



Can lameness prevalence in dairy herds be predicted from farmers' reports of their motivation to control lameness and barriers to doing so? An observational study from New Zealand

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ABSTRACT

Understanding what motivates and prevents behavioral change in farmers is a critical step in disease control in dairy cattle. A total of 101 New Zealand dairy farmers across 8 regions were randomly enrolled into a cross-sectional study to investigate farmer barriers and motivators to lameness control for cows managed 100% at pasture and the relationship between these responses and the true lameness status on farm. Trained technicians lameness scored all lactating cows on the enrolled farms on 2 occasions during one lactation. Farm-level prevalence proportions were calculated as the mean of the 2 lameness scores. Enrolled farmers were asked their perception of lameness in the current milking season and responded to 26 ordinal Likert-type items with 5 options ranging from not important at all to extremely important. The questions were grouped under 3 categories; barriers to lameness control ($n = 9$), impacts of lameness ($n = 10$), and motivators to control lameness ($n = 7$). The association between farmer perception of lameness and lameness prevalence was reported using linear regression. Multiple-factor analysis was conducted to identify latent variable themes within the responses. Linear discriminant analysis was used to assess whether barriers, impacts, and motivators could be used to predict farmer perception of lameness and lameness prevalence. Lameness prevalence was 0.8% greater on farms where farmers perceived lameness as a moderate or a major problem compared with farms where the farmer perceived lameness as a minor problem or not a problem. Farmers ranked all potential motivators to lameness control as important and declared few barriers to be important at preventing them from controlling lameness. Feeling sorry for lame cows and pride in a healthy herd were the most important motivators, with lack of time and skilled labor the most important

barriers. The most important effects of lameness were cow-related factors such as pain and production, with farm and industry impacts of less importance. Farmers place different weightings of importance on barriers to lameness control compared with motivators for lameness control. The impacts and motivators were strongly correlated with the first dimension from the multiple-factor analysis, with only weak correlation between barriers and the first dimension. Linear discriminant analysis identified that the importance that farmers place on barriers, motivators, and impacts of lameness were poor predictors of farmers' belief in regard to their lameness problem or actual lameness prevalence (above or below the median lameness prevalence for the study cohort). Despite relatively low lameness prevalence, many New Zealand dairy farmers believe lameness is a problem on their farm, and they rank welfare effects of lameness of high importance. To investigate how farmer behavior change can be used to manage lameness, future studies should consider theoretical social science frameworks beyond the theory of planned behavior or involve prospective interventional studies investigating farmer actions instead of beliefs.

Key words: dairy cow, farmer beliefs, lameness, barriers

INTRODUCTION

Despite lameness being one of the major animal health and welfare concerns of dairy cattle farming internationally (Huxley, 2013), few control methods exist that are associated with a consistent large-percentage reduction in lameness incidence across a population or, in epidemiological terms, interventions that have a large population-attributable fraction. For example, although evidence exists for the effects of routine foot trimming on reducing lameness prevalence and incidence (Griffiths et al., 2018), in many countries where routine foot trimming is recommended, lameness prevalence remains greater than 20% (Solano et al., 2015; Griffiths et al., 2018). This highlights the complex multifacto-

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rial interaction between risk factors for lameness and also that concentrating on specific interventions, even if they are evidence-based, may not result in meaningfully large reductions in lameness prevalence (Hueston, 2003; Biesheuvel et al., 2021).

Instead, it may be appropriate to elicit from the main stakeholders, the farmers, what they believe are the barriers to controlling lameness on their farms and the factors that motivate them to control lameness. Farmers are a critical piece of the puzzle in disease control (Kristensen and Jakobsen, 2011; Biesheuvel et al., 2021) and are often underappreciated and underrepresented in lameness disease control and research. Involving farmers in the process of lameness control has resulted in greater acknowledgment of lameness problems on farms (Main et al., 2012) and subsequent reduction in lameness prevalence (Main et al., 2012; Chapinal et al., 2014). True lameness-control success is thus likely to be in the form of interventions that influence farmers' behavior in regard to lameness control (Biesheuvel et al., 2021).

A wealth of data exists from multiple countries and various dairying systems on the poor agreement between the proportion of the herd that the farmer believes is lame and what a trained locomotion scorer reports as lame, as summarized in Fabian et al. (2014) and Babatunde et al. (2019). Thus, lack of acknowledgment of the lameness problem by farmers appears to be a universal issue for managing lameness. Until these discrepancies are eliminated, or at least reduced, then optimal lameness control is nearly impossible, because the prompt identification and treatment of lameness is critical to lameness-control success (Alawneh et al., 2012; Newsome et al., 2016; Pedersen and Wilson, 2021). Therefore, understanding and influencing barriers to lameness control and motivations to control lameness become an important piece of the lameness puzzle (Babatunde et al., 2019; Biesheuvel et al., 2021).

Acknowledging that an issue with lameness exists, or becoming more aware of lameness, on farms is critical to controlling lameness. In a multiyear randomized clinical trial, a reduction in farmer tolerance to a lameness problem resulted in a reduction in lameness prevalence over time (Leach et al., 2013). Therefore, the key questions may be how this lameness tolerance can be influenced. Lameness prevalence is reportedly lower in pasture-based herds common in New Zealand compared with cattle which are housed for some of the year (Fabian et al., 2014; Griffiths et al., 2018; Browne et al., 2022). However, anecdotally, New Zealand dairy farmers still do report lameness as a concern, and ranges of lameness incidence and prevalence are reported on these units (Gibbs, 2010; Fabian et al., 2014). Investigating farmer beliefs around lameness in

these pasture-grazing dairying systems may provide valuable insight into lameness control on such farms. Therefore, repeating a similar survey to that conducted in the United Kingdom over 10 years prior (Leach et al., 2010a,b) was of interest to identify barriers to and motivators for lameness control.

In addition, previous analyses of such data have used statistical techniques that may not be appropriate for Likert-scale data, which is ordinal in nature. Previously both Pearson correlation (Leach et al., 2010b) and Spearman's rank correlation coefficients (Bruijnis et al., 2013; Leach et al., 2013) have been used when polychoric correlations may be more appropriate (Holgado-Tello et al., 2010; Ekström, 2011). Furthermore, previous studies have focused on correlations (Leach et al., 2010a,b; Bruijnis et al., 2013) or thematic (Croyle et al., 2019; Wynands et al., 2022) and have not explored whether farmer beliefs and themes have a predictive ability in regard to whether a farmer believes they have a lameness problem or whether they have high lameness prevalence. Recent improvements in machine-learning techniques have made it possible to produce quantitative inferences from qualitative data (Harpe, 2015; Biesheuvel et al., 2021). If farmer barriers to, and motivators for, lameness control can be used to predict a farmer's tolerance in relation to lameness, this could significantly aid the development of lameness-control strategies (Main et al., 2012; Leach et al., 2013). The application of quantitative methods such as multiple-factor analyses (**MFA**) can also rank farmer beliefs and thoughts, providing evidence-based control priorities on farms (Abdi et al., 2013).

Thus this study had several objectives: (1) to describe the relationship between whether New Zealand dairy farmers believed lameness to be a problem on the farm and lameness prevalence as evaluated by a trained external observer; (2) to investigate the variables that motivate farmers to control lameness, factors that farmers report as barriers to lameness control variables, and variables that they believe are important consequences of lameness in grazed pasture systems; (3) to identify correlations between barriers, motivators, and impacts of lameness and investigate underlying themes and sources of variance both within and between the 3 groups of questions; and (4) to investigate whether the themes identified in the farmers' responses to barriers, motivations, and importance of lameness can be used to predict whether a farmer believes they have a lameness problem and whether lameness prevalence is high.

METHODS

The study was designed as a cross-sectional descriptive study, with all procedures approved by Massey

University human ethics committee, application number 4000025095 and Massey University animal ethics committee application number 22/36 and 21/55.

Farm Enrollment

This study was part of a larger body of work investigating lameness prevalence and risk factors on New Zealand dairy farms. A one-stage cluster-sampling method was performed, with a systematic randomization sampling framework used to enroll farms. A total of 120 pasture-grazing non-housed dairy farms across 8 major dairying territorial regions in New Zealand were enrolled in a cross-sectional study investigating lameness prevalence over 2 time points across these farms. Enrollment was carried out by local veterinary practices within each region. Each practice listed their dairy clients in alphabetical order and excluded farms that were greater than a 1-h drive away or that were known to have a parlor design that meant post-milking lameness scoring was challenging. From the remaining eligible population, 15 farm clients were then systematically randomly enrolled. To do this a random number between 1 and 10 was generated in Microsoft Excel, with this number used to select the first farm on the list. Then every n th farm (where $n = \text{total number of eligible farms}/15$) on the list was enrolled. No farmers refused to be involved in the study.

The study was split into 2 years, with 60 North Island farms in year one (2021–2022 dairy season) and 60 South Island farms in year 2 (2022–2023 dairy season). Lameness score (LS) data was collected on 2 occasions from each farm, once between September and November (peak lactation, spring) and again between January and March (mid-late lactation, summer).

Lameness Scoring

Details on lameness scoring methods are described in full in Mason et al. (2023). In brief, all lactating animals present on the farm on each of the 2 visit days were lameness scored by a trained observer using a 4-point LS scale (0–3), adapted from the DairyNZ Lameness Scoring system (Supplemental Table S1; <https://doi.org/10.6084/m9.figshare.25092407>; Mason, 2024b). Animals were scored immediately after milking while walking on a flat concrete surface; scoring was conducted by trained and calibrated observers (one observer for each region), as described in Mason et al. (2023). This included animals that had been previously identified as lame by the farmer and had been placed into a separate herd at the time of the lameness scoring visit. The prevalence of lameness at each visit was defined as the proportion of animals with an LS ≥ 2 .

Survey Design

The full survey consisted of 11 questions, adapted from the survey used by Leach et al. (2010a,b) for New Zealand dairy farmers. Farmers were asked to select 1 of 3 options on their perception of lameness in the current milking season (June–May); major problem, moderate problem, and minor or not a problem. Farmers then listed the sources where they get their advice about treating or preventing lameness.

A total of 26 ordinal Likert-type items with 5 options ranging from not important at all to extremely important were asked of the farmers, grouped under 3 questions: motivators for lameness control, barriers to lameness control, and impacts of lameness. The motivator grouping of questions ($n = 7$) revolved around how important certain factors were in motivating them to manage lameness. For barriers to lameness control, farmers were asked how important certain factors were at preventing them from controlling lameness on their farm ($n = 9$ items). For impact-related questions ($n = 10$) farmers were asked to rank the importance of potential problems arising from lame cattle on their farm.

Before release of the survey, draft versions of the survey questions were tested on several veterinarians and local dairy farmers (who were not eligible for the study) to mitigate any areas of ambiguity.

The primary decision maker on each farm was selected to respond to the survey—this could be the owner, manager, or share-milker, depending on the farm. A share-milker is a dairy farmer that owns the dairy cattle being milked and operates the farm on behalf of the farm owner. They receive a percentage of the milk income (most commonly 50%) and all money from the sale of livestock. The LS data were not communicated to the farmers until the completion of the study. The survey was distributed to the farmers around the time of their second LS visit. Three response methods were implemented to attempt to maximize response rate; first, the surveys were distributed to all 120 farmers online via Survey Monkey (<https://www.surveymonkey.com/>). If they did not respond via this method, each veterinary clinic called the nonresponders. Finally, surveys could be answered in person on the farm with the questions asked by a veterinary clinic representative.

Statistical Analysis

Statistical analysis was split into sections: first, the relationship between farmer beliefs in relation to the lameness problem on their farms and lameness prevalence, and, second, the analysis of the association within and between Likert-type items relating to barriers to

lameness control, impact of lameness, and motivations to control lameness.

Descriptive statistics were tabulated and presented for the number of responding farmers by geographical region and North and South Island. Boxplots and unconditional linear regression were used to describe the relationship between farmers' belief of a lameness problem on the farm and lameness prevalence. For statistical analyses, due to low numbers in the major problem group, farmers reporting lameness as major and moderate problems were collapsed into one category, resulting in farmers' belief in regard to their lameness problem becoming a binary variable. For the purpose of this study, prevalence was reported as the mean value of the 2 prevalence scores, and all subsequent mention of lameness prevalence relates to this definition unless stated otherwise. Before this, the lameness prevalence at the first and second LS were compared using a Wilcoxon rank sum test to identify if differences existed between the 2 scores. Assumptions of normality of residuals and heteroskedasticity were assessed graphically, with transformation of non-normal variables and variance weighting if heteroskedasticity was identified. Bar graphs centered around the neutral response were used to present the Likert items for the motivations, barriers, and lameness impacts.

The polychoric correlations between each of the 26 Likert items were calculated and presented with a correlation matrix plot, with the size and direction of the polychoric correlation coefficient represented by the size and color of the circle in the plot (Supplemental Figure S1; <https://doi.org/10.6084/m9.figshare.25091804>; Mason, 2024a).

Polychoric correlations between barriers, motivations, and lameness impacts, and underlying themes both within and between the 3 groups of questions were assessed using 2 methods. First, factor analysis (FA), and then MFA, accounting for the grouping within the survey questions. The aim of FA is to reduce several often highly correlated variables into a smaller number of uncorrelated variables or dimensions. In this way, FA can identify "latent" factors that the original variables are explaining (Yong and Pearce, 2013). Thus, in the current study, the aim was to reduce the 26 variables across the 3 groups into themes or "factors" that could explain most of the variation in responses among farmers. The number of factors identified was determined using the scree-plot, with all further components removed after the plot of eigenvalue against components formed an "elbow." Maximum likelihood was then employed to determine the factors, with varimax rotation used to minimize correlation between the identified factors. Outputs are presented as supplementary

information, with the main purpose of this analysis to produce predictor factors for the linear discriminant analysis (LDA) described below.

Multiple-factor analysis was used to stratify the FA by the question grouping. Thus, each group of questions is equally weighted in regard to its influence on the dimensions identified by the MFA. This method reflects our a priori grouping of the survey questions, which may have resulted in farmers responding differently within each group of questions. It also gives us information on correlations between the groups (i.e., barriers, motivations, and impacts) allowing us to study the links between these groups (Lê et al., 2008; Abdi et al., 2013). A scree-plot was used to determine the number of dimensions to include, as described above under FA. The proportion of variation explained by the 3 groups for each dimension was calculated, as was the correlation between the 3 groups and each dimension. The coordinates for the first and second dimension calculated during the MFA were plotted for both the groups of questions and each individual Likert item, colored by their grouping. The relative contribution to the first and second dimension for each of the Likert items was calculated, with the 5 variables that contributed the greatest amount of variation reported.

The last analysis used was LDA, a form of supervised learning used for class separation (classification). We used LDA to investigate whether barriers, motivations, or impacts could be used to predict whether a farmer believed they had a lameness problem (i.e., if they responded they had a major or moderate problem with lameness) and, second, if they actually did have a lameness problem based on locomotion scoring (i.e., their farm-level prevalence exceeded the median for this study). The factors identified in the FA were used as the predictors for the LDA models. Because only 2 possible classifications existed for both outcome variables, only one linear dimension was produced for each model. The eigenvector of the first linear discriminant for each farmer was plotted in a boxplot, grouped by the 2 outcomes. The predictive abilities of the models were reported as (1) area under the curve (AUC) of the posterior probabilities of the LDA and (2) the accuracy at correctly predicting based on a contingency table of predicted and actual classification.

Missing data were imputed depending on the data type by multiple imputation chained equations, provided that such data constituted less than 5% of a variable. If more than 5% of data were missing from a variable, then it was removed from any analysis. The unit of interest for all analyses was the farm, with all analyses and data manipulation undertaken using R Version 4.2.3 (R Core Team, 2022). Specific R packages

used for the analyses included FactoMineR (Lê et al., 2008), missMDA (Husson et al., 2013), psych (Revelle and Revelle, 2015), as well as the suite of packages contained within the Tidyverse (Wickham et al., 2019).

RESULTS

Descriptive

Of the 120 enrolled farms, 101 responded to the survey. The median herd size was 430 (interquartile range [IQR]: 315–623) cows, with the predominant breed on 47/101 farms a Holstein-Friesian/Jersey cross; the predominant breed on 38 farms was Holstein-Friesian, and the predominant breed on 15 farms was Jersey. Spring calving occurred 100% of the time on 94/101 farms; the other 7 farms calved the majority of their cows in the spring and a minority in the autumn. All farms continually managed cattle at pasture during lactation and the dry period. Reasons for the 19 nonresponders were not formally collected, although lameness prevalence was similar between the responders and nonresponders. The online survey method accounted for 86% of responses. The 101 participants were located throughout the 8 dairying regions, with a median of 14 farms per region (range 8 to 15). Only 8 of 15 Northland farmers participated in the prevalence study because of communication issues when emailing the surveys out to them. All Likert items had between 1% and 4% missingness, and thus these missing data points were imputed before undertaking analyses, with no variables removed. Median lameness prevalence was 2.7% (IQR 1.6–4.2%), with a range from 0.4% to 13.2%. The median farm-level lameness prevalence at the first LS (spring) was 2.99 (IQR 1.36–4.73) and at the second score (summer) was 2.57 (IQR 1.52–4.20), with no difference in the median LS between the seasons identified ($P = 0.50$).

Median Lameness Prevalence Versus Farmer Perception of Lameness Problem

Of the respondents, 45 of 99 (46%; 95% CI 36–55%) perceived lameness as minor or not a problem, and 40 of 99 (40%; 95% CI 31–50%) perceived it as a moderate problem. Farmers who perceived lameness as a major problem had a median lameness prevalence of 3.3% across the 2 visits (range 1.1–13.2%; Figure 1). In contrast, those that perceived lameness as minor or not a problem had a median lameness prevalence of 2.3% (range 0.5–8.9%).

Log-transformation of lameness prevalence data resulted in normal distribution of the residuals as illustrated by a straight line QQ-plot. When back-transformed, lameness prevalence was 0.80% (95% CI

0.61–1.04%) greater on farms where farmers perceived lameness as a moderate or a major lameness problem than on farms where they perceived lameness as minor or not a problem.

Where Farmers Go for Lameness Advice

Eight options were available for farmers to select where they get advice on treating and preventing lameness. The most frequent response was the veterinarian, with 89% (89 of 101) of respondents noting that this was where they got their lameness advice from (Table 1). Their own ideas and other farmers were the second and third most frequent source of lameness advice.

Barriers, Motivators, and Impacts of Lameness

The top 3 motivating factors for putting time and resources into improving lameness were pride in a healthy herd, feeling sorry for lame cows, and feeling guilty for lame cows, with greater than 80% of farmers responding that these factors were very or extremely motivating (Figure 2). The importance of farm assurance plans and wanting to do better than peers scored lower than other factors, yet still more than half of the farmers ranked these as very or extremely important motivating factors.

The 3 barriers to management of lameness that farmers ranked the most important were a lack of time, lack of skilled labor, and poor foot-crush facilities; however, 40% or fewer farmers ranked these as very or extremely important (Figure 3). The least important barriers to lameness control were solutions not affordable, conflicting advice, and lack of information, with at least 69% of respondents stating that these were either slightly or not important barriers to lameness control on their farm.

Most of the potential impacts of lameness were considered important to farmers overall, with the exception of the requirement for extra labor and the hassle of another herd (Figure 4). All farmers ranked the impact of lameness on the pain and suffering of the cow as very (11%) or extremely (89%) important. Factors related to the individual cow were generally ranked higher than those that related to the farm or industry.

Relationships Between Lameness Motivators, Barriers, and Impacts

With the grouping structure of farmer responses related to motivators, barriers, and impacts of lameness retained, MFA identified 3 dimensions that explained 53.5% of the total variance from the 26 Likert items. The first dimension explained 27.5% of the variation,

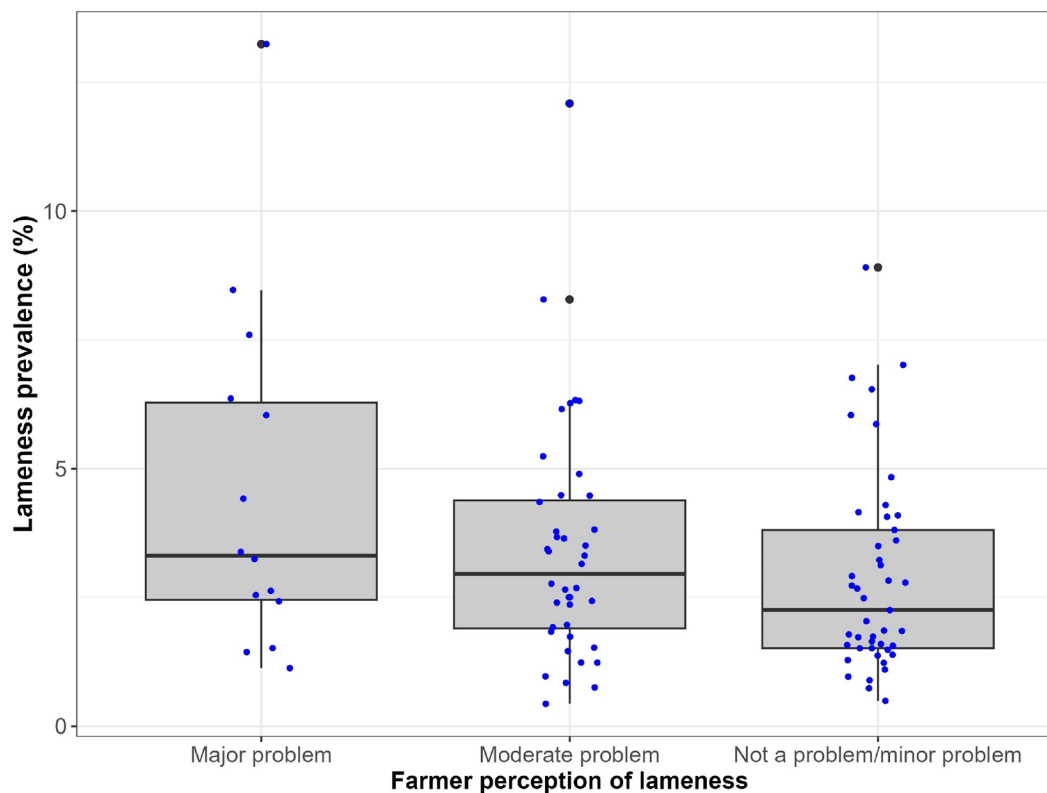


Figure 1. Boxplots of the lameness prevalence (mean of 2 scoring events), as defined by trained lameness scorers, grouped by the farmer-perception-of-lameness problem. The upper and lower edges of the boxes indicate the 75th and 25th percentiles, respectively, with the median represented by the bold horizontal line within the box. The whiskers represent the maximum and minimum values, excluding outliers. Outliers, shown as solid black dots, represent values more than 1.5 times the interquartile range. The blue dots represent each farm within each farmer-lameness-perception category ($n = 99$ farmers across the 8 dairying regions in New Zealand).

the second dimension 17.5%, and the third dimension 8.6%. The correlation plot of the first and second dimensions, illustrates that both motivators and impacts contributed equally to the variance in both the first and second dimension, indicating that these 2 groupings of questions elicited similar responses by farmers (Figure 5; Table 2). In other words, farmers that believed motivators for lameness control to be important also thought that impacts of lameness were important. In the first dimension, motivators and impacts each

contributed 46% of the variation, with correlations of 0.90 between the motivators and the first dimension, and 0.91 for impact and the first dimension, respectively. In contrast, the variance contribution that the grouping of barrier Likert items provided suggests a different theme to the other 2 groups of questions (Figure 5a). Barriers contributed 8.2% of the variation of the first dimension and had a correlation coefficient with the first dimension of 0.39.

All Likert items were positively correlated with each other in the first dimension (Figure 5b). In the second dimension, the barriers-to-lameness-control variables were negatively correlated with some, but not all, motivators to control lameness. The coordinates were close together for the first and second dimensions for all the barrier items, indicating little variations in responses by farmers for each of these Likert items. The 5 variables that contributed the greatest amount of variation across dimensions 1 and 2 were all motivators. Lameness cows losing money, good public image, losing farm assurance plans, wanting to do better than peers, and pride in a healthy herd each explained between 4.8% and 5.6% of the total variation in the first 2 dimen-

Table 1. Sources of advice for farmers on treating and preventing lameness¹

Advice source	Number of responses
Veterinarian	89
Farmer's own ideas	44
Other farmers	40
Hoof trimmer	34
DairyNZ	23
Nutritionist	12
Farm consultant	12
Other	13

¹Farmers could select as many options as applicable ($n = 101$).

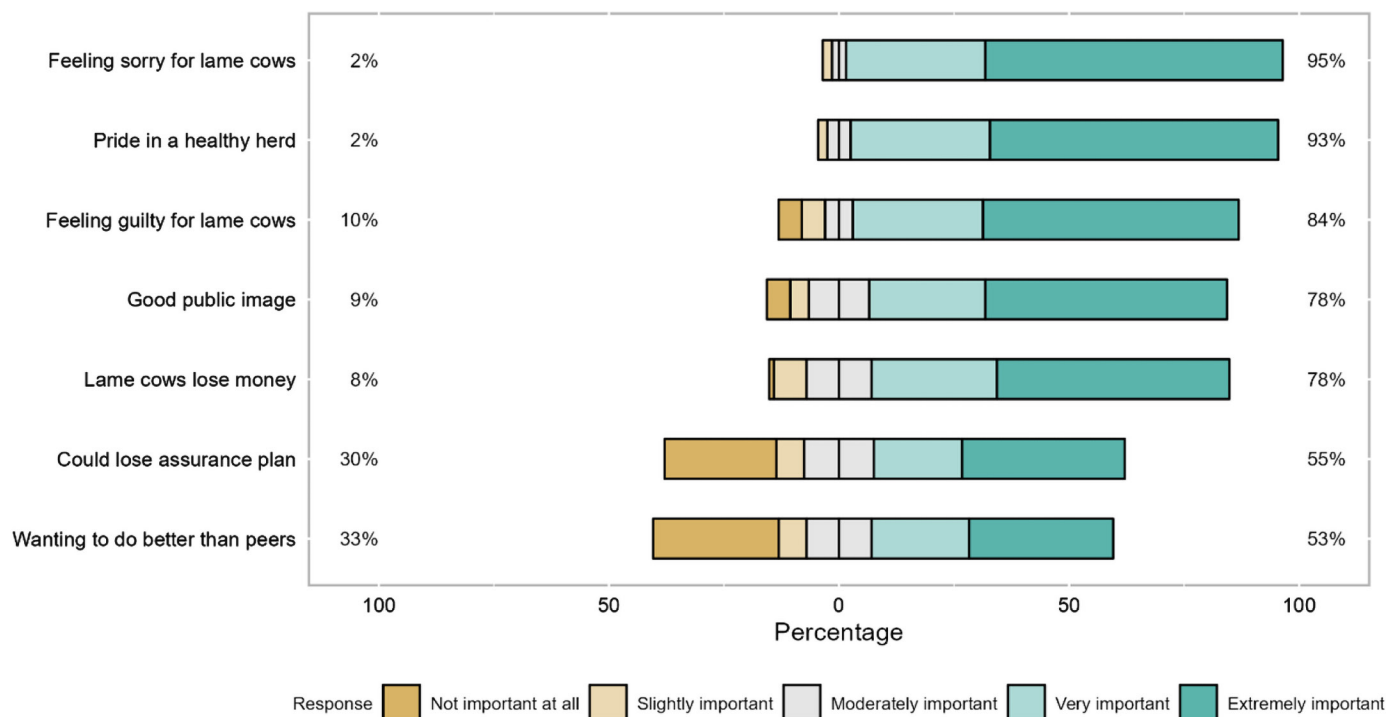


Figure 2. Likert items of farmer ranking the importance of each factor for motivating them to put time and resources into improving lameness ($n = 97-101$). The percentages represent the proportion of respondents giving an answer of “not or slightly important” (left axis) or “very or extremely important” (right axis).

sions. The remaining Likert items contributed between 2.2 and 4.7% of the variation.

Predicting Lameness and Lameness Perception from Farmer Themes

The screen-plot identified 4 factors that were responsible for 63.3% of the variance in farmer responses to the questionnaire (Table 3). The first factor explained 22% of the variance and was influenced by all the barriers to lameness control with the addition of the importance of the requirement for extra labor that lameness creates (Table 4). The theme of this factor was thus defined as lameness-control barriers. The theme of factor 2 (which explained 16% of the variance) was public perception and challenges beyond the farm gate as the importance of farm assurance, public perception, and benchmarking were the most influential variables in this factor. Factor 3 (which explained 14% of the variance) was related to cow welfare; the variables with the greatest correlation weighting for this factor consisted of the importance of lameness as a cause of pain and suffering as well as both feeling guilty and sorry for lame cows as a motivator for lameness control. The other key influencing variables for this factor were the impact of lameness on reproduction and of the impact of lameness on body

condition. The final factor (which explained 11% of the variance) had a theme of profitability as it was most influenced by the importance of the impact of lameness on profitability and on milk production.

These 4 factors were used as the predictors for the LDA. The boxplots of the first linear discriminant show clear overlap with outcome for both farmers’ belief of lameness problem and for median lameness prevalence (Figure 6). With farmers’ belief as the outcome, the LDA had an accuracy of 0.59 (95% CI 0.49–0.69) and an AUC of 0.69 (95% CI 0.59–0.80). With lameness prevalence as the outcome (less than median vs. greater than median), the LDA had an accuracy of 0.53 (95% CI 0.43–0.63), and AUC 0.58 (95% CI 0.49–0.72).

DISCUSSION

Despite lameness prevalence being much lower than in most studies of lameness prevalence recently reviewed by Thomsen et al. (2023), many farmers in this survey believed that lameness was a moderate or major problem on their farm. Our data suggests that farmers place different weightings on barriers to lameness control compared with motivators for lameness control. However, the importance that farmers place on barriers to controlling lameness, motivators for lameness con-

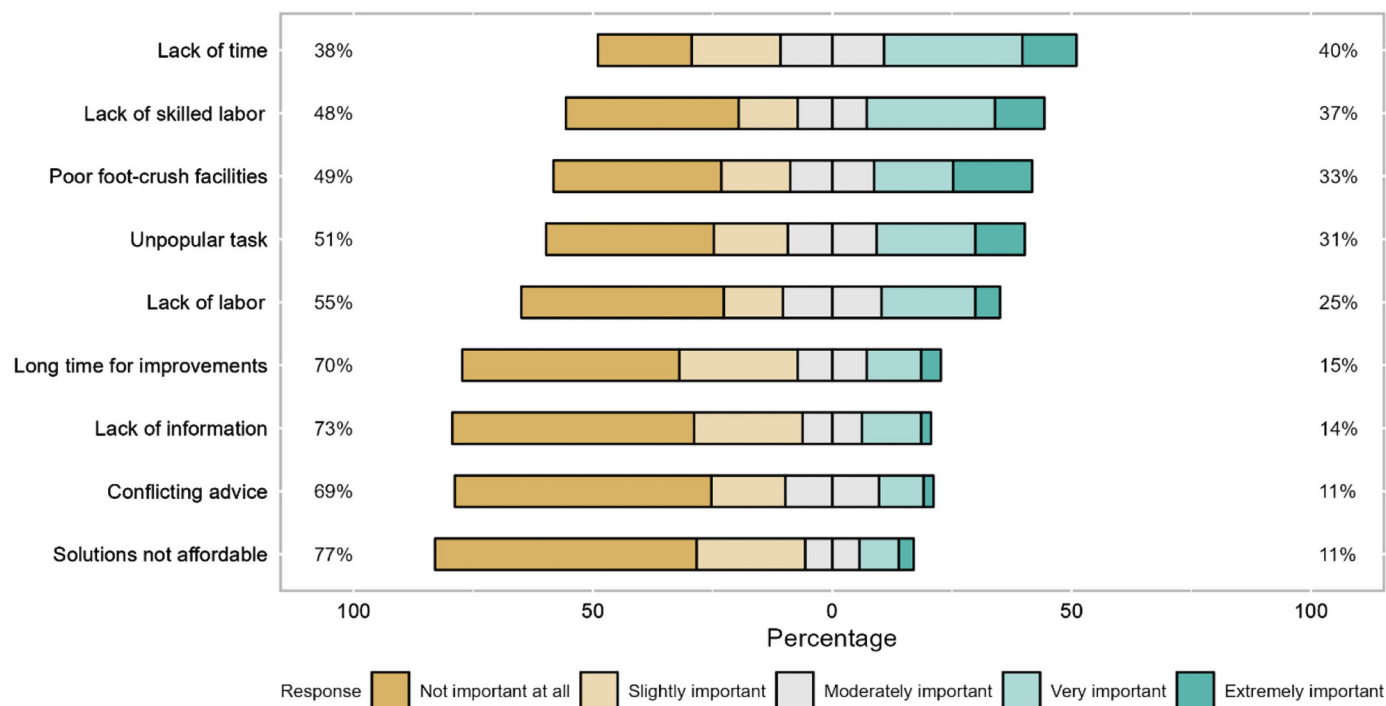


Figure 3. Likert items of farmer ranking barriers that prevent farmers from managing lameness in an ideal way ($n = 97-101$). The percentages represent the proportion of respondents giving an answer of “not or slightly important” (left axis) or “very or extremely important” (right axis).

trol, and impacts of lameness are not good predictors of farmers’ belief in regard to their lameness problem on their farm or actual lameness prevalence.

Of the farmers surveyed, 45% believed lameness to be a moderate problem on their farm and 40% believed lameness was minor or not a problem. Very few believed lameness to be a major problem. In comparison, Leach et al. (2010a) reported that 33% of their UK respondents described their lameness problem as minor, 56% as moderate, and 11% as major, suggesting that New Zealand farmers believe lameness to be less of a problem than their UK colleagues. However, these differences are relatively small and in stark contrast with the median lameness prevalence of the 2 studies, with Leach et al. (2010a) reporting a median lameness prevalence of 36% (>10 times that of the current study). Furthermore, despite the large difference in median prevalence, the relative importance farmers placed on barriers and motivators was similar to that reported by Leach et al. (2010a,b). Thus despite vastly different dairy farming systems, risk factors, and baseline lameness prevalence, there may be mutually beneficial international research opportunities to assess lameness-control strategies that influence farmer behavior that could result in success across different systems (Green et al., 2020).

Dairy farmers have diverse awareness and perception of lameness. Although associations between farmer be-

lief of a lameness problem and true lameness prevalence were reported in the current study, with less than 1% predicted difference between farmers that perceived lameness to be a problem or not, this association can be considered biologically weak. Leach et al. (2010a) reported a similar association. Furthermore, in both the current study and Leach et al. (2010a), there were farmers who believed they did not have a lameness problem who had a lameness prevalence in the top 5% of all enrolled farmers and, conversely, farmers who believed they had a major lameness problem who had lameness prevalence in the bottom 5% of farmers. Although awareness of a disease problem alone is not usually enough to motivate change (Ritter et al., 2017), it is still often a prerequisite step in the process (Leach et al., 2013; Ritter et al., 2017). Further research is required to investigate how farmer perception of lameness can be improved in a country with a relatively low baseline of lameness such as New Zealand.

A key finding of our study is that farmers do care about the welfare of lame animals, with the most extreme responses in both the motivation and importance of lameness groupings of questions related to the pain that lameness causes an animal. Similar themes have been expressed before, with the majority of Swiss dairy farmers reporting that reducing lameness pain to the lowest possible level was of “absolute” importance

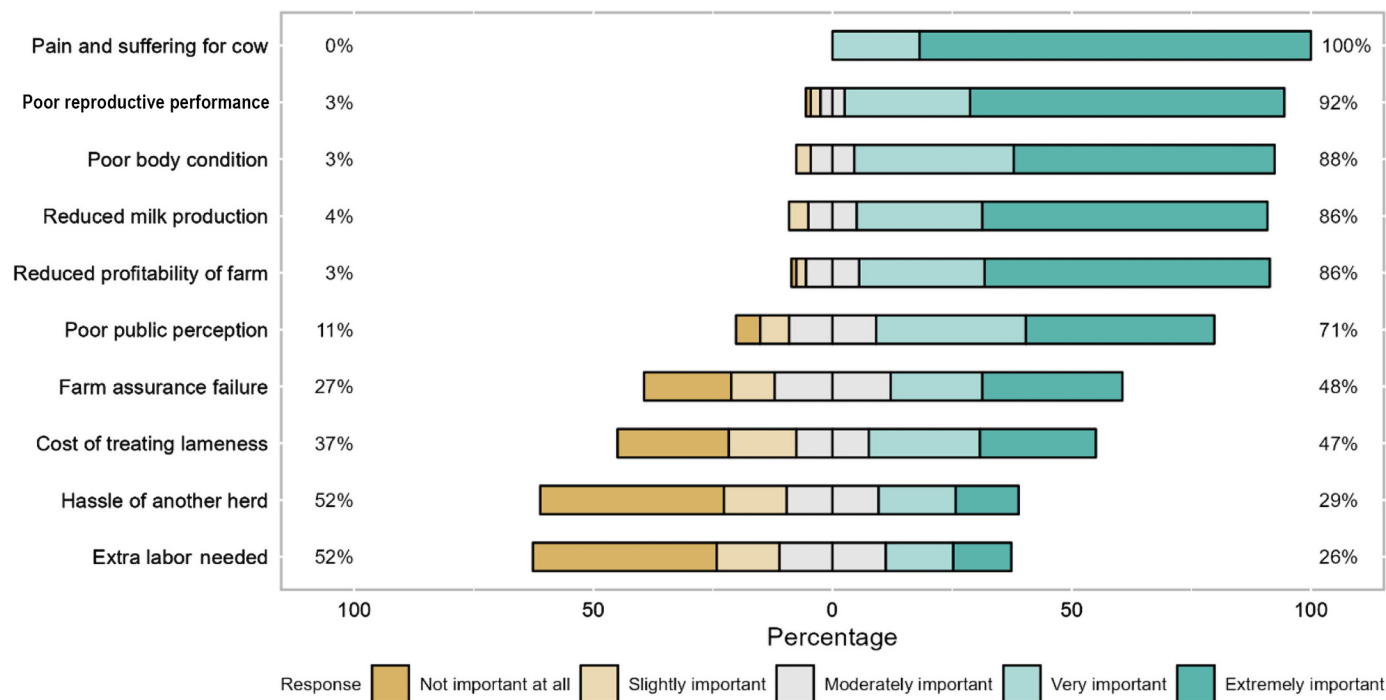


Figure 4. Likert items of farmer ranking of the importance of impacts of lameness on the cow, the farm, and the industry ($n = 97-101$). The percentages represent the proportion of respondents giving an answer of “not or slightly important” (left axis) or “very or extremely important” (right axis).

(Becker et al., 2013). Yet at the same time, farmers’ beliefs about the welfare of lame cattle was not associated with intention to implement or the cost-effective nature of the intervention (Bruijn et al., 2013), nor the cost of treatment deemed an important barrier in this current study or from Swiss dairy farmers (Becker et al., 2013). There is an apparent disconnect between dairy farmers claiming to care about the welfare of lame cattle and a lack of appreciation by farmers of the welfare implications of lameness. This is further highlighted both with the previously discussed large contrast between lameness prevalence as determined by farmers and lameness prevalence by trained lameness scorers, and also in the lack of awareness by farmers regarding the need for analgesia when confronted with extremely painful hoof lesions such as sole ulcers (Becker et al., 2013).

The veterinarian was the primary source for lameness treatment and prevention advice, with a proportion greater than double the nearest advisory source in this current study. The veterinarian was also the most common source of advice for lameness control by UK dairy farmers (Leach et al., 2010a). Veterinarians have a unique role in their ability to influence dairy farmer behavior with respect to animal health and welfare (Biesheuvel et al., 2021). Similar to Swiss dairy farmers (Becker et al., 2013), we report that cost of treatment of lameness is not of major importance or concern for

farmers. Yet veterinary practitioners considered pain reduction to the lowest possible level less important than did dairy farmers (Becker et al., 2013). The upside of all of this is that these findings challenge animal health advisers, particularly veterinarians, to improve their advice for welfare control of lameness, and prejudices and biases of what animal health advisers believe a farmer will act upon should be left at the door. Jorritsma et al. (2023) concluded that because most Dutch farmers report they are aware of the importance of preventive lameness measures, veterinarians may not need to spend time on convincing farmers of the importance. However, ample opportunity remains for animal health advisers, particularly veterinarians, to improve the welfare of lame cattle by providing farmers with more tools, including nonsteroidal anti-inflammatory drugs and hoof blocks, and educating farmers on the benefits of these as well as implementation of strategies such as early detection of lameness (Pedersen and Wilson, 2021).

Farmers’ responses with respect to the cost of lameness control were also contradictory. More than 80% of surveyed UK farmers did not consider the affordability of control solutions to be an important barrier for lameness control (Leach et al., 2010a), which is similar to the 78% in this current survey. Yet in the same survey, the UK farmers were asked whether they implemented new

Table 2. The contribution of variance and correlation of question groupings on the first 3 dimensions from a multiple-factor analysis¹

Grouping	Dimension 1		Dimension 2		Dimension 3	
	Contribution (%)	Correlation	Contribution (%)	Correlation	Contribution (%)	Correlation
Barriers	8.2	0.39	71.3	0.90	6.9	0.30
Impacts	46.0 ²	0.91 ³	19.7	0.65	58.5	0.79
Motivators	45.8	0.90 ³	9.0	0.41	34.6	0.59

¹The 3 groupings of questions were barriers, impacts, and motivators. The percentage of variation that they explained for each of the 3 dimensions, respectively, and the correlation coefficient between each grouping and each dimension, are reported.

²Impacts of lameness contributed 46% of total variation for the first dimension.

³Impacts of lameness and motivators had very strong polychoric correlation coefficient (0.90 and 0.91, respectively) with the first dimension.

control ideas they had sought advice for. Only 21% of farmers that had searched out lameness-control advice implemented all of the lameness-control suggestions, with the most common reason for not implementing the control measures being cost. Although we did not ask farmers if they implemented control plans in the current survey, given their similar responses for barriers and motivators, there is no reason to believe this to be any different in New Zealand. This may be in part a function of dairy farmers believing they have already done enough to control lameness (Bruijnjs et al., 2013).

This study reports on how farmer beliefs could influence lameness outcomes, but not how we can predict farmer behavior nor explicitly assess the decision-making process for lameness control. It is one thing for a farmer to claim an intention to change, but something quite different to act on it (Biesheuvel et al., 2021). There may be opportunities for animal health advisers and farmers to think laterally to address some of the barriers identified. For example, in this study, we were surprised to find farmers did not believe that needing extra labor was an important barrier to lameness con-

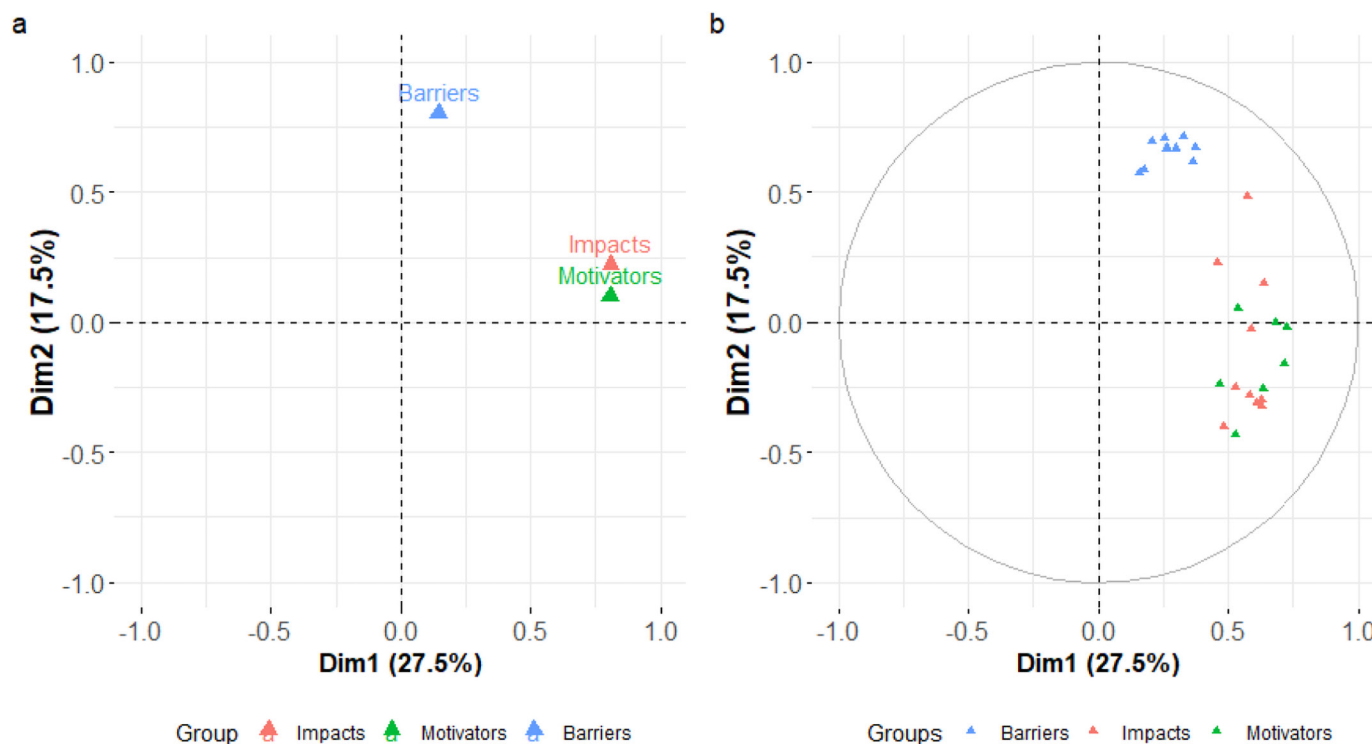


Figure 5. First and second dimensions (Dim1 and Dim2, respectively) from a multiple-factor analysis of the barriers, impacts, and motivators for lameness control as reported by New Zealand dairy farmers ($n = 101$) for (a) the grouping of questions on barriers, motivators, and impacts and (b) the 26 Likert items, colored by barrier, motivators, and impacts of lameness. The x and y -axes of both plots are the squared correlation coefficient and represent, respectively, the proportion of variation explained for the first and second dimensions.

Table 3. Polychoric correlation matrix of 26 Likert items on lameness barriers, impacts, and motivators on the first 4 factors identified from a factor analysis¹

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Barrier				
Labor	0.735	0.271		
Skilled labor	0.709	0.106		
Time	0.720			-0.145
Facilities	0.604			-0.180
Not affordable	0.666			
Unpopular task	0.725		-0.103	0.101
Conflicting advice	0.822		-0.147	0.116
Long time	0.768			0.173
Knowledge	0.879			
Impact				
Pain	-0.135	0.173	0.933	0.202
Profit		0.250	0.338	0.799
Milk production		0.158	0.433	0.884
Reproduction		0.108	0.637	0.467
Body condition		0.238	0.753	0.324
Farm assurance		0.826		
Public perception		0.704	0.289	
Treatment cost	0.317	0.382	0.160	0.454
Extra labor	0.639	0.306		0.267
Lame herd	0.367	0.126	0.136	0.355
Motivator				
Pride	-0.126	0.330	0.654	0.140
Sorry for lame		0.284	0.665	0.100
Guilty for lame	0.221	0.470	0.452	0.164
Money		0.508	0.329	0.590
Public image		0.698	0.321	0.175
Farm assurance	0.143	0.913	0.148	0.166
Benchmarking	0.193	0.671	0.296	0.198

¹Values are in bold when the polychoric correlation coefficient for that factor was >0.6 and represent Likert items that explain a significant proportion of the latent theme of that particular factor. Factor 1 = barriers; Factor 2 = public perception; Factor 3 = cow welfare; Factor 4 = profitability.

trol. With the low lameness detection risk ubiquitous among dairy farmers, one way to address low detection would be via the addition of extra labor dedicated to the task of detecting and treating lameness, even in the form of external hoof trimmers or veterinarians. Lack of time was the most important barrier in our study, and moderate correlation existed between time and labor, preventing farmers from controlling lameness ($\rho = 0.68$). Lack of time was reported as the biggest barrier for lameness control by UK dairy farmers (Leach et al., 2010a) and the most needed resource for claw health by Dutch dairy farmers (Jorritsma et al., 2023). Furthermore, a prospective study identified that farmers who placed time as a significant barrier to lameness control were able to reduce lameness to a greater extent than those where time was not an important barrier to lame-

ness control (Leach et al., 2013). So, although farmers may not see the lack of labor as a major barrier, the provision of extra labor may address what they saw as the biggest barrier to lameness control, a lack of time.

The latent factors influencing what farmers perceive as barriers to lameness control on the farm were different from the factors that influence farmers' motivation to control lameness. This was irrespective of the farmers' perception of the lameness problem and of the true status of lameness on farm. This makes interpretation of farmers' responses challenging. Although barriers and motivators were not directly compared in Leach et al. (2010a,b) and reported in separate manuscripts, the overarching themes of the barriers and motivations between UK and NZ dairy farmers were similar. There were few factors that UK farmers identified as

Table 4. Themes from the 4 factors, ordered from factor explaining greatest to least percentage of variation

Factor	Variance (%)	Cumulative variance (%)
1: Barriers	22.1	22.1
2: Public perception	16.0	38.1
3: Cow welfare	14.3	52.4
4: Profitability	10.8	63.3

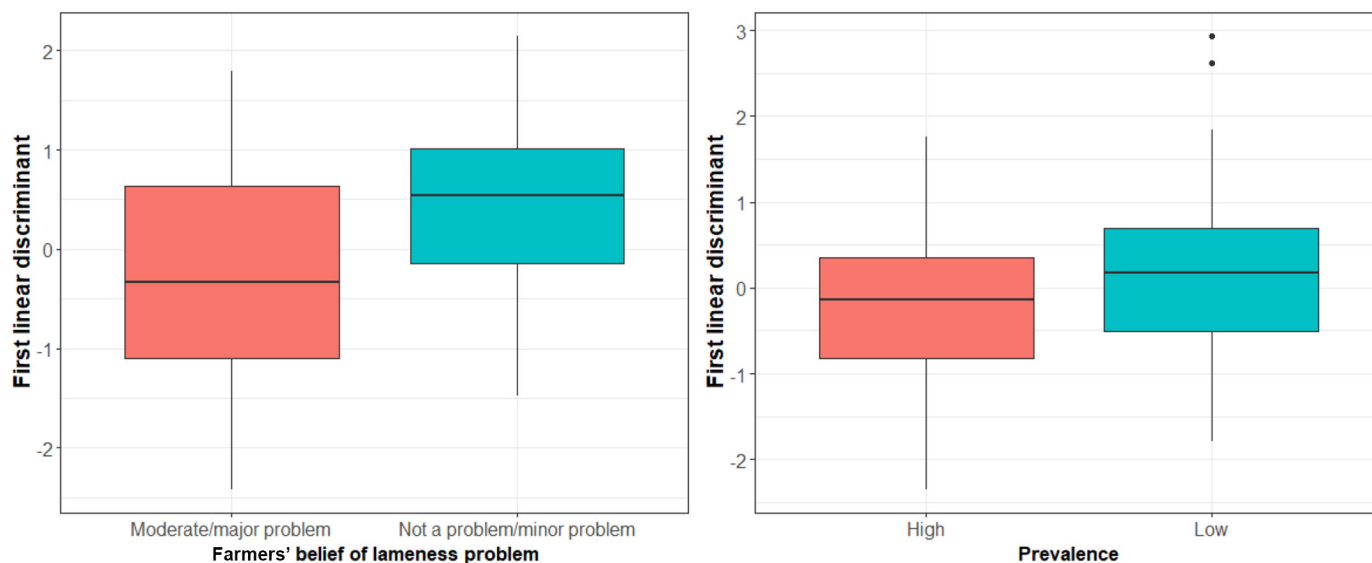


Figure 6. Boxplots of the discriminant function from 2 linear discriminant analyses, (a) farmer perception of lameness and (b) lameness prevalence above (high) and below (low) the median lameness prevalence, from 4 latent factors produced by a factor analysis from 26 Likert items on lameness barriers, impacts, and motivators. A good class prediction should result in little overlap between the linear discriminants between the 2 classes. The upper and lower edges of the boxes indicate the 75th and 25th percentiles, respectively, with the median represented by the bold horizontal line within the box. The whiskers represent the maximum and minimum values excluding outliers. Outliers, shown as solid black dots, represent values more than 1.5 times the interquartile range.

important barriers to lameness control, but at the same time, the majority of the factors influencing their motivation were considered very important. It is possible farmers in these types of surveys are responding with what they believe the survey authors and society want to hear—that they are motivated to control lameness and that no major factors prevent them for controlling lameness. This phenomenon, known as social desirability bias (Grimm, 2010), is well documented when the public are surveyed on animal welfare issues (Lusk and Norwood, 2010; Lai et al., 2022), and we hypothesize that similar biases may be present in this current study. This phenomenon may have been less of an issue in the farmers enrolled in Leach et al. (2010a,b) because they were enrolled in an intervention study, in contrast to the current study, where farms were enrolled in a monitoring study with no goal of direct improvement in their farms' lameness prevalence. These differences in study objectives may have resulted in different answers from farmers, with those agreeing to be involved in an intervention study potentially more likely to provide a more honest response. Further targeted interviewing of farmers using strategies such as forced-choice items is warranted to investigate the effect of social desirability bias directly (Nederhof, 1985).

Another limitation of the study was the possible ambiguity with some of the questions. For example, “preventing you from being able to manage lameness”

could be interpreted by some farmers to be related to managing lameness that is already present, with other farmers interpreting this as relating to all components of lameness control. We do not know how this may have biased the study, although it is possible that this could have accounted for the range of responses from farmers for time and skilled labor. However, because the rankings for the lameness barriers were similar to those reported by UK dairy farmers (Leach et al., 2010a), we have no reason to believe that this is an important source of bias.

This study reports for the first time that the barriers and motivators to lameness control that farmers report have very little predictive ability at detecting whether a farmer perceived lameness to be a problem or whether true lameness prevalence was high on their farm. The 4 main factors identified in the FA resulted in a predictive accuracy not much greater than a 50:50 guess on whether farmers believed they had a lameness problem or the true status of the lameness problem. To be of any practical use, we would have liked to have seen accuracy of at least 0.80. Thus, the value of the theory of planned behavior (Biesheuvel et al., 2021), as used in the current study, to directly assess lameness control in dairy cattle is questionable. Researchers are encouraged to investigate further theoretical frameworks designed to elicit sociological themes (Biesheuvel et al., 2021), such as the COM-B models, or transtheoretical models,

investigated by Jorritsma et al. (2023) or changes in the methods of delivery, such as focus groups involving various stakeholders (Wynands et al., 2022).

Evidence-based scientific advice does have the potential to reduce lameness prevalence, but for sustained and widespread reductions in lameness prevalence, changes in farmer behavior and multi-party engagement are required (Wynands et al., 2022). A great practical success story is foot rot in sheep in the United Kingdom (Green et al., 2020). The use of systemic antibiotics, instead of foot trimming, for the treatment of foot rot in sheep has demonstrated significant improvements in the recovery risk of these animals to such an extent that the global burden of the disease would be substantially reduced if implemented routinely (Kaler et al., 2010). Although lameness prevalence in sheep declined somewhat from 2004 to 2013 with the advent of “best-practice” recommendations of prompt, appropriate treatment of cases, the majority of the UK sheep farmer population were still not following best practices (Winter et al., 2015). The behavior shift has come more recently, following targeted extension of the evidence. In response to education, training, and one-on-one discussions of the evidence, both veterinarians (Higgins et al., 2013) and farmers (Green et al., 2020) shifted their beliefs on appropriate foot rot control strategies. Critically, sheep farmers in Green et al. (2020) initially saw time and money as one of the major barriers to implementing changes into their system to control foot rot. Yet after one-on-one discussions around the current best practices in foot rot control, cost and time became a major driver of change (Green et al., 2020). If it is possible to change the behavior of sheep farmers from a method that historically has been seen as “good” (i.e., hoof trimming; Green et al., 2020) resulting in reductions in the prevalence of foot rot on farms, then there is promise that similar approaches can be successful for dairy cattle lameness control.

We conclude that New Zealand dairy farmers do care about the welfare of lame cattle, despite considerably lower lameness prevalence compared with their counterparts in the United Kingdom, and that they do have strong beliefs on the welfare implications of lameness for their cows. The latent themes expressed by farmers on their barriers appear different to those expressed by farmers on their motivators for lameness control. These themes were not able to predict the prevalence of lameness on the days of measurement of the herd nor farmer perception of lameness.

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REFERENCES

- Abdi, H., L. J. Williams, and D. Valentin. 2013. Multiple factor analysis: Principal component analysis for multitable and multiblock data sets. *Wiley Interdiscip. Rev. Comput. Stat.* 5:149–179. <https://doi.org/10.1002/wics.1246>.
- Alawneh, J. I., M. A. Stevenson, N. B. Williamson, N. Lopez-Villalobos, and T. Otley. 2012. The effect of clinical lameness on live-weight in a seasonally calving, pasture-fed dairy herd. *J. Dairy Sci.* 95:663–669. <https://doi.org/10.3168/jds.2011-4505>.
- Babatunde, S. M., S. Z. Ramanoon, W. M. Shaik Mossadeq, R. Mansor, and S. S. Syed Hussain. 2019. Dairy farmers' perceptions of and actions in relation to lameness management. *Animals (Basel)* 9:270. <https://doi.org/10.3390/ani9050270>. PubMed
- Becker, J., M. Reist, K. Friedli, D. Strabel, M. Wüthrich, and A. Steiner. 2013. Current attitudes of bovine practitioners, claw-trimmers and farmers in Switzerland to pain and painful interventions in the feet in dairy cattle. *Vet. J.* 196:467–476. <https://doi.org/10.1016/j.tvjl.2012.12.021>.
- Biesheuvel, M. M., I. M. Santman-Berends, H. W. Barkema, C. Ritter, J. Berezowski, M. Guelbenzu, and J. Kaler. 2021. Understanding farmers' behavior and their decision-making process in the context of cattle diseases: A review of theories and approaches. *Front. Vet. Sci.* 8:687699. <https://doi.org/10.3389/fvets.2021.687699>.
- Browne, N., C. D. Hudson, R. E. Crossley, K. Sugrue, E. Kennedy, J. N. Huxley, and M. Conneely. 2022. Lameness prevalence and management practices on Irish pasture-based dairy farms. *Ir. Vet. J.* 75:14. <https://doi.org/10.1186/s13620-022-00221-w>.
- Bruijnjs, M., H. Hogeveen, C. Garforth, and E. Stassen. 2013. Dairy farmers' attitudes and intentions towards improving dairy cow foot health. *Livest. Sci.* 155:103–113. <https://doi.org/10.1016/j.livsci.2013.04.005>.
- Chapinal, N., D. M. Weary, L. Collings, and M. A. G. von Keyserlingk. 2014. Lameness and hock injuries improve on farms participating in an assessment program. *Vet. J.* 202:646–648. <https://doi.org/10.1016/j.tvjl.2014.09.018>.
- Croyle, S. L., E. Belage, D. K. Khosa, S. J. LeBlanc, D. B. Haley, and D. F. Kelton. 2019. Dairy farmers' expectations and receptivity regarding animal welfare advice: A focus group study. *J. Dairy Sci.* 102:7385–7397. <https://doi.org/10.3168/jds.2018-15821>.
- Ekström, J. 2011. On the relation between the polychoric correlation coefficient and Spearman's rank correlation coefficient. Department of Statistics, UCLA. Accessed Jun. 13, 2023. <https://escholarship.org/uc/item/7j01t5sf>.
- Fabian, J., R. A. Laven, and H. R. Whay. 2014. The prevalence of lameness on New Zealand dairy farms: A comparison of farmer estimate and locomotion scoring. *Vet. J.* 201:31–38. <https://doi.org/10.1016/j.tvjl.2014.05.011>.
- Gibbs, S. J. 2010. Dairy lameness in the South Island. Pages 424–427 in Proc. 4th Australasian Dairy Science Symposium, Christchurch, New Zealand. Caxton Press.
- Green, L., J. Kaler, N. Liu, and E. Ferguson. 2020. Influencing change: When “best practice” changes and the prototypical good farmer turns bad. *Front. Vet. Sci.* 7:161. <https://doi.org/10.3389/fvets.2020.00161>.
- Griffiths, B. E., D. Grove White, and G. Oikonomou. 2018. A cross-sectional study into the prevalence of dairy cattle lameness and associated herd-level risk factors in England and Wales. *Front. Vet. Sci.* 5:65. <https://doi.org/10.3389/fvets.2018.00065>.
- Grimm, P. 2010. Social desirability bias. In *Wiley International Encyclopedia of Marketing*. John Wiley & Sons. <https://doi.org/10.1002/9781444316568.wiem02057>.

- Harpe, S. E. 2015. How to analyze Likert and other rating scale data. *Curr. Pharm. Teach. Learn.* 7:836–850. <https://doi.org/10.1016/j.cptl.2015.08.001>.
- Higgins, H. M., L. E. Green, M. J. Green, and J. Kaler. 2013. How does reviewing the evidence change veterinary surgeons' beliefs regarding the treatment of ovine footrot? A quantitative and qualitative study. *PLoS One* 8:e64175. <https://doi.org/10.1371/journal.pone.0064175>.
- Holgado-Tello, F. P., S. Chacón-Moscoso, I. Barbero-García, and E. Vila-Abad. 2010. Polychoric versus Pearson correlations in exploratory and confirmatory factor analysis of ordinal variables. *Qual. Quant.* 44:153–166. <https://doi.org/10.1007/s11135-008-9190-y>.
- Hueston, W. D. 2003. Science, politics and animal health policy: Epidemiology in action. *Prev. Vet. Med.* 60:3–12. [https://doi.org/10.1016/S0167-5877\(03\)00078-3](https://doi.org/10.1016/S0167-5877(03)00078-3).
- Husson, F., J. Josse, M. F. Husson, I. Facto, and R. Mine. 2013. Package 'missMDA'. *Methods* 153:79–99.
- Huxley, J. N. 2013. Impact of lameness and claw lesions in cows on health and production. *Livest. Sci.* 156:64–70. <https://doi.org/10.1016/j.livsci.2013.06.012>.
- Jorritsma, R., J. Swinkels, T. van Werven, N. Lahaye, M. Martena, and M. Stok. 2023. Drivers and perceived constraints on Dutch dairy farms to engage in disease prevention. *Front. Vet. Sci.* 10:1124500. <https://doi.org/10.3389/fvets.2023.1124500>.
- Kaler, J., S. Daniels, J. Wright, and L. Green. 2010. Randomized clinical trial of long-acting oxytetracycline, foot trimming, and flunixin meglumine on time to recovery in sheep with footrot. *J. Vet. Intern. Med.* 24:420–425. <https://doi.org/10.1111/j.1939-1676.2009.0450.x>.
- Kristensen, E., and E. B. Jakobsen. 2011. Challenging the myth of the irrational dairy farmer; understanding decision-making related to herd health. *N. Z. Vet. J.* 59:1–7. <https://doi.org/10.1080/00480169.2011.547162>.
- Lai, Y., A. Boaitay, and K. Minegishi. 2022. Behind the veil: Social desirability bias and animal welfare ballot initiatives. *Food Policy* 106:102184. <https://doi.org/10.1016/j.foodpol.2021.102184>.
- Lê, S., J. Josse, and F. Husson. 2008. FactoMineR: An R package for multivariate analysis. *J. Stat. Softw.* 25:1–18. <https://doi.org/10.18637/jss.v025.i01>.
- Leach, K. A., E. S. Paul, H. R. Whay, Z. E. Barker, C. M. Maggs, A. K. Sedgwick, and D. C. J. Main. 2013. Reducing lameness in dairy herds—Overcoming some barriers. *Res. Vet. Sci.* 94:820–825. <https://doi.org/10.1016/j.rvsc.2012.10.005>.
- Leach, K. A., H. R. Whay, C. M. Maggs, Z. E. Barker, E. S. Paul, A. K. Bell, and D. C. J. Main. 2010a. Working towards a reduction in cattle lameness: 1. Understanding barriers to lameness control on dairy farms. *Res. Vet. Sci.* 89:311–317. <https://doi.org/10.1016/j.rvsc.2010.02.014>.
- Leach, K. A., H. R. Whay, C. M. Maggs, Z. E. Barker, E. S. Paul, A. K. Bell, and D. C. J. Main. 2010b. Working towards a reduction in cattle lameness: 2. Understanding dairy farmers' motivations. *Res. Vet. Sci.* 89:318–323. <https://doi.org/10.1016/j.rvsc.2010.02.017>.
- Lusk, J. L., and F. B. Norwood. 2010. Direct versus indirect questioning: An application to the well-being of farm animals. *Soc. Indic. Res.* 96:551–565. <https://doi.org/10.1007/s11205-009-9492-z>.
- Main, D. C. J., K. A. Leach, Z. E. Barker, A. K. Sedgwick, C. M. Maggs, N. J. Bell, and H. R. Whay. 2012. Evaluating an intervention to reduce lameness in dairy cattle. *J. Dairy Sci.* 95:2946–2954. <https://doi.org/10.3168/jds.2011-4678>.
- Mason, W. 2024a. Farmer perception of lameness Mason et al. (2023) Supp. Figure 1. Figshare. <https://doi.org/10.6084/m9.figshare.25091804.v1>.
- Mason, W. 2024b. Farmer perception of lameness Mason et al. (2023) Supp. Table 1. Figshare. <https://doi.org/10.6084.m9.figshare.25072407.v1>.
- Nederhof, A. J. 1985. Methods of coping with social desirability bias: A review. *Eur. J. Soc. Psychol.* 15:263–280. <https://doi.org/10.1002/ejsp.2420150303>.
- Newsome, R., M. J. Green, N. J. Bell, M. G. G. Chagunda, C. S. Mason, C. S. Rutland, C. J. Sturrock, H. R. Whay, and J. N. Huxley. 2016. Linking bone development on the caudal aspect of the distal phalanx with lameness during life. *J. Dairy Sci.* 99:4512–4525. <https://doi.org/10.3168/jds.2015-10202>.
- Pedersen, S., and J. Wilson. 2021. Early detection and prompt effective treatment of lameness in dairy cattle. *Livestock (Lond.)* 26:115–121. <https://doi.org/10.12968/live.2021.26.3.115>.
- R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org>.
- Revelle, W., and M. W. Revelle. 2015. Package 'psych.' Comprehensive R Archive Network, Vienna, Austria. <https://CRAN.R-project.org>.
- Ritter, C., J. Jansen, S. Roche, D. F. Kelton, C. L. Adams, K. Orsel, R. J. Erskine, G. Benedictus, T. J. G. M. Lam, and H. W. Barkema. 2017. Invited review: Determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. *J. Dairy Sci.* 100:3329–3347. <https://doi.org/10.3168/jds.2016-11977>.
- Solano, L., H. W. Barkema, E. A. Pajor, S. Mason, S. J. LeBlanc, J. C. Zaffino Heyerhoff, C. G. R. Nash, D. B. Haley, E. Vasseur, D. Pellerin, J. Rushen, A. M. de Passillé, and K. Orsel. 2015. Prevalence of lameness and associated risk factors in Canadian Holstein-Friesian cows housed in freestall barns. *J. Dairy Sci.* 98:6978–6991. <https://doi.org/10.3168/jds.2015-9652>.
- Thomsen, P. T., J. K. Shearer, and H. Houe. 2023. Prevalence of lameness in dairy cows: A literature review. *Vet. J.* 295:105975. <https://doi.org/10.1016/j.tvjl.2023.105975>.
- Wickham, H., M. Averick, J. Bryan, W. Chang, L. D. A. McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. Pedersen, E. Miller, S. Bache, K. Müller, J. Ooms, D. Robinson, D. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, and H. Yutani. 2019. Welcome to the Tidyverse. *J. Open Source Softw.* 4:1686. <https://doi.org/10.21105/joss.01686>.
- Winter, J. R., J. Kaler, E. Ferguson, A. L. KilBride, and L. E. Green. 2015. Changes in prevalence of, and risk factors for, lameness in random samples of English sheep flocks: 2004–2013. *Prev. Vet. Med.* 122:121–128. <https://doi.org/10.1016/j.pvetmed.2015.09.014>.
- Wynands, E. M., S. M. Roche, G. Cramer, and B. A. Ventura. 2022. Promoting farm advisor engagement and action toward the improvement of dairy cattle lameness. *J. Dairy Sci.* 105:6364–6377. <https://doi.org/10.3168/jds.2021-21745>.
- Yong, A. G., and S. Pearce. 2013. A beginner's guide to factor analysis: Focusing on exploratory factor analysis. *Tutor. Quant. Methods Psychol.* 9:79–94. <https://doi.org/10.20982/tqmp.09.2.p079>.

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