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RESEARCH ARTICLE

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Prevalence and incidence rate of clinical lameness in three New Zealand dairy goat farms

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ABSTRACT

Clinical lameness has an impact on animal welfare and profitability in different livestock industries. The objective of this study was to estimate the prevalence and incidence rate of clinical lameness within New Zealand dairy goat farms. Up to 3246 goats on three dairy goat farms were observed 4–5 times over one year. Data on locomotion scores and animal information were collected between June 2019 and June 2020. A 5-point (0–4) locomotion scoring scale was used, where scores 3 and 4 were classified as clinical lameness. The average herd-level prevalence of clinical lameness for farms A, B, and C were 23, 12, and 10%, respectively. The annual incidence rate of clinical lameness for farms A, B, and C were 104, 56, and 55 cases per 100 goat-years, respectively. Lameness appears to be a significant welfare issue, with incidence varying between farms and between goats. Investigating both farm-level and goat-level factors is required to understand the epidemiology of lameness and design evidence-based control and prevention measures. Further investigation should be undertaken to identify variables affecting the goat's odds of becoming clinically lame. This study sets the foundation for future study of lameness in commercial dairy goat farms nationally and internationally.

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Clinical lameness; dairy goats; prevalence; incidence rate; commercial farming; subjective scoring

Introduction

Lameness can be defined as the impairment of normal locomotion of an animal due to pain caused by an injury, disease, or claw disorder and is an indication of claw health (Vieira et al. 2015). The aetiology of lameness can be infectious and non-infectious. Infectious diseases of the claw are due to pathogenic bacteria or viruses that colonise on or within their host, causing injury when the conditions are favourable. Non-infectious factors, such as nutrition, management, environment, and genetics, may predispose

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the animal to lameness (Mathews 2016). As lameness is a manifestation of pain it makes it a significant animal welfare concern. Animal welfare is an essential aspect of farming and has recently been the subject of multiple studies on dairy goats (Anzunio et al. 2010; Muri et al. 2013; Hempstead et al. 2021).

Regardless of what causes lameness, the impact on the animal's productivity and longevity is negative. In dairy cattle and sheep, lameness has been associated with a low body condition score, reduced milk production and reproductive performance, and an increased risk of culling or death within the herd (Clarkson et al. 1996; Booth et al. 2004; Green et al. 2014). A body condition score ≤ 2.5 (on a scale of 1–5) was associated with lameness, milk production was lower in lame cows than in non-lame cows (Randall et al. 2015), and depending on the stage of lactation, lame cows were estimated to be 1.1–2 times as likely to be culled than non-lame cows (Booth et al. 2004). In dairy goats, reduced milk production, fertility, and longevity have been associated with lameness (Eze 2002; Christodoulopoulos 2009; Solis-Ramirez et al. 2011). Annual milk production (220-day) decreased by 16.4 kg in lame goats, while it decreased by 25.7 kg in lame goats with a foot lesion (Christodoulopoulos 2009). Observing that kidding intervals for lame goats were 4.3 months longer than for non-lame goats, Eze (2002) hypothesised that this was due to the lower body condition of the lame goats. One study surveyed the dairy goat industry in New Zealand and reported reasons for culling of goats (Solis-Ramirez et al. 2011). The principal reasons were low production and fertility problems, while lameness represented 6% of the culled goats. However, some of the poor performing goats could have been culled due to lameness as a secondary reason.

The full extent of lameness in the dairy goat industry, including its impact on welfare, production, and economics, has not been fully understood. Many international studies conducted so far on dairy goat farms are welfare studies. These studies looked at many aspects of welfare, including body condition score, skin lesions and lameness (Muri et al. 2013; Battini et al. 2015). In terms of lameness, they only reported the prevalence of lameness, indicating the percentage of lame goats on a farm at a given point in time. The limitation of these studies was that the lameness prevalence may have been under or overestimated because the results were based upon subset of goats within the herds. Another limitation was that there were no follow-up observations of these groups of goats. In dairy cows, it has been reported that the prevalence of lameness changed throughout the year (Clarkson et al. 1996). The prevalence of lameness was defined as the proportion of cases within a herd at a given locomotion scoring event, while the incidence rate was defined as the number of new lameness cases between two locomotion scoring events (Dohoo et al. 2003). The annual incidence rate provides further information on how quickly clinical lameness develops within the herd. This has not been studied in goats. In New Zealand, there has only been one small (Deeming et al. 2021) and one large-scale study (Chesterton et al. 2022) on the prevalence of lameness in dairy goats on commercial farms in New Zealand. Deeming et al. (2021) followed 80 goats on one farm for their first two years of life – the second year being their first year of lactation. Clinical lameness prevalence was reported to be between 0% and 6%. Chesterton et al. (2022) estimated lameness prevalence on three farms (3445 goats) on two subsequent farm visits to range between 6.7% and 25.5% of the herd. In their study, the two farm visits were close together (15 weeks apart) and goats were not individually identified. Therefore, it is unclear how the prevalence of lameness

may have changed over a production year and the incidence rate of lameness within these herds.

There are currently no longitudinal studies on lameness, specifically clinical lameness, of dairy goats on commercial farms in New Zealand or elsewhere in the world. The incidence rate of lameness is a novel aspect of this study because it has not yet been studied longitudinally in dairy goat herds. This study aimed to determine the prevalence of clinical lameness and to estimate its annual incidence rate in three commercial dairy goat herds.

Materials and methods

The animal study protocol was approved by the Ethics Committee of Massey University, New Zealand (MUAEC Protocol 19/51 and 29/05/2019).

Study population

Data were collected on three commercial dairy goat farms in the Waikato region of New Zealand between July 2019 and June 2020 (Table 1). All farms volunteered to participate in this study and were members of the Dairy Goat Co-operative (NZ) Ltd. Because of this, they may have known of, or perceived an issue with lameness in their herd. The participating farms were required to have at least four herd tests throughout the year. These

Table 1. Descriptive statistics for three dairy goat farms, located in Waikato, New Zealand, within the July 2019–June 2020 production year.

Farm characteristic	Farm A	Farm B	Farm C
Number of locomotion scoring events/year	5	4	4
Herd size (lactating goats, May 2020)	1497	623	763
Milking parlour setup	Rotary (100 bales)	Herringbone (40 aside)	Rotary (80 bales)
Kidding season	July 2019–October 2019	July 2019–August 2019	July 2019–August 2019
Bedding type	Wood shavings	Wood shavings and elephant grass	Wood shavings
Percentage of goats with extended lactation (>305 DIM)	55.6	23.9	38.6
Median age of the extended lactation group (years)	4	6	5
Interquartile range of the extended lactation group (years)	3	4	2
Median age of the seasonal lactation group (years)	2	2	2
Interquartile range of the seasonal lactation group (years)	3	3	2
The number of herd groups[a]	2	1	4
Stocking density (m^2 per goat)	2.19–2.68	2.94–3.61	2.63–2.70[b]
Treatment between hoof trimming events [c]	Sometimes[d]	Weekly	Sometimes
Footbath or mat protocols (using $CuSO_4$)[g]	Sometimes[e]	Sometimes	Daily[f]

[a]This excludes any hospital groups that were sometimes present throughout the season.
[b]This figure is the area of the inside barn. These goats have access to an outside area that decreases the stocking density to 3.59–3.77 m^2 per goat.
[c]Comprised of drafting out a lame goat, inspecting the affected foot and treating it.
[d]When the workers had time to treat the goats.
[e]After hoof trimming or a couple of times a week after milking.
[f]Only daily from February 2020 onwards and was not present before this time.
[g]$CuSO_4$ = Copper Sulphate.

farmers had witnessed lameness within their herds and were interested in reducing its prevalence on the farm. All farms kept goats of various breeds, including Saanen, Toggenburg, Alpine, and their crosses. Like most New Zealand farms, most goats were Saanen (Scholtens et al. 2017). Two of the selected farms had herd sizes similar to the national average of 750 milking does (Scholtens et al. 2017), while one farm was significantly larger, with over 1600 milking does. Goats entered the study following parturition, which occurred before the first locomotion scoring event for most goats (87%). The remaining 13% entered the study between the first and the third locomotion event.

Goats were classified as seasonal or extended lactation goats and were aged 1–12 years old. The seasonal lactation goats were defined as having given birth between August and December 2019, while the extended lactation goats had kidded before June 2019 and were over 305 days in milk at the beginning of the study. Overall, the extended lactation goats had been lactating continuously for, on average, 2.97 years, with a median of 3 years. Seasonal and extended lactation goats were managed the same. All goats were milked twice a day.

The diet consisted of a partial mixed ration with freshly cut grass-fed ad libitum. The partial mixed ration varied from farm to farm. It generally consisted of forage, such as grass and/or maize silage, a protein meal, such as distiller's dried grain, and additional supplements. All farms fed corn kernel or goat meal as part of their partial mixed ration or whilst in the milking parlour.

Locomotion scoring event logistics

Depending on the farm, locomotion scoring events were carried out 4–5 times a year during both morning and afternoon milkings (Figure 1). Apart from the first locomotion scoring event from farm A, all the locomotion scoring events took place during or just after herd testing. The goats were video-recorded walking as they exited the milking parlour, after being milked, thereby reducing the impact of a full udder on the goat's gait. Two cameras were used to record their movement to ensure that the goats were observed moving without being disturbed. The cameras were mounted and positioned to capture

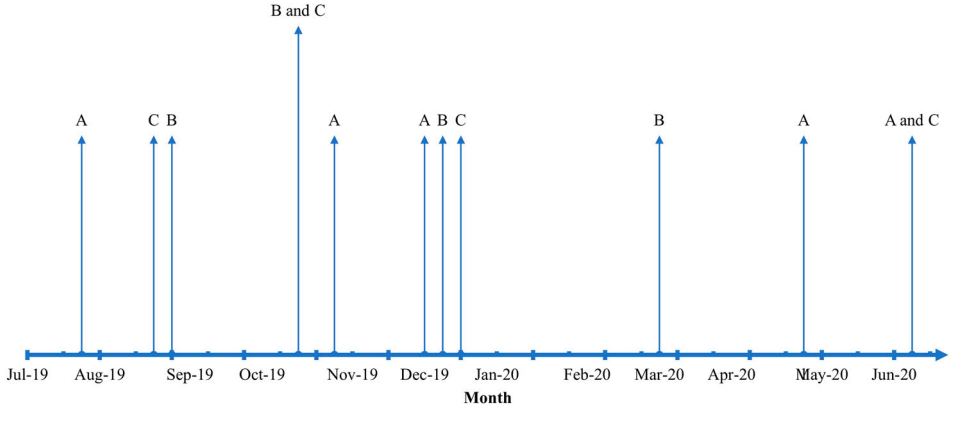

Figure 1. The timeline of locomotion scoring events for each dairy goat farm A, B and C- located in Waikato, New Zealand. The x-axis is the month starting in the first week of July 2019 and ending in the third week of June 2020.

at least four strides of walk (Deeming et al. 2018) from both the back and side of the goats. Farms A and C had a rotary milking parlour system that meant goats could exit the milking parlour 2–3 at a time. Farm B had a herringbone milking parlour, which released 40 goats at once. For farm B, to see the goats one at a time, a race was created to ensure goats made their way back to the barn in a single file. All goats were filmed walking across a flat, concrete surface. The goats were identified on the video footage using a unique number sprayed onto their rump corresponding to their electronic identification. Two video-recording sessions were conducted (one in the morning and one in the afternoon) at each locomotion scoring event to capture as many goats walking as possible. Where it was possible, goats were scored at both video sessions. If goats were scored at both video sessions, the average of their scores was used.

This research was affected by the Covid-19 pandemic. The last herd test on Farm C was postponed until June 2020. As a result, only half of their herd herd tested because the other half had been dried off in preparation for the following kidding season. This meant half the herd had their locomotion scored three times instead of four.

Validation of the subjective locomotion assessment

Using the videos, the first author conducted the locomotion analysis. They were familiar with goats' lameness and were trained to use the 5-point scoring system developed by Deeming et al. (2018) (Table 2). Two segments of video footage were used to train the observer, and a third video segment was used to cross-check the scores with the developer

Table 2. Locomotion scoring strategy used to measure lameness in dairy goats (adapted from Deeming et al. 2018).

Severity score	Label	Clinically lame	Limping	Gait description	Modifications
0	Normal/not lame	No	No	Moving forward with even strides where hooves track up. Weight-bearing and no apparent head nodding.	
1	Uneven gait	No	Uneven	Moving forward with shorter strides where hooves do not track up[a]. Weight-bearing, and having an absent head nodding, however, have joints that may show stiffness.	
2	Mildly lame	No	Yes	Moving forward with shorter strides where hooves do not track up. One or more legs/feet may be affected. Weight-bearing, and having an absent head nodding however may show a mild limp.	
3	Moderately lame	Yes	Yes	Reluctant to move forward and may display a moderate limp. One or more legs could be affected and may display some goose-stepping.	
4	Severely lame	Yes	Yes	Refusal to bear any weight on one foot. Severe limping or extreme goose-stepping or walking on the knees.	If there is no limp, but there is reluctance to move forward. Multiple feet are involved.

[a]Track up refers to the movement of the hind hooves stepping into the hoofprints left by the front hooves.

of the scoring system (inter-reliability) and cross-check the scores over time (intra-reliability) (see supplementary material).

The first video segment was obtained from Deeming et al. (2018) and showed one goat at each locomotion score. The second video segment was collected during a pilot study at farm A. This pilot study was also used to test the procedure's logistics. The third video segment contained roughly 60 goats at each locomotion score and is referred to as the farm reference footage. The third video segment was used for the validation analysis (inter- and intra-reliability). Each farm needed a reference video as the camera positions differed slightly because of the different milking parlour designs between farms, therefore, needed to ensure reliability and consistency of locomotion scoring across the 3 farms. The reference videos were obtained when a trial run of the locomotion scoring event was conducted at each farm.

For an accurate gait score to be assigned at least two consecutive strides of walk needed to be visible on the video (Flower & Weary, 2006). Goats who displayed irregular transitioning from one gait to another, jogging, rushing from the parlour (fast trotting or cantering), head shaking, coughing, and obstruction from anything within the goat's environment (goat blocking other goats) were not scored during that event. Another consideration was that the locomotion scoring system did not quite capture the goats with multiple leg/feet issues, as often these goats were not limping. Therefore, the scoring system developed by Deeming et al. (2018) was modified to reflect if the goat was not limping but was reluctant to move forward and bear weight. In this case, the score of this goat was considered 'severe' and was given a four.

Prevalence and incidence rate of lameness

Clinical lameness was defined as a goat having a locomotion score of 3 or 4. The prevalence of lameness was defined as the proportion of cases within a herd at a given locomotion scoring event. The incidence rate of clinical lameness was the number of new clinical lameness cases between the first and last scoring event (between July 2019 and July 2020)over the total animal-time at risk (Dohoo et al. 2003). The prevalence (P) and incidence rate (I) of clinical lameness were calculated using the following equations (Dohoo et al. 2003):

where, a = the number of cases of clinical lameness (locomotion severity scores 3–4) in a population at a point in time. b = the number of goats in the population at risk at that point in time.

$$\mathrm{I} = \frac{\text{Number of new cases in the herd between July 2019 and June 2020}}{\text{Goat-days at risk}} \times 365 \times 100$$

$$\text{Goat-days at risk} = \Sigma(c - 28 \text{ days} \times d - 14 \text{ days} \times \mathrm{e})$$

where, I = annual incidence rate per 100 goat-years. c = the number of days between the first and last locomotion scoring event for each goat. d = the number of lameness casespresent between the first and last locomotion scoring event for each goat multiplied by the assumed lameness duration of 28 days (Clarkson et al. 1996). e = the lameness status, absence or presence (0/1), at the last and first locomotion scoring event for each goat multiplied by half the assumed duration (14 days).

The first and last locomotion event for each goat was the first time and the last time that there was a record for them. Reasons for entering the study at a later locomotion scoring event could be that they kidded later and therefore entered the herd at a later date or they could not be scored at an earlier scoring event. Reasons for exiting the study earlier is because they may have died or been culled by the owner. The formula for the denominator of the incidence rate allowed accounting for these abnormal study entries and exits.

It was assumed that any lameness event lasted 28 days (Clarkson et al. 1996). Because the exact start and end date of lameness were unknown, it was assumed that for the first and last scoring event the measurement occurred at the mid-point of the lameness event. Because there were more than 28 days between successive locomotion scoring events, repeated cases were considered new cases.

A logistic regression analysis was carried out to test the difference between farms for prevalence and incidence rate of clinical lameness. The dependent variables used for the prevalence and incidence rate were the number of clinical lameness cases and the number of new cases, respectively. The number of new cases was adjusted for over-dispersion (determined by the Lagrange Multiplier test), by using a negative binomial distribution instead of a Poisson distribution. Farm was the only independent variable used in the model. The software SAS (version 9.4, SAS Institute Inc., Cary, NC) was used for all analyses.

Results

Prevalence and incidence rate of clinical lameness

At each locomotion scoring event, 77–91% of the herd was scored at least once (Table 3). Less than 100% of the herd was scored because some goats were not video-recorded having at least 2 consecutive strides of walk. The average prevalence and incidence rate of clinical lameness are presented in Table 4. The prevalence of clinical lameness fluctuated across the season and differed between farms across the 2019–2020 production year (Figure 2). Farm A had the highest prevalence of clinical lameness (estimate difference = −0.106 to −0.096, $P < 0.001$) across all the farms. On farm A, the prevalence ranged from 18 to 29% across the year, peaking in December 2019 at 29%. Farms B and C had similar prevalence of clinical lameness. They varied from 9 to 14% across the year and peaked in October 2019 with 12 and 14% clinically lame goats, respectively. Farm A also had the highest incidence rate of clinical lameness compared with farms B

Table 3. Number of dairy goats at each locomotion scoring event between July 2019 and June 2020 across the three commercial farms in New Zealand. The percentage of dairy goats scored at least once at each scoring event are displayed in parathesis.

Locomotion scoring event	Farm A	Farm B	Farm C
July 2019	1229 (80)	–	–
August 2019	–	758 (77)	840 (80)
October 2019	1626 (89)	767 (84)	825 (91)
December 2019	1639 (90)	749 (90)	798 (88)
March 2020	–	744 (90)	–
April 2020	1542 (87)	–	–
June 2020	1366 (80)	–	401 (87)

Table 4. Average prevalence and annual incidence rates (with 95% confidence intervals in parenthesis) of lameness and clinical lameness in dairy goats within three New Zealand commercial farms across the 2019–2020 production year.

	Lameness[1]		Clinical lameness[1]	
Farm	Prevalence[2] (%)	Incidence rate[3]	Prevalence (%)	Incidence rate
A	38 (28–48)[a]	172 (163–181)[a]	23 (18–28)[a]	104 (97–111)[a]
B	31 (20–42)[b]	191 (174–208)[b]	10 (8–12)[b]	57 (48–66)[b]
C	34 (29–39)[b]	161 (147–175)[c]	12 (9–15)[b]	55 (47–63)[b]
P value	<0.001	<0.05	<0.001	<0.001

[1]Lameness and clinical lameness were defined as having a locomotion score of 2–4 and 3–4, respectively, using a 5-point scoring system (0 to 4).
[2]The average prevalence across the 2019–2020 production year.
[3]The annual incidence rate was defined as the number of new cases per 100 goats.
[a,b]Means with different superscripts within the same column are significantly different ($P < 0.05$).

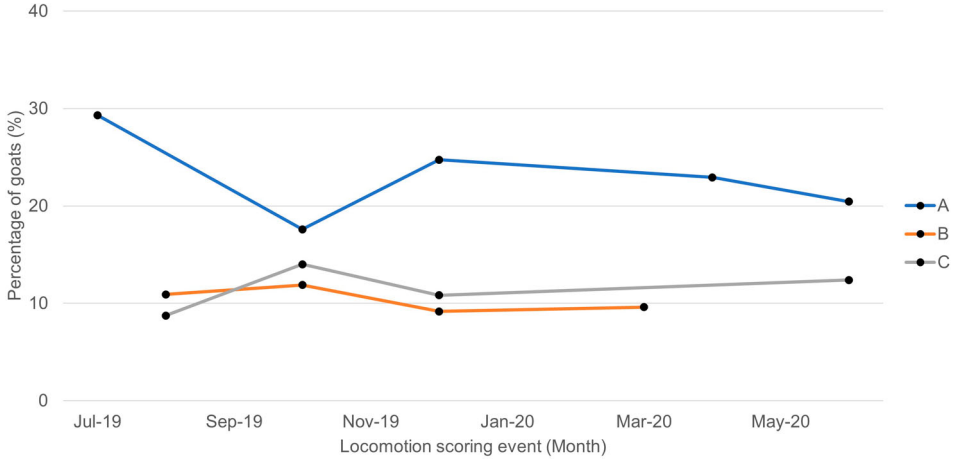

Figure 2. The prevalence of clinical lameness (locomotion severity scores 3 or 4) in dairy goats across three New Zealand farms (A, B, and C) during the 2019–2020 production year.

and C (difference between estimates = −0.61 and −0.68, respectively, $P < 0.001$). For every 100 goats within a year, 104 cases had a locomotion score of 3 or 4. Farms B and C had 57 and 55 cases of clinical lameness over one year in every 100 goats scored.

Discussion

This study is the first longitudinal assessment of lameness on commercial dairy goat farms with a strategy that can measure many goats continuously over several events. The objective of this study was to provide insight into the prevalence and annual incidence rate of clinical lameness in New Zealand dairy goats using a verified 5-point gait scoring system.

Prevalence of clinical lameness

The prevalence of clinical lameness estimated from the three farms within this study (12–23%) was similar to the prevalence reported in national and international lameness

studies. In New Zealand, two recent studies estimated the prevalence of lameness on dairy goat farms, and our study's results were similar to the results reported by Chesterton et al. (2022; 6.7–25.5%), although it was a lot higher than the results reported by Deeming et al. (2021; 0–6%). A reason for this difference in results compared with Deeming et al. (2021) is most likely due to the small cohort group that they had selected from a single farm, i.e. 80 goats compared with over 3000 goats included in this study and the study of Chesterton et al. (2022) across three farms. Another reason could be the difference in the prevalence of clinical lameness by age where older goats have significantly higher odds of clinical lameness compared with younger goats (1.18–2.39 times higher than in one-year-old goats, Jaques 2022), i.e. where Deeming et al. (2021) studied goats up to 2 years of age, our study had goats aged from 1 to 12 years old because the entire herd was observed. The age range in our study may have been similar to the study of Chesterton et al. (2022), however, this was not presented in their paper.

In Europe, over the last ten years, the prevalence of lame goats within a herd has ranged from 1.7 to 67% (Anzunio et al. 2010; Groenevelt et al. 2015a, 2015b; Hill et al. 1997). In the UK, between October 1995 and January 1996, lameness prevalence in dairy goat herds was estimated to be between 2.7 and 23.4%, with an average of 9.1% (Hill et al. 1997). Since then, lameness has increased in dairy goat farms, with some farms presenting 67% of the goats as lame (Anzunio et al. 2010; Groenevelt et al. 2015a, b). Norwegian and American studies had the lowest prevalence of lameness in their herds (1.7 and 1.2%, respectively), however, these figures were suggested to be underestimated (Muri et al. 2013; Hempstead et al. 2021) due to possible differences in the methodology used to score locomotion. Our study also supports conclusions in other New Zealand studies that lameness is an important problem for dairy goat farmers.

Except for Chesterton et al. (2022), many past studies have observed sub-groups of goats, and only a few observed entire herds. Moreover, all past studies collected lameness data at only one point in time. A potential issue with observing sub-groups of a herd is this could calculate a lameness prevalence that under or over-estimates the true prevalence within the herd, depending on how the goats were selected. In these studies, lameness prevalence is often scored while goats are within a pen with other goats present, which brings certain limitations to the interpretation of results. These limitations include- missing goats, goats or double counting goats, other goats or environmental obstruction preventing a clear view of a goat's gait, and soft bedding masking lameness severity. As a result, applying these results to a region's whole herd or potential goat population should be interpreted cautiously due to differences between farms, such as age and breed structures.

Potential risk factors such as age, breed, parity, stage of lactation or time of year have not been analysed statistically. The prevalence of clinical lameness reported in this study fluctuated over the farms' 2019–2020 production year. Farm A appeared to fluctuate more than farms B or C (Figure 2). Clinical lameness appeared to peak between October and December 2019 on all farms. On farm A clinical lameness increased in July 2019, which was not recorded on other farms. Season and lactation stage have been reported to impact on lameness prevalence in goats (Eze 2002; Christodoulopoulos 2009), dairy cattle (Solano et al. 2015) and sheep (Smith et al. 2014). Christodoulopoulos (2009) reported in dairy goats that the prevalence of lameness fluctuated over the year, which could have corresponded to changes in the climate between seasons. Chesterton

et al. (2022) assessed locomotion during the New Zealand Summer and Autumn on three farms between two visits. Two farms had an increase in the lameness prevalence between visits, while one farm had a decrease in lameness prevalence. The reason for this difference was unclear. In dairy cows, studies reported that the prevalence of lameness changed over time, with increased lameness in Winter and Spring compared with Summer (Rowlands et al. 1985; Clarkson et al. 1996; Haskell et al. 2006). Our study indicated that the time of year (either stage of lactation or season) could affect the prevalence of lameness and clinical lameness, and it should be considered a possible risk factor in future analyses in further research. Body condition score, which can also fluctuate over the milking season due to changes in the stage of lactation, diet or feed intake, has been associated with lameness in dairy cows, where cows with a lower body condition score (<2) were at greater risk of being lame (Randall et al. 2015).

A limitation of the current study was that the number of goats scored per locomotion scoring event varied between events for each farm (Table 3). This may have influenced the prevalence and incidence rate of clinical lameness. Firstly, for farm A, there were some logistical issues with the first locomotion scoring event, which resulted in fewer goats being scored compared to other scoring events. These issues were corrected at subsequent locomotion scoring events, for example, by slowing down the rotary so that only one or two goats exit the rotary at one time rather than four or five goats when the rotary was rotating very quickly. Secondly, for the farms, the first locomotion scoring event occurred at the beginning of the kidding season, corresponding to the introduction of goatlings (one-year-olds) into the main herd. The younger goats were less likely to walk back to the barns from the milking parlour in an orderly behaviour. The goatlings either trotted or stayed in the race around the milking parlour and obstructed other goats as they walked back to the barn. The obstruction from the goatlings reduced the number of young goats being scored during this time. Thirdly, fewer goats were recorded for farm A in June 2020 because of technical issues with the cameras, so not all goats were recorded twice. Fourthly, the specificity and the sensitivity of the locomotion scoring system that was used was not investigated. For example, if someone further evaluated the goats (identified from the video), they could identify whether the goats had signs of inflammation (clinical symptoms) but may not have presented clinically lame by the definition of our locomotion scores, thus clinical lameness could have been underestimated. Lastly, some goats were not scored due to environmental obstructions, including obstruction by surrounding goats or their behaviour, such as trotting or cantering instead of walking, as they exited the milking parlour. These four reasons could have influenced the results, resulting in an over- or underestimated lameness prevalence within the herd.

There were two visits on separate farms where there could be potential bias within the prevalence results. These visits occurred in farm A in July 2019 and Farm C in June 2020. For farm A, the locomotion scoring event occurred halfway through the farm's kidding season. Many one-year-old goats had not been scored for lameness at this time event because they had yet to kid and enter the main herd. Due to the prevalence of clinical lameness in the younger age groups being lower than in older goats (Jaques 2022), the herd lameness prevalence could have been overestimated at this time point compared with the other two farms. Due to the Covid-19 pandemic, farm C postponed its last herd test from March 2020 until June 2020. By this time, half of their herd had already been dried off in preparation for the next kidding season. The change in the

herd's age structure created a bias within the data at this time point because most of the younger goats (aged less than three years old) had been dried off. Due to lameness being more prevalent in the older goats and the possible selection against lame goats for breeding (Jaques 2022), lameness on this farm would have been overestimated in June 2020. Due to the herd tests being planned by an outside company, the subsequent dates of our locomotion scoring events were out of our control.

Since the logistics of lameness scoring have been developed within this study, the next phase of this research would be to conduct lameness scoring on multiple farms to identify risk factors associated with clinical lameness. Currently, the number of farms included in this sample is too small to look at the herd-level factors such as bedding type, herd size, bedding dryness, footbath or mat use, and other management issues that may potentially be associated with clinical lameness (dairy cows; Solano et al. 2015). Other variables that were not measured at the goat-level should be considered for future studies: body condition score, presence of claw disorders or leg injuries, and milk production. These variables are considered to be associated with lameness in dairy cows (Green et al. 2014, Solano et al. 2015). Investigating the diagnosis of clinical lameness was small part of this study, where other clinical signs of leg or foot problems, such as inflammation, were not investigated as it was out of the scope of this study. Other clinical signs should be investigated further and it would be interesting to study goats that are clinically lame but without claw disorders.

The incidence rate of clinical lameness

Incidence rate is a measure that has more bearing on production economics than prevalence as it reflects the time of the year that lameness may impact on cost for reduced milk production and treatment. The incidence rate of clinical lameness in farm A was nearly double the rate compared with farms B and C ($P < 0.001$). To date, no studies have reported lameness incidence rates on dairy goat farms. For dairy cows, the reported incidence rates were between 1.5 and 111.5 cases per 100 cow-years (Barkema et al. 1994; Clarkson et al. 1996; Hedges et al. 2001). The results from our study were similar to the results by Hedges et al. (2001), which reported an average lameness incidence rate of 70 cases per 100 cow-years across 5 farms, with a range of 31.6–111.6 cases per 100 cow-years. In that study, the definition of clinical lameness used by the farmers and veterinarians identifying only lame cows was unclear, with authors mentioning that cases of mild lameness may have also been included. Clarkson et al. (1996) calculated the clinical lameness (scores >3 on a scale of 1–5) incidence rate, which was, on average, 18.3 cases per 100 cow-years. This incidence rate was lower than our study's incidence rate of clinical lameness in dairy goats. Our study's incidence rates were perhaps underestimated because there were fewer visits per farm within a season than Clarkson et al. (1996) or Hedges et al. (2001), with 4 or 5 visits versus at least 3–11 visits per farm per year. In the study reported by Hedges et al. (2001), veterinarians were called out to treat cows when farmers found them lame, in addition to veterinarians visiting the farms every two months. Alternatively, farms in this study could have volunteered because of a known or perceived lameness issue, therefore, these farms could have a higher lameness incidence than the population average. Conversely, the assumption by Clarkson et al. (1996) that lameness events lasted 28 days in dairy cows, may not be valid for dairy

goats and needs further investigation. For example, as presented in Appendix A, several goats had been identified as having clinical lameness over consecutive lameness scoring events, indicating either multiple new cases of lameness or one lameness that endured for months. As the duration of lameness events is unknown in dairy goats, a dairy cattle estimation was used when calculating the incidence rate. The authors recognise that this may have impacted the calculated incidence rate in the current study, and that a duration rate for goats is needed.

Incidence rate can be used to monitor lameness within a farm and is independent of the herd's changing population (due to the entry and exit of goats). A limitation to the interpretation of the results of our study is that the number of locomotion scoring events for each farm was different, and farmers did not record new lameness cases in between locomotion scoring events. Farm A had five locomotion scoring events, while farms B and C only had four events. Also, the time interval between locomotion scoring events was different. Another limitation to this study, is that data was collected 4 or 5 times across a year rather than daily observations. For future consideration, to improve the accuracy of the incidence rate of clinical lameness, it is advisable to record information on lameness diagnosis and include information on other clinical signs, such as the presence of inflammation and treatments between locomotion scoring events.

One addition to the limitations indicated above, another limitation of this study was the small number of farms included, all volunteering and hence likely not representative of the entire industry. This study only had three farms participating. This represents roughly 3% of dairy goat farms in New Zealand, therefore, for some information, results cannot be extrapolated to the broader population. Due to the low number of farms, farm-level risk factors such as herd size could not be established. The small number of farms included in this study enabled us to establish the project's logistics. The next step would be to assess farm-level risk factors by including a large number of farms within the study.

Clinical lameness is a health and welfare issue on dairy goat farms in New Zealand. The average herd prevalence of clinical lameness across three farms was between 10 and 23%. The incidence rate ranged from 55 to 104 cases per 100 goat-years. The prevalence differed between farms and fluctuated over time. Therefore, the timing of locomotion scoring events should be considered when comparing farms within the same study and within the farm to quantify the problem accurately. This study creates a foundation for future epidemiological research to identify more risk factors associated with lameness and increase the understanding of lameness within dairy goat farms at a commercial level.

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Disclosure statement

The authors declare no conflict of interest. However, one of the authors, Sally-Anne Turner, from Dairy Goat Co-Operative (NZ) Ltd, was involved in the design and collection of data of this study,

as well as supervision of the PhD student, however, was not involved in the analyses or interpretation of data and in the original writing of the manuscript.

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Appendix A.

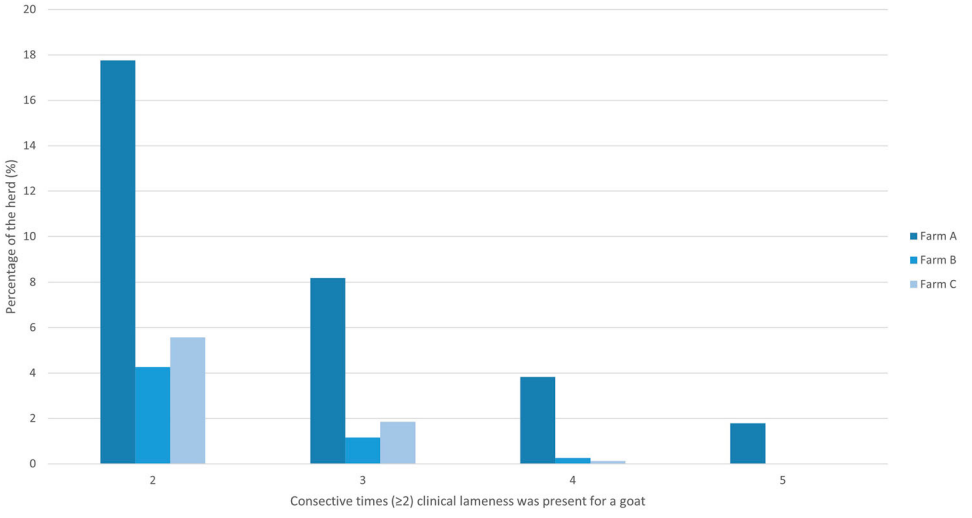

Figure A1. Percentage of dairy goats within the herd with consecutive clinical lameness events (locomotion score 3 or 4) across recording events within the 2019–2020 production year in three commercial farms (A, B and C). Farms were in Waikato, New Zealand.