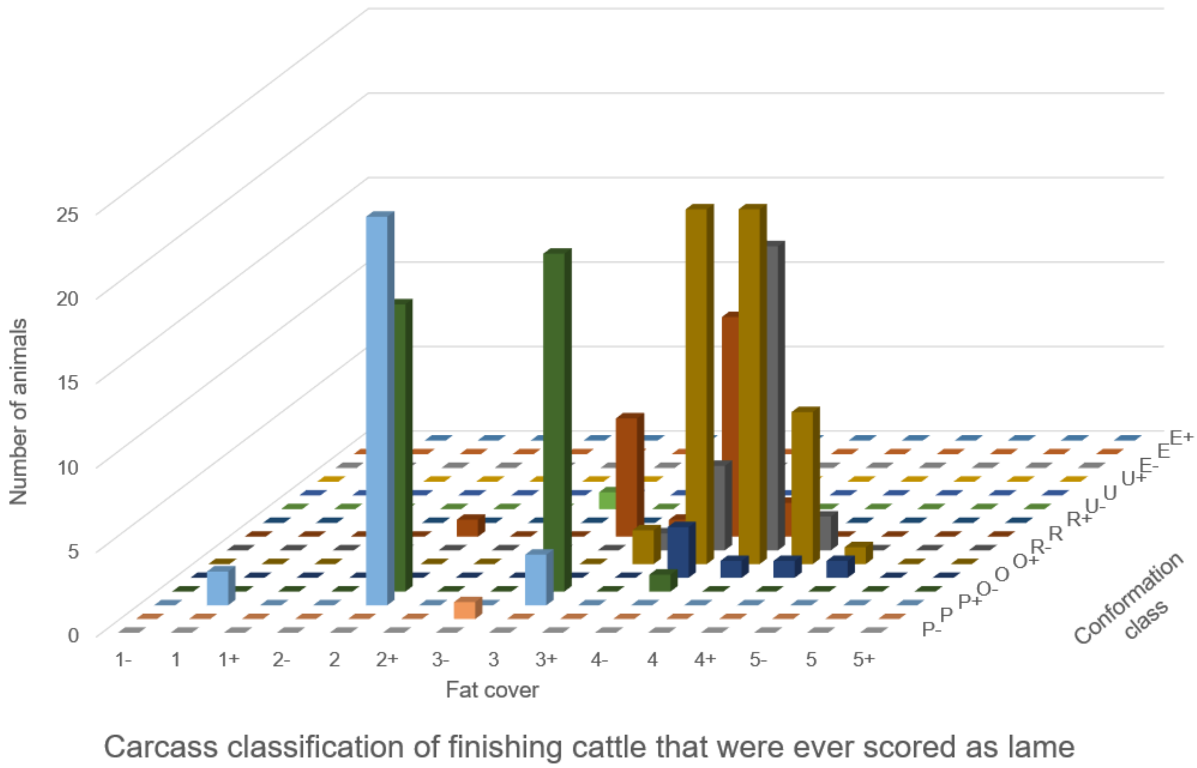


Figure 4.3 Carcass classification frequency for finishing cattle that never scored as lame (n=464, top panel), and finishing cattle that were scored as lame once or more (n=178 bottom panel). Carcass classification applying the 15-point scale.

4.5 Discussion

There was no statistical difference in age at slaughter between animals that were never recorded as lame, and those that were. This may be because of UK restrictions (63) on transporting lame animals and generally barring them from being slaughtered as prime cattle preventing farmers from sending them to slaughter early, as occurs in other countries (31,216). Equally, it could be that most lame animals suitably recovered within the target finishing period, or that any early-sent cattle were cancelled out by any late-sent ones. Given the wide range of age at slaughter observed on the three farms, the may be a true difference, which is not being detected.

A study of feedlot cattle in Kansas (212) suggested that most lameness cases (66%) resolved within two weeks of detection, and almost all were resolved by three weeks. Early treatment is likely to accelerate recovery (217), and as such, it may be that those cattle in this study repeatedly recorded as lame were either remained lame between visits, or recovered between visits, and then become lame again. Once an animal becomes lame, it remains at a greater risk of future lameness events (66,128,218), either because of biological changes secondary to lameness, or animals remaining exposed to the same risk factors.

ADLG was lower for animals that were scored lame, and was lowest for animals that were lame during a greater proportion of their scoring sessions. This supports Italian studies that demonstrated lower body weight for lame beef bulls at slaughter (40) compared to their non-lame counterparts. It may also explain the lower price received at slaughter in some studies (31,41), including dairy cows (219), both as a result of being lighter and potentially of a lighter animal (or one in poorer body condition) being less favoured.

Entire males, also known as bull beef, were significantly more likely to be lame than females or castrated males. This could be due to hormonal influences, rapid growth (220) or due to different husbandry or management systems, including diet. Chapter 3 indicated that finishing animals on an *ad lib* concentrate diet, as bull beef systems tend to use, had greater odds of being lame than those on total mixed rations. It should be noted that in this study, only one farm kept entire males, and they made up the majority of the cattle on that farm, so unidentified confounding farm factors should be considered when extrapolating this result.

The ADLG for entire males, which were all on farm 1, was 1.36Kg (SD 0.41), which is below the target (215). Bull beef systems aim to finish animals earlier, with entire males suitable for intensive rearing and capable of achieving higher ADLG. However, castrated males in this study had a significantly higher ADLG than entire males, at 1.46Kg (SD 0.58). This indicated that farm 1 was not meeting ADLG targets, and castrated males were exceeding targets (215). Although farm 1 had a greater proportion of animals scoring lame than farm 2, it is the author's opinion that other, unrecorded farm level factors are likely to have influenced this.

The reduction in ADLG seen in lame animals will have an influence on the already tight profit margins of finishing units. Many UK beef farms fail to achieve a positive net margin, with feed and bedding costs having a large impact on margins (6). Feed and bedding filter into daily maintenance costs of an animal, and those with lower ADLG maintenance costs will be higher in relative terms. Based on performance figures in this study and assuming that an animal becomes lame halfway through a 90-day finishing period, the 240g reduction in ADLG for any lameness event would add about eight days to the finishing period, with animals repeatedly scoring lame (480 grams reduction in ADLG) incurring a 15 day longer period. Alternatively, if an animal were to be sent to slaughter following a 45-day lameness duration (halfway through a 90-day finishing period), with a 240g reduction in ADLG, it would be

10.8Kg lighter. Assuming that loss would be reflected similarly in the deadweight (i.e. losses are to the carcass) and based on a 362.3 p/Kg deadweight price (4), that animal would be expected to lose £39.13, without taking into account any treatment costs that may have been given, time to examine and treat, and any hospital pen or management costs. If 8.3% (Chapter 3) of the 1.994 million prime cattle slaughtered in 2016 (4) were lame for 45-days of their finishing period, the cost to the industry would be £6.5 million per year.

There was little variation between the carcass classifications of animals that did or did not ever receive a lame score (**Figure 4.3**). The primary determinant of when an animal is sent to slaughter are the opinion and skill of the farmer. Farmers may wait until lame, or previously lame cattle are considered in optimal condition for slaughter before sending them. UK regulations restrict the transport of lame animals (63), and farmers will receive little return for animals culled whilst lame (31). Some beef farmers are unaware of the true costs of lameness (164), and so may consider it worth keeping lame animals until they reach target slaughter specifications, without a full appreciation of the indirect costs including the maintenance cost of the animal. Studies of dairy cattle have shown negative effects of lameness on carcass characteristics (59,64). However, as the production of meat is not the primary goal of this industry, it may be that dairy farmers are more prepared to send cattle for slaughter before they have fully recovered and have reached slaughter specifications.

The 22 animals scored as lame intermittently could support the notion that animals having a history of lameness are at a greater risk of subsequent lameness (66,128,218). They could also suggest a weakness with the repeatability of the locomotion scoring system, however, the system used has been investigated for reliability (chapter 2) (180), and is considered acceptable.

Missing data resulted in some data points not being included in this research. Of particular note was the missing slaughter data for 154 animals, as this constitutes data missing not at random. Animals remaining on farm at the end of the study contributed to some of this missing data. These animals included some which had been scored as lame, but did not reach slaughter stage, likely biasing the study by not being included in the analysis. No animals enrolled within the study were reported to have been culled for lameness related reasons. Additionally, the different target markets and finishing systems between the farms, in particular the differences between intensive bull beef unit and the other two semi-intensive units, makes comparison between factors such as age at slaughter between farms difficult.

4.6 Conclusions

Lameness had a significant effect on ADLG of finishing cattle in this study, with an increasing effect seen with increasing time spent lame. This effect is clinically relevant, and indicates prevention of lameness, and prompt treatment and resolution of lameness is important for productivity, and therefore farm profitability, as well as animal welfare. Further work to investigate the association between bull beef systems and a possibly increased risk of lameness is suggested. A possible impact of lameness on carcass conformation should be explored further, both by larger cohort studies, as well as investigating body conformation changes during a lameness period, for example by using imaging analysis or other objective technologies. Recording the changes in conformation due to lameness, and performing economic analyses such as partial farm budget, will help to further identify the costs of lameness in UK finishing cattle.

4.7 Funding and acknowledgements

This study was funded by the Animal Welfare Foundation (AWF; grant reference Norman Hayward Fund NHF 2016 05 KM). AWF is a fundraising and grant giving charity (charity number 287118) directed by veterinary and animal welfare professions which uses veterinary knowledge to improve the welfare of animals through science, education and debate. More information can be found at www.animalwelfarefoundation.org.uk. The author would also like to thank the veterinary practices and industry bodies that supported the research, and the farmers and their teams, who repeatedly gave up their time to make this research achievable.

Chapter 5

Lameness in Beef Cattle: UK Farmers' Perceptions, Knowledge, Barriers and Approaches to Treatment and Control

Tunstall J, Mueller K, Grove White D, Oultram JWH, Higgins HM.

Lameness in Beef Cattle: UK Farmers' Perceptions, Knowledge, Barriers, and Approaches to Treatment and Control. Front Vet Sci. 2019;6:1–14.

5 Lameness in Beef Cattle: UK Farmers' Perceptions, Knowledge, Barriers and Approaches to Treatment and Control

5.1 Abstract

Lameness in the beef industry has received little attention in the United Kingdom (UK), despite the fact that it is a well-recognised problem in the dairy industry. The aims of this study were to (i) compare UK beef farmers' estimates of lameness prevalence to that of researchers, (ii) explore beef farmers' attitudes towards lameness and (iii) help identify farmer reported barriers to lameness control and treatment.

Beef farmers (11 finishing units and 10 suckler farms) were recruited from England and Wales. Farmers were asked to estimate their lameness prevalence, before a researcher conducted locomotion scoring using a five point scale, and a Bland Altman analysis performed. Face to face interviews were also conducted using a semi structured interview script aimed at capturing information such as current approaches and protocols as well as their views of lameness importance. Interviews were recorded and transcribed. An inductive thematic analysis was performed.

All but two farmers underestimated lameness prevalence on their farms when compared to the researcher. Farmers initially underestimated lameness prevalence compared to the researchers estimates, with a mean underestimate of 7% (95% CI 5-9%). This is an important barrier to lameness detection and treatment. Thematic analysis identified four major themes: 1. Perception of lameness prevalence, 2. Technical knowledge and skills, 3. Perception of the impact of lameness and 4. Barriers to the treatment and control of lameness.

This study highlights that some approaches to lameness treatment are likely to be causing harm, despite being done with the intention to help the animal. There were four key areas of concern identified: recognition of lameness, treatment approaches, the training provided to farmers and confusion over transport and slaughter options available to farmers. This suggests an urgent need for future work to quantify and then address the problem, and to provide evidence to justify the role of prevention and potentially start to break down barriers to control and treatment of lameness.

5.2 Introduction

Lameness is well recognised to be a problem in United Kingdom (UK) dairy industry, as well as internationally (20,99). It is considered to be one of the top cattle health and welfare challenges (79), and is considered to cause considerable pain and distress to cattle (149). In dairy herds, recent reports have estimated the within farm prevalence to be 31.6% with a notable amount of variation between farms (34). However, there is little known of the prevalence of lameness in beef cattle, particularly in the UK. A Norwegian study identified a lameness prevalence of 1.1% in suckler herds, although claw and limb disorders were identified in 29.6% of animals (21). A University of Nebraska review of records on US feedlots showed 2% of cattle were treated for lameness, and it accounted for 5% of animal deaths (31). However, this study required lame animals to be identified, treated and recorded, which risks underestimation if they are not identified, or if the lameness is not treated, or if it is not recorded. Furthermore, both of these studies were of cattle in different husbandry and management condition to UK beef cattle. Some studies have sought to compare dairy farmer reported estimates of prevalence to that of researchers. These have shown that dairy farmers are typically underestimating lameness within their farms (19,103). However, beef farmers estimates of lameness prevalence have not been studied. If farmers do not accurately assess lameness it is likely to be a fundamental barrier to tackling the problem.

Even if farmers can accurately estimate lameness prevalence within their herds, that alone does not necessarily equate to action being taken. There has been some attention given to farmer perceptions and motivations in a broader sense. A 2011 review explored New Zealand dairy farmer decision making, with a particular focus on veterinarians motivating dairy farmers (104). This review discusses how farmers may not act on advice, despite the promise that an action will improve a situation. The review considers how this lack of uptake of advice may be due to a number of factors including self-confidence, habit and desire to maintain simplicity, amongst other factors. Valeeva *et al*. studied motivation to improve dairy cattle mastitis on Dutch farms, and found that motivators could be categorised into three groups: those focused on penalties or premiums, those driven by a desire to have an efficient farm that meets regulations, and those motivated by simple economics (105). However, Hansson and Lagerkvist concluded that the most important factor within a study of Swedish dairy farmers motivating values regarding dairy cattle mastitis was for a farmer to be happy that their dairy cows are “well-kept” (221).

Farmers approach to dealing with the risk of a new issue, or a current issue getting worse could be important when considering lameness prevention, as shown by Garforth *et al*. They performed an interview study of UK pig and sheep farmers, considering risk management, and highlighted how farmers actions following advice are strongly related to their attitudes towards risk, and how they were more likely to react to a current local situation rather than to prevent the silent spread of an unknown disease (106). The authors also discussed how farmers’ perceptions of risk are different from the veterinary profession and from Defra. This study also identifies that farmers were willing to change habits, but require sufficient convincing to do so. This indicates that even if a specific lameness risk is known by farmers, a willingness to take risk can affect the uptake of any prevention strategies. It also highlights how that may lead to a difference in opinion between different areas of the industry.

Industry collaboration is likely to be important in preventing lameness, providing knowledge as well as treatment options and services. However, this may be difficult with differences of opinion, and may be made more difficult if the industry cannot provide these when required. Kaler and Green identified that UK sheep farmers perceived that their veterinarians have insufficient knowledge in flock health planning and of the farmers own circumstances to be of value for flock level planning (108). This contrasts with the study by Garforth *et al*, where veterinarians were considered as the most credible and relevant source of disease information, and may even be used to filter, fact check, or even summarise new information (106). However, when considering cattle lameness, a questionnaire study of Dutch dairy farmers identified that the feed advisor and the foot trimmer appear to have the most influence on the farmers intentions to improve (107). These contrasting reports may represent either different stages of a changing picture of influential roles, or that there is variation between livestock sectors or between geographical areas. It is likely to be important that whoever a farmer is influenced by can provide adequate knowledge and support.

It has been demonstrated that farmers might find defensive reasons why they are unable to meet specific requirements. Naylor *et al.* suggested that farmers may blame government organisations for failings in disease outbreak situations, or the uncontrollable nature of a disease (222). The authors reported specific differentiation by some participants between ‘good’ and ‘bad’ farmers, with bad farmers being responsible for problems within the industry. Farmers from the poultry and pig industries in particular were likely to stratify their industry, with ‘hobby’ farmers being more likely to be perceived as ‘bad’ farmers. A UK cattle and sheep study also identified that some farmers blamed policy and regulations for previous disease outbreaks, justifying the lack of action they were taking, as well as considering some diseases to only be a problem for ‘bad’ farmers (223). This blaming of organisations such as the government may have an impact in the likelihood of advice from these sources being accepted and utilised in the future (224).

In terms of cattle lameness perceptions, Bruijnis *et al*, the authors of the Dutch questionnaire study (107), also identified that 25% of the respondents did not perceive that cattle can experience pain. This may be due to the stoical nature of cattle masking the signs of pain, but may suggest that these farmers perceive that their cattle are well-kept even if lame, and as such there may be a reduced drive to resolve lameness.

There have been qualitative studies seeking to explore the perceptions of lameness amongst dairy farmers (225), and the motivators and barriers to its control, and while this existing literature does provide useful insight into farmer perceptions and barriers that are present, to the authors knowledge, there have been no equivalent types of qualitative studies in the UK beef industry. There are clear differences in terms of management and husbandry between the dairy and the beef industries, therefore, it is not necessarily appropriate to directly extrapolate our current knowledge of lameness practices and perceptions within the dairy industry to the beef industry.

To help to fill this gap in the literature, the aims of this study were (i) to compare UK beef farmers' estimates of lameness prevalence to that of researchers, (ii) to explore their attitudes towards lameness and (iii) to help identify farmer reported barriers to lameness control and treatment.

5.3 Methods

This study was approved by the University of Liverpool Veterinary Research Ethics Committee (VREC 533). It is reported in accordance with the consolidated criteria for reporting qualitative research (COREQ) checklist, see **appendix 4** (226).

5.3.1 Identification and recruitment of beef farmers

A sample size typical for this type of research study was determined, allowing identification and exploration of key opinions and insights. Guidance for this sample size came from Guest *et al*. (227), who discuss how with increasing sample size, the new themes and even the number of new codes decreases. Based on this guidance it was decided to initially recruit approximately 10 finishing unit farmers and 10 suckler herd farmers as these can be considered as two distinct important sectors within the beef industry. As data was accrued, it was continually assessed for saturation, and after 21 interviews the final assessment was made, where it was deemed that saturation had occurred. The inclusion criteria for the suckler herds were having suckler cows housed at the time of study (January – April 2018). The inclusion criteria for the finishing units were having finishing cattle housed at the time of study (June – October 2017), on their final ration, and due to be sent to slaughter directly from the farm. Farms having less than 60 suitable animals were excluded to minimise the impact of lameness prevalence estimates varying due to single animals. This could not be based on a sample size calculation due to the lack of pre-existing data. Convenience sampling and snowball sampling were employed. Twenty farms were recruited via the professional contacts of the researchers, including approaching 32 veterinary practices and 18 industry bodies. 150 farms were approached by JT, and were also asked to suggest other potential participants. One farm was recruited via this snowball sampling.

5.3.2 Data collection

Face to face interviews were conducted by JT at the farmer's address with the person responsible, or jointly responsible, for making management decisions on farm. A semi structured interview script was designed by the author in conjunction with the research team (DGW, HMH, JO and KM) and piloted with two farmers (see supplementary material sheet, **appendix 5**). The pilot data is not included in the data set. The questions were a mixture of open and closed questions. The main topics covered were (i) current approaches to individual lame animals, (ii) herd lameness prevention plans and (iii) understanding of the effect of lameness on farm. Farmers were asked about current and previous cases of lameness on their farms, including discussing how they identify and treat lame animals.

The interviewer ensured all questions were asked, using prompts where required, but farmers could choose not to provide an answer. The interviewer allowed flexible discussion, encouraging exploration of responses. Lesion pictures were available to confirm descriptions (taken from Archer *et al*. (20)) and drawings were encouraged when appropriate. The interviews were audio recorded by the researcher and transcribed verbatim with secretarial support.

Farmers were also asked how many lame animals they had (within the group in question – cows / finishing cattle). Following this they were then presented with the information in Table 1, and asked how many animals they had of each score. The scoring system was a five point modified scale combining that used by Sprecher *et al*. (12) and one promoted by the Agriculture and Horticulture Development Board (28). Any animal scoring two or above were classed as lame.

Table 5.1 Five point Locomotion scoring system used. Adapted from Tunstall *et al* (180).

Score	Category	Description
0	Normal	Even weight bearing and rhythm on all four feet. The back is level.
1	Imperfect locomotion	Uneven steps or shortened strides, but affected limb not identifiable. The back may show minimal arching while walking.
2	Impaired locomotion	Uneven weight bearing or shortened strides. Affected limb is identifiable (unless multiple limbs affected). The back may show arching while walking.
3	Severely impaired locomotion	Slower pace - Unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected), but whole foot placed to floor. An arched back may be noted while standing and walking.
4	Severely impaired locomotion with non-weight bearing limb(s)	Slower pace - Unable to keep up with the healthy herd. Affected limb easily identifiable (unless multiple limbs affected). An arched back may be noted while standing and walking. One or more limb non weight bearing or toe touching.

Farmers were either interviewed before locomotion scoring took place (20/21), or were absent for the locomotion scoring, and interviewed afterwards without knowledge of the results (1/21). The process of locomotion scoring varied slightly on farms depending upon facilities available, but typically cattle would be run through a purpose built handling system, where their official ear tag or management tag were recorded, and then cattle were locomotion scored on leaving the handling system. An alternative process involved releasing animals individually from a gated holding pen, and a management tag being read on release. In all cases, the cattle were individually identified and then scored on a hard surface, generally concrete. If the researcher needed a second opportunity to view an animal, the animal was either returned to the handling system or released again from a holding pen. Locomotion scoring was carried out on all farms by JT either on the same day as the interview (n=20), or within 5 days (n=1). In the case of the latter, the farmer reported no change in lameness rate between day of interview and day of researcher scoring. On some farms, it was not possible to locomotion score all eligible animals for logistical reasons. Therefore a pragmatic decision was made based upon what could be achieved in one day using the facilities available. This did mean that on some farms, fewer animals were locomotion scored than the number required for recruitment onto the study. These farms remained within the study. Although farmers had some control over which animals / pens were chosen, it is the author's belief that this choice was based on logistical or safety reasons, rather than an attempt to manipulate the outcome.

5.3.3 Data analysis

An inductive thematic analysis was performed on the interview transcripts as described by Braun and Clark (228) using NVivo qualitative data analysis software, (QSR international Pty Ltd. Version 10, 2012) by JT and HMH. Themes were refined following discussion, while ensuring that they were directed by the data. This included frequent reference to both the coded extracts and the transcripts to ensure that the themes represented the data.

Microsoft Excel (Microsoft Office Professional Plus 2013, version 15) was used to record and analyse the quantitative data. Bland Altman plots were used to compare farmer to researcher locomotion scoring estimates.

5.4 Results

5.4.1 Characteristics of participants

Interviews lasted between 24 and 78 minutes. The study included 5 farms located in the North West of England, 3 in the West Midlands, 1 in the East midlands and 12 across North Wales. All interviews included at least one of the main decision makers, but some included more than one partial decision maker for at least part of the interview. The main interviewee in 20/21 interviews was male. The exception was a joint interview with one male and two females, all responsible for management decisions on farm. The mean age of the main interviewee was 49 and ranged from 27 to 72 (one farmer declined to provide an age). Out of the 21 main interviewees, 15 (71%) had attended an agricultural college or university. The median total number of cattle on the farms was 285 at the time of interview, with a range of 100 to 800. This includes cattle ineligible for study (for example breeding bulls and young stock). The median number of eligible cattle on the farms was 120, with a range of 59 -525. The mean number of cattle locomotion scored was 91 (Range 49 to 133). All eligible cattle were scored on 13 farms, 62-75% of eligible cattle were scored on three farms and 20-37% of eligible cattle were scored on 5 farms. Lameness prevalence as scored by the researcher ranged from 0 to 43%.

5.4.2 Beef farmer and researcher estimates of lameness prevalence

Without knowledge of the scoring system, all but two farmers estimated a lower prevalence of lameness than the researcher (**Figure 5.1**). The remaining two farmers estimated the same prevalence as the researcher. The Bland Altman (229) plot (**Figure 5.2**) show that the mean difference between the farmer without knowledge of the scoring system and the researcher was -7% (95% CI -5 to -9%). The upper line of agreement was at 3% (95% CI -1 to 7%), and the lower line of agreement was at -17% (95% CI -13 to -21%). This represents a 20 percentage point difference in lameness estimate, and shows that farmers could be expected to be 3 percentage points higher in their estimate, or 17 percentage points lower than the researcher. With knowledge of the scoring system, three farmers estimated the same percentage as the researcher, and one farmer estimated a higher prevalence than the researcher (**Figure 5.3**). The remaining 17 farmers estimated a lower prevalence of lameness than the researcher. **Figure 5.4** shows that the mean difference between the farmer with knowledge of the scoring system and the researcher was -6% (95% CI -3 to -8%). The upper line of agreement was at 6% (95% CI 1 to 11%), and the lower line of agreement was at -17% (95% CI -13 to -22%). This represents a 23 percentage point difference in lameness estimate, and shows that farmers could be expected to be 6 percentage points higher in their estimate, or 17 percentage points lower than the researcher. The differences between the farmer and the researcher of 20 and 23 percentage points would not be clinically acceptable.

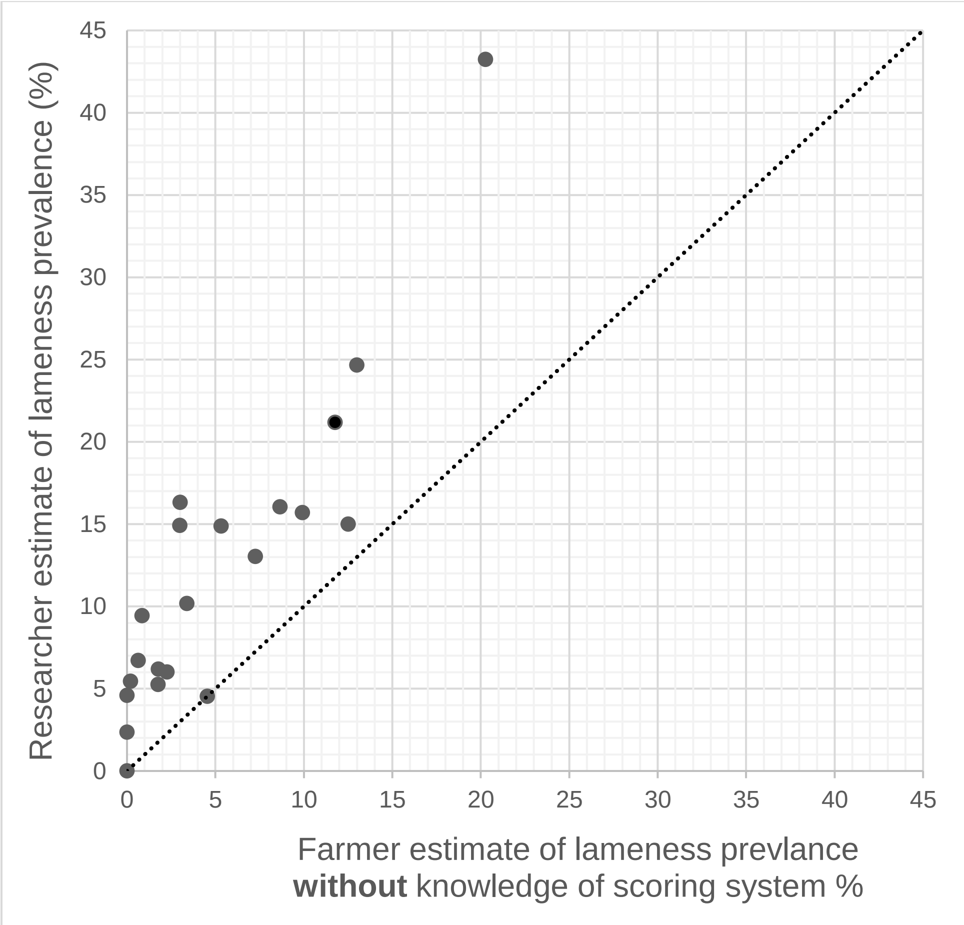


Figure 5.1 Scatter plot of researcher's estimates of lameness prevalence following locomotion scoring against farmers' estimates without knowledge of the scoring system to be used. The line shows equivalence.

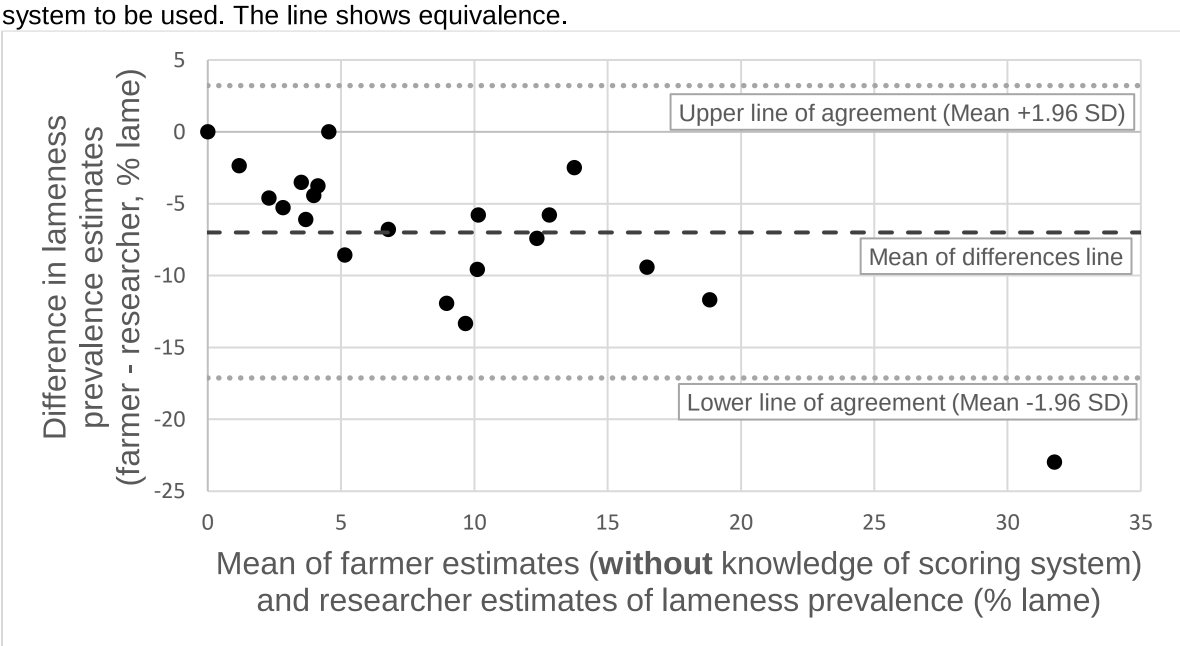


Figure 5.2 Bland Altman plot of farmer estimates of lameness prevalence before being shown the scoring system and the researcher estimates of lameness prevalence from locomotion scoring.

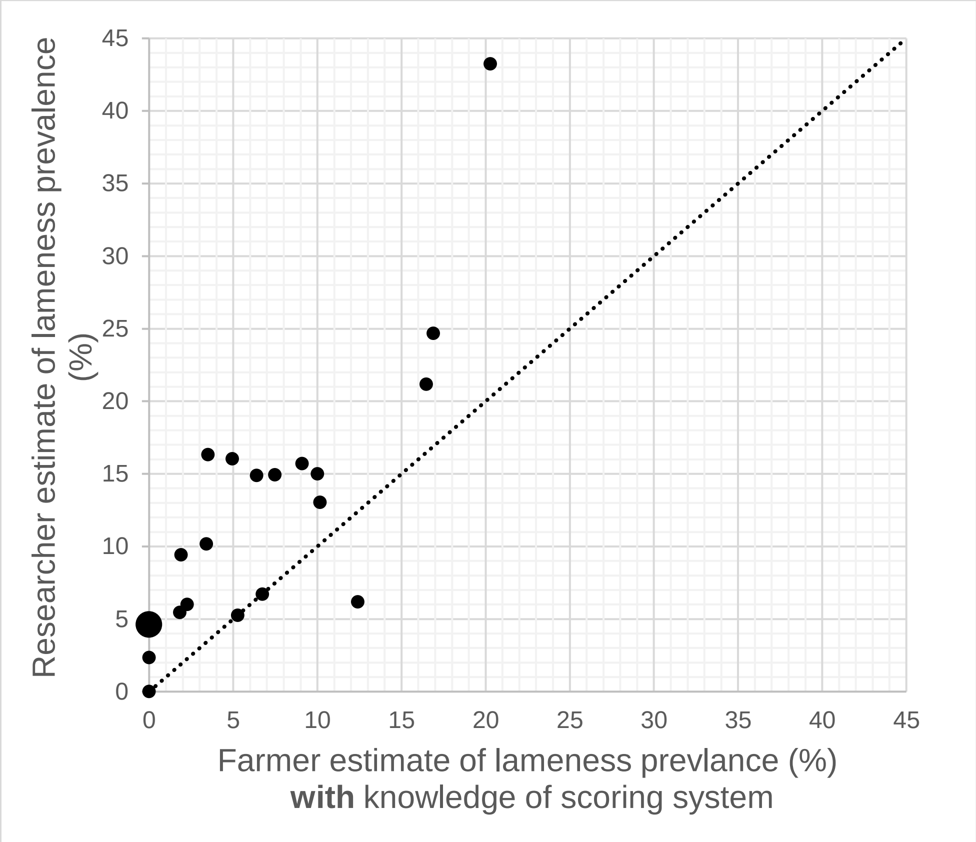


Figure 5.3 Scatter plot of researcher's estimates of lameness prevalence following locomotion scoring against farmers' estimates after being shown the locomotion scoring system. The line shows equivalence. Large data point represents the values of 2 researcher / farmer results with overlapping responses.

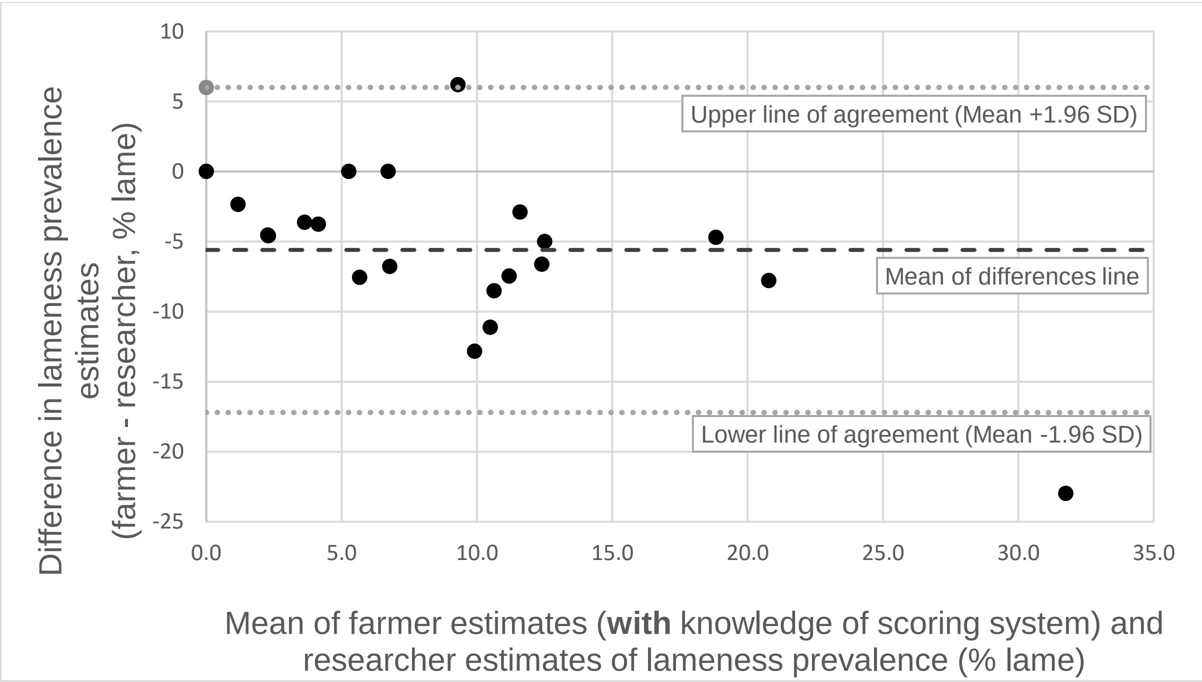


Figure 5.4 Bland Altman plot of farmer estimates of lameness prevalence after being shown the scoring system and the researcher estimates of lameness prevalence from locomotion scoring.

The change in farmer's estimate of lameness prevalence before and after being shown the locomotion scoring system was variable (**Figure 5.5**). Some farmers reduced their estimates (n=4), some kept the same estimate (n=6), however the majority (n=11) increased their estimate. One farmer increased their estimate from less than 2% to over 12% after seeing the scoring system.

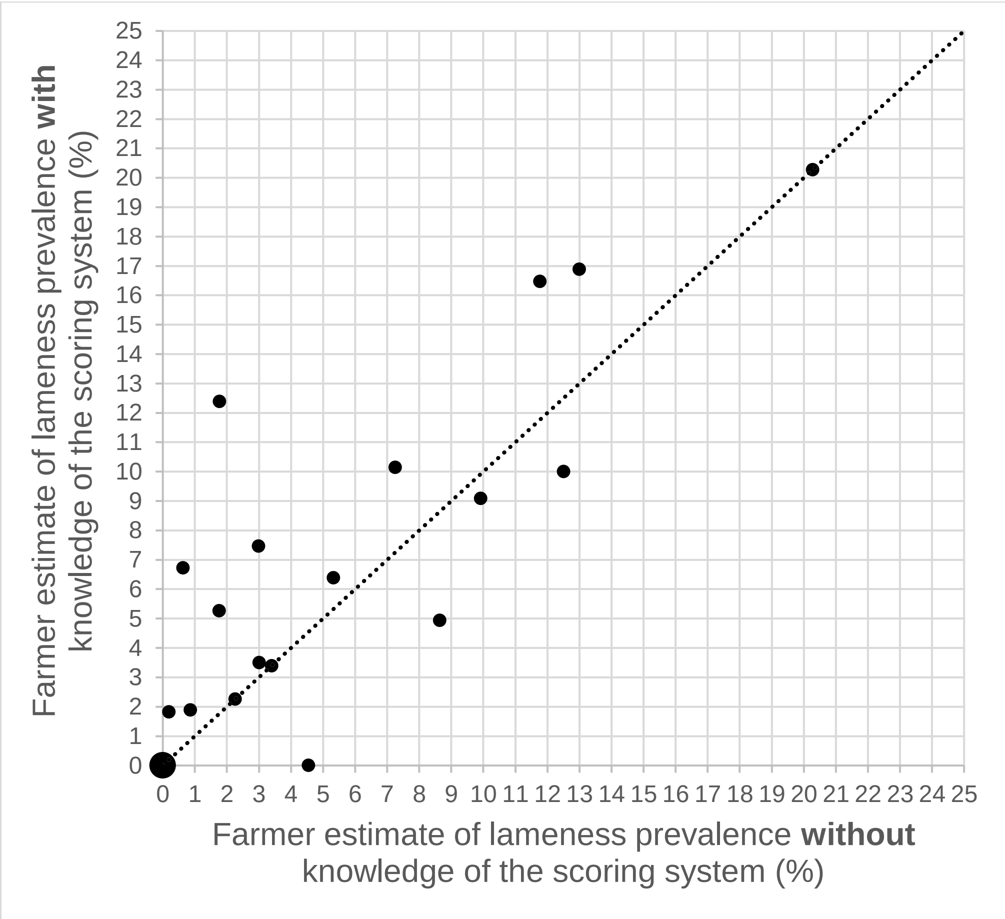


Figure 5.5 Scatter plot of farmers' estimates of lameness prevalence on their farm before and after being shown the locomotion scoring system in Table 1. The line shows equivalence. Large data point represents the values of 3 farmers with overlapping responses.

5.4.3 Thematic analysis

Four main themes were identified during analysis, with a number of sub themes: (1) farmers perception of lameness prevalence, (2) technical knowledge and skills, (3) farmers perception of the impact of lameness, and (4) Barriers to the treatment and control of lameness (**Figure 5.6**).

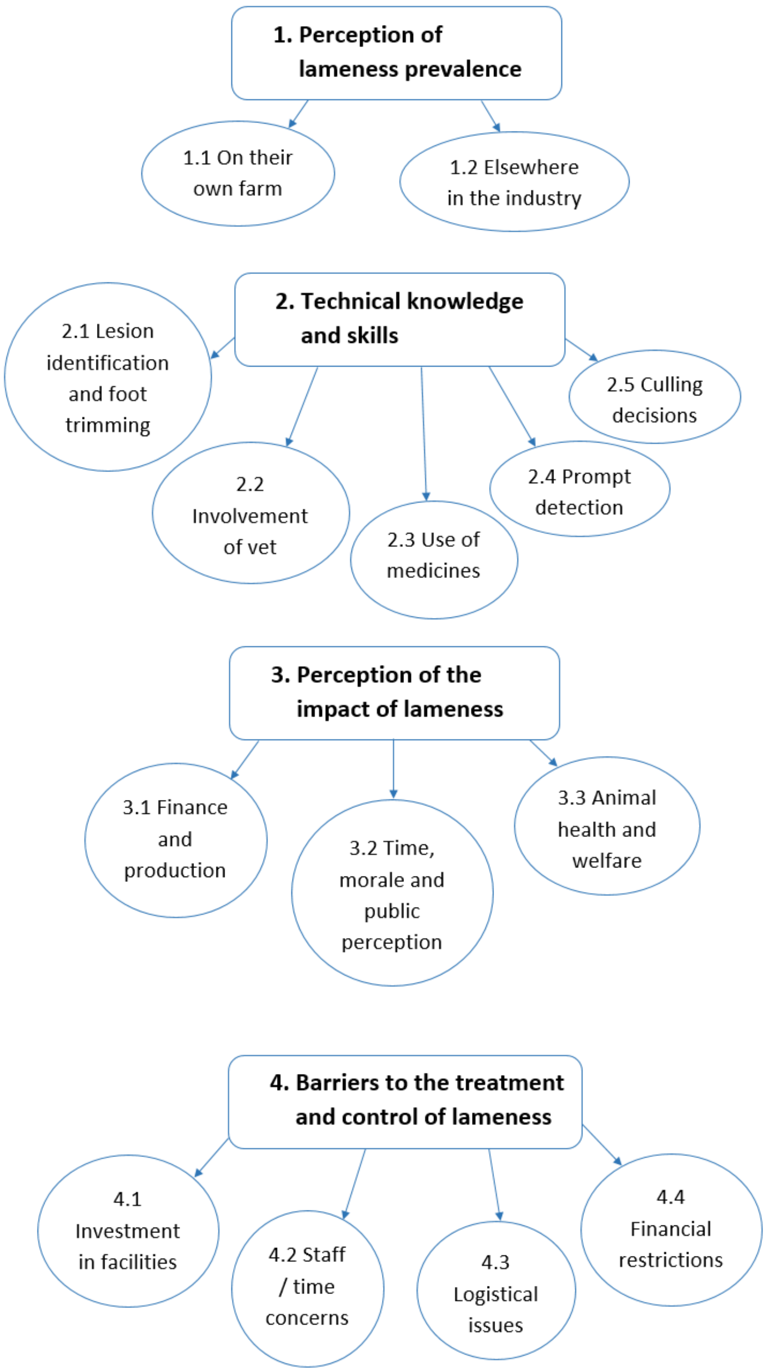


Figure 5.6 Flow diagram showing the four major themes, and their respective minor themes identified from the data following thematic analysis.

5.4.3.1 Theme 1: Farmer perception of lameness prevalence

There are two sub themes, each described below. Record keeping, which may enable monitoring of lameness prevalence was variable. Some farmers reported keeping full records, although many felt that they knew in their heads who the chronically lame animals were. However, on investigation, records were generally only kept if drugs were administered. In some cases, these records were vague. In addition, some farmers reported only starting to keep records once they had a serious lameness problem at herd level.

5.4.3.1.1 Farmer perception of lameness prevalence on their own farm

One farmer acknowledged how they struggle to identify lame cows:

"Yes, it's hard to see without having them walking, because they're housed inside, they don't walk much."

"Anything slightly lame, on straw, doesn't always show as easily as something on concrete"

In addition, one felt that it can become normal for them to be lame:

"We're used to seeing her terrible, so you don't really… They are probably never not lame actually."

None of the farmers were using a formal lameness scoring system, and most reported that they look for lameness when feeding, bedding or scraping passageways, meaning animals are observed while on various flooring, including deep straw bedding. Limping, hobbling, not fully weight bearing or being slow to get up / refusing to get up were the most common things looked for in identifying lame animals. This list also included not eating, observed swelling or redness and being able to *"just tell".*

Farmers also frequently commented that what they considered to be lame may differ from what a researcher may consider lame. Furthermore, when looking at the scoring system, some farmers did use language indicating that they were either trying to second guess what the researcher might say was lame, or exaggerating the number of animals of each locomotion score:

"I can't think of any [of that score], but put two for that."

In addition, farmers described some animals that they would not call lame, helping to identify where their threshold may be when asked if there are any lame cows:

"There are one or two that aren't carrying their full weight, but they are not… [Farmer trailed off]."

Hoof shape caused notable confusion amongst a small number of farmers, as some would call any with abnormal hoof shape lame (regardless of how they walk or bear weight), whereas others would use hoof shape to excuse lame animals (that were scored as lame by the researcher), and not call them lame:

"Erm, not got any lame ones but a couple have, er, where the hooves have grown in a particular shape."

Others would excuse animals from a lame list for other reasons:

"…But it might not have been lameness, it might have been a hip problem, maybe."

Some farmers progressed to speak of how they felt that the way an animal walked may not be affecting the animal:

"It's not bothering them too much, but you can tell he's not moving as he should be."

"There's one that's lame. There are a couple of others that need foot trimming or maybe are just a tad tender."

There was variation in the abilities of farmers to examine lame animals, as some could not lift feet at all with the facilities available, and some could only lift the back feet. Some said that they could lift feet, but did not feel that it was safe to do so.

5.4.3.1.2 Farmer perception of lameness prevalence elsewhere in the industry

Farmers were asked how they felt any lameness on their farm compared with other similar units. Most reported that they had little idea of what lameness was like on other similar units. Furthermore, many farmers appeared to have little access to other similar units:

"I've no idea, I don't know what other beef units do."

5.4.3.2 Theme 2. Technical knowledge and skills

There are 5 sub themes within technical knowledge and skills. Notably, almost three quarters of the farmers had been to college or university. However, one felt it had not helped:

"…For all the good it is…You can learn as much at home, to be honest with you."

5.4.3.2.1 Lesion identification and foot trimming

Many farmers described how they had or had not learned to trim cattle feet. Although some had learned in college or similar, a number were not confident and therefore not willing to trim feet. Others reported that they were self-taught using a variety of methods:

"A bit self-trained I think. When we had the horses we used to do all our own farriery. So I do know a bit about things like that."

"It was self-explanatory. A bit of common sense, you try to trim the feet like the feet should be – you know, square and flat and round and whatever."

Some farmers were using power tools to trim feet, or considering trying them. This included farmers reporting to have had no training in cattle foot trimming.

Farmer knowledge of lesion types was variable, but generally limited to a small number of lesion types:

“So basically, I’m assuming anything that’s not foul is digi [digital dermatitis].”

Furthermore, terminology and communication of lesion types often required drawings, pictures or descriptions as names were not known or potentially confusing:

“We do see blisters…like a soft putty bleeding lump.”

Some practices were employed that indicated a need for further awareness of the underlying causes of lameness lesions, as well as the welfare of cattle. For example, when discussing how sole ulcers were dealt with by a farmer:

“[I] burn them out with dehorning iron.”

No farmers reported using routine, preventative foot trimming. However, some farmers did use an external foot trimmer, either expecting to book them a certain number of times a year, or just calling them as and when they felt they were required. However, some farmers reported difficulties in getting hold of a trimmer, either getting them within a suitable time frame, or at all:

“He didn’t even bother to turn up because he had plenty of better customers than one animal, that’s the general feel.”

“He’s got his own set timetable. He can only fit us in on cancellation.”

5.4.3.2.2 Involvement of Veterinary Surgeon (Vet)

Farmers repeatedly reported that their vets have little involvement with lameness on their farms, and when they do call their vet, it is once the lameness is *“really bad”.*

Farmers mentioned cost, not knowing how their vets could help, or vets not being able to provide a *“magic injection”* as reasons for not involving the vet more. Furthermore, some farmers questioned whether their vets were able to provide suitable advice:

"…They look more on the dairy side, well I don't think you can compare the dairy side and the beef side. So it's a job for them to… They would give us advice I think, but would it be the right advice because they look more on the dairy side?"

Three quarters of farms had written herd health plans. All but one farmer said that they would not look at their plan if they had a problem on farm. The one farmer that said that they would, did not have lameness written within their plan. Some did not know if their plan had lameness mentioned within it. Most farms spoke negatively of the written herd health plan:

"…It's a hoop we have to jump through. I don't see it as being particularly helpful to us, to be honest. It's just something we have to do."

5.4.3.2.3 Use of medicines

Farmers showed varying opinions towards antibiotic treatments, with some treating all lame animals identified, without reaching a diagnosis:

"We injected all of them with Tylan (tylosin) at one stage when it first began…we put Linco-Spectin (lincomycin and spectinomycin powder) on and gave them a course of Tylan."

Whereas others would avoid antibiotic treatment for differing reasons:

"We wouldn't jab it to start with because of the withdrawal period really."

Or one farmer's opinion after reporting that they were advised to use ceftiofur.

"I'm not over keen, being a third-generation drug, and the abattoirs don't really want us to...I tend to shy away from those."

One farmer reported that they never use any drugs for lameness reasons. Some reported that the severity of lameness, rather than the diagnosis, would determine whether they use antibiotics, or would change the type of antibiotic used. Others stated that although they administer treatments for lameness, they never lift the feet of lame animals.

An off license lincomycin, spectinomycin combined powder treatment was mentioned as a treatment used by a number of farmers. Two had previously used it as a herd or group treatment in a footbath, and others had used it to treat individual cases. Some farmers appeared to discuss topical antibiotic treatments as if they were not an antibiotic:

“We’ll put the Terramycin [oxytetracycline] spray and a bit of Linco [lincomycin, spectinomycin combined powder] on it, bandage it up, and [depending] on how severe it is whether we give them antibiotics or not.”

Some farmers implied a feeling of ‘better’ antibiotics:

“We’ve sort of ramped up the antibiotic armoury, going from a standard long acting penicillin through to Naxcel [ceftiofur].”

Anti-inflammatory drugs were rarely given as part of lameness treatments, with only 4 farmers reporting that they might use anti-inflammatory drugs to treat some cases of lameness. Farmers reported not using anti-inflammatory drugs even in cases where pain was acknowledged to be involved in lameness.

Lameness vaccines were mentioned as something they would like to have available by a small number of farmers, linking with their knowledge of a vaccine being available for use in sheep. However, no link was made between the multitude of lameness lesions that might be found in cattle, and whether the causes of lameness on their farm was infectious.

5.4.3.2.4 Prompt detection

Some farmers reported that they do not always treat at first:

“If it’s a little bit [lame] you might leave it because it might have just sprained its leg. You’d leave it a bit before you’d do anything to it and then you’d get it in because it might have a stone in it or something like that.”

Some felt that lameness will just get better irrelevant of treatment:

“As I say, I’m not proud of saying it, but most of the time they burn themselves out.”

5.4.3.2.5 Culling decisions

Most farmers acknowledged that they have had to cull, or prematurely slaughter animals due to lameness. Others had not, and felt that they keep lame cows that do not get in calf:

“We do give them lots of chances before we actually sell them”

“But you see we’re soft and we give everything a second chance.”

Similarly, a finishing unit farmer acknowledged that one animal that was not culled was later regretted as it became more severely lame and could not travel, as well as being given treatment and being under withdrawal periods:

“In hindsight, I wish he’d have gone, without injecting him sometimes you think it’s better for him to go.”

Conflicting experiences were noted with regard to what to do with lame animals that farmers wished to cull:

“Maybe some people don’t know what to do with a lame cow…you can send a lame cow [to the abattoir], can’t you… [You’re] better off getting rid of a lame cow than just having it hold its leg… Maybe some people need educating about what to do with lame cows, don’t they?”

In contrast, another farmer, when asked what was stopping him culling the lame animals reported:

"We can't get them into the slaughter houses…If they'd let us go direct to the slaughter houses, them animals would be in less pain and out of the way quicker."

Another farmer acknowledged this as a *"minefield"*, and complained that the legislation was a *"grey area"*.

5.4.3.3 Theme 3. Farmers' perception of the impact of lameness

There are three sub themes within this theme. Importantly, farmers held varying views on how they felt lameness impacted on their cattle, and their farm in general. Some felt that it was not a priority for them:

"I don't think a lot of suckler farms are that worried with lameness. I think it's more of an issue with dairy farms"

5.4.3.3.1 Financial and production impact

Some farmers did perceive that lameness negatively affects fertility. Some also noted that lame cows can produce less milk, having an impact on calf growth rates. However, for one farmer the costs were limited:

"As long as it's still breeding a calf, it doesn't have a cost. The cost is, if it isn't in calf."

Furthermore, many suckler and finishing unit farmers acknowledged that lame animals can lose weight, or at least have decreased growth rates. Some finishing farmers appreciated the effects of this:

"They get pushed through the finishing system…but obviously months behind."

However, others felt that the effect had to be severe to be worth intervening:

"So as long as those feet aren't that severe and that it stops them eating and putting weight on, then we just leave them……………it's economics, okay?"

A second farmer went further:

"….it never knocks them off their grub."

A small number of farmers mentioned that animals had died, or they felt they had nearly died, due to lameness:

"You could lose the beast if you let it get bad enough."

Some farmers discussed a concern regarding the contagious risk of lameness. They felt that the potential for spread could multiply the impact on their farm. However, it was not acknowledged that this may be similar for non–contagious lameness causes, where it is equally likely that all animals are exposed to the same risk factors as an animal that has become lame.

Many farmers did not appear to appreciate the indirect costs that may be attributed to lameness, however, some farmers did:

"You're taking up space in sheds with animals that should have gone but are still on the farm"

A lot of farmers interviewed did state that they were aware that lameness did cost them financially, although none were confident of how much lameness was costing:

"No, I wouldn't have a clue. I'm sure it's quite considerable if you were to put pen to paper and add it up."

This lack of awareness of specific costs was repeated in numerous areas, as indicated by one farmer who felt that he did not want to spend money on preventative measures because:

"The cost of prevention can be more than cure, at the minute."

However, when asked about what the actual costs were, an answer could not be given.

Some farmers did highlight that it can be difficult to appreciate the impacts of lameness, using lame animals on dairy farms as a comparison:

“Erm, well performance because they don’t milk the same, we should be the same with beef because they don’t perform.”

And a second farmer described it as:

“… A hidden cost, because you don’t physically see the money going out of your pockets… That’s what I mean about farmers… You don’t physically see the money, then you don’t really know.”

5.4.3.3.2 Impact on time, morale and public perception

The impact of lameness on a farmer’s time was repeatedly mentioned. For some farmers it was a negative impactor on their time when discussing herd level prevention and individual treatment:

"It is a nightmare really, it wasn’t a problem, and then suddenly became like, we’re trimming feet all the time…”

The effects on farmer and staff were variable. For example:

“Well, I don’t see how that’s going to affect the morale of the staff, I don’t see where that should come into it.”

This contrasts with the experiences of other farmers:

“The constant battle we’re fighting and not winning is mentally… what’s the word… deflating.”

Some farmers felt that having lame animals in a visible location, for example near a public road, might affect the public view of farming, but this was often felt to be more of an issue for both the dairy and the sheep industries than the beef industry.

5.4.3.3.3 Animal health and welfare

Importantly, some farmers spoke of how they did not feel that what they considered to be lame was significant enough to take action, both on a herd level, and an individual animal level:

"If she's slightly hobbling, we tend to leave them… if you can tell she's in distress, we will have a look at them."

When asked generally about the down sides of lameness, some farmers mentioned some individual cow related factors:

"Pain, you don't want it in pain, in distress, or anything like that."

And some added how having to get the animal out and treat it may cause additional stress. However, many farmers did not mention pain, or welfare of the cow until asked more specifically about whether lameness has a welfare or pain component. Some farmers even compared it to how they would be in pain if they were lame. However, for some it was not clear cut:

"Depending on the severity, yes"

However, one added to this:

"Yes, when they get to a point, score three or four…From a welfare point of view yes, you need to sort it out, but it's not your doing. They just go lame don't they?"

5.4.3.4 Theme 4: Barriers to the treatment and control of lameness

There were a large number of farmer perceived barriers to lameness control and treatment that were identified during interview. Although some of these barriers have been revealed in the previous three themes, others were identified which farmers perceived were reducing their ability, or likelihood of treating or controlling lameness.

5.4.3.4.1 Investment in facilities

Farmers mentioned a number of barriers which stopped them investing in their farm. Some rented all or part of their farm, and so wanted investment from the landlord to improve the facilities. Others felt they could not handle or footbath animals when they were outside as they did not have suitable facilities to do so. Some farmers presented general concerns regarding hesitation in making expensive investments in their farm. When speaking about their own handling facilities, one farmer highlighted how without further investment, climatic conditions may stop treatment being performed:

"…it needs to be inside, then the weather conditions don't alter it then, do they?"

One farmer summed up their opinion on investment within their farm by stating:

"The job doesn't pay"

5.4.3.4.2 Staff / time concerns

There were a number of time / staff issue which were identified as barriers. Some farmers perceived that during some periods they did not have time do some things that might help prevent lameness (foot bathing in this case):

"We stopped because of the amount of time it was taking…We got towards spring time and there were other jobs that wanted doing."

Whereas others felt some jobs required more staff:

"I don't think a footbath is practical here…because you're on your own."

5.4.3.4.3 Logistical issues

A number of logistical barriers were discussed by farmers. Some farmers interviewed were trying to increase their herd size, and as such did not want to cull any animals. This means that non resolving lame animals would remain in the herd. Others could not cull a cow they had intended to because she was pregnant. As discussed in Theme 2, some farmers felt there was a grey area around transport and slaughter of lame animals, which acted as a barrier to culling.

Lack of slurry pit or waste (mainly feces) storage was a barrier to more frequent cleaning out for some farmers, and the availability of certain types of bedding was affecting the choice made.

As discussed in Theme 2, concerns regarding withdrawal periods were a barrier to treating animals, and in particular the unknown duration of time an animal has left on the farm made it difficult for some farmers to decide whether to treat or not. Withdrawal periods were also a barrier to culling, as one farmer discussed following a long withdrawal period product applied on arrival to the farm:

"…and if they injure themselves in the first week of coming here, we have to nurse them along until we can kill them."

Safety was discussed as a barrier for some farmers, safety of both themselves and their cattle, preventing them from examining and dealing with some animals. In addition, if a cow is heavily pregnant, or if the temperament may make it difficult to get the animal into the handling facilities, they may not do so:

"I'm not going to get it into the crush if it's an idiot am I?"

Farmers' identification and perception of lameness was identified as a specific barrier to the control and treatment of lameness. As discussed in theme 3, some beef farmers see lameness as a problem for dairy farmers to worry about. In addition to the difficulty in identifying animals in straw bedding, or while inside housing, some farmers discussed how their finishing cattle will go to slaughter anyway, so they did not worry too much about some lameness, especially if animals still grow above a minimum threshold. Others felt that as some animals are permanently lame, they stop noticing them, whereas others simply do not consider lameness to be a problem with beef herds. Another farmer discussed how it was easier and quicker to spot performance deficits with dairy cattle, compared to beef cattle:

“My [dairy farming] *neighbour says if something is doing the cows no good, the milk is down. You don’t see that with sucklers until something like six weeks down the line.”*

5.4.3.4.4 Financial restrictions

Financial barriers were also discussed. Variability in prices, for example straw, was used to explain why some farmers felt they were not doing what they would ideally or normally be doing. The cost of various potential treatments being perceived to be too high by some farmers, although little was known of the financial benefit of using the treatment discussed. Cash flow was also considered a barrier by some farmers, who may have felt an approach was worthwhile, but felt they could not go ahead with it. Some farmers also said that they are waiting for a grant to become available to assist in investment in new facilities. However, if no grant becomes available, or if lameness cases develop in the meantime, this dependence on potential grants will have been a barrier.

5.5 Discussion

The aim of this paper is not to estimate the prevalence of lameness in beef cattle, rather to compare farmer's estimates with that of a researcher. The small sample size and the snowball sampling strategy, along with the combination of sucklers and finishers, make the prevalence of lameness identified potentially unsuitable for extrapolation to a wider population. However, it does highlight the variation that exists, which compares with the dairy industry, where there is also a large amount of variation between farms (34). It should be borne in mind that this study locomotion scored cattle during housing, from June to October 2017 for finishing units, and January to April 2018 for suckler herds, and as such may not take into account any seasonality effects on lameness prevalence. However, this should have little effect on the differences between prevalence estimates.

The difference between the upper and lower lines of agreement in both Bland Altman plots could be considered clinically important, with a difference of 20 percentage points for the farmers' initial estimate of lameness and the researchers estimate, and 23 percentage points when the farmer had knowledge of the scoring system. This means that we cannot use farmers estimate as an alternative for researcher estimates. This correlates with similar studies in the dairy industry (19). The fact that the five point locomotion scoring method has not been tested for intra or inter-observer reliability is a potential limitation of this study. Additionally, the researcher's awareness of the farmers' estimates prior to locomotion scoring can be considered a potential bias. However, the fact that the same researcher locomotion scored all cattle is a strength. In addition, the researcher was experienced in locomotion scoring, and had used this scoring system before.

The variation in age (and so likely time since education), as well as the different institutions and levels of courses attended, may mean that there are differences in previous teaching and exposure to locomotion scoring and lameness detection. For some, any exposure while in education may have been some years ago. This may reflect the differences in variation between different farmers and the researcher, with some farmers estimating the same as the researcher estimate, and some estimating notably less. However, we do not have data regarding any training since formal education.

Comparing **Figure 5.1**, **Figure 5.2**, and **Figure 5.3** combined suggests that presenting the information in Table 1 to farmers is not sufficient to enable them to assess the lameness in their herd. Combining this with the difficulties expressed by farmers in terms of identification of lame animals suggests that training and practice is required in order to enable farmers to improve the prompt detection of lame animals. Although some dairy cattle studies have suggested that training may provide limited improvements in intra- and inter-observer agreement when locomotion scoring (158,159), inter-observer reliability has been shown to increase with increased time / scoring sessions (162). Also, experienced scorers have been shown to perform better than less experiences scorers when using video footage of cattle (163). This suggests that farmers can be assisted to improve their reliability in scoring. A 2014 review of locomotion scoring dairy cattle showed that although intra- and inter-observer reliability was variable for scales with over two levels, when the scales were considered at a lame / not lame level, all scoring systems exceeded the acceptance threshold (17), meaning that a binary locomotion scoring system may be best suited to on farm situations. This would be suitable where the next step from both a welfare and a production point of view would be further examination of any lame animals.

Although three quarters of farmers had been to college or university, Theme 2 suggests areas of weakness in both lameness knowledge and skills of beef farmers. Lesion identification, aetiology knowledge and farmer description of foot trimming technique indicate an urgent need for further training to improve both the treatment and prevention that farmers can deliver for themselves. Crucially, some trimming techniques employed carried a significant risk of making a problem worse.

External support is not regularly being utilised, which is likely to be leading to suboptimal management of lameness, and reduced success rates. In particular, less veterinary time on farm, when compared to the dairy industry, may lead to less opportunity to ask questions and gain general information which a farmer may feel does not warrant a visit in its own right, but may be important in developing long term prevention and treatment strategies. This is marked when considering drug use, especially the lack of anti-inflammatory medication.

Herd health plans are generally written by both a farmer and their vet, and are required or at least recommended for assurance or certification schemes. They are often required to be reviewed and updated on an annual basis. The fact that herd health plans were not being used for lameness planning may not be surprising, as a Defra survey of farmers in all livestock groups, with over half of the respondents having a beef enterprise, showed that approximately half of the respondents claimed that health plans were effectively unimportant (230). It also compares with a study of dairy farmers where, despite overall mixed views, many felt that the main benefits to having a herd health plan were to meet external requirements, and that the plan was not in use (231). The fact that the farmers were not using their health plans, or did not have lameness covered within it suggests that this may be a missed opportunity. Ignoring the compulsory requirement for many farmers to have a plan, the process of reviewing and updating the plan provides an opportunity for the farmer to discuss lameness, as well as other performance and welfare parameters, with their veterinary advisor, and may enable appreciation of a problem, and discussion of improved solutions.

The approach to chronically lame animals was of particular importance: these animals can be expected to be in pain, yet potentially become trapped in a cycle of either being treated but not fully resolving, or not treated and not resolving, and therefore remaining lame. The variation in farmers' views suggests various experiences and that the information available is not clear, which is highlighted by one farmer calling it a grey area. Not being allowed to transport lame animals represents a barrier to culling these animals. The reported variation in whether an abattoir will accept lame animals leads to confusion and frustration.

There is a clear difference between farmers in their perception of the impact of lameness. For those who do not consider it to have a significant impact, there is less incentive to prevent it, or treat it as a priority. Furthermore, if farmers do not appreciate the full impact that less severe lameness can have both on productivity, and the welfare of the animal, some cases may be ignored. There may be some comparison with the study by Bruijnis *et al.* (107), and some farmers may not be perceiving that cattle can feel pain, or perhaps some do not perceive lameness as a painful condition. Although there is evidence detailing the impact of lameness in dairy cattle which can be provided to dairy farmers, to the authors knowledge there is no such data available for beef cattle.

The barriers identified are generally ones that can be overcome. If evidence can be produced, this could be considered the first step in breaking down barriers, and if the impact of lameness can be appreciated by farmers, there is potential for its order in a farmer's priority list to be elevated.

In terms of future work, establishing reliable and representative estimates for farm level prevalence of lameness within the UK will be important to quantify the scale of the situation, and research to provide evidence regarding the impact of lameness within beef cattle will be essential to give farmers and those advising them the confidence to invest in the prevention and control of lameness. In addition, identifying lameness detection methods that are suitable for routine use on beef farms will be of great value. However, this will need to be combined with a greater understanding of the complex interactions which lead to human behaviour change, and a full understanding of beef farmers' priorities. Therefore, further studies to understand both the barriers and pathways to change that exist for beef farmers would increase the potential for success.

Farm facilities represent a notable barrier to appropriate treatment. Farmers reporting that it is dangerous to examine lame animals using their facilities, or that their animals are likely to hurt themselves, means that significant investment, incorporating foot examination facilities is required to ensure the safety of farmers and their cattle.

Farmer impressions that veterinary knowledge is mainly of the dairy industry highlights a barrier to requesting advice or assistance. A relationship needs to be established where beef farmers feel that they can trust the quality of the service of their vet, and the value that can be added by appropriate guidance and assistance.

One hundred and fifty farmers were approached by the author during the recruitment process. The recruitment for this study may have led to a possible non response bias. A small number of farmers (n<5) who declined to participate suggested that lameness was not an issue for them, so it was less worthwhile participating. It is possible that farmers may not have wanted the researchers on farm if they had a substantial lameness issue.

5.6 Conclusions

This research identified four key areas of concern. The first was the recognition of lame animals, including both ability and opportunity. The second was treatments, in that some treatments were likely to be directly harming animals, and some farmers were not promptly treating lame animals, both leading to a concern for the health and welfare of these cattle. Thirdly, the practical training provided to farmers was a concern. There was evidence that some farmers did not recognise a number of common lesion types and similarly did not know how to treat them. Finally, the study suggests that some farmers are confused over transportation and slaughter options for their cattle. This suggests an urgent need for future work to identify and address the scale of these concern, and to provide evidence to justify the role of prevention, and thus helping to break down some of the barriers to lameness control and treatment in beef cattle.

5.7 Funding and acknowledgements

This study was funded by the Animal Welfare Foundation (AWF; grant reference Norman Hayward Fund NHF 2016 05 KM). AWF is a fundraising and grant giving charity (charity number 287118) directed by veterinary and animal welfare professions which uses veterinary knowledge to improve the welfare of animals through science, education and debate. More information can be found at www.animalwelfarefoundation.org.uk. The author would like to thank the funders, along with veterinary practices and industry bodies that supported this research, and the farmers who gave up their time, without whom it would not have been achievable.

UNIVERSITY OF LIVERPOOL

Chapter 6

Lameness in Beef Cattle: A Cross Sectional Descriptive Survey of On-farm Practices and Approaches

6 Lameness in Beef Cattle: A Cross Sectional Descriptive Survey of On-farm Practices and Approaches

6.1 Abstract

Cattle lameness is a concern to the United Kingdom (UK) cattle industry, negatively impacting upon both welfare and production. An interview study has identified that some farmers underestimate lameness prevalence, but also that farmers vary in their perception of the impact of lameness. Technical knowledge and skills of farmers were also identified as a potential concern, and farmer reported barriers were identified. However, the extent to which these views can be extrapolated to the wider UK beef farmer population is unknown. Therefore the aim of this study was to produce descriptive results of UK beef farmer lameness-related behaviours relating to activities such as lameness identification, examination, treatment and prevention, and investigate perceptions regarding lameness prevalence, barriers to treatment and control, and training.

Questionnaires were piloted before being circulated online and via post. Postal questionnaires were sent to registered Approved Finishing Units, and a stratified sample of registered holding addresses for England and Wales. Online questionnaires were circulated on social media and via targeted emails to selected industry bodies and veterinary practices. Descriptive results were produced, and thematic analysis performed on free text responses.

There were 532 eligible responses, with a median farmer reported lameness prevalence of 0% (range 0 – 20%). Most respondents did not perform any locomotion scoring, and most reported that it either was not possible, or was not safe to pick up front or back feet. Half of respondents reported that tetracycline was

an antibiotic of choice for lame cattle. Over half of farmers did not use a foot bath, but of those who did, formaldehyde was the most commonly used foot bath product, with some farmers reporting use of antibiotic foot baths. Most farmers reported dealing with lame animals within 48 hours, but some reported that they only dealt with them if they are walking quite badly, and some felt that lame animals would get better by themselves. Varying views were presented regarding options available to deal with cases of chronic lameness, with over 30% selecting emergency slaughter as an option. Many farmers reported that they had received no training regarding various lameness topics, but most of these reported a desire to have further training.

These results suggest that farmers may be underestimating lameness, especially if not locomotion scoring. Diagnosis is likely to be challenging, with either no facilities, or unsafe facilities for lifting feet, which may lead to inappropriate treatment. The reported high threshold by some farmers for attending to a lame animal is a cause for concern, negatively impacting upon animal welfare, but this is also likely to have negative consequences for animal performance and farm profitability. A desire for farmer training represents an opportunity for further knowledge exchange regarding lameness in beef cattle.

6.2 Introduction

Cattle lameness is a concern to both the United Kingdom (UK) dairy and beef sectors, due to its impact on welfare and on production (79,102). Its economic impact is well recognised in the dairy sector (68). Despite this, the mean farm level prevalence of lameness in UK dairy cattle has remained over 20% for over 20 years, with a recent estimate suggesting a mean farm level prevalence of 32% (13,34,37,39). Although it is acknowledged to be one of the most important disease processes in beef production too (41), there is less known about its impact or prevalence in this sector. Canadian work suggested notable financial losses due to lameness in feedlot systems (41). In Chapter 3 of this thesis, an up-to-date estimate of the UK mean farm level prevalence of lameness was found to be to be 8.3% (95% CI 5.58 – 10.99) for finishing cattle, and 14.2% (95% CI 7.83 – 20.63) for suckler cows.

There are a number of dairy sector studies identifying risk factors for lameness, some of which may be within a farmer's control. Herd size (129), duration of housing or grazing access (14,38,39,205,206,232), depth of bedding material (39,129,233,234), provision of deep litter yards (14,39,235), stocking density (198), footbath provision, routine foot trimming provision and concentrate feeding (34) all have been associated with lameness risk for dairy cattle. However, in terms of beef cattle, there is a relative paucity of research in this area. Chapter 3 has identified increasing age and decreased ventilation as being associated with increased likelihood of lameness in suckler cows. Reduced stocking density, poor ventilation, high grip flooring and low body condition score were all associated with a finishing animal being more likely to be lame.

As many risk factors are under the control of farmers, it is essential to understand farmers' perceptions, and their role in the treatment and prevention of lameness. It has been suggested that dairy farmers might underestimate lameness on their farms (19,170), and beef farmers may do the same (164), which may affect the importance that they place on lameness prevention, and may inhibit treatment if lame animals are not identified.

Farmers' perception of the impact of lameness on production, animal welfare and on farm staff was previously identified in chapter 5 as a theme amongst beef farmers (164), with some leaving them untreated, as long as it does not become "too bad", or as long as a cow still conceives. Lesion identification and foot trimming ability, appropriate use of medicines, prompt detection of lameness and decision making relating to culling a lame animal have all been identified as issues for some beef farmers in Chapter 5 (164). Furthermore, some farmers stated a lack of time or lack of capable staff, or felt that they could not justify investing in their facilities in order to better treat or prevent lameness, due to expecting a poor return on investment (164). These issues all have the potential to compromise welfare within the UK beef industry, and also decrease the efficiency of the industry, if it is assumed that lame beef animals suffer from similar performance deficits as dairy cattle.

However, these perceptions and potential obstacles were identified by interviewing a select sample of beef farmers (n=21). Hence more research was required to build on these findings and establish to what extent the results from chapter 5 were applicable to the wider UK beef farmer population. The intent of this study was therefore to use the findings from chapter 5 to inform the design of a cross-sectional questionnaire which could be deployed on a considerably wider scale, thereby yielding quantitative descriptive data that would provide further insight into the population at large. The specific aims of this study were to produce descriptive results of UK beef farmer lameness-related behaviours, enabling i) insights into beef farmer perceptions of lameness prevalence on their farms, ii) exploration of lameness identification, examination and treatment choices on UK beef farms, iii) identification of barriers to lameness treatment and prevention, and iv) investigation of beef farmer training and confidence regarding lameness identification, treatment, prevention and control.

6.3 Methods

This study was approved by the University of Liverpool Research Ethics Committee (VREC 533).

6.3.1 Questionnaire design

The questionnaire was based on the findings from the qualitative study involving beef farmer interviews (conducted in Chapter 5) and informed by the literature and clinical experience. The question topics were initially proposed by JT, and discussed with all members of the research team at length (DGW, HMH, KM and JO). This enabled draft questions to be constructed by JT which were scrutinised and further refined in discussion with the research team, leading to the creation of the near final version. The questionnaire was grouped into sections that covered demographic information, ability and method of management and treatment, dealing with chronically lame animals, training, lameness prevalence and perceived barriers. There were 32 questions, of which 20 were closed and 12 were free text replies.

The near-final version of the questionnaire was then initially piloted in its paper format with 10 beef farmers. Minor alterations were made before the online version was created, which was then successfully piloted with two beef farmers. The pilot surveys enabled an estimate of the time taken to complete the questionnaire to be established, which was approximately 10 minutes. The responses from the pilot study were not included in the analysis.

The questionnaire was designed to require mainly tick box or Likert scale (236) responses, with some closed questions to provide product names, or occasionally reasons for decisions. Regular free text boxes were provided to enable those wishing to expand on their answers to do so.

The online questionnaire provided automated skipping of unrelated questions, for example farmers who stated they did not treat lame animals were not asked about products they used. For the online version, one question deemed to be essential (the number of animals present on the farm) was enforced, but all other questions could be skipped. Multiple choice answers or topics within questions, were randomised (where the responses were not logically ordered, such as age category). This randomisation was not performed with the paper version. However, guidance regarding skipping unrelated questions was provided in the text.

Both online and paper versions provided a participant information sheet and requested consent, which was mandatory for online respondents to continue. The paper questionnaire provided instructions for a change of mind on individual questions once marked, whereas the online version allowed respondents to change their selection by selecting an alternative option. The postal questionnaire is available in **Appendix 6**. Respondents were offered the opportunity to win a pair of wellington boots as an incentive to complete the questionnaire. Those wishing to enter were asked to provide their contact details, which were used solely for the purposes relating to the prize.

Due to the multiple channels of questionnaire distribution, the snowball nature of online social media circulation, and the ability of postal questionnaire recipients to complete online using the link provided, it was not possible to determine a response rate for the questionnaire because the denominator (number of eligible people who received the questionnaire) was unknown.

6.3.2 Identification and recruitment of farmers

The target population was defined as UK beef farmers, working with either breeding beef heifers or cows, or weaned cattle being reared for beef production (including stores, fattening or finishing cattle). Farmers that owned, managed or worked on a farm were considered eligible, regardless of herd size or cattle numbers. Farmers involved with more than one eligible farm were asked to answer questions for the unit that they had the most ‘hands on’ involvement with the cattle.

6.3.2.1 Online circulation

The questionnaire was uploaded to Qualtrics online survey platform (Qualtrics, Provo, Utah, USA) in February 2019 and remained open for 12 months. A link was added to The University of Liverpool social media outlets that was shareable by other social media users. The link was also emailed to targeted industry bodies and veterinary practices (n= 10 and n=50 respectively, identified via press, online media and personal contacts) with the request to circulate to relevant farmers. The link provided a participant information page, and access to the online questionnaire, as well as details of how to request a paper copy of the questionnaire.

6.3.2.2 Postal circulation

Paper questionnaires were distributed via post. The first launch was to 340 farmer addresses listed as Approved Finishing Units (AFUs) in England and Wales, obtained via the UK Government Bovine TB website (237), and occurred in April 2019. These farmers received a postal reminder in May 2019.

The Animal and Plant Health Agency (APHA) provided access to a list of registered beef holdings in England and Wales (n=46,999). Access to data for Scotland and Northern Ireland was not granted. A random sample of 2000 holdings, stratified by farm type (suckler cow or non suckler cow), county registered in, and herd size (1-9, 10-29, 30-49, 50-99, 100-149, 150-499 and 500+ cattle) was selected using STATA/MP 14.1 (Statacorp, College Station, Texas, USA) for Windows. Paper copies of the questionnaire were sent to the selected 2000 farmers in December 2019. The paper questionnaire also provided a link to the online version, offering recipients the choice to complete it using their preferred method. No postal reminders were sent to this cohort.

All postal questionnaire recipients received a postage paid, self-addressed envelope, along with a pen to encourage completion and return.

6.3.3 Data analysis

Once the questionnaire was closed, data from both Qualtrics and the paper questionnaire responses were uploaded to Microsoft Office Excel (Microsoft 2016). The data was then uploaded to STATA/MP 16.1 (Statacorp, College Station, Texas, USA) for Windows for descriptive and statistical analysis. Plausible associations between variables were investigated using Fisher's exact test. Data was exported to Minitab statistical software (Minitab 18, PA, USA) for the purposes of graphical representation. Thematic analysis was performed on free text replies, i.e. the qualitative data as described by Braun and Clark (228) using NVivo Pro qualitative data analysis software (QSR international Pty Ltd. Version 12, 2018).

6.4 Results

6.4.1 Responses

There were 398 postal responses, six of which were returned blank and seven declared that they did not have any cattle of interest (breeding cows or heifers, or weaned cattle that are being reared for beef production), and as such were ineligible. There were 200 online responses, 50 of which did not get beyond giving consent, and one response was ineligible due to not having any cattle of interest. As this study was aimed at UK farmers, one response each from France and Ireland were considered ineligible. Ineligible responses were removed, leaving 385 postal responses and 147 online responses. Postal and online responses were then combined to provide 532 total eligible responses.

Partial completion was possible for both postal and online questionnaires. The only compulsory online questions were an initial consent box and a declaration of the number of animals of interest (serving to confirm eligibility as well as demographic information). If part of a response was not possible to decipher (illegible etc.), that part was removed, but the remaining response was retained. The number of responses varied across different questions. The number of respondents answering each question is indicated in brackets throughout this manuscript. Exact wording of questions has been shortened for illustrative purposes on some figures, however, the question (Q) numbers have been provided in figure legends where appropriate for clarity, and refer to the question numbers in the original questionnaire (provided in full in **appendix 6**).

6.4.2 Respondents

In total, 483 respondents answered the question pertaining to their location and 87% (422/483) of these were farming in England, 11% (54/483) in Wales, 1% (6/483) in Scotland and 0.2% (1/483) in Northern Ireland (**Figure 6.1**). There was a gender bias to the responses, with 82% (406/494) male and 18% (88/494) female. The age range of respondents (n=493) is shown in Figure 6.2, with a distribution of participants around a modal age of 56 – 65 years apparent. No respondents selected the 15 years or less category.

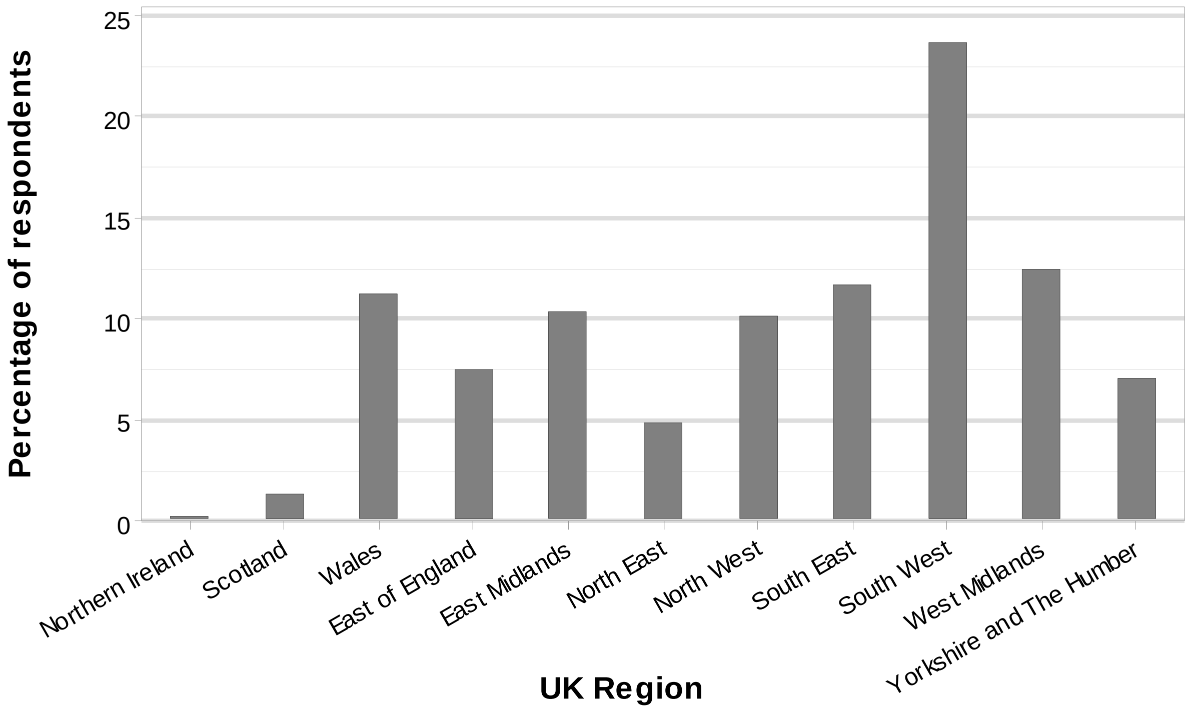


Figure 6.1 Farm location of respondents, by region, as a percentage of respondents (Q29, n=483). Regions utilised are Northern Ireland, Scotland, Wales, and the nine official regions of England. There were no respondents from Greater London.

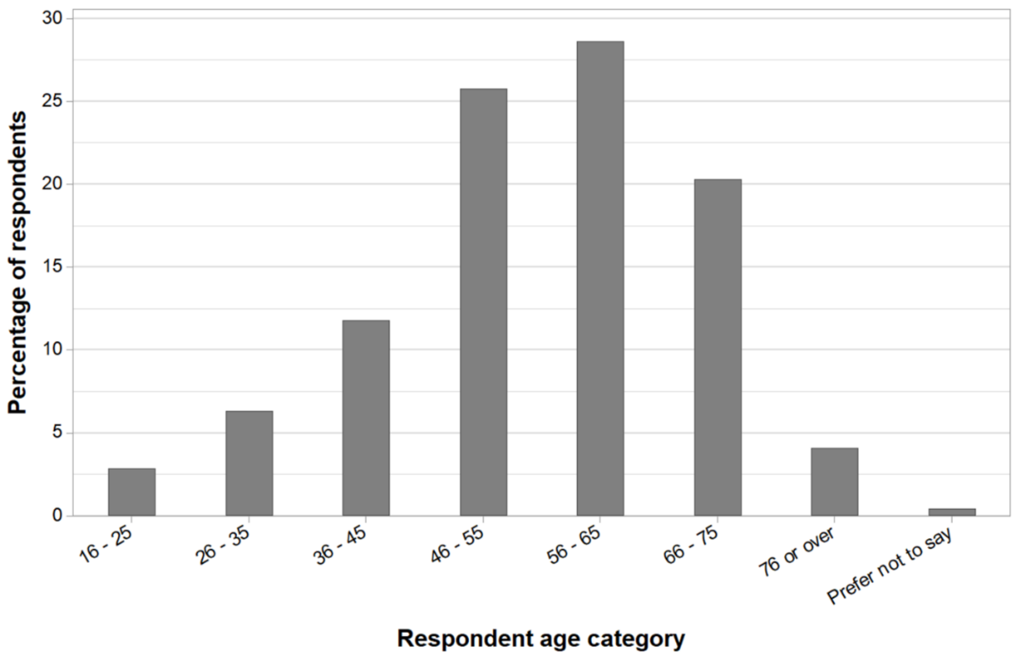


Figure 6.2 Age of respondent grouped into categories, as a percentage of respondents (Q27, n=493).

Of 485 responses, 83% (402/485) described themselves as the farm owner, 17% (81/485) as a farm manager, and 17% (82/485) as a farm worker, with 19% (90/485) selecting ‘other’, either exclusively (55/90), or in addition to other options (35/90). Respondents could select multiple answers.

Participants were asked to select a response relating to their main source of income, to which 60% (290/481) declared that beef farming was either their main source of income, or an equal top share with another source. Another 10% (47/481) stated that their main source of income was derived from livestock, but not beef farming, and 6% (27/481) stated that arable farming was their main source of income. Neither livestock nor agriculture was the main source of income for 24% (117/481) of respondents.

Farmers were asked, regarding the beef cattle component of the farm in question, whether they were responsible for long term farm planning, day to day management decision making, or day to day stockman ship / animal care, and were requested to select all options that apply. Of 487 responses, 86% (420/487), 87% (425/487), and 88% (428/487), respectively, declared responsibility for these three areas.

When considering some specific management systems, the vast majority (93% (457/493)), were not organic, 7% (34/493) declared their cattle to be classified as organic, with 0.4% (2/493) of respondents unsure. About two-thirds (62% (308/496)) did not consider rearing and selling beef breeding stock to be a major part of their business There were 37% (182/496) who did and 1.2% (6/496) of farmers were unsure if it was a major part of their business.

6.4.3 Number of animals and lameness prevalence

A total of 71% (376/532) of respondents provided non-zero answers regarding the number of beef breeding cows, including in calf heifers, on their farms, and 95% (359/376) of these farmers stated the number of animals they believed to be lame. The mean number of cows, including in calf heifers, was 50 (range 1 to 600), with a total of 18,653 animals (**Figure 6.3**). The median farmer reported farm level prevalence was 0% (Mean 2%, range 0 – 20%, **Figure 6.4**).

A total of 83% (441/532) of farmers provided non-zero responses regarding the number of animals being reared on their farms for meat, from weaning to slaughter, and 94% (413/441) of these provided the number of animals that they believed were lame. The mean number of animals reared for meat, from weaning up to slaughter was 155 (range 1 – 4000), with a total of 68,333 animals (**Figure 6.3**). The median farmer reported farm level lameness prevalence was 0% (mean 0.6%, range 0 – 17%) (**Figure 6.4**).

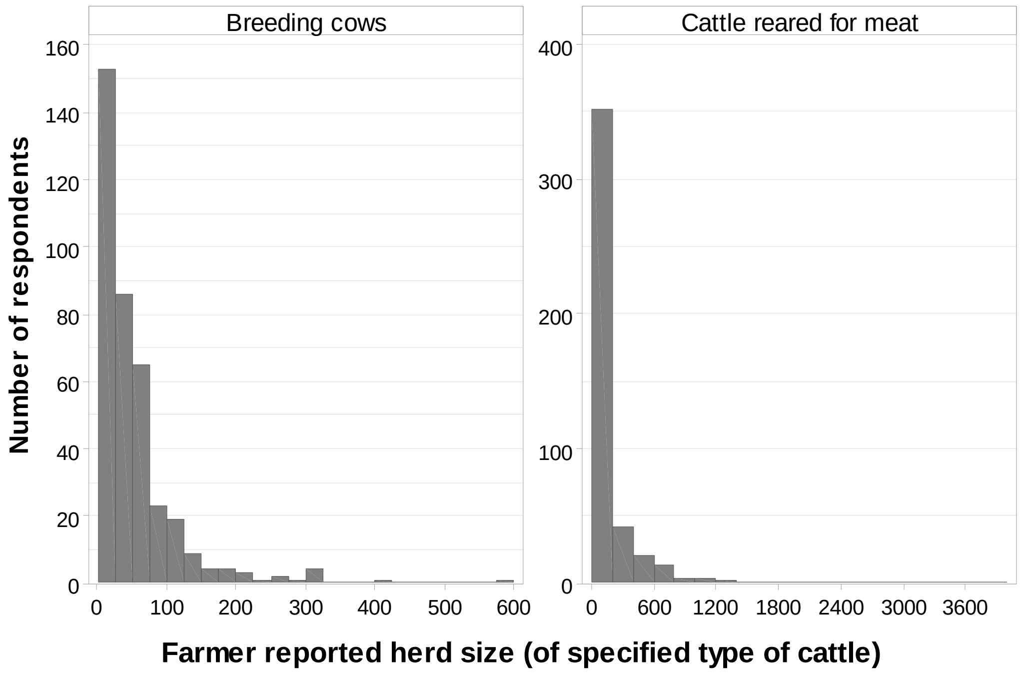


Figure 6.3 Farmer reported number of cattle of interest on their farm, subdivided by type of cattle i) Breeding cows and in calf heifers and ii) cattle reared for meat, from weaning to slaughter (Q16, n=376 and n=441).

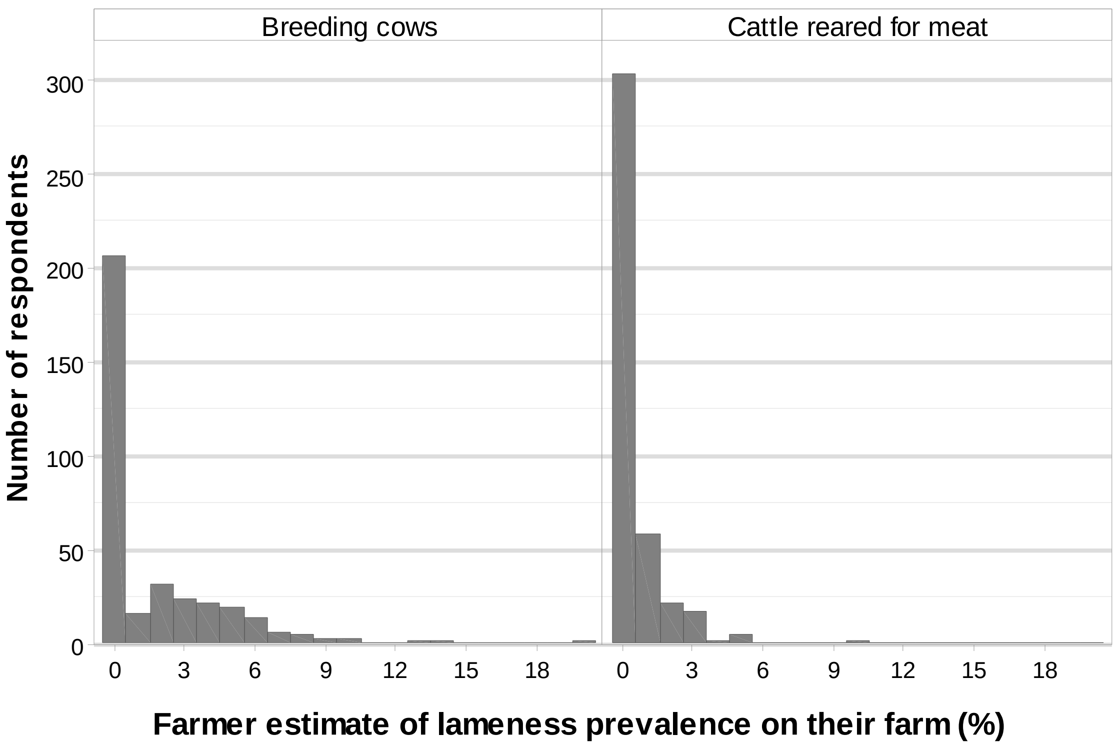


Figure 6.4 Farmer reported lameness prevalence on their own farm, subdivided by type of cattle i) Breeding cows and in calf heifers and ii) cattle reared for meat, from weaning to slaughter (Q16, n=359 and n=413).

6.4.4 Lameness identification, examination and treatment

6.4.4.1 Locomotion scoring and examination

Of respondents, 89% (422/475) declared that they do not perform any locomotion scoring themselves, 3% (15/475) specified that they were unsure if they locomotion score, and just 8% (38/475) did locomotion score. Of respondents, 35% (177/513) stated that they always treat lame beef cattle themselves, and approximately half (52%, 266/513) stated that they sometimes do, with 14% (70/513) never treating lame beef cattle themselves. When farmers were asked about lifting front and back feet of cattle, most farmers selected that lifting and examination is possible, but is generally not safe for either the animal or the person (56% (286/510) and 57% (290/511) for front and hind feet respectively). Lifting and examination was considered possible and generally safe by 13% (68/510) and 11% (58/511) of farmers for front and back feet, respectively. Lifting and examination was considered not possible by 31% (156/510) and 32% (163/511) of farmers for front and back feet, respectively.

6.4.4.2 Treatments

Farmers who treated lame animals themselves were asked about treatments they use for lame beef cattle (with an emphasis on their own regimes, rather than what an external professional might use on their farm). Responses were given on a 5 point Likert scale of ‘never’ to ‘always’, including an option to state if they were unsure. Responses are shown in **Figure 6.5**. Over half of farmers declared that they never used foot blocks (71%, 288/404), foot baths (66%, 275/414) or bandages (57%, 233/406) on their farms. There were 407, 434 and 428 responses regarding topical antibiotics, injectable antibiotics and anti-inflammatory products, respectively, with these products being used at least sometimes by the majority of respondents.

These farmers were also asked to name the two most common antibiotic injection products they use to treat lame beef cattle (**Figure 6.6**).

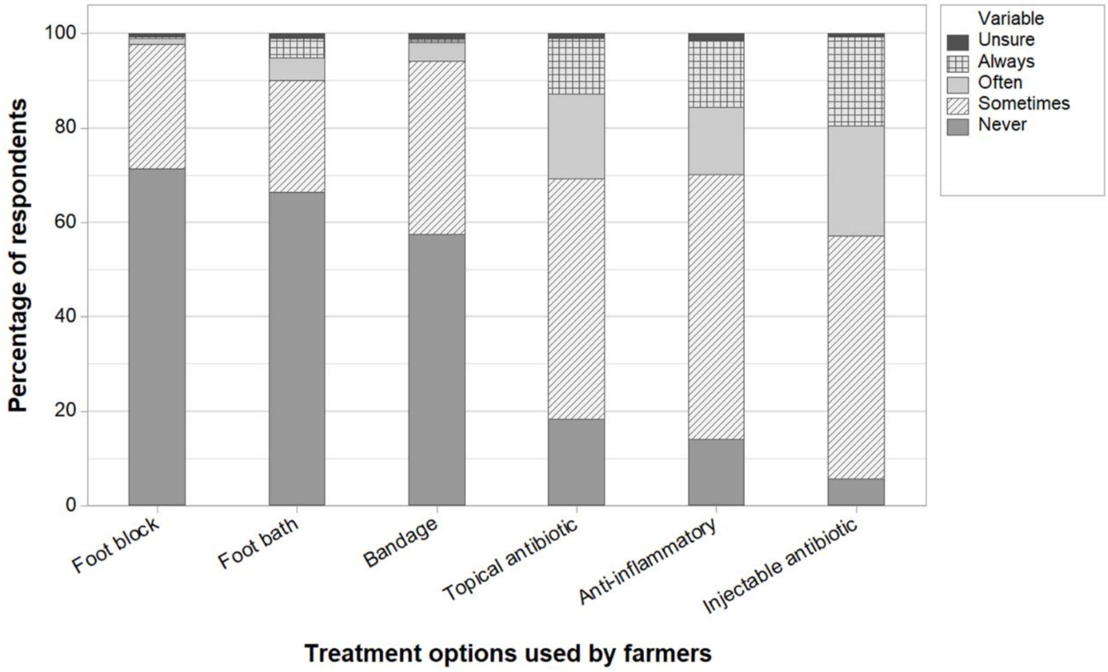


Figure 6.5 Farmer responses to frequency of use of potential treatment options, as a percentage of respondents (Q5 and Q6, n=404, 414, 406, 407, 428 and 434 respectively).

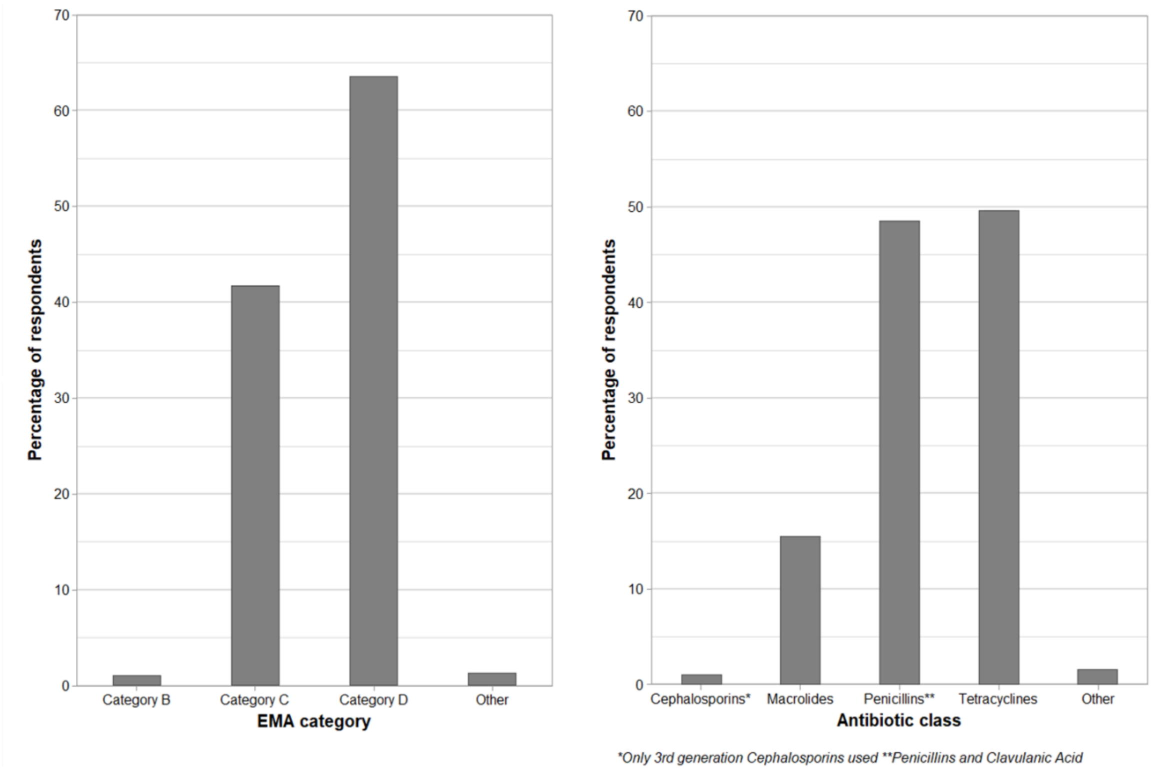


Figure 6.6 Left hand panel: Farmer self-reported injectable antibiotics used to treat lame beef cattle, as a percentage of respondents, grouped by the European Medicines Agency categorisation (27). Right hand panel: Same data but grouped by antibiotic classification. 'Other' includes 5 unspecified antibiotics, and 1 farmer using florfenicol. Farmers could state multiple antibiotics. There were 3% (11) of farmers that reported that they do not use an injectable antibiotic (Q8, n=381).

The most common antibiotic class was tetracycline, with 50% (189/381) of respondents stating that they use a product from this class, followed by 49% (185/381) stating that they use a product from the penicillin and clavulanic acid class. There were 15% (59/381) of respondents who stated they use macrolides, and 1% (4/381) of farmers using 3rd or 4th generation cephalosporins. An amphenicol was used by 0.3% (1/381) of farmers, and an unnamed antibiotic by 1% (5/381) of farmers. Non-steroidal anti-inflammatory drugs (NSAIDs) were listed by 14% (53/381) of respondents, despite the question asking for injectable antibiotic use. Some farmers only listed one antibiotic (or multiple from the same class), and some listed more than two. A minority of farmers (3%, 11/381) specified that they do not use any antibiotics of their own accord.

Respondents were also asked to provide names of any footbath products they use, with multiple answers allowed. **Figure 6.7** indicates the footbath products used, with the most popular product being formaldehyde, used by 24% (59/244) of farmers, followed by 7% (16/244) and 5% (11/244) of farmers using copper based and zinc based products, respectively. Of respondents, 9% (23/244) used another disinfectant based product (including household disinfectant products, chlorhexidine, an iodophor based disinfectant, salt water or an unnamed disinfectant) and 5% (12/244) used an antibiotic foot bath, all of whom reported using a lincosamide product (which are not licenced for this use). The 5% (11/244) of farmers in the category 'other' included those using a water foot bath, a product that could not be remembered, or a product that would be selected dependent on advice at the time. A further 53% (130/244) of farmers stated that they did not use a footbath product. Some farmers provided more than one answer to this question.

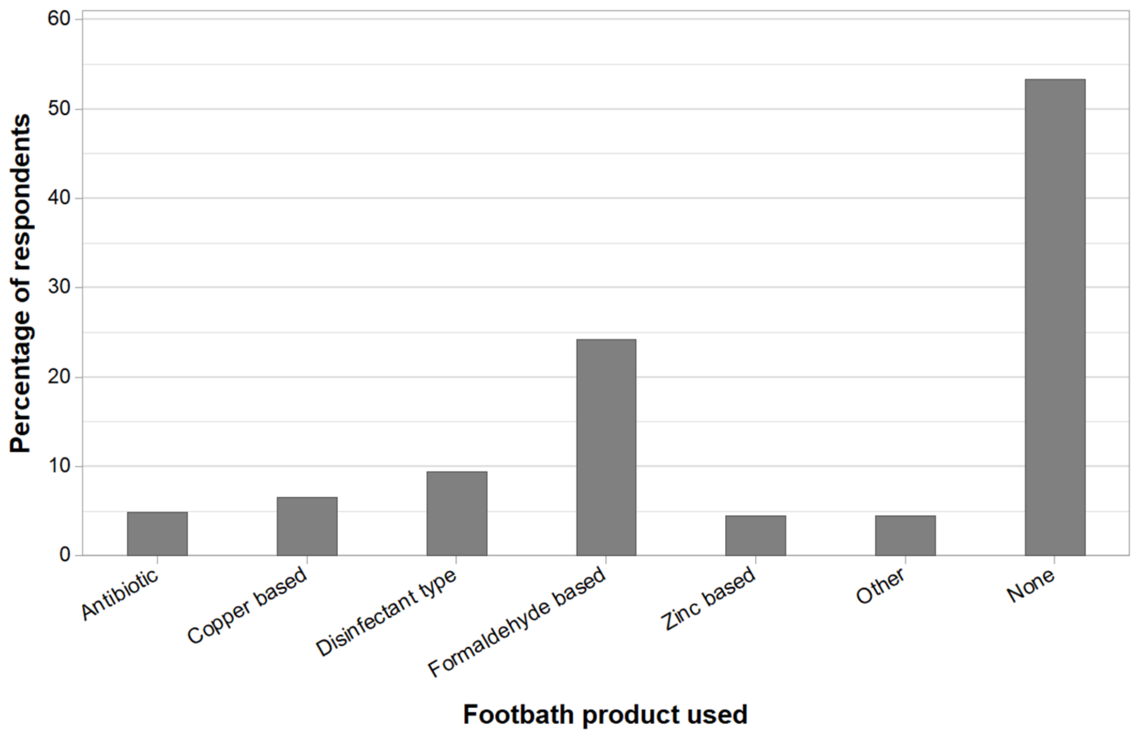


Figure 6.7 Farmer self-reported foot bath products, as a percentage of respondents. Farmers could state multiple products. 'Other' included: a water footbath, products that could not be remembered or farmer stating that the product used would be based on advice at the time of foot bathing. There were 53% (130) farmers that reported they do not use a footbath product (Q9, n=244).

6.4.4.3 Promptness of examination of lame animals

Respondents were provided with six statements regarding dealing with lame animals, and asked to declare a level of agreement, from strongly agree to strongly disagree (**Figure 6.8**). The statements (and number of respondents) were i) I pick up the foot of a lame animal within 48 hours (483), ii) I personally never pick up feet, but I get my vet or foot trimmer to do it as soon as possible (478), iii) I only examine animals if they are walking quite badly (477), iv) I ask the vet to look at a lame animal, but only if the vet happens to be on farm already (473), v) I give lame animals a week or two before examining them, to see how they do (476), and vi) I never deal with lame animals, as they get better by themselves (473). Whilst the majority of respondents (59%, 284/483) reported that they would pick up feet within 48 hours, a minority (3%, 16/473) reported never dealing with lame animals, as they feel they get better by themselves.

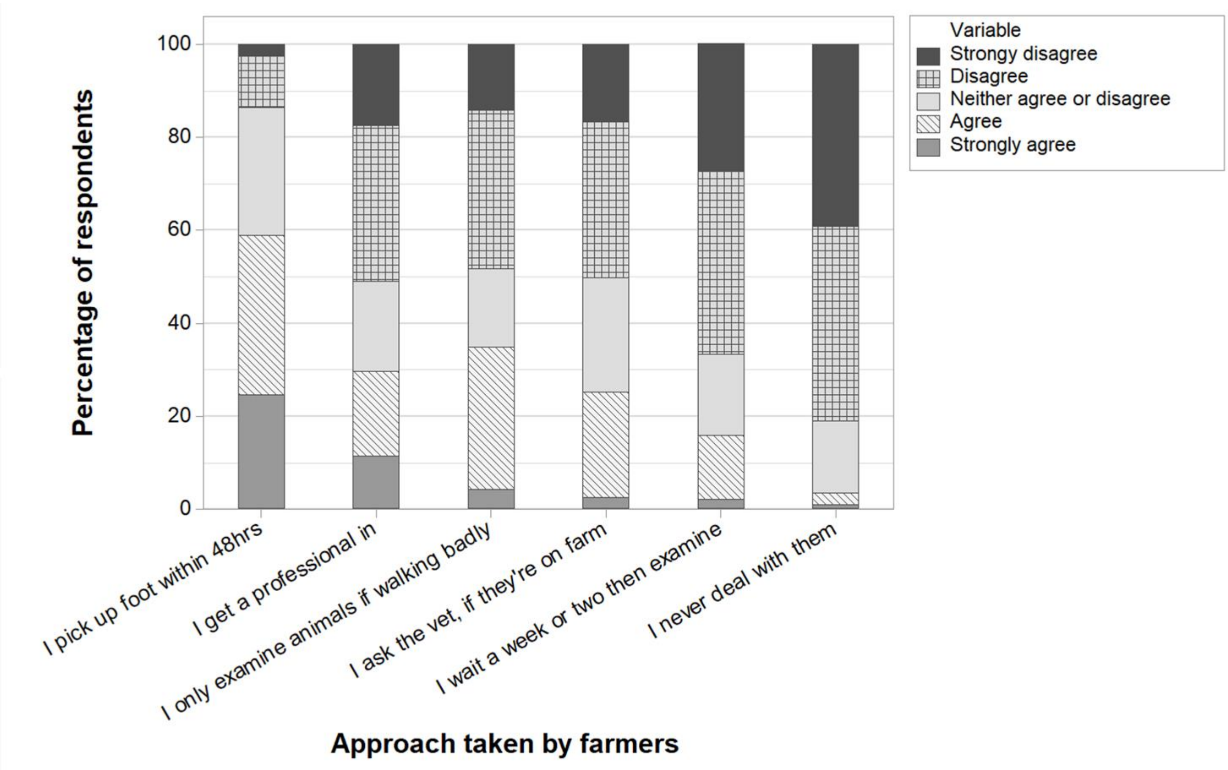


Figure 6.8 Farmer responses to level of agreement with approaches that might be taken to deal with lame animals, as a percentage of respondents (Q18, n=483, 478, 477, 473, 476 and 473 respectively).

Farmers were also asked to select answers that they feel are available to beef farmers to deal with animals that have ongoing lameness, and to select as many as they feel apply (**Figure 6.9**). Of respondents, 85% (424/501) felt that they might arrange treatment and keep the animal on the farm, however 48% (238/501) felt that they might monitor the animal and allow time to recover, without treatment. Calling a knacker man or hunt kennel for collection and disposal was considered an option by 40% (202/501) farmers, and transporting the animal to a slaughterhouse was considered an option by 35% (177/501) of farmers. Calling the vet for an emergency slaughter certificate (on farm slaughter) was considered an option by 34% (172/501) of farmers, whereas 2% (9/501) of respondents felt that none of these options were available to deal with beef animals with ongoing lameness. Of these 9 farmers, two left comments suggesting that they would get a professional in, and three suggested that they do not experience ongoing lameness problems in their cattle. Four provided no further comment.

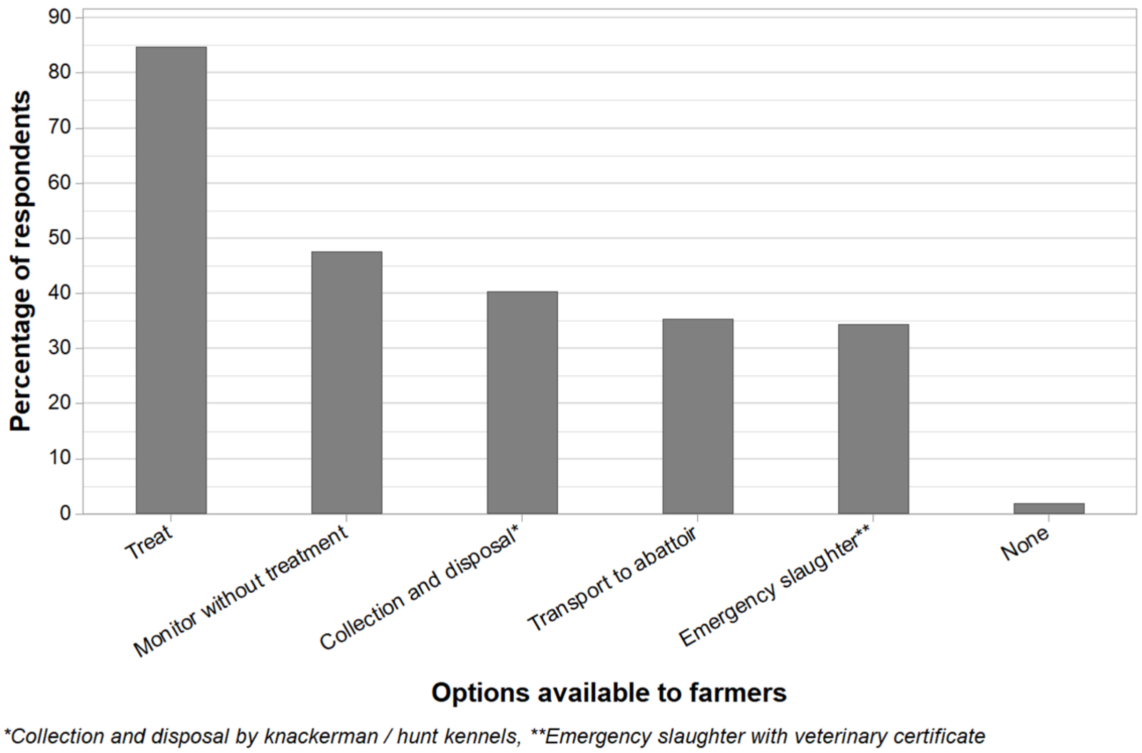


Figure 6.9 Farmer self-reported options available to them to deal with animals that have ongoing lameness, as a percentage of respondents. Farmers could select multiple answers (except if selecting 'None' (Q10, n=501).

6.4.5 Barriers to treating lameness

Following on from the above lameness related questions, farmers were asked about what, if anything, prevents them from treating lameness or makes treatment difficult, and were provided a free text box to respond, to which 396 farmers responded. Four major themes were identified, these being: i) facilities and location, ii) staff, time and knowledge, iii) concerns over drug use, and iv) nothing.

Facilities and location was the most frequently mentioned theme, with four sub themes, namely i) location of cattle, ii) inadequate facilities, iii) dangerous animals and iv) safety of staff. One farmer highlighted that:

"*An old crush is up at* [site away from main farm]*, but treatment is not easy.*"

Another farmer highlighted that:

"*Sometimes animals are too wild*."

Staff, time and knowledge had four sub themes, namely i) staff availability and time, ii) staff ability, iii) knowledge on lameness, iv) perceived requirement to treat lameness. A number of farmers mentioned staff availability in general was a problem, whereas others mentioned the ability of their staff or themselves, with either age, ill health or knowledge being a concern, with one stating:

"*More training on lameness in cattle is needed*."

Some farmers stated that they simply did not have any to treat, whereas another stated:

"*They get better by themselves 90% of the time*."

Concern over drug use was mentioned generally in terms of withdrawal period concerns:

"*Drug withdrawals make decisions hard close to slaughter*."

However, two farmers did consider responsible use of antimicrobials:

"*I don't want to overuse antibiotics*."

Of respondents, 20% stated that nothing prevents treatment of lame beef cattle, or makes it difficult. Some also highlighted the welfare importance:

"*Nothing prevents me, it has to be treated quickly for the welfare of the animal*."

6.4.6 Barriers to preventing lameness

In addition to the previous section, which asked farmers what may hinder them *treating* lame animals, farmers were also asked about what, if anything, stops them from *preventing* lameness in beef cattle, or makes prevention difficult, and they were provided with a free text box in order to reply. This question received 319 responses, and three themes were identified: i) facilities and location, ii) staff, time and knowledge, and iii) nothing.

Facilities and location again had four sub themes, a) location, terrain and weather, b) inadequate facilities, c) dangerous animals and d) safety of staff. A number of farmers mentioned weather, particularly wet weather, muddy gateways and trough areas and the presence of stones, and some mentioned wet housing conditions as an issue. Several also mentioned issues with either unsuitable facilities, such as handling facilities, or facilities likely being too far from the cattle. One highlighted that they felt footbaths could not be used:

"[You] *could footbath in a dairy situation, but not our beef unit*."

Staff, time and knowledge had four sub themes, namely i) staff availability and time, ii) staff ability, iii) knowledge of lameness topics and iv) perceived requirement to prevent lameness. Some farmers mentioned staff shortages in the livestock sector, and some highlighted time as an issue, including one farmer who stated:

"*Time. In an ideal world we would do more trimming as a prevention of lameness*."

A number of farmers felt that knowledge and training of prevention methods was an issue:

"*Lack of knowledge of prevention techniques*"

And

"*Knowing what to do and when*."

A number of farmers simply stated that lameness was not 'a big problem' on their farm, with one farmer stating:

"*If it isn't broke, don't try to mend it*"

And another, when discussing the issues with prevention pointed out that they were:

"*Not looking for any more work or expense*."

However, one farmer stated that the only reason for not preventing lameness was:

"*Just laziness of owners*."

Over a quarter of respondents stated that nothing stops them preventing lameness, or makes prevention difficult, with one farmer clarifying:

"*Prevention of lameness is a priority, and I would seek advice when needed*."

6.4.7 Farmer training

In order to investigate farmers' training, they were presented with five lameness related topics, and firstly asked about their source of any training, selecting the one answer that best applied to their situation. The possible responses to this first question were a) 'I have received specific training (e.g. from a foot trimmer or at college)', b) 'I am self-trained', or c) 'I have had no training'. Some farmers did select two responses to some questions and these responses were excluded from analysis (n = 24 responses from 8 individual farmers).

Secondly, respondents were then asked to select if they felt sufficiently competent, and if they would like further training on the same five lameness related topics. The number of respondents to the first (source of training) and second (competence or desire for further training) question, and the number that responded to both were, by topic: i) Recognition of different foot conditions (488, 476, 458), ii) How to trim feet (485, 408, 392), iii) How to treat lameness (483, 461, 443), iv) How to prevent lameness (476, 461, 438) and v) Locomotion / mobility scoring (461, 396, 380). Respondents who answered both questions on each topic are presented in **Figure 6.10**, displaying how responses on previous training related to feeling competent or requiring further training.

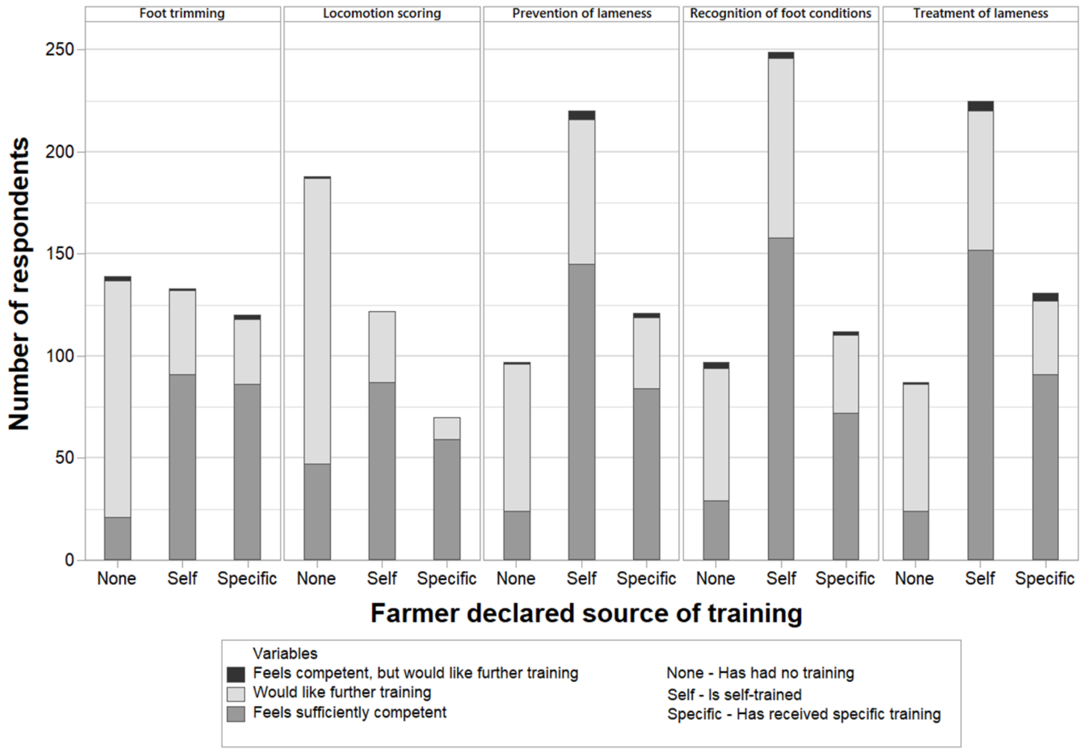


Figure 6.10 Farmer self-reported previous training regarding five lameness topics, with corresponding declaration of either feeling sufficiently competent, wanting further training, or both. The five topics were: how to trim feet, locomotion / mobility scoring, how to prevent lameness, recognition of different foot conditions and how to treat lameness. Note, only farmers responding to both questions on each topic are included in this figure (Q12 and Q14, n=392, 380, 438, 458 and 443 respectively).

6.4.8 Associations between responses

Female respondents were less likely to declare that they felt sufficiently competent at foot trimming (Fisher's exact p = <0.001), treating lameness (Fisher's exact p = 0.007) and lameness prevention (Fisher's exact p = <0.016).

Respondents who reported that their main source of income is not derived directly from livestock or agriculture were more likely to declare that they had less than 10 suckler cows (Fisher's exact p = 0.002), and less than 10 weaned animals being reared for beef (Fisher's exact p = <0.001) than respondents declaring one of several options where agriculture was the main source of income. They were also less likely to select that it was possible, and safe, to pick up front (Fisher's exact p =

<0.001) or back feet (Fisher's exact p = <0.001), and were also less likely to always treat lame animals themselves (Fisher's exact p = <0.001). In addition, they were more likely to have had no training in recognition of different foot conditions (Fisher's exact p = <0.001), foot trimming (Fisher's exact p = <0.001), lameness treatment (Fisher's exact p = <0.001), lameness prevention (Fisher's exact p = <0.001) or locomotion scoring (Fisher's exact p = 0.005). The same respondents were more likely to state that they would like further training in each of the five topics (Fisher's exact p = 0.001, p = <0.001, p = <0.001, p = <0.001 and p = 0.001 respectively).

Farmers who declared their cattle to be classified as organic were more likely to strongly agree that they might give lame animals a week or two before examining them, to see how they do, compared with farmers who stated they were not organic (Fisher's exact p = 0.038). However, the number of farmers with organic cattle who answered question 18 was only 31.

6.5 Discussion

6.5.1 Lameness prevalence

Farmers reported a mean farm level lameness prevalence of 2% for suckler herds, and 0.6% for finishing units. This contrasts with earlier work (Chapter 3), where a mean farm level lameness prevalence of 14.2% (range 0 to 43.2%) for suckler farms and 8.3% (range 2.0 to 21.2%) for finishing units was identified by the author locomotion scoring. However, there is evidence in both beef and dairy settings that farmers tend to estimate a lower prevalence of lameness than researchers (19,164). This could be due to the lack of locomotion scoring, with just 8% of respondents in this study stating that they locomotion score their cattle, or it could be due to the method of lameness detection that is performed – perhaps difficulty in classifying or defining a lame animal which some farmers find particularly difficult because of facilities or location performed (164) or lack of training (161). Recall bias may have affected the numbers provided in the responses, especially if lame animals are not recorded. No matter what the reason for the lower estimates, if it is the case that lame animals are not being identified, this will be a barrier to treatment, as well as acknowledgement and prevention of any farm level problem.

6.5.2 Lameness identification, examination and treatment

Over 85% of responding farmers reported that picking up the feet of lame animals was either not safe or not possible. This is concerning, considering both the fact that many lameness causes will require lifting of feet for both diagnosis and treatment, and the perceived difficulties previously identified in getting professional foot trimmers to examine individual lame animals promptly (164), and the importance of prompt treatment, both for prognosis and animal welfare (143).

The difficulty in lifting feet may in part explain the low number of farmers that use foot blocks, or bandages, as these require suitable facilities. The motivators of the

19% of respondents stating that they always give antibiotics when treating lame animals may be an area for further investigation. Especially considering that some of these may not be lifting feet, and so a diagnosis supporting antibiotic use as appropriate may not have been reached. Findings of Chapter 3 suggest that claw horn lesions are more prevalent in beef cattle, for which antibiotics will offer no benefit.

Non-steroidal anti-inflammatory drugs were used at least sometimes by 85% of farmers, which is likely to be important for alleviating pain, and for recovery (97).

Antibiotic choice suggests the most commonly used products are from European Medicines Agency (EMA) category D, which is the category to be used prudently as a first line treatment (238). Although the UK has not fully adopted this categorisation, it provides a useful basis to evaluate the farmer reported use of antibiotics. There were a number of products in category C, namely macrolides, amoxicillin and clavulanic acid, dihydrostreptomycin and florfenicol which, under the guidance, should be used with caution. Very few farmers used a category B drug (ceftiofur, stated by 4 respondents), which, under the guidance, should be restricted. Injectable macrolides (stated as being used by 15% of farmers), may be attractive because of the long acting nature of some products in this group. A potential concern is that three farmers suggested they used tilmicosin, despite this product being restricted to veterinary administration only. Some of these respondents may be both farmers and veterinary surgeons, or they may have misunderstood the question. While the common use of category D drugs is reassuring, the findings on antibiotic usage also show an opportunity for improved veterinary input on appropriate drug choices.

Foot baths were used as a treatment by just under a third of respondents, and the popularity of products used contrasted with a dairy farming study in the United States, where copper sulphate was the predominant product, with formaldehyde used by just 7.7% (239). Antibiotics were used by 17% of farmers in the same study, compared to 5% of respondents in this study. Solely using a water foot bath was suggested by a small number of farmers. This may be intended to clean the hoof. However, due to the lack of any disinfectant capability, there is a risk that this may spread infection. Over 65% of farmers reported that they do not use a foot bath. This may be because of a difficulty in providing a foot bath to cattle, both when at grass and when housed (164), with less occasions of routine journeys through farm buildings or handling systems in beef units compared to dairy herds. There is limited literature regarding optimal foot bath products, but antibiotics and disinfectants such as formaldehyde and copper sulphate are generally considered beneficial for the control of lameness (131,144). However, the use of antibiotics in foot baths constitutes off-license application in the UK, and under the responsible use of antimicrobials aspect, their use is difficult to justify (148). Formaldehyde is classed as a potential carcinogen, and copper sulphate is not degraded in the environment, and as such the future availability of each of these products is uncertain.

Of particular concern were 4% of respondents who selected that they strongly agree or agree with the statement ‘I never treat lame animals, as they get better by themselves’. Additionally, the 16% of respondents who agreed or strongly agreed that they would ‘wait a week or two before examining lame animals to see how they do’, and the 35% of farmers that agreed or strongly agreed that they only examine lame animals if they are ‘walking quite badly’. These approaches to a lameness case are likely to leave animals in pain, and may lead to more severe lesions, and affect the recovery potential (143), perhaps indicating a lack of knowledge on the consequences of such actions. However, the 59% of farmers who agreed, or strongly agreed, that they ‘pick up the foot of a lame animal within 48 hours’ should be considered a positive sign. This wide variation between farmers’ approaches compares with the earlier interview findings of UK beef farmers from chapter 5 (164).

When farmers were asked to select options for dealing with ongoing lameness cases, no information about severity of lameness or chronicity was collected. However, the 35% of respondents that selected that they can transport the animal to slaughter remains an approach that divides opinion (102,240). Farmers must bear in mind UK regulation requiring that animals must not be transported ‘in a way likely to cause them injury or undue suffering’ (63). The animal must also bear weight on all four limbs when standing or walking, and stand up unaided under fitness to travel rules (241). These requirements are likely to preclude many cases of lameness from being transported, although there are very limited exceptions for ‘slightly injured or ill’ animals with Official Veterinarian agreement, provided improved transport conditions and direct sending for immediate slaughter are met (242).

Only 40% of farmers in this study thought that on-farm euthanasia and disposal by the knacker man / hunt kennel was an option available to them. However, for animals with chronic lameness who are in pain and not responding to treatment, this is an option for all farmers, and in some cases may be the only option to preserve welfare. Over a third of responding farmers selected that they might call the veterinarian to request an emergency slaughter certificate. For lameness cases, it is likely that the veterinarian will be unable to provide a certificate, because the condition of ‘a healthy animal that has suffered an accident’ is not met (242). Stojkov *et al.* (243) conducted a study at Canadian dairy cull cow markets, and identified that almost a third of cows at these livestock markets had poor fitness for transport. It is unknown to what extent this problem may occur in the UK.

Farmer reported barriers to both treatment and prevention of lameness were largely similar. The questions did follow sequentially, so some order effect may have occurred, but results compare to findings in the author’s earlier interview study of beef farmers (Chapter 5) (164), where facilities and location of animals, staff, time and knowledge were all important concerns for farmers. This suggests that these are important areas for improvement, either with improved awareness, understanding of incentives or alternative sources of support and knowledge exchange.

6.5.3 Farmer training

Farmers reported a large proportion of self-training in lameness related topics. Despite this, over half of this group self-reported to be sufficiently competent in each topic. There was also a large proportion of farmers who reported to have no training, yet still felt sufficiently competent. This may be because they do not feel that they need to be trained in it, perhaps relying on expert advice or getting professionals to perform lameness related tasks instead, or because they perceive it to be unimportant. An animal welfare concern would be unconscious incompetence, where they feel competent, but are not, and this may apply to some respondents.

However, a high proportion of farmers did select that they would like further training in each of the 5 topics. This correlates with the reported barriers to treatment and prevention relating to their lack of knowledge and training. Some farmers selected that they felt sufficiently competent, but still wanted further training. This may be due to either a general desire for knowledge, or a belief that, although they deem their current ability as satisfactory, further training may improve their skills. There may also be an element of social desirability bias occurring, such that some may be reluctant to admit that they are not sufficiently competent given that they are treating animals themselves, and therefore self-report that they are competent. These findings compare to earlier interview findings (164), where some farmers reported that they did not feel confident enough to trim feet, and others displayed little knowledge of lesion recognition. Further training to those who would like it could lead to reduced lameness and improved welfare and production, and this study supports the notion that there is considerably more scope and demand for lameness training for beef farmers.

Of particular interest is the high likelihood of respondents with a small herd (less than ten breeding cows or weaned cattle reared for beef) to declare having had no training and desiring further training, compared to those with larger herds. These farmers may make prompt, appropriate use of professional services. However, with evidence of some farmers having difficulties accessing foot trimmers when only presenting a small number of cattle (164), and these farmers being less likely to be able to safely lift the feet of lame animal themselves, there is a real risk of lame animals in such small herds being left untreated or incorrectly treated.

6.5.4 Representativeness of responses and respondents

Data from the UK Cattle Yearbook 2019 (using 2017 data) indicates that the number of non-dairy holdings across the UK is 61,460, with a distribution of 45% in England, 12% in Wales, 16% in Scotland and 27% in Northern Ireland (4). If it was assumed that all these holdings were eligible for participation, approximately 0.9% of farmers were sampled. These questionnaire responses are biased towards farmers in England, with 87% of respondents in England. Wales was almost proportionately represented with 11% of respondents, but Scotland and Northern Ireland were underrepresented. This is not unexpected, with addresses for beef farmers in Scotland and Northern Ireland not available for a directed distribution. The yearbook data suggests that the mean beef herd sizes are 27 for England, 48 for Scotland and 18 for Northern Ireland (no data for Wales) (4), which is comparable to the mean number of cows on farms of respondents, which was 50. The spread of respondents across English regions was considered acceptable, having responses from all regions but London. The median age of UK registered agricultural holders (the person in whose name a holding is operated) in the UK is 60 years, with those 55 – 64 years of age representing 36% of holdings in 2016 (1). This compares to 29% of respondents to this questionnaire being in the 56 – 65 years of age category.

6.5.5 Limitations

When interpreting the results of this study, it must be recognised that the nature of a voluntary questionnaire may lead to a non-response bias, as those choosing to respond may have differed in some way to those that chose not to respond. Selection bias may have also occurred, as online circulation will have favoured those farmers with access to, and more regular use of online media. In addition, the first launch of the paper questionnaire was sent to all AFU addresses in England and Wales, and so was biased toward farmers with finishing units, who had reason to register their holding as an AFU online. The list of farm addresses used for the stratified sample to receive a postal questionnaire only included holdings in England and Wales, which added selection bias. There was also a risk of recall bias in naming products used and stating the number of lame animals believed to be on farm. All questions were asked in the same order, although for online respondents, sub questions were randomised. This may have introduced an order bias, for example by asking farmers about their handling facilities before asking about difficulties in treating lame animals, alongside a social desirability bias, whereby respondents may have wanted to provide a perceived ‘correct’ answer. Despite these limitations, the questionnaire is still a useful tool to capture findings for a large number of farmers, and, in the author’s opinion, these results provide important information regarding farmer perceptions and protocols.

6.6 Conclusions

This research identified beef farmers’ perceived lameness prevalence on their farms to be generally low, with previous work suggesting this may be an underestimation. Approaches to lameness are extremely variable amongst beef farmers, and farmers acknowledged a need for further training relating to lameness. Important themes posing barriers to lameness treatment and prevention were i) facilities and location of cattle, with over 50% of farmers unable to lift all four feet safely, and ii) staffing, time and knowledge base. As an example for the second theme, over 90% of respondents did not locomotion score, and so may not identify a problem, where one exists. This potential lack of identification may explain the possible underestimation of lameness prevalence seen here and elsewhere (Chapter 5 (164)), and is a critical barrier to a farmer instigating both treatment and prevention plans. Additionally, farmer awareness of appropriate options to deal with ongoing lameness cases is a concern. For example, do the 35% of farmers that consider transporting lame animals to slaughter as an option understand the regulations and requirements for transport, and is this option applied to inappropriate cases? However, some farmers felt nothing was a barrier to dealing with lameness, suggesting that some consider it to be important. Future work to identify how best to support farmers, with knowledge exchange regarding approaches to treating and preventing lameness, as well as training in these areas has the potential to improve both animal welfare and farm productivity.

6.7 Acknowledgements

This study was funded by the Animal Welfare Foundation (AWF; grant reference Norman Hayward Fund NHF 2016 05 KM). AWF is a fundraising and grant giving charity (charity number 287118) directed by veterinary and animal welfare professions which uses veterinary knowledge to improve the welfare of animals through science, education and debate. More information can be found at www.animalwelfarefoundation.org.uk.

The author would like to thank the funders, along with the Animal and Plant Health Agency for provision of the farmer addresses, the veterinary practices and industry bodies that assisted with circulation, and the farmers that gave up their time to complete either the pilot or the final questionnaire.

7 Summary discussion

Lameness in the UK beef industry has previously received very little attention, despite a welfare concern over lame beef animals being recognised (102). To the author's knowledge, there is no published literature regarding the prevalence of lameness in UK beef cattle, and no evidence of the lesion frequencies or their associations with lameness. In addition, there is a paucity of information regarding the impacts of lameness on UK beef cattle, such as the impact upon average daily live weight gain in finishing cattle. The perceptions of UK beef farmers, and their treatment and prevention protocols regarding lameness are also generally unknown.

This is despite approximately 1.6 million suckler cows in the UK (1), and just under 2 million prime beef cattle that are predicted to be slaughtered in 2020 (244). More attention has been given to the UK dairy industry, with a recent estimate of mean farm level lameness prevalence of 31.6% (34). Foot lesion types are reported to be more commonly diagnosed than upper limb lesions in dairy cows (37,143). Research has also investigated lameness treatment and prevention methods in this sector (130,143,245). In addition, risk factors for lameness in dairy cattle have been identified, with the type of resting area provided, concrete grooving characteristics, foot trimming timing / frequency, foot bathing frequency and the amount of concentrate feeding all associated with lameness (34). Dairy farmer behaviours have also been studied, with poor record keeping and underestimating lameness prevalence reported as concerns (103). Dairy farmer use of terminology and perceptions were suggested to impact their urgency to treat lame animals (225), and staff resources and farm infrastructure can limit the ability to treat lame animals effectively and promptly (225,246).

The findings of this research identify that beef cattle can be locomotion scored using an observer based system (Chapter 2 (180)), similar to a protocol recommended within the UK dairy industry (149). This system was found to be acceptable for both intra and inter-observer agreement for researchers, clinicians and veterinary students, following online training.

This should give clinicians the confidence for its use in practice and, while not specifically validated with farmers and farm staff, it encourages industry bodies to promote its uptake in the field. The system could also form the basis of a more complex score for research purposes, although this study found no advantage in further discriminating severe lameness levels.

The mean farm level prevalence was estimated to be 8.3% (range 2.0 – 21.2%) for finishing cattle and 14.2% (range 0 – 43.2%) for suckler cows (Chapter 3). White line disease and claw overgrowth were both particularly important for finishing cattle, and white line disease was important for suckler cows. The importance was due to both the frequency of these lesions, and their association with lameness, with their presence significantly increasing the odds of an animal being lame. Risk factors for lameness were studied, and pen ventilation, flooring grip and pen area provided per animal for finishing cattle, and pen ventilation along with age for suckler cows were amongst the factors identified to be of particular interest and worthy of further investigation.

The mean farm level prevalence estimated suggests that lameness is a prevalent welfare problem on UK beef units, and warrants further attentions. Lesions identified suggest that treatment requires examination and appropriate treatment of lame animals, which will require sufficient expertise and facilities.

The impact of lameness upon finishing cattle was investigated, and estimated to reduce average daily live weight gain significantly (Chapter 4), with finishing cattle that were ever lame estimated to having a 240g reduction in their average daily live weight gain over the finishing period. Using average daily live weight gain achieved by the study farms and assuming that an animal becomes lame halfway through a 90-day finishing period, this reduction would add eight days to achieve target weight, further reducing the tight profit margins experienced by beef farmers. Additionally, the greater the number of times that a finishing animal was scored as lame, the greater the impact upon its weight gain. Lameness also appeared to be associated with sex, with entire males at a higher risk.

This suggests that lameness is having a notable impact upon the beef finishing industry, and is financially important.

During interviews (Chapter 5 (164)), beef farmers underestimated lameness on their farms when using recall, compared to estimates from a researcher locomotion scoring, with a mean underestimate of 7% (95% CI 5-9%). Thematic analysis of beef farmer interview data brought out four themes that were important regarding lameness on beef farms: i) perception of lameness prevalence, ii) technical knowledge and skills, iii) perception of the impact of lameness and iv) barriers to the treatment and control of lameness. Variability between farmer behaviour was highlighted, such as some transporting lame animals, some feeling transport was a grey area, and some specifically not transporting lame animals. Some farmers were treating lame animals themselves, and others leaving them, feeling that they "*burn themselves out*". Some contra-indicated treatment methods were also being employed.

Lack of identification of lame animals is a crucial barrier to resolution. Furthermore, having the knowledge and skills to deal with lameness presents an urgent challenge for the beef industry.

A large scale questionnaire (Chapter 6) highlighted that farmers were generally reporting very low levels of lameness, with mean farm level prevalence of 0.6% for finishing units, and 2% for suckler herds. Most farmers reported that it either was not possible, or was not safe to pick up all four feet. Farmers reported that tetracyclines were the most popular antibiotic of choice for lameness cases, and some volunteered information regarding non-steroidal anti-inflammatory use. However, some farmers did declare that they wait a while before treating lame animals, and some declared that they never treat them. Variable responses were given regarding dealing with chronic lame animals, with transport and emergency slaughter both considered as options available by over 30% of respondents each. Reported barriers to both treating and preventing lameness largely mirrored the themes identified in Chapter 5 being i) facilities and location, ii) staff, time and knowledge and iii) concerns over drug use.

This questionnaire study mirrors findings from the previous interview study, suggesting facilities and staff time and knowledge are important barriers to resolving farm level lameness problems.

This research demonstrates that lameness is present on UK beef farms, and the range of prevalence between farms indicates that some farms have notable lameness problems. However, lameness is likely to be underestimated and its impacts unappreciated on many of these farms. Aside from the welfare aspect, this study demonstrating an effect on production further supports the case that increased awareness of beef cattle lameness is called for. Expanding on this work may enable a direct cost-benefit of lameness management to be established. Farm facilities are likely to require investment to enable on farm lameness management, and some farmers lack the technical knowledge and skills within their team to confidently tackle lameness on their own farms. However, some farmers are using inappropriate and ineffective treatments methods, which are likely to be compromising welfare of their animals. Furthermore, farmers are unclear regarding transportation of lame animals, and the options available to them for dealing with chronically lame cattle.

While there was a total paucity of evidence previously, this thesis has proven that lameness is a significant welfare and production problem for some UK beef farms. Policy makers and industry bodies should now build on this and encourage further work to understand and prevent the problem. Lameness is a welfare concern (79), and the presence of lameness on UK beef farms is not supportive of the five freedoms (87), so it is imperative that we work towards a reduction in lameness. Engaging with and supporting farmers and their advisors to deal with their own situations on their farms will be advantageous. Providing better guidance regarding transportation of lame animals, and communicating the options available regarding chronically lame animals more clearly will help to support farmer decision making.

Motivating farmers to change behaviour will be important in many cases. Providing support for farmers, in terms of farmer knowledge exchange, practical training opportunities and ongoing engagement regarding lameness in beef cattle is likely to be beneficial. A multimodal approach will be best, involving all stakeholders of the beef industry, including industry bodies as well as trusted advisors such as veterinary surgeons, foot trimmers and nutritionists as well as farmer interest groups.

This research was intended to establish a baseline of information, which it achieved. It will be important for further research to continue this work. Although locomotion scoring is possible, its uptake in the dairy industry has involved industry pressure (29), which suggests uptake on a regular basis may be challenging on some beef farms, especially when farmers report time and staff availability to be an issue (Chapter 5 and 6). Alternative lameness detection methods would be beneficial to ease, or even automate, this process. Risk factors for lameness need to be further investigated to enhance prevention plans, and the production impacts of lameness across the various beef systems, such as suckler systems, need to be studied in order to help justify investment in prevention plans.

7.1 Recommendations

1. Department for Environment, Food and Rural Affairs: Improved guidance must be made regarding the transport of lame animals, and emergency slaughter, and this must be circulated widely within the industry. This research has highlighted confusion within the industry over whether lame animals can travel, with differing opinions relating to the use of emergency slaughter.

2. Agriculture and Horticulture Development Board (AHDB), Quality Meat Scotland (QMS) and Hybu Cig Cymru (Meat promotion Wales, HCC), as levy boards, along with other industry bodies: Support farmers with further knowledge exchange and training regarding lameness in beef cattle, promoting awareness and guiding farmers through change. This research has proved that some farmers want and need support in the form of training, both to help them prevent and treat lameness. Assistance with farm planning to justify improvement in facilities is likely to be worthwhile. These organisations are experienced in this type of work, and are looked to by many farmers for this type of support.

3. Veterinary surgeons, cattle foot trimmers and other trusted farm advisors: Lameness must be on the agenda when visiting beef farms, and undertaking health plans or business reviews. As with other industry bodies, there is a place for farmer training and knowledge exchange, and evidence suggests that some of these professionals are amongst those that farmers trust the most, so may be best placed to provide this support.

4. Research funding bodies and academic bodies: This research has established a baseline, highlighting the importance of the subject. Further research is required in order to build on this work and lead to both welfare and performance improvements, for which investment will be required. This includes:
    a. Investigating the reliability of farmer locomotion scoring.
    b. Further investigation of lameness risk factors, and identification of the aietiopathogenesis.
    c. Identifying the impact of lameness upon carcass characteristics, possibly including conformation changes during lameness.
    d. Identifying and comparing behaviour change opportunities for farmers, in the context of lameness within their herds.
    e. Identifying opportunities and methods for lameness detection on beef farms.
    f. Investigation of the impact of lameness in other beef sectors, namely suckler herds.

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Appendix 1 – Supplementary material relating to Chapter 3

Table A1.1 Lesion descriptors used to record lesions identified on both finishing cattle and suckler cows (20,110,111,112).

Lesion name	Lesion description
White line disease	Separation of the white line, with or without blood or purulent exudation
Sole haemorrhage	Yellow, pink or red discolouration of the sole
Sole ulcer	Penetration of sole horn with visible corium protruding, in the region of the sole-heel junction, relating to the flexor process of the pedal bone
Overgrown sole	Sole visibly overgrown beyond wall horn, with weight bearing occurring mainly on sole horn
Double sole	Under-run sole with two or more layers of sole horn
Overgrown claws	A toe angle (dorsal wall horn to sole horn) less than 50 degrees due to overgrown claws (247-249)
Axial fissure	Vertical horn defect to axial wall
Interdigital phlegmon	Symmetrical swelling of foot, interdigital skin necrosis with characteristic smell
Digital dermatitis	Skin erosion / ulceration / hyperkeratosis, commonly found at palmar / plantar aspect of heel-skin junction, but also found on the dorsal horn-skin junction or between claws. A mild skin erosion or inflammation between claws is classed as interdigital dermatitis.
Interdigital dermatitis	Any skin erosion / inflammation between claws that is not classed as digital dermatitis or interdigital phlegmon
Heel horn erosion	Erosion of the heel horn, often causing pits or fissures
Toe necrosis	Necrosis of sole aspect of toe
Interdigital hyperplasia	Protruding soft tissue mass between claws
Horizontal horn fissure	Horizontal abaxial or axial wall horn defect
Vertical horn fissure	Vertical abaxial wall horn defect
Ulcer - Other	Penetration of sole horn, with visible corium protruding. Not located at sole ulcer site. Likely to be at heel or toe
Corkscrew claws	Rotation of the claw capsule

Appendix 2 Supplementary material to Chapter 3

Table A2.1. Odds ratios and baseline odds (95% CI) derived from logistic regression models for the likelihood of both a non-lame and a lame finishing animal having a lesion on a hind claw versus front claw.

	Non-lame					**Lame**			
Baseline - front claw	**Number of claws with lesion (front / hind)**	**Odds Ratio**	**95% Confidence Interval**	**p value**		**Number of claws with lesion (front / hind)**	**Odds Ratio**	**95% Confidence Interval**	**p value**
Any lesion	363/362	0.99	0.81 - 1.23	0.957		362/341	0.83	0.63 - 1.08	0.157
baseline odds		1.06	0.92 - 1.23	0.407			2.41	2 - 2.92	<0.001
Claw horn lesion	125/85	0.64	0.47 - 0.86	0.003		237/220	0.87	0.68 - 1.12	0.285
baseline odds		0.22	0.18 - 0.26	<0.001			0.86	0.72 - 1.03	0.093
White line disease	8/4	0.5	0.15 - 1.66	0.256		79/58	0.7	0.49 - 1.01	0.055
baseline odds		0.01	0.01 - 0.02	<0.001			0.18	0.14 - 0.23	<0.001
Sole haemorrhage	1/0	1				4/7	1.76	0.51 - 6.05	0.369
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Sole ulcer	0					4/7	1.76	0.51 - 6.05	0.369
baseline odds							0.01	0 - 0.02	<0.001
Overgrown sole	1/0	1				15/12	0.8	0.37 - 1.72	0.559
baseline odds		0	0 - 0.01	<0.001			0.03	0.02 - 0.05	<0.001
Double sole	27/12	0.43	0.22 - 0.87	0.018		57/54	0.94	0.63 - 1.4	0.763
baseline odds		0.04	0.03 - 0.06	<0.001			0.13	0.1 - 0.16	<0.001
Overgrown claws	90/70	0.75	0.54 - 1.05	0.094		127/122	0.95	0.71 - 1.26	0.716
baseline odds		0.15	0.12 - 0.18	<0.001			0.33	0.27 - 0.4	<0.001
Axial fissure	7/1	0.14	0.02 - 1.15	0.068		18/21	1.17	0.62 - 2.23	0.625
baseline odds		0.01	0 - 0.02	<0.001			0.04	0.02 - 0.06	<0.001
Dermatitis	4/20	5.12	1.74 - 15.05	0.003		24/43	1.86	1.11 - 3.12	0.018
baseline odds		0.01	0 - 0.02	<0.001			0.05	0.03 - 0.07	<0.001
Digital dermatitis	2/16	8.16	1.87 - 35.63	0.005		6/23	3.97	1.6 - 9.83	0.003

baseline odds		0	0 - 0.01	<0.001			0.01	0.01 - 0.03	<0.001
Interdigital dermatitis	2/8	4.03	0.85 - 19.07	0.078		18/28	1.59	0.87 - 2.91	0.134
baseline odds		0	0 - 0.01	<0.001			0.04	0.02 - 0.06	<0.001
Foul	0					2/4	2.01	0.37 - 11.01	0.422
baseline odds							0	0 - 0.02	<0.001
Heel horn erosion	269/290	1.13	0.91 - 1.4	0.253		164/145	0.84	0.64 - 1.1	0.196
baseline odds		0.62	0.53 - 0.72	<0.001			0.47	0.39 - 0.57	<0.001
Toe necrosis	0/1	1				4/8	2.02	0.6 - 6.74	0.255
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Other lesion	4/7	1.76	0.51 - 6.03	0.37		34/25	0.72	0.42 - 1.23	0.23
baseline odds		0.01	0 - 0.02	<0.001			0.7	0.05 - 0.1	<0.001

Table A2.2. Odds ratios and baseline odds (95% CI) derived from logistic regression models for the likelihood of both a non-lame and a lame finishing animal having a lesion on a medial claw versus lateral claw.

	Non-lame					Lame			
Base - lateral claw	**Number of claws with lesion (lateral / medial)**	**Odds Ratio**	**95% Confidence Interval**	**p value**		**Number of claws with lesion (lateral / medial)**	**Odds Ratio**	**95% Confidence Interval**	**p value**
Any lesion	358/367	1.05	0.85 - 1.3	0.631		359/344	0.87	0.67 - 1.14	0.312
baseline odds		1.03	0.89 - 1.2	0.651			2.35	1.94 - 2.84	<0.001
Claw horn lesion	101/109	1.09	0.82 - 1.47	0.55		243/214	0.79	0.62 - 1.02	0.068
baseline odds		0.17	0.14 - 0.21	<0.001			0.9	0.76 - 1.07	0.251
White line disease	7/5	0.71	0.22 - 2.25	0.564		77/60	0.75	0.52 - 1.08	0.119
baseline odds		0.01	0 - 0.02	<0.001			0.18	0.14 - 0.23	<0.001
Sole haemorrhage	1/0	1				5/6	1.2	0.36 - 3.96	0.762
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Sole ulcer	0					9/2	0.22	0.05 - 1.02	0.053
baseline odds							0.02	0.01 - 0.03	<0.001
Overgrown sole	0/1	1				14/13	0.93	0.43 - 1.99	0.845
baseline odds		0	0 - 0.01	<0.001			0.03	0.02 - 0.05	<0.001
Double sole	15/24	1.62	0.84 - 3.12	0.147		60/51	0.83	0.56 - 1.24	0.366
baseline odds		0.02	0.01 - 0.04	<0.001			0.13	0.1 - 0.17	<0.001
Overgrown claws	77/83	1.09	0.78 - 1.51	0.614		127/122	0.95	0.71 - 1.26	0.716
baseline odds		0.12	0.1 - 0.16	<0.001			0.33	0.27 - 0.4	<0.001
Axial fissure	5/3	0.6	0.14 - 2.51	0.483		18/21	1.17	0.62 - 2.23	0.625
baseline odds		0.01	0 - 0.02	<0.001			0.04	0.02 - 0.06	<0.001
Dermatitis	12/12	1	0.45 - 2.24	1		33/34	1.03	0.63 - 1.69	0.899
baseline odds		0.02	0.01 - 0.03	<0.001			0.07	0.05 - 0.1	<0.001
Digital dermatitis	9/9	1	0.39 - 2.53	1		14/15	1.07	0.51 - 2.25	0.851
baseline odds		0.01	0.01 - 0.02	<0.001			0.03	0.02 - 0.05	<0.001

Interdigital dermatitis	5/5	1	0.29 - 3.47	1		23/23	1	0.55 - 1.81	1
baseline odds		0.01	0 - 0.02	<0.001			0.05	0.03 - 0.07	<0.001
Foul	0					3/3	1	0.2 - 4.98	1
baseline odds							0.01	0 - 0.02	<0.001
Heel horn erosion	277/282	1.03	0.83 - 1.28	0.785		149/160	1.11	0.85 - 1.45	0.454
baseline odds		0.65	0.56 - 0.75	<0.001			0.41	0.34 - 0.5	<0.001
Toe necrosis	0/1	1				4/8	2.02	0.6 - 6.74	0.255
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Other lesion	5/6	1.2	3.65 - 3.96	0.76		31/28	0.9	0.53 - 1.52	0.69
baseline odds		0.01	0 - 0.02	<0.001			0.06	0.45 - 0.09	<0.001

Table A2.3. Odds ratios and baseline odds (95% CI) derived from logistic regression models for the likelihood of both a non-lame and a lame finishing animal having a lesion on a weight bearing claw versus non-weight bearing claw.

	Non-lame					Lame			
Base - non-weight bearing claw	**Number of claws with lesion (non-weight bearing / weight bearing)**	**Odds Ratio**	**95% Confidence Interval**	**p value**		**Number of claws with lesion (non-weight bearing / weight bearing)**	**Odds Ratio**	**95% Confidence Interval**	**p value**
Any lesion	362/363	1.01	0.82 - 1.24	0.957		354/349	0.96	0.73 - 1.24	0.736
baseline odds		1.06	0.91 - 1.23	0.451			2.24	1.86 - 2.7	<0.001
Claw horn lesion	102/108	1.07	0.8 - 1.43	0.654		223/234	1.09	0.85 - 1.4	0.489
baseline odds		0.17	0.14 - 0.21	<0.001			0.77	0.65 - 0.92	0.004
White line disease	7/5	0.71	0.22 - 2.25	0.564		59/78	1.38	0.96 - 1.98	0.082
baseline odds		0.01	0 - 0.02	<0.001			0.13	0.1 - 0.17	<0.001
Sole haemorrhage	1/0	1				4/7	1.76	0.51 - 6.05	0.369
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Sole ulcer	0					2/9	4.56	0.98 - 21.22	0.053
baseline odds							0	0 - 0.02	<0.001
Overgrown sole	0/1	1				14/13	0.93	0.43 - 1.99	0.845
baseline odds		0	0 - 0.01	<0.001			0.03	0.02 - 0.05	<0.001
Double sole	0	1.62	0.84 - 3.12	0.147		2/9	0.9	0.61 - 1.34	0.615
baseline odds		0.02	0.01 - 0.04	<0.001			0.13	0.1 - 0.17	<0.001
Overgrown claws	79/81	1.03	0.74 - 1.43	0.867		125/124	0.99	0.74 - 1.32	0.942
baseline odds		0.13	0.1 - 0.16	<0.001			0.32	0.26 - 0.4	<0.001
Axial fissure	4/4	1	0.25 - 4.01	1		21/18	0.85	0.45 - 1.62	0.625
baseline odds		0.01	0 - 0.02	<0.001			0.04	0.03 - 0.07	<0.001
Dermatitis	12/12	1	0.45 - 2.24	1		34/33	0.97	0.59 - 1.59	0.899
baseline odds		0.02	0.01 - 0.03	<0.001			0.07	0.05 - 0.1	<0.001
Digital dermatitis	9/9	1	0.39 - 2.53	1		15/14	0.93	0.44 - 1.95	0.851

baseline odds		0.01	0.01 - 0.02	<0.001			0.03	0.02 - 0.05	<0.001
Interdigital dermatitis	5/5	1	0.29 - 3.47	1		23/23	1	0.55 - 1.81	1
baseline odds		0.01	0 - 0.02	<0.001			0.05	0.03 - 0.07	<0.001
Foul	0					3/3	1	0.2 - 4.98	1
baseline odds							0.01	0 - 0.02	<0.001
Heel horn erosion	281/278	0.98	0.79 - 1.22	0.87		156/153	0.97	0.74 - 1.27	0.838
baseline odds		0.66	0.57 - 0.77	<0.001			0.44	0.36 - 0.53	<0.001
Toe necrosis	1/0	1				6/6	1	0.32 - 3.12	1
baseline odds		0	0 - 0.01	<0.001			0.01	0.01 - 0.03	<0.001
Other lesion	4/7	1.76	0.51 - 6.03	0.37		30/29	0.96	0.57 - 1.63	0.89
baseline odds		0.01	0 - 0.15	<0.001			0.06	0.04 - 0.09	<0.001

Table A2.4. Odds ratios and baseline odds (95% CI) derived from logistic regression models for the likelihood of both a non-lame and a lame suckler cow having a lesion on a hind claw versus front claw.

	Non-lame					Lame			
Base - front claw	**Number of claws with lesion (front / hind)**	**Odds Ratio**	**95% Confidence Interval**	**p value**		**Number of claws with lesion (front / hind)**	**Odds Ratio**	**95% Confidence Interval**	**p value**
Any lesion	322/309	0.9	0.7 - 1.16	0.406		325/318	0.92	0.69 - 1.24	0.599
baseline odds		1.66	1.39 - 1.98	<0.001			2.73	2.21 - 3.37	<0.001
Claw horn lesion	62/55	0.87	0.59 - 1.28	0.492		156/153	0.97	0.74 - 1.28	0.833
baseline odds		0.14	0.1 - 0.18	<0.001			0.54	0.45 - 0.66	<0.001
White line disease	27/25	0.92	0.53 - 1.61	0.776		104/100	0.95	0.7 - 1.3	0.75
baseline odds		0.06	0.04 - 0.08	<0.001			0.31	0.25 - 0.38	<0.001
Sole haemorrhage	8/10	1.25	0.49 - 3.21	0.635		0/6	1		
baseline odds		0.02	0.01 - 0.03	<0.001			0.01	0.01 - 0.03	<0.001
Sole ulcer	1/0	1				3/5	1.67	0.4 - 7.05	0.482
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Overgrown sole	0/1	1				0/3	1		
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Double sole	1/0	1				15/7	0.46	0.18 - 1.13	0.092
baseline odds		0	0 - 0.01	<0.001			0.03	0.02 - 0.06	<0.001
Overgrown claws	34/32	0.94	0.57 - 1.54	0.799		53/54	1.02	0.68 - 1.53	0.918
baseline odds		0.07	0.05 - 0.1	<0.001			0.14	0.1 - 0.18	<0.001
Dermatitis	0/2	1				3/11	3.73	1.03 - 13.48	0.044
baseline odds		0	0 - 0.02	<0.001			0.01	0 - 0.02	<0.001
Digital dermatitis	0					3/7	2.35	0.6 - 9.16	0.217
baseline odds							0.01	0 - 0.02	<0.001
Interdigital dermatitis	0/2	1				0/4	1		
baseline odds		0	0 - 0.02	<0.001			0.01	0 - 0.02	<0.001

Heel horn erosion	272/272	1	0.78 - 1.28	1		248/242	0.95	0.73 - 1.23	0.686
baseline odds		1.11	0.94 - 1.33	0.218			1.27	1.05 - 1.53	0.014
Toe necrosis	0					5/2	0.4	0.08 - 2.06	0.271
baseline odds							0.01	0 - 0.03	<0.001
Other lesion	1/1	1	0.06 - 16.03	1		14/13	0.93	0.43 - 1.99	0.845
baseline odds		0	0 - 0.01	<0.001			0.03	0.02 - 0.06	<0.001

Table A2.5. Odds ratios and baseline odds (95% CI) derived from logistic regression models for the likelihood of both a non-lame and a lame suckler having a lesion on a medial claw versus lateral claw.

	Non-lame					Lame			
Base - lateral claw	**Number of claws with lesion (lateral / medial)**	**Odds Ratio**	**95% Confidence Interval**	**p value**		**Number of claws with lesion (lateral / medial)**	**Odds Ratio**	**95% Confidence Interval**	**p value**
Any lesion	320/311	0.93	0.72 - 1.19	0.565		335/308	0.74	0.55 - 0.99	0.043
baseline odds		1.63	1.37 - 1.95	<0.001			3.07	2.48 - 3.81	<0.001
Claw horn lesion	65/52	0.78	0.53 - 1.15	0.203		186/123	0.53	0.4 - 0.7	<0.001
baseline odds		0.14	0.11 - 0.19	<0.001			0.72	0.6 - 0.87	0.001
White line disease	35/17	0.47	0.26 - 0.85	0.012		135/69	0.42	0.3 - 0.58	<0.001
baseline odds		0.07	0.05 - 0.1	<0.001			0.44	0.36 - 0.53	<0.001
Sole haemorrhage	10/8	0.8	0.31 - 2.04	0.635		3/3	1	0.2 - 4.98	1
baseline odds		0.02	0.01 - 0.04	<0.001			0.01	0 - 0.02	<0.001
Sole ulcer	1/0	1				6/2	0.33	0.07 - 1.65	0.176
baseline odds		0	0 - 0.01	<0.001			0.01	0.01 - 0.03	<0.001
Overgrown sole	1/0	1				3/0	1		
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Double sole	0/1	1				13/9	0.69	0.29 - 1.62	0.39
baseline odds		0	0 - 0.01	<0.001			0.03	0.02 - 0.05	<0.001
Overgrown claws	35/31	0.88	0.53 - 1.45	0.611		55/52	0.94	0.63 - 1.41	0.757
baseline odds		0.07	0.05 - 0.1	<0.001			0.14	0.11 - 0.19	<0.001
Dermatitis	1/1	1	0.06 - 16.03	1		7/7	1	0.35 - 2.87	1
baseline odds		0	0 - 0.01	<0.001			0.02	0.01 - 0.03	<0.001
Digital dermatitis	0					5/5	1	0.29 - 3.48	1
baseline odds							0.01	0 - 0.03	<0.001
Interdigital dermatitis	1/1	1	0.06 - 16.03	1		2/2	1	0.14 - 7.13	1
baseline odds		0	0 - 0.01	<0.001			0	0 - 0.02	<0.001

Heel horn erosion	272/272	1	0.78 - 1.28	1		245/245	1	0.77 - 1.3	1
baseline odds		1.11	0.94 - 1.33	0.218			1.23	1.02 - 1.48	0.029
Toe necrosis	0					3/4	1.34	0.3 - 6.01	0.705
baseline odds							0.01	0 - 0.02	<0.001
Other lesion	2/0	1				14/13	0.93	0.43 - 1.99	0.845
baseline odds		0	0 - 0.02	<0.001			0.03	0.02 - 0.06	<0.001

Table A2.6. Odds ratios and baseline odds (95% CI) derived from logistic regression models for the likelihood of both a non-lame and a lame suckler cow having a lesion on a weight bearing claw versus non-weight bearing claw.

	Non-lame					Lame			
Base - non-weight bearing claw	**Number of claws with lesion (non-weight bearing / weight bearing)**	**Odds Ratio**	**95% Confidence Interval**	**p value**		**Number of claws with lesion (non-weight bearing / weight bearing)**	**Odds Ratio**	**95% Confidence Interval**	**p value**
Any lesion	313/318	1.04	0.81 - 1.34	0.749		315/328	1.16	0.86 - 1.55	0.329
baseline odds		1.54	1.29 - 1.84	<0.001			2.44	1.99 - 3	<0.001
Claw horn lesion	54/63	1.19	0.81 - 1.75	0.377		133/176	1.54	1.16 - 2.03	0.003
baseline odds		0.12	0.09 - 0.15	<0.001			0.43	0.35 - 0.52	<0.001
White line disease	20/32	1.64	0.92 - 2.91	0.09		81/123	1.72	1.25 - 2.36	0.001
baseline odds		0.04	0.03 - 0.06	<0.001			0.22	0.18 - 0.28	<0.001
Sole haemorrhage	8/10	1.25	0.49 - 3.21	0.635		3/3	1	0.2 - 4.98	1
baseline odds		0.02	0.01 - 0.03	<0.001			0.01	0 - 0.02	<0.001
Sole ulcer	1/0	1				1/7	7.1	0.87 - 57.92	0.067
baseline odds		0	0 - 0.01	<0.001			0	0 - 0.02	<0.001
Overgrown sole	0/1	1				0/3	1		
baseline odds		0	0 - 0.01	<0.001			0.01	0 - 0.02	<0.001
Double sole	0/1	1				6/16	2.73	1.06 - 7.04	0.038
baseline odds		0	0 - 0.01	<0.001			0.01	0.01 - 0.03	<0.001
Overgrown claws	31/35	1.14	0.69 - 1.88	0.611		51/56	1.11	0.74 - 1.67	0.606
baseline odds		0.06	0.04 - 0.09	<0.001			0.13	0.1 - 0.17	<0.001
Dermatitis	1/1	1	0.06 - 16.03	1		8/6	0.75	0.26 - 2.17	0.591
baseline odds		0	0 - 0.01	<0.001			0.02	0.01 - 0.04	<0.001
Digital dermatitis	0					6/4	0.66	0.19 - 2.37	0.528
baseline odds							0.01	0.01 - 0.03	<0.001
Interdigital dermatitis	1/1	1	0.06 - 16.03	1		2/2	1	0.14 - 7.13	1

baseline odds		0	0 - 0.01	<0.001			0	0 - 0.02	<0.001
Heel horn erosion	272/272	1	0.78 - 1.28	1		245/245	1	0.77 - 1.3	1
baseline odds		1.11	0.94 - 1.33	0.218			1.23	1.02 - 1.48	0.029
Toe necrosis	0					1/6	6.07	0.73 - 50.61	0.096
baseline odds							0	0 - 0.02	<0.001
Other lesion	1/1	1	0.06 - 16.03	1		11/16	1.47	0.68 - 3.21	0.331
baseline odds		0	0 - 0.01	<0.001			0.03	0.01 - 0.05	<0.001

Appendix 3 – Supplementary material relating to Chapter 3

Table A3.1 Odds ratios and baseline odds (95% CI) derived from univariable logistic regression models for the likelihood of a finishing animal being lame by recorded lesion.

Lesion	No. animals with lesion (lame / non-lame)	Odds Ratio	95% CI[1]	p value
Any lesion	122 / 126	8.07	3.34 - 19.5	<0.001
Baseline odds		0.12	0.04 - 0.34	<0.001
Claw horn lesion	100 / 48	13.79	7.36 - 25.84	<0.001
Baseline odds		0.21	0.13 - 0.33	<0.001
White line disease	67 / 9	14.58	7.66 - 27.73	<0.001
Baseline odds		0.30	0.2 - 0.44	<0.001
Sole haemorrhage	7 / 1	0.77	0.13 - 4.7	0.778
Baseline odds		0.87	0.67 - 1.12	0.268
Overgrown sole	6 / 1	9.94	1.22 - 80.78	0.032
Baseline odds		0.80	0.62 - 1.04	0.101
Double sole	22 / 16	2.35	0.21 - 26.25	0.488
Baseline odds		0.85	0.66 - 1.1	0.218
Overgrown claws	36 / 29	16.98	2.18 - 132.01	0.007
Baseline odds		0.77	0.59 - 1	0.047
Axial fissure	13 / 3	1.58	0.83 - 3.04	0.167
Baseline odds		0.79	0.59 - 1.05	0.1
Infectious lesion	67 / 101	1.09	0.65 - 1.82	0.743
Baseline odds		0.82	0.55 - 1.21	0.318
Dermatitis	21 / 8	11.29	1.41 - 90.61	0.022
Baseline odds		0.80	0.61 - 1.03	0.087
Digital dermatitis	14 / 6	2.35	0.21 - 26.25	0.488
Baseline odds		0.85	0.66 - 1.1	0.218
Interdigital dermatitis	11 / 4	0.97	0.58 - 1.62	0.909
Baseline odds		0.88	0.6 - 1.28	0.495
Heel horn erosion	53 / 94	7.70	1.68 - 35.19	0.008
Baseline odds		0.78	0.6 - 1.01	0.063
Toe necrosis	10 / 1	0.12	0.04 - 0.34	<0.001
Baseline odds		13.79	7.36 - 25.84	<0.001
Other lesion	20 / 5	0.21	0.13 - 0.33	<0.001
Baseline odds		14.58	7.66 - 27.73	<0.001

[1] CI = confidence interval

Table A3.2 Odds ratios and baseline odds (95% CI) derived from univariable logistic regression models for the likelihood of a suckler cow being lame by recorded lesion.

Lesion	**No. animals with lesion (lame / non-lame)**	**Odds Ratio**	**95% CI[1]**	**p value**
Any lesion	107/96	9.20	3.14 - 26.91	<0.001
Baseline odds		0.12	0.04 - 0.34	<0.001
Claw horn lesion	91/32	13.79	7.36 - 25.84	<0.001
Baseline odds		0.21	0.13 - 0.33	<0.001
White line disease	78/18	14.58	7.66 - 27.73	<0.001
Baseline odds		0.30	0.2 - 0.44	<0.001
Sole haemorrhage	2/3	0.77	0.13 - 4.7	0.778
Baseline odds		0.87	0.67 - 1.12	0.268
Sole ulcer	8/1	9.94	1.22 - 80.78	0.032
Baseline odds		0.80	0.62 - 1.04	0.101
Overgrown sole	2/1	2.35	0.21 - 26.25	0.488
Baseline odds		0.85	0.66 - 1.1	0.218
Double sole	13/1	16.98	2.18 - 132.01	0.007
Baseline odds		0.77	0.59 - 1	0.047
Overgrown claws	25/20	1.58	0.83 - 3.04	0.167
Baseline odds		0.79	0.59 - 1.05	0.1
Infectious lesion	66/74	1.09	0.65 - 1.82	0.743
Baseline odds		0.82	0.55 - 1.21	0.318
Dermatitis	9/1	11.29	1.41 - 90.61	0.022
Baseline odds		0.80	0.61 - 1.03	0.087
Interdigital dermatitis	2/1	2.35	0.21 - 26.25	0.488
Baseline odds		0.85	0.66 - 1.1	0.218
Heel horn erosion	62/73	0.97	0.58 - 1.62	0.909
Baseline odds		0.88	0.6 - 1.28	0.495
Other lesion	21/2	7.70	1.68 - 35.19	0.008
Baseline odds		0.78	0.6 - 1.01	0.063

[1] CI = confidence interval

Appendix 4 – Supplementary material relating to Chapter 5: Consolidated criteria for reporting qualitative studies (COREQ) table reporting level of adherence to guidelines.

Domain 1: Research team and reflexivity	
Personal Characteristics	
Interviewer/facilitator	Jay Tunstall conducted all interviews
Credentials	BSc BVetMed MRCVS
Occupation	PhD Student
Gender	Male
Experience and training	Practice interviews, previous veterinary experience with farmers
Relationship with participants	
Relationship established	Farmers were approached prior to the interview to discuss requirements of the study and arrange a suitable time and date
Participant knowledge of the interviewer	Participants were aware that the interviewer was a veterinary surgeon, researching the topic of lameness in beef cattle
Interviewer characteristics	The interviewer was conducting wider studies on the topic of lameness in beef cattle

Domain 2: Study design	
Theoretical framework	
Methodological orientation and theory	Inductive thematic analysis
Participant selection	
Sampling	Convenience and snowball sampling were employed
Method of approach	Farmers were approached face to face, with further telephone calls to arrange a suitable time and date
Sample size	21 farmers were studied
Non-participation	150 farms were directly approached by the interviewer, as well as an unknown number by industry bodies. The main reasons given for non-participation were not wanting to give the time, not wanting to handle the animals due to the risk of stress or not being able to arrange a convenient time. A small number reported not feeling lameness was a significant problem, so it was less worthwhile participating
Setting	
Setting of data collection	Interviews were carried out at the farm of the participant, at a location to suit them
Presence of non-participants	Some participants chose locations with other family / staff members present. Some of these participated, some were simply present in the background.
Description of sample	Demographic data is presented within the text
Data collection	
Interview guide	The interview schedule is attached as appendix 2. It was piloted successfully with two farmers, and their data was not included

Repeat interviews	Repeat interviews were not carried out
Audio / visual recording	All interviews were audio recorded and transcribed verbatim
Field notes	Field notes were made during the interviews and locomotion scoring
Duration	Interviews lasted between 24 and 78 minutes
Data saturation	Data saturation was achieved in the main areas of interest
Transcripts returned	Transcripts were not returned to participants
Domain 3: Analysis and findings	
Data analysis	
Number of data coders	The data was initially coded by one researcher, but then refined by two researchers
Description of coding tree	The basic coding tree is displayed in Figure 4
Derivation of themes	Themes were extracted from the data, without prior identification
Software	NVivo qualitative data analysis software, (QSR international Pty Ltd. Version 10, 2012)
Participant checking	Participants haven't had the opportunity to feedback on the findings
Reporting	
Quotations presented	Quotations have illustrated many of the findings
Data and findings consistent	The data is represented by the findings
Clarity of major themes	The major themes, as displayed in Figure 1, are presented in the findings
Clarity of minor themes	The minor themes, as displayed in Figure 1, are presented in the findings

Appendix 5 – Supplementary material relating to Chapter 5: Interview Schedule used for all interviews

Lameness in beef cattle: Establishing a knowledge base

In depth interviews

Thank you for agreeing to take part in this study, I'm just going to remind you that you can 'pass' on any questions you would prefer not to answer, and also that your answers will be anonymous. The first few questions are just background information, so I can understand a little more about your farm. Please remember, there are no wrong answers. If I ask you 'is there anything else you can think of?', it isn't because I think you've missed anything, it's just because I want to make sure I've got all your opinions. You may feel some questions overlap. This allows you to express all opinions you may have.

<table>
<tr><td>Total number of cattle on farm:</td><td></td><td colspan="5">Are you the sole person responsible for herd management decisions?

Full / part time (%)</td><td colspan="2"></td></tr>
<tr><td>Management groups and other species on farm:</td><td></td><td colspan="5">Are you the sole person responsible for day to day decision making?

Full / part time (%)</td><td colspan="2"></td></tr>
<tr><td>Farm type

Rented, owned, mix other enterprise</td><td></td><td colspan="5" rowspan="2">Do you have any formal training, qualifications or experience, either in farming or elsewhere?</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Is beef farming your main source of income?</td><td></td></tr>
<tr><td>How long have you been farming beef cattle?</td><td></td><td colspan="5">Gender:</td><td colspan="2"></td></tr>
<tr><td>No of regular workers / staff / family helpers:

Full / part time (%)</td><td></td><td rowspan="2">Age:</td><td><20</td><td>20-30</td><td>30-40</td><td>40-50</td><td>50-60</td><td>60+</td></tr>
<tr><td>Location (county):</td><td></td><td colspan="6">Prefer not to answer</td></tr>
</table>

I'm now going to ask you some questions aimed at your finishing cattle / suckler cows, so please relate your answers to just that group of animals.

1. Please could you give me your current top three cattle health concerns?

2. Please can you tell me your most common reasons to cull animals (prematurely if finishing) in the last 12 m?
   a) How many of each

3. (If lameness not A to Q1) You said lameness wasn't in your top three concerns, is it something that concerns you?
   a) Why / why not?
   b) Already have control measures?

4. (If lameness not A to Q2) You didn't mention lameness as a common reason to cull, have you had to cull any animals due to lameness in the last 2 years?

5. Please can you tell me about how you are dealing with your lameness issues?
   OR
   Please can you tell me about how you deal with any lameness issues, for example if you came across an issue tomorrow?
   Tell me about a case that you were involved in…
   a) How **ID**, knowledge / **training** of a formal scoring system
   b) What looking for – **back**, **weight bearing**, head, feeding, any **records** kept
   c) How examine – **crush** / race / lying
   d) How treat – **trimming methods**, drugs, records, isolation
   e) **Who** treat (internal / external)
   f) When, **how long** following ID
   g) Any herd level **controls**
   h) Confirm 'lesions' / show 2 or 3 pictures
   i) What involvement, if any, does your **vet** have
   j) Any control measures already in place

6. Have you got any lame animals on farm today?
   Y / N / unsure

7. (If yes to Q6 or 8) Tell me about any lame animals you have today, within the finishing cattle / suckler cows.
   c) How many
   d) Are they all of a similar **severity** – scale
   e) **How long** have they been lame for
   f) **Diagnosis** (inc. no of each) - pictures

8. (If no to Q6) Have you had any in last 1m (If no ask about 6m if no, ask about 12m? (If yes revert back to Q7 relating to this answer, if no, Q9)

9. Please could you tell me if this lameness / lack of lameness has changed over the last 12m (24m if no to Q6 & 8)?
    a) Amount
    b) Type / causes

10. I will be using a scoring system to grade how your animals walk. This involves watching each animal walking past me and giving them a score 0 – 4. I'm going to describe each score, and ask you how many animals you have of each score once I've described them all.

11. (Refer to Q5) You told me earlier on…. Is there anything you would like to be able to do or change to tackle your lameness situation / a lameness situation that may occur, but you aren't currently doing / able to do?
    a) Can you think of anything else

12. Please tell me what is preventing you from resolving an issue the way you mentioned you would like to? (refer to specific points)

13. Is there is anything else which you know of that may help, or others think may help to deal with lameness, inc. vets, advisors, farmers?

14. How do you feel lameness / lack of lameness on your farm compares with other farms?
    a) Other finishing / suckler farms
    b) Amount
    c) Actions / controls

15. (If no lameness issue: Some farmers do have a lameness concern..) Is there anything which may assist, motivate or facilitate you (them) to deal with lameness?
    a) **Vet** – proactive / enthusiastic
    b) **Industry** involvement / advice

16. Do you have a HHP, and if so, does it include lameness?
    a) What does it say about lameness?
    b) Do you refer to it?
    c) Do you use it to help you make decisions?

17. What would you say the downsides of lameness are, please mention as many as you can think of?
    a) Are there any others you can think of?
    b) Financial – treatments, culls, growth
    c) Morale
    d) Welfare / suffering / pain
    e) Public perception

18. What would you say the benefits of having low levels of lameness are, please mention as many as you can think of?
    a) Are there any others that you can think of?
    b) Financial – treatments, culls, growth
    c) Morale
    d) Welfare / suffering / pain

Thank you very much, your time and help is really appreciated, and obviously your opinion is essential to this.

19. Are there any other comments you would like to add on this topic, or anything that we've discussed?

Get copy of foot trimming / scoring.

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Appendix 6 – Supplementary material relating to Chapter 6:

Lameness in Beef Cattle

My name is Jay Tunstall, and I am a farm vet undertaking research at The University of Liverpool about **lameness in beef cattle**. Please read on if you are involved with beef cattle farming: **breeding heifers or cows**, or weaned cattle that are being reared for **beef** production (including **stores, fattening, finishing**). Please continue, no matter whether you feel lameness affects the cattle you're involved with or not.

Your responses will be **anonymous**, and you do not need to leave your name or other details if you do not wish to do so. You will have the option to enter a **prize draw**. If you enter the draw, your details will be used solely for the purposes of the prize draw.

For most questions, we will ask you simply to **tick boxes**. There are opportunities to leave additional comments, and we very much welcome these. The questionnaire should only take about 10 minutes to complete.

If you would prefer to complete an online version of the questionnaire, please use the link below, or scan the QR code below.

www.bit.ly/beef-lameness

Many thanks for your help with this study.

For more details on the study, please see Participant Information Sheet.

Please select the option below to confirm that you have read the Participant Information Sheet and consent to participation in the study, and also that you understand:

•That you will not be identifiable from any data used in this study
•That you may withdraw at any time without giving a reason and without incurring a disadvantage
•That you may request destruction of the data you supply, up until the point at which it has been anonymised
•That you agree to the use of the information provided for this study and for future research

○ **I have read, understand and agree**

○ **I have not read, understood, or I do not agree**

To select an answer, please mark it like any of the answers below.

This,
This,
Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

Original answer
Newly selected answer

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If you are involved with more than one beef unit (breeding, rearing or finishing), please answer all questions for the unit that you have the most 'hands on' involvement with the cattle.
If you are **not** involved with beef cattle, thank you for your interest, but this questionnaire is not applicable to you.

Q1 When thinking about lifting the **FRONT** feet of beef cattle, how would you best describe the facilities on farm?
Please select one answer, and don't include facilities brought in by a contractor / foot trimmer / vet.

- ◯ Lifting and examination is possible, but is generally NOT safe for either the animal or the person
- ◯ Lifting and examination IS possible and generally safe for animal and person
- ◯ Lifting and examination is NOT possible

Q2 When thinking about lifting the **BACK** feet of beef cattle, how would you best describe the facilities on farm?
Please select one answer, and don't include facilities brought in by a contractor / foot trimmer / vet.

- ◯ Lifting and examination is possible, but is generally NOT safe for either the animal or the person
- ◯ Lifting and examination IS possible and generally safe for animal and person
- ◯ Lifting and examination is NOT possible

Q3 Please add any additional comments in the space below.

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To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

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Q4 Do you treat lame beef cattle yourself?

- ◯ Always
- ◯ Sometimes
- ◯ Never (if never, please skip to **Q10**)

Q5 When **you** treat lame beef cattle, what treatments do **you** use?
Please select one answer per row.

	Never	Sometimes	Often	Always	Unsure
Antibiotic product, applied onto foot	◯	◯	◯	◯	◯
Antibiotic product given by injection	◯	◯	◯	◯	◯
Pain relief / anti-inflammatory product (Veterinary product, e.g. Metacam / Ketofen)	◯	◯	◯	◯	◯

Q6 When **you** treat lame beef cattle, what other treatments do **you** use?
Please select one answer per row.

	Never	Sometimes	Often	Always	Unsure
Foot block	◯	◯	◯	◯	◯
Foot bath	◯	◯	◯	◯	◯
Bandage / wrap	◯	◯	◯	◯	◯

To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

Q7 Please add **any other treatments** or additional comments in the space below.

____

____

Q8 Please tell us the two most common antibiotic injection products you use when you treat lame beef cattle.

____

____

Q9 Please tell us what products you use in a foot bath.

____

____

Q10 What options do you feel are available to beef farmers to deal with animals that have ongoing lameness?
Please select as many answers as you feel are available to beef farmers.

- ☐ Call knackerman or hunt kennel for collection and disposal
- ☐ Arrange treatment and keep the animal on farm
- ☐ Transport to slaughterhouse
- ☐ Call the vet for emergency slaughter certificate / on farm slaughter
- ☐ Monitor animal and allow time to recover, without treatment
- ☐ None of the above

To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

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Q11 Please add any other options you feel are available to beef farmers to deal with animals that have ongoing lameness.

____

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Q12 Have you had any training on lameness?
Please select the one option that best applies to your situation for each of the topics below.

	I have had no training	I am self-trained	I have received specific training (e.g. foot trimmer, college)
Recognition of different foot conditions	○	○	○
How to trim feet	○	○	○
How to treat lameness	○	○	○
How to prevent lameness	○	○	○
Locomotion / mobility scoring	○	○	○

Q13 Please write any comments in the space below.

____

____

To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

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Q14 For each topic below, please select all options that apply
Please select options that apply.

	I feel sufficiently competent	I would like further training
Recognition of different foot conditions	☐	☐
How to trim feet	☐	☐
How to treat lameness	☐	☐
How to prevent lameness	☐	☐
Locomotion / mobility scoring	☐	☐

Q15 Please write any comments in the space below.

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____

To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

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Q16 How many beef cattle of each type are on the farm, and how many of each would you say are currently lame?
Please complete all four boxes (using 0 if none).

	How many animals?	How many lame?
Breeding (suckler) cows including in-calf heifers		
Animals being reared for meat, from weaning up to slaughter		

Q17 Please add any comments in the space below.

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To select an answer, please mark it like any of the answers below.

This,

This,

Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

Original answer

Newly selected answer

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Q18 Following discussions with beef farmers, the following are all approaches that might be taken to deal with lame animals.
Please select one answer per row to indicate your level of agreement or disagreement.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I pick up the foot of a lame animal within 48 hours	○	○	○	○	○
I never deal with lame animals, as they get better by themselves	○	○	○	○	○
I give lame animals a week or two before examining them, to see how they do	○	○	○	○	○
I personally never pick up feet, but I get my vet or foot trimmer to do it as soon as possible	○	○	○	○	○
I only examine animals if they are walking quite badly	○	○	○	○	○
I ask the vet to look at a lame animal, but only if the vet happens to be on farm already	○	○	○	○	○

Q19 Please add any comments in the space below.

____

____

____

____

To select an answer, please mark it like any of the answers below.

This,

This,

Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

Original answer

Newly selected answer

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Q20 Do you mobility score / locomotion score beef cattle on the farm?

- ◯ No (If No, please skip to **Q22**)
- ◯ Yes
- ◯ Unsure

Q21 How **often** do you mobility score / locomotion score and **how** exactly do you usually do it?

____

____

____

____

Q22 What, if anything, prevents you treating lame beef cattle, or makes treatment difficult?

____

____

____

____

Q23 What, if anything, stops you preventing lameness in beef cattle, or makes prevention difficult?

____

____

____

____

To select an answer, please mark it like any of the answers below.

This,

This,

Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

Original answer

Newly selected answer

Thank you for helping us to understand lameness on your farm. The survey is almost complete. Please could you now answer a small number of questions to help us understand you and your farm.

Q24 When considering the beef cattle part of your farm, would you consider yourself responsible for:
Please select all answers that apply.

- ☐ Long term farm planning
- ☐ Day to day management decision making
- ☐ Day to day stockmanship / animal care

Q25 Which of the following best describes you?
Please select one answer.

- ○ Beef farming is my main source of income
- ○ Arable farming is my main source of income
- ○ Beef farming provides an equal top share of my income with another source
- ○ Livestock, but NOT beef farming, is my main source of income
- ○ My main source of income is NOT derived directly from livestock or agriculture

To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

Q26 How would you describe yourself?
Please select all answers that apply.

☐ Farm owner

☐ Farm manager

☐ Farm worker

☐ Other (please specify) ____

Q27 Please select your age

○ 15 or less

○ 16 - 25

○ 26 - 35

○ 36 - 45

○ 46 - 55

○ 56 - 65

○ 66 - 75

○ 76 or over

○ Prefer not to say

Q28 Please select your sex

○ Male

○ Female

○ Other

○ Prefer not to say

To select an answer, please mark it like any of the answers below.

This,

This,

Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

Original answer

Newly selected answer

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Q29 Please state the county that your farm is in (for example Herefordshire).
If your farm crosses boundaries, please consider the county within which most cattle are currently in.
This will not be used to identify you, but you may skip this question if you wish.

____

____

Q30 Is rearing and selling beef **breeding** stock a major part of your business?

◯ No

◯ Yes

◯ Unsure

Q31 Are your cattle classified as organic?

◯ No

◯ Yes

◯ Unsure

Q32 Do you have any final comments on lameness, your involvement, or the farm?

____

____

____

____

To select an answer, please mark it like any of the answers below.

- This,
- This,
- Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

- Original answer
- Newly selected answer

Thank you for reaching the end of the survey. If you would like to be entered into the prize draw to win a pair of Muck Boot Company wellies, please leave your name, contact details and wellie size below.
Please note, these details will only be used in relation to the prize draw.

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If you wish to receive a summary of the results of this questionnaire, please leave your name and postal or email address.

◯ Please use details provided for the draw

◯ Name and address ____

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To select an answer, please mark it like any of the answers below.

This,

This,

Or this.

If you change your mind on your answer, please cross the entire box out clearly, and mark the newly selected box.

Original answer

Newly selected answer