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Lying behaviour of lactating dairy cows in a cow-calf contact freestall system

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ABSTRACT

Conventional dairy farming practices usually involve early separation of calves from their dams. Cow-calf contact (CCC) systems may offer an alternative rearing solution that allows for the expression of natural behaviours, such as suckling and bonding. However, literature exploring the effects of CCC systems on lying behaviours of lactating cows is limited. Thus, the aims of this study were to assess: (1) the lying behaviours of lactating dairy cows with and without access to a CCC area, and (2) freestall use and lying patterns of cows and calves with access to a CCC area over a 14-week suckling period. Cow-calf pairs (Swedish Holstein: n = 15; Swedish Red: n = 25) were assigned one of two treatments after calving: dam-calf contact rearing (full contact; FC, n = 19), where calves were housed in a CCC area in the same facility as their dams, or separation shortly after parturition (no contact; NC, n = 18). The CCC area contained stalls and concentrate feeders which only FC cows had access to. Daily lying time – as well as the duration and frequency of lying bouts – was collected for cows automatically using leg-mounted tri-axial accelerometers. Video recordings were also collected and used to perform scan sampling of cow and calf lying location at 10-minute intervals for a 24-hour period each week. Behavioural data was collected during 14 weeks, starting when all cow-calf pairs had entered the experimental pen and continuing until separation. Access to full CCC did not affect daily lying time nor the frequency of lying bouts. Overall, mean daily lying time increased with stage of lactation. Lying bout duration and frequency were affected by an interaction between stage of lactation and parity, with the frequency of lying bouts decreasing as lactation progressed, but only for primiparous cows in post-peak lactation. Average bout duration increased with stage of lactation for primiparous cows, and from early to post-peak lactation for multiparous cows. Moreover, there was an interactive effect of treatment and parity on lying bout duration, with multiparous FC cows performing longer bouts than primiparous FC cows. FC cows spent 77.3(28.4)% (mean(SD)) of their total lying time within the CCC area across all weeks. These results combined indicate that lying behaviour in this CCC system was likely influenced by factors other than CCC. Furthermore, cows with access to CCC maintained their individual patterns of stall use throughout the suckling period investigated in this study.

1. Introduction

Conventional dairy farming often practices the separation of cow and calf immediately after birth, thereafter raising the calf either individually or with conspecifics. Reasons cited for early separation are often related to calf health and economics, as disease transmission and milk intake can be more easily controlled in artificial rearing settings (Flower and Weary, 2001). Furthermore, some producers have raised concerns regarding the emotional stress of separation for both cow and calf if permitted to form a strong bond (Ventura et al., 2013), as well as the potential challenges of updating infrastructure and management routines to allow for a system that permits dam rearing (Neave et al., 2022). However, there are both production and welfare benefits to keeping dams and calves together. Delayed separation – where cow-calf pairs remain together for a suckling period of a few days up to a few weeks or months – has been shown to consistently result in higher calf growth rates prior to weaning and lower instances of abnormal behaviour (i.e., cross-sucking, tongue-rolling) (Meagher et al., 2019). As a result, new

Abbreviations: CCC, cow-calf contact; FC, full contact; NC, no contact; SR, Swedish Red; SH, Swedish Holstein.

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housing systems have been developed that facilitate contact between dams and calves. These systems, known as dam-calf or cow-calf contact (CCC; Sirovnik et al., 2020) systems, provide increased opportunities for cows and calves to express natural behaviours, such as bonding and suckling (as reviewed by de Oliveira et al., 2020). Within these housing systems, cow-calf pairs are housed together with either free or restricted contact, allowing for the development of a maternal-filial bond and natural suckling behaviours (Johnsen et al., 2016).

Previous research on alternative calf rearing systems has been largely focussed on calf behaviours and production measures, including separation stress response (Fröberg et al., 2011), pre- and post-weaning growth rates, and cross-sucking or social behaviours (Roth et al., 2009). The effects of different CCC systems on cows have also been explored, but to a lesser extent and with an emphasis on production measures, such as milk yield (de Passillé et al., 2008) and udder health during the suckling period (Fröberg et al., 2008). Very little is known about lying behaviours in cows within a CCC system, such as the daily amount of time spent lying down. Lying time is particularly important to monitor, as acute changes in this behaviour may lead to adverse changes in behavioural and physiological functioning, as well as indicate potential injury or illness. Johnsen et al. (2021) recently evaluated the lying behaviours of cows in a CCC system, but their study was limited by the small sample size (8 cow-calf pairs in total) and lack of behavioural measures on control cows.

Lying behaviour is an important measure of cow health and comfort; when offered the opportunity, cows lie down for 12–13 h/d (Jensen et al., 2005). As such, animal management guidelines sometimes include 'healthy' minimum lying times, with the implication that a failure to meet these recommendations may result in reduced welfare. For example, the Canadian Code of Practice advises that cows achieve daily lying times of at least 12 h/d (National Farm Animal Care Council, 2009). As reviewed by Tucker et al. (2021), there may be several reasons for the variation in lying time – including parity, stage of lactation, reproductive state and management-related factors (i.e., stocking density) – and a shorter lying time does not necessarily indicate bad welfare.

There is currently a lack of information relating to lying patterns and behaviours in different CCC systems. It is possible that cows may be motivated to alter these behaviours when adapting to the added contact time with calves. Thus, the primary objective of this experiment was to determine if access to a CCC area affects the lying behaviours – including daily lying time, as well as the frequency and duration of lying bouts – of lactating dairy cows housed in a freestall system with automatic milking. Additionally, the study aimed to explore stall use by cows and calves across the 14-week suckling period.

2. Materials and methods

This study was conducted at the Swedish University of Agricultural Sciences' Swedish Livestock Research Centre in Uppsala, Sweden from September 2020 to January 2021 as part of a larger research project. All procedures outlined were approved by the regional ethics committee (ID-No: 5.8.18–18138/2019).

2.1. Animals and treatments

A total of 40 Swedish Red (SR; primiparous: n = 12, multiparous: n = 13) and Swedish Holstein (SH; primiparous: n = 9, multiparous: n = 6) cows were enrolled in this experiment, which was a field trial with a parallel group design. All cows in the herd that calved from September 1 to October 15, 2020 were eligible for inclusion, providing they had no history of lameness or *Staphylococcus aureus* mastitis. Upon calving, cow-calf pairs were assigned one of two treatments: dam-calf contact rearing (full contact; FC), where calves were housed in the same experimental pen as their dams, or separation shortly after parturition (no contact; NC). Within the FC group, CCC was cow-driven with a post-milking traffic flow; this meant that CCC was primarily determined by cows, but only after passing the milking robot. Moreover, CCC was full (i.e., whole-day CCC with no restrictions on suckling) and lasted for a total duration of 4 months, after which calves were permanently separated. Treatment groups were balanced semi-randomly for calf age and gender, such as that every other heifer calf or bull calf born was separated following parturition. Potential confounders dam breed (FC: SH = 7, SR = 12; NC: SH = 6, SR = 12) and (mean(SD)) parity (FC: 1.7(1.0); NC: 2.1 (1.3)) were also considered during treatment allocation. FC cows and calves spent 2.5(0.6) days together in individual calving boxes prior to entering the experimental pen.

The study period – 14 weeks in total – began once the 6-week enrollment period had ended and lasted until the first calves were removed from the experimental pen. On average, 27.9(11.2) kg and 28.4 (10.1) kg of saleable milk/d was harvested from FC and NC cows, respectively, during this period. Calves (range in age from youngest to oldest: 42 days) were on average 24(13) days old when the study period – and thus observations – began. Plastic nose flaps (QuietWean, JDA Livestock Innovations Ltd., Saskatoon, Canada) were applied to the oldest 10 calves during week 12 as part of a two-step weaning and separation process. On average, calves were 113(7) days old during weaning and separated at 127(7) days of age.

During the study, one FC calf was euthanized due to severe lameness, one FC cow died following treatment for *Escherichia coli* mastitis and a NC cow was removed after being diagnosed with *S. aureus* mastitis. The final number of cow-calf pairs available for statistical analysis was 37 (19 FC and 18 NC).

Post-study period, lactating cows were returned to the herd. Heifer calves remained in the system, while bull calves were euthanized at 5 months of age for another study.

2.2. Experimental facility and management

Cows of both treatment groups were housed in the same insulated freestall barn with automatic milking. The experimental pen was divided into four distinct areas: the feed alley, the milking area, the general lying area and the CCC area (Fig. 1). Cow traffic through the pen was managed with the use of an automatic selection gate (DeLaval smart selection gate SSG, DeLaval International AB, Tumba, Sweden), operating a Feed First™ system (DeLaval International AB, Tumba, Sweden). The only way for cows to exit the feed alley was to enter the automatic selection gate. Upon entering the selection gate, cows were sorted in one of three directions, depending on treatment and milking permission status. Cows that were due to be milked were directed into a waiting area, which led to an automatic milking robot (DeLaval VMS™ Classic, DeLaval International AB, Tumba, Sweden) and thereafter returned to the feed alley. Milking permission was granted 6 h following the previous milking session. FC cows were otherwise directed forwards to the CCC area, while NC cows were guided to the general lying area. There was an average 54(3) cows in the entire experimental pen across all weeks, resulting in an overall stocking density of 91.3(5.4)%.

The CCC area was accessible by both FC cows and FC calves and contained a total of 24 freestalls; two of these stalls were blocked off and intended for calf use. In this area, dams had full, unrestricted access to their calves, as well as controlled access to two concentrate feeding stations (DeLaval feed station FSC400, DeLaval International AB, Tumba, Sweden). Cows were offered a mix of commercial pelleted concentrate (Komplett Norm 180, Konkret Mega 28, Komplett Xtra 205; Lantmännen Lantbruk & Maskin, Malmö, Sweden) tailored to their individual expected daily milk yields. FC calves also had access to a separate calf creep: a 73.2 m^2 deep-bedded wood-shavings area that ran the entire length of the pen. Roughage and water were available ad libitum to calves within the creep, while concentrate was accessible via two concentrate feeding stations (DeLaval concentrate station calves, DeLaval International AB, Tumba, Sweden). Access to the creep was limited to calves by way of horizontally placed wooden boards. NC calves were housed in a separated area of the barn and were unable to

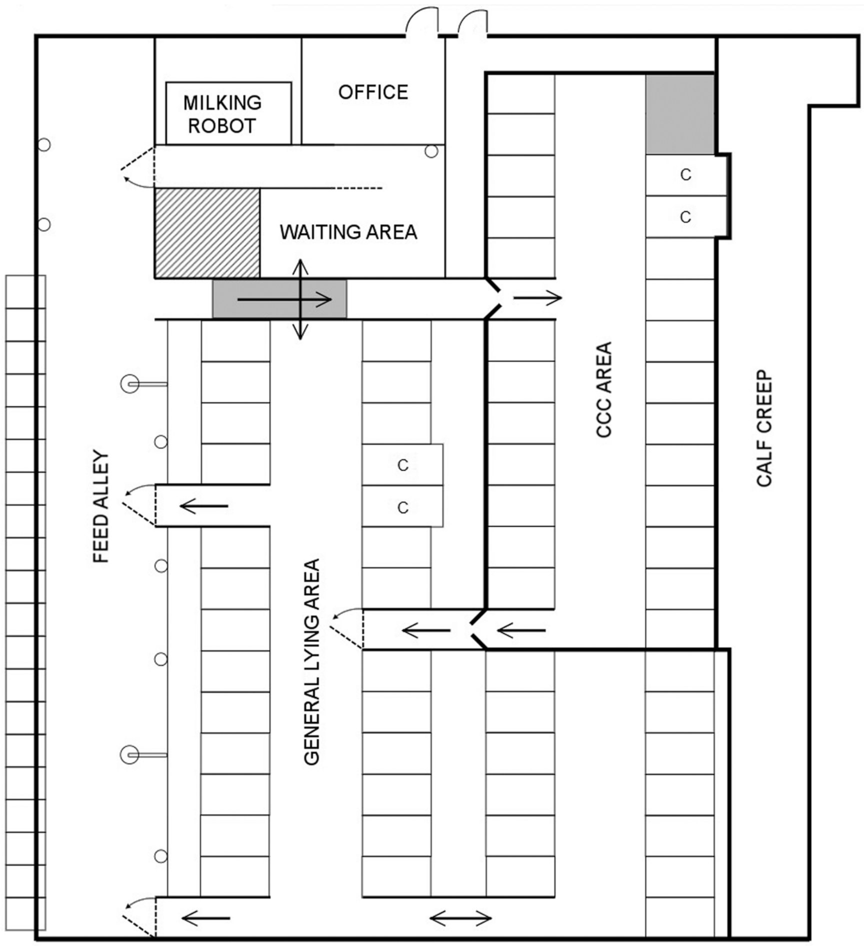

Fig. 1. Design of the experimental pen. Throughout the 14-week study period, the pen housed (mean (SD)) 54(3) cows and 19 calves. Cows were assigned to treatment groups upon calving: FC (n = 19), where cows and calves were housed together with access to full cow-calf contact (CCC), or NC (n = 18), where the cow and calf were separated following parturition. The CCC area was only accessible to FC cows and FC calves; all cows – including FC cows – could access the general lying area, feed alley, waiting area and milking robot. Only calves could enter and exit the calf creep. Arrows indicate the direction of traffic flow throughout the pen, while concentrate feeding stations are depicted with a ‘C′.

access contact (visual, auditory or olfactory) with cows in the experimental pen. FC cows were able to exit the CCC area through a pair of spring-loaded one-way gates (FeedSelect, GEA Farm Technologies GmbH, Bönen, Germany), which led directly to the general lying area.

The general lying area consisted of 37 stalls, distributed unevenly across four rows. Two of these rows of stalls lined a center alley that ran adjacent to the feed alley, while the remaining rows were situated in an alley alongside the calf creep (see Fig. 1). As such, cows could access visual, auditory, and olfactory contact with the FC calves from this area; physical contact was, however, largely restricted due to metal fence panels that were placed as a barrier. Cows in the general lying area also had access to concentrate via two concentrate feeding stations (DeLaval feed station FSC400, DeLaval International AB, Tumba, Sweden). From the lying area, cows could return to the feed alley through one of two different one-way gates.

In the feed alley, cows had free access to seven water bowls, 20 individual forage bins (CRFI, BioControl AS, Rakkestad, Norway) and two mechanical rotating brushes (DeLaval swinging cow brush SCB, DeLaval International AB, Tumba, Sweden). Fresh feed (grass-clover and corn silage, with up to 3% inclusion of wheat straw) was delivered to the bins 5 times per day via a rail-suspended distribution wagon (DeLaval FS1600, DeLaval International AB, Tumba, Sweden).

Flooring throughout the alleyways encompassing the lying areas was solid grooved concrete, while the feed alley was equipped with rubber mats. The waiting area leading to the milking robot was the only area containing rubber slatted flooring. Manure was removed using automatic scrapers, which ran through the feed alley once every 30 min, and through the primary alley encompassing the general lying area once per hour. In the CCC area, the scraper was initially run manually during day hours to minimize the risk of injury to young calves. During week 4 (calf age: 49(13) days), the scraper was set to start running automatically during the day while still being turned off at night. From week 6 (calf age: 61(13) days) onwards, manure scraping in the CCC area was conducted automatically during both day and night hours.

Stalls throughout both lying areas were 2.1 m in length from rear curb to brisket locator and 1.2 m wide, with neck rails placed at a height of 1.3 m. All stalls, with the exception of those in the CCC area, had open fronts. Additionally, stalls were bedded with rubber mattresses (M40R, DeLaval International AB, Tumba, Sweden) and a layer of sawdust of approximately 3 cm, which was topped up 4 times per day by use of a rail-suspended shavings dispenser (JH miniStrø COW, MAFA i Ängelholm AB, Ängelholm, Sweden). Each stall was scraped to remove soiled bedding several times per day, while the calf creep was cleaned and topped up as needed. Stalls in the CCC area received three additional distributions of sawdust throughout the day.

2.3. *Collection of data*

2.3.1. *Behavioural observations*

A total of eight fisheye cameras (Samsung SNF-8010VM, Samsung Techwin Co., Ltd., Seoul, South Korea) were used to continuously monitor the experimental areas throughout the duration of the study. All cameras were mounted to provide an overhead view (height from floor or stall base: 3.1(0.1) m), with four placed over both the calf creep and CCC area. Additionally, two cameras were positioned over the general lying areas, one overlooking the milking waiting area and selection gate passageway, while the final camera was placed above the feed alley. Video recordings were later viewed using the program BackupViewer (v2 1.4.6_M190708, Hanwha Techwin Co. Ltd., Seongnam-si, South Korea).

Each FC cow was marked with a unique symbol on her sides and back using blue (KRUUSE Marking Spray, Jørgen Kruuse A/S, Langeskov, Denmark) or yellow (RAIDEX Animal Marking Spray, RAIDEX GmbH, Dettingen an der Erms, Germany) animal-safe paint to facilitate identification of individuals on the video recordings. Markings were refreshed every 7(1) days. Scan sampling was performed by a single observer at 10-minute intervals for a 24-hour period on the same day each week using the video recordings, starting at 00:00 h and ending at 23:50 h. During each scan, the IDs of all cows lying down in stalls that were located within the CCC area were recorded. The number of stalls occupied by lying or standing (minimum two feet in stall) cows, as well as those occupied by resting calves, was also logged at each scan for the entire pen, including the general lying area. Cows in the process of lying down or getting up (i.e., not in a fully horizontal position) were considered to be standing for ease of observations.

To determine the intra-observer reliability, two half days (24 h of video data in total) were randomly selected and an identical procedure of scan sampling was performed, as described above.

2.3.2. Lying behaviours

To assess lying behaviour, all experimental cows were equipped with leg-mounted tri-axial accelerometers (IceQube, IceRobotics, Edinburgh, UK) which automatically recorded the time spent lying, as well as the frequency and length of individual lying bouts (first validated by McGowan et al., 2007; lying bouts validated by Kok et al., 2015) on a per-second basis. Once every week, data was manually downloaded from each cow using an IceReader (IceRobotics, Edinburgh, UK) and laptop containing the IceManager program (IceRobotics, Edinburgh, UK).

2.4. Data handling and statistical analysis

All data handling and statistical analyses were carried out using SAS OnDemand for Academics (v. 3.1.0, SAS Institute Inc., Cary, NC, USA). Within this study, significant differences were declared when $P < 0.05$, and results are presented as LSMeans ± SEM or mean(SD) if not stated otherwise.

2.4.1. Lying behaviours

Prior to analysis, IceQube data was manually transformed into.csv files using the IceManager software. Using the SUMMARY procedure in SAS, daily summaries per cow were obtained for lying time (h/d) and lying bout frequency (bouts/d), while daily mean per cow was calculated for lying bout duration (min/bout). Lying bout duration and frequency were totaled according to start date, resulting in the possibility of bouts that overlapped in days. To correct for potentially false lying bouts, all records of bout duration less than 33 s were removed following the recommendation of Kok et al. (2015). Each lying behaviour was then averaged weekly across a 3-day period, based on previous research that suggests this is the minimum observation time necessary to attain an accurate estimate (Ito et al., 2009). The days included in the 3-day period were chosen to avoid disturbances such as health checks, in regards to the study protocol of the larger project, and included the day of video scan sampling. The term 'observation' hereafter refers to the data entry containing the 3-day mean of each lying behaviour for an individual cow, of which there is one per week. Lactation weeks were calculated for cows using their calving dates; observations with a lactation week less than 1 were removed from the dataset. Furthermore, all observations during which a cow was in estrus were removed. Estrus was detected using DeLaval Herd Navigator™ (DeLaval International AB, Tumba, Sweden) and confirmed via determination of milk progesterone concentration. Means composed of fewer than three complete days of data were not included in the final dataset. Parity data was used to classify cows either as being primiparous (parity = 1) or multiparous (parity > 1). Observations were further grouped based on stage of lactation, resulting in observations that took place during early (lactation weeks 1–5), peak (weeks 6–8) and post-peak (weeks 9–19) lactation (Table 1). Finally, two FC cows and one NC cow were temporarily moved to a sick pen while undergoing treatment for mastitis and lameness, respectively; observations occurring during this time period were subsequently removed. Overall, five observations were lost due to malfunctioning IceQubes, 128 to estrus events, two to cows being in lactation week 0 and four as the result of sick cows. The final dataset contained a total of 379 observations (FC: 177; NC: 202), with an average 10.2(2.52) observations per cow. Each of the three lying behaviours was checked for normality using the UNIVARIATE procedure of SAS. Due to the nature of the experimental data, treatment was not blinded and authors were aware of treatment allocations during data collection and statistical analysis.

Each of the three lying behaviours (lying time, lying bout frequency and lying bout duration) were analyzed as continuous dependent variables using the MIXED procedure, with individual cow identity (the experimental unit across all procedures) included as a random effect using a RANDOM statement. A first-order autoregressive covariance structure was specified in the model. Breed (SH and SR), parity (primi- and multiparous), treatment (FC and NC) and stage of lactation (early, peak and post-peak) were included as fixed effects in each model, as well as two-way interactions, identified by performing backwards elimination using the exclusion criteria of $P > 0.1$. In addition to main effects, the final model for daily lying time included the interaction of breed and treatment, while those for lying bout duration and frequency both contained parity × treatment and parity × lactation stage interaction effects. Post-hoc comparisons of LSMeans were conducted using the Tukey-Kramer adjustment for multiple pairwise comparisons.

2.4.2. Lying time within CCC area

The 14 days of observational data collected via the video recordings was summarized to obtain the estimated daily lying duration within the CCC area for each FC cow. This data was then combined with the 1-day mean daily lying time corresponding to the observation dates, and thereafter used to calculate the average weekly proportion of time spent lying down within the CCC area. Estrus events were removed from the dataset. A MIXED procedure was used to test the fixed effects of breed, parity (primi- or multiparous) and lactation stage (early, peak and post-peak) on the proportion of time spent lying down in the CCC area. Two-way interaction effects were tested in the model using the backwards elimination method described above. Ultimately, the final model did not contain any interactions. Finally, cow identity was specified as a RANDOM effect with a first-order autoregressive covariance structure.

Table 1
The total number of cow-day observations included within each treatment and parity group (PP, primiparous; MP, multiparous) per stage of lactation – early (weeks 1–5), peak (weeks 6–8) and post-peak (weeks 9–19) – during the 14-week study period. The week following and including a calving event was referred to as lactation week 0. Cows were enrolled over a 6-week period, resulting in cows that were already entering the peak lactation stage during the first study week. Data is based on the final cleaned dataset.

	Treatment group[a]			
	FC (n = 19)		NC (n = 18)	
Stage of lactation	PP	MP	PP	MP
Early	19	12	20	15
Peak	21	13	20	20
Post-peak	61	51	59	68

[a] Cows were assigned one of two treatment groups upon calving and thereafter housed in the same experimental pen: FC = access to a cow-calf contact (CCC) area within the experimental pen, where they could access full contact with their calves; NC = separation following parturition.

2.4.3. Stall use

Observations of stall use by FC calves in the CCC area were used to calculate the mean number of stalls occupied by calves per hour and date. Additionally, hourly means were calculated for the number of stalls occupied by lying or standing cows in both the CCC area and general lying area. Hourly means were thereafter used to determine the mean across the entire study period.

2.4.4. Intra-observer reliability

All observational data, including stall use by all cows and calves, as well as the daily lying duration within the CCC area by FC cows, was tested for reliability using the FREQ procedure to calculate Cohen's kappa. The intra-observer reliability for observations of stalls shared by lying cows and calves ($k = 0.63$) and calf stall use in general ($k = 0.75$) was 'good', while the remaining behavioural observations could be considered to have 'excellent' reliability ($k > 0.90$; Kaufman and Rosenthal, 2009).

3. Results

3.1. Lying behaviour

3.1.1. Daily lying time

Overall, cows spent an average 11.5(1.9) h/d lying down across the entire experiment, and daily lying time increased significantly with stage of lactation, from 10.3 ± 0.31 h in early lactation, to 11.4 ± 0.31 h in peak and 12.0 ± 0.28 h in post-peak lactation ($P < 0.01$; $F_{2,340} = 50.95$). Neither parity ($P = 0.59$; $F_{1,340} = 0.29$), treatment ($P = 0.83$; $F_{1,340} = 0.04$), nor breed ($P = 0.28$; $F_{1,340} = 1.19$), nor the interaction of breed and treatment ($P = 0.076$; $F_{1,340} = 3.18$), had an effect on daily lying time.

3.1.2. Duration of lying bouts

There was an interactive effect of treatment and parity on lying bout duration ($P < 0.01$; $F_{1,338} = 7.54$). Post hoc pairwise comparison showed that multiparous cows in the FC treatment had longer lying bouts (65 ± 4.3 min) compared to primiparous cows in the FC treatment (42 ± 3.7 min; $P < 0.001$; Fig. 2). No other post hoc comparison of means for treatment × parity differed significantly.

In addition, the interaction of parity and stage of lactation affected the duration of lying bouts ($P = 0.01$; $F_{2,338} = 4.35$; Fig. 3). Between parities, multiparous cows in early lactation had longer lying bouts than primiparous cows in early lactation ($P < 0.05$), and they also had longer bouts in peak lactation compared to primiparous cows in both early and peak lactation ($P < 0.05$). Moreover, lying bout duration of multiparous cows in post-peak lactation was greater than the duration of lying bouts of primiparous cows in both early and peak lactation ($P < 0.001$). Breed did not affect lying bout duration ($P = 0.22$; $F_{1,338} = 1.48$).

3.1.3. Frequency of lying bouts

Cows performed an average of 14(5) lying bouts each day, regardless of treatment. The interaction of parity and stage of lactation had a significant effect on lying bout frequency ($P < 0.05$; $F_{2,338} = 3.74$; Fig. 4). Primiparous cows in post-peak lactation had fewer lying bouts compared to primiparous cows in both early ($P < 0.001$) and peak lactation ($P < 0.001$), but there was no other significant differences for this interaction in the post hoc pairwise comparison of the means. There was no effect of treatment ($P = 0.83$; $F_{1,338} = 0.05$), breed ($P = 0.17$; $F_{1,338} = 1.89$), and the interaction of treatment × parity ($P = 0.09$; $F_{1,338} = 2.92$) on the frequency of lying bouts.

3.2. Lying time within CCC area

FC cows spent on average 77.3(28.4)% of their total daily lying time within the CCC area. The proportion of time spent lying in the CCC area varied numerically between study weeks, but no significant effect of week was identified ($P = 0.27$; $F_{13,194} = 1.21$). Moreover, neither parity ($P = 0.18$; $F_{1,194} = 1.78$) nor breed ($P = 0.38$; $F_{1,194} = 0.79$) had any influence on this proportion.

3.3. Stall use

Across all weeks, approximately 63.8(6.5)% of stalls throughout the entire pen were occupied on an hourly basis. Of these stalls, 82.6(5.1)% contained cows or calves that were lying down, while standing or perching cows encompassed an average 17.4(5.1)%. Stalls located in the

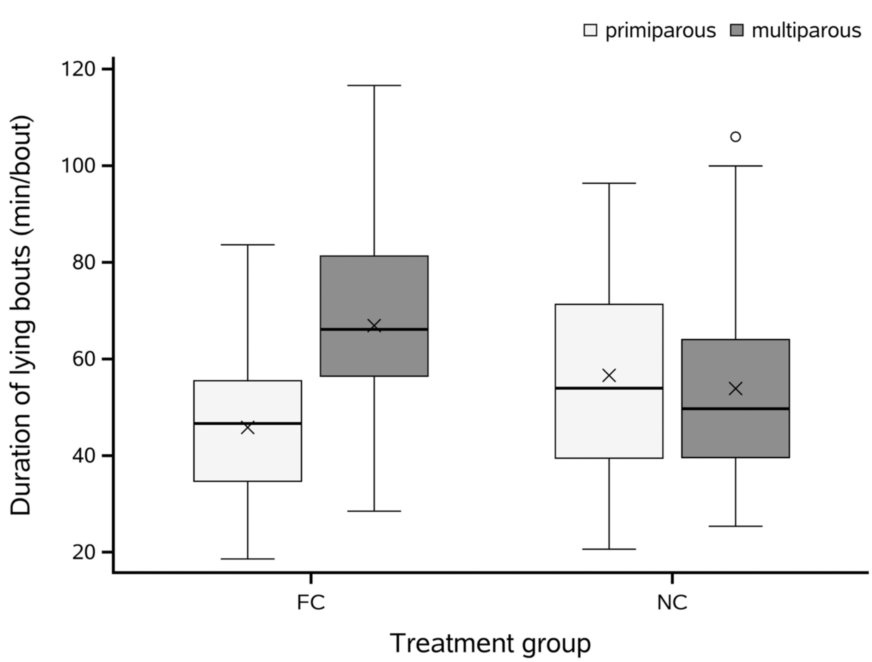

Fig. 2. Boxplots of the duration of lying bouts (min/bout) of primi- (n = 21) and multiparous (n = 19) FC and NC cows. Cows were assigned to treatment groups upon calving: FC (n = 19), where cows and calves were housed together with access to full cow-calf contact (CCC), or NC (n = 18), where the cow and calf were separated following parturition. Mean values are indicated by X, median by the solid black line and outliers by open circles. Data is based on observed values.

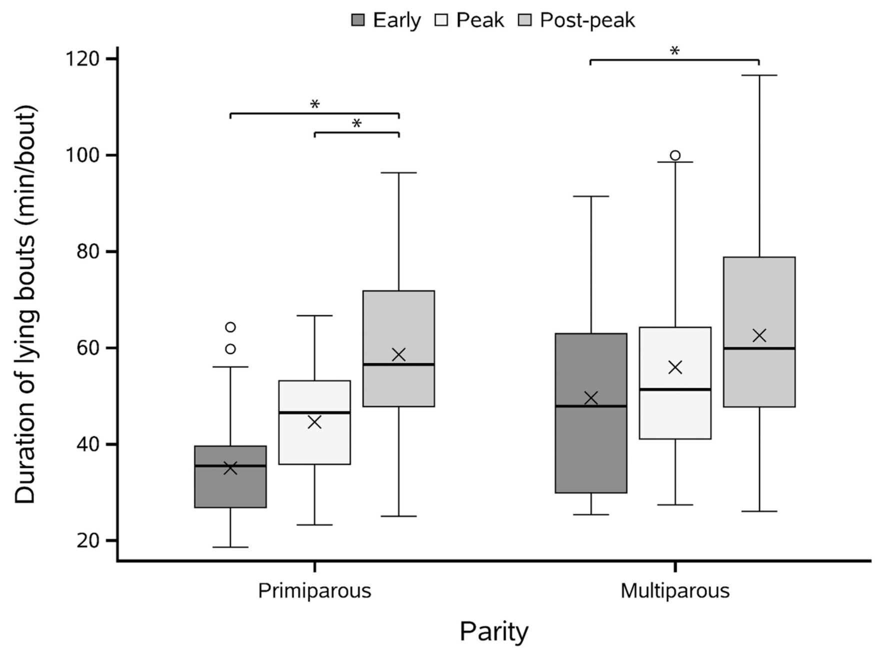

Fig. 3. Boxplots of the duration of lying bouts (min/bout) of primi- (n = 21) and multiparous (n = 19) cows during 3 different stages of lactation – early (weeks 1–5), peak (weeks 6–8) and post-peak (weeks 9–19). Mean values are indicated by X, median by the solid black line and outliers by open circles. Data is based on observed values. Stars represent differences between LSMeans ($P < 0.05$).

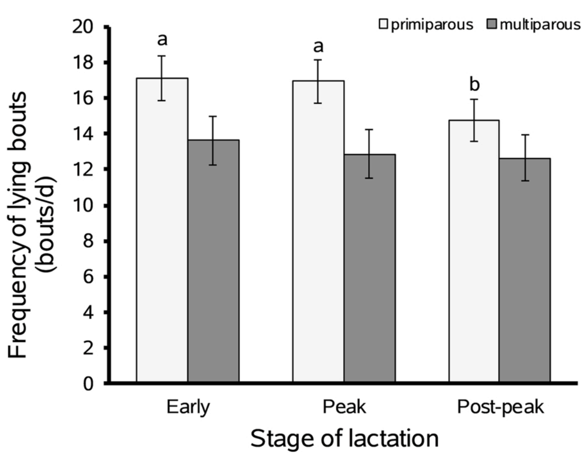

Fig. 4. Mean frequency of lying bouts (bouts/d) of primiparous (n = 21) and multiparous (n = 19) cows during 3 different stages of lactation – early (weeks 1–5), peak (weeks 6–8) and post-peak (weeks 9–19). Data is based on LSMeans and error bars represent the standard error of each mean. Different letters represent differences between means ($P < 0.05$).

general lying area were occupied at 63.5(7.7)% capacity, meaning that an average 14(3) stalls out a total 37 were free per hour. The CCC area was similarly occupied, averaging 63.4(12.0)% of stalls in use. Lying calves (n = 19) occupied approximately 6(2) stalls at any given hour within the CCC area, not including stalls that were shared with cows lying down (Fig. 5).

4. Discussion

This study is believed to be the first to directly compare the lying behaviours of cows housed in a cow-driven CCC freestall system, with and without their calves. Daily lying time was not directly affected by treatment; cows with access to full contact with calves maintained similar levels of rest as cows without calf contact. The general lying area, while technically overstocked at only 37 stalls available for an average 54 cows, was regularly occupied at around 64% of its maximum capacity. It should also be noted that despite having access to a dedicated lying space with nearly 3.85 m^2 per individual, calves consistently chose to lie down in stalls intended for FC cow use. Still, the average lying times in this study were comparable to those previously reported for freestall-housed herds with automatic milking (10.8–11.4 h/d; Deming et al., 2013; Westin et al., 2016; King et al., 2017). Similar lying times were reported by Johnsen et al. (2021) for dams housed in a CCC system with either free or partially-controlled access to calves.

Similar to the lack of treatment difference for daily lying time seen in our study, Margerison et al. (1999) reported no difference in lying time within a 24-hour period for cows with and without restricted calf contact. The contact in this case was in the form of 15-minute suckling periods prior to each milking session; thus, cows were likely able to compensate this reduction in available day hours by altering their time budgets. A similar explanation is perhaps possible for the cows within our own study. Cattle are known to prioritize lying over other activities (i.e., feeding, socializing) when time constraints are implemented, and will increase the relative proportion of time dedicated to lying in order to maintain adequate levels of rest (Metz, 1985; Munksgaard et al., 2005). In our study, it is possible that FC cows were experiencing time budget reductions due to their participation in cow-calf interactions, such as suckling, and learned to adjust the time spent on other activities in order to attain sufficient rest. At 10 weeks of age, calves with full, unrestricted access to their dams have been shown to spend almost a quarter of an hour per 4 h suckling (Roth et al., 2009). However, without close analysis of the daily time budgets for cows within a CCC system, this theory cannot be confirmed.

Cows increased their daily lying time by as much as 1.7 h/d from the start to the end of the 14-week period. It is known from previous experimental (Maselyne et al., 2017; Vasseur et al., 2012) and association studies (Ito et al., 2014; Solano et al., 2016; Westin et al., 2016) that beyond the first few weeks of lactation, daily lying time generally increases with DIM.

Parity – while not influential as a main effect – had an interactive effect with stage of lactation on both the duration and frequency of lying bouts for cows within our study. During early and peak lactation, multiparous cows performed longer lying bouts than primiparous cows.

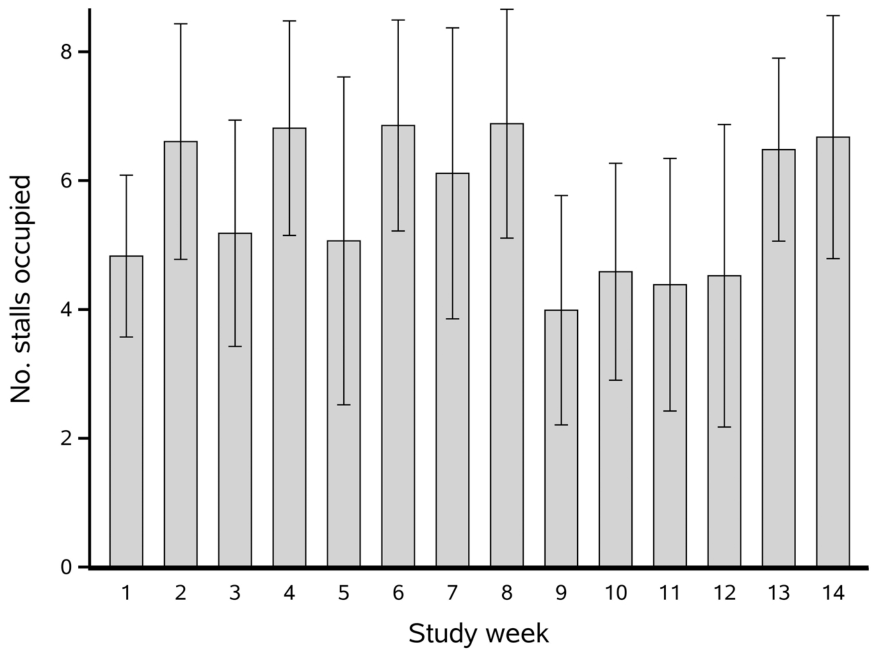

Fig. 5. Mean number of stalls per hour occupied by FC calves (n = 19) across all study weeks. Calves were (mean(SD)) 24(13) days old when the 14-week study period began, during which time they had shared access to a cow-calf contact (CCC) area with their dams. Error bars indicate the standard deviation of each observed mean.

Similarly, Vasseur et al. (2012) found that parity was positively associated with bout duration during early and mid-lactation stages. Further studies exploring lying behavior within the first 3 weeks of lactation have confirmed this relationship (Sepúlveda-Varas et al., 2014; Neave et al., 2017).

In our study, lying bout duration also increased from early to post-peak lactation for all cows. Increased bout duration between early (10–40 DIM) and middle (100–140 DIM) stages of lactation has previously been reported for primiparous cows (Vasseur et al., 2012). The relationship between lying bout duration and lactation stage has also been explored in various herd-level association studies, with contrasting conclusions. Westin et al. (2016) reported an associated increase in lying bout duration with increasing lactation month, whereas Gomez and Cook (2010) and Ito et al. (2014) found no association of DIM with either lying parameter. Additionally, we found that primiparous cows performed substantially fewer lying bouts in post-peak lactation compared to earlier in lactation. This pattern of shorter, but more frequent, lying bouts for primiparous cows in early lactation could be an indication of unease or restlessness. This could be due to the CCC system, or any of the physiological or management-related changes they undergo after calving for the first time (i.e., new routines with milking and handling). However, as this behaviour is shown also in systems without CCC (Solano et al., 2016), as well as for our NC cows, we do not believe the addition of calf contact created this response.

Our results suggest that the effect of parity on lying bout duration in our study may have been treatment specific, as multiparous FC cows had longer lying bouts than primiparous FC cows, whereas there was no difference in the NC treatment group. As shorter lying bouts are suggestibly linked with restless behaviour (Silper et al., 2017), longer bouts for healthy cows may be interpreted as representing more calm animals. Our results would then suggest that the CCC system may have a calming effect on the multiparous cows but not on the primiparous cows. Numerically, multiparous cows in the CCC system displayed the longest lying bouts of all cows in the study, and the lack of significant effects between treatments might be due to the small sample size and large variation in lying bout durations. Why CCC did not have a similar effect on the primiparous cows could be due to the fact that the whole system was completely new to them, likely entailing additional stress, whereas primiparous cows in the NC group had been trained in that system prior to entering the herd as lactating cows.

Across all weeks, cows performed approximately 14 lying bouts each day. Comparatively, observations of herds with automatic milking have reported cows to lie down fewer times per day, with frequencies of about 9–10 bouts/d (Deming et al., 2013; Westin et al., 2016; King et al., 2017). One explanation for the difference in behaviour may be our decision to exclude events of estrus from our dataset. When in heat, cows are known to be more active and lie down less frequently relative to days not in estrus (Dolecheck et al., 2015; Silper et al., 2017). This decrease in lying bout frequency (but not duration) results in an overall decrease in daily lying time during estrus events, which can last anywhere from 7 to 18 h (Diskin and Sreenan, 2000). The removal of these cows likely resulted in the higher mean frequency of lying bouts we observed. However, without confirmation of how many cows were in heat during each of the herd-level studies, this theory cannot be tested for certainty.

Cows with access to the CCC area spent a large majority of their total daily lying time within this area – a behaviour that did not change throughout the entirety of our study. This is interesting, as it suggests that cows may be choosing to remain in close proximity to their calves for a large portion of each day, even as calves near 3–4 months of age. In contrast, observations of semi-wild, free-ranging herds of Maremma cattle found an increasing distance between cow-calf pairs as the calves grew older (Vitale et al., 1986). Moreover, within the first 11 days after calving, maternal-filial contact behaviours have been seen to shift from being dam-initiated to primarily calf-initiated (Jensen, 2011). While these previous findings contradict the behaviour observed in our study, it is important to point out that the selection gate directed dams straight towards the CCC area. Thus, it is also possible that cows simply chose to lie down in the first available stall, remaining in the CCC area to obtain rest rather than contact with calves. Recently, Johnsen et al. (2021) observed that within the first month after calving, dams visited a CCC area approximately 4.6 times per day for 28 min/visit when access was granted upon successful milking, and nearly 8 times per day (20 min/visit) when access was free. These frequent visits occurred despite the fact that the CCC area did not contain any stalls. Additionally, Wenker et al. (2020) observed that cows with nightly access to full CCC (i.e., unrestricted suckling) were willing to push a weighted gate of up to 90 kg to access their calves during the day. Combined, these findings suggest that the motivation for cows in our study to remain within the CCC area may not have been entirely based on the availability of stalls, nor on the fact that they were directed to the area after milking. To better understand cow choice for lying location, a suggestion for future research is to explore lying time in a CCC area with different types of cow traffic, primarily in relation to calf access (i.e., pre-milking vs post-milking access to a CCC area).

The results of this study suggest that a combined cow-calf housing system does not alter the various lying behaviours of lactating cows. However, there were a few constraints that may limit the applicability of these findings to CCC systems in a broader setting. Firstly, the setup of the CCC system would likely need to be adapted to accommodate differences in management (i.e., parlour-based systems opposed to automatic milking systems). Additionally, we recognize the inherent limitations set in place through our use of both primi- and multiparous cows. Besides directly acting as a confounding factor for lying behaviour, parity may also have inadvertently influenced behaviour in the pen since age and dominance are thought to be correlated (Beilharz and Zeeb, 1982). As dominance in cattle is further known to be resource-dependent (Val-Laillet et al., 2008), it is not unlikely that some older cows may have influenced younger cows' use of stalls and, therefore, their lying behaviour. Finally, after stringent editing of the dataset, some experimental weeks contained observations for as a few as 9 FC dams and 10 NC cows. Further research with additional cows is thus needed to confirm the results of our study.

5. Conclusions

Overall, access to a CCC area did not affect daily lying time nor frequency of lying bouts for lactating cows that were housed in a free-stall barn with automatic milking. Cows altered their lying behaviours as lactation progressed, generally increasing their daily lying time by performing longer – and, in the case of primiparous cows, fewer – lying bouts. Cows with access to CCC were found to spend over 75% of their daily lying time within the CCC area – an observation that remained relatively constant throughout the 14-week suckling period. CCC systems, while still a relatively novel concept, may offer an alternative to early cow-calf separation and allow cows and calves to be housed together without compromising important lying behaviours in dams. Further research is needed on these systems in order to make sound recommendations for their use on a larger scale.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2023.105851.

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