Integrating epidemiology and stakeholder perspectives toward the improvement of dairy cattle lameness

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Chapter 1: Literature review

1.1 Dairy cattle lameness

Lameness in cattle is the clinical presentation of impaired locomotion. It is a visible symptom caused by a range of foot and leg conditions including injury and disease. The most common cause of lameness are hoof lesions caused by infectious agents or internal and external forces (Murray et al., 1996).

Lameness impacts how cows rest, how they eat, their ability to socialize, and decreases their productivity (Bicalho et al., 2008; Cramer et al., 2009; Gomez & Cook, 2010). Productivity is decreased through reduced reproductive efficiency (Garbarino et al., 2004), reduced milk production (Hernandez et al., 2005), and increased culling (Booth et al., 2004). The cost of a sole ulcer lesion has been estimated to be between $178 to $216 and the cost of a case of digital dermatitis between $64 to $133 (Cha et al., 2010; Dolecheck et al., 2019). The exact financial costs of lameness depend on milk price, cost of replacement cows, days in milk at incidence, and many other factors. Such economic estimates do not take into account all the welfare cost of lameness.

Lameness is a leading welfare concern in the dairy industry (Ventura et al., 2015). The consequences of lameness on a cow's expression of behavior are diverse (Whay and Shearer, 2017). As lame cows have an altered time budget and spend more time lying down than non-lame herd mates (Ito et al., 2010) they may not get up to eat, drink or compete for resources, causing hunger and thirst. Lame cows can suffer discomfort through inappropriate stall design impairing their ability to get up and down. Lesions causing lameness are painful as demonstrated by an altered gait and behavioral changes to protect the affected limb (Shearer et al., 2013). Cows may be isolated from

herd mates in a separate pen or for treatment, and they may be hurried during travel to the parlor, potentially causing fear and distress (Whay and Shearer, 2017).

Lameness prevalence estimates for US freestall herds have ranged from 10-55% (Espejo et al., 2006; von Keyserlingk et al., 2012). A survey of large high producing Wisconsin dairy herds identified an average prevalence of lameness of 13% with a range of 3 to 36% (Cook et al., 2016). The latest NAHMS Dairy report (2014) indicated that 6.9% of cows in the United States dairy herd were mild or moderately lame and 2.7% were severely lame (Adams et al., 2017). It is possible, however, that the comparably lower estimates from the NAHMS study could be accounted for by the methods used to locomotion score cows. Locomotion scoring is a subjective measure with various scoring systems used (Thomsen et al., 2008). The NAHMS study used 76 different evaluators with minimal training to locomotion score 184 operations, likely resulting in an underestimate. It is well established that inter-observer reliability suffers from high variability (Van Nuffel et al., 2015). Previous and relatively recent studies show a large herd-to-herd variation in lameness prevalence. The high prevalence of lameness in at least a proportion of dairy herds in the United States represents an unsustainable animal welfare issue (O'Callaghan, 2002; Shearer et al., 2013).

The majority of lameness originates in the hoof (Murray et al., 1996) and the most common hoof lesions found in North America are digital dermatitis, sole ulcers and white line disease (Cramer et al., 2008; DeFrain et al., 2013; Solano et al., 2016). Digital dermatitis is an infectious disease primarily affecting the skin of the heel and there is scientific consensus that digital dermatitis has a bacterial origin (Plummer and Krull, 2017). Sole ulcers and white line disease appear to be associated with trauma within the hoof and damage to the internal anatomy of the hoof through internal and external

concussive forces (Newsome et al., 2016). Diagnosing hoof lesions can be challenging, as there is an imperfect association between visible gait abnormality and hoof lesions (Tadich et al., 2010).

A variety of herd level risk factors that influence lameness and lesion prevalence have been identified, including: bedding depth, access to pasture, time away from pen, hoof trimming timing, hoof trimming of heifers prior to calving, frequency of alley cleaning, and foot bathing frequency. (Cook, 2003; Espejo and Endres, 2007; Cramer et al., 2009; Chapinal et al., 2013). However, due to the cross sectional observational nature of the cited studies, they are unable to show causality or the temporal relationship between the presence of risk factors and the development of lameness.

The study of lameness is complicated by the multifactorial nature of the condition. The broad definition of lameness and the difficulty and cost in diagnosing specific hoof lesions add further complications. Lameness exists at the crossroads of many different factors, including: environmental risk factors (e.g., decreased lying time, housing hygiene); properties of the hoof (e.g., bone remodeling, hoof overgrowth, hoof trimming practices); and physiological events associated with calving (e.g., ligament laxity, body fat mobilization) (Newsome, 2016). More work is needed to understand the complex array of conditions that cause lameness.

1.2 Lameness and metabolic disease

There is therefore a need to better understand the causative factors of lameness, with special attention to high-risk periods for lameness and lesions, including the transition period around calving. The behavior and physical properties of cows during the transition period have been shown to influence the risk of lameness in the next lactation

(Proudfoot et al., 2010; Machado et al., 2011). More specifically, low body condition score and the thickness of the digital cushion have been identified as risk factors for lameness. The digital cushion is composed of connective tissue and fat and is a force absorbing supportive structure in the hoof (Räber et al., 2004). A decrease in body condition score, or a low body condition score, has been shown to increase the risk of lameness (Green et al., 2014; Lim et al., 2015; Randall et al., 2015). A single herd study showed an association between the thickness of the digital cushion and lameness such that cows with a thinner digital cushion were more likely to have a sole ulcer or white line lesion (Bicalho et al., 2009; Machado et al., 2011). Body condition score has also been positively associated with digital cushion thickness (Bicalho et al., 2009). Based on these studies, we hypothesize that a longer duration and extent of fat mobilization a cow experiences during the start of her lactation, and the resulting higher loss of body and digital cushion fat, can influence lameness. The relationship between digital cushion function, concussive forces, and lesion development is described further in Chapter 2.

Hyperketonemia occurs during periods of excessive fat mobilization in early lactation when cows mobilize body reserves to fulfill the nutritional demands of milk production (Duffield, 2000). Hyperketonemia is typically defined based on blood beta-hydroxybutyrate (BHB) concentration (>1.2 mmol/L) (McArt et al., 2013). A relationship has been found between hyperketonemia and producer-recorded lameness (Suthar et al., 2013; Berge and Vertenten, 2014). Suthar et al. (2013) found on increased odd of lameness within 30 days in milk (DIM) in cows with greater blood BHB concentrations between 2 and 15 DIM. Lameness was recorded by farmers based on visual observation and the specific lesions were not known. Given that the volume of the digital cushion is one third fat (Wilson et al., 2021) and that the digital cushion thickness follows a pattern

similar to body condition score loss (Bicalho et al., 2009) it seems plausible that the process involved in hyperketonemia has a causative role in the development of hoof lesions.

More recently, Newsome et al. (2017) identified that a thin digital cushion predisposed cows to lameness and lesions later in lactation (absolute thinness), but thinning of the digital cushion tissue did not influence future lameness or lesion incidence (change over time). Newsome et al. (2017) and Wilson et al. (2021) hypothesized that the digital cushion is influenced by other factors such as integrity of the suspensory apparatus, not just the body condition of the cow or the change in body condition over the lactation. Foot structure changes during the transition period require further study.

1.3 Stakeholders in lameness management

As research continues on the causes of lameness, we must also acknowledge the importance of stakeholders in preventing and treating lameness. Stakeholders can address lameness with our current best management practices as we continue to refine those practices as our understanding of hoof lesions develops. There are many diverse stakeholders in lameness management including the cow, farmer, farm staff, veterinarian, hoof trimmer, nutritionist, and other farm advisors. Of particular interest are stakeholders who work directly with cows and make decisions affecting cow welfare. This thesis focuses on four critical stakeholder groups; farmers, veterinarians, hoof trimmers, and nutritionists.

Farmers ultimately make the management, financial, and ethical decisions for their farms (Driessen, 2012) and researchers are increasingly directing attention to

farmer motivations and barriers in lameness management. For example, Leach et al. (2010) found that farmers were motivated by the pain and suffering of lame cows and pride in a healthy herd, and that farmers reported lack of time and labor as important barriers to implementing lameness management practices. Other reported barriers included a lack of necessary equipment, knowledge or training (Dutton-Regester et al., 2019). Farmers have cited veterinarians as the most important partner in animal welfare due to their established relationships and expertise in animal care and welfare (Croyle et al., 2019). Veterinarians provide information on all aspects of animal health and are often key advisors in health management programs. The role of veterinarians in dairy cattle practice has shifted from one of providing individual animal care to providing advice and consultation (LeBlanc et al., 2006). As our understanding of health broadens, veterinarians are no longer alone in providing this support as other farm advisors work with farmers on the development and evaluation of health management programs.

Hoof trimmers work directly with the cows' hooves and are also a source of lameness management information. In 2013, 88.6 percent of U.S. dairy herds surveyed performed some degree of hoof trimming, with a professional hoof trimmer employed in 80.2 percent of those herds (NAHMS, 2014). Croyle et al. (2019) reported farmers viewed hoof trimmers as a source of lameness management advice, in addition to providing hoof care services. However, little information exists about hoof trimmers and their role. Only two North American studies have included hoof trimmers and both are surveys, one on treatment practices (Kleinhenz et al., 2014) and one on billing practices (Dolecheck et al., 2018).

Lastly, nutritionists also provide advisory services in addition to developing and monitoring feeding programs on dairy farms. Depending on the farm, nutritionists may be

involved more broadly in other areas of management impacting cattle dry matter intake, production, and welfare. Historically, nutrition was considered an important factor in the development of laminitis (Peterse, 1979; Nocek, 1997). More recently, the use of laminitis terminology has been challenged, and nutritional causes of lameness are considered to be in the minority (Randall et al., 2018). Despite the limited role nutritional factors play in lameness, nutritionists are still important stakeholders in lameness, due to their interests in dry matter intake, cow health, and farm profitability. Previous research including nutritionists has focused on nutritionists' recommendations on ration formulations (Silva et al., 2019) and to our knowledge no research has explored their role in lameness management.

1.4 Behavior change theories and qualitative research in dairy health and welfare

People weigh decisions based on a complex array of their circumstances, beliefs, and goals (Ajzen, 1991). Many theories have been developed to understand and influence people's motivation and behavior (NIH, 2005). Behavioral theories are particularly useful in investigating intrapersonal factors such as knowledge, attitudes, motivation, experiences, and how they influence practices. Two foundational frameworks used to understand socio-psychological variables in decision-making are the theory of planned behavior (TPB) (Ajzen, 1991) and the health belief model (Janz and Becker, 1984). The TPB posits the best predictor of a behavior is behavioral intention (readiness to perform a given behavior), which is in turn determined by attitude toward the behavior and social normative perceptions (beliefs of relevant others). The last TPB construct is perceived control over performance of the behavior (perceived ease or difficulty in

performing the behavior). The health belief model includes similar constructs but adds perceived susceptibility and perceived seriousness of the disease or adverse outcome. It is also important to note that other individual factors are important to understanding behavior and decision-making, including demographics, personality, previous experiences, routines, and economic influences (Ritter et al., 2017). Furthermore, individuals are not making decisions alone, but rather within complex interpersonal relationships influenced by culture and regulations (Shortall et al., 2016). Behavioral change frameworks have been applied to mastitis and Johne's disease control (Jansen et al., 2010; Roche et al., 2015) and are valuable tools for understanding stakeholder attitudes and experiences in lameness management.

Qualitative methods are often used to explore the factors influencing decisions and behaviors (Berkwits and Inui, 1998). Qualitative research uses non-numeric data in the form of words to understand the meaning of human action and encompasses many methodologies, including phenomenology (the study of phenomena through our experiences), ethnography (the study of societies or communities through immersion), and narrative analyses (the study of the stories people create) (Jackson et al., 2007). Qualitative research methods for gathering data include interviews, focus groups, participant observations, and case studies (Jackson et al., 2007). Qualitative research complements quantitative research by allowing for a more in-depth investigation of human experiences than what can be represented numerically. Qualitative methods allow researchers to explore the socio-psychological and external factors that influence decisions. Within dairy health and welfare research, qualitative methods have been used extensively (Croyle et al., 2019; Rink et al., 2019; Mills et al., 2020), for example to explore farmer perspectives of receiving information on udder health management

(Jansen et al., 2010) and to explore veterinarian perspectives on calf welfare in North America (Sumner et al., 2018). Ultimately, qualitative research enables the further understanding of people's lived experiences and can guide the improvement of individual communications, extension efforts, and educational programs.

1.5 Efforts to improve lameness control

Social science approaches, such as behavior change theories and qualitative methods, can be applied to the development and deployment of extension programs. Agricultural extension programs are used to: communicate, raise awareness, educate, motivate, support, and facilitate behavioral changes for improvement, such as increased productivity or disease prevention (Black, 2000). Agricultural extension has undergone a large change over the last several decades in that it has switched from a 'top-down' approach with researchers placed as the creators and holders of knowledge, to a more 'bottom-up' approach that uses interactive learning and participatory methods (Pretty and Chambers, 1993; Black, 2000). This participatory approach centers the participants and their experiences and expertise within complex agricultural systems (Carberry, 2001). Participants are not viewed as receivers of passive knowledge from researchers but rather empowered to develop their own lines of inquiry and solutions (Kidd and Kral, 2005). A participatory and farmer-led approach has been employed by Morgans et al. (2021) to reduce antimicrobial use on UK farms and Mills et al. (2020) to develop standard operating procedures on dairy farms.

Farmers weigh decisions based on many factors, including, previous experiences, goals, regulations, and economics (Ritter at al., 2017). For example, a survey conducted by Leach et al. (2010), UK farmers cited time and labor as important

barriers to the adoption of lameness control measures, and they cited lack of information as less important. In order for an extension program to be successful, we must move beyond one-way giving of information to passive farmers towards developing programs as partners that will appeal to their internal and external motivators. Internal motivation refers to performing a behavior for one's interest or enjoyment, whereas external motivation refers to performing a behavior in order to obtain a separate outcome (Ryan and Deci, 2000). In designing programs, it is also important to consider the intersecting roles of lameness stakeholders, where stakeholders share concerns and where they offer complementary perspectives, to avoid conflict and utilize existing expertise and relationships. Decision making on a farm does not occur in a vacuum as farmers and other stakeholders exist in complex social networks and communities. This is of particular interest when trying to improve management practices because a variety of stakeholders (e.g., veterinarians, hoof trimmers, other farmers, family) can provide information to farmers and influence decision-making (Kristensen & Jakobsen, 2011; Ritter et al., 2017).

An example of a participatory-based approach to lameness control is the Healthy Feet Programme in the United Kingdom. This program recognized the importance of facilitators and veterinarians in the implementation of management changes related to lameness and engaged farmers in the development of action plans. Participating farms received both lameness monitoring and intervention support as part of the project (Main et al., 2012; Whay et al., 2012; Leach et al., 2013). The support offered included traditional technical advice on farm-specific solutions, facilitation techniques to encourage farmer participation, and the application of social marketing to promote change. Whay et al. (2012) found farmers implemented more changes likely to positively

impact lameness when the ideas were generated with the direction of a veterinarian rather than on their own when told to generate a list. The reduction of lameness over time was greater on farms that were monitored and offered additional support compared to farms that only received monitoring (Main et al., 2012). The Healthy Feet Programme has many strengths, including its size with 189 farms participating and the implementation of a long-term intervention at the herd-level with the program offering lameness monitoring and support for 3 years. The Healthy Feet Programme has since been taken up nationally in the UK (AHDB, 2021) and replicated in other countries including Australia and New Zealand (Dairy NZ, 2021).

1.5.1 Summary

Designing and implementing lameness extension and control efforts is a formidable challenge. This is in part due to the multifactorial nature of the disease and the complexity of the multiple disease pathologies, for example, a herd with a digital dermatitis problem requires a different approach than a herd with a sole ulcer problem (Bell et al., 2009). Lameness can also be a chronic condition where prevention strategies may have no impact on already affected animals, therefore requiring a long time to see the impact of a change (Bell et al., 2009). We also lack an accurate and feasible way to monitor lameness over time (Schlageter-Tello et al., 2014). Due to the high prevalence, lack of monitoring, and prolonged nature of the condition, financial losses due to lameness are not always obvious and this can make farmers hesitant to invest in control measures (Leach et al., 2010). Lameness extension and control efforts must facilitate collaboration among stakeholders and appeal to stakeholders' internal and external motivations. Employing a combination of approaches using both

quantitative and qualitative data is needed to advance our understanding of the causes of lameness and stakeholder perspectives.

1.6 Thesis aims

Lameness remains a significant welfare issue and management challenge in the dairy industry. The first aim of this thesis was to contribute to the understanding of the causes of lameness, particularly how metabolic changes that may impact the structure of the foot predispose cows to hoof lesions. Given the multiple stakeholders involved in lameness management on a dairy farm, the second aim of this thesis was to explore farmer, hoof trimmer, and veterinarian perceptions of the barriers to lameness management. Furthermore, we also aimed to identify stakeholder perceptions of their own role in lameness management as well as their expectations of other stakeholders. Improved understanding of roles and expectations will aid in developing interventions with stakeholders. Given the importance of farm advisors in delivering advice and support, the final aim of the thesis was to increase collaboration between hoof trimmers, veterinarians, and nutritionists through facilitating lameness management advisory groups.

1.6.1 Objectives

1) Evaluate the role of hyperketonemia in sole ulcer and white line hoof lesion development.

2) Explore farmer, hoof trimmer, and veterinarian perceptions of barriers in lameness management, perceptions of their own roles in lameness management, and their expectations of other stakeholders.

3) Facilitate lameness management advisory groups and explore hoof trimmer, nutritionist, and veterinarian perceptions of the lameness management groups.

Chapter 2: Evaluating the role of hyperketonemia in sole ulcer and white line hoof lesion development by 150 DIM in dairy cattle

2.1 Summary

This study was an observational cohort with cows enrolled from 7 freestall dairy herds in Minnesota and Wisconsin. The objective was to determine the role of hyperketonemia on incident sole ulcer and white line hoof lesions (SUWL). Multiparous cows were enrolled at the time of their precalving hoof trim, at the end of their previous lactation. Enrolled cows were hoof trimmed twice: precalving between 90 to 21 days before calving (n=2,037), and postcalving between 21 to 150 days after calving (n=1,408). We trained 7 commercial hoof trimmers employed by the farms in lesion identification to standardize lesion recording. Hoof trimmers conducted therapeutic trimming as well as diagnosing and treating lesions. After parturition, cows between 3 and 16 days in milk were tested once weekly for hyperketonemia using a handheld ketone meter. Farm staff and research personnel conducted the beta-hydroxybutyrate (BHB) testing. Cows were classified as hyperketonemic (HYK+) if they had a blood BHB ≥1.2 mmol/L. At the precalving hoof trim 15.6% of cows trimmed had a lesion and 1.9% of cows had a SUWL; cows with a SUWL were excluded from further analysis (n=38). At the postcalving hoof trim 25.8% of cows trimmed had a hoof lesion, and 3.6% of cows had a SUWL. The majority of diagnosed lesions at the pre and postcalving hoof trims were digital dermatitis and corkscrew lesions. The incidence of hyperketonemia among cows was 22.1% (421/1,999) and incidence on farms ranged from 5.7% to 29.1%. After excluding cows due to being hoof trimmed outside our designated window, the multilevel logistic regression model for the odds of SUWL at the postcalving hoof trim included

1,209 cows (HYK+ = 257/1,209; SUWL = 42/1,209). The odds of having SUWL given HYK+ was 0.66 (95% CI: 0.29, 1.49). For cows diagnosed with a lesion (digital dermatitis, corkscrew, toe, footrot, or other lesion) at their precalving hoof trim (n=199), the odds of having SUWL given HYK+ were 0.43 (95% CI: 0.05, 3.92). Overall, we found no evidence that elevated concentrations of blood BHB cause postcalving incident sole ulcer or white line lesions in cows with or without a hoof lesion precalving. Future research should investigate other transition period factors (e.g., inflammation or structural changes to the foot) that may have a causative role in the development of sole ulcer and white line hoof lesions.

2.2 Introduction

Lameness is a leading animal welfare concern in the dairy industry (Ventura et al., 2015) with substantive economic repercussions (Dolecheck and Bewley, 2018). The majority of lameness originates in the hoof (Murray et al., 1996) and the most common hoof lesions found in North America are digital dermatitis, sole ulcers, and white line lesions (Cramer et al., 2008; DeFrain et al., 2013; Solano et al., 2016). Solano et al. (2016) found the cow level prevalence of sole ulcer and white line lesions (SUWL) to be 11.6% in 28,607 cows in Alberta, CA. SUWL are thought to be caused by trauma within the hoof and damage to the internal anatomy of the hoof through internal and external concussive forces (Newsome et al., 2016). It is becoming clearer that a cow's first case of SUWL is associated with changes in the hoof anatomy, primarily the suspensory apparatus (Lischer et al., 2002; Tarlton et al., 2002) and the supporting structures under the third phalanx or pedal bone (Bicalho et al., 2009; Newsome et al., 2017b). It has been suggested that when the function of these structures is impaired, extra concussive

force is exerted on the horn producing tissue, leading to the disruption of horn production and the formation of SUWL (Newsome et al., 2017). Once SUWL are present the size and shape of the pedal bone changes due to exostosis, increasing the chance of chronic lameness due to a cycle of excessive concussive forces (Newsome et al., 2016). Therefore, it is important to consider previous lameness history in both observational and controlled studies (Wilson et al., 2021).

There is a need to better understand the causative mechanism of SUWL, with particular attention to high risk periods for lameness and lesions. The transition period is increasingly being recognized as a high risk time for lesion development due to physical changes to the suspensory apparatus and behavioral changes. Evidence is growing suggesting that lameness might be triggered during the transition period (Proudfoot et al., 2010; Lim et al., 2015). The behavior and physical properties of cows during the transition period have been shown to influence the risk of lameness in the next lactation (Proudfoot et al., 2010; Machado et al., 2011). More specifically, low body condition score and the thickness of the digital cushion have been identified as risk factors for lameness (Randall et al., 2015; Wilson et al., 2021). In the UK, a decrease in body condition score, or a low body condition score, has been shown to increase the risk of lameness (Green et al., 2014; Lim et al., 2015; Randall et al., 2015). A single herd study in New York showed an association between digital cushion thickness and lameness (Bicalho et al., 2009; Machado et al., 2011) such that cows with a thinner digital cushion were more likely to have a sole ulcer or white line lesion. Newsome et al. (2017a) similarly found that cows who developed sole ulcers or hemorrhages had thinner sole soft tissues. Body condition score has been positively associated with digital cushion

thickness (Bicalho et al., 2009; Newsome et al., 2017a,b) and follows a similar lactation curve pattern.

A relationship has been found between hyperketonemia and producer-recorded lameness (Suthar et al., 2013; Berge and Vertenten, 2014). Suthar et al. (2013) found that cows with greater blood BHB concentrations between 2 and 15 DIM had an increased odds of lameness within 30 DIM, though lameness was recorded by farmers based on visual observation and the specific lesions were not known. Hyperketonemia occurs during periods of excessive fat mobilization in early lactation when cows mobilize body reserves to fulfill the nutritional demands of milk production (Duffield, 2000). Hyperketonemia is typically defined based on blood BHB concentration ($\geq$1.2 mmol/L) (McArt et al., 2013). Given that the volume of the digital cushion is one third fat (Wilson et al., 2021) and that the digital cushion thickness follows a pattern similar to BCS loss (Bicalho et al., 2009) it seems plausible that the process involved in hyperketonemia has a causative role in the development of SUWL through a reduction in the hoof's force absorption.

Previous studies did not evaluate the relationship between hyperketonemia and specific lesions nor did they consider the impact of previous lesion status. Therefore this study sought to determine the causal effect of hyperketonemia diagnosed between 3-16 DIM on incident SUWL diagnosed between 21-150 DIM in cows with and without a hoof lesion (digital dermatitis, corkscrew, toe, footrot, or other lesion) between 90-21 days before calving.

2.3 Materials and methods

This study was approved by the University of Minnesota Institutional Animal Care and Use Committee (Protocol Number: 1603-33595A).

2.3.1 Farm enrollment and data collection

The number of cows available for data analysis was set by the sample size required for another study, therefore no sample size calculation was performed for the specific objectives of the current study. Data for this cohort study were collected from 6 commercial dairy herds in Minnesota and 1 herd in Wisconsin from September 2016 to August 2017. Criteria for enrollment included: willingness to carry out weekly BHB testing or allow research technicians to conduct the testing, evidence in records of hoof trimming cows both around dry-off and midlactation, use of DairyComp 305 management software (DC305, Valley Ag Software), and enrollment with the Dairy Herd Improvement Association. At the time of herd enrollment, the first author (EW) assessed the milking herd lameness prevalence through visually locomotion scoring the milking herd as they exited the parlor after milking. This was a single time measurement and all cows were assigned a locomotion score from 1 to 4 (1 - no gait abnormality, 2 - slight lameness, 3 - moderate lameness, 4 - severe lameness). The scoring system was a combination and adaptation of Thomas et al. (2015) and Cook (2003) (Appendix 2.1). The prevalence of lameness was calculated by dividing the number of cows with a locomotion score of 3 or 4 by the total number of cows scored on that farm.

All second and greater parity cows who calved during the data collection period were enrolled at the time of calving. First parity cows were excluded post hoc due to not having a precalving hoof trim. Blood BHB concentration was measured twice between 3 and 16 DIM. For 3 enrolled farms the farm personnel conducted the BHB testing and on

4 farms it was done by research technicians. Blood samples were collected from the coccygeal vessels using a 1 mL syringe (EXELINT International CO. 1 ml Luer lock) and 21G x 1 needles (Monoject COVIDIEN). Immediately after collection, blood BHB concentrations were measured using an electronic handheld device (NovaVet™; Nova Biomedical Co.) previously validated for use on dairy cows (Bach et al., 2016). A calibration slope of 1.0 (default setting) was utilized to adjust for differences in hematocrit and to maximize the sensitivity and specificity of the test (Rodriguez et al., 2021). All samples were collected when cows returned to their home pen after morning milking. Culling and death events were entered into the farm management software by farm personnel. Disease events (milk fever, retained fetal membranes, displaced abomasum, metritis, mastitis) were recorded by farm personnel based on the farms' protocol. A diagram detailing the flow of study animals is presented in Figure 2.1.

2.3.2 Hoof trimming records

At the time of farm enrollment, a member of the research team (EW or GC) met with the hoof trimmer employed by the farm to discuss the project and their lesion recording. Each farm had a different hoof trimmer and all hoof trimmers agreed to modify their lesion recording if necessary. Hoof trimmers completed a lesion identification quiz to standardize lesion recording using lesion descriptions modified from Cramer et al. (2008) and ICAR Claw Health Atlas (Egger-Danner et al., 2020) (Appendix 2.2). The hoof lesions recorded were: sole ulcers, white line lesions, digital dermatitis, toe lesions, corkscrew claws, footrot, injury, and other. Hoof trimming records were recorded on paper or in hoof trimming software and then entered into the farm management software by farm personnel. The on-farm management software (DC305) was modified by study

personnel to facilitate consistent data entry, exporting of data, and creating hoof trimming lists for the farm.

2.3.3 Statistical analysis

For data analysis we exported the hoof trimming data from either the hoof trimming software program (n=1) or the herd management software (n=6). Data were then merged with cow demographic data exported from DC305 into STATA 16 (STATA Corp). As our intent was to study the causal relationship between hyperketonemia and hoof lesions, we followed a target trial approach which applies design principles from randomized trials to the analysis of observational data (Hernan et al., 2016). Our target trial was the enrollment of cows with exposure to elevated concentration of blood BHB between 3 and 16 DIM. Considering that our exposure variable, elevated concentration of blood BHB, would be present from 21 days before to 21 days after calving (Weber et al., 2013), we excluded cows hoof trimmed 21 days before to 21 days after calving as it would not be possible to determine a temporal relationship between hoof trimming and hyperketonemia exposure for cows hoof trimmed during this time period. To accomplish this aim, we defined precalving hoof trim as a hoof trim that occurred 90 to 21 days before calving. The outcome, postcalving hoof trim, was defined as a hoof trim that occurred 21 to 150 days after calving. For cows hoof trimmed multiple times within the time period, we selected the hoof trim closest to the calving date. Due to the known confounding or effect modification impact of previous lesion status, prior to initiating data analysis we used the precalving hoof trim lesion data to stratify cows into 2 groups. Cows with no lesion were used to model causal question 1. Cows with a digital dermatitis, toe, corkscrew, injury, other, or footrot lesion were used to model causal

question 2. Cows with a sole ulcer or white line lesion at the precalving trim were excluded from further analysis.

All statistical analyses were performed in STATA 16 (STATA Corp) and cow was used as the observational unit. Descriptive data of lesion prevalence and lesion type at the precalving and postcalving hoof trims were calculated. The exposure variable of interest was hyperketonemia diagnosed between 3 and 16 DIM. On 5 of the enrolled farms, cows were tested once between 3-9 DIM and once between 10-16 DIM. On the other 2 of enrolled farms, the farm protocol was to test cows at day 3, 7, and between 11-16. For cows that were tested three times we removed the day 3 test and classified hyperketonemia using the 7 and 11-16 d tests. Cows with a BHB measurement of ≥1.2mmol/L in at least one of the two samples taken were deemed hyperketonemia-positive (HYK+). For cows with only one sample taken, if the BHB measurement was ≥1.2mmol/L they were also classified as HYK+. Otherwise, cows were classified hyperketonemia-negative (HYK−). For all models, the outcome was defined as having an incident SUWL diagnosed at the postcalving hoof trim. We used 2 generalized linear mixed models (with logistic link) to evaluate our 2 causal questions. To guide our modeling approach a directed acyclic graph (DAG) was drawn to summarize our understanding of the underlying causal relationships between the variables available in our data set. A complete DAG with all variables identified as potential confounders is available at www.dagitty.net/mSqOJo9, a simplified DAG showing only variables included in our model is shown in Figure 2.2. Variables that met the criteria of confounders (common cause of the exposure and outcome of interest) were included in the multivariable models (Hernán and Robins, 2020). These included the cow-level and herd-level variables. No variables were removed from the model to avoid selection bias

and overestimation of parameters (Sauerbrei et al., 2020). To account for the clustering of cows within herds and differences in the management practices between herds, the herd variable was included as a random effect in all the models. Results are discussed in the context of precision of the estimate using confidence intervals (Poole, 2001). For both the no lesion and lesion models, parity, breed, disease prior to 17 DIM, previous lactation milk yield, and season at calving were included as confounders. Diseases occurring prior to 17 DIM were collapsed into a dichotomous variable using the following diseases as recorded by the farm personnel: milk fever, retained fetal membranes, displaced abomasum, metritis, mastitis. Season at calving was also dichotomous with calvings that took place during summer (May-August) or other seasons. Previous lactation milk yield was included as previous lactation 305ME.

2.4 Results

Our 7 enrolled farms had a lameness prevalence that ranged from 11.9% to 43.0%. Table 2.1 contains herd and cow demographic characteristic information. At the precalving hoof trim (n=2,037), 15.6% of cows trimmed had a lesion (Table 2.2) and 1.9% of cows had a SUWL; cows with a SUWL were then excluded from further analysis (n=38). At the postcalving hoof trim (n=1,408), 25.8% of cows trimmed had a hoof lesion, and 3.6% of cows had a SUWL. The majority of diagnosed lesions at the pre and postcalving hoof trims were digital dermatitis and corkscrew lesions. Of 1,408 cows included in the models, 28 were trimmed twice during the precalving hoof trim time period, 80 were trimmed twice during the postcalving hoof trim time period, and 4 cows were trimmed twice during both the pre and postcalving hoof trim time periods. For cows

with 2 recorded hoof trims, we selected the hoof trim closest to the calving date to determine lesion status.

The farm-level incidence of hyperketonemia ranged from 5.7% to 29.1%. The overall incidence of hyperketonemia was 22.1% (421/1,999). For the no lesion group the multilevel logistic regression model for the odds of SUWL at the postcalving hoof trim included 1,209 cows (HYK+ = 257/1,209; SUWL = 42/1209) (Table 2.3). The odds of having SUWL given HYK+ was 0.66 (95% CI: 0.29, 1.49). For cows diagnosed with a lesion at their precalving hoof trim (n=199), 41 cows were HYK+ and 8 had a SUWL (Table 2.4). The odds of having SUWL given HYK+ were 0.43 (95% CI: 0.05, 3.92).

2.5 Discussion

In our study herds, the overall lameness prevalence at the start of the study period ranged from 11.9% to 43.0%. This is similar to previous studies, for example, a survey of large Wisconsin dairy herds estimated the prevalence of lameness at 13% with a range of 3 to 36% (Cook et al., 2016), and von Keyserlingk et al. (2012) showed a lameness prevalence of 55% with a range from 12 to 80% in Northeastern US freestall herds. In both the pre and postcalving hoof trimming records we found digital dermatitis and corkscrew lesions to be the most prevalent. DeFrain et al. (2013) and Solano et al. (2016) similarly found digital dermatitis to be the most common lesion in freestall herds. Interestingly, we had a high percent of corkscrew lesions, mostly contributed by 2 herds suggesting the hoof trimmers at these herds may have been more likely to diagnose and record corkscrew lesions. Few studies have examined corkscrew lesions. Cook et al. (2019) found an overall prevalence of corkscrew claw syndrome of 16% in heifers and 33% in mature milking cows in a survey of 43 herds in the Upper Midwest in 2017.

Overall, we found no evidence of a causal relationship between hyperketonemia and postcalving SUWL in both our no lesion and lesion strata. This result is consistent with recent research be Wilson et al. (2021) who hypothesized structural changes to the foot predisposing cows to SUWL are more complex than changes to the amount of fat, as discussed further below. This result should be interpreted in the context of the limitations of the study. We found many cows did not fit our inclusion criteria of being trimmed within our designated windows (n=850). We selected the time periods to best define precalving lesion status and to include only incident SUWL cases as our outcome. The selected time periods were also to allow time for the possible effect of the exposure and for a lesion to develop postcalving. We tried to limit the issue of cows not being trimmed within our defined time periods by selecting farms for the study that had a trimming schedule that included both a dry-off and midlactation hoof trim. Due to the observational nature of this study, we did not have control over the timing of hoof trims. Cows who developed a lesion within the follow-up period may have been more likely to be trimmed, leading to an overestimate of the incidence of SUWL. The incidence of hyperketonemia was found to be similar for cows excluded due to missing trimming data as for cows with complete data. The inclusion of a longer time period before and after calving would have increased our sample size but also reduced our ability to attribute the possible effect to our exposure.

A further limitation was the low number of incident SUWL. Omontese et al. (2020) found a similar low incidence (4.4%) of SUWL diagnosed in a hoof chute at 120 DIM. Estimating sample sizes using incidence lesions presents a challenge as most studies calculate lesion prevalence (Solano et al., 2016), and when incidence is given they do not consider the impact of lesion history. Few longitudinal studies exist on lesion

development (Mahendran et al., 2017; Newsome et al., 2017; Omontese et al., 2020). Future studies should use appropriate lesion incidence numbers for sample size calculations. Another limitation is that we did not measure hemorrhages due to the difficulty in gathering consistent data with multiple hoof trimmers. The diagnosis of sole hemorrhage has been shown to vary between hoof trimmers (Cramer et al., 2008; Holzhauer et al., 2006). Hemorrhages have been shown to decrease lying time (Omontese et al., 2020) and treating hemorrhages with therapeutic trimming, foot block, and NSAID therapy improves cure rates (Thomas et al., 2015). Newsome et al. (2016) has suggested that hemorrhages are the beginning stage of sole ulcer development, therefore we are likely missing part of the sole ulcer disease process in not capturing hemorrhage information.

Despite the challenges in collecting lesion data, studies investigating lesion development pathways should use first lesion incidence due to the evidence that claw horn lesions change the structure of the foot and carry over from one lactation to the next, making future lesions more likely (Newsome et al., 2016; Randall et al., 2018). As we continue to unravel the pathogenesis of lameness it is also important to define and specify which lesions are under investigation. In this study, we chose to use lesion data recorded by hoof trimmers. Using hoof trimming records avoids a bias of dairy farm personnel underestimating the level of lameness in their herds (Wells et al., 1993; Espejo et al., 2006). In this study, we were only able to determine lesion status twice so we did not have continuous monitoring of lesion status. However, SUWL have a long development time and we selected the trimming time points strategically to cover the highest-risk period for lesion development. Additionally, no method exists for non-

invasive continual lesion monitoring as lifting a cows' foot, cleaning, and potentially removing horn to look for lesions may impact the development of lesions.

In this study, we measured hyperketonemia, which is an imperfect indicator of negative energy balance and fat mobilization (McArt et al., 2013). Nonesterified fatty acids (NEFA) is a more direct measure but there is presently no way to measure NEFA cow-side. Even with the stated limitations, we believe it is likely there is no causal link between hyperketonemia and SUWL. The mobilization of fat is more complicated than simply measuring circulating fatty acids and ketone bodies, as shown by investigation of inflammation events and endocrine changes (Contreras et al., 2017). Furthermore, Newsome et al. (2017) and Wilson et al. (2021) have shown significant accuracy issues in measuring the digital cushion. Their work has suggested foot structure changes during the transition period, potentially caused by inflammation, are likely more important and require further study.

In this study, we took a causal inference epidemiological approach (Hernan and Robins, 2020). It is not possible to randomize cows to a hyperketonemia exposure, therefore we attempted to emulate a randomized trial with a defined exposure and outcome period allowing for more robust inferences from observational data (Labrecque et al., 2017). This is a different approach compared to previous studies examining lameness or lesion prevalence and associations with cow- and herd-level risk factors (Cramer et al., 2008; Chapinal et al., 2013; Solano et al., 2016). As we continue to move beyond investigating lameness as a broad category of multiple origins, it is important to consider individual lesions types and their specific causal pathways. As our understanding of specific hoof lesions continues, we encourage future research to use causal inference methods to move beyond looking for associations in observational data.

2.6 Acknowledgements

We thank the students and research technicians for their help during data collection, as well as the participating farms and hoof trimmers for their time and contributions. This work was supported by the Minnesota State Legislature through the Rapid Agricultural Response Fund (Project #00057257) managed by the Minnesota Agricultural Experiment Station (St. Paul, MN, USA). The authors report no conflicts of interest.

Table 2.1. Farm characteristics of 7 participating sand-bedded freestall dairy herds in Minnesota and Wisconsin, USA.

	Farm							
Characteristic	A	B	C	D	E	F	G	Overall
Herd size[1]	640	1190	270	2080	1430	1220	700	
Cows enrolled	355	650	56	423	301	124	90	1999
Breed	Holstein	Mixed[2]	Holstein	Holstein	Holstein	Holstein	Holstein	
Parity at enrollment (n)								
2	141	269	19	200	131	59	31	850
3	119	228	19	109	92	34	26	627
4+	95	153	18	114	78	31	33	522
Milk production (kg/lactation)[3]	13,610	14,949	14,589	12,871	15,014	13,472	14,917	14,178
Days dry (median)	56	48	55	52	46	47	52	51
Lactating herd lameness prevalence (%)	23.6	43.0	16.0	27.1	21.6	36.1	11.9	
Transition disease incidence (n,%)[4]	64(18.0)	69(10.6)	15(26.8)	94(22.2)	16(5.3)	16(12.9)	19(21.1)	293(14.7)
Hyperketonemia incidence (n,%)[5]	87(25.5)	178(29.1)	14(27.5)	48(11.6)	74(26.1)	15(12.4)	5(5.7)	421(22.1)

[1]Average of milking and dry cows over the farm BHB test period
[2]30% crossbreds
[3]Previous lactation (305-d mature equivalent)

[4]Combined incidence of milk fever, retained fetal membranes, displaced abomasum, metritis, and mastitis occurring prior to 17 DIM as recorded by farm personnel

[5]Hyperketonemia incidence for all cows tested between 3 and 16 DIM. Cows were classified as hyperketonemic if they had a blood BHB ≥1.2 mmol/L.

Table 2.2. Lesion prevalence at precalving and postcalving hoof trims. (n,% of cows with lesion)

Lesion	Prevalence at precalving trim (n=2,037)[2]	Prevalence at postcalving trim (n=1,408)
No lesion	1,719	1,045
Any lesion[1]	337	377
White line	28 (1.4)	35 (2.5)
Sole ulcer	10 (0.50)	16 (1.1)
Digital dermatitis	134 (6.6)	113 (8.0)
Corkscrew	96 (4.7)	179 (12.7)
Toe	38 (1.9)	11 (0.8)
Footrot	4 (0.2)	2 (0.1)
Injury	11 (0.54)	15 (1.1)
Other	16 (0.8)	6 (0.4)

[1]19 cows had two lesions at precalving trim; 14 cows had two lesions at postcalving trim

[2]2,037 = 1,999 cows plus 38 with SUWL

Table 2.3. Multilevel logistic regression model for the odds of having a lesion at the postcalving hoof trim in cows without a pre-calving lesion in 1,209 cows in 7 freestall dairy herds in Minnesota and Wisconsin, USA (number with exposure = 257/1,209; number with outcome = 42/1,209).

			OR (95% CI)			
Variable	Coefficient	SE	OR	LCL	UCL	P-value
Intercept	-4.24	1.3	-	-	-	-
Hyperketonemia	-0.42	0.4	0.66	0.29	1.49	0.31
Lactation						
2	Referent					
3	0.36	0.4	1.43	0.63	3.28	0.39
4+	1.21	0.4	3.35	1.55	7.25	0.002
Breed	0.27	0.5	1.30	0.50	3.44	0.59
Season	0.73	0.4	2.07	0.91	4.71	0.08
Transition disease	-0.22	0.6	0.80	0.23	2.76	0.72
Prev. lact milk yield	<-0.01	<0.1	0.99	0.99	1.0	0.70
Random intercept: farm	ICC: 0.23 (95%CI: 0.05-0.61)					

Confidence interval for the odds ratio: lower (LCL) and upper (UCL) confidence limits.

Table 2.4. Multilevel logistic regression model for the odds of having a lesion at the postcalving hoof trim in cows with a pre-calving lesion (DD/toe/corkscrew/injury/other/footrot) in 199 cows in 5 freestall dairy herds in Minnesota and Wisconsin, USA (number with exposure = 41/199; number with outcome = 8/199).

				OR (95% CI)		
Variable	Coefficient	SE	OR	LCL	UCL	P-value
Intercept	-1.98	3.1	-	-	-	-
Hyperketonemia	-0.83	1.1	0.43	0.05	3.92	0.46
Lactation						
2	Referent					
3	1.08	1.0	2.95	0.45	19.32	0.26
4+	0.96	1.0	2.55	0.39	17.62	0.32
Breed	-1.85	1.3	0.16	0.01	2.08	0.16
Season	0.90	0.9	2.45	0.41	14.76	0.33
Transition disease	-0.45	1.1	0.64	0.07	5.64	0.68
Prev. lact milk yield	<-0.01	<0.1	0.99	0.99	1.00	0.84
Random intercept: farm						

Confidence interval for the odds ratio: lower (LCL) and upper (UCL) confidence limits.

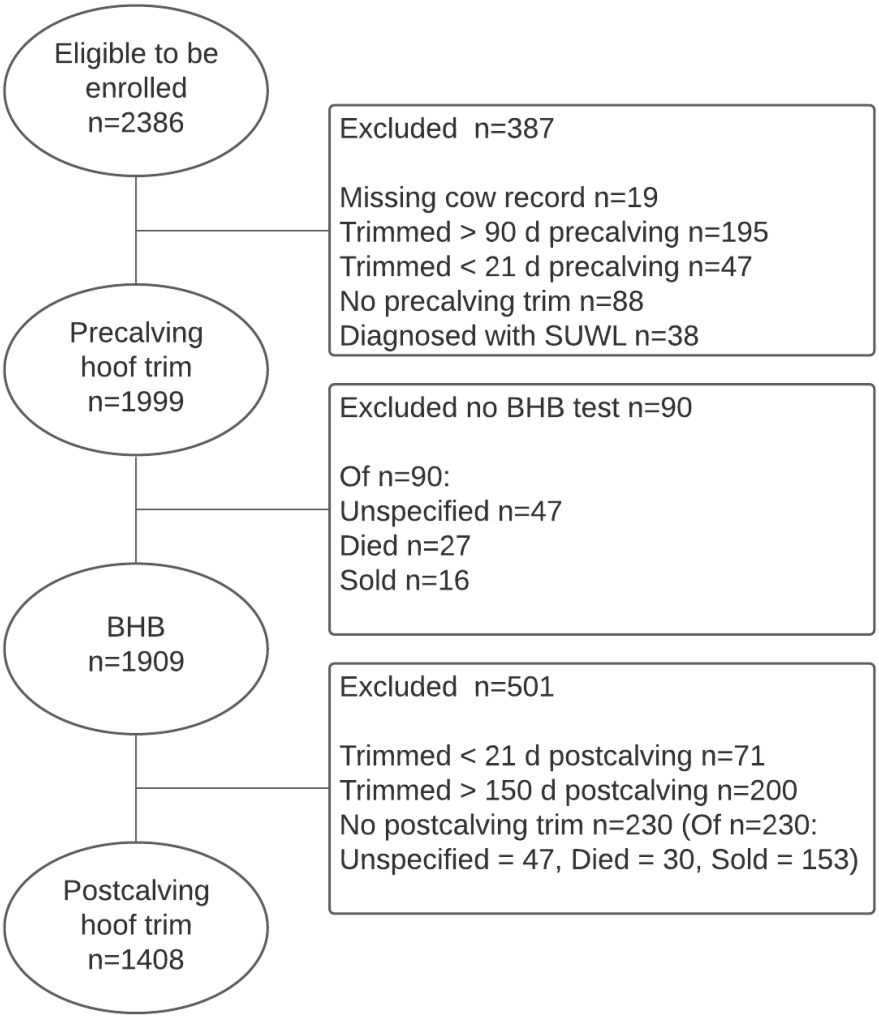

Figure 2.1. Diagram of cows removed from the study, from top to bottom. Top represents the beginning of the study period (90 d before calving), and the bottom represents the end of the study period (150 d after calving).

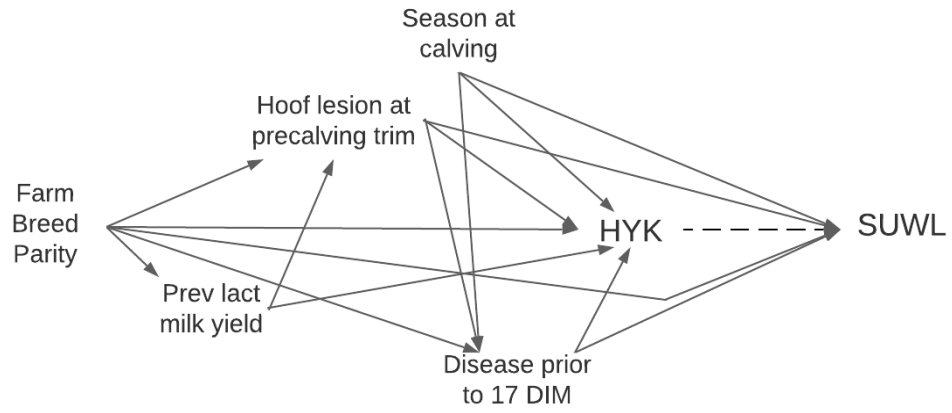

Figure 2.2. Directed acyclic graph outlining our theoretical understanding of the variables included in our models. The prev lact milk yield node represents previous lactation 305ME. The hoof lesion at precalving trim node represents hoof lesions (sole ulcer, white line, digital dermatitis, corkscrew, toe, footrot, or other lesion) diagnosed between 90-21 days before calving. The disease node represents milk fever, retained fetal membranes, displaced abomasum, metritis, mastitis occurring prior to 17 DIM. The HYK node represents hyperketonemia status as determined by blood BHB concentration between 3-16 DIM. The SUWL node represents incident sole ulcer and white line lesions diagnosed between 21-150 DIM.

Chapter 3: Dairy farmer, hoof trimmer, and veterinarian perceptions of barriers and roles in lameness management

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3.1 Summary

Lameness is a leading animal welfare concern in the dairy industry. Multiple stakeholders are involved in lameness management on a dairy farm, including farmers, hoof trimmers, and veterinarians. This study sought to explore perceptions of lameness, perceptions of roles in lameness management, and barriers to improved lameness management in these groups. Fourteen homogeneous focus groups were held in Minnesota, Wisconsin, and New York, USA from April 2017 to March 2020; 5 with farmers (n = 31), 4 with hoof trimmers (n = 32), and 5 with veterinarians (n = 25). The 1-h facilitated discussions were audio-recorded, transcribed verbatim, and common themes identified through thematic analysis. Lameness was perceived by participants as a complex health problem and one in which the connections between pathogenesis, facilities, and management were not always well understood or easy to change. The complexity of the problem encompassed the lack of agreement on a definition of lameness, normalization to its signs, and the interconnectedness of lameness with other health and management issues. These issues appeared to contribute to resignation by participants that lameness was inevitable. Despite shared concerns about lameness amongst these groups, respondents reported a lack of communication, especially between hoof trimmers and veterinarians. Participants also voiced a desire to work

together more productively, with hoof trimmers and veterinarians valuing the ability to deliver a consistent message to farmers. These findings suggest a need for increased efforts to facilitate collaboration between farmers, hoof trimmers, and veterinarians to improve lameness management on dairy farms.

3.2 Introduction

Lameness is the clinical presentation of impaired locomotion and is caused by a range of foot and leg conditions, the most common of which are hoof lesions caused by infectious agents or internal and external forces (Murray et al., 1996). Lameness is a leading animal welfare concern in the dairy industry (Ventura et al., 2015). It also has substantive economic repercussions (Dolecheck and Bewley, 2018), as productivity is decreased through reduced reproductive efficiency (Bicalho et al., 2007) and milk production (Archer et al., 2010) and increased culling (Booth et al., 2004). Various best management practices for preventing lameness (Bell et al., 2009; Main et al., 2012) and treating lame cows have been developed (Groenevelt et al., 2014; Thomas et al., 2015). Despite this growing knowledge, lameness persists as an industry problem; for example, a survey of large Wisconsin dairy herds estimated the prevalence of lameness at 13% with a range of 3 to 36% (Cook et al., 2016), and von Keyserlingk et al. (2012) showed a lameness prevalence of 55% with a range from 12 to 80% in Northeastern US freestall herds.

Increasingly, there has been an interest in understanding the psychology and experiences of key stakeholders (people with an interest or concern in a system or organization; Bryson, 2004), as they choose to adopt or recommend disease management strategies on dairy farms (Ritter et al., 2017; Sumner et al., 2020). The

most meticulous disease control and prevention strategies are of little use if stakeholders do not implement or support them. Therefore, it is important to understand the barriers faced by farmers and farm advisors as they make cow health and welfare decisions. This knowledge can help guide our research, interventions, and communications within the area of lameness management so our work can better resonate with stakeholders working on farms.

There are many important stakeholders in lameness management, including farmers, hoof trimmers, and veterinarians. Farmers ultimately make the management, financial, and ethical decisions for their farms (Driessen, 2012) and researchers are increasingly directing attention to farmer motivations and barriers in lameness management. For example, Leach et al. (2010) found that farmers were motivated by the pain and suffering of lame cows and pride in a healthy herd, and that farmers reported lack of time and labor as important barriers to implementing lameness management practices. Other reported barriers included a lack of necessary equipment, knowledge or training (Dutton-Regester et al., 2019).

Veterinarians and hoof trimmers are also of interest for understanding lameness management, as they often take on advisory or supportive roles. Veterinarians provide information on all aspects of animal health and are often key advisors in health management programs (LeBlanc et al., 2006). As the understanding of health and welfare broadens, veterinarians are no longer alone in providing expertise and advice. In 2013, 88.6 percent of U.S. dairy herds surveyed performed some degree of hoof trimming, with a professional hoof trimmer employed in 80.2 percent of those herds (NAHMS, 2014). Croyle et al. (2019) found farmer participants in their focus group study viewed hoof trimmers as a source of lameness management advice, in addition to

providing hoof care services. However, despite their importance, little information exists about hoof trimmers' perceptions of their work and contributions to lameness management. To our knowledge, just two studies have included any focus on hoof trimmers in North America, one which surveyed their lameness treatment practices (Kleinhenz et al., 2014) and another which focused on billing practices (Dolecheck et al., 2018). These studies explored hoof trimmers' selected therapies for lesions and costs of specific treatments, but we still lack a clear understanding of hoof trimmers' experiences as stakeholders in lameness management.

Lameness has multiple causes and areas of management concern, including but not limited to: hoof horn health, infection pressure, forces on the feet, and early detection and treatment (Hulsen, 2011). Due to the multiple factors involved, implementing a management change can often involve collaboration between farmers and farm advisors, each of whom may have unique and overlapping roles. There is some evidence to support that lameness can be managed more successfully in consultation with advisors. For example, Whay et al. (2012) found farmers implemented more changes likely to positively impact lameness when the ideas were generated with the direction of a veterinarian rather than on their own. Similarly, the reduction of lameness over time was greater on farms that were monitored and offered additional support from researcher and veterinarian stakeholders compared to farms that only received monitoring (Main et al., 2012).

As the importance of talking to stakeholders and understanding the beliefs that influence their decisions becomes clearer, information is still lacking on how some of these individuals perceive lameness management and navigate challenges in their own roles and in collaboration with others. Therefore, the objective of this study was to use

focus groups to explore dairy farmers', hoof trimmers', and veterinarians' perceptions of barriers to lameness management. Specifically, we sought to identify stakeholder perceptions of lameness, perceptions of their own roles in lameness management, and their expectations of these other stakeholders.

3.3 Materials and methods

This study was approved as exempt from review (Study Number: 1702P08721) by the University of Minnesota Institutional Review Board.

3.3.1 Positionality statement

Positionality refers to an individual's worldview and the position they adopt within a research study (Holmes, 2020). This statement provides transparency in how our interests, beliefs, and experiences may influence our analysis. E. Wynands is a researcher in dairy cattle health management and welfare. She grew up on a dairy farm and she has worked with farmers, hoof trimmers, and veterinarians in the area of lameness management but is not a farmer, hoof trimmer, or veterinarian herself. She carried out this study as part of her PhD research and the other authors are part of her PhD advisory committee. S. Roche is an animal scientist with an interest in dairy cattle health and welfare, and a consultant who works closely with farmer, veterinarian, and other farm advisory organizations internationally. G. Cramer previously owned and operated a dairy farm and a lameness specific veterinary practice; he is now a researcher in dairy health management and a veterinarian specializing in foot health. B. Ventura is neither farmer, veterinarian, nor dairy advisor; she is an animal scientist with an interest in animal welfare and stakeholder communication. All authors entered into

this research with an interest in dairy cow welfare and approached this topic with the understanding that these stakeholders are experts at what they do and that we can learn from their lived experiences.

3.3.2 Study design

People weigh decisions based on a complex array of their circumstances, beliefs, and goals (Ajzen, 1991) and qualitative methods are often used to explore the factors influencing decisions and behaviors (Berkwits and Inui, 1998). A focus group methodology allows for an open discussion to explore a range of perceptions and experiences, both from the individual and from the group (Krueger and Casey, 2015). Focus groups have been used to understand farmer motivations in udder health management (Shock et al., 2020), Johne's disease (Roche et al., 2019), and expectations for animal welfare advice (Croyle et al., 2019). We used a multiple-category design (Kreuger and Casey, 2015) to capture the experiences of our different stakeholder groups. This strategy entails conducting focus groups with several types of participants, allowing for comparisons within categories (e.g., farmers with small herds to farmers with large herds) and from one category to another (e.g., comparing farmers to veterinarians). Focus groups were kept homogeneous with respect to stakeholder category (farmer, veterinarian, hoof trimmer), as these individuals have different roles in lameness management and discussions are easier amongst people who have shared experiences (Krueger and Casey, 2015). We framed lameness as a challenge for stakeholders and used a critical realist perspective to understand the complexity and context in lameness management decisions (Maxwell, 2012). Critical realism is an integration of the acknowledgment that a real world exists and our understanding of the

world is constructed through our perspective and worldview (Maxwell, 2012). Within this perspective, we did not intend the results to be generalizable as defined within the positivist paradigm (Denzin and Lincoln, 2000).

3.3.3 Participant recruitment

Though this study did not aim to be representative of the stakeholder population, we include the following as context about the populations from which the participants were drawn. Minnesota and Wisconsin have a high density of dairy farms and were therefore the region of interest for this study. There were 2,325 dairy farms in MN (MDA, 2021) and 6,932 in WI (USDA, 2021) as of January 1, 2021 and the majority of milking cows are housed inside year-round. The number of hoof trimmers in MN and WI is not known, but the majority of dairy farms use a professional hoof trimmer (NAHMS, 2014). Likewise, the number of veterinarians in dairy practice is unknown, though this can be approximated by membership data from the professional organization American Association of Bovine Practitioners. As of January 20, 2021 there were 156 registered members in MN and 345 registered in WI, though these members include veterinarians not in dairy practice. The majority of dairy farms in the United States are registered with National Dairy FARM Program Animal Care, including 98% of dairy farms in MN and 95% of dairy farms in WI (The National Dairy FARM Program, 2021). This program requires a minimum level of veterinary involvement on dairy farms.

We conducted 14 focus groups between April 2017 and March 2020: 5 with farmers, 4 with hoof trimmers, and 5 with veterinarians. To be eligible for recruitment, farmers had to be the owner or manager of a dairy farm, hoof trimmers had to be full-time commercial hoof trimmers, and veterinarians had to be full-time practitioners

working primarily in dairy practice. The recruitment process, location, and general focus group characteristics are presented in Table 1. Focus groups were held in Minnesota, Wisconsin, and New York. Most focus groups were held at existing conferences or meetings (n = 9) and we recruited participants from meeting attendees. Focus groups were advertised via email prior to the meetings and included in meeting agendas. We also contacted hoof trimmers and veterinarians through professional networks to invite them to a workshop on lameness management (n = 3 focus groups). We held the focus groups prior to presenting the workshop content. Finally, we also recruited individual dairy-focused veterinary clinics through professional contacts and held a group with all the veterinarians in that clinic (n = 2 focus groups). All participants were paid an honorarium of $50 for their participation. We sought for a range of 4 to 8 participants per group based on recommendations for thematic analysis using focus group data (Braun and Clarke, 2013).

3.3.4 Data collection

We developed and pre-tested a questioning guide prior to data collection with small groups of hoof trimmers, veterinarians, and veterinary students. The questioning guide was composed of a series of open-ended questions and follow-up probing questions (Appendix 3.1). Questions focused on eliciting participants' attitudes toward and perceptions of lameness, challenges or barriers they faced in lameness prevention and treatment, and their view of their own and other stakeholders' role in lameness management. Participants were also asked about their experiences with lameness extension programs and what they would need or want from an extension program (responses from these questions are not presented in this paper). Question wording was

adjusted slightly depending on the respective stakeholder group. Prior to the discussion, participants were briefed on the aims of the project and consented to participating. All focus groups took place in quiet, private locations and lasted approximately 1 to 2 hours. A single trained facilitator (EW) moderated all focus group discussions. Immediately following each focus group, the facilitator wrote memos to capture group dynamics and key impressions (Birks et al., 2008). All focus groups were digitally audio-recorded and transcribed verbatim by a professional transcription service.

3.3.5 Data analysis

Following transcription, transcripts were checked for accuracy against the original audio by the first author (EW). Thematic analysis, a qualitative methodology used to identify, analyze, and report patterns in written data, was used to analyze the transcripts (Braun and Clarke, 2006). The first author (EW) read and re-read the transcripts and made initial notes, labels, and reflective memos. The transcripts were then coded inductively, a process of assigning labels and categorizing content. Initial codes were discussed with other authors (BV, SR, GC) and refined. Throughout the process, we worked on one stakeholder group at a time (e.g., coding only the veterinarian transcripts before moving on to the hoof trimmer transcripts). Once initial codes were developed for each stakeholder group, we then considered all the stakeholders together and searched for similarities and differences in the codes. We were interested in where the experiences of stakeholders overlapped and where they were unique. EW, in consultation with BV and SR, then organized the codes into broader themes. The themes were then checked across the transcripts to evaluate their depth and robustness. After reflecting on the initial themes through the transcripts, EW, SR, and BV

decided on the final themes and written theme descriptions. Throughout the analysis, EW wrote memos to explore and reflect on the data. All labeling and coding was done using the program Quirkos (Quirkos; Quirkos Ltd.).

Quotations are presented below as examples of the themes and to incorporate the participants' own voices when describing them. Ellipses indicate where text was omitted, square brackets indicate the authors' additions for clarity, and quotes are labeled by participant ID. The letter indicates the focus group and the number indicates the participant (e.g., Veterinarian B3 was participant 3 from veterinarian focus group B).

3.4 Results

Focus group interviews ranged in length from 46 to 86 min (median length = 61 min). In total, 31 farmers participated, all based in MN, with tiestall or freestall barns and herd sizes ranging from 28 milking cows to 1,200 (median size = 100 cows). Twenty-four farmers identified as men and 7 as women, ranging in age from 27 to 77 (median age = 51). The median number of years dairy farming was 30 (range of 5-55 years). We had 32 hoof trimmer participants with an age range of 22 to 73 (median age = 40), all men. Eleven hoof trimmers were from MN, 9 WI, 2 ID, 2 MI, 1 PA, 1 NY, 1 GA, 1 OH, 1 CT, and 2 unknown. The median number of years hoof trimming was 16 (range of 1-47 years). Lastly, 25 veterinarians participated (17 men, 8 women) aged 26 to 66 (median age = 43). Eighteen practiced in MN, 5 in WI, 1 in CO, and 1 in IA. The median number of years in practice was 18 (range of 1-41 years).

3.4.1 Thematic analysis

Themes were organized around two questions: what are the primary barriers in lameness management? (Theme 1) and what are the barriers and motivators in lameness management related to roles and expectations of others? (Theme 2). Theme 1 provides a descriptive framing of participants' views toward lameness as a management challenge (subthemes: lameness as complex, farm-to-farm variation), while Theme 2 captured stakeholders' role in lameness management (subthemes: perception of own role, expectations of others). Figure 3.1 provides a thematic map depicting the themes, subthemes, and relationships. In our thematic analysis, there was substantial overlap between hoof trimmers and veterinarians as they share a role as farm advisors; therefore, when a subtheme explanation is relevant to both hoof trimmers and veterinarians, we describe them as farm advisors.

3.4.2 Theme 1: Lameness as a management challenge

Lameness was acknowledged as an important, critical challenge by all stakeholder groups. Participants focused on a few specific conditions: white line lesions, sole ulcers, abscesses, foot rot, and digital dermatitis. The most commonly discussed lesion was digital dermatitis; for example, Farmer D7 said, "*If it wasn't for hairy warts [digital dermatitis], I don't think it would be as big of a problem."* Regardless of condition, stakeholders worried about lameness due to its economic significance. For example, participants noted the cost of preventative measures: "*They can spend as much on hoof products as they do on veterinary products total. Easy. Or more...that's a hell of a lot of money,*" (Veterinarian B2). Participants also discussed the economic impact of production losses from lame cows, as Hoof Trimmer D6 said, "*It's like—you're seeing the cost of us trimming it, but what you're not seeing is the milk loss and the unhealthy cow,*

and you end up shipping her; it's the long-term costs that you're losing." The time and labor involved in lameness management were also a concern as described by Veterinarian A2 as they worked to solve a lameness issue on a farm: *"It takes a lot of time and a lot of effort."* Similarly, Farmer A4 shared, "...*pretty much do all the work myself. Time is an issue.*" Though discussed less frequently, lameness was also viewed by some participants as important due to the cow being in pain and subsequent impact on cow welfare. For example, Hoof Trimmer C1 said, "*...this cow is living in pain to put milk in your bulk tank. It ain't right,"* while Veterinarian E5 explained, "*I tell them [farmers] lameness is, if not number one, it's getting there as far as welfare concern in the industry and that this is something they need to pay attention to."*

3.4.3 Lameness as complex

Lameness was viewed by participants as a complex management challenge, perceived differently by different stakeholders, and one in which the connections between pathogenesis, facilities, and management were not always well understood or easy to change. The complexity stemmed from a number of different factors, including: the lack of agreement on a definition of lameness, normalization to the signs of lameness, the interconnectedness of lameness with other health and management issues, and the multifactorial nature of lameness, which ultimately appeared to contribute to resignation by participants that lameness was inevitable.

Differing definitions. Participants described having differing definitions of lameness and what signs constituted a lame cow, particularly between advisors and farmers. Hoof trimmers expressed picking up on more subtle signs of lameness than the farmers they worked with. For example, Hoof Trimmer D7 said, *"It's getting on the same*

page on the definition of lameness, some people are a little bit too loose with the term that it's—a lame cow is not a cow that won't get up. A cow that won't get up is a dead cow. A cow that you can tell she's uncomfortable on her feet or she's dancing a lot, her balance is off, bruising. There's wide variation of lameness that a lot of people don't recognize as lameness."

Normalized. Veterinarians and hoof trimmers agreed that farmers did not always notice the lame cows in their own herds and that lameness could become commonplace or normalized. Hoof Trimmer D1 commented, "*They get used to it. They get used to seeing it."* while Veterinarian E5 stated, *"But with lameness, I think they've just gotten used to seeing it and haven't maybe appreciated the big deal that it really is."* As outside observers to the farm, advisors felt it was easier for them to notice lame cows, for example, Hoof Trimmer A3 said, *"...it takes lameness a lot longer to develop and it's so incremental...unless you're new eyes coming onto the place looking around...everyone else thinks it's business as usual."*

Connected to other health problems. Lameness was also viewed as complex because of its close relationship to other health problems. Participants viewed lameness as a risk factor for other diseases. Farmer A3 said, "*Many times I'll have a fresh cow that has a twisted stomach. You go look at her and, oh, she has a sore foot, or you got a cow that's not expressing heat. Well, she's got a sore foot...so much of the time, it's the underlying factor for a lot of other health issues I guess I see on my farm."* Lameness was seen as a cause of subsequent metabolic or production issues, since a cow who cannot move easily will struggle on the farm, as voiced by Farmer E4, *"Lameness probably dictates your metabolic issues, your mastitis, your repro, everything. So, [she] can't get up and eat, [which] starts the whole thing."*

Advisors described lameness as multifactorial, with the causes and solutions not readily apparent. Veterinarian A5 said, *"If you have 15 percent of cows that have some level of ambulation trouble, why? Maybe it's one thing. Maybe it's three. You don't know."* Participants acknowledged that there are many facility, management, and farmer decisions that contribute to lameness on a farm. Hoof Trimmer B4 said, *"...you have a farm that is focused on cow comfort, cow care, and healthy animals, or you have a farm saying we need the dollars, we're going to cram them in there, we're going to pack them through. So the variables are the key thing."* Veterinarians were particularly frustrated by the multifactorial nature of lameness and the lack of simple answers to give to clients. For example, Veterinarian E4 said, *"...when you can't give a farmer a straight answer...When you can't just say, 'This is the answer, boom'. They're like, 'I'm not wasting my time.' So how do you try to convince them that the latest research is the way to go at the moment?"*

The complexity of lameness and the management challenges presented also appeared to contribute to a feeling of resignation amongst farmers, as Farmer E4 shared: "*Yeah, I believe it's the number one issue on the farm. Because if you've got concrete, you've got lameness and there's no way around it. How do you manage it? No idea."* Frustration that lameness management was an endless burden was a common theme, captured by Farmer B1's lament: "*I mean all we're doing is repetitiveness with treating and treating and treating and treating. Treating and trimming and treating and trimming, but unless you can make them that their hooves don't grow...that's it."*

3.4.4 Farm-to-farm variation

Advisors agreed there was a great deal of variation among farms, with some struggling with lameness and some managing it successfully. Hoof Trimmer B1 said, *"It varies on the farm, it varies on the producer. Lameness can be a very intense problem at one dairy and two miles down the road it's a non-issue. So there are so many variables."* Advisors saw a number of reasons for variation among farms, including farm facilities and farmer mindset. For example, Veterinarian E2 said, *"...new facilities have decreased lameness, but it's still an individual thing, how they pay attention to it. We can go to brand new barns and find one guy that just has a horrid problem with it, but he can ignore it. And then we can—the other guy who's in tune to it, he can have less facilities and still manage it much better. I don't know if it's—lameness is kind of like manure. It can pile up or it can get hauled out, [laughter] for lack of a better description."* Advisors also saw the prioritization of lameness by farmers as an important factor. Hoof Trimmer D5 said, *"…the producer needs to take a lot of responsibility to keep those feet in check.*" Some farmers also noted the variation, for example, Farmer B10 said, *"Some places have absolutely nothing and the next place is the same situation and full blown,"* but most spoke about their own farms and their own experiences.

3.4.5 Theme 2: Role in lameness management

Overall, no single experience of lameness emerged from the discussions; rather, advisors and farmers shared that farms experienced lameness management differently depending on a variety of internal and external factors. Throughout the discussions, participants highlighted how multiple people have a role in lameness management and that lameness management is a shared responsibility.

3.4.6 Perception of own role

Farm advisors (hoof trimmers and veterinarians) discussed their role in lameness management as three-fold, encompassing the day-to-day farm level technical work and management, a consultative role that was more people-focused, and a role in advocating for the welfare of the cows.

Advisors - Technical Role. The technical work for hoof trimmers consisted of maintenance trimming, treating lesions, and record keeping, as described by Hoof Trimmer A5, "*I always think there are three 'I's to hoof trimming: identify the cow; investigate; induce treatment."* Most hoof trimmers viewed maintenance trimming as an important part of their role in preventing lameness; for example, Hoof Trimmer D5 said, "*For me, I run a really strict protocol for maintenance, and I won't trim for a farm that doesn't want to do strict maintenance because I don't want to be using a lot of blocks. I don't want lameness on my herds, and it's much easier to just go trim and not repair*."

For veterinarians, the technical role varied from treating individual cows, to monitoring footbath practices, to looking for lame cows while at the farm doing other tasks. For example, Veterinarian E3 said, "*...for a handful of those smaller clients, it's still to come out to the barn and pick up the foot and clean it up, open the abscess, and put a block on it.*" and Veterinarian C1 said, "*Verifying foot bath protocols. Making sure they're still doing what they were doing last month or six months ago. Checking products.*"

Advisors – Consultative Role. In their consultative roles, advisors shared how they discussed prevention strategies, assisted with goal setting, provided education, and monitored data. This consultative role was people-focused, with advisors describing their efforts to initiate discussion on lameness management or answer farmer questions. For example, Veterinarian D2 shared, "*I think at a base level, we do walk pens frequently so*

to identify severely lame cows. But, then, also to have a discussion about why those cows are there. And what might be done about the fact that there are lame cows," while Veterinarian E1 said, "*I think we have a role too as far as educating how lameness occurs.*" Hoof trimmer comments echoed this people-focused role, as Hoof Trimmer D5 said, "*And like [D7] said it, identifying other stuff, not just being the hoof trimmer, but the hoof care professional for the farm. Identifying, coaching them, opening their eyes to anything that could help them potentially make more money or be more efficient.*"

Advisors - Animal Advocate Role. Finally, some advisors were very explicit in describing themselves as advocates for the animals. For these individuals, this role involved pushing for lameness treatments and prevention to improve the welfare of the cows on the farms they worked with. Veterinarian A4 said, "*...the most important role for the veterinarian [is] being the animal welfare advocate,*" while Veterinarian B5 shared, "*You don't just leave them be until the hoof trimmer [arrives]...In reality, that is not very humane and I think we need to instill some cow-care in these animals.*"

A few hoof trimmers similarly raised this theme; for example, Hoof Trimmer D5 said, "*Yeah, the animal welfare. I've told some farms. I said if these were dogs, you'd be in prison. If you had a dog get this bad, somebody got a picture of that, you go to jail for that. And I know that's pushy and that's risking getting pushed right off that farm, but on the same hand, somebody's got to speak for the cows. They can't speak for themselves."*

At the same time, advisors also acknowledged the limits of their role in resolving lameness. Hoof trimmers, for example, noted that they alone are not the solution to lameness, as stated by Hoof Trimmer C4: "*I think we all need to keep in mind that some guys put too much pressure on themselves to be the sole solution for lameness. I think*

we have got to keep in mind that that's not possible, not feasible. We need to see it's a whole industry collaboration to improve it. Not just us." Meanwhile, veterinarians acknowledged being faced with limitations on their time and attention (i.e., needing to serve other roles) and that they often were peripheral in importance compared to hoof trimmers, as voiced by Veterinarian D4: "*...there's so many other things that we're focusing on when we're on a farm or trying to help manage at the farm or help the herdsmen manage their farm...lameness kind of falls to the sideway.*" This issue was echoed by Veterinarian B2: "*Now they have somebody to take care of the acutely-lame cows, the chronic-lame cows, the routine hoof trimming well, what's left?... Once again, as many things in veterinary medicine, we hand off these problems to other people, right? That's okay, but then sometimes it's difficult to get back in that loop.*"

Farmers. In contrast to the relatively lengthy time spent in discussion of advisors' own perceived roles in lameness, farmers spent less time articulating their roles. For example, Farmer D3 stated their role in lameness management was to "*identify and fix.*" Generally, farmers envisioned their role as one composed of daily tasks and took ownership and responsibility for the health of their cows, as captured by Farmer A1, "*I'm the one who gets to fix them*" and Farmer D5, *"Do what I can to help her out—alleviate the pain."*

Similar to their advisors, farmers also discussed their role as technical and people-focused. Technical tasks included observing cows, treating lame cows, running footbaths, organizing lists, while people-focused roles included employee management and consulting advisors. For example, Farmer E4 said, "*When you're walking, does it feel right? If it's slippery, make it a big deal. Hey there's something wrong here, let's make sure we mark that to get it grooved up more. So that's our role, is just prevention,*

prevention, prevention." Farmers also managed scheduling herd visits with advisors and sought counsel from advisors. For example, Farmer D3 said, "*Call the hoof trimmer and schedule him to come and identify our—and sort the cows off that need to be trimmed or worked on*."

3.4.7 Expectations of others

Farmers' expectations of advisors. Farmers often viewed the role of hoof trimmers and veterinarians in lameness management as being different, and seemed to look much more to hoof trimmers for lameness support. For example, Farmer E4 said, "*I just put more emphasis on the hoof trimmer. That's their problem and their responsibility*." Farmers relied on the hoof trimmer to be another set of eyes and expected hoof trimmers to make connections between hoof issues and herd-level changes. Farmer A4 said, "*He or she [the hoof trimmer] also should see what patterns they see across the herd or changes from the last month they were there or season they were there or whatever. It shouldn't just be fixing cows and leaving the farm and see you next time. It's got to be—we expect more than that from our employees.*"

Though some farmers valued the veterinarian in investigating herd-level issues (e.g., as Farmer A3 said, "*I think a good vet can help spot issues and reasons why you are having problems and help you with that more than fixing feet,*"), farmers more commonly voiced that they found veterinarians to play a limited role in lameness management. As Farmer B2 expressed, *"Most of the vets I deal with, he'll tell you get a hoof trimmer and be done with it, because for what it's going to cost him to do it he said it's not worth it"* and Farmer B6*, "I don't think most vets look forward to come out if you tell them it's a hoof."*

Farmers did appreciate that advisors travel to multiple farms and could learn and share what other farms have tried and what had worked. This knowledge was particularly valued for its practicality, as it came from other farmers experiencing similar problems and constraints. For example, Farmer D6 said, "*Sometimes, just having them—someone like the vet, who's been to umpteen different farms. And if you're willing to listen to them, and ask them, what do you see that could be done? Probably be one of the best things you could do.*" However, though the majority of farmers worked with a veterinarian and hoof trimmer in some capacity, facilitated collaboration between veterinarians and hoof trimmers was limited. For example, Farmer C2 said, "*We work with the veterinarian and we work with the hoof trimmer, but not together.*"

Advisors' expectations of farmers. While advisors expected farmers to take responsibility for lameness and proactively work toward solutions, they also appreciated that farmers faced barriers in lameness management, particularly related to time, money, and labor resources. As shared by Veterinarian B6, "*They [farmers] have X amount of time and they're going to put it where they think they can see those—it's probably up to me to be as much proactive and say, 'well, you can gain a lot by this' and keep hammering it home...It still ends up being their decision where they're going to put their time and effort and what time they've got.*" Advisors empathized with the workload of farmers and understood that making a management change may be low priority if a farm was struggling financially or otherwise, as Hoof Trimmer C4 shared, "*I see too some of my managers are just so overworked, and they don't realize it, but you can't give from a cup that's half full. So then when we go and have suggestions or try to get a moment of their time to explain or talk about the day."*

At the same time, advisors were also frustrated due to their view of farmers as a key bottleneck in lameness management. Advisors reported running into farmer-level barriers, such as giving advice that is not listened to or farmers who are resistant to change. For example, Veterinarian E5 commented, "*You get kind of tired of seeing the same thing over and over again and nothing changes... It's frustrating.*" Many felt that, ultimately, the decisions on the farm come down to the farmer and there is only so much advisors can do. For example, Hoof Trimmer C5 said, "*Like everybody has said, we can pick them out. We can talk to them. We can try to teach them. We can try to do as much as we want, but at the end of the day it's still their herd of cows and it's our business to come into their herd, do our job.*"

Some hoof trimmers wanted to be more involved in management decisions around lameness control. Hoof Trimmer A5 said, "*Sometimes I don't think farmers give enough respect to the hoof trimmers, that [we] can help in things besides wrapping a foot or blocking it."* This was also described by Hoof Trimmer C4 as a desire to be included in management meetings with farmers and their advisors, "*I think everybody that trims feet needs to push to be a part of those meetings because if we can learn what's going on and the reality is too...you're probably on that farm just as much as anyone else in that meeting*."

Advisor expectations of other advisors. Advisors acknowledged that veterinarians and hoof trimmers have different technical roles in lameness management and that their people-focused consultative roles overlap considerably. Advisor discussions encompassed both the negative (potential for conflict) and positive aspects of working together (being on the same page, alignment in recommendations and goals).

While advisors ideally wished for goal alignment and collaboration between hoof trimmers and veterinarians, many expressed uncertainties about the degree to which they should 'stay in their own lane.' This uncertainty hindered their confidence in trying to reach out to collaborate cohesively, as Veterinarian C4 said: "*I think it [veterinarians asking hoof trimmers about hoof health] is probably in the same room as the hoof trimmer asking us about repro protocols. We'd probably get defensive about the same thing because that's what we're very good at. So it's just how comfortable are you with what you know...Are you willing to work with them, or are you going to be reserved and stay-in-your-lane mentality?"*

Compounding the difficulty of establishing collaborative relationships, many advisors were critical of others' knowledge, education, and intentions relative to lameness management. While some advisors acknowledged the variation among individuals (for example, Hoof Trimmer A5 said, "*I think veterinarians are about as diverse as hoof trimmers. You've got some that want hands on with you and are there...Then you have others that tell their clients, 'Call a hoof trimmer'...others that don't want anything to do with you period.*"), a common refrain among both veterinarians and hoof trimmers was skepticism of the others' expertise. For example, Hoof Trimmer A5 shared, "*I think hoof trimmers know more on the foot than a vet. That's not degrading vets because they have to look at a lot more than we do. I think we have to work together and vets have to respect hoof trimmers in that regard and most of them do. If they don't, I think they should because we do have some expertise in that area.*" Some hoof trimmers wanted veterinarians to prioritize lameness management to a greater extent than they were perceived to do. Hoof Trimmer B9 said, "*What I don't understand is these veterinarians coming into these herds for herd health quite a bit, and they see all*

these lame cows and rarely do I see them telling the farms you should maybe trim a few more cows and—". In contrast, some veterinarians were dismissive toward hoof trimmers: for example, Veterinarian E6 said, "*Yeah, with the hoof trimmers, we've all gone to graduate school. We're all professionals, we've been trained. So, when you deal with hoof trimmers and the relationship with them, I mean, they've gone to training, they've done that. Not to the level that we have, but are they taking their knowledge or are they just coming out there and trimming feet and trying to put as many wraps and blocks on as possible to dollar up the bill?*"

Though advisors clearly expressed barriers in working collaboratively on lameness management, not all discussion was focused on complaints. Advisors also commonly expressed their desire to work together and their hope for improved relationships built upon mutual respect. For example, Hoof Trimmer A6 shared that, "*I think the vets are actually learning too, that the hoof trimmers are a major role...They actually work with us more, but they also recognize our profession is educated more on that than the vets, especially the schools we go in and teach at, they respect us just as much as we respect them.*" Veterinarian E5 summarized this as well, stating: "*I think hoof trimmers respond well too if you come at it as a team approach. I'm not better than you, I'm not superior, my knowledge isn't superior...the struggles that I'm having in having the conversations with the producers are the same exact ones that they're having. And so, if we can kind of brainstorm what is the number one concern? What should we kind of address together and approach the producer together as how to do this? Sometimes two voices are better than one.*"

The ability to deliver a consistent message through collaboration was particularly compelling, with some sharing examples of past successes through this approach. For

example, Veterinarian B6 said, "*I think with the more communication you have with the hoof trimmer, you get more of a pulse of what's actually going on in the dairy.*" Similarly, Hoof Trimmer D7 reported a successful collaboration with a veterinarian: "*I work with one vet...If he sees something, he'll shoot me a text and he'll say, 'Hey, I'm kind of seeing this. Are you seeing anything on your end?' Or vice versa."* Finally, participants emphasized the importance of communication, as Hoof Trimmer C4 said, "*If we can all talk with each other, we can deliver a consistent and concise—most importantly concise—message to the farmer.*"

3.5 Discussion

The goal of this work was to explore perceptions of lameness and barriers to improved lameness management among dairy farmers, hoof trimmers, and veterinarians. The results of this study highlight the complexities of managing lameness, the barriers stakeholders face, and stakeholders' perceptions of their own role and their expectations of others in lameness management.

3.5.1 Perceptions and barriers of lameness management

Participants discussed barriers that apply to the management of many diseases in dairy cattle, including time, money, and facility limitations. These physical resource barriers have been well characterized related to the management of lameness (Leach et al., 2010; Dutton-Regester et al., 2019) as well as other dairy cow diseases (for example, Johne's disease; Roche et al., 2019). Participants also discussed challenges that were specific to lameness, such as: having no way to easily monitor lameness, dealing with multiple lesion types with different causes, and control measures that can

be difficult to implement. In addition, because lameness can be chronic, it may take a long time to see a benefit of a control measure. Participants also observed that the costs of lameness are indirect and can be difficult to observe, particularly when compared to more apparent direct costs, e.g., milk down the drain in the case of mastitis. Though the cost may be difficult to observe, lameness is clearly costly (Bruijnis et al., 2010; Dolecheck et al., 2019). Making farmers aware of these costs is one approach to improve motivation, though cost-effectiveness is only one of many factors that farmers weigh when considering management changes (Ritter et al., 2017).

Despite the many challenges faced in lameness management, some farms manage lameness successfully and have few lame cows. Lameness prevalence varies widely (anywhere from 3% to 80%; von Keyserlingk et al., 2012; Cook et al., 2016). This wide range in lameness prevalence was echoed by our participants, as advisors discussed large farm-to-farm variation in lameness issues. Advisors viewed differences in farm facilities, the management attention that lameness received, and farmer mindset as reasons for the variation they saw in lameness prevalence. This observation by our participants is supported by literature emphasizing the importance of housing and housing management (Chapinal et al., 2013; Adams et al., 2017) and farmer perception and prioritization (Leach et al., 2010; Bruijnis et al., 2012).

An important finding from this study is that advisors described experiencing normalization of lameness, i.e., that lameness can become commonplace on farms and not recognized by farmers. Acceptance of a certain level of disease by stakeholders on farms has been previously documented (Tremetsberger and Winckler, 2015; Sumner et al., 2018). Croyle et al. (2019) described this issue as ‘barn-blindness’, defined as a lack of perception of problems in one’s own herd. Multiple diseases and welfare issues can

become normalized, but this challenge may be particularly relevant for lameness management, as the primary way to diagnose lame cows is through visual observation. The lack of objective lameness detection methods may play a role in normalization, as farmers, hoof trimmers, and veterinarians may have different definitions for what lameness looks like and when a cow may benefit from treatment. Farmers have been shown to underestimate lameness on their herd (Espejo et al., 2006; Higginson Cutler et al., 2017) but it has been hypothesized the difference may be due to differing definitions of lameness among different stakeholders, with farmers looking at the balance of evidence over weeks and months and considering cow history, whereas trained assessors examining a one-time visual locomotion score (Eriksson et al., 2020). Farmers may also use different language to describe lame cows, for example using ‘impaired mobility’ rather than ‘mildly lame’ (Horseman et al., 2014). Though we did not specifically ask our participants to explain their definition of lameness, advisors did point to different definitions between farmers and advisors as a barrier. Both differing definitions and normalization may slow changes in lameness management, as farmers cannot change an issue that is not seen or recognized. Both farmer and advisor participants noted this area offers a role for advisors: to notice and bring attention to lameness issues going unseen by the farmer. However, it is likely advisors can also become accustomed to seeing lameness, as veterinarians have also been shown to underestimate lameness (Denis-Robichaud et al., 2020). Opportunities to better identify and monitor lameness on herds include emerging technologies to offer objective assessments (Alsaaod et al., 2019), routine training for more consistent assessments (Croyle et al., 2018), and benchmarking (von Keyserlingk et al., 2012).

The complexity and magnitude of the lameness problem on their farms appeared to leave some farmer participants with a feeling of inevitability. This described feeling of resignation to the inevitability of lameness may result in ambivalence towards making changes focused on lameness or allow complacency to develop. This may impact farmers' willingness to adopt recommendations for improvement. The Theory of Planned Behavior (TPB) is a psycho-social framework that may provide some context for this finding. The TPB has been used to predict behavioral intention or the readiness to perform a given behavior (Ajzen, 1991) and emphasizes the role of perceived control over the performance of the behavior (perceived ease or difficulty in performing the behavior). The more barriers to controlling lameness one perceives, the lower one's level of perceived behavioral control. Control beliefs are based on past experiences, the presence of needed resources, second-hand experience, and perceived barriers (Ajzen, 1991). In our study, farmers who discussed digital dermatitis lesions as the biggest cause of lameness on their farms also reported that the barriers to improved control were very high, e.g., difficulties in running a footbath, the cost of treatment, and difficulties in changing manure management. These barriers may lead to low perceived behavioral control and a low willingness to adopt recommendations for improvement. It should be noted that TPB has been criticized for its focus on framing individuals as sole-actors and external factors (e.g., cultural, regulatory, interpersonal) as being important to the extent that they influence the individual (Shortall et al., 2016). Further work should continue integrating the individual, interpersonal and contextual barriers. Previous research has shown the barriers that farmers face in reducing lameness on their herds include: low detection, a high tolerance of lameness, lack of awareness of the welfare impact of lameness, and other herd health issues being given priority (Leach et al.,

2010; Sadiq et al., 2019). As our understanding of these barriers increases, more attention must be paid to developing tailored interventions to address these specific barriers and support farmers and advisors in adapting or changing existing lameness management practices.

3.5.2 Roles of stakeholders

Multiple stakeholders are involved in lameness management and hence we chose to include farmers, hoof trimmers, and veterinarians in our study. Engaging multiple stakeholders is needed to create and support partnerships and ensure long-term viability of organizations, plans, and programs (Bryson, 2004). Our participants described how the tasks and management of lameness were shared by farmers, hoof trimmers, veterinarians, farm staff, nutritionists, and others. These different stakeholders bring unique insights into issues and solutions, and we can harness this to improve lameness management.

Advisors discussed their role in lameness management as threefold: technical, advisory, and animal advocates. These areas overlap and within a single interaction they may navigate all three. Though not all advisors brought up animal welfare, some of our participants felt very strongly about their role in improving welfare and pushing farmers for improved welfare practices. They discussed emphasizing the poor welfare caused by lameness as a way to encourage farmers to see lameness management as a priority. Several hoof trimmer participants described a choice to use the language of pain and suffering when pushing farmers to make a lameness management improvement. Studies have demonstrated that farmers consider pain and suffering of lame cows as a motivating factor for making on-farm changes (Leach et al., 2010; Croyle et al., 2019),

though lameness, particularly mild cases, is not universally considered by farmers to be painful (Bruijnis et al., 2013). More work is needed to better understand welfare as a motivating factor with respect to lameness management.

The role of the veterinarian within health management has been discussed, often through the lens of a shifting role, from offering medical care to individual animals to a more consultative role (LeBlanc et al., 2006). Veterinarians are trusted sources of information, both on health and welfare (Ritter et al., 2017). Both veterinarians and hoof trimmer participants saw a role for veterinarians to be more involved in lameness management, which aligns with our farmer participants largely reporting that veterinarians were not involved in lameness management on their farms. The treatment of certain hoof lesions can be considered a medical procedure and veterinarians can be further involved in developing treatment protocols, especially for lesions that require antimicrobials and pain control. Veterinary involvement is not an area for improvement limited to lameness. Mills et al. (2020) found veterinarian involvement in transition period management could be improved and increased access to veterinary advice has been shown to be beneficial in managing Johne's disease and improving calf welfare (Ritter et al., 2015; Sumner et al., 2020). One study has demonstrated that increased veterinarian or advisor involvement improved lameness outcomes (Main et al., 2012; Whay et al., 2012). Taken together with previous work, our findings point to the need for further involving veterinarians in both individual animal and herd-level lameness management strategies on farms.

Hoof trimmers also have an important role in lameness management, though little research has included hoof trimmers beyond collecting lesion or billing data (Solano et al., 2016; Dolecheck et al., 2018). Becker et al. (2013; 2014) surveyed Swiss hoof

trimmers on their attitudes towards painful therapeutic hoof-trimming of dairy cattle. Participants in our study described hoof trimmers as very commonly used and relied upon for lesion detection and treatment. Participants additionally described hoof trimmers as valued and trusted sources of lameness management information and advice. Croyle et al. (2019) similarly reported that farmers trusted hoof trimmers and held their opinions and recommendations in high regard. Furthermore, both our farmer and veterinarian participants largely placed the responsibility of complex lesion treatments on hoof trimmers. Due to their clear importance as advisors in lameness management, there is an opportunity to increase collaboration between hoof trimmers and other lameness management stakeholders, as well as further include hoof trimmers in lameness research and extension activities beyond data collection.

3.5.3 The need for increased stakeholder collaboration

In this study, participants spoke about success stories of working together, and how the match of a farmer with a skilled and invested advisor can lead to beneficial changes. Participants discussed valuing being part of a team, both in an acknowledgement that the task of lameness management cannot be done alone, but also that multiple voices can provide ideas, motivation, and support. Lameness research from the Healthy Feet Programme in the UK showed some evidence that collaboration between advisors and farmers can reduce the prevalence of lameness (Main et al., 2012). Increased dairy farmer-veterinarian cooperation has been shown to be beneficial in other areas of dairy health management (Ritter et al., 2015; Sumner et al., 2020). Collectively, this work suggests cooperation between these stakeholders is key to improving lameness management.

Stakeholder collaboration is not without potential areas of disagreement and conflict. Bell et al. (2009) highlights that a multi-stakeholder collaboration in lameness management can indeed fail, though the reasons that program did not succeed are unclear. The conflicts described by our participants appeared to stem from expectations of one another that were sometimes unfulfilled. For example, advisor participants described unmet expectations of farmers, viewing farmers as a bottleneck in lameness management and wanting farmers to take their advice and make changes. Advisors who feel this is a barrier may need to tailor their communication approach to individual clients. Lam et al. (2011) described that effective communication with farmers must take into account different learning styles, be proactive, be realistic, and offer personalised messages. Advisor participants also reported conflicts with other advisors over differing expectations of roles and responsibilities. Advisor conflicts can be further complicated by their different commercial interests. As we continue to explore how to develop stakeholder teams with unified goals, farmers can and likely need to be the champions of the team approach as they are paying these independent advisors. That said, advisors should bring ideas to the table in an effort to be proactive and have more impact. Future work on improving lameness management on dairy farms should explore specific strategies to improve stakeholder collaboration.

3.5.4 Limitations

This study offers many insights into stakeholder perceptions and experiences with lameness management, but it has several limitations. The majority of discussion was based around barriers and challenges in lameness management, a result of our problem-centric research approach (Boyd and Bright, 2007). We framed lameness as a

problem in need of solving and questions were more focused on understanding participants' perceptions of difficulties rather than successes. Our themes are thus representative of our focus group discussions and we acknowledge that a different framing on positives, successes, and motivators would yield different responses.

We recruited the majority of our participants at meetings, conferences, and workshops. It is possible that they were more informed on the topic of lameness or more progressive in their thinking than stakeholders who do not typically attend these types of events. Wherever possible we held our focus groups prior to the conference or workshop programming, but in 8 instances the timing of groups was outside our control. This is a limitation, as participants may have been exposed to conference or meeting information on lameness and hence may have been primed to focus on certain topics. However, we do not believe this to be a large source of bias because the question guides encouraged participants to focus on their own experiences. Additionally, for a single hoof trimmer focus group (in NY) we recruited participants from a national conference, and therefore the hoof trimmer participants were from a wider geographic area than other participants. However, upon analysis the participant experiences in this group aligned with the themes found among our other groups, and so we elected to include them in this report.

We also recruited veterinarians who practiced at the same clinic and we might expect some of their thoughts to be clustered by clinic, as they may have talked about lameness management as a clinic or have taken continuing education programming together. That said, each veterinarian has their own clients, their own unique experiences, and have formed their own opinions and views on challenges and best practices. We also had two veterinarians who participated in two different groups; this was allowed in one instance to benefit the participant and in the second it was not

noticed until after the group had finished. We note that these individuals did not dominate the discussions and that effort was made to ensure that the codes and themes resulting from analysis were representative of all focus groups.

3.6 Conclusions

In summary, dairy farmer, hoof trimmer, and veterinarian participants in this study viewed lameness as a highly complex management challenge. Participants highlighted that multiple stakeholders have a role in lameness management and found lameness to be a shared responsibility on a dairy farm. Increasing farmer, hoof trimmer, and veterinarian communication and collaboration in making decisions may help achieve improvements in lameness management.

3.7 Acknowledgments

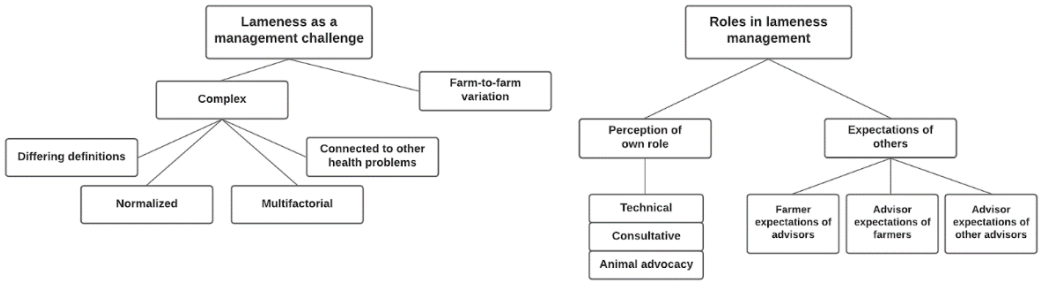
The authors thank the participants for contributing to this study, as well as all who helped in arranging focus groups. This work was supported by the Minnesota State Legislature through the Rapid Agricultural Response Fund managed by the Minnesota Agricultural Experiment Station (St. Paul, MN, USA). The authors have not stated any conflicts of interest.

Table 3.1. Focus group stakeholder category, meeting type, and date for 14 focus groups: 5 with farmers, 4 with hoof trimmers, and 5 with veterinarians. Focus groups were held in Minnesota, Wisconsin, and New York, USA from April 2017 to March 2020.

Stakeholder category	Location	Event Type	Number of participants	Date	Length (min)
Veterinarian	MN	Regional conference	5	Apr 2017	80
Veterinarian	MN	Regional conference	6	Feb 2018	54
Veterinarian	MN	Veterinary clinic	5[1]	Dec 2019	50
Veterinarian	WI	Veterinary clinic	5	Jan 2020	56
Veterinarian	MN	Workshop	6	Jan 2020	71
Hoof Trimmer	NY	National conference	7	July 2017	86
Hoof Trimmer	WI	Regional conference	9	Feb 2018	71
Hoof Trimmer	MN	Workshop	8	Dec 2019	69
Hoof Trimmer	WI	Workshop	8	Jan 2020	67
Farmer	MN	Regional conference	5	Nov 2018	66
Farmer	MN	Regional meeting	11	Feb 2019	54
Farmer	MN	Regional meeting	4	Feb 2019	53
Farmer	MN	Regional meeting	7	Feb 2020	46
Farmer	MN	Regional meeting	4	Mar 2020	55

[1]Includes two veterinarian participants who attended a previous group.

Figure 3.1. Thematic map outlining the themes and subthemes of thematic analysis generated from 14 focus groups: 5 with farmers, 4 with hoof trimmers, and 5 with veterinarians. Focus groups were held in Minnesota, Wisconsin, and New York, USA from April 2017 to March 2020.



Chapter 4: Promoting advisor engagement and action toward the improvement of dairy cattle lameness

4.1 Summary

Lameness is a major welfare and economic concern in the dairy cattle industry and represents a significant management challenge. Many advisors are involved with lameness management in addition to farmers, including hoof trimmers, nutritionists, and veterinarians. These advisors provide lameness prevention and treatments as well as advice and consulting services, but little is known about how advisors view their work together. This study used qualitative participatory methods to facilitate lameness management advisory groups with aims to 1) have advisors engage with one another to develop lameness action plans and to 2) explore participants' experiences of the groups through interviews and thematic analysis. Thirteen advisors (5 hoof trimmers, 4 nutritionists, 4 veterinarians) from Minnesota, USA were recruited for the project, during which they attended planning meetings, a workshop, lameness advisory group meetings, and developed lameness action plans for 10 dairy farms. Advisors were interviewed at the end of the project to document their attitudes and experiences of the lameness management groups and their interactions with one another. Interviews were audio-recorded, transcribed verbatim, and common themes identified through thematic analysis. Participants widely reported positive views toward the project and voiced appreciation about the quality of discussions and opportunity to connect with other advisors. Participants reported improved communication with other advisors via sharing reports and farm information as well as increased confidence in reaching out to other advisors. Participants noted the challenge of bringing lameness management issues to

the farmer when that may not fit within the farmers' goals or priorities. Participants also questioned other advisors' knowledge and intentions. Despite the challenges, this study shows a promising avenue of facilitating advisor engagement, though more work is needed to determine if further engagement translates to on-farm improvements in lameness management.

4.2 Introduction

Lameness in dairy cattle is a multifactorial condition with multiple causes and areas of management concern. Lameness management best practices include, but are not limited to: keeping infection pressure low through hygiene and foot bathing, low forces on the feet through providing a comfortable environment, and early detection and appropriate treatment for lame cows (Hulsen, 2011).

There are many important stakeholders in lameness management, including farmers, hoof trimmers, nutritionists, and veterinarians. Due to the multiple factors involved, implementing a lameness management change can often involve collaboration between farmers and multiple farm advisors, each of whom may have unique and overlapping roles. A lameness intervention study from the UK has shown that collaboration between advisors and farmers can reduce the prevalence of lameness (Main et al., 2012). Increased dairy farmer-veterinarian cooperation has likewise been shown to be beneficial in managing Johne's disease and improving calf welfare (Ritter et al., 2015; Sumner et al., 2020). Farmer and advisor collaboration has been studied but little information is known about advisors' interactions with other advisors (e.g., interactions between a hoof trimmer and veterinarian working on the same farm, etc.).

Further, we do not know how interactions between advisors limit or promote on-farm changes or priorities.

People taking on advisory or supportive roles in lameness management are of particular interest to involve in interventions, as farm advisors are often trusted sources of information. Veterinarians, for example, provide information on all aspects of animal health and are often key advisors in health management programs (LeBlanc et al., 2006). Farmers also consider their veterinarian to be an influential advisor on animal welfare (Pothmann et al., 2014; Wolf et al., 2016). As the understanding of health and welfare broadens, veterinarians are no longer alone in providing this type of expertise and advice. Hoof trimmers and nutritionists also provide consultative services regarding preventative hoof care, facilities, and feed management. In 2013, 88.6 percent of U.S. dairy herds surveyed performed some degree of hoof trimming, with a professional hoof trimmer employed in 80.2 percent of those herds (NAHMS, 2014). Croyle et al. (2019) reported farmer focus group participants viewed hoof trimmers as a source of lameness management advice, in addition to providing hoof care services. Dairy farms commonly employ nutrition service companies to formulate rations, analyse feed samples, and access feed additives. Nutritionists can also provide further services such as analysing profitability data and management consultation. Previous research including nutritionists has focused on nutritionists' recommendations on ration formulations (Silva et al., 2019). We lack an understanding of both nutritionist and hoof trimmer roles as farm advisors, their interactions with farmers, and their roles in promoting management changes.

As we consider complex dairy farm systems and interventions aimed at human behavior change, it is important to have a high level of participant interest and investment. Participatory research uses an approach where researchers and participants

collaborate to develop lines of inquiry, methods, and the implementation of results (Kidd and Kral, 2005). This approach acknowledges that research efforts to understand or influence the management of agricultural systems will only be successful with meaningful participation of system stakeholders (Carberry, 2001). In lameness management there is a gap between best practices and management on farms. Participatory approaches offer a way to bridge this gap through engaging agricultural communities in intervention planning (Mallonee et al., 2006).

One example of participatory farmer research are “stable schools” or “farmer field schools” where small groups of farmers meet regularly to discuss specific problems and collectively find solutions. Such groups are assisted by a facilitator to aid in administrative tasks (Glanville et al., 2020). Vaarst et al. (2007) developed stable schools for Danish organic dairy farmers that allowed farmers to work toward goals common in the group as well as identify problems and solutions for their own farm specific goals. Program participants reported the stable schools had been valuable and led to herd improvements. Another example of a participatory-approach is Focus Farms, which aimed to change dairy producer behavior to control Johne’s disease in Ontario, Canada (Roche et al., 2015). This program also used trained facilitators and self-directed participant meetings. An example of a lameness control program that used facilitation techniques (using discussion to promote ownership of problems and solutions) to encourage farmer participation is the Healthy Feet Project in the United Kingdom (Main et al., 2012). This program encouraged farmer participants to develop lameness control action points aided by a facilitator or veterinarian (Whay et al., 2012) and the reduction of lameness over time was greater on farms that were monitored and

offered additional support from the research team compared to farms that only received monitoring (Main et al., 2012).

Previous participatory approaches have largely focused on farmers and farmer decision making, but we still lack information on how other advisors work together and how we may be able to harness existing advisor relationships to improve lameness management. Therefore, the objectives of this study were to use a participatory approach to facilitate lameness management advisory groups and to explore our participants' experiences of the groups through interviews and thematic analysis. Specifically, we sought to identify hoof trimmer, nutritionist, and veterinarian participants' perceptions of the positive and negative aspects of the lameness management groups facilitated for the purpose of this study.

4.3 Materials and methods

This study was determined exempt from review (Study Number: 00005789) by the University of Minnesota Institutional Review Board. Participants were briefed on the aims of the project and consented to participating. Participants were also informed of their right to not answer questions or to withdraw from the study at any time.

4.3.1 Positionality statement

Positionality refers to a researcher's worldview and the position they adopt within a study (Holmes, 2020). E.M. Wynands carried out this study as part of her PhD research. She grew up on a dairy farm and has worked with farmers, hoof trimmers, and veterinarians in the area of lameness management through her PhD research but is not a farmer, hoof trimmer, or veterinarian herself. S. Roche is an animal scientist with an

interest in dairy cattle health and welfare, and a consultant who works closely with farmer, veterinarian, and other farm advisory organizations internationally. G. Cramer is a researcher in dairy health management and a veterinarian specializing in foot health. He previously owned and operated a dairy farm. He has been involved in education and outreach for farmers, hoof trimmers, and veterinarians on lameness prevention and treatment. B. Ventura is neither farmer, veterinarian, nor dairy advisor but rather is an animal scientist with an interest in animal welfare and stakeholder communication. We approached this topic with the understanding that farm advisors are experts at what they do and that we can learn from their lived experience.

4.3.2 Theoretical Framework

This study used a small number of participants with the intention of developing knowledge about participant needs and experiences that can be applied to larger lameness intervention programs. By design, this study was not randomized and does not have a control group. We did not intend the results to be generalizable as defined within a positivist paradigm (i.e., that a single reality exists and it can be measured and understood; Denzin and Lincoln, 2000). Rather, we used a critical realist perspective, an integration of the acknowledgment that a real world exists and our understanding of the world is constructed through our perspective and worldview (Maxwell, 2012). This perspective allows us to understand the complexity and context in lameness management decisions. Within this framing, we used participatory methods to gather feedback and modify research activities to accommodate our participants' needs. We entered the project with the aim to promote engagement between farm advisors but we

were flexible on the stakeholders included, activities planned, information and resources provided, and timing of activities.

People weigh decisions based on a complex array of their circumstances, beliefs, and goals (Ajzen, 1991) and many behavioral theories have been developed to predict and influence behavior (Michie et al., 2011). We used the Theory of Planned Behavior (TPB) to inform our project planning, implementation, and evaluation. The TPB has been used to predict behavioral intention or the readiness to perform a given behavior and emphasizes the importance of behavioral beliefs, normative beliefs (e.g., regarding social norms, expectations of others), and control beliefs (i.e., the perceived ease or difficulty in performing a behavior). Extensions of the TPB also include background influences such as personality, previous experiences, knowledge, and culture (Fishbein and Ajzen, 2011). For this study, we focused on the behavior of farm advisors and their willingness to communicate and collaborate with other farm advisors. Our approach was intended to influence peer views or normative beliefs (e.g., through providing opportunities to observe other advisors' care toward lameness) and self-views or control beliefs (e.g., feeling they can make a difference in lameness). We encouraged direct experience with reaching out and collaborating with other advisors. We developed the research activities (e.g., group discussions, workshop) to function as beneficial extension activities for the participants, so they not only participated in research but actively benefitted in the process.

4.3.3 Participant recruitment

This study took place in a region of Minnesota with a high density of dairy farms from April 2018 to February 2019. Further details on the area are withheld to protect

participant anonymity. In total, 13 stakeholders participated; 5 hoof trimmers, 4 nutritionists, and 4 veterinarians. Participants were paid an honorarium of $500 as a recognition of their time attending the workshop, organizing and attending the advisory meetings.

We initially recruited a single veterinary practice via email explaining the project (100% dairy production medicine, n=4 veterinarians at the practice). The veterinary practice was known to GC via professional networks and one veterinarian had previously expressed an interest in becoming more involved in lameness management. The second stage of recruitment involved recruitment of hoof trimmers who worked in a similar geographic area of the veterinary clinic. Some hoof trimmers were known to EW and GC through their participation in other research projects, while others were suggested by the veterinarians at the practice. All hoof trimmers contacted (n=5) agreed to participate.

Two planning meetings were then held in April and June of 2018 (one with veterinarians and one with hoof trimmers). The goal of these planning meetings was to present our vision for the project, elicit participant input about expectations, and clarify any practical considerations moving forward. We also sought feedback on a lameness risk assessment tool (e.g. would they use the risk assessment and how should we modify it) modified from van Huyssteen et al. (2020) and GC's previous work (unpublished). During the hoof trimmer planning meeting, they requested that nutritionists also be involved in the project, sharing that they had strong working relationships with these individuals and that they perceived them to be important lameness advisors. We then asked our veterinarian and hoof trimmer participants to identify potential nutritionists for recruitment and contacted these individuals (n=4

contacted, with 4 agreeing to participate) to invite them into the project. We were deliberate in our recruitment process to ensure the involved advisors had shared clients.

4.3.4 Preliminary survey

After recruitment, all participants completed an online survey hosted on Google Forms with 14 total questions. Questions gathered demographic information (e.g., age, number of years working in their profession, and what continuing education they had participated in) and included three open-ended questions: “What are the challenges of working with other advisors?”, “What are the benefits of working together?”, and “What do you expect to gain from the project?”.

4.3.5 Workshop

The next stage of the project was a multi-stakeholder workshop held in August 2018 at a local community center central to the region. The goal of the workshop was to establish working relationships between advisors, create a dialogue, and provide approaches and discussion areas that could be used in advisors’ subsequent meetings with farmers. The 4 hr workshop was facilitated by EW and GC and all but one individual participated (1 veterinarian, unable to attend but who was subsequently provided with resources and still participated in the remaining stages). The workshop was composed of 2 stages: first, we divided participants into homogeneous stakeholder groups (3 groups) to discuss their roles and duties when visiting farms, and then came together for a facilitated group discussion about complementary roles on farm (2 hrs). Second, we divided participants into heterogeneous groups (3 groups) and worked through two lameness case studies (2 hrs). Case studies were short paragraphs describing a farm

lameness problem and were developed by GC (Appendix 4.2). Each group received the same case studies. We asked participants how they would approach the described lameness issue if they were working as an individual and then how they would approach the issue if they were working as a team (e.g., what would they do? who would do what?).

The workshop concluded with everyone participating in a facilitated discussion of how the different groups approached the case studies and their plans to work together. The next steps of the project were discussed and participants were assigned "homework" to design, initiate, and facilitate lameness advisory meetings on two of the farms with which they worked. Individual advisors could either work together with other recruited participants and identify shared clients to approach, or they could go to their own clients and find out their veterinarian, nutritionist, hoof trimmer and request a meeting together. We did not give participants any criteria for selecting the farms. The goal of the lameness advisory meetings was to develop a lameness action plan for each respective farm. While we asked participants to lead the organization of these meetings, they were asked to work with the other stakeholders (e.g., farmers and other farm advisors not recruited as participants) on the farm in developing the action plans. Participants decided on a goal of holding two meetings within a 4-month time frame, but did not want an overly prescriptive or required format for the meetings. Participants had time to talk to one another after the workshop, identify potential herds they had in common, and decide who should approach them. Some participants expressed an interest in receiving support from EW in organizing meetings. To aid participants in their advisory group meetings and action plan development, we distributed resource toolkits (risk assessment, factsheets on assessing a herd hoof trimming program, floor grooving,

footbath design, instructions for using the lameness manager module in DairyComp 305 herd management software).

4.3.6 Advisory group meetings

In the next stage of the project, participants planned and attended their advisory group meetings (Sept - Dec 2018) with email and phone contact and support provided to participants by EW. EW attended as many lameness team meetings as possible (6 out of 10 meetings), in part to encourage participants but also to observe interactions between participants and farmers. EW wrote memos following the team meetings to capture the topics of discussion and attendee interactions (Birks et al., 2008).

Overall, participants held 10 advisory group meetings on 10 different farms; Table 1 describes attendees at each meeting. One advisor usually took the lead to organize a meeting with other advisors and the farmer. Some meetings also included herdspeople, on-farm hoof trimmers, and heifer raisers. Meetings were held at the farms and included going over data, farm walk-throughs, discussion of problems, group problem solving, and goal setting. In addition to these formal meetings, advisors also discussed issues on 5 additional farms, but decided not to proceed with meetings for a variety of reasons (the farmer was not interested, not the right time, etc.). Two participants did not attend any advisory group meetings, 5 participants attended 1 meeting, 2 participants attended 2 meetings, and 4 participants attended 3 meetings. Of the participants who attended meetings, most (n=8) participants took the lead on organizing at least 1 meeting, while a few (n=3) participants only attended advisory meetings organized by another advisor. All but 1 participant engaged with at least 1 other advisor within our recruited group (spoke on the phone about a potential farm to

hold an advisory meeting at, organized a meeting together, attended the same meeting).

4.3.7 Interviews

Lastly, we evaluated the project through individual semi-structured interviews with all participants (n=13, Jan - Feb 2019). A semi-structured interview format allows for open-ended questions and discussion between the interviewer and the interviewee (Corbin and Strauss, 2008). We first developed an interview guide that included open-ended questions and follow-up probes (Appendix 4.3). The first questions asked participants to recall and describe the process, then to share their assessment of how it went, and any perceived impact on their herds. We also asked questions about future directions, how they thought a similar project would work in other contexts and any ideas to improve the process. EW scheduled and conducted all interviews, which were held at locations convenient to the participants (their homes or offices). Interviews lasted 31 to 91 minutes (median = 60 min), were digitally audio-recorded and transcribed verbatim by a professional transcription service. Following each interview, the interviewer wrote memos to capture group dynamics and key impressions (Birks et al., 2008).

4.3.8 Data analysis

Following transcription, interview transcripts were checked for accuracy against the original audio by the first author (EW). Thematic analysis, a qualitative methodology used to identify, analyze, and report patterns in written data, was used to analyze the transcripts (Braun and Clarke, 2006). EW coded the transcripts from a deductive perspective using the following a priori questions: (1) *What worked?* (2) *What did not*

work? These questions represented a priori themes and were applied to participants' discussions about all stages of the project: participant recruitment and planning meetings, workshop, and advisory group meetings. Additional data sources were used to supplement coding and interpretation: these included memos written by EW after the advisory group meetings and interviews, and written action plans from participants.

After the initial round of coding, EW consulted with BV and GC to organize and finalize the theme list and descriptions. Throughout the analysis, EW wrote memos to explore and reflect on the data. All labeling and coding was done using the program Quirkos (Quirkos; Quirkos Ltd.). Quotations are presented below as examples of the themes and to add the participants' own voice when describing them. Ellipses indicate where text was omitted, square brackets indicate the authors' additions, and quotes are labeled by the participant ID, where letter indicates the stakeholder group and number indicates the participant (H=hoof trimmer, N=nutritionist, V=veterinarian).

4.4 Results

In total, we had 13 participants, 5 were hoof trimmers, 4 were nutritionists, and 4 were veterinarians. All participants were based in MN. Eleven participants identified as men and 2 as women. Participants ranged in age from 30 to 62 (mean = 46), and their number of years working in their profession ranged from 3 to 37 (mean = 19). The number of herds they worked with ranged from 15 to 45 (mean = 28). All but 1 participant had participated in continuing education in the past year. Continuing education activities included professional conferences, meetings, webinars, or farm visits with peers or industry leaders. All hoof trimmer participants had received formal training. Answers to the open-ended questions from the preliminary survey about challenges and

benefits of working together are presented in Table 2. Themes were organized around two questions: what were the positive aspects of the project? (Theme 1) and what were the challenges? (Theme 2). Theme 1 focused on participants' interactions with one another, changes in practices, and specific positives from the process. Theme 2 focused on challenges related to farmers, interactions between participants, questions about research goals, and specific areas in the program for improvement.

4.4.1 Theme 1: Positives

Overall, the project was viewed positively by participants, who reported valuable experiences, "*I'm just glad that you asked me to be a part of it. I appreciate that, because again, I'm always trying to do my best to improve and learn...it gets you out of your comfort zone a little bit, too (H5).*" In addition to the project being personally beneficial, some participants also reported farmers appreciated the advisory meetings. For example, "*It was a good review. Both farmers thought it was awesome, and one farmer said, 'I didn't really know what to expect.' The owner, he goes, 'but that was really, really productive'. I felt the same way because I didn't really think that—I didn't know what to expect, either. And I felt it was pretty productive, especially with the specific action plan (H3).*"

4.4.2 Interactions with other advisors

Connecting with colleagues. Participants appreciated the opportunity to connect with colleagues, "*It's nice to know that the people who are working in the same field or profession as you, you can bounce ideas off of them and talk and share things with. That's just a small side effect from some of these meetings that I feel like I've*

gotten a better relationship with a few of the trimmers (H5)." Bringing together hoof trimmers, nutritionists, and veterinarians for the workshop was described as a new experience. For example: "*...just getting vets, and consultants, and trimmers together, I thought that was really good, and that's something that we should do more often...I don't know if I've ever been in the same room with that many qualified people together all at once (N3).*" Some participants knew one another and some did not and reported the opportunity to meet one another as valuable, "*I thought it was nice for everyone to get to know each other and learn each other's personalities or that you existed (V1).*" Participants also reported learning about other advisors' level of interest and knowledge, "*I was impressed at the level of interest, particularly by the hoof trimmers primarily. And not just interest in the topic [of lameness], but interest in communicating and being in the loop (V3).*"

Valuable discussions. Participants reported the advisory meetings generated good discussion with the different stakeholders: "*That [meeting] was with me, the producer, the herdsman, and then the trimmer. And that was really—felt like a lot of really, really good discussion was stemmed from that. There was actually some action that stemmed from that meeting (V4).*" The project also served to remind participants of the value of teamwork and that other advisors can be a resource to them. For example, "*There continues to be value in groups working together, teamwork. I've known it for a long time…This project reiterated it. You can get stuff accomplished when you work together and can talk, give more—what's the right word? More options from that team approach…They bring different things (N4).*"

4.4.3 Process

Risk assessment. The optional risk assessment tool that we provided was used by participants in the majority of the advisory group meetings and was viewed positively as a discussion starter. For example, "*I really liked the assessment spreadsheet because I don't think one single person can answer all these questions. Doesn't matter if you're the farm owner or the herdsman or the hoof trimmer or the nutritionist, we can't answer this accurately without talking to each other. So, I guess that's what I liked, it encouraged us to have conversations (V1).*" Participants also liked that the risk assessment provided an area of lameness management to focus on: "*I was apprehensive at first. I just thought, gosh, all these pages of questions, how is this going to go? But when you really get into it, you can go through the questions very quickly and get the answers you need and then find the focus area and get it taken care of (N4).*"

In-person approach. Participants had the option of holding the advisory group meetings remotely, or discussing the action plan via email, but all participants chose to have their advisory group meetings in-person. For example, "*I communicate a lot better in person. Emails, are they going to read all of it or are they just going to skim it, delete it? (H4).*" Participants clearly preferred the in-person approach, "*I think trying to do it any other way would have been difficult to get the same amount of—to get everybody on the same page and also get a little buy-in as far as doing something for follow-up. I think the in-person approach was valuable (V3).*"

Participatory approach. Finally, participants also liked being able to give input and ideas to the project, "*I really liked the idea and how you brought it towards us and you really took our input (H5).*" They also appreciated receiving information during the planning stage, "*I'm glad that you reached out and we did that, so we had an idea before we had the workshop (V1)*."

4.4.4 Changes in practices

Sharing reports. Some participants reported changing their practices to share reports, farm data, and observations with other advisors (with the consent of the farm). For example, "*We always have a report. So, what we do is—we will include the hoof trimmer in that report since this meeting. And I have gotten responses back from three hoof trimmers with some comments about things they were seeing...we do see more communication follow-up both ways since then (V3).*" Participant H1 similarly shared, "*They [veterinarians] will email me the herd report and I'll email them my trim report. The nice thing is I really enjoy reading their notes (H1).*"

Intention to reach out. Participants also shared that their intention to reach out in the future had grown, as described by Participant N4, "*So I learned a lot there, and he [H3] would definitely be somebody I would talk to in the future if I ended up with other herds that he trims for...he's very active and he was great. So, yeah, no, really good. I knew [V3] well, but I did not know [H3] at all.*" Another reported change was an increase in confidence when reaching out to other advisors. As participant V1 shared: "*Most people, if I approach them, they want to work with me. Like it's okay to reach out to them and not be nervous about that. Because if I'm respectful and communicate that I value their opinion and I think there's an issue, usually you have a good working relationship. So yeah, I really value the relationships I got out of doing this project and I do think that they will persist on some farms.*" Participant H4 echoed this sentiment, "*The most important thing that I took away was that other people are willing to work with you and want to know what's going on as well, and are willing to help make it happen...call*

somebody. Get someone else involved. And now you know, after working with them on these projects, that they're more than willing to help out.

4.4.5 Theme 2: Challenges

Despite the overall positive reception the project received, participants also shared about the challenges they faced in the process and their recommendations for future projects.

4.4.6 Outside comfort zone

As part of the project, we asked the advisor participants to recruit farms for a lameness advisory meeting, which may be outside their perceived role on the farm, as N2 described: "*How do I initiate this? Can we do better with lameness? Is that really what the farmer wants me to do? I don't know. Because let's say I offend the client by getting into the lameness side. He may look at me and go, well, what do you know about that? That's not your deal.*" In addition to asking participants to reach out to farmers, we also asked them to lead a meeting and some participants reported not being comfortable in the role. For example: "*I think it's just trying to take charge of—it's just not really my comfort zone (H1).*"

4.4.7 Research goals and intentions

Despite our efforts to provide adequate information to our participants, some still had questions about the goals of the project, as explained by participant N2, "*I'm questioning where this really stems from. Was [it] that somebody felt there was a need*

for hoof health improvement? How did this get started? Because in my area, we're very blessed...for the most part it [lameness] is really not an issue."

A few participants also questioned our motivation and intentions in doing this research. For example, "*I said when this whole thing started, I thought maybe it was a conspiracy theory against me...I don't think my herds are that bad...but it turns out it wasn't like that. It was just to help everybody (H4).*" When participant H4 was asked if we could have done anything at the start of the project to ease his skepticism he responded, "*I just had to see it play out.*"

4.4.8 Questioning advisor intentions

Some participants strongly questioned other participants' skills, knowledge, and intentions. For example, "*I would say way less than 50 percent of hoof trimmers know not to put the grinder between the claws. If they're running the meeting, if somebody like that who doesn't even know basic anatomy is running the meeting, what could be accomplished is what I'm curious—that's all I'm kind of curious of. I think there's some basic qualifications that even most vets and most nutritionists have that this industry just does not. It just doesn't (H3)*." Participants recognized they all have different expertise and experiences and some advisors may be more knowledgeable in lameness management than others, e.g., "*I know the steps and balances for the most part, but what vet would know? Vets maybe would know some, but then it's been a lot of years and they haven't looked into it. Are feed guys going to know? (N2).*" Participant V3 similarly shared, "*So the hoof trimmer—they're doing feet every day and they're thinking of reasons why stuff happens. And it might be building design, it might be cow handling, it might be dirty cows, it might be nutrition. And we would look at it the same way—*

whereas a nutritionist's focus is narrower just by nature. And they may [have] as much knowledge in those areas, but they may not."

A challenge some participants noted from the workshop was the difficulty in bringing together competitors (e.g. two nutritionists working for different companies) and how that may impact participants' willingness to engage in discussions. For example, "*I think it would be pretty hard to get rid of the competitiveness in any room on anything like that. The one thing that you had going, I think all of the vets were from one office so they're a team. And then as you noticed, the nutritionists, they were all from different offices, so they were kind of hard to really—they didn't want to let none of their secrets out of the bag. It's the same way with the hoof trimmers (H2).*" Participant N2 described: "*Okay, so we have competitors in the same room. So are we really, let's say that I'm a little insecure about something going on at the farm. And I'm probably gonna try to hold back information because competitors, veterinarians, everybody's in there with eyes on.*"

4.4.9 Farmer priorities

This project was developed at the advisor level, and participants were cognizant that making an on-farm change required the interest and enthusiasm of the farmer. Participant V3 summarized this issue well, "*It's always a little hard when you have—it's not being driven by the farm, right? So that's always a little challenging because farmers have lots of problems to deal with. So, we decide that this is important, and maybe for them you worry that it may not be something they necessarily want to address...I think as you look going forward, that initial farmer buy-in—if you don't have it, it's going to be really hard. And luckily for me with all three of those, I think it worked well. But I see situations where it's not going to work so well. If we're pushing it, and it's not the farmer's*

goals, it's not going to work (V3)." Similarly, some participants perceived farmer disinterest or a low prioritization of lameness as a challenge for recruiting farms to hold advisory group meetings. For example, "*We had some other herds in mind. Didn't want to do it. Probably they feel lameness wasn't an issue, which it [lameness] probably isn't [on those herds] (N2).*"

Some participants were also wary of adding additional tasks to farmers' plates, "*Just from experience, how many tasks can you give a farm to change anyway? How many things in a year can they realistically work? I mean, a lot of time it's two (N2).*" Participants were also aware of the timing of bringing up concerns to farmers, "*A mistake we made is there were management things that as a group we [advisors] were concerned about but it probably wasn't a good time to bring it up [to the farmer] in that meeting (V1).*"

4.4.10 Process

***Herd selection*.** One difficulty participants described in completing the advisory meeting and action plan was recruiting farms to participate. Some participants had only a few herds that overlapped with other participants. This added a challenge for those participants as they not only had to convince the farmer to participate but also the veterinarian, or hoof trimmer, or nutritionist, who did not attend the workshop and was not familiar with the project. For example, "*You know one farm, the owner was real interested, but you know his veterinarians hadn't been a part of this meeting and his nutritionist hadn't been a part of this meeting (H1).*" One participant suggested making more time for identifying potential herds to approach, "*But I wonder if there would have*

been some value in having a short brainstorming session for people...like [to identify] people who work on the same farms (V1)."

Workshop improvements. Participants reported the workshop could have been more engaging by improved facilitation and making the process more visual, for example, "*Just for a visual, for myself, maybe have one person record when each person shares common ideas (H5).*" Some participants also suggested offering something "new" to participants. For example, presenting resources on the latest lameness research, "*I know I said it shouldn't be any longer but to help incentivize people coming you know is to have a review of some data piece or something that would be applicable to both veterinarians and hoof trimmers plus or minus the nutritionists (V1).*"

Structure. A few participants wanted more structure to the project: "*Maybe some more structure—what to expect…when you approach people, you say, "okay, here's how this is going to work. Here's what we're going to have at the end. Here's what it looks like."... I think more of a set structure, saying, "okay, this is going to happen. Here's your version—here's your copy of how this is going to happen. Here's what we expect to happen. Here's what we expect for your follow-up (V3).*" Participants who wanted more direction, particularly in organizing the advisory group meetings, reported a lack of clarity in the process for themselves and also how to explain the project to others.

Time concerns. Participants were aware of the time involved in taking part in the project, as participant N3 shared, "*But, if you have another one [workshop], keeping it rolling and keeping it concise.*" Participants were also extremely conscious of not wasting other participants' and farmers' time. For example: "*I would probably try to take the same approach but maybe be selective on which people I would have involved [in*

the advisory meeting]. Nothing against the nutritionist or the vet or the hoof trimmer, but maybe this really doesn't have anything to do with the hoof trimmer or with the vet (N4)." Some participants were hesitant to plan advisory meetings due to questioning whether the outcome would be valuable enough for the time taken, as participant V3 explained, "*But you still have that—anytime you schedule a meeting, time's valuable. And so, who's going to pay for that time? And the farmer has to, in a way, get paid for that time somehow. The hoof trimmer has to get paid for that time, the vet has—so it really has to be worthwhile, and it's got to come from somewhere. And that's ultimately the challenge, I think, in those kinds of programs (V3).*" Another challenge in planning advisory meetings was scheduling: "*There's always something to be done, right? The tricky part is finding the time in everybody's schedule (H5).*"

4.5 Discussion

The goal of this project was to develop and implement lameness management advisory groups and to examine our participants' experiences of the research activities and lameness advisory group meetings. The results of this study demonstrate the overall positives of facilitating advisor engagement as well as areas where there are challenges. Also discussed below are our recommendations for implementing a lameness intervention aimed at advisors.

Overall, the project was viewed positively by participants. The majority of participants felt the opportunity to connect with other advisors was valuable and the discussions generated in the advisory meetings were useful. Advisors reported learning about one another and also about lameness management on the farms that they worked with.

Some participants reported changing their behaviors because of participating in the project and some reported an intention to change. Within the TPB framework (Ajzen, 1991), it appears we were successful in influencing peer views or normative beliefs (see other advisors care about lameness; perceive others as valuable resources) and self-views or control beliefs (confidence in reaching out to other advisors). Through the experience of discussing lameness with advisors at the workshop and reaching out to them in organizing a meeting and creating an action plan, this may make it easier to reach out in the future.

Participants liked the risk assessment we provided them. It gave them a starting place to generate discussion during the lameness advisory meetings, particularly on farms that had little lameness data recorded. Van Huyssteen et al. (2020) evaluated a lameness risk assessment against herd lameness and lesion prevalence and the associations were nonexistent or weak. Though their risk assessment was not accurate at identifying risk for lameness or lesions, they similarly viewed it as a helpful approach for generating discussion between producers and advisors. Risk assessments and benchmarking have been used previously as conversation tools (Roche et al., 2015; Sumner et al., 2020) and this an accepted approach for generating ideas and working towards tailored on-farm solutions. Lam et al. (2011) noted that asking open questions and personalized messages, such as in a discussion generated by a risk assessment, are one of the best strategies for veterinarians to improve influence on farms.

Participants overall responded positively to engaging with other advisors, but there were still challenges in facilitating the workshop and advisory meetings. Notably, some participants described the social complexity of advisor-advisor relationships. Some advisors would be classed as competitors, for example, if two nutritionists were working

in the same area but for different companies. Participants viewing others as competitors may have been reluctant to share their knowledge or barriers they faced in their work. In our facilitation we tried to be sensitive to this issue, for example, we did not ask participants to discuss particular farms they worked with but rather provided fictitious case studies. Another issue was advisors distrusting one another or questioning others' knowledge or motivations. As researchers involved in the dairy industry, we had knowledge of the dairy community and how different participants' roles may influence their ability or desire to engage with us and other participants. Researchers attempting to bring together advisors must be aware of these complex social relationships. Knowledge brokers, neutral people who promote mutual understanding and facilitate the exchange of knowledge, have been used to create relationships among groups of people with shared concerns within healthcare systems (Conklin et al., 2013). Such an approach may help ease discussions between advisors and allow farmers to benefit from different perspectives.

Some participants reported preferring a more structured approach in which researchers would tell them what to do at each stage. Our approach was more flexible, for example, not providing a required structure for the advisory meetings, but this approach did not meet the preferred working style and personality of each participant. Also, some participants found the task of requesting and leading an advisory meeting to be outside their perceived role or outside their comfort zone. Though after doing it once, some reported gaining confidence with it. Participants also discussed further practical limitations in the workshop and advisory group meetings, including: farmers choosing not to participate, not enough time, and having few shared farms with other advisors. Morgans et al. (2021) used professionally trained facilitators in an intervention to reduce

antimicrobial use to keep meetings focused, engage all farmers, help farmers address problems, and facilitate peer-to-peer learning. Offering advisor participants facilitator training may assist them in leading advisory meetings.

In the project we did not center farmers, but rather centered farm advisors as trusted sources of information within agricultural systems. A strength of this advisor-centered approach is that we recognize that decision making on a farm does not occur in a vacuum. Farmers and other stakeholders exist within communities and this creates multiple avenues to influence change. Previous research has generally focused on single farms and a single advisor, but in reality farmers work with, and receive advice from, multiple advisors. Our project highlights some of the challenges and benefits of multi-advisor teams. While participants did perceive positive outcomes of advisor engagement, they also recognized the limitations of this approach; namely that farmers are decision makers and that if a farmer is not interested in pursuing improved lameness management as a goal there is only so much an advisory team can do. We recognize the importance of farmers but in this project we chose to focus on the role of and impact of advisory teams. An intervention aimed at advisors may change their practices but may not translate to changes at the farm-level. For this reason, we recommend future programs include farmers and center their priorities and goals.

Previous participant-led interventions aimed at changing on-farm practices have been quite extensive in the length of the interventions and time commitment required from both researchers and participants (Vaarst et al., 2007; Morgans et al., 2021). Though this project is more modest in its intervention we suggest our multi-stakeholder workshop represents an example of a more attainable change that the industry can make to foster advisor collaboration. Examples of this include holding continuing

education events for multiple advisor groups and farmers, lameness research conferences that include hoof trimmers and hoof trimmer experiences, veterinary schools introducing trainee veterinarians to the hoof trimming profession. The positive response of our participants shows efforts to facilitate advisor engagement are worthwhile, but more work is needed to determine impact and refine the process to address the challenges participants raised.

4.5.1 Limitations

These results must be interpreted with a degree of caution. Firstly, we do not know how the reported attitudes translate into action nor do we know if reported changes will be sustained. This project was limited by the short timeline and modest intervention. Without long-term sustained engagement it is difficult to create a lasting change. The participants in this project were self-selected and we acknowledge that the advisors who chose to participate in this study were likely already interested in improving lameness practices or were more progressive. Future work should aim to engage advisors that are harder to reach or those that hold values different from our own.

A challenge of this project was in having participants continue to engage in the process, particularly holding the advisory meeting. We asked for their time and commitment and it can be difficult to continue with many competing priorities. Throughout the project, we tried to build engagement and buy-in for the project through involving participants in the planning stage and continuing to communicate with them about their advisory meetings. Through this contact, we developed trust with participants and they all agreed to complete the final interview.

Another challenge is social desirability bias, a tendency for participants to answer questions to be viewed favorably by others (Polkinghorne, 2007). This can never be fully eliminated, but we tried to encourage truthful responses through careful interview techniques, such as reminding participants there are no correct answers, leaving enough time in the interview for them to fully consider the questions, and revisiting any contentious topics later in the interview (Polkinghorne, 2007).

This project was focused on farm advisors and not farmers, therefore we do not have information on what the farmers thought of the process. In this study, we do not have animal-based measures. Due to the chronic nature of lameness, even multi-year studies have difficulty measuring changes at the cow-level. Participants may report a change was made but we have no way of evaluating if it made a difference to the cows. Future projects should try to include the number of changes made, what those changes were, and determine if the incidence of lameness changed.

4.6 Conclusions

The participating hoof trimmers, nutritionists, and veterinarians in this study reported the activities developed to increase advisor engagement had been valuable. They appreciated the opportunity to connect and discuss issues with colleagues. Participants noted the challenges of working with other advisors, including questioning other advisors' knowledge and intentions. Participants suggested including farmers in interventions is important to motivating on-farm changes.

4.7 Acknowledgments

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Table 4.1. Meeting attendees from lameness advisory group meetings held between September and December 2018.

Farm advisory meeting	Participant who planned the meeting	Meeting attendees
1	V3	V3, H4, farmer, vet student, hoof trimming assistant, EW
2	V3 and H3	V3, H3, N4, farmer, EW
3	V2	V2, H4, farmer, nutritionist, EW
4	V4	V4, H1, farmer, farm employee, EW
5	H5	H5, V3, farmer, herdsperson, farm employee responsible for on-farm foot treatments, nutritionist, 2 people from contract heifer grower, EW
6	N4	N4, H1, 2 farmers, veterinarian, EW
7	N4	N4, farmer, herdsperson, veterinarian, hoof trimmer
8	V1 and H4	V1, H4, N3, farmer, herdsperson
9	V4	V4, H1, 2 farmers
10	H3	H3, N2, farmer

Table 4.2. Survey responses from 13 dairy farm advisor participants (5 hoof trimmers, 4 nutritionists, 4 veterinarians).

What are the challenges of working with other advisors to address lameness?	Communication; do not get to meet regularly; time and scheduling; farmer and their level of interest in lameness; false information and egos
What are the benefits of working with other advisors to address lameness?	Information sharing and better relationships with other advisors; someone to brainstorm solutions with and to help explain things to the farmer; Everyone sees the cows in different settings, so together we can get a better overall picture of lameness management on the farm; Reduced lameness; healthier, more productive cattle No benefits.
What do you expect to gain from participating in this project?	Learn what the other people on the dairy team expect from me and how we can assist each other better; networking and meeting new people; A better understanding of hoof issues, treatments, and preventative options as well as becoming more involved in hoof health. I don't really know what to expect; Arguing

Chapter 5: Summary and conclusions

5.1 Reflection

As researchers we must examine our place within our work. This reflection provides transparency in how my worldview may have influenced my research. I grew up on a dairy farm which my family still owns and operates. I lived at my family farm during much of the writing of this thesis. I consider farming to be a difficult pursuit to devote one's life to and I have seen many of the challenges up close.

I came to this doctoral program following my masters degree in epidemiology. My masters research was focused on dairy cow reproduction and by the end I was no longer interested in production or efficiency, but rather the welfare of cows. As I more closely considered the lives of cows it became clear I must also consider the humans responsible for their care. I also came to this work with an eye for applied research, not just pursuing understanding but also trying to put understanding into action.

As I come to the end of this degree, I leave with an appreciation for how intertwined the lives of cows are with the lives of people, not just farmers but entire communities made up of farm advisors, farm workers, researchers, and more. Qualitative research requires openness and for myself that meant letting go of the idea that I know best. I became more open minded through this work, learning to respect participants' expertise and to listen.

The knowledge in this thesis is co-constructed, between myself and my research community, as well as the farmers, hoof trimmers, nutritionists, and veterinarians who contributed their stories. I did my best to represent their stories sincerely. A doctoral

degree requires one to challenge their assumptions and I look forward to a life where I continue to examine my assumptions, evolve, and grow.

5.2 Objective 1

The first objective of this thesis was to evaluate the role of hyperketonemia in sole ulcer and white line hoof lesion development. Overall, we found no evidence that elevated concentrations of blood BHB cause postcalving incident sole ulcer or white line lesions in cows with or without a hoof lesion precalving. The relationship between calving, the transition period, changes in the structure of the foot, and the development of sole ulcers and white line lesions is more complicated than just fat mobilization and hyperketonemia. This result should be interpreted in the context of the limitations of the study, including a limited sample size, as discussed in Chapter 2.

As this project progressed from conception to analysis our methodological approach changed. We started the project with a plan for a risk factor analysis examining the association between hyperketonemia and hoof lesions. As we learned more about causal inference and target trial approaches, we realized the causal pathway under investigation required more exploration and specificity. This led to much discussion of our directed acyclic graph, and the arrival at our slight but important change in hypothesis, moving from all hoof lesions as an outcome to only sole ulcer and white line lesions as well as separate models for cows with or without a previous lesion.

As discussed in Chapter 2, this study was challenged by sample size. It leaves me with an appreciation for the difficulty in conducting longitudinal hoof lesion research, as we lack methods to collect consistent lesion information overtime. Furthermore, much previous lameness research has focused on the prevalence of hoof lesions, leaving us

mostly in the dark on the incidence of specific lesions. As we learn more about the structural changes in the foot caused by hoof lesions, such as bone remodeling, it has shown the importance of accounting for previous lesions within research studies (Newsome et al., 2017; Wilson et al., 2021). Future work can continue in developing ways to examine the structure of the foot, and how that structure changes through growth, calving, and lesion development.

5.3 Objective 2

The second objective of this thesis was to use focus groups to explore farmer, hoof trimmer, and veterinarian perceptions of barriers in lameness management, perceptions of their own roles in lameness management, and their expectations of other stakeholders. As discussed in Chapter 3, this study provided interesting insights into barriers in lameness management, particularly those faced by hoof trimmers as they had never been explored before to my knowledge. For myself, the most interesting pieces were those of stakeholders discussing their own role, positive collaborations with other stakeholders, as well as the potential conflicts they face in working together. As we continue working with these stakeholders, there is more to learn in how best to build and support lameness management teams with multiple advisors.

Like many grad students before me, I was full of questions and wanted to take the biggest bite I could. I wanted to know everything all my stakeholders ever thought about lameness, their role, and one another. Now, with my greater experience in qualitative research, I see that a more manageable and specific question will yield more in-depth results. The richness in my data came from participants talking about their role and what they expected from one another. I see how this speaks to the importance of

these relationships in lameness management, that it is not one person working alone but rather a shared responsibility. I used the Theory of Planned Behavior, a psycho-social framework used to predict behavioral intentions, to aid in question development and interpretation (Ajzen, 1991). Other frameworks, such as the social ecology perspective (Shortall et al., 2016), may more fully take into account these important social relationships.

Though we covered barriers in lameness management, less well understood are our participants' vision for the future: what would lameness management look like in an ideal world? Who is involved? What would they do? What would you do? We did capture answers to some of these questions, for example advisors wished to communicate more and align their recommendations, but a greater focus on their vision may yield further creative ideas and insights for education or extension programs.

In this study, I chose to talk to stakeholders whom I viewed as having decision making power and influence. This is perhaps a good place to start, as business owners and operators are leading the culture within their organizations. As dairy farms grow, we also have stakeholders working directly with cows who are not positioned to make management-level decisions. A future avenue of research would be to talk to farm workers and ask about their experiences with lame cows. As the welfare of cows is interconnected with human well-being, further understanding the challenges farm workers face may present an avenue to improve the lives of cows, but more importantly, support those tasked with this difficult work.

Finally, I now further see how focus groups can be used as a research outreach or motivation tool. Though not universally true, many participants seemed to really enjoy the focus groups and the time to connect with other farmers, hoof trimmers, or

veterinarians who were facing the same issues as them. I remember moderating groups full of jokes, laughter, and connections between colleagues. The value of reaching out to stakeholders can have direct benefits beyond generating knowledge.

5.4 Objective 3

The final objective of this thesis was to facilitate lameness management advisory groups and explore hoof trimmer, nutritionist, and veterinarian participant perceptions of the positive and negative aspects of the lameness management groups. This project served as a continuation of our previous focus group project. We attempted to use what we had learned in the focus groups to develop an intervention, as veterinarian and hoof trimmer participants in our focus groups expressed an interest in working together more closely and talked about the benefits of being on the same page and delivering a consistent message to farmers. Though this project may not provide a perfect roadmap to a functional lameness reducing intervention, it does offer insight into the experience of our participants in working together as lameness advisory teams. As discussed in Chapter 4, this project was limited in the number of participants as well as the scope of the intervention, but a benefit of fewer participants was my ability to connect with all participants during the advisor group meeting planning, attend a majority of the meetings, and conduct in-depth interviews with participants on their experiences.

This project was aimed at the advisor level, but as we asked advisors to go forth and work together in some capacity this necessitated the inclusion of farmers. Some participants reported finding farmers willing to get together for a meeting focused on their herd lameness management, but other participants reported farmers that were not interested. We therefore recommend future programs to include farmers, but this does

create a challenge in how best to structure an intervention with farmers and advisors, and how to best generate interest and buy-in for all groups. Previous interventions have focused on farmers as the primary participant and used veterinarians or other research personnel as facilitators (Whay et al., 2012; Roche et al., 2015; Morgans et al., 2021). The Healthy Feet Programme in the UK trained both hoof trimmers and veterinarians across the country to be ‘mobility mentors’ to facilitate diagnosing problems, devising action plans, and skill development. Offering this type of specialized facilitator training to lameness-interested farm advisors is one direction for future interventions. I am particularly interested in this idea as a way to include hoof trimmers in outreach, as they have previously been overlooked as advisors when compared to veterinarians. Based on our results, as well as those from previous dairy health interventions, I suggest future programs offer opportunities for participants to meet and discuss salient management issues. This creates opportunities for peer-to-peer learning and building their networks.

We continue to recognize the role of farm advisors as influential, both in agenda setting (what is viewed as important, what gets prioritized) as well as how issues are framed (production problem, welfare problem, economic benefits). As farmers make decisions, they are influenced by others and more work is needed to understand farmers’ social referents and their role in on-farm decision making.

5.5 Conclusions

As lameness continues to represent a management and welfare challenge, multiple creative approaches to research and interventions are needed. In this thesis, I used a combination of quantitative and qualitative methods to examine causes of lameness, barriers faced by stakeholders, and ways to facilitate collaboration between

lameness advisors. This research helps better elucidate the role of farmer, hoof trimmer, nutritionist, and veterinarian stakeholders in lameness management and how best to create functional multi-stakeholder lameness management teams.

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Appendices

Appendix 2.1 Locomotion scoring system

Four point locomotion scoring system used to evaluate the gait of cows during the study. Combination and adaptation of Thomas et al. (2015) and Cook, (2003).

4-Point Locomotion Scoring System

1. Not lame: Cow walks comfortably and at the same speed as the rest of the herd. Cow has even stride lengths and weight-bearing on all limbs, with a straight back.

2. Slightly lame: A change in walking speed or stride length may be shown but gait is still fluid and change in stride length is similar for both legs. May have a slight back-arch. Cannot easily or quickly identify which limb is affected.

3. Moderately lame: These cows may walk slower than normal with an irregular walking rhythm and shortened stride-length on one or both hind limbs. Cows may have an obvious head bob or back arch. Limb is identifiable due to decreased weight bearing during stance phase of locomotion. May also notice sinking of dewclaws and increase in flight-phase of non-affected limb. Cow may also appear to be walking stiff or non-fluid or placing legs rigidly and have shortened strides if both legs are affected.

4. Very lame: Easy to identify the affected limb and the cow is reluctant to bear weight on it. Cows walk much slower than the rest of the herd with severe slower shortened stride lengths and a prominent back arch.

Appendix 2.2 Lesion descriptions

Lesion descriptions used by hoof trimmers to diagnose lesions in enrolled cows. The lesion descriptions were modified from Cramer et al. (2008) and ICAR Claw Health Atlas (Egger-Danner et al., 2020).

Lesion name (alternate common names)	Definition
Sole ulcer	A defect in the sole horn that exposes the corium; can be accompanied by granulation tissue or a severe hemorrhage that is painful with hoof testers.
White line	Separation of the white line with or without purulent exudation.
Digital dermatitis (hairy heel wart, wart)	Painful, raw, sometimes hairy area on the skin around the heels and between the hooves; can have a white rim around the lesion.
Toe	Any lesion located in the toe triangle including thin soles, ulceration, or necrosis.
Corkscrew claw	As viewed from the front: the hoof is turned towards the other hoof and has an upward rotation. As viewed from the sole: the outer hoof wall is rotated and the hoof is typically longer and pointed with a flared out inner hoof wall.
Foot rot	Symmetrical swelling above the hooves on one foot with spreading of the toes. Usually accompanied by cracked, dead, smelly pieces of skin between the digits.
Injury	Cow is lame, but no lesions were found in or on the foot, and the cow has another cause of lameness; usually on the upper leg such as swollen hock.
Other	Any other lesion not listed here such as interdigital hyperplasia, axial and horizontal wall cracks.

Appendix 3.1 Focus group question guide

Focus group question guide to elicit attitudes and perceptions about lameness, barriers in lameness management, and perceptions of own role in lameness, and expectations of others. Questions were modified slightly for farmer, veterinarian, and hoof trimmer groups.

Perceptions of importance and prevalence of lameness in the dairy industry

1. I'd like to start out by getting your opinions on lameness in the dairy industry. How big of a challenge do you think it is, is it a challenge at all, if so, where would you rank it against other cow health and well-being challenges?
2. What's your personal experience dealing with lame cattle?
3. Do you find a range, why do you think it's better or worse on some farms than others?

Lameness management - Perceptions of barriers

1. What, if any, barriers do you find yourself facing with regards to lameness?
2. *Let them take on prevention and treatment, and depending on the convo, recap* "so what I've heard from you is that you really see issues with lameness prevention. Can you also speak to your views on treatment?"
3. *Probes*: What about at the herd level?

Role in lameness management, role of other stakeholders

1. How do you see your role, if any, in contributing to lameness management? What do you view your role is in lameness control?
2. Do you think anyone else has important roles to play?
3. Do you have an active relationship with a veterinarian/hoof trimmer? Can you tell me more about that? Probe: why is that relationship valuable or challenging? If you did have this relationship, what would you find valuable or challenging?
4. Have you previously approached any advisors about a lameness issue? Can you share the steps you took? Were you satisfied with the outcome? Why/why not? Let's say you approach an advisor about a lameness issue, what would you envision happening?

Appendix 4.1 Risk assessment

Minnesota Lameness Risk Assessment Instructions

1 Start by entering Farm Data in Farm tab
2 Enter Scores for Risk Assessment in yellow boxes for each sheet (10 in total)
3 Look at Summary sheet to evaluate overall risk assessment score for each area
4 Use information collected to guide discussion

University of Minnesota Lameness Risk Assessment

Farm	0
Address	0
City	0
State	0

Hoof trimmer	0
Veterinarian	0
Nutritionist	0

Summary of Lameness RA scoring

Scores Interpretation >60% Opportunities <40% Good

	Infectious		*Non-Infectious*	
Summary	***Score***	***Max***	***Score***	***Max***
Biosecurity	0	20		
Feeding Management			0	30
Breeding Age Heifers	0	40	0	30
Dry Cows	0	40	0	37
Lactation Cows	0	60	0	60
Flooring	0	10	0	60
Prevention			0	50
Footbathing	0	30		
Lameness Therapy	0	30	0	30
Total Score	0	*230*	0	297

Farm Concerns

1	0
2	0
3	0

Section 1

Descriptive Farm Information

Farm Name				
Owner				
Herdsperson/Contact				
Address				
City				
State				
Zipcode				
Contact email				
Contact phone				
Housing Type	Freestall	Tiestall	Pack	Lot
Milking Cows				
Far off Dry cows				
Close up dry cows				
Breeding age heifers				
Pregnant heifers				
Herd Size				
Hoof Trimmer				
Veterinarian				
Nutritionist				

Top 3 lameness/hoof health related concerns

1	
2	
3	

Section 2

Biosecurity

Question

1		***In the last 12 months have you added cows/bulls or heifers to the herd?***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*Nothing added*				
	4	*Heifers only (prior to calving) added or use an off site heifer grower*				
	7	*One animal added to mature herd*				
	10	*More than one animal added to mature herd*				
2		***Do the people (hoof trimmer/veterinarian) that hoof trim or treat your lame animals use clean equipment?***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*All equipment (chutes/knives) is always clean or use farm's equipment*				
	4	*All equipment (chutes/knives) is always clean except when it is freezing cold*				
	7	*Some equipment (chutes/knives) is always diry*				
	10	*All equipment (chutes/knives) are always dirty and not cleaned between farm*				
			Infectious		***Non-Infectious***	
			Score	***Max***	***Score***	***Max***
		Total Biosecurity	**0**	**20**		**0**
		Questions	*1,2*			

Section 3

Feeding Management Risks

Question

1		***Feeding Frequency***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*Fed 2 or more times/day year around*			
	4	*Fed 2x in summer 2x in winter*			
	7	*Fed 1x but at least 1 milking has fresh feed*			
	10	*Fed 1x but no milking has fresh feed. (Feeding happens after milking)*			
2		***Feed push up frequency***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*Feed pushed up >5x/day*			
	4	*Feed pushed 4-5x/day*			
	7	*Feed pushed 2-4x/day*			
	10	*Feed pushed up<2x/day*			
3		***Additional Concentrate Feeding***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*No concentrate fed outside of the TMR*			
	4	*Some concentrate is fed in free access robot OR multiple computer feeders OR <=1 kg is topdressed >2 x in a Tie-stall*			
	7	*Some concentrate is fed in feed first robot OR =<1 kg is topdressed 2 x in a tiestall*			
	10	*Some concentrate is fed in 1 single computer feeder or there is limited access to the computer feeder due to location/competition OR > 2kg of concentrate is fed 2x or less in tiestall*			
			Infectious		***Non-Infectious***
			Score	***Max***	***Score***	***Max***
		Total Feeding Management			**0**	**30**
		Questions			*1,2,3*	

Section 4

Heifer risks (From Breeding Age to Close Up)

Question					
1		***Visibly assess the hygiene of heifers and base score on majority of animals. If heifers are not available look at heifers that have just arrived from their other location***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*The cows have no manure visible on hind legs, teats or udde*			
	4	*Manure is present on hind legs but not above dewclaws, and not on teats or udder*			
	7	*Manure is present on hind legs up to the hocks OR is present on the surface of the teats and*			
	10	*Manure is present above the hocks AND is present on the teats or udder*			
2		***Scraping/Pattie Cleaning frequency:***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*Tractor Scraped 2x/day OR automatic slat cleaner*			
	4	*Tractor Scraped 1 x/day score or automatic alley scraper 2-3x/day OR Slats scraped with alley scrape*			
	7	*Tractor Scraped <1x/daily or automatic alley scraper 4-5x/day OR Slats not scraped*			
	10	*Tractor Scraped as needed or automatic alley scraper >5x/day*			
3		***Stall dimension: Based on cow observations +/-stall measurements***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If stall dimensions are adequate for 90-100% of cows in this herd*			
	4	*If stall dimensions are adequate for 75-89-100% of cows in this herd*			
	7	*If stall dimensions are adequate for 50-74% of cows in this herd*			
	10	*If stall dimensions are inadequate for most of the herd <50% of cows in this herd*			
4		***Competition for Resources***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*No dead ends, <=100 % stocking density in CUD pen at least 18-24 inches of bunk space and at least 2 waterers and 2 inches of linear space/heifer*			
	4	*No overcrowding of stalls but 1 of following is present: Headlocks, Dead ends, <18 inches of bunk space, < 2 waterers or <2 inches of linear space/heifer*			
	7	*Overcrowding of stalls and 1 of following is present: Headlocks, Dead ends, <18 inches of bunk space, < 2 waterers or <2 inches of linear space/heifer*			
	10	*Overcrowding of stalls and/or >2 of following is present: Sand bedding, Headlocks, Dead ends, <18 inches of bunk space, < 2 waterers or <2 inches of linear space/heifer*			
5		***Determine if heifers are adjusted to lactating cow housing prior to calving.***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If heifers are always adjusted and at least 2 month before calving*			
	4	*If heifers are always adjusted, but only 2-3 weeks before calving*			
	7	*If heifers are only adjusted rarely when there is room*			
	10	*If heifers have never been exposed to lactation cow housing*			

Section 4

Heifer risks (From Breeding Age to Close Up)

6		***Assess risk of heifers (before entering close up pen) being exposed to DD from milking or dry cow manure. Assess risk for heifers prior to movement to transition area***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*Heifers are housed in a separate barn, heifers are never moved from milk cow barn to heifer barn AND manure scraping equipment is not shared between barns AND there is no exposure to cow manure by run-off or splashing*				
	4	*Heifers are housed in a separate barn but one of the following occurs infrequently: heifers are moved from milk cow barn to heifer barn OR manure scraping equipment is shared between barns OR exposure to cow manure by run-off or splashing occurs*				
	7	*Heifers are housed near cows and direct contact is possible OR manure scraping equipment is shared between barns OR exposure to cow manure by run-off or splashing occurs*				
	10	*Heifers are housed with cows or next to cows (milking or dry) where direct contact always*				
			Infectious		***Non-Infectious***	
			Score	***Max***	***Score***	***Max***
		Total Breeding Heifers	**0**	**40**	**0**	**30**
		Questions	*1,2,3,6*		*3,4,5*	

Section 5

Dry Cow and Close up Heifer Risks

Question

1		***Visibly assess the hygiene of cows currently in the dry cow herd and base score on majority of animals***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*The cows have no manure visible on hind legs, teats or udde*				
	4	*Manure is present on hind legs but not above dewclaws, and not on teats or udder*				
	7	*Manure is present on hind legs up to the hocks OR is present on the surface of the teats and*				
	10	*Manure is present above the hocks AND is present on the teats or udder*				
2		***Bedding amounts in stalls or pens***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*90% or more of stalls have 90% of stall surface completely covered by at least 5 cm (2 inches) of bedding (or if sand bedded, 90% of stalls are level and have no bedding hollows)*				
	4	*50 to 90% of stalls have 90% of stall surface completely covered by at least 5 cm (2 inches) of bedding (or if sand bedded, 50% have no hollows)*				
	7	*Less than 50% of stalls have 90% of stall surface completely covered by at least 5 cm (2 inches) of bedding (or if sand bedded, less than 50% of stalls are without hollows)*				
	10	*There is little or no bedding (i.e. less than 30% of stall surface covered in most stalls) or most sand bedded stalls have hollows*				
3		***Scraping/Pattie Cleaning frequency:***				
	Score	*Score Explanation*		**Enter Score here**		
		If freesttall or pack with scrape alley				
	1	*Tractor Scraped 2x/day OR automatic slat cleaner*				
	4	*Tractor Scraped 1 x/day score or automatic alley scraper 2-3x/day OR Slats scraped with alley scrape*				
	7	*Tractor Scraped <1x/daily or automatic alley scraper 4-5x/day OR Slats not scraped*				
	10	*Tractor Scraped as needed or automatic alley scraper >5x/day*				
		If Tie-Stall or pack without scrape alley. Visibly score the bedding				
	1	*No visible manure, new bedding has been added, bedding/stalls is dry*				
	4	*Visible manure covering 10% of the bedding/stalls*				
	7	*Visible manure covering 50% of the beddin/stalls*				
	10	*Visible manure covering 60% (2/3rds) or more of the bedding/stalls*				

Section 5

Dry Cow and Close up Heifer Risks

4		***Stall dimension: Based on cow observations +/-stall measurements***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If stall dimensions are adequate for 90-100% of cows in this herd*				
	4	*If stall dimensions are adequate for 75-89-100% of cows in this herd*				
	7	*If stall dimensions are adequate for 50-74% of cows in this herd*				
	10	*If stall dimensions are inadequate for most of the herd <50% of cows in this herd*				
5		***Competition for Resources***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*No dead ends, <=100 % stocking density in CUD pen at least 24 inches of bunk space and at least 2 waterers and 2 inches of linear space/cow*				
	4	*No overcrowding but 1 of following is present: Dead ends, <24 inches of bunk space, < 2 waterers or <2 inches of linear space/cow*				
	7	*Overcrowding and 1 of following is present: Dead ends, <24 inches of bunk space, < 2 waterers or <2 inches of linear space/cow*				
	10	*Overcrowding and/or >2 of following is present: Dead ends, <24 inches of bunk space, < 2 waterers or <2 inches of linear space/cow*				
6		***Determine if there is an extreme housing change for cows from lactating housing to dry cow housing. Any dry cow housing qualifies.***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If loose pen housing in dry period to either tie or free stall OR freestall to freestall*				
	4	*If dry cows are housed in tiestall and milk cows are housed in freestall OR dry cows in a freestall and milk cows in a tiestall*				
	7	*If dry cows are housed in tiestall AND milk cows are housed in tiestall*				
	10	*Do not use for this questions*				
7		***Heat abatement***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If there are Fans and sprinklers and run at appropriate temps ~68-70F or appropriate tunnel with correct CFM*				
	4	*If there are fans or sprinklers or tunnel but run when its hot or on manual*				
	7	*If there are fans or sprinklers or tunnel, but not Dry cows OR fans only but doesn't reach all cows such as with too few fans or HVLS fans in the feed alley*				
	10	*No heat abatement*				
			Infectious		***Non-Infectious***	
			Score	***Max***	***Score***	***Max***
		Total Dry and CU Heifer	**0**	**40**	0	**37**
		Questions	*1,2,3,4*		*4,5,6,7*	

Section 6

Lactating Cows

Question						
1		***Visibly assess the hygiene of cows currently in the lactating herd and base score on majority of animals***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*The cows have no manure visible on hind legs, teats or udde*				
	4	*Manure is present on hind legs but not above dewclaws, and not on teats or udder*				
	7	*Manure is present on hind legs up to the hocks OR is present on the surface of the teats and*				
	10	*Manure is present above the hocks AND is present on the teats or udder*				
2		***Bedding amounts in stalls or pens***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*90% or more of stalls have 90% of stall surface completely covered by at least 5 cm (2 inches) of bedding (or if sand bedded, 90% of stalls are level and have no bedding hollows)*				
	4	*50 to 90% of stalls have 90% of stall surface completely covered by at least 5 cm (2 inches) of bedding (or if sand bedded, 50% have no hollows)*				
	7	*Less than 50% of stalls have 90% of stall surface completely covered by at least 5 cm (2 inches) of bedding (or if sand bedded, less than 50% of stalls are without hollows)*				
	10	*There is little or no bedding (i.e. less than 30% of stall surface covered in most stalls) or most sand bedded stalls have hollows*				
3		***Scraping/Pattie Cleaning frequency:***				
	Score	*Score Explanation*		**Enter Score here**		
		If freesttall or pack with scrape alley				
	1	*Tractor Scraped 2x/day OR automatic slat cleaner*				
	4	*Tractor Scraped 1 x/day score or automatic alley scraper 2-3x/day OR Slats scraped with alley scrape*				
	7	*Tractor Scraped <1x/daily or automatic alley scraper 4-5x/day OR Slats not scraped*				
	10	*Tractor Scraped as needed or automatic alley scraper >5x/day*				
		If Tie-Stall or pack without scrape alley. Visibly score the bedding				
	1	*No visible manure, new bedding has been added, bedding/stalls is dry*				
	4	*Visible manure covering 10% of the bedding/stalls*				
	7	*Visible manure covering 50% of the beddin/stalls*				
	10	*Visible manure covering 60% (2/3rds) or more of the bedding/stalls*				
4		***Stall dimension: Based on cow observations +/-stall measurements***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If stall dimensions are adequate for 90-100% of cows in this herd*				
	4	*If stall dimensions are adequate for 75-89% of cows in this herd*				
	7	*If stall dimensions are adequate for 50-74% of cows in this herd*				
	10	*If stall dimensions are inadequate for most of the (>50%) of cows in this herd*				

Section 6

Lactating Cows

5		***Competition for Resources***			
	Score	*Score Explanation*		**Enter Score here**	
	1	***In All Pen*** *s: No dead ends, <=100 % stocking density in all pens at least 24 inches of bunk space and at least 2 waterers and 2 inches of linear space/cow OR tiestall*			
	4	***No overcrowding of stal*** *ls but 1 of following is present in 1 pen: Dead ends, <24 inches of bunk space, < 2 waterers or <2 inches of linear space/cow*			
	7	***Overcrowding of stalls, but not fresh or high grou*** *p and 1 of following is present in 1 pen only: Dead ends, <24 inches of bunk space, < 2 waterers or <2 inches of linear space/cow*			
	10	*Overcrowding of stalls in fresh or high group OR overcrowding in 1 group barn AND/OR >1 of following is present in multiple pens: Dead ends, <24 inches of bunk space, < 2 waterers or <2 inches of linear space/cow*			
6		***Time in holding area***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If all cows spend <3 hours total time/day (2x/3x) OR tiestall*			
	4	*If 1 groups (not fresh) spend 3-4 hours total time/day*			
	7	*If multiple groups (not fresh) spend 3-4 hours total time/day*			
	10	*If all groups spend >4 hours total time/day or fresh cows spend> 3 hours total time/day*			
7		**How often are cows forced to be away from stalls for more than 30 minutes (typical eating bout), other than milking time. This time can include being locked in headlocks, being sorted away from home pen for breeding/ preg checks, or being let outside in tiestall**			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If occurs <1x/week OR if tie stall there is an opportunity for cow to lie down AND < 2 hours daily*			
	4	*If occurs 1-3x/week OR if tie stall there is NO opportunity for cow to lie down OR < 2 hours daily*			
	7	*If occurs >3x/week OR if tie stall there is no opportunity for cow to lie down AND 2-4 hours daily*			
	10	*If fresh group is locked up daily for >30 min OR if tie stall there is no opportunity for cows to lie down for > 4 hours daily*			
8		***Heat abatement***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If there are Fans and sprinklers and run at appropriate temps ~68-70F or appropriate tunnel with correct CFM*			
	4	*If there are fans or sprinklers or tunnel but run when it's hot or on manual*			
	7	*If there are fans or sprinklers or tunnel but doesn't reach all cows such tunnel with too few fans or HVLS fans in the feed alley*			
	10	*No heat abatement*			

Section 6

Lactating Cows

			Infectious		*Non-Infectious*	
			Score	*Max*	*Score*	*Max*
		Total Lactating Scores	**0**	**60**	0	**60**
		Questions	*1,2,3,4, 5,8*		*2,4,5,6, 7,8*	

Section 7

Flooring

Question

1		***Estimate % of floors that have pooled manure or puddles or exposure to mud***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If none anywhere*			
	4	*If 1-10% of floors OR on way to exercise area for tiestalls*			
	7	*If 10-25% of floors,OR on way to exercise area for tiestall*			
	10	*If most of cow walking area OR holding area OR exposure is occurs for >50% of cows (for example on in a transfer lane there's dip that all cows need to walk through)*			
2		***Estimate % of floors that have rough or damaged concrete***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If none anywhere*			
	4	*If 1-10% of floors OR on way to exercise area for tiestalls*			
	7	*If 10-25% of floors,OR exercise area for tiestall*			
	10	*If most of cow walking area or holding area*			
3		***Estimate % of floors that are slippery (including rubber) Slippery means you observe cows slipping***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If no slippery floors anywher*			
	4	*If 1-10% of floors OR on way to exercise area for tiestalls*			
	7	*If 10-25% of floors,OR exercise area for tiestal*			
	10	*If most of cow walking area or holding area*			
4		***Estimate % of floors that are steep >4% slope***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If no steep slopes anywhere*			
	4	*If 1-10% of floors OR exercise area for tiestall OR all steep slopes have rubber*			
	7	*If 10-25% of floor*			
	10	*If most of cow walking area or holding are*			
5		***Assess location of slats and estimate % of time on slats***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*If no slats anywhere*			
	4	*If small area for manure drops or low traffic areas*			
	7	*If in holding area only*			
	10	*If main barn alley*			

Section 7

Flooring

6		**Evaluate cow behaviour when cows are being moved, sorted and handled in the holding area**				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If no cows are observed running or slipping in any location*				
	4	*If cows are observed running/slipping with a single handler AND cows are NOT physically*				
	7	*If cows are observed running/slipping with multiple handlers AND cows are NOT*				
	10	*If cows are observed running/slipping with multiple handlers OR cows are physically*				
			Infectious		***Non-Infectious***	
			Score	***Max***	***Score***	***Max***
		Total Flooring Scores	**0**	**10**	0	**60**
		Questions	*1*		*2,3,4,5, 6*	

Section 8

Prevention

Question

1		**From trimming records determine how often cows are trimmed as a preventative.**				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If >80% cows are trimmed 2x/year or more and hoof trimmer visits occur >2x/yea*				
	4	*If < 80% cows are trimmed 2x/year OR hoof trimmer only visits farm 2x/year*				
	7	*If cows are trimmed 1x/year*				
	10	*If cows are trimmed as needed*				
2		**Evaluate hoof trimming technique and look for over/under trimming (see document)**				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If HT preserves non-weight bearing heel and claw, balances heels, does some modelling of weight bearing claw and leaves appropriate length and thickness*				
	4	*If HT DOES NOT do 1 of the following: preserves non-weight bearing heel and claw, balances heels, does some modelling of weight bearing claw and leaves appropriate length and thickness*				
	7	*If HT DOES NOT do >1 of the following: preserves non-weight bearing heel and claw, balances heels, does some modelling of weight bearing claw and leaves appropriate length and thickness*				
	10	*If HT trims the abaxial or axial wall*				
3		***Assess if there is an on farm chute available for use by on farm staff. Also assess ease of use and safety.***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If there is an on farm chute present that is safe, easily accessible (is in a permanent location), cow can be moved to chute by one person and a person on farm has been trained on appropriate treatment techniques*				
	4	*If on farm chute is safe to use, but 1 of the following criteria is NOT met easily accessible (is in a permanent location), cow can be moved to chute by one person and a person on farm has been trained on appropriate treatment techniques*				
	7	*If >1 of the following criteria is NOT met: on farm chute is safe to use, easily accessible (is in a permanent location), cow can be moved to chute by one person and a person on farm has been trained on appropriate treatment techniques*				
	10	*If No on farm chute*				
4		Determine if heifers are trimmed before calving.				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If every heifer is trimmed 2-3 months before calving (this requires more than 2 HT visits/year)*				
	4	*If every heifer is trimmed before calving, but it occurs at bi-annual HT visit*				
	7	*If only heifer close to calving are trimmed at annual or bi-annual HT visits*				
	10	*If heifers are never trimmed before calving*				

Section 8

Prevention

5		**Is there a separate area where severely lame cows can be put to recover quicker?**				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If there is a dedicated recovery area for lame/sick cows*				
	4	*If the recovery area is the maternity pen, and there is more than 1 pen*				
	7	*If the recovery area is the maternity pen, but there is only 1 pen OR seasonally use pasture*				
	10	*If lame cows are never removed from cow housing*				
			Infectious		***Non-Infectious***	
			Score	***Max***	***Score***	***Max***
		Total Prevention Scores		**0**	0	**50**
		Questions			*1,2,3,4, 5*	

Section 9

Footbathing

Question

1		**Determine the suitability of the farm's preventative infectious lameness program. Assess frequency of use (can be chemical or water only) and cleaning**				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If the farm has a written protocol and 1 of the following: uses a footbath 4-7x/week AND solution gets changed after 150-200 cows OR has a monthly spraying protocol that is at least 4-5 consecutive days OR does not have DD*				
	4	*If the farm DOES NOT have a written protocol, but does do 1 of the following: uses a footbath 4-7x/week AND solution gets changed after 150-200 cows OR has a monthly spraying protocol that is at least 4-5 consecutive days*				
	7	*If the farm uses a footbath 1-3x/week OR more than 200 go through 1 solution daily OR has a monthly spraying protocol that is <4 consecutive days*				
	10	*If the farm uses a footbath as needed OR sprays only the problem cows OR does not have protocol at all*				
2		**Measure length and depth of footbath**				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If the footbath is at least 10 ft (3m) long AND depth of water is at least 3 inches (6.5cm) AND there is no pre bath OR if 1 fill of the sprayer can spray the entire herd*				
	4	*If the footbath is at least 8 ft (2.4m) long AND depth of water is at least 3 inches (6.5cm) AND there is no pre bath*				
	7	*If it takes more than 1 fill of the sprayer to spray the herd OR If the 1 of the following criteria is present: footbath is <8 ft (2.4m) long OR depth of water is < 3 inches (6.5cm) OR there is a pre bath*				
	10	If the 2 of the following criteria is present: footbath is <8 ft (2.4m) long OR depth of water is < 3 inches (6.5cm) OR there is a pre bath				
3		***Determine frequency of preventative protocol on heifers/dry cows.***				
	Score	*Score Explanation*		**Enter Score here**		
	1	*If heifers do not have DD AND are housed separate from mature cows AND Dry cows are treated weekly more than once (can be repeated on same day) OR if Dry cows and heifers are treated weekly more than once (can be repeated on same day)*				
	4	*If Dry cows and heifers are treated every other weeky more than once (can be repeated on same day)*				
	7	*If Dry cows and heifers are treated as needed*				
	10	*If Dry cows and heifers are never treated*				
			Infectious		***Non-Infectious***	
			Score	***Max***	***Score***	***Max***
		Total Footbath Scores	**0**	**30**		**0**
		Questions	*1,2,3*			

Section 10

Lameness Therapy

Question

1		**Assess timelines of treatment and if there is 1 specific lameness personnel. To assess pick out an obviously lame cow and ask her history and who's job it was to find her.**			
	Score	*Score Explanation*		**Enter Score here**	
	1	*90% of cows are treated within 2 days of identification AND there is 1 designated cows side person in charge of lameness*			
	4	*90% of cows are treated within a week of identification AND there is 1 designated cows side person in charge of lameness*			
	7	*>75% of cases are treated by veterinarian or > 1 week, OR there is NOT 1 designated cows side person in charge of lameness*			
	10	*>75% of cases are treated by hoof trimmer or delay is > 3 weeks*			
2		**Evaluate treatment technique/protocol for Sole Ulcer/WLD/DD**			
	Score	*Score Explanation*		**Enter Score here**	
	1	*There is a written treatment protocol for the 3 major hoof diseases on the dairy AND there is evidence that the protocols followed appropriately AND the protocol includes ALL of the following: the use of appropriately size hoof blocks, if wraps are used no evidence of wraps on cows >1 day, automatic rechecks of cows with blocks, a dose for the treatment used for DD*			
	4	*There is NO written treatment protocol for the 3 major hoof diseases on the dairy BUT there is evidence that the actual protocols followed includes ALL of the following: the use of appropriately size hoof blocks, if wraps are used no evidence of wraps on cows >1 day, automatic rechecks of cows with blocks, a dose for the treatment used for DD*			
	7	*There is NO written treatment protocol for the 3 major hoof diseases on the dairy AND there is evidence that the actual protocols followed DOES NOT include 1 of the following: the use of appropriately size hoof blocks, if wraps are used no evidence of wraps on cows >1 day, automatic rechecks of cows with blocks, a dose for the treatment used for DD*			
	10	*There is NO written treatment protocol for the 3 major hoof diseases on the dairy AND there is evidence that the actual protocols followed DOES NOT include >1 of the following: the use of appropriately size hoof blocks, if wraps are used no evidence of wraps on cows >1 day, automatic rechecks of cows with blocks, a dose for the treatment used for DD*			
3		***Lameness and hoof trimming records***			
	Score	*Score Explanation*		**Enter Score here**	
	1	*All lameness case, treatmentand hoof trimming events are recorded and entered into permanent recording system*			
	4	*All lameness cases, treatments and hoof trimming events are recorded in on-farm paper records*			
	7	*Few lamenes cases, treatment or hoof trimming records of any kind*			
	10	*No lamenes or hoof trimmingt records at all*			

Section 10

Lameness Therapy

			Infectious		*Non-Infectious*	
			Score	*Max*	*Score*	*Max*
		Total Lameness Therapy Scores	**0**	**30**	0	**30**
		Questions	*1,2,3*		*1,2,3*	

Appendix 4.2 Workshop case studies

Case study 1: A client with a 400 cow dairy has become concerned with the level of digital dermatitis in their herd. They attended a meeting put on by a supplier that suggested they score cows in the parlor for DD and 70% of the cows have evidence of DD lesions. They are currently spraying feet with Lincomycin weekly and run a copper sulfate footbath 2x per week. They have asked you for input to develop an action plan.

Case study 2: A client who has a 1600 cow dairy has recently noticed an increase in lame cows due to what appears to be sole ulcers. The dairy converted from mattresses to recycled sand in the past 5 years and added a cross vent barn for milking cows. They recently built a cross vent barn to house calves and dry cows. They have asked for your input to fix the situation.

Appendix 4.3 Interview guide

Introduction
Thank you for taking the time to meet with me today. This should take about 1 hour depending on the conversation. The goal today is to openly discuss your opinions and experiences with the lameness project you participated in. There are no right or wrong answers and I am interested in your honest opinions, so please feel comfortable expressing them. I have a series of questions for you that we'll go through; we'll talk about the process itself, your assessment of how it went, its impact on your work and the herds, and where to go from here.

I will be audio recording the discussion today for data analysis. Our research team will be the only ones with access to these recordings. All personal information will be kept confidential and we will not release identifying information.

Do you have any questions before we get started?

RECALL AND DESCRIBE PROCESS-

- Initial stages: recall the planning meetings/the workshop, how did those go? Any elements you found helpful? Anything that we should know to improve them?
    - Is there anything else you would like to share about the workshop?
- Can you share with me what happened after the workshop regarding your action plans?
    - I'm interested in how you recruited your farms, stayed connected and communicated with each other, can you tell me about that?
    - How often did you connect with each other? [vet, trimmer, nutritionist]
    - Can you share why you chose to meet in person? What was it about the in-person approach that made the most sense for you/your group?
    - Can you share what you did to follow up on action plans?

    - [Did not complete action plans] Was there anything in particular that prevented you from doing the action plan? Can share about that?
        Were there any barriers to recruiting farms, staying connected, or communicating with each other?

THEIR ASSESSMENT OF IT Let's talk about your action plans. How do you think it went?

- Are there any particular elements that you liked, or that worked well? What elements of the process worked particularly well?
- Are there any things that you didn't like, or didn't work well? Is there anything that you would have wanted different or changed?
    - Did it get is resolved, how so? If not, any thoughts as to why?
    - How did the meetings go? Comfort with reaching out, planning meetings, speaking up in meetings, etc.

    - Did comfort/confidence with these tasks change through the meetings you attended?
    - confidence in being able to better manage lameness through this process?
- What do you think the other advisors thought of the process?

Impact on farmers/herds

- What do you think the farms thought of the process?
- Do you think this process had any effects on the farms you worked with? Please share...
    - Did they make any management changes?
        - Yes: What changes? Do you have any ideas as to why they made those changes?
        - No: any thoughts as to why they may not have? Any barriers that you saw?
    - Did you detect any change in your relationships with the farmers, or your dynamics?
      their attitudes?
- Would you recommend another one of your herds participate in this project? Why/why not?

Future direction

- Moving forward - do you have any plans to follow up on anything with the farms you did your action plans with?
- Are you interested in integrating this approach into your routine/approach?
    - In terms of how you work with other farms? Other stakeholders?
    - If yes, how will they do it? If no, why? What are the barriers? What support do they need?
- Do you think this type of process is actually useful/could work on a larger scale?
    - Is this something that the average trimmer/nutritionists/vet could fit into their working life/time in their day?
    - How about in terms of financial viability?
    - How about in terms of having the appropriate knowledge/skills?

I'm interested in your opinion, as a participant: we had some folks who dropped out, or who didn't follow up much- do you have any suggestions, based on your experience, of things that we could have done better to incentivize continued engagement?

Almost done: What is the biggest suggestion you have for us from participating in this project? What is the most important thing you took away from this experience?

Is there anything else you'd like us to know?