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Suckling behavior of calves in seasonally calving pasture-based dairy systems, and possible environmental and management factors affecting suckling behaviors

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ABSTRACT

In recent years, interest has been increasing in whether farmed animals are able to live a reasonably natural life, with one particular area of concern being calf-dam separation. The objectives of this study were to monitor the timing and frequency of suckling behavior of calves left on pasture to suckle their dams for up to 24 h (interquartile range 4.0–15.5 h) and to investigate possible risk factors that may contribute to any variability seen. Over 2 yr, a convenience sample of 8 farms (4 in the North Island, 4 in the South Island of New Zealand) were involved in an observational study where cows and calves were observed for 24 h a day over a 2-wk-long period per farm. During the observation period, farmers continued to remove calves at the same frequency they normally did (which ranged from once a day to 4 times a day). Cows (between 2 and 12 yr old) and calves were observed from a scissor lift in or beside the calving paddock. Cows had numbers written on them, and observers used binoculars and spotlights. Observers recorded the length of stage 2 labor, time of birth, standing, and first suckling, number of suckling events, time of calf removal from the dam, temperature where the cows were grazing, and size of the grazing area they were calving in. Dams were body condition scored before calving, and their age was extracted from farm records. A total of 697 calves were observed during the study. A total of 444 of 697 calves [63.7%; 95% confidence interval (CI) = 60.0–67.3%] suckled in the calving paddock (farm range 40.0% to 90.2%). Of the 444 calves that suckled in the calving paddock, 407 (58.4%; 95% CI 54.6–62.1%) suckled within the first 6 h after birth (farm range 33.0% to 83.6%). Individual risk factors associated with the hazard rate ratio (HR) for time to first suckling event were time to standing (calves who took more than 1.3 h to stand had a longer time from birth to first suckle) and age of the dam [compared with calves that were born from dams >7 years of age, calves born to dams that were 2–3 and 4–7 yr of age had a 1.49 (95% CI 1.07–2.06) and 1.19 (95% CI 0.89–1.60) HR, respectively, for time from birth to first suckle in the calving paddock]. Farm risk factors associated with the HR of suckling were frequency of calf collection [calves that were born on farms that collected calves once a day suckled earlier than calves on farms that removed calves more than once a day (HR 1.52; 95% CI 1.25–1.84)] and temperature [a minimum temperature of <10°C within 6 h of a calf being born was associated with a 0.69 (95% CI 0.53–0.89) hazard of suckling in the calving paddock]. We observed very large farm variability that urgently requires further investigation if pasture-based farms are ever to adopt a system where calves remain with their dams for longer than 24 h.

Key words: dairy calves, pasture, suckling, risk factors, dams

INTRODUCTION

In recent years, interest from the general public about farm animal welfare has been increasing. People's interests and judgments about farm animal welfare focus on 3 broad areas: (1) that animals are farmed in conditions that promote good biological function (health, growth, reproduction); (2) that these conditions minimize suffering and promote contentment; and (3) that they allow the animal to live a reasonably natural life (Fraser, 2003; Buller et al., 2018; de Boer and Aiking, 2022).

Internationally, it is common practice to remove calves off the dam within 1 to 4 h of birth and to feed them with a set volume of high-quality (often pasteurized) colostrum (Beam et al., 2009). The aim of this management practice, applied by so many around the world, focuses on the first 2 broad areas of animal welfare: promoting good biological function (health) and minimizing suffering. First, early removal of calves has been advocated as a way of reducing the distress caused

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for both calf and dam by later removal (Flower and Weary, 2003; Pérez-Torres et al., 2016; Meagher et al., 2019). Second, removing calves off the dam soon after birth and then giving them a fixed amount of high-quality colostrum is designed to reduce the number of calves that have failure of transfer of passive immunity (**FPT**). Failure of transfer of passive immunity results in increased morbidity and mortality (Tyler et al., 1998; Pardon et al., 2015; Cuttance et al., 2018b) and decreased growth rates (Furman-Fratczak et al., 2011; Pardon et al., 2015; Cuttance et al., 2019). Finally, early removal has been proposed to reduce exposure to certain harmful pathogens such as *Cryptosporidium* and *Mycobacterium avium* var. *paratuberculosis* (Faubert and Litvinsky, 2000; Norton et al., 2009).

However, the practice of early separation does not necessarily promote animal welfare (Beaver et al., 2019; Meagher et al., 2019). This is especially so if it is looked at through the lens of "living a natural life." Allowing the natural behavior of the cow feeding and bonding with her calf is also seen by the public to be an important natural behavior (Busch et al., 2017; Hötzel et al., 2017). Hence, the management of cows and calves after calving has become a focus for animal rights groups (Viva, 2012; SAFE for Animals, 2020). Furthermore, the impact on health of cow-calf separation is probably less certain than commonly claimed. A review of the literature on the impact of separation of cow and calf on diarrhea, cryptosporidiosis, Johne's disease, pneumonia, immunity, and mortality in calves (Beaver et al., 2019) concluded that overall the literature was highly variable, making clear conclusions on most outcomes impossible. However, that review also highlighted a citation bias in the literature toward separation from the dam that was largely unsubstantiated by available research.

Nevertheless, in contrast to the known benefits of feeding a calf a known volume of high-quality colostrum, we need more research on the factors that affect how successful calves are at suckling and ultimately feeding if left with the dam. Only a few moderately sized or larger studies have examined the time between calving and suckling in dairy cows (Table 1). Those studies observed between 20 and 161 cow and calf pairs, and reported a range of suckling behaviors. The lowest recorded percentage of calves suckling from cows within 6 h of birth was 50% (Selman et al., 1970b; 10 cows and 10 heifers observed), and the highest was 87.5% of calves suckling within 6 h in cows housed in stalls (Illmann and Špinka, 1993; 32 cattle observed). The studies also looked at potential risk factors for suckling and reported a range of such factors, including poor udder and teat conformation, poor maternal behavior, slippery floor, weak teat-seeking drive, genetics, and environment [e.g., temperature; Edwards (1982) suggested that calves may have been more lethargic in colder weather]. Almost all of these studies have used housed cow-calf pairs, with, as far as the authors are aware, only one study of suckling behavior in dairy cow-calf pairs at pasture (Wesselink et al., 1999). This is despite suckling behavior being particularly prevalent in seasonal, pasture-based dairy systems, such as those practiced in New Zealand. In such systems, calves are regularly left with the dam for 12 to 24 h (Cuttance et al., 2018a), so farmers are often relying on calves to intake sufficient colostrum before they are housed. Wesselink et al. (1999) monitored the suckling behavior of 21 calves. Of the 14 of 21 calves that had suckled before separation, 11 had suckled within the first 6 h after birth, 2 had suckled between 6 and 12 h of birth, and the remaining calf more than 12 h after birth. After monitoring for FPT (45%, based on 74 calves sampled before feeding in the shed), Wesselink et al. (1999) concluded that up to 50% of calves may not get enough colostrum if left with the dam and recommended that calves be collected at least 4 times per day.

Despite these conclusions being based on suckling behavior measurements from only 21 calves (combined with FPT assessment of 74 calves), the study by Wesselink et al. (1999), together with the overseas research, has resulted in significant pressure from veterinarians and advisors in New Zealand over the past 20 yr to encourage farmers to collect calves from the calving paddock more than twice daily. However, as well as failing to meet many of the public's perceptions in regard to the natural behavior of the cow and calf, this approach has not produced positive results on many New Zealand dairy farms. Cuttance et al. (2018a) showed that across New Zealand, only 4 of 101 dairy farmers (4%) achieved more than 2 pickups per day, with 66 of 101 picking up less than twice a day. The failure of over 20 yr of pressure to change calf pickup management strategies on most farms highlights a failure of research and extension to focus on what is achievable by farmers. The lack of response to the pressure strongly suggests that, to farmers working in a seasonal calving system, picking up calves 4 times a day is not an achievable goal. However, research and extension have previously failed to identify this issue, so that more than 20 yr after Wesselink et al. (1999), we are left knowing that 4-times-a-day pickup is impractical on most New Zealand dairy farms. However, we are in a position where we do not have any research in dairy cattle at pasture on how to optimize colostrum uptake without having to artificially feed and pick up calves more than twice a day. Research on optimizing colostrum intake from the dam is urgently needed and will also be useful for understanding how

Table 1. Description of current available literature on the number of calves suckling dams and the time period over which this occurred

Country	Breed	Number of animals	Number of animals that suckled	Time frame monitored	Time to suckle (h)	Management	Reference
Scotland	Ayrshire and mixed beef cattle	30 total (10 dairy heifers, 10 dairy cows, 10 beef cows)	8/10 dairy heifers 7/10 dairy cows 8/10 beef cows	Within 8 h	*Average:* Dairy heifers: 2.6 Dairy cows: 4.4 Beef cows: 1.35	Housed	Selman et al. (1970b)
England	Friesian	82 (28 heifers, 54 cows)	17/28 heifers 8/54 cows 25/28 heifers 29/54 cows	Within 2 h Within 6 h	Not reported	Housed	Edwards and Broom (1979)
England	Friesian	127	90/127	Within 6 h	Not reported	Housed	Edwards et al. (1982)
England	Friesian	161 (48 heifers, 113 cows)	10/161 31/161 28/161 15/161 13/161 13/161	Within 1 h Within 2 h Within 3 h Within 4 h Within 5 h Within 6 h	Not reported	Housed	Edwards (1982)
Unknown	Salers and Friesian	13	13/13	Within 4 h	All suckled within 2.2 h	At pasture	Le Neindre (1989)
Sweden	Holstein Friesian	21	17/21 19/21	Within 6 h Within 12 h	*Median:* 4 h, 9 min *Range:* 50 min–11 h, 44 min	Housed	Ventorp and Michanek (1991)
Sweden	Holstein Friesian	42 (14 heifers, 28 cows)	36/42	Within 12 h	Not reported	Housed	Ventorp and Michanek (1992)
Czechoslovakia	Simmental	32 heifers	28/32	Within 6 h	Not reported	Housed	Illmann and Špinka (1993)
Sweden	Swedish Red and White and Swedish Friesian	22	15/22	Within 4 h	2 h, SD 55.1 min	Housed	Lidfors (1996)
New Zealand	Friesian	21	11/21 13/21 14/21	Within 6 h Within 12 h Within 24 h	Not reported	Pastoral	Wesselink et al. (1999)

to delay cow-calf separation under New Zealand conditions while optimizing calf health.

Given the interest in delaying cow-calf separation and the practicality of it on New Zealand dairy farms, the aim of this study was to monitor the timing and frequency of suckling behavior of calves who are left to suckle their dams for up to 24 h across a large number of calves and to investigate possible risk factors that may contribute to any variability seen.

MATERIALS AND METHODS

All manipulation of animals was approved by the AgResearch (Ruakura, New Zealand) Animal Ethics Committee, application number 14794.

This study was a prospective observational and descriptive study carried out on 8 farms in the North Island (Waikato region; n = 4) and the South Island (Canterbury region; n = 4) of New Zealand. Sample size was chosen based on practical feasibility and budget. Half of the farms, evenly split over the regions, were observed in spring (August) 2019 and half in spring 2020. Eligible farms were conveniently selected by considering the location of the farm, location and accessibility of calving paddocks, calving management (timing and frequency of calf pickup), calving spread, previous data collected on FPT, and willingness to participate.

Farms were enrolled to allow 12 full days of 24-h observation of cows and calves (6 consecutive observation days, followed by a 1-d break, followed by another 6 consecutive observation days) in 2019 and 8 full days of 24-h observation (4 consecutive days, followed by a 3-d break, and then another 4 consecutive days) in 2020. The dates chosen for the observation periods were to align with period of peak calving. Before the beginning of the observation period, all cows due to calve within the following 7 to 14 d had their ear tag number sprayed in large writing on their back and sides with blue spray paint and were body condition scored by a veterinarian on a 1-to-10 scale (Roche et al., 2004). The farmers carried out their normal farm protocols for the duration of the trial. Therefore, they checked the cows with their typical frequency (3–6 times a day), and removed calves and transported them to housing with their typical frequency (1–4 times a day). In addition they moved the cows onto feed pads, if required, every morning, and managed pasture availability as normal (e.g., back fencing to prevent regrazing or allowing access to the whole grazing area). The observation team worked around each individual farm management protocol.

Observations were carried out by trained technicians working in pairs or triplets (depending on the farm), on 4- to 5-h shifts at a time over a 24-h period. Observers were all trained by the primary investigators (authors) to ensure that everyone was clear on the measurements and their definitions. Observers were positioned on a scissor lift in the middle or on the edge of the area that was being grazed by the calving cows. The scissor lift was moved to a new location as needed every time the cows moved their calving paddock. One member of the pair of observers was responsible for recording the observations, and the other member or members of the pair or triplet carried out observations. Observers had multiple high-powered torches and binoculars to aid in observations. If absolutely needed (although discouraged), a technician would quietly walk around the perimeter of the cows, if they were unable to see what was happening to a cow or calf.

The observations collected are presented in Table 2, and examples of the process are shown in Figures 1 and 2. Calves were excluded from any observations if they were born dead or died before the farmer collected the calves, or if the cow or calf was removed from the calving paddock (out of sight of the observation team) before general calf pickup (e.g., to assist calving or seek treatment). As calves were born, they were assigned a letter grouping: AA, followed by AB, AC, and so on. This was not written on the calf, so as to not disturb any observations, but was accompanied by an accurate description of the calf on a whiteboard. These identifications and descriptions were written on the record forms as well as a large whiteboard for easy tracking by the team and handover to other teams.

When the farmers came to the calving paddock throughout the day or night as part of their usual farm protocols, they would either place a temporary necklace on the calf with colored tags (e.g., 2 purple, 1 white) or tag the calf with an ear tag identification. This identification was recorded alongside the letter grouping to help with accuracy of recording (especially when multiple calves were all black without distinguishing features). Any cows or calves deemed to be suffering (e.g., in pain, unable to stand) or likely to be experiencing dystocia or milk fever were identified and reported to the farmer. They were removed from the study observations.

Potential risk factors contributing to suckling behaviors and colostrum quality were also collected daily. Every calving paddock supplied to the calving cows was measured for area size using a measuring wheel, and pasture cover was then measured using a pasture meter. When cows were moved, the residual pasture remaining in the previously grazed calving paddock was also measured by plate meter to get an indication of pasture offered and pasture consumed over the observation period in that area. Temperature was measured every 30 min using an anemometer (HoldPeak HP-866B). In

Table 2. Details of the observations collected from calves and cows from a study observing the calving cows and their calves in calving paddocks before removal from the calving paddock

Animal	Data recorded	Description
Cow	Time at start of second stage of labor	Cow actively starts pushing. This was described to observers as the cow using her abdominal muscles, straining, arched back, raised tail, may have a wide base stance, or lying down.
	Time of first presentation of feet at the vulva	First observation of hooves.
	Start and finish time of dam licking	The tongue applied to any part of the calf. Once a break of at least 10 min occurred, the cow was considered to have stopped licking, and the stop time was recorded back when she first stopped licking.
	Time of birth and identification (ID) of calf	Time that the calf was completely out of the cow.
	Any unusual observations	E.g., mis-mothering, vocalization, farmer disruption.
Calf	Time of birth	All calves were labeled from the beginning as AA, then AB, AC, and onward.
	Time of first stand	Calf successfully stood for any length of time on all 4 feet.
	Start and finish time of first suckle off dam	Feeding was defined as an animal visibly suckling on a teat. As the first feed often involves coming on and off the teat, the stop time was defined when there was a 5-min period where the calf stopped attempting to feed, after which a subsequent feed was defined as a separate feed.
	Start time of subsequent suckles off dam or other cows (ID recorded)	Feeding was defined as an animal visibly suckling on a teat.
	Time collected from the paddock by farmer and taken to calf shed	Time that the calf was removed from the dam.
	Any unusual observations or observations that may affect feeding behavior	E.g., calf stealing by other cows, bullying, misadventure, factors inhibiting standing (e.g., mud), farmer walking through mob.

addition, a rain gauge was used on site, with a measurement taken every 24 h. The numbers of cows in the observation area were recorded daily, and data on cow breed and age were downloaded from the farm information management software. Observations ceased for a particular calf when it was removed from the calving paddock by the farmer and taken to calf housing.

Statistical Analysis

The data from this study were used as follows:

(1) To describe the distribution of cow and calf behaviors in the calving paddock, in particular the number and rate of calves suckling. These were described as the proportion of calves with the event.
(2) To assess the association between animal level risk factors (BCS, age, and length of stage 2 labor for the cow, and time from birth to standing for the calf) and the hazard rate ratio (**HR**) for the time to first suckling event in the calving paddock.
(3) To evaluate the association between farm-level risk factors (farm, temperature, pickup frequency, and area allocated) and the HR of suckling.

Descriptive Analysis. Median and interquartile ranges (**IQR**) for the length of stage 2 labor, time from birth to licking, length of first licking event, birth to standing, and standing to suckling were reported for each farm and overall. Descriptively, both the incidence risk of suckling in the calving paddock and the time from birth to first suckle in the calving paddock were reported as outcome variables. The incidence risk was defined as the number of animals that suckled at any stage, or that suckled within the first 6 h after birth in the calving paddock, and was reported by farm and overall. The proportion of animals that suckled was also reported if animals were left in the calving paddock for at least 6 h, along with the number of suckling events that a calf had while in the calving paddock, and whether they attempted to suckle from a cow that was not their dam. Finally, the median and IQR for the number of suckling events based on the length of time that calves remained in the calving paddock after birth ($\geq$6 h or $<$6 h) were reported.

Kaplan-Meier survival curves were produced for time from birth to suckling and time from birth to removal from the calving paddock by farm, along with the number of hours for 10%, 25%, 50%, 75%, and 90% of calves to suckle or be removed from the calving paddock, respectively. For the time from birth to first suckle outcome, calves were right-censored if they had not suckled by the time they were removed from the calving paddock. For each calf, the time from birth to first suckle when in the calving paddock, or the length of time they were in the calving paddock if they were removed before suckling, was rounded to the nearest hour, and the proportion of animals that suckled for

Figure 1. The scissor lift, with added roof and sides, that was the observation hut from which observers watched calving cows and calves. This scissor lift moved locations whenever the cows moved to a new calving paddock.

Figure 2. Observer with binoculars looking at cows and calves in the calving paddock. This observer would communicate observations to a recorder.

the first time for each subsequent hour they remained in the calving paddock was tabulated. These data were presented as the hourly instantaneous hazard of suckling, with locally weighted hazards and confidence intervals (CI). As the denominator changed for each hour (i.e., a calf that is removed from the calving paddock does not have the ability to subsequently suckle in the calving paddock), this accounts for varying time at risk for each calf. This enabled inferences to be formed on different rates of feeding depending on how long a calf remained in the calving paddock.

Risk Factor Analysis. The outcome variable of interest when assessing animal- and farm-level risk factors was the time to first suckle in the calving paddock. Because the time in the calving paddock varied greatly between calves, incidence risk over the entire study period would not have been appropriate, as it would not account for the time at risk. The farm-level risk factors included farm, pickup frequency, area allocated per cow, and minimum temperature around the time of birth. Area allocated per cow (m^2) at the time of birth was calculated by dividing the area of pasture (in the calving paddock) that the cattle had access to by the number of pregnant cows in the calving group on that day. (The latter is not the area of fresh ungrazed grass allocated but the total area available for the cows to walk around in.) The 30-min-interval temperature data were collapsed into 6-h periods throughout the day (i.e., 0000 to 0559 h, 0600 to 1159 h, 1200 to 1759 h, and 1800 to 2359 h). The minimum temperatures recorded over these periods were then matched to time of birth. Minimum temperature was further collapsed into $\leq$10°C and >10°C within 6 h of birth, to represent the lower bounds of the thermoregulatory zone of newborn calves, and this became the predictor of interest (Diesch et al., 2004). Cox proportional hazard models were carried out, with farm, pickup frequency, temperature, and area allocated per cow included in separate univariable models as the predictors of interest. Censoring was conducted as described earlier for Kaplan-Meier analysis in the Descriptive Analysis section. No model selection was carried out, as all analyses were already full models, with farm included as a frailty term for area allocated and temperature models. Results from the models were reported as HR with associated 95% CI. Outliers and influential observations were investigated. Proportional hazards assumption was assessed using a global statistic based on Schoenfeld residuals, and scaled Schoenfeld residuals plotted over time for each variable with a smoothing line and 95% CI to visually assess any deviation from proportional hazards.

Individual cow-level risk factors included age, breed, and BCS of the cow prior to calving, as well as duration of stage 2 labor and the time from birth to standing. The relationship between time from birth to first suckling event in the calving paddock and duration of stage 2 labor, and the time from birth to standing, were reported descriptively. The duration of stage 2 labor and the time from birth to standing were categorized into their respective quartile distributions. Median and IQR for time from birth to suckling were reported for each quartile and presented in Kaplan-Meier (for example, the median and IQR range of time from birth to suckling for 25% of calves that stood most rapidly after birth). The BCS and age of the dam were investigated with respect to time from birth to first feed in the calving paddock. Pre-calving BCS was collapsed into ≤4/10 and >4/10. For the association between age of dam and rate of suckling in their offspring, age of dam was collapsed into first- and second-calving animals (2–3 yr old), 4- to 7-yr-olds, and greater than 7-yr-olds. Age and BCS were analyzed in separate models, with farm included as a frailty term in both. Model assumptions and diagnostics were carried out as described previously.

All statistical analysis and data manipulation were carried out using R (version 4.1.0, R Foundation for Statistical Computing).

RESULTS

Across 8 farms over 2 yr, 697 calves had records for time of birth and time of removal from the calving paddock. Farm characteristics are described in Table 3.

Stage 2 Labor of Dam and Licking of Calf

The median duration of stage 2 labor was 1.0 h (IQR 0.6–1.6), with little differences noted between farms (Table 4). Cows initiated licking their calves almost immediately after birth, within 2 min of birth in 75% of cows, and within 6 min in 95% of cows.

Standing of Calf

Observations on time to stand after birth were incomplete for >50% of calves on farm 4, and thus all

Table 3. Characteristics of the New Zealand farms enrolled in the study investigating the calf and dam relationship from birth to removal from the calving paddock[1]

Item	Farm							
	1	2	3	4	5	6	7	8
Total cow numbers	480	890	245	335	723	530	430	700
Hectares	147	240	85	109	160	150	135	180
Annual milk solid production, kg	126,000	427,200	100,000	150,000	350,000	157,000	190,000	330,000
Start of calving	July 12	August 4	July 10	July 21	July 27	August 1	July 10	August 2
Year enrolled	2019	2020	2020	2019	2019	2020	2020	2019
Region	Waikato	Ashburton	Waikato	Waikato	Ashburton	Ashburton	Waikato	Ashburton
Predominant breed	Jersey	HF	Kiwi-Cross	Kiwi-Cross	HF	HF	Kiwi-Cross	Kiwi-Cross
BCS								
<4.5	25	13	0	0	31	3	0	5
4.5	42	50	7	10	53	31	0	31
5	10	30	19	43	43	28	30	48
5.5	0	9	10	14	11	9	18	12
>5.5	0	4	3	7	0	2	9	2
NA	6	4	0	11	7	1	4	2
Median cow age (IQR), yr	5 (3–6)	5 (4–7)	5 (4–8)	4 (3–5)	4 (3–5)	4 (3–6)	5 (4–7)	4 (3–5)
Calf numbers	83	110	39	85	145	74	61	100
Calf pickup frequency	TAD	OAD	OAD	OAD	3–4 AD	OAD	OAD	TAD

[1]HF = Holstein-Friesian; NA = not applicable; IQR = interquartile range; OAD = once a day; TAD = twice a day; 3–4 AD = 3–4 times a day.

observations on farm 4 (n = 85) for time from standing to suckling were removed from any further analysis for standing. Of those calves that had data on time to stand (517/612), 50% of them stood within 0.8 h (IQR 0.4–1.3) of birth, again with little difference observed between farms (Table 4). Calves stood a median of 1.0 h (IQR 0.4–1.8; range 0–12.6 h) before suckling. A total of 95 calves were recorded as never standing unassisted before being removed from the calving paddock (median time from birth to removal from calving paddock 2.6 h, IQR 0.75–5.5 h); 14 of these had a suckling event recorded.

Suckling

A total of 444/697 (63.7%; 95% CI 60.0–67.3%) calves suckled while in the calving paddock. Across the 8 farms, this proportion ranged from 40.0% to 90.2% (Table 5). In total, 407 (58.4%; 95% CI 54.6–62.1%) suckled within the first 6 h after birth, with a range across farms from 33.0% to 83.6%. In all, 449 calves remained in the calving paddock for at least 6 h after birth, and 340 of those suckled from their dam (75.7%; 95% CI 71.4–79.6%). Of those that suckled in the calving paddock, 378/444 (85.1%; 95% CI 81.4–88.2%) suckled more than once, with 140/444 (31.5%; 95% CI 27.3–36.1%) suckling 5 or more times. The median number of suckling events for calves that were in the paddock for at least 6 h after birth was 2 (IQR 1–5), compared with a median of 0 (IQR 0–2) for those calves that remained in the calving paddock for less than 6 h. A total of 103 (14.8%; 95% CI 12.3–17.6%) calves suckled from a cow that was not their dam.

The hourly hazard of a first suckling event varied depending on how long the calf had been in the calving paddock after birth (Figure 3). The probability of suckling for the first time within the first hour was 0.13, rising to 0.29 between 1 and 2 h after birth. This then decreased rapidly to approximately 9 h after birth, where the probability of suckling for the first time in the calving paddock was 0.06. However, the probability of suckling remained relatively stable from this point up until approximately 14 h after birth. Therefore, if 100 7-h-old calves in the calving paddock had not suckled, we would expect 40 of those 100 calves to have suckled by the time they were 14 h old if left with their dam.

For those calves that were removed from the calving paddock within 6 h of birth (n = 80), the median number of suckling events was 2 (IQR 1–3). From 7 to 18 h in the calving paddock (n = 202), the median number of suckling events was 2 (IQR 1–4). However, if calves remained in the calving paddock between 18 and 24 h (n = 96), the median number of suckling events was 4 (IQR 3–6).

Table 4. Time taken (in hours) for 50% (and 25–75%) of cows or calves to demonstrate behavior on each farm, and overall in a study investigating the calf and dam relationship from birth to removal from the calving paddock[1]

Item	Farm									
	1	2	3	4	5	6	7	8	Total	NA
Length of birthing	1.2 (0.9–1.7)	1.3 (0.6–2.1)	1.1 (0.4–1.6)	1.3 (0.8–1.8)	0.8 (0.6–1.2)	1 (0.6–1.7)	1.1 (0.9–1.5)	0.8 (0.6–1.2)	1.0 (0.6 –1.6)	96
Time to first lick	0 (0–0)	0 (0–0.03)	0 (0–0.02)	0 (0–0)	0 (0–0.02)	0 (0–0.02)	0 (0–0.05)	0 (0–0.02)	0 (0–0.02)	13
Length of first lick	0.6 (0.4–0.8)	0.4 (0.3–0.7)	0.5 (0.3–0.7)	0.5 (0.3–0.6)	0.5 (0.3–0.8)	0.5 (0.3–0.8)	0.4 (0.3–0.8)	0.5 (0.3–0.7)	0.5 (0.3–0.7)	144
Time to stand	1 (0.7–1.5)	0.8 (0.5–1.4)	0.7 (0.4–1.1)	0.8 (0.5–1.5)	0.7 (0.3–1.1)	0.7 (0.4–1.4)	0.8 (0.3–1.3)	0.7 (0.4–1)	0.8 (0.4–1.3)	95
Time to stand to suckle	0.6 (0.2–2.3)	1.1 (0.5–2.5)	0.6 (0.3–1.6)	NA	0.8 (0.4–1.4)	1.2 (0.4–1.8)	0.9 (0.6–1.5)	1.3 (0.6–2.2)	1.0 (0.4–1.8)	96

[1]NA = not applicable. Data on time to stand in farm 4 incomplete.

Table 5. Numbers and percentages of calves that suckled in the calving paddock at any stage, and that suckled in the paddock within 6 h of being born for each of the 8 farms and in total, in a study investigating the calf and dam relationship from birth to removal from the calving paddock

	Farm								
Item	1	2	3	4	5	6	7	8	Total
Suckled in paddock									
No	42	41	7	11	66	20	6	60	253
Yes	41	69	32	74	79	54	55	40	444
% suckled	49.4	62.7	82.1	87.1	54.5	73.0	90.2	40.0	63.7
Suckled within 6 h									
No	49	49	8	19	68	20	10	67	290
Yes	34	61	31	66	77	54	51	33	407
% suckled	41.0	55.5	79.5	77.6	53.1	73.0	83.6	33.0	58.4

Removal of Calves from the Calving Paddock

Farm practice was once-a-day calf removal for 5 farms (farms 2, 3, 4, 6, and 7), twice a day on farms 1 and 8, and up to 4 times a day on farm 5. Across the entire study, the median time between birth and calf removal was 8.7 h (IQR 4.0–15.5). At the farm level, the median time between birth and removal of a calf from the calving paddock ranged from 3.8 to 15.3 h (Figure 4a and Table 6). On farm 5, 90% of calves were removed within 8.2 h of birth; the equivalent figure was 22.2 h on farm 6.

Individual Calf Risk Factors and Time to Suckling

The median time (and IQR) from birth to suckling for those calves that stood within <0.41 h of birth was 1.6 h (0.8–3.4); for calves that stood between 0.41 and 0.78 h, 1.7 h (1.1–4.0); and for calves that stood between 0.79 and 1.33 h after birth, 2.4 h (1.6–8.7). The median time from birth to suckling for calves that took >1.33 h to stand after birth was 6.6 h (lower quartile 3.2 h), with less than 75% of these suckling in the calving paddock (Figure 5a).

The median and IQR for the time from birth to first observed suckling event did not vary greatly for the different quartiles of duration of stage 2 labor (Figure 5b). Calves from cows with stage 2 labor of less than 0.6 h had a median time from birth to first feed of 2.1 h (IQR 1.1–9.2), compared with calves born from cows with stage 2 labor of >1.5 h, with median time from birth to first feed 3.1 h (IQR 1.7–10.5).

Descriptive statistics for BCS, age, and breed for each of the 8 farms are presented in Table 3. Unconditional survival analysis between BCS and hazard of suckling identified that calves born from cows with a pre-calving BCS ≤4/10 had HR of time to first suckle in the calving paddock of 0.74 (95% CI 0.54–1.02). After accounting for farm as a frailty term, calves born from cows with a pre-calving BCS ≤4/10 were associated with HR of time from birth to first suckle in the calving paddock of 0.86 (95% CI 0.61–1.21). Age of dam was associated with the hazard of time to first suckle in the calving paddock by a calf. Compared with calves born from dams >7 yr of age, unconditional survival analysis revealed that calves born from dams 2 to 3 yr of age had a 1.43 (95% CI 1.05–1.97) times hazard, and calves born from dams 4 to 7 yr of age had a 1.18 (95% CI 0.89–1.58) times hazard for first suckle in the calving paddock. After accounting for farm as a frailty term, compared with calves that were born from dams >7 yr of age, calves born to dams 2 to 3 yr of age had a 1.49 (95% CI 1.07–2.06) times hazard, and calves born from dams 4–7 yr of age had a 1.19 (95% CI 0.89–1.60) times hazard for time from birth to first suckle in the calving paddock. Proportional hazard assumptions were not violated for either age or BCS models.

Farm Risk Factors Associated With Suckling

Kaplan-Meier survival curves of time to first suckling in the calving paddock are presented in Figure 4b. A large difference between farms was noted in time to suckling for the calves, with 50% of calves on farm 4 suckling within 1.7 h, whereas it took 8.3 h for 50% of calves on farm 8 to suckle (Table 7). The Cox proportional hazard model confirmed differences between farms in the hazard of suckling for the first time ($P <$ 0.001; Table 7). Compared with the farm whose calves had the slowest suckling rate (farm 8), the other 7 farms exhibited a range of 1.3 to 3.0 times HR for time to suckling, with 5 of the 7 farms having population HR with the lower bound of the 95% CI greater than 1. Farm 7 had 3.0 (95% CI 2.0–4.6) times and farm 4 had 2.8 (95% CI 1.9–4.2) times the HR of suckling compared with farm 8. Despite the differences in the rate of suckling, no deviation from the proportional hazard assumption was detected.

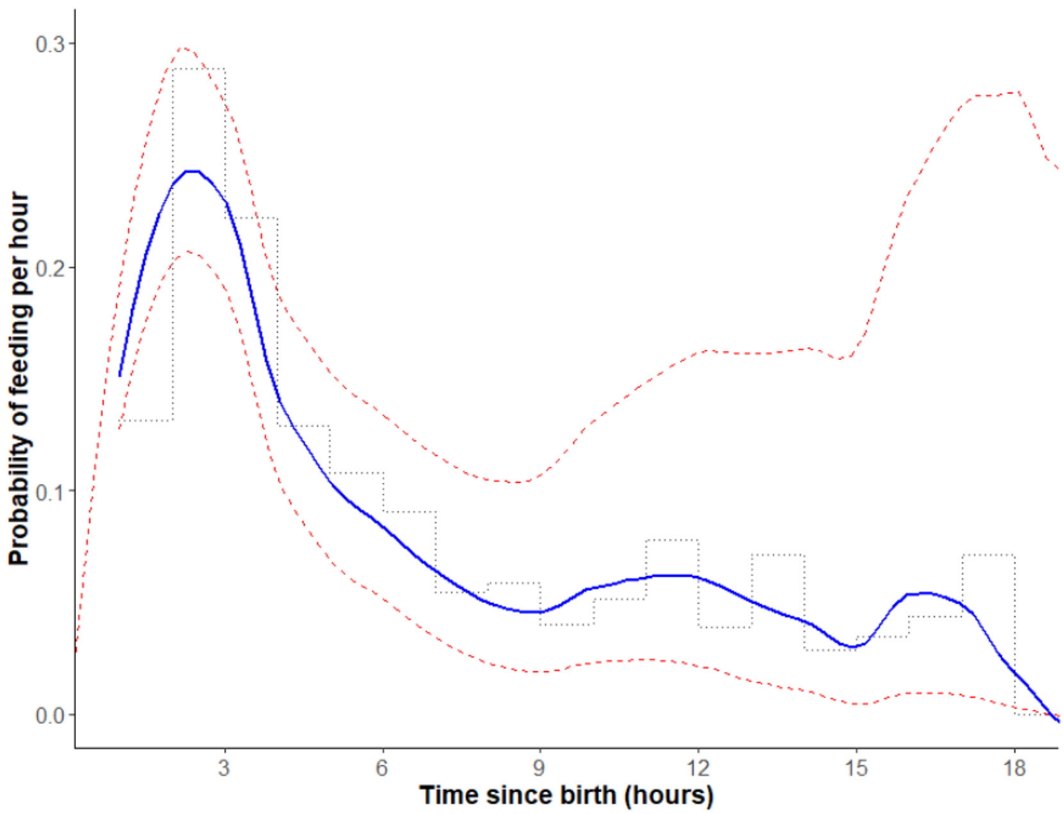

Figure 3. Instantaneous hazard for probability of a calf suckling for the first time in the calving paddock for each hour that they have remained in the calving paddock since birth. The dotted gray line is the raw hourly hazard of suckling, the blue line a locally weighted smoothed regression line of the hourly hazard, and the dotted red lines represent 95% confidence limits of the locally weighted regression line. Data are from 697 calves from 8 New Zealand farms involved in a study investigating the calf and dam relationship from birth to removal from the calving paddock.

Frequency of calf pickup was also associated with the HR of suckling. Calves born on farms where they were removed from the calving paddock once a day were associated with 1.52 times (95% CI 1.25–1.84) HR of suckling in the calving paddock compared with calves born on farms that removed calves more often than once a day (also highlighted as farms with dashed lines in Figure 4b).

The median area allocated per cow was 40.5 m^2, with a range of 9.2 m^2 to 347.4 m^2 (IQR 23.2–119.3 m^2). The range of the median allocated area between farms was large (20.6–208.0 m^2). No trends or associations were found between area per cow and hazard of suckling, either between farms or within farms. After accounting for differences between farms, the hazards of suckling in the calving paddock decreased by 0.01 (95% CI −0.03 to 0.02) for every 10 m^2 of additional area allocated per cow.

We observed an association between minimum temperature around the time of birth and the hazards of suckling from the dam. After accounting for farm as a frailty term in a Cox proportional hazard analysis, a minimum temperature of <10°C within 6 h of a calf being born was associated with a 0.69 (95% CI 0.53–0.89) hazard of suckling in the calving paddock.

DISCUSSION

This is the largest study to date investigating the suckling behavior of calves left to suckle their dams for up to 24 h, and one of very few looking at this relationship while animals are at pasture. Overall, across all farms, a total of 63.7% (444/697; 95% CI 60.0–67.3%) of calves suckled before removal from in the calving paddock, with 58.4% (407/697; 95% CI 54.6–62.1%) of calves suckling within 6 h after birth. This is consistent with the range reported in other studies around the world (Table 1) in cows and heifers calving in housed conditions. As far as the authors are aware, the only peer-reviewed study of suckling behavior in calves at pasture is that by Wesselink et al. (1999). Their equivalent figures (for calves left with the dam for at least 6

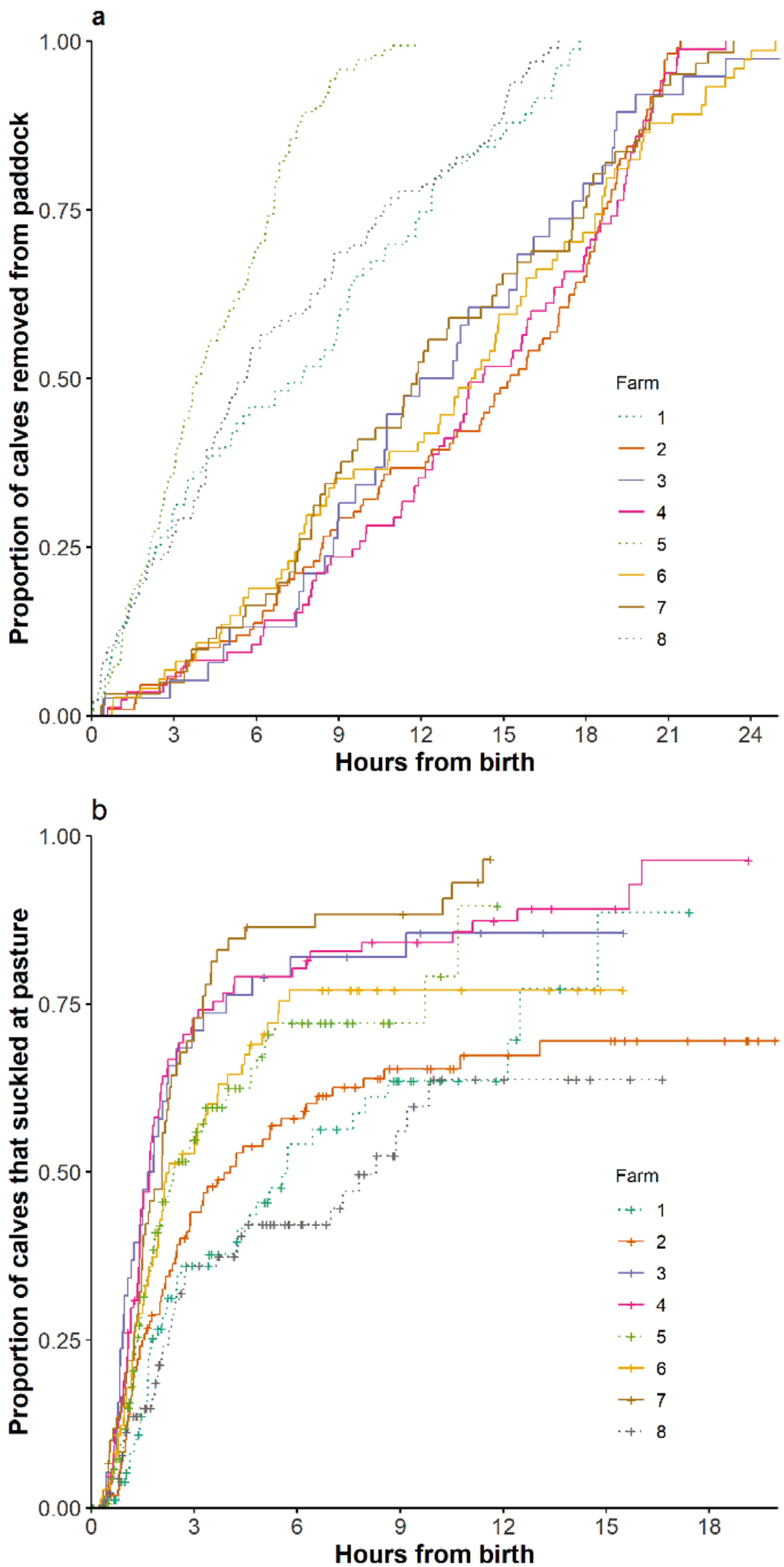

Figure 4. Kaplan-Meier time to event survival curves for the hours from birth of a calf to (a) removal from the calving paddock and (b) first suckling event in the calving paddock for each of the 8 New Zealand farms involved in a study investigating the calf and dam relationship from birth to removal from pasture. Dotted lines represent farms that removed calves from pasture more than once a day. Solid lines represent farms that removed calves from pasture once a day. Plus marks in the curves represent censored calves that were removed from pasture before suckling.

Table 6. Time taken (in hours) for 10%, 25%, 50%, 75%, and 90% of calves to be removed by the farmer from the calving paddock in each of the 8 New Zealand farms involved in a study investigating the calf and dam relationship from birth to removal from the calving paddock

Farm	10%	25%	50%	75%	90%
1	0.88	2.35	7.68	12.38	16.02
2	3.80	8.40	15.25	18.63	20.33
3	4.80	8.80	12.56	17.52	19.80
4	5.83	9.77	14.25	19.13	20.43
5	1.10	2.15	3.83	6.63	8.17
6	3.82	7.55	13.89	18.58	22.20
7	4.27	7.58	11.83	17.92	20.38
8	0.57	2.85	5.65	10.68	15.03

h) were 55% within 6 h and 70% within 24 h (although 2 calves were removed from the dam between 6 and 12 h after birth without having suckled).

In 1971 the Code of Recommendations for the Welfare of Livestock (Ministry of Agriculture, Fisheries and Food, 1971) stated that it is vital that every calf receives colostrum as soon as possible after it is born and certainly within the first 6 h of life. From this point onward, the published literature has focused on reporting suckling within the first 6 h of life, and very little detail is reported beyond this point. One of the challenges of studies investigating and reporting when calves suckled is that the denominator changes over time, as the number of calves that have not suckled and not been removed from the calving paddock is constantly changing. Therefore, a simple prevalence of animals suckling, keeping the denominator constant as reported in articles such as those of Wesselink et al. (1999), Edwards and Broom (1979), or Edwards (1982), does not actually give us information about calves' suckling behavior over time and will bias the total prevalence of suckling beyond 6 h toward 0. One way to overcome this issue is to use the instantaneous hazard of suckling, where, every hour, the denominator of calves changes to represent only calves that have not suckled and have not been removed from the calving paddock at the start of that hour. Therefore, the instantaneous hazard in this study identifies the most likely times that calves will suckle for the first time in the calving paddock. The majority of first suckling events occurred between hours 1 and 3 following birth. Afterward, the hazard of suckling decreased every hour until approximately 9 h after birth. Critically, though, even at a lower incidence, calves still continued to suckle for the first time in the calving paddock well beyond 6 h. Further research is required to identify whether this late suckling is of value to the calf, particularly in relation to the transfer of passive immunity, and care must be taken not to assume that successful suckling is synonymous with successful transfer of passive immunity.

The hazard of suckling varied between farms, and, as the proportional hazard assumption was not violated over the ~20 h following birth that were investigated, our data suggest that the difference in the hazard of suckling between farms is consistent over time. Thus, our analysis showed that calves born on farm 7 had a hazard of suckling 3 times that of calves on farm 8, and that this association was the same at, for example, 1 h after birth and 10 h after birth, despite the large change in the base hazard of suckling over those times. Thus, farm-level risk factors seem to affect calves over the whole period in the calving paddock, suggesting that management strategies to increase suckling soon after birth will increase suckling over the whole period during which calves are kept with their dams in the calving paddock.

Nevertheless, on farms with poor suckling rates, numerically greater numbers of calves will suckle from their dam at later times if they are left in the calving paddock. This is one of the dangers of blanket statements or recommendations on calf suckling, such as implying that calves do not feed after 6 h. The latter claim is not true, as in our study, approximately 40% of 7-h-old calves that had not suckled would have suckled for the first time from 7 to 14 h following birth. On farms with the slowest rates of suckling, removing calves from the calving paddock as rapidly as possible would result in a lower proportion of calves arriving at the calf house having suckled, which may negatively affect calf welfare unless it is also accompanied by an improvement in farmer-managed colostrum feeding (Denholm et al., 2017).

The process of a calf being born, until the point of suckling from its dam, requires a combination of dam, calf, and environmental factors to allow it to happen. The dam needs to have the energy following calving, combined with maternal instinct to be willing to allow the calf to make advances to suckle, and, even better, to make postural changes or direct the calf to the udder (Selman et al., 1970a). The conformation of the udder (influenced by age and genetics) itself has role to play as well. Selman et al. (1970a) reported that when the udder and teats were situated at the highest part of the underbelly, pushing from the calf to seek a teat was mainly, sometimes almost exclusively, concentrated on the udder area. In dams where the abdomen and udder were large, and hence the highest part of the underbelly was the xiphoid-axillary region, teat-seeking was frequently carried out around the forelegs. Edwards (1982) reported that calves from cows with pendulous udders spent more time teat-seeking on incorrect parts of the body of their dam before suckling, and spent more time nuzzling at the udder without successfully locating and suckling a teat. The calf's abilities to stand and walk, and the teat-seeking drive to search for the teats, play a role as well, and can be affected by en-

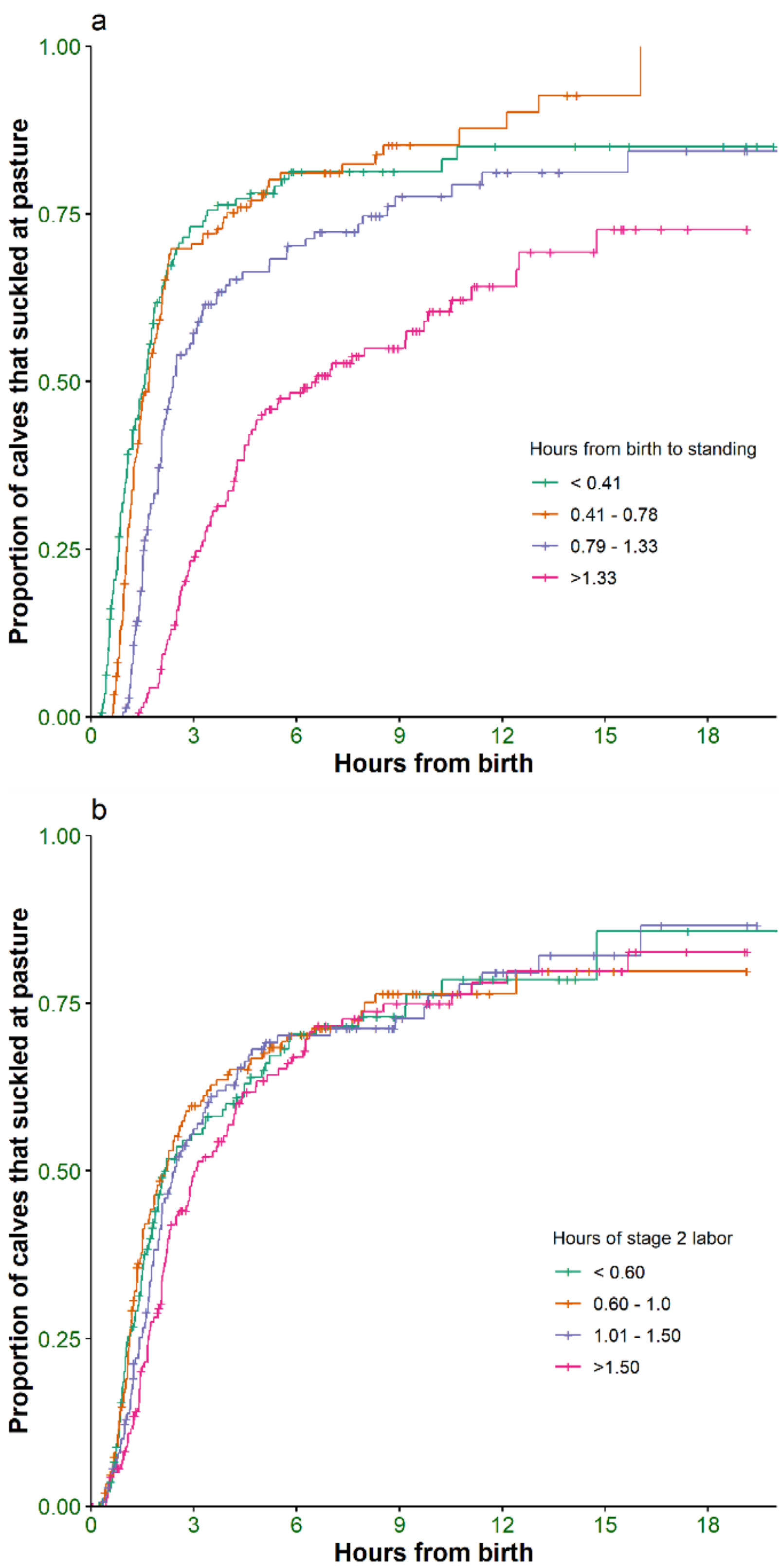

Figure 5. Kaplan-Meier time to event survival curves for the hours from birth of a calf to first suckling event in the calving paddock for (a) hours from birth to standing, categorized into quantiles, and (b) hours of stage 2 labor, categorized into quantiles. Data are from calves from 8 New Zealand farms involved in a study investigating the calf and dam relationship from birth to removal from pasture. Plus marks in the curves represent censored calves that were removed from pasture before suckling.

Table 7. Time taken (in hours) for 10%, 25%, 50%, 75%, and 90% for the first suckling event after birth in each of the 8 New Zealand farms in a study investigating the calf and dam relationship from birth to removal from the calving paddock with the calf daily pickup frequency; hazard ratios (and 95% CI) from a Cox proportional hazard model for the hazard rate ratio (HR) of feeding relative to farm 8 are also presented[1]

Farm	Pickup	10%	25%	50%	75%	90%	HR (95% CI)
1	TAD	1.32	1.75	5.72	12.48	NA	1.22 (0.79–1.88)
2	OAD	1.00	1.55	4.05	NA	NA	1.34 (0.9–1.97)
3	OAD	0.73	0.92	1.73	3.93	NA	2.76 (1.73–4.4)
4	OAD	0.68	1.08	1.70	3.55	15.67	2.83 (1.92–4.16)
5	TAD	0.93	1.33	2.40	9.72	NA	1.93 (1.32–2.82)
6	OAD	0.78	1.25	2.27	5.47	NA	1.98 (1.32–2.98)
7	OAD	0.55	1.25	2.07	3.25	10.23	3.04 (2.02–4.58)
8	TAD	0.97	2.25	8.30	NA	NA	Reference

[1]OAD = once a day; TAD = twice a day or more. NA = not applicable.

vironmental factors such as slippery ground (Selman et al., 1970b) or low temperature (Wesselink et al., 1999). Given the complexity of the calf and dam relationship, and the number of factors that can influence successful suckling, several individual and farm-level factors were investigated in our study to understand what may have influenced suckling in the study animals. Individual risk factors associated with time to first observed suckling event were time to standing and age of the dam.

The variation in time to standing and the effect this has on suckling has been implied by previous studies but not actually directly analyzed before. Selman et al. (1970b) reported a significant difference between the time to stand of their 10 observed beef calves (35.4 min) and 10 observed dairy calves (58.1 min). They later reported differences in time to suckling between beef cows (1.4 h), dairy heifers (3.6 h), and dairy cows (4.4 h), but this may well have been contributed to by many factors other than just standing. Ventorp and Michanek (1991) reported a high correlation between standing and teat-seeking of 0.89 but did not analyze the relationship between standing and suckling. Although our study found a relationship between first standing and suckling, this relationship was certainly not linear. In fact, the relationship only existed in the 25% of calves that took 1.3 h or more to stand. We are unsure of the potential causes of this relationship, but taking >1.3 h to stand maybe a proxy indicator of low calf vigor and activity, which affects teat-seeking drive (Vasseur et al., 2009). Teat-seeking drive and vigor have been shown in numerous studies to affect survival of lambs (Nowak and Poindron, 2006; Dwyer and Bünger, 2012). Cloete (1993) found that lambs that died before weaning had been slower to stand and tended to be slower at progressing from standing to suckling than lambs that survived until weaning. Further research is required to identify whether the delay in time to first suckling influences other outcomes such as risk of FPT.

The association we found between suckling behavior and dam age has been reported before. Edwards and Broom (1979) reported a higher suckling percentage from calves born to heifers than cows. However, in our study, the relationship was more specific to older cows (>7 yr), rather than just animals >2 yr of age. It is hard to know what factors are contributing to this association, but this has been indicated before in New Zealand. Cuttance et al. (2017) reported that for every 1-yr increase in age of the dam, the concentration of total protein in calf serum (measured between 1 and 8 d of age) decreased by 0.47 g/L. As calf serum total protein concentration is strongly associated with colostrum intake, this association may have been mediated by reduced hazard of suckling in the calving paddock. One likely contributor to the effect of age on suckling behavior is udder conformation, which changes as cows age. Selman et al. (1970b), Edwards and Broom (1979), Edwards (1982), and Ventorp and Michanek (1992) all suggested that udder and teat size, conformation, and distance from the ground affected calves' ability to suckle. These findings have 2 practical implications for farmers. The first is that heifers can, in fact, feed their calves and may not be as much of a concern as we have previously thought. The second is that the calves born to older dams may need to be monitored more closely, in particular if a dam has an obviously large or poorly formed udder.

Once-a-day removal of calves from the calving paddock was associated with an increased hazard of calves suckling compared with more frequent calf removals. This was not simply because animals were left with the dam for longer, as the survival analysis accounts for the removal of calves before suckling. It is unclear why this association occurred. Several possible hypotheses will need further investigation. Anecdotally, the farms that carried out once-a-day pickup (n = 5) were mostly traditional family farms, having raised animals, with once-a-day calf pickup, for decades. This raises possible theories of genetic selection, where calves that survive are born to dams with better mothering ability and udder conformation, and calves themselves have greater vigor and teat-seeking drive. It is also plausible that traditional family farms may cull more readily on such traits such as udder conformation than farms that are more intensive and more production-focused. Another possibility is that less frequent pickups result in less interruption to the suckling process. Although dairy cattle in New Zealand are accustomed to humans, the presence of a farmer on a motorbike throughout the day may still disrupt the mothering and teat-seeking processes. These hypotheses cannot be tested in a study with only 8 farms (especially where farms were selected on a convenience basis). Further research is required to confirm the relationship between frequency of pickup and hazard of suckling on other farms, and, if present, the underlying reason for the association.

The only environmental factor found to have an association with suckling was minimum temperature around the time of birth; a minimum temperature of <10°C within 6 h of a calf being born was associated with a 0.69 (95% CI 0.53–0.89) hazard of suckling while in the calving paddock. This is consistent with the results from Diesch et al. (2004), who reported data from 167 Friesian and 50 Angus-cross single calves born in New Zealand. They reported that Friesian calves born into air temperatures below 10°C had a significantly lower rectal temperature, took longer to stand, and had higher plasma glucose concentrations than calves born into air temperatures above 10°C. They also reported that calves that were born in still dry or windy dry conditions stood significantly earlier than those born in windy wet conditions. It should be noted that only ambient temperature was analyzed in this study, and the perceived temperature, accounting for wind chill and rain, was not assessed. It is common practice for farmers to pick up calves and take them to the rearing sheds more frequently in inclement weather (Cuttance et al., 2018a), which is an action certainly supported by the data from this study.

One risk factor that did not affect suckling behavior was the space allowed for cows and calves in the calving paddock. Anecdotally, the teams carrying out the study commented that increased space reduced the apparent rate of mis-mothering and increased the ability of cows to move away from the main group to feed their calves. However, this was not supported by the analysis of the data collected, which found no association of area with time to first observed suckling event, between or within farm. However, this lack of association may be due to the small sample size and fundamental issues with measuring this variable. The range of space allocated per cow was large (ranging between 9.2 and 347.4 m^2). This is likely to reflect how farmers managed the calving paddock. Calving paddocks are generally split up into small sections so that calving cows can eat high-quality pasture. Once they have been moved to the next grazing section (usually at least daily), some farmers will back fence this new section so the cows cannot regraze the previous grazing area. However, some farmers will not back fence, principally because back fencing may limit access to water troughs. Therefore, in some circumstances, very large areas were recorded because a large area was accessible to the cows. However, previous grazing areas may not have been used by the cows because they were muddy and pasture availability was limited. Therefore the area per cow measured in this study may not necessarily represent the utilized area per cow. In addition, the use of the simple area-per-cow figure does not reflect other factors such as topography and areas of shelter, which may also influence cow behavior and time to suckling.

Despite the overall number of calves that suckled being consistent with previous research (see Table 1), undoubtedly the most significant practical finding from this study was the variability in suckling rates between the farms. Although these farms may not necessarily be representative of all New Zealand dairy farms, nonetheless, across the 8 farms this proportion ranged from 40.0% to 90.2%, and the range in which 50% of calves suckled was between 1.7 and 8.3 h. This finding of differing feeding rates between farms has 2 very important implications. First, advice from the industry needs to be tailored to each individual farm about whether animals should be collected more than once a day, rather than applying a blanket approach to advice. This individualized advice needs to be in combination with what is achievable with colostrum management and the prevalence of FPT of calves across the calving period. Suckling from the dam is not necessarily synonymous with adequate passive transfer, but, in combination with FPT prevalence on the farm, provides excellent information on the success of farm practices. Second, this finding implies the existence of currently unknown farm-level variables that influence how calves feed in the paddock. If pressure from consumers leads the dairy industry worldwide on a pathway to leave calves to suckle from the dam, more research must be undertaken to understand the reasons for such pronounced farm variability and how we may influence it.

One of the major limitations of a large observational study run on commercial dairy farms is that of data errors. For instance, 14 calves had a suckling event recorded without a standing event. Although it may be possible for a calf to suckle without standing, this is unlikely and more probably represents measurement error. However, although there will undoubtedly be some bias in this data set, due to large number of calves observed and complexity of observational recordings, we believe that the impact of this bias will not be large, for 3 reasons. First, the effects sizes reported for the differences between farm are large. Second, many of the findings are consistent with previously reported smaller-scale studies, and, apart from the aforementioned 14 calves, the timeline of events all followed a biologically plausible order. And third, the external validity of the study remained high. Although the 8 farms selected are not necessarily representative of all New Zealand dairy farms, they were conducted in 2 different regions, across 2 different years, and with varying calf management policies. We therefore feel it is appropriate to extend many of the findings to the greater New Zealand dairy industry, at least with relevance to other pastoral industries.

CONCLUSIONS

A total of 63.7% (95% CI 60.0–67.3%) of calves suckled in the paddock. Individual risk factors associated with suckling were age of the dam and time to standing, with calves born to >7-yr-old dams and calves in the highest quartile of time to standing having a reduced hazard of suckling. Farm-level risk factors associated with suckling included the frequency with which calves were removed from the calving paddock, with calves on farms that removed calves once daily feeding earlier than calves on farms that collected more frequently. Temperatures <10°C were associated with a lower hazard of suckling. We found very large farm variability that urgently requires further investigation if pasture-based farms are ever to adopt a system where calves remain with their dams for longer than 24 h.

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