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Farm management and husbandry practices associated with spontaneous humeral fractures in New Zealand dairy heifers

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ABSTRACT

Aims: To use a farm-based survey to identify characteristics of the New Zealand dairy system associated with the risk of spontaneous humeral fracture in dairy heifers.

Methods: A questionnaire was designed and made available in print and online to collect information from dairy farmers and/or veterinarians, across New Zealand, about the management and nutrition of cows from birth to first lactation. Data were collected from July 2019 to March 2020 from farms that either had recorded (case farms) or not recorded (control farms) cases of humeral fractures in dairy heifers.

Results: A total of 68 completed questionnaires were returned, with 35 responses from case farms and 33 responses from control farms. Twenty-six responses (38%) were from the South Island (13 case farms and 13 control farms) and 38 responses (56%) were from the North Island (20 case farms and 18 control farms). For four questionnaires (6%) farm location was not given. Adjusting for the effect of age when calves accessed pasture, case farms had increased odds of having Holstein-Friesian Jersey crossbreed cows as the predominant breed (OR = 9.7; 95% CI = 3.1–36.0; $p < 0.001$). Adjusting for the effect of breed, allowing calves access to pasture a week later decreased the odds of being a case farm (OR = 0.68; 95% CI = 0.47–0.90; $p = 0.006$).

Conclusions: Cows being Holstein-Friesian Jersey crossbreed was identified as a possible risk factor associated with spontaneous humeral fracture in dairy heifers in New Zealand. Given the small sample size, the likely multifactorial aetiology for humeral fractures, and the non-randomised survey, this risk factor, and the possible association between age at turn out and herd production with humeral fractures, all require further investigation.

Abbreviations: HFxJ: Holstein-Friesian Jersey crossbreed; KS test: Kolmogorov–Smirnov test; R1: Rising 1-year-old; R2: Rising 2-year-old; R3: Rising 3-year-old; VIF: Variance inflation factor

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Introduction

Since the first catastrophic outbreak of spontaneous humeral fractures in primiparous dairy heifers in New Zealand in 2008, there has been a rise in the reported incidence and prevalence of this condition by veterinarians and farmers (Weston 2008; Wehrle-Martinez *et al.* 2023b). Furthermore, surveillance reports from the Ministry for Primary Industries have raised concerns over the identification of potential causes or risk factors that may be associated with the condition (Anonymous 2015).

The prevalence of spontaneous humeral fractures in New Zealand is largely unknown but a randomised national survey of 505 dairy farmers throughout New Zealand, conducted in 2014–2015, estimated that this condition occurred in first and second lactation heifers in 9.7% and 7.4% of dairy herds, respectively. The estimated within-herd prevalence of fractured humeri was 2.1% (95% CI = 1.4–2.6%) in first lactation cows and 2.5% (95% CI = 1.6–3.4%) in second lactation heifers, which was equivalent to approximately 4,620 animals affected nationally (J. Hunnam and S. McDougall[1], pers. comm.).

Previous studies on humeral fractures in New Zealand have reported that the condition is associated with recent periods of inadequate feed quality, leading to decreased bone formation, and increased abnormal bone resorption that severely impairs bone quality and strength in affected cows (Wehrle-Martinez *et al.* 2023a, 2023b, 2023c). Additionally, a study that investigated the role of copper deficiency in the occurrence of humeral fractures in dairy cows in New Zealand and compared the collagen and collagen cross-link content in heifers with and without humeral fractures concluded that copper deficiency is not a major factor in the occurrence of humeral fractures (Wehrle-Martinez *et al.* 2022).

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A further factor that remains to be investigated is the role that farm management (including herd health and nutrition) has in the occurrence of spontaneous humeral fractures. Compared to other dairy systems around the world, the New Zealand dairy system is seasonally driven, extensive, and pasture based (Clark *et al.* 2006). The use of pasture as the main source of dry matter intake is a major difference between the New Zealand dairy industry and other dairy industries around the world (Back 2017). Reports of spontaneous humeral fracture are almost unique to New Zealand, with a small number of reports from Australia, so it is highly likely that some unique facet of the New Zealand dairy system is an important risk factor (Anonymous 2020).

The aim of this study was to use a farm-based survey to identify characteristics of the New Zealand dairy system associated with the risk of spontaneous humeral fracture in dairy heifers.

Materials and methods

Study design

This was a case–control study to identify risk factors associated with spontaneous humeral fractures in New Zealand dairy heifers. A questionnaire was designed and used to compare retrospectively how frequently the exposure to a risk factor was present on farms that had cases of humeral fractures in dairy heifers (case farms) with farms that did not (control farms). The study was judged to be low risk through peer evaluation and an online risk assessment by the Research Ethics Office, Massey University (Palmerston North, NZ), and therefore did not require review by a human ethics committee.

Survey design and distribution

The questionnaire (Supplementary Material 1) was divided into four sections that included: (a) contact information and farm location, (b) farm information, (c) herd health and nutrition, and (d) calf rearing practices. The survey was made available as both a printed questionnaire and an online survey, with both methods using the same version of the questionnaire. The online survey was designed using commercially available software (QualtricsXM, Seattle, WA, USA). The survey was advertised to veterinarians and farmers who contacted members of the humeral fracture research group (Massey University, Palmerston North, NZ) about heifer humeral fractures and/or who submitted samples from cases of spontaneous humeral fractures to Massey University's School of Veterinary Science Postmortem Service. Additionally, 100 printed copies with a stamped return envelope were sent to the Animal Care team at DairyNZ (Palmerston North, NZ) for distribution during their 2019/2020 farmer consults. A link for the online survey was also posted on the Massey heifer fracture research group Facebook page (@masseyheiferfracture). Questionnaires were filled out by farmers and/or veterinarians between July 2019 and March 2020. We did not specify whether veterinarians should fill in the survey with/for farmers or whether it should be passed on to farmers. Farmers and veterinarians chose whether they wanted to participate or not (self-selection).

Data analysis

Data from the paper-based surveys were manually entered into an Excel spreadsheet (Microsoft, Redmond, WA, USA) of the online survey results and imported into R statistical software version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria). Partial responses (where respondents did not complete all survey questions) and duplicates (defined as responses with the same contact person's name and/or farm address) were excluded. A dummy variable was created based on the responses to the survey question "Have you ever had broken shoulders in your herd?" with those answering "yes" categorised as a case farm and those answering "no" categorised as a control farm. Univariable logistic models were built to screen survey answers associated with case farms and control farms and the OR, 95% CI, and global p-values were reported for all unadjusted univariable associations. Prior to univariable analysis, the Box–Tidwell test (Box and Tidwell 1962) was used to assess the assumption of a linear relationship between the log odds of the dependent variable, humeral fracture, and the three continuous independent variables, herd production (2018–2019 season), volume of milk fed, and age when calves access pasture, controlling for the effect of breed. Those variables with a non-linear relationship were converted into quantiles for the univariable analysis.

All variables from the univariable analysis with a global p-value < 0.20 were then considered for inclusion in a final multivariable model. Prior to building the model, a causal diagram was constructed (Figure 1) using the variables identified by the univariable analysis reconciled against the results from Wehrle-Martinez (2022). This was to understand the nature of any confounding among the variables, examine the biological plausibility of these variables and inform model construction. This clearly showed that herd production (2018–2019 season) is a descendant of breed and as such doesn't need to be tested in the model. For inclusion in the final multivariable model the predominant breed of cow on the farm was simplified to Holstein-Friesian Jersey crossbreed (HFxJ) or not. Variables were selected for inclusion

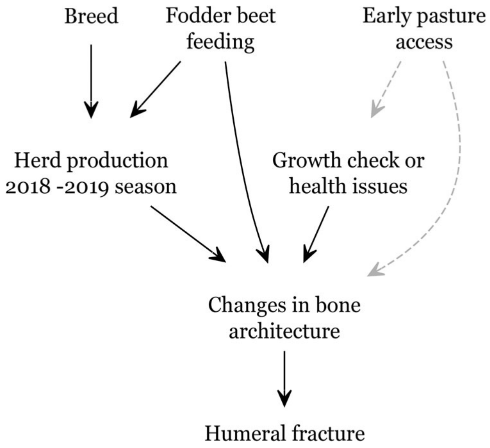

Figure 1. Causal diagram demonstrating the hypothesised relationships between the risk of humeral fracture and variables carried forward from a univariable analysis of farm and management factors associated with the risk of humeral fracture in dairy heifers. Dashed grey arrows show possible pathways for which there is less evidence.

into the multivariable model using backwards stepwise selection until all remaining variables had a p-value < 0.05 using the likelihood-ratio test, or the removal of a variable resulted in a > 20% change in the coefficient of a predictor variable already retained in the model. Model fit was checked by calculating McFadden's pseudo-R^2 and assessing the distribution of the model residuals using the DHARMa package (Hartig 2020) and the Kolmogorov–Smirnov (KS) test. Multicollinearity among the independent variables of the final model was also checked by measuring the variance inflation factor (VIF).

The longitude and latitude for each survey farm was estimated from Google maps (Google LLC, Menlo Park, CA, USA) and plotted on a map using a World Geodetic System 1984 projection.

Results

Out of 171 returned questionnaires, a total of 68 (40%) questionnaires were found suitable for analysis, which represented 0.6% (68/11,179) of dairy farms for the 2019/2020 season. Thirty-five responses were from case farms and 33 responses from control farms. The median number of years fractured humeri were reported on case farms was 2 (min 1, max 9) years. In 16/35 (46%) case farms, the 2019/2020 season was the first time that cases of humeral fractures occurred, whilst 9/35 (26%) case farms had experienced humeral fractures for 2 years, and a further 10/35 (29%) case farms had reported cases occurring for > 2 years. Analysis of farm location showed a similar distribution of case and control farm responses from the North and South Island of New Zealand. There were 26 responses from the South Island (13 case farms and 13 control farms) and 38 responses from the North Island (20

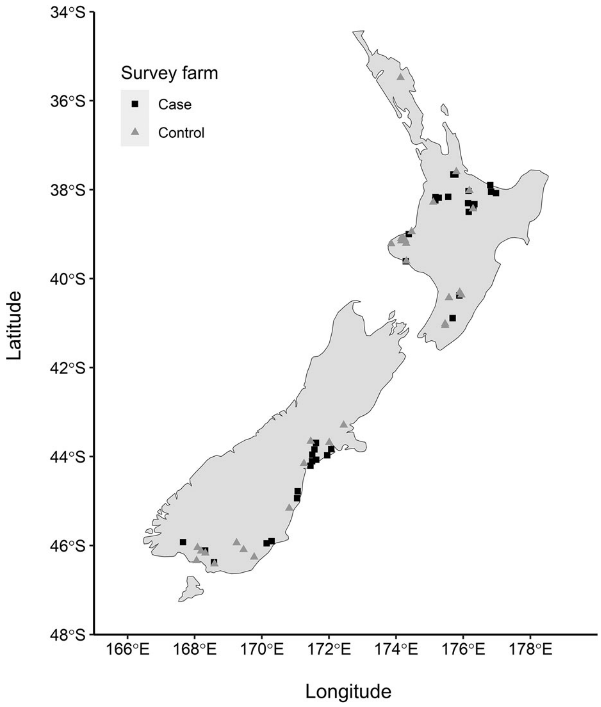

Figure 2. Map of New Zealand showing the geographical location of farms that did (case; black squares) or did not (control; grey triangle) report cases of humeral fractures among dairy heifers. Four farms (two case and two control) are not shown due to farmers withholding their locations. Clusters of case farms are observed in the Waikato and Canterbury regions and clusters of control farms are observed in the Taranaki and lower South Island regions.

case farms and 18 control farms). However, within each island, the spatial distribution of case and control farms was not homogeneous (Figure 2), with an apparent excess of case farms from the Waikato and Canterbury regions and an excess of control farms from the Taranaki and lower South Island regions. There was insufficient data for spatial analysis, particularly given that four returned questionnaires (two case and two control farms) had no farm location provided.

The Box–Tidwell test showed that the data were compatible with the volume of milk fed (p = 0.86) and age when calves accessed pasture (p = 0.62) modelled as a linear relationship with the log odds of humeral fracture. The OR, 95% CI and p-values from the univariable logistic models are shown in Table 1. For volume of milk fed and age when calves accessed pasture, the mean and SD for case and control farms are shown. Interpretation of OR is not intuitive and requires careful thought; for example, an OR of 7.65 (95% CI = 2.47–26.72), as seen in row 4 of Table 1, means that the odds of HFxJ being the main farm breed were 7.65 times higher among the case farms than control farms. Furthermore, because the OR is greater than 1.0, and the 95% CI does not include 1, HFxJ breed may be a risk factor for humeral fracture. However, this is an unadjusted assessment and does

Table 1. Results of univariable logistic regression for association of farm characteristics and management factors with the unadjusted OR (95% CI) for risk of a farm having cases of spontaneous humeral fracture in dairy heifers.

Variable (global p-value)	Case farms (n = 35)	Control farms (n = 33)	OR (95% CI)	p-value[a]
Breed (p < 0.001)				
Holstein-Friesian	6/35 (17%)	17/33 (52%)	0.35 (0.13–0.85)	0.03
Jersey	1/35 (3%)	6/33 (18%)	0.47 (0.13–3.64)	0.52
Holstein-Friesian x Jersey	27/35 (77%)	10/33 (30%)	7.65 (2.47–26.72)	0.0007
Other[b]	1/35 (3%)	0/33 (0%)	NA	NA
Calving pattern (p = 0.95)				
Spring	33/35 (94%)	31/33 (94%)	1.06 (0.12–9.32)	0.95
Autumn	0/35 (0%)	0/33 (0%)	NA	NA
Split	2/35 (6%)	2/33 (6%)	1.00 (0.12–8.33)	1.00
Herd production 2018–2019 season (kg MS) (p = 0.15)				
275–380	13/31 (42%)	5/29 (17%)	2.6 (0.98–8.1)	0.07
381–410	6/31 (19%)	7/29 (24%)	0.33 (0.07–1.44)	0.15
411–460	7/31 (23%)	7/29 (24%)	0.38 (0.08–1.64)	0.2
461–600	5/31 (16%)	10/29 (34%)	0.19 (0.04–0.81)	0.03
Frequency of milking (p = 0.57)				
All once a day	2/35 (6%)	4/33 (12%)	0.36 (0.04–2.35)	0.49
All twice a day	22/35 (63%)	21/33 (64%)	0.76 (0.25–2.25)	0.62
Mix	11/35 (31%)	8/33 (24%)	1.38 (0.56–3.55)	0.49
Previous diagnosis of Cu deficiency (p = 0.25)	9/34 (26%)	5/33 (15%)	2.02 (0.61–7.32)	0.26
Supplement Cu (p = 0.31)	29/35 (83%)	24/33 (73%)	1.81 (0.57–6.1)	0.32
Supplement lime flour (p = 0.73)	23/35 (66%)	23/33 (70%)	0.83 (0.3–2.31)	0.73
Feed fodder beet (p = 0.19)	14/35 (40%)	10/33 (30%)	1.94 (0.72–5.38)	0.19
Growth check or health issues (p = 0.024)	8/28 (29%)	2/30 (7%)	5.6 (1.24–39.81)	0.041
Milk fed to calves (p = 0.26)				
Whole milk	28/34 (82%)	20/31 (65%)	2.52 (0.75–9.28)	0.14
Milk powder	1/34 (3%)	2/31 (6%)	0.9 (0.04–11.95)	0.94
Both	5/34 (15%)	9/31 (29%)	0.56 (0.17–1.61)	0.29
Volume of milk fed (L/calf/day)[c] (p = 0.89)	4.99 ± 1.33	4.9 ± 0.92	1.07 (0.7–1.65)	0.77
When meal fed to calves (p = 0.31)				
Pre-weaning	3/35 (9%)	1/30 (3%)	2.63 (0.32–54.7)	0.41
Post-weaning	0/35 (0%)	1/30 (3%)	NA	NA
Both	32/35 (91%)	28/30 (93%)	1.14 (0.69–1.91)	0.61
Calf age when accessed pasture (weeks)[c] (p = 0.022)	3.37 ± 1.91	4.53 ± 2.24	0.68 (0.47–0.90)	0.006

[a]Significance of variable in univariable logistic model
[b]Ayrshire
[c]Mean ± SD
MS = milk solids; NA = not applicable

not consider the effect of confounding from other variables. The magnitude of the OR, when > 4 or < 0.25, also suggests a strong association; however, wide 95% CI, when present, may reflect model instability due to inadequate sample size or complete separation.

From the examination of the 95% CI for the OR and the associated p-values there was no evidence for a difference in this unadjusted analysis between case and control farms in the calving pattern, milking frequency, history of Cu deficiency, Cu supplementation, type of milk fed to calves, volume of milk fed, or when a supplement meal was fed to calves. There was evidence for a difference between case and control farms in breed ($p < 0.001$), history of growth checks or health issues ($p = 0.024$), and the age when calves accessed pasture ($p = 0.22$).

Questions 9 and 10 were only completed by those respondents that answered "yes" to whether Cu supplementation was used on their farm. The answers from both questions were highly descriptive and as such were considered unsuitable for inclusion in the univariable analysis, but are presented here for completeness. Of the 29 case farms that reported that they used Cu supplementation, 13/29 (45%) used boluses, 9/29 (31%) used injections, 1/29 (3%) used fertiliser, and 9/29 (31%) used another form of supplementation, with three respondents selecting more than one choice. Of the 24 control farms that supplemented Cu, the type of supplementation used was: 7/24 (29%) used boluses, 7/24 (29%) used injections, 2/24 (8%) used fertiliser, and 10/24 (42%) used another form of supplementation. On case farms Cu supplementation was administered to all ages on 16/29 (55%) farms, rising 1-year-olds (R1) on 9/29 (31%) farms, and milkers (lactating cows) on 4/29 (14%) farms. Similarly, on control farms Cu supplementation was administered to all ages on 13/24 (54%) farms, R1 on 4/24 (17%) farms, milkers on 6/24 (25%) farms, and on 1/24 (4%) farms there was no information regarding what age group was supplemented.

Similarly, questions 12 and 14 were only completed by those respondents that answered "yes" to whether lime flour or fodder beet was fed on their farm. Again, the answers to these questions were highly descriptive and were considered not suitable for inclusion in the univariable analysis. On case farms, different commercial formulations of calcium carbonate (80–100% limestone) were the most frequently used lime flour supplement. Supplement rates between 50 and 300 g/cow/day were reported for case farms, and in six responses pasture dusting was described as the method of delivery. One respondent described mixing Ca with molasses, and another gave Ca as a drench. Similar supplementation rates (50–200 g/cow/day) were reported for control farms, with six respondents using pasture dusting and one administering it in molasses. The responses to which age groups were fed fodder beet and when showed that on six case farms, cattle were grazed on fodder beet during the winter and on four case farms, cattle were grazed on fodder beet during the autumn. The reported age groups of cattle that grazed on fodder beet on case farms were: R1 on four farms, rising 2-year-olds (R2) on four farms, all cattle on six farms, calves on one farm, and 3-years-olds (R3) on two farms. On control farms, cattle grazed on fodder beet during winter on nine farms, and one farm each reported fodder beet being offered to milkers in autumn, milkers in summer, and R1 over autumn. On control farms, the reported age groups that grazed on fodder beet were: R1 on two farms, R2 on four farms, milkers on five farms, R3 on two farms, all ages on three farms, and calves on one farm.

Variables carried forward from the univariable analysis and tested in the final multivariable model were breed (simplified to HFxJ or not) history of growth checks or health issues, calf age when accessed pasture, and feeding of fodder beet. The multivariable model found strong support for a difference in cow breed, with case farms being 9.7 times (95% CI = 3.1–36.0; $p < 0.001$) more likely to have HFxJ cows than control farms. There was also support for a protective effect of the age when calves were allowed access to pasture with a curvilinear decrease in the odds of being a case farm (OR = 0.68; 95% CI = 0.47–0.90; $p = 0.006$) for each week older calves were at turn out. There was no support for a difference in growth checks or health issues (OR = 3.19; 95% CI = 0.5–28.9; $p = 0.23$), or fodder beet feeding (OR = 1.27; 95% CI = 0.37–4.3; $p = 0.7$) between case and control farms. The pseudo-R^2 for the final model was 0.24 and the residuals were normally distributed (KS test $p = 0.59$). The VIF results gave no evidence of multicollinearity. The change in probability of a farm having a humeral fracture, over the range of ages that calves first had access to pasture, where the main breed was HFxJ or not, is shown in Figure 3.

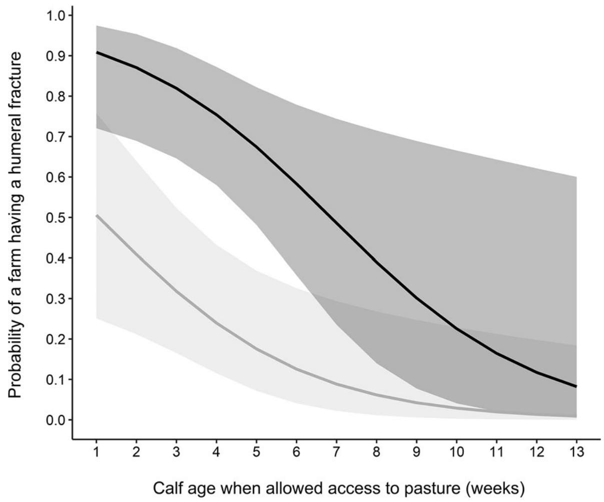

Figure 3. Graph showing the change in probability of humeral fracture among heifers for a farm where Holstein-Friesian Jersey crossbreed is the main breed of dairy cow (black line and dark 95% CI) or not (grey line and light grey 95% CI), over the range of ages that calves first had access to pasture.

Discussion

By surveying different aspects of farm management and husbandry practices on farms in New Zealand that have and have not had cases of spontaneous humeral fractures in dairy heifers, two potential risk factors were identified. First, more cases were reported for farms where the predominant breed was HFxJ and second, calves from case farms had access to pasture earlier than calves from control farms, with later access to pasture being protective.

In the last 30 years there has been a rapid expansion in the population of HFxJ cows in the national dairy herd (Harris 2005). From the 1998/1999 season to the 2008/2009 season (when the first outbreak of humeral fractures was reported in New Zealand), there was a 16% increase in HFxJ at the expense of Holstein-Friesian (14.2% less) and Jersey (2.2% less) cows (DairyNZ and LIC 1999, 2009). Over the decade following the 2008/2009 season, a similar trend was observed with the number of HFxJ cows increasing by 14.7%, reaching almost 50% of the population of dairy cows in New Zealand by 2021 (DairyNZ and LIC 2009, 2021) (Supplementary Material, Figure S1). However, this breed data represents the total number of cows in New Zealand and not the numbers of farms with each breed.

In New Zealand, crossbreeding dairy cattle is a widespread practice, which differs from the global norm (Buckley *et al.* 2014). The increased number of HFxJ cows in New Zealand is related to the better hybrid vigour of crossbred cows and their higher production worth index (Harris 2005; Buckley *et al.* 2014). This survey suggests that there might be an association between farms with increased crossbreeding and the incidence of humeral fractures in New Zealand. This association may partly explain why fractured humeri seem to be unique to New Zealand. Interestingly, it is not the first time an association between HFxJ cows and humeral fractures has been suggested. Abdul Rashid (2012) described that 66/113 (58%) cases occurred in HFxJ cows compared with 23 (20%) for Friesian and 24 (21%) for Jersey cows. These data were collected from 2007 to 2012, during which time the proportion of HFxJ cows in the national herd increased from 31.6% to 40.8% (DairyNZ and LIC 2007, 2012). Using the 2012 figure of 40.8% HFxJ in the national herd, the exact binomial test shows strong evidence that the proportion of HFxJ cows found by Abdul Rashid (2012) was significantly different to the national prevalence of that breed ($p < 0.001$). However, cases of humeral fractures have been reported in Holstein-Friesian and Jersey cows (Wehrle-Martinez *et al.* 2023b) and we have also observed cases in Ayrshire cows (A. Wehrle-Martinez, unpublished data). As such, this potential association of humeral fractures with HFxJ breed requires further investigation.

The finding that delaying access of calves to pasture was protective against humeral fracture was an interesting result. For many farms the age when calves are put outside the shed to graze is dictated by the size of the shed, the number of calves it can house, geographical location (associated with weather conditions) of the farm, and calf management at turn out, which is highly variable between farms and between different ages of calf. Farmers usually turn calves out in fine weather or when the calf shed gets too full (Back 2017). The uneven distribution of case and control farms, where case farms on each island are generally located further north, might suggest a potential spurious association. This could be due to calves from farms in the northern regions being placed on pasture earlier, possibly because of better weather conditions. However, this finding requires further investigation. Certainly, a calf that is younger at turn out may be more likely to experience a growth check.

The finding of the univariable analysis, that higher herd production in the 2018–2019 season (i.e. > 460 kg milk solids), was protective (Table 1) likely supports the finding that being Holstein-Friesian is also protective, given that Holstein-Friesian cows produce more milk than most other breeds. However, cases do still occur in Friesians, and herd production could also be acting as a proxy for some unknown farm management factor (good nutrition or milking frequency), age and/or efficiency of feed conversion, that both prevents humeral fractures from occurring and results in higher yields. As with the other risk factors identified by this study, this will also need further investigation.

The univariable logistic model found a significant association between growth checks or health issues and case farms that was not supported by the final multivariable model. It is possible that the difference between case and control farms found in the univariable analysis was due to recall bias. Recall bias is a well-reported systematic error that occurs when participants in a case–control study do not remember previous events or experiences accurately; for example, people with lung cancer are more likely to remember that they smoked than people without lung cancer (Coughlin 1990). In this case it is possible that farmers with outbreaks of fractured humeri are more likely to remember growth checks than farmers from control farms. In regards to using an appropriate control group, farms with no history of humeral fractures were identified as the control farms. Since this categorisation relies on accuracy of both diagnosis and recall by respondents there could be an opportunity for misclassification bias. Misclassification bias will often bias the results of a case–control study towards the null hypothesis. Failing to identify confounding variables or exposures in a condition that likely has a multifactorial aetiology is also a genuine concern for this study, especially with a one-page questionnaire; however, the poor response rate to a previously very detailed questionnaire guided the decision to use a more limited survey.

A major limitation of this study was the poor response rate. The response rate for this survey was very low, and it is important to recognise that analysing such a small data set could easily produce biased results. As can be seen, the CI for the two significant variables in the final multivariable model are quite wide, suggesting that the model was unstable, possibly because of inadequate sample size. Three other commonly cited limitations to case–control studies are recall bias, using an appropriate control group, and failing to identify confounding variables or exposures.

To maximise the response rate the authors developed diverse methods for delivery of questionnaires, but despite this, responses were received from only 0.6% of dairy farms in New Zealand (based on data from DairyNZ and LIC 2020). A previous questionnaire, developed by the Massey University heifer fracture research group, which also aimed to determine risk factors associated with humeral fractures, only collected data from nine case farms and seven control farms despite giving and/or publishing questionnaires to veterinarians of the Dairy Cattle Veterinarians branch of the New Zealand Veterinary Association, consultants at Dairy NZ, Livestock Improvement Corporation farmers, the Massey University Bachelor of Veterinary Science alumni Facebook page, and in the *NZ Dairy Exporter* (K Dittmer, unpublished data). This illustrates the difficulties in surveying farmers in New Zealand. One way to address this issue could be to use in-person and/or telephone surveys to collect quality data, with a random selection of case and control farms across the whole of New Zealand. This would be expensive but as there are up to 4,620 cases of humeral fracture each year (J. Hunnam and S. McDougall[2], pers. comm.) there is a real urgency to get meaningful data on this condition.

[2]J. Hunnam and S. McDougall, Cognosco, Anexa Animal Health, Morrinsville, NZ

In conclusion, this study has identified the HFxJ crossbreed as a possible risk factor associated with the incidence of spontaneous humeral fractures in dairy heifers in New Zealand. The study also found a possible association with calf age at turn out. Both of these risk factors require further investigation.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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