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BRIEF REPORT

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Repeatability of whole herd lameness scoring: an analysis of a New Zealand dataset

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ABSTRACT

Aims: To assess whether a whole-herd lameness score on a New Zealand dairy farm in spring could predict lameness prevalence on the same farm in summer (and vice versa) and whether a single-herd lameness score could be used to determine whether herd lameness prevalence was < 5% in both spring and summer.

Methods: Prevalence data (proportion of the herd with lameness score ≥ 2 and with score 3; 0–3 scale) from a study where 120 dairy farms across New Zealand were scored in spring and in the following summer were analysed using limits-of-agreement analysis. In addition, farms were categorised as having either acceptable welfare (lameness prevalence < 5% in both spring and summer) or not (lameness prevalence ≥ 5% in either spring or summer or both). The accuracy and specificity of a single, whole-herd lameness score at identifying herds with acceptable welfare were then calculated.

Results: The limits-of-agreement analysis suggests that 95% of the time, the prevalence of lameness in summer would be expected to be between 0.23 and 4.3 times that of the prevalence in spring. The specificity and accuracy of identifying a farm as acceptable on both occasions from a single observation were, respectively, 74% and 92% in spring, and 59% and 87% in summer.

Conclusions: A single, one-off, whole-herd lameness score does not accurately predict future lameness prevalence. Similarly, acceptable status (lameness prevalence < 5%) in one season is not sufficiently specific to be used to predict welfare status in subsequent seasons.

Clinical relevance: Whole-herd lameness scoring should be used principally as a means of detecting lame cows for treatment. A single whole-herd lameness score by an independent assessor should not be used to determine a herd's welfare status.

Abbreviations: LS: Lameness score.

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Locomotion score; welfare assessment; predictive ability; lameness prevalence; dairy cattle

Introduction

In dairy cattle, lameness (locomotion) scoring is commonly used as a method of assessing the impact of lameness on the welfare of a herd (Laven and Fabian 2016; Sapkota *et al.* 2022a, 2022b). For lameness scoring to be useful for such an assessment, it needs to be repeatable and reliable. The repeatability of lameness scoring at the individual level, defined as the agreement between successive lameness scores of the same animal (both for the same observer and for different observers), has been a focus of multiple studies (e.g. Winckler and Willen 2001; Thomsen *et al.* 2008; Dahl-Pedersen *et al.* 2018). Measures of repeatability (such as Cohen's kappa) are commonly used to demonstrate that an observer has received sufficient training in lameness scoring for their results to be valid (e.g. Werema *et al.* 2022), although this practice can be criticised on multiple grounds (Mason *et al.* 2023).

There has been less attention paid to the repeatability of lameness scoring at the herd level, i.e. the agreement between successive estimates of herd lameness prevalence made using lameness scoring (or how accurately one assessment of herd prevalence can predict future herd lameness prevalence over the short to medium term). This lack of attention has occurred despite a single assessment of lameness prevalence being commonly used in studies estimating herd prevalence in a region or country (e.g. Tadich *et al.* 2005; Fabian *et al.* 2014; Salem *et al.* 2023) in studies assessing risk factors for herd lameness prevalence (e.g. Barker *et al.* 2010; Sjöström *et al.* 2018), and in protocols for dairy cattle welfare assessment (e.g. Sapkota *et al.* 2022a, 2022b). Furthermore, although many studies have recorded herd- or group-level lameness prevalence on multiple occasions (e.g. Leach *et al.* 2012; Bran *et al.* 2019; Werema *et al.* 2023), many of those studies have

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included treatment groups where treatment is expected to decrease lameness prevalence over time (Leach *et al.* 2012; Werema *et al.* 2023), which limits their value as repeatability studies. As far as the authors are aware, only three previous studies have directly addressed the repeatability of herd lameness prevalence estimates based on lameness scoring (Clarkson *et al.* 1996; Winckler and Willen 2001; Winckler *et al.* 2007). These studies produced variable results. Clarkson *et al.* (1996) stated that a single visit during summer/winter could be used as a measure of lameness status for the whole of that season; Winckler and Willen (2001) that scoring should be undertaken at least twice during the housing period; and Winckler *et al.* (2007) that a single timepoint might be a useful predictor for the average prevalence over a 10-month period. All three studies were undertaken in housed cattle or in cows that had been housed and reported prevalences of lameness much higher than in New Zealand in cattle kept almost permanently at pasture (Mason *et al.* 2023). We thus lack data on the repeatability of lameness scoring under New Zealand conditions.

It is commonly suggested that dairy cow lameness in New Zealand is significantly seasonal, and that this seasonality depends on which island the farm is on (Gibbs 2010; Lawrence *et al.* 2011). To account for this seasonality, Fabian *et al.* (2014) measured lameness in the North Island and the South Island at their anticipated time of maximum prevalence (October/November for the North Island and January/February for the South Island). However, Mason *et al.* (2023) measured lameness prevalence on farms in both islands in both periods and found that the seasonality was much less pronounced than previously reported, especially in the South Island. This lack of significant seasonality increases the risk that seasonal targeting of lameness prevalence assessment as used by Fabian *et al.* (2014) may not identify farms with lameness problems. Thus, the aim of this study was to use the data from Mason *et al.* (2023) to assess whether, under New Zealand conditions, a single timepoint measure of assessment could be used to estimate herd-level lameness prevalence.

Materials and methods

The data collection process is described in Mason *et al.* (2023). In brief, 120 farms from eight territorial regions of New Zealand, four in the North Island and four in the South Island were lameness-scored on two occasions (October–December ("spring") and then again in January–March ("summer")) in the same lactation season. North Island farms were scored in the 2021/2022 season and South Island farms in the 2022/2023 season (median 91 (min 48, max 127) days between visits).

Lameness scores were collected by one trained veterinary technician per region using the 0–3 DairyNZ lameness scoring (LS) system (Mason *et al.* 2023). All animals being milked at each visit were scored, including those that had been previously identified as lame by the farmer and had been placed into a separate "lame" herd. Scoring was carried out immediately after milking (either morning or afternoon). Individual animals were not identified but a tally of the number of cows with a LS of 2 and a LS of 3 were recorded alongside the total number of animals scored. Farmers were not aware of the results of lameness scoring until after the end of data collection in the summer and no lameness management programmes were put in place by the research team (although farmers were free to institute their own programmes at any time).

Statistical analysis

All analyses were undertaken using SPSS version 29 (IBM, Armonk, NY, USA). The correlation between lameness prevalence (% of the herd with LS $\geq$ 2) in spring and summer was calculated using Pearson's correlation coefficient. Limits-of-agreement analysis was then used to assess the agreement between lameness prevalence for a herd in spring and the lameness prevalence for the same herd in summer. Two measurements of herd prevalence were used: 1) percentage of the herd with LS $\geq$ 2; and 2) percentage of the herd LS = 3. To account for the association between variance and mean in binomial prevalence data, we $\log_{10}$-transformed the prevalence data and plotted the mean of the log-transformed values against their difference (Bland and Altman 1999). This transformation allows the mean difference (bias) and limits of agreement to be directly interpreted as ratio values. For the percentage of the herd where LS = 3, there were a large number of herds with 0%, which precluded simple log transformation (and thus direct interpretation as ratio values), so in addition to the log-transformed limits of agreement for herds with LS% > 0, we also calculated non-parametric limits of agreement (2.5 and 97.5 percentiles from 1,000 bootstrapped samples).

The herds were then categorised (per Sapkota *et al.* 2022a, 2022b) into acceptable welfare (< 5% prevalence of LS $\geq$ 2), unacceptable welfare (> 10% LS $\geq$ 2), and marginal welfare (5–10% LS $\geq$ 2). The categories "unacceptable welfare" and "marginal welfare" were then merged ("unacceptable"), and specificity and accuracy were then calculated to determine the effectiveness of a single lameness scoring occasion at predicting whether a farm would have acceptable lameness-related welfare on both observation occasions.

Results

Across all 120 farms, the mean prevalence in spring of LS ≥ 2 was 3.78% (min 0, max 17%) and in summer was 3.37% (min 0, max 14.9%). For North Island farms only, the equivalent figures were 4.74% (min 0.49, max 17%) and 3.88 (min 0.33, max 14.9%), and for South Island farms, they were 2.81% (min 0, max11.8%) and 2.86% (min 0, max 12.7%). The proportion of a herd with LS ≥ 2 in spring was correlated to the proportion of a herd with LS ≥ 2 in summer (r = 0.52; 95% CI = 0.37–0.64). Further descriptive data are presented in Mason *et al*. (2023).

Two herds had a prevalence of LS ≥ 2 of 0% (one each in spring and summer). The lameness prevalence for these two herds was 0.87 and 1.8% in the previous/subsequent season. The data from these herds were excluded from further limits-of-agreement analysis for prevalence of LS ≥ 2. In the remaining 118 herds, the mean difference between the overall mean log % prevalence of LS ≥ 2 in spring (0.44) from that in summer (0.415) was 0.025% (95% CI = −0.62 to 0.113%). There was therefore no clear systematic bias resulting from predicting the prevalence in summer from that in spring. The mean-difference plot for the log-transformed data is presented in Figure 1. Log transformation eliminated the association between mean and difference ($r^2 = 0.016$; p = 0.17). The 95% limits of agreement were 0 ± 0.634. Back-transforming these limits, our data suggest that, 95% of the time, the prevalence of lameness in summer would be expected to be between 0.23 and 4.3 times that of the prevalence in spring; i.e. for an average herd with 3.78% of cows with a LS ≥ 2 in spring, we would anticipate that in summer 95% of such herds will have between 0.88 and 16.3% of cows with a LS ≥ 2.

Across all 120 farms, the mean prevalence in spring of LS = 3 was 0.87% (min 0, max 4.63%) and that in summer 0.57% (min 0, max 4.37%). In spring there were 25 herds with no cows observed with a LS = 3. In summer, 14 of these herds also had no cows with LS = 3. In the remaining 11 herds prevalence of LS = 3 ranged from 0.13–0.83%. In the summer, 33 herds had no LS = 3, of which 14 also had no cows with LS = 3 in spring. In the remaining 19 herds the prevalence of LS = 3 ranged from 0.15–3.47%.

Across the 76 farms where there was at least one cow with LS = 3 in both spring and summer, the mean prevalence in spring of LS = 3 was 1.17% (min 0.1, max 4.63%) and in summer 0.85% (min 0.13, max 4.37%). In contrast to the analysis for LS ≥ 2, there was systematic bias with overall mean log prevalence of LS = 3 in the remaining 76 herds in spring (−0.055) being higher than that in summer (−0.215) (mean difference between these log prevalences was −0.16; 95% CI = −0.24 to −0.08). The mean-difference plot for the log-transformed data is presented in Figure 2. Log transformation eliminated the association between mean and difference ($r^2 = 0.004$; p = 0.58).

The 95% limits of agreement were 0.498 and −0.818. Back-transforming these limits, our data suggest that, 95% of the time, the prevalence of severe lameness in summer would be expected to be

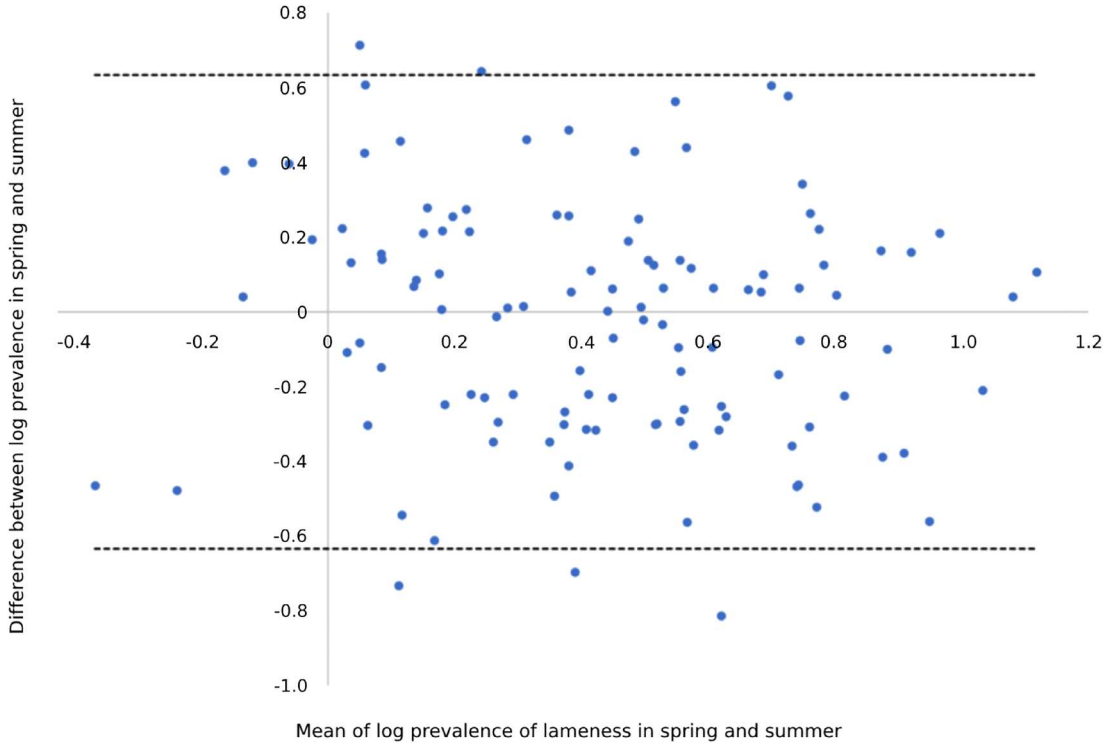

Figure 1. Mean-difference plot of $\log_{10}$ prevalence in spring (October to December) and summer (January to March) of lameness (lameness score ≥ 2) for 118 dairy farms in New Zealand scored using the DairyNZ lameness scoring system (scale 0–3; Mason *et al*. 2023). Dotted lines are the 95% limits of agreement.

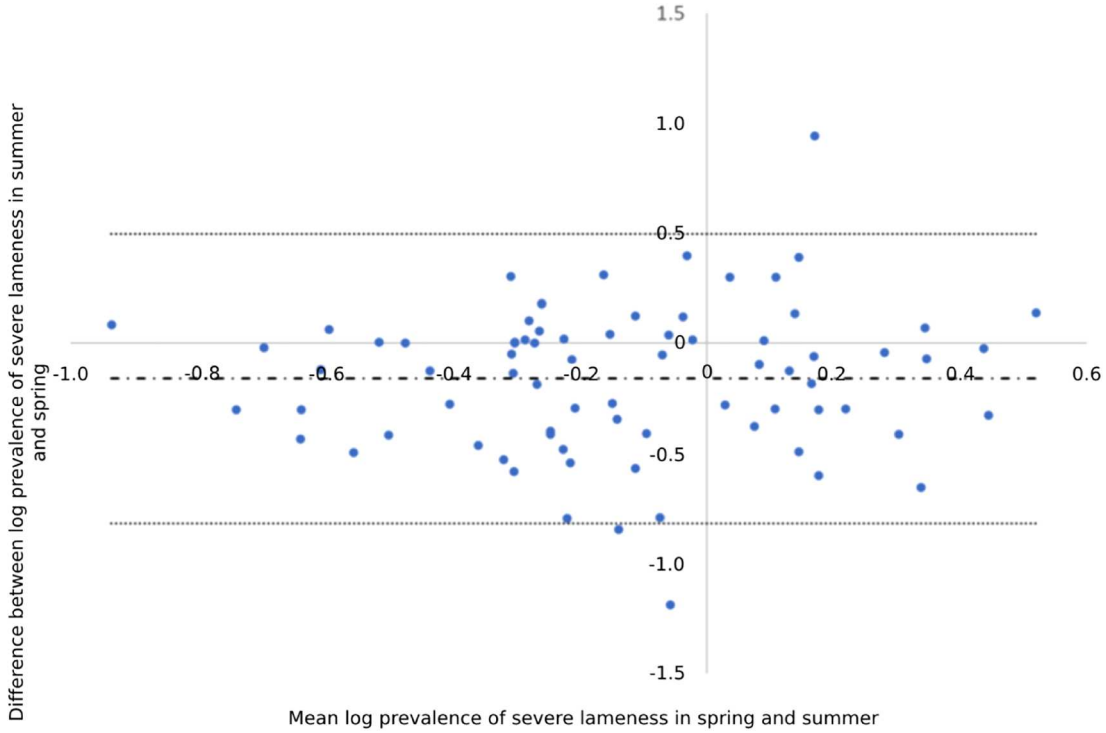

Figure 2. Mean-difference plot of log prevalence in spring (October to December) and summer (January to March) of severe lameness (lameness score = 3) for 76 dairy farms in New Zealand scored using the DairyNZ lameness scoring system (scale 0–3; Mason *et al*. 2023). Dotted lines are the 95% limits of agreement, and the dashed line is the mean difference between log prevalence in summer and spring.

between 0.15 and 3.15 times that of the prevalence in spring; i.e. for a herd with 1.17% of cows with a LS = 3 in spring, we would anticipate that in summer 95% of such herds will have between 0.18 and 3.69% of cows with a LS = 3. The non-parametric limits-of-agreement, which used untransformed data and thus included all 120 herds were −3.19 and 1.06; i.e. our data suggest that in summer 95% of herds will have a prevalence of LS = 3 that is between 3.2% lower than in spring and 1.1% higher.

The data on welfare category by season are shown in Table 1. Of the 120 farms, 107 were categorised as having acceptable welfare based on lameness prevalence (< 5% of cows with LS ≥ 2) on at least one of the two occasions. Twenty-six of those 107 farms were categorised as having acceptable welfare on only one occasion, with 20 of those 26 farms being categorised as marginal (5–10% of cows with LS ≥ 2) and six as unacceptable (> 10% of cows with LS ≥ 2).

Table 1. Classification of herd lameness welfare status (based on recorded prevalence of lameness score ≥ 2; Sapkota *et al*. 2022a, 2022b) for 120 New Zealand dairy herds scored in the spring and summer using the DairyNZ lameness scoring system (scale 0–3; Mason et al. 2023).

	Welfare category (summer)			
Welfare category (spring)	< 5%	5–10%	≥ 10%	Total
<5%	81	8	2	91
5–10%	12	7	2	21
>10%	4	2	2	8
Total	97	17	6	120

Nevertheless, if a farm was identified as having acceptable welfare based on lameness prevalence in spring, the probability of it being identified as having acceptable welfare in summer was 81/91 (89%; 95% CI = 81–94%). In contrast to the eight farms identified as having inadequate welfare based on lameness prevalence in spring, the probability of being identified as having inadequate welfare in summer was 2/8 (25%; 95% CI = 7–59%). Overall, 14 farms were identified as having unacceptable welfare on at least one occasion but only two were identified as having unacceptable welfare on two occasions.

If we combine farms categorised as marginal or unacceptable there were 39 farms in this category of which only 13 were unacceptable on both occasions. If a farm was identified as having unacceptable welfare based on lameness prevalence in spring, the probability of it being identified as having unacceptable welfare in summer was 13/29 (44.8%; 95% CI = 28.4–62.5%). The specificity and accuracy of identifying a farm as acceptable on both occasions from a single observation were, respectively, 74.4% (95% CI = 58.9–85.4%) and 91.7% (95% CI = 85.3–95.4%) in spring, and 59% (95% CI = 43.4–72.9%) and 86.7% (95% CI = 79.4–91.6%) for summer (see Supplementary Tables 1 and 2 for explanation of how these were calculated).

Discussion

Clarkson *et al.* (1996) reported that an individual herd lameness score was an accurate measure of the

corresponding winter or summer period. They based this on high correlations (r > 0.83), which were markedly higher than the correlation between the two results found in this study (r = 0.52). However, there are two issues with the analysis by Clarkson *et al.* (1996). Firstly, they compared an individual result for a period with the mean of that period, which results in higher correlations that incorrectly reflect the association between measures (if we had compared our spring results to the mean of spring and summer then our r would have been 0.89 rather then 0.52). This comparison of mean and individual prevalences was also used by Winckler *et al.* (2007), who reported higher correlations between individual timepoints and the mean than between individual timepoints. Secondly, and most importantly, correlation is just a measure of the linear relationship between two variables, and it is a poor measure of agreement (Bland and Altman 1986); i.e. you can have high correlation but poor agreement. In their paper, Clarkson *et al.* (1996; Figure 4) present the data from the winter 1990 period when the correlation was at its highest (r = 0.893). This figure provides sufficient data to allow a limits-of-agreement analysis (data available on request), which shows no systematic bias or association between mean and difference (see Supplementary Figure 1). The limits of agreement for this comparison are ± 16%, i.e. the data presented by Clarkson *et al.* (1996) suggest that 95% of their individual December results will be within an absolute 16% of the mean winter prevalence, showing that, despite the high correlation, agreement was poor and that a single timepoint assessment was not an accurate predictor of herd prevalence throughout a season. The true agreement between individual herd scores is likely to be even poorer, as to calculate the limits of agreement we compared an individual result with a mean that includes that result. This is likely to have reduced variability (compared to using two individual results) and thus increased apparent agreement.

The limits of agreement found in this study were not simple limits of agreement because, unlike the data from Clarkson *et al.* (1996), there was a very strong association between variance and mean (i.e. range and variability of the difference between the two results increased as their mean increased). This meant that our outcome was not a simple addition/subtraction but a ratio using back-transformed limits of agreement calculated using log-transformed data. Nevertheless, the conclusion from the limits-of-agreement analysis of our dataset is the same as that from our limits-of-agreement analysis of the data from Clarkson *et al.* (1996): a single herd lameness prevalence assessment (based on LS ≥ 2 or equivalent) is not predictive of subsequent or previous herd lameness prevalence, even when those assessments are only 2–4 months apart. From our dataset, if we have a herd with mean prevalence of 3.87% from a single herd assessment, our analysis suggests that the herd lameness in 95% of herds tested ~ 2–4 months before or after that will have a prevalence of LS ≥ 2 between 0.88 and 16.3% in summer (i.e. actual prevalence could be more than 12% higher).

The analysis of prevalence of severe lameness (LS = 3) resulted in limits of agreement of log-transformed data with a similar range to that from LS ≥ 2 (0.15–3.15 *vs*. 0.23–4.3, respectively). However, the expected differences in prevalence between spring and summer were much smaller because mean prevalence of LS = 3 in spring was much less than that of LS ≥ 2 (0.87 *vs.* 3.6%, respectively). Nevertheless, the back-transformed upper limit of the 95% limits of agreement for an average spring herd (0.87% prevalence LS = 3) was 2.74% (0.87*3.15 the upper multiplier of the limits of agreement), a figure that was exceeded by only 10/240 (4.2%) herd prevalence scores in this dataset, i.e. for a herd with a mean prevalence of LS = 3 in spring, we cannot rule out that that herd will be in the worst 5% of herds in summer, again showing that prediction of severe lameness prevalence from a single assessment is of limited value. The value of the log transformation for severe lameness is limited by the large proportion of farms with at least one visit when there were no LS = 3 cows, but even the non-parametric limits of agreement were markedly wider than the average prevalence of severely lame cows.

However, from a welfare assessment perspective, accurately predicting herd lameness prevalence is a nice-to-have rather than a must-have. We may not be able to accurately predict lameness prevalence but if we can accurately predict lameness welfare category, then a single assessment can still be useful. If we categorise farms on the basis of whether they were assessed as having acceptable lameness-related welfare on both occasions (i.e. < 5% LS ≥ 2 in both spring and summer) or having unacceptable lameness-related welfare (i.e. ≥ 5% LS ≥ 2 in either spring or summer or both), the examination in spring correctly assigned 110/120 (91.7%) farms to the correct category, with 81/91 (89%) farms identified as being acceptable (< 5% LS ≥ 2) in spring being acceptable in both spring and summer. Nevertheless, although we are categorising most farms correctly, a single assessment will wrongly categorise a relatively high percentage of the unacceptable farms. For example, of the 39 farms that had at least one unacceptable assessment (i.e. ≥ 5% LS ≥ 2), 10 (25.6%) were categorised as acceptable based on the single spring examination. These results suggest that one independent assessment of lameness may have limited value for identifying lameness-associated welfare status: not only is the proportion of poor welfare herds identified too low, but the classification does not distinguish herds where lameness is a temporary problem from

those where it is ongoing. This means that, if such assessments are to become part of the approach to demonstrating acceptable welfare on New Zealand dairy farms, we need to combine them with regular locomotion scoring by trained farmers or external scorers, as we need more frequent scoring to properly establish a farm's lameness status. This approach is used in many welfare assessment schemes in Europe (e.g. Anonymous 2023).

Conclusions

Data from Mason *et al.* (2023) demonstrated that the seasonality of lameness prevalence in New Zealand was much less than previously thought. This suggested that a targeted, single, one-off, lameness assessment in spring or summer might miss an elevated high prevalence of lameness. This analysis has shown that a single lameness assessment on a farm in spring cannot accurately predict subsequent lameness prevalence in summer (and *vice versa*). Furthermore, although a single assessment was reasonably accurate at predicting that a farm would be categorised as having acceptable welfare in both spring and summer, it failed to identify a significant proportion of farms that failed to meet the target of having acceptable lameness-related welfare in both spring and summer.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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