

Calf presence in the cow herd: Associations with growth, health, and herd horn status in a cow-calf contact system

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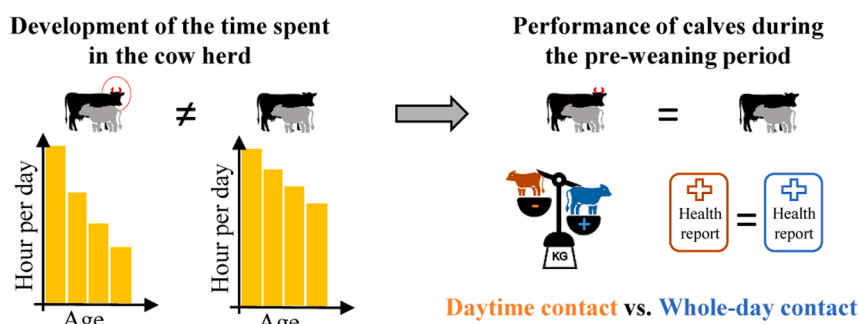
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HIGHLIGHTS

- The amount of time calves spent in the herd decreased with increasing age.
- Whole-day contact calves had higher weight gains than calves with half-day contact.
- Calves spent less time in the herd with horned cows.
- Health status of calves with or without contact to the dairy herd did not differ.

GRAPHICAL ABSTRACT



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ABSTRACT

Prolonged cow-calf contact in dairy farming is receiving considerable attention. However, research on systems that allow calves to access the whole dairy herd has been limited. This study investigated the time that German Holstein calves spent daily within the dairy herd of their dams, its association with calf growth and health, and the effect of herd (horned vs. polled). The calves with whole-day contact (WDC, $n=23$) could enter the herd at any time during the day, except during milking; the calves with daytime contact (DTC, $n=26$) had only access between morning and evening milking. Calves with no herd contact (NOC, $n=42$) served as a control. Calves were weighed weekly and their health status was assessed. Between the 2nd and 11th weeks of life, the time spent in the cow herd decreased in WDC calves (h d^{-1} , horned WDC: -10.9 , polled WDC: -3.7 , $P<0.001$), but did not differ in DTC calves ($P>0.1$). More time in the herd was associated with higher growth rates ($P=0.003$). However, no effect of the herd was observed on calf growth or health. WDC calves had the highest growth rate compared to DTC and NOC (g d^{-1} , 991 ± 36 , 718 ± 35 , 869 ± 28 , respectively, $P<0.05$). Unrestricted access to the cow herd resulted in individual variation in the time calves spent within the herd, with no observed effects on growth or health.

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1. Introduction

In common dairy farming, cows and calves are separated after calving leading to an artificial rearing of calves (Flower and Weary, 2003). However, in natural settings, cows and calves are strongly motivated to remain together during the first weeks after calving (Kerr and Wood-Gush, 1987; Lidfors, 1996; Vitale et al., 1986). During this time, the dam initiates most of the nursing episodes (von Keyserlingk and Weary, 2007). However, as the calf grows older, it becomes the primary initiator of suckling (Veissier et al., 1998; Vitale et al., 1986). In dairy systems, the practice of cow-calf contact (CCC) addresses the motivation of cows and calves to stay together (Jensen et al., 2024; Wenker et al., 2020) and exert a beneficial influence on the behavioral development of the calf (e.g., Wagner et al., 2012; Whalin et al., 2025). In a wide range of dairy systems, CCC rearing has already been implemented across multiple countries (Bertelsen and Vaarst, 2023; Eriksson et al., 2022; Vaarst et al., 2020), and the number of dairy farms planning to implement CCC systems in northern Europe is increasing (Hansen et al., 2023). However, knowledge gaps concerning the management of CCC systems persist, mainly due to the wide range of setting possibilities. As described by Sirovnik et al. (2020), contact between cow-calf pairs can be scheduled at different periods of the day (part-time, day-time (DTC), or whole-day (WDC)), at different moments (before milking, after milking), in different locations (away from the cow herd (e.g., group-pen) or in a dedicated place reachable independently by cows and calves (e.g., specific CCC meeting-area or a part of the cow area)), and initiated by different agents (cow, calf, cow and calf, or farmer).

In a calf-driven system, only the calf can establish contact with its dam (Sirovnik et al., 2020), though the dam may attempt to initiate contact by vocalizing. While such systems aim to reflect natural behaviors (Newberry and Swanson, 2008; Wenker et al., 2021), their implementation is often limited by practical aspects, among which building constraints are one of the most significant challenges (Eriksson et al., 2022). Nevertheless, the construction of an additional building is not necessary to provide calves with access to the cow herd, as opposed to the construction of group-pens. However, allowing calves into the cow area of the dairy barn increases space requirements, as calves tend to remain in close proximity to their dams (Hirata et al., 2003; Swain and Bishop-Hurley, 2007). This need for more space may be particularly important in herds with horned cows, as the cows' individual space can be repeatedly disturbed if the housing recommendations are not followed, leading to an increase in agonistic interactions between cows (Bouissou, 1980; Ebinghaus et al., 2025). In a calf-driven CCC system, this may also affect calves in contact with the dairy herd, as they can be subject to agonistic interactions from other cows, such as threats and displacement (Waiblinger et al., 2020). Therefore, the horn status of the cows, in conjunction with the cow area design, may influence the presence of calves in the cow herd.

The amount of time calves spend in contact with cows may affect their suckling duration in calf-driven CCC systems. Since the rumen of pre-weaned calves is not fully developed for digesting solid feed, milk is the main source of metabolizable energy, driving calf weight gain (Khan et al., 2016). Therefore, it can be assumed that calves with restricted access to the cows due to the CCC method (e.g., DTC), or whose suckling is disturbed by agitation within the cow herd (e.g., cows in estrus, horn status), may experience reduced suckling time, resulting in lower weight gains. In addition, Costa et al. (2016) reviewed that milk intake, housing management, and group size influence disease transmission in calves. Therefore, it is important to assess the health of calves under various CCC conditions, including different contact periods and herd horn status.

To the best of our knowledge, the presence of the calf in the cow herd during the pre-weaning phase under different access time periods, as well as the effects of this on calf weight gain and health, has not yet been investigated. The aim of our study was therefore to determine how much time WDC and DTC calves spend in their dams' herd each day, and

whether this affects their growth and health. A group of calves with no herd contact served as a control. Furthermore, the effect of the herd (horned/polled) was investigated.

We hypothesized that the time spent in the cow herd 1) would decrease with calf age, 2) would only be affected by the access time but not by the herd of the dam, 3) would not impact the growth rate, neither the health of the calves. Furthermore, we assumed that the health status of calves with contact to a whole dairy herd would not differ from the health status of artificial reared calves.

2. Materials and methods

This retrospective study is based on calf examinations that are weekly performed on the research farm of the Thünen Institute of Organic Farming (Germany). The analyzed data were collected over two time periods (period 1: August 2020 – April 2021 and period 2: August 2021 - June 2022) during the study by Schneider et al. (2024), in which the effect of indoor CCC on dams' ultradian and circadian activity rhythms was investigated. The data covered the pre-weaning period of the calves, from the second week of life (11 ± 2 days) until the day before the weaning process began (79 ± 2 days).

2.1. Animal housing

Two herds of cows (genetically polled, horned) were housed in a mirrored barn. The calves were kept in the calf area adjacent to the cows' area (see Wagner et al., 2012 for description). In the calf area, calves were provided with a straw bedded area, a rubber-coated walking area and an automatic calf brush (Schurr Gerätebau GmbH).

After calving, cow-contact calves remained in a single calving pen for about 5 ± 1 days together with their dam to strengthen their bond. The dam was milked twice a day with the entire herd in the milking parlor at milking times (at about 5:00 – 8:00 a.m. and 4:00 – 7:00 p.m.). Following the period in the calving pen, the dam was grouped into the cow herd that consisted of lactating and dry dairy cows. The calf was fitted with a transponder collar (Förster Technik GmbH, Germany) and moved to the calf area. During the first few days, the calf was trained to use a selection gate to gain access to the cow herd including its dam, until it was able to do so independently (photo of the selection gate in Johnsen et al. 2016). The selection gate was transponder-controlled and allowed the calves to access the dairy herd outside the milking hours, at times defined by their assigned treatment.

Artificially reared-calves (No Contact: NOC) were separated from their dams within hours of birth and spent their first 8 days of life in individual igloos. Then, the calves were transferred to the calf area and were grouped with cow-contact calves on the side of the barn to which their dam belonged. However, artificially-reared calves could not access the cow herd.

2.2. Animals and study design

Schneider et al. (2024) applied three treatments (WDC, DTC, NOC) to the cows and their calves depending on the herd (polled or horned) and the period (1 or 2). After calving, cows and calves were randomly allocated to the contact or NOC groups. The treatment groups were stratified by calf sex and dam parity (primiparous or multiparous). The WDC, DTC and NOC treatment groups included calves from 9, 9 and 14 primiparous cows, respectively. In total, 67 cows were included, 24 of which calved twice (once in each experimental period). For each calving, the calves from these cows were assigned to either a different contact time (18 calves) or the NOC group (6 calves). Furthermore, three pairs of twins were reared as NOC calves. A total of 91 German Holstein calves were included in the study (Table 1).

Only one type of contact was allocated to each herd in each period to prevent DTC calves from entering the cow area at night without authorization. This was because, in previous studies, it was observed

Table 1

Number and sex of calves allocated to the treatment groups (WDC: whole-day contact, DTC: daytime contact and NOC: no contact to the cow herd) depending on the herd and the experimental period.

Herd	Experimental period 1				Experimental period 2				Total
	Polled		Horned		Polled		Horned		
	Male	Female	Male	Female	Male	Female	Male	Female	
WDC	7	4	0	0	0	0	5	7	23
DTC	0	0	8	6	6	6	0	0	26
NOC	5	6	6	4	6	7	3	5	42
Total	12	10	14	10	12	13	8	12	91

that calves displaced other calves when they passed through the selection gate (Vogt et al., 2024). In period 1, only WDC and NOC calves were in the polled herd, while only DTC and NOC calves were in the horned herd. In period 2, WDC and DTC were reversed between the polled and the horned herd (Schneider et al. (2024).

In both herds, the size of the calf group was dynamic due to new calving or the regrouping of the weaned calves in the young stock barn. Hence, there were on average 8 (2–20) and 9 (2–18) calves present in the polled and horned calf areas, respectively. Likewise, due to culling or introduction of fresh cows, the number of cows present in the cow herds varied as well. On average, the polled herd included 43 (32–47) cows and the horned herd 39 (28–46) cows.

2.3. Calf feeding

The colostrum management was similar for all calves. Within the first few hours following birth, the calves received 3 liters of colostrum via a teat bottle. If the calving occurred shortly before milking, the colostrum was from the mother. Otherwise, the calf received thawed colostrum from the colostrum bank (Brix level > 22). Contact calves were observed for spontaneous suckling behavior, and if absent, farm staff assisted the calf three times daily to promote proper suckling. For the first five days of life, NOC calves were fed only milk from their own dam or, if the dam's milk production was insufficient, milk from another recently calved cow.

No additional milk was provided to WDC and DTC calves beside the milk they suckled from the dams. Once in the calf area, NOC calves received whole milk from the automated-milk feeder (Förster Technik GmbH, Germany), which was transferred from the delivery tank. Calves could drink up to 12 L per day (a maximum of 4 L per meal). In the calf area, all calves had ad libitum access to water, hay and a total mixed ration (TMR). The TMR (63.6 % grass silage, 30.0 % corn silage, 6.2 % concentrate feed in the form of coarse grain, and 0.2 % mineral feed) was fresh provided once a day in the afternoon. Moreover, calves were provided concentrate feed in pellets (56 % wheat, 32 % triticale, 10 % peas, 2 % minerals) at a concentrate feeder (Förster Technik GmbH, Engen, Germany). Calves were allowed to eat up to 1.5 kg of concentrate per day in 50 g portions.

2.4. Data collection

2.4.1. Time spent in the cow herd

The planned maximum access duration per day was 17 h for WDC calves and 7 h for DTC calves. However, depending on the farm's workload and the duration of milking, this access time could vary from day to day.

The entrance of the calves into the cow area, as well as their subsequent exit, were recorded continuously, using cameras positioned above the selection gates, providing an aerial view of the calves' passages. The evaluation of these recordings was necessary because the selection gate only registered the animals' entry, not their exit, and recognition errors could occur during periods of high traffic and when animals displaced each other.

In total, four videos of six hours' duration were recorded each day for

412 days (morning, afternoon, evening, and night). This resulted in 19,776 h of video material being recorded. Due to technical issues, 25 days had to be removed from the dataset of the horned herd, resulting in a total of 375 days available for data analysis. For the polled herd, 39 days had to be removed, resulting in 361 days being available for data analysis.

Six trained observers utilized the software BORIS© (Friard and Gamba, 2016) to document the entrance of the calf in the cow area (when the calf had passed through the selection gate and stand with all four legs in the cow area) and the return of the calf in the calf area (when the calf had passed through the selection gate and stand with all four legs in the calf area). The observers were not blinded to the treatment of the calves, as they were provided with the following information for each calf: treatment, herd, sex, birth date, as well as four photographs (head, right side, left side, and rear) to identify each calf. To assess the inter-observer reliability, a Fleiss Kappa score was calculated using one randomly selected video per part of the day at four different dates. The measured Fleiss' Kappa was 0.92 ($P < 0.001$).

The time in the cow herd (TIC) was calculated by summing the time between entry and exit for each calf on a daily basis. In addition, the daily amount of time the cow area was accessible to the calves between two milking was documented. During milking, the selection gate was mechanically closed. At the end of milking, the farm staff removed the lock. As several young calves (2–3 weeks of age) were already waiting in front of the gate, they entered the cow area right after opening. The first entry of a calf into the cow area post-milking marked the start of the access time to the cow area. Similarly, before milking, the farm staff moved the calves that were still in the cow area back to the calf area. Once the last calf passed through the gate, the farm staff locked it mechanically, thereby ending the access time to the cow area.

2.4.2. Calf weight and health

All calves were weighed by experienced technicians every Tuesday in the calf area at the time of morning milking using a commercial calf weighing scale (Patura, Germany, accuracy: ± 1 %). During the fixation of the calves for weighing, the health status of the calves was assessed and the rectal temperature was measured. Health monitoring was performed using a 0–1–2 grading scale (0: no health issue, 2: severe symptom – see Table 2) following a method adapted from Roth et al. (2009b). The scoring system evaluated nasal discharge, ocular discharge, cough, cleanliness of the hindquarters and navel inflammation. As fecal samples were not collected in the study by Schneider et al. (2024), the incidence of diarrhea was estimated from the cleanliness of the hindquarters. All medications and the reason for any veterinary treatment were also documented.

2.5. Statistical analysis

2.5.1. Data preparation

Prior to analyzing TIC, data from calves that received veterinary treatment were removed one day before and one day after the veterinarian's visit, because sickness reduces activity in young ruminants (Bowen et al., 2022) and may have resulted in a TIC that was not caused by the experimental treatment.

Table 2
Description of the health monitoring parameters scored on a weekly basis (adapted from Roth et al. (2009b)).

Clinical parameter	Score		
	0	1	2
Nasal discharge	None	Watery discharge or completely dry nose	Bilateral mucopurulent discharge
Ocular discharge	None	Slight watering of both eyes	Bilateral white eye discharge
Spontaneous cough	None	Sporadic coughing	Repeated coughing
Cleanliness of the hindquarters	Clean	Hindquarters dirty but dried up	Hindquarters dirty and wet
Navel inflammation	Inconspicuous	Swollen, without discharge	Swollen, with discharge

In order to assess the overall growth rate, the average daily weight gain (ADG) was calculated on a weekly basis for each calf by dividing the difference between the actual weight and the birthweight by the age of the calf in days. To obtain a comprehensive overview of the health state of the calves, the rectal temperature was initially examined as continuous variable. Subsequently, the values of the rectal temperature were converted into scores according to the scheme developed by Wenker et al. (2022): Score 0: 37.8–38.2 °C; Score 1: 38.3–38.8 °C; Score 2: 38.9–39.4 °C; and Score 3: >39.4 °C or <37.8 °C. These scores were then summed up with all the other health scores to calculate the weekly health score (WHS) for each calf.

Additionally, over the 2- to 11-week age range, the scores for each clinical symptom documented weekly were aggregated for each calf resulting in five specific health parameter scores (SHPS) for nasal discharge, ocular discharge, spontaneous cough, cleanliness of the hindquarters and navel inflammation.

Since only one value per week and per calf was collected to calculate the ADG, the rectal temperature, WHS and SHPS, all weight and health data recorded were retained for the analysis even if the calf received medical treatment on a given week.

2.5.2. Data analysis

Statistical analyses were performed with the software R version 4.1.2. (R Core Team, 2021). The calf was the experimental unit. Continuous variables (TIC, ADG, rectal temperature) were analyzed by linear mixed-effects models using the packages lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017). Score variables (WHS) were analyzed by cumulative link mixed models (Stenfelt et al., 2022) using the package ordinal (Christensen, 2024). Treatment (WDC, DTC, NOC), herd (Horned, Polled), parity of the dam (Multiparous, Primiparous) and sex of the calf (Male, Female) were used as fixed factors. Age of the calf in days was included as continuous variable. A random effect to account for the repetition of measurements on the same calf was added, along with a cross-random effect consisting of calendar week merged with the experimental period (1, 2) to account for the weekly change in group composition (Cafri et al., 2015). In all models, interactions between variables were checked using a stepwise forward selection method. If the interaction contributed to a reduction of the Akaike information criterion of the model, the interaction was kept in the model; otherwise, it was removed. The assumptions of distribution and homoscedasticity were checked by graphical inspection of the model residuals. Statistical significance was decided at $P < 0.05$. Multiple pairwise comparisons were corrected using the Tukey method. Post-hoc tests were run at the week level (every seven days). Results are reported in $LSM \pm SE$.

Two ADG models were run: one exclusively for contact calves (ADG_{CC}) to include the weekly mean TIC as explanatory variable and one for all calves without the weekly mean TIC as explanatory variable. In the ADG_{CC} model, the absence of collinearity between treatment, age of the calf and the weekly mean TIC was checked. No collinearity issue

was detected (Variance Inflation Factor = 1.2). Likewise, two WHS models were run. However, the WHS model that included the weekly mean TIC as an explanatory variable failed to converge. Therefore, only one WHS model without the weekly mean TIC as explanatory variable was considered for the data analysis.

To compare each specific health parameter among treatments, five cumulative link models were run (one for each SPHS), with Treatment (WDC, DTC, NOC) included as the sole explanatory variable. Finally, a Kruskal-Wallis test was conducted to compare the number of veterinary treatments received by calves across treatment groups.

3. Results

3.1. Time spent in the cow herd

During the study period, the cow area was open for an average of (mean \pm SD) 17.2 ± 0.7 h d⁻¹ for WDC calves and for 6.9 ± 0.6 h d⁻¹ for DTC calves. The TIC was influenced by an interaction between calf's age, treatment, and herd ($F_{1, 2496.2} = 112.8$, Table 3 and Fig. 1). The parity of the dam and the sex of the calf did not affect the TIC.

Between the 2nd and 11th weeks of life, WDC calves exhibited a significant decrease in TIC, which was more pronounced in WDC calves from the horned herd (h d⁻¹, horned WDC: - 10.9, polled WDC: - 3.7, $P < 0.001$). In contrast, as DTC calves aged, their TIC remained stable ($P > 0.05$) and showed no significant differences between the horned and polled herds ($P > 0.05$).

In the polled herd, the difference in TIC between WDC and DTC calves persisted until the 11th week of life ($P < 0.001$). However, in the horned herd, from the 8th week of life onward, TIC no longer differed between WDC and DTC calves ($P > 0.05$).

3.2. Calf weight gain

The average birth weight (\pm SD) of calves was 40.1 ± 6.0 kg. A one-way ANOVA indicated no differences in birth weight between treatments ($P = 0.061$), neither between herds ($P = 0.181$).

The analysis of the ADG_{CC} model showed no interaction between the age and the treatment of the calf. The ADG of WDC calves was 214 ± 45 g d⁻¹ higher than DTC calves ($P < 0.001$). The sex of the calf ($P = 0.218$), the parity of the dam ($P = 0.216$) and the herd ($P = 0.863$) had no effect on the ADG. A positive correlation was observed between ADG and calf age ($P < 0.001$), as well as between ADG and mean weekly TIC (Supplementary Fig. S1, $P = 0.003$). One additional hour spent in the cow

Table 3

Model results for time spent in the cow herd by calves with whole-day (WDC, $n = 23$) or daytime (DTC, $n = 26$) contact to the cow herd.

Explanatory variable	Level	Estimate (h d ⁻¹)	Test statistics	
			DF Num, DF Den, F-value	P-value
Treatment	WDC	0	$F_{1, 52.1} = 235.6$	<0.001
	DTC	- 11.9		
Herd	Horned	0	$F_{1, 53.8} = 0.1$	0.842
	Polled	-1.0		
Parity	Multiparous	0	$F_{1, 41.8} = 3.2$	0.082
	Primiparous	-1.2		
Sex	Female	0	$F_{1, 42.4} = 0.3$	0.567
	Male	-0.4		
Calf age	Day	- 0.2	$F_{1, 176.2} = 353.5$	<0.001
Treatment x Age	WDC	0	$F_{1, 2870.1} = 464.3$	<0.001
	DTC	0.2		
Herd x Age	Horned	0	$F_{1, 2861.1} = 166.2$	<0.001
	Polled	0.1		
Treatment x Herd	DTC x Polled	2.4	$F_{1, 54.3} = 2.7$	0.1
Age x Treatment x Herd	DTC x Polled	- 0.1	$F_{1, 2496.2} = 112.8$	<0.001

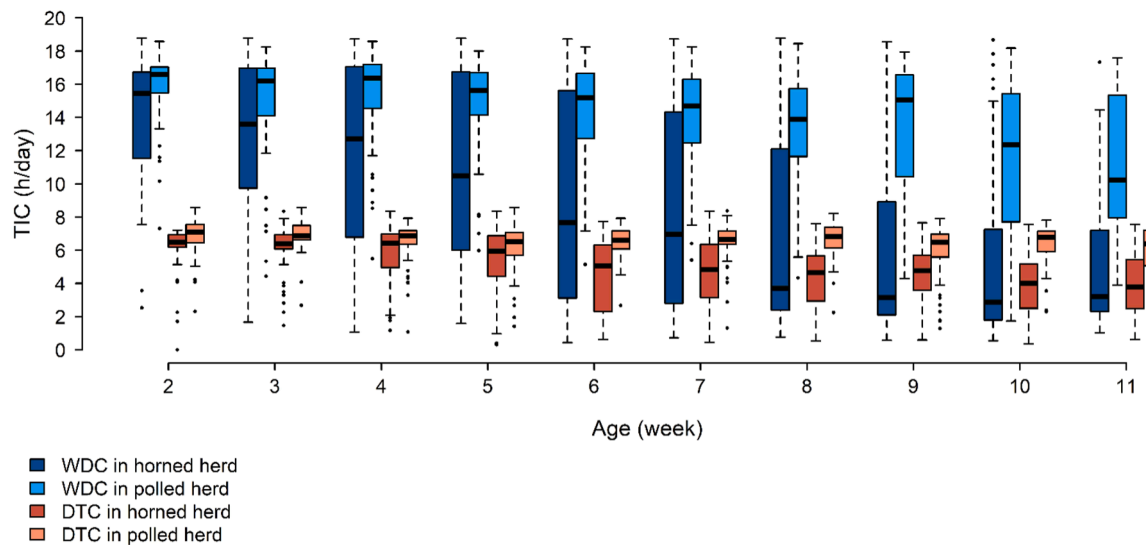


Fig. 1. Time spent in the cow herd (TIC, in h d^{-1}) according to the age of the calf (in weeks), the treatment (WDC: whole-day contact to the cow herd, $n=23$, DTC: daytime contact to the cow herd, $n=26$) and the herd the calves belonged to (horned, polled). The box plots show the distribution of the raw data based on the TIC averaged over the age of the calves (in week). Horizontal lines within each box represent the median TIC values. The whiskers extend up to 1.5 times the interquartile range, and individual dots indicate outliers beyond these limits.

herd resulted in an increase in ADG of $5 \pm 2 \text{ g d}^{-1}$ ($P=0.003$).

The analysis of the ADG model including WDC, DTC and NOC calves indicated that ADG was influenced by an interaction between treatment and calf age (Fig. 2), as well as by calf sex. Neither the herd (Supplementary Fig. S2) nor the parity of the dam influenced the ADG of the calves (Table 4). Between the 2nd and the 11th weeks of age, WDC calves had the highest overall growth rate, followed by NOC and DTC calves (LSM \pm SE in g d^{-1} , 991 ± 36 , 869 ± 28 , 718 ± 35 , respectively, $P < 0.05$). Male calves exhibited a higher ADG than female calves ($81 \pm 36 \text{ g d}^{-1}$, $P=0.027$). In the period of the 2nd to 11th weeks of age, the difference in ADG between WDC and DTC calves persisted ($P < 0.05$). However, as calves aged, the differences in ADG between contact and NOC calves shifted. From the 2nd to the 6th weeks of age only, DTC calves exhibited lower ADG than NOC calves ($P < 0.05$), whereas from the 9th week of life onward, WDC calves exhibited higher ADG than NOC calves ($P < 0.05$).

3.3. Calf health

From week 2 to week 11 of age, the median WHS was 3.3 (range: 0–10) for WDC calves, 3.5 (range: 1–9) for DTC calves, and 3.3 (range: 0–9) for NOC calves, with no difference between treatments ($P=0.240$), neither between herds ($P=0.227$). As calves aged, the WHS decreased by 0.01 ± 0 each day ($P < 0.001$). The WHS of two-week-old and eleven-week-old calves were 3.7 ± 0.1 and 3.1 ± 0.1 , respectively. Calves born to multiparous dams exhibited higher WHS than calves born to primiparous dams (0.4 ± 0.1 , $P=0.020$). Male calves exhibited higher WHS than female calves (0.34 ± 0.2 , $P=0.025$).

Analysis of rectal temperature throughout the 2- to 11-week age period showed no difference between WDC and DTC calves ($P=0.091$), neither between NOC and DTC calves ($P=0.796$). However, rectal temperature in WDC calves was $0.13 \pm 0.04 \text{ }^\circ\text{C}$ higher than in NOC calves ($P=0.011$). Rectal temperature in calves was significantly

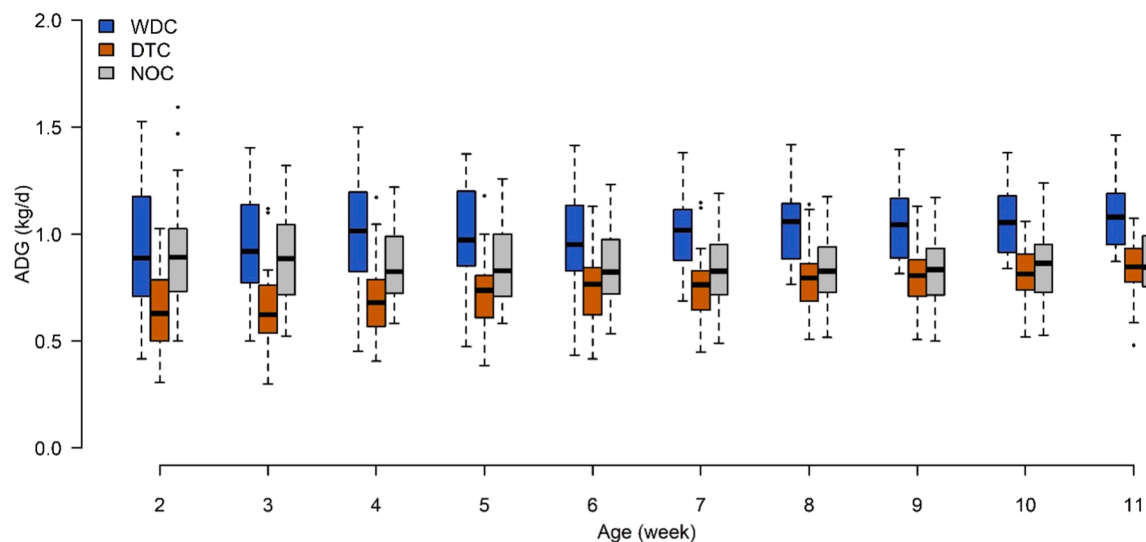


Fig. 2. Average daily weight gain (ADG, in kg d^{-1}) of the calves depending on age of the calf in weeks and treatment (WDC: whole-day contact ($n=23$), DTC: daytime contact ($n=26$), NOC: no contact ($n=42$) to the cow herd). The box plots show the distribution of the raw data. Horizontal lines within each box represent the median ADG value. The whiskers extend up to 1.5 times the interquartile range, and individual dots indicate outliers beyond these limits.

Table 4

Model results for average daily weight gain (ADG, in g d^{-1}) of calves with whole-day (WDC, $n=23$), daytime (DTC, $n=26$) or no contact (NOC, $n=42$) to the cow herd.

Explanatory variable	Level	Estimate (g d^{-1})	Test statistics	
			DF Num, DF Den, F-value	P-value
Treatment	WDC	0	$F_{1, 124.3} = 31.8$	<0.001
	DTC	-339.0		
	NOC	20.5		
Herd	Horned	0	$F_{1, 81.8} = 0.2$	0.678
	Polled	-15.2		
Parity	Multiparous	0	$F_{1, 81.5} = 3.3$	0.070
	Primiparous	-69.5		
Sex	Female	0	$F_{1, 81.7} = 5.1$	0.027
	Male	81.1		
Calf age	Day	1.7	$F_{1, 286.6} = 25.2$	<0.001
Treatment x Age	WDC	0	$F_{2, 870.7} = 52.8$	<0.001
	DTC	1.5		
	NOC	-3.2		

influenced by age ($P < 0.001$), whereas herd ($P = 0.465$), dam parity ($P = 0.132$), and calf sex ($P = 0.932$) had no significant effect.

From week 2 to week 11 of age, no differences between treatments across the five SHPS were observed ($P > 0.017$, Fig. 3), nor in the number of veterinary treatments the calves received (Kruskal-Wallis test: Chi-Square = 1.221, DF = 2, $P = 0.543$). For all treatments, the median number of veterinary treatments received per calf was 0. However, 23 of the 91 calves received at least one veterinary treatment (4 WDC, 6 DTC, and 13 NOC calves).

4. Discussion

The present retrospective study describes the daily visit duration of calves in a cow herd, that included only polled or only horned cows. However, due to the study design, the effect of the horn status of the cows could not be separated from the effect of the herd. Therefore, the differences observed between the herds can be attributed to both horn status and herd composition. Nevertheless, we found that WDC calves spent less time in the horned cow herd than in the polled cow herd,

whereas DTC calves spent a similar amount of time in both herds. Additionally, no differences in the growth rate or health status of calves were noticed between the horned and polled herds.

4.1. Time spent in the cow herd

In our setting, contact calves needed to enter the cow herd because this was the only way to interact with their dams and receive milk through suckling. The decline in TIC observed in WDC calves as they aged could be attributed to a reduction in time spent with the dam and an increase in time spent with other calves in the calf area. Under natural conditions, as the calf aged, the frequency and duration of suckling interactions with its dam decline, while interactions with other calves increase (Odde et al., 1985). Moreover, three-month-old calves on pasture spent more time lying down together in a Kindergarten than one-month-old calves (Gillet et al., 2023; Sato et al., 1987). The design of our calf area allowed calves to lie together in a Kindergarten at any time, which was possible in the cubicles only if adjacent cubicles were free. Therefore, the decrease in TIC can also be attributed to the increased time spent lying down in the calf area rather than in the cubicles. Nevertheless, DTC calves spent the majority of their cow herd's access time in the cow area. The prohibition of contact to the dam during the night may have exacerbated the hunger of the calves (Neave et al., 2024) and prompted them to prioritize proximity to the milk resource, thereby avoiding voluntary return to the calf area. However, a lack of social interaction with the dam at night may also influence the calves' decision to spend more time in the cow area during the day.

The difference in TIC observed in WDC calves between the two herds might be attributed to the horn status of the cows. Despite the nearly identical cow-cubicle ratio in the two herds (polled herd = 1:1.2, horned herd = 1:1.3), horned cows may have perceived a higher stocking rate compared to the polled cows (Lutz et al., 2019). This could have resulted in more social conflicts among horned cows than among polled cows (Ebinghaus et al., 2025). For this reason, unlike WDC calves in the polled herd, WDC calves in the horned herd may have preferred to remain for extended periods of time in the calf area to avoid displacement occurring in the cow area. This hypothesis is supported by Wegner and Ternman (2023), who found that calves consistently lay down in the cubicles when in contact with hornless cows, despite the calf area offering 3.85

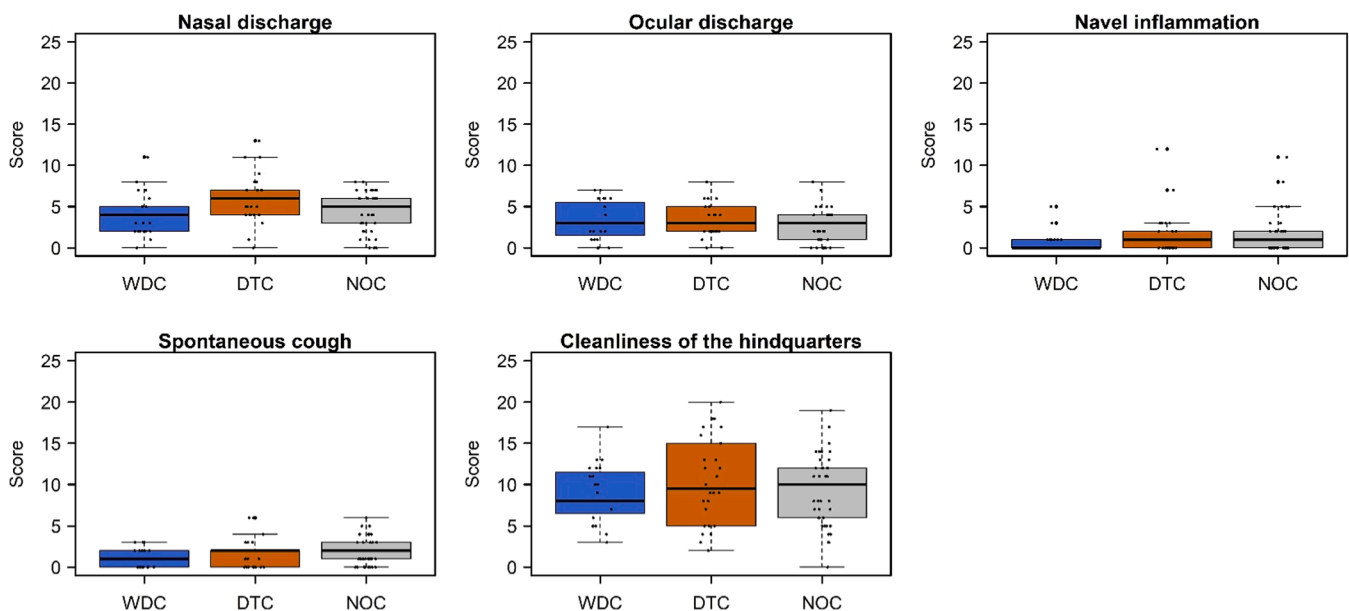


Fig. 3. Health parameter scores aggregated for each calf between the 2nd and the 11th weeks of age, according to the treatment (WDC: whole-day contact ($n=23$), DTC: daytime contact ($n=26$), NOC: no contact ($n=42$) to the cow herd). The box plots show the distribution of the raw data. Horizontal lines within each box represent the median score value. The whiskers extend up to 1.5 times the interquartile range, and individual dots indicate outliers beyond these limits.

m² per calf and being the sole location with accessible feed for calves. Nevertheless, no differences in TIC were noticed in DTC calves between the two herds. Additionally, by the 8th week of life, the WDC calves of the horned herd had reached the same TIC that was recorded for DTC calves in both herds. This emphasizes our suggestion that DTC calves primarily accessed the cow herd to fulfil their need to suckle and to interact with their dams.

One limitation of this retrospective study is that no behavioral data of the calves was available. The analysis was based exclusively on farm routine data (TIC, calf weight, calf health state records), which limits the outcomes of our study. Behavioral data, including suckling frequency and lying location, might have provided a more comprehensive understanding of the development of TIC among the calves over time. This would have enabled us to better understand the significant inter-individual variability in TIC observed in WDC and DTC calves, particularly in the horned herd.

4.2. Calf weight gain

The differences in ADG observed between treatments are probably due to variations in milk intake rather than the rearing system itself. This is supported by Roth et al. (2009a), who reported a similar ADG in WDC and part-time contact calves with 15 min of contact twice daily before milking. The ADG in NOC calves was intermediate between that of WDC and DTC calves. NOC and WDC calves showed similar ADG during the first eight weeks of life, suggesting that NOC calves received a high milk supply, nearly ad libitum. Johanssen et al. (2024) reported that artificially reared calves that consumed 12 L milk d⁻¹ achieved similar growth rates to WDC calves. Additionally, the milk consumed by NOC calves in our study was comparable in composition to the milk consumed by contact calves because NOC calves were fed whole milk from the delivery tank. Therefore, the lower ADG exhibited by DTC calves compared to NOC calves suggests that DTC calves may not have consumed an equivalent amount of milk, likely due to limited contact with their dams.

The higher ADG of WDC calves compared to DTC calves may be due to the ability of WDC calves to suckle with ad libitum access throughout the day and night, except during milking times. Under natural conditions, calves suckle at sunrise and sunset (reviewed by Whalin et al., 2021), which corresponds to the periods following the end of morning and evening milking in our experiment. Furthermore, we assume that calves that suckle immediately after milking will still be provided with larger amounts of milk. Due to the documented milk ejection issues in CCC systems (Bruckmaier, 2024; de Passillé et al., 2008), the dam's udder will not be completely empty at that time. Moreover, calves could suckle from cows other than their own dams, which increased the amount of milk the WDC and DTC calves could potentially consume. Therefore, WDC and DTC calves may have consumed similar amounts of milk during the post-morning milking period, but DTC calves were not allowed to suckle after the evening milking. The lower weight gain in DTC calves suggests that the time between morning and evening milking was insufficient for the cows to produce enough milk, or that the calves were unable to adjust to the limited contact time by increasing their milk intake before evening separation.

Although WDC calves spent less time in the horned herd, the herd did not affect the ADG of the calves. Even with a lower TIC, WDC calves of the horned herd probably suckled as much as those of the polled herd. Given that three-month-old WDC calves typically suckle on average once every two hours in 24-hour period (Bertelsen and Jensen 2023a), it might be that older WDC calves in the horned herd visited the cow herd almost exclusively for suckling and went back to the calf area once satiated. Additionally, given the restricted access of DTC calves to the cow herd, it is plausible that visits were primarily allocated to suckling, thereby explaining the similar ADG between calves from the two herds.

4.3. Calf health

Calf health was not influenced by access to the cow herd. Nevertheless, other studies using a comparable scoring system reported that the health status of WDC calves was inferior compared to NOC calves (Wenker et al., 2022) or compared to NOC and night-time contact calves (Sinnott et al., 2024). In both studies, the authors attributed the observed discrepancy in health status to the different housing and environmental conditions of the WDC calves compared to the other calves. This is in contrast to our study, where all calves had access to the same calf area. Consequently, although the NOC calves were not directly exposed to pathogens from adult cattle, they could still become infected by being in contact with WDC or DTC calves. However, in our study, 25.3 % of the calves were treated with veterinary drugs, which is only slightly higher than the 21 % and 21.8 % of calves treated with veterinary drugs in the studies conducted by Wenker et al. (2022) and Sinnott et al. (2024), respectively. Moreover, in group housed calves with a comparable large age difference of 60 days and no contact with an entire cow herd, Cramer et al. (2016) reported a similar proportion of 22 % of calves treated with veterinary drugs. Consequently, contact with cows did not appear to have a significant impact on the health status of the calves in our study.

The WHS method used to compare the health status between the treatment groups was not optimal since we combined two different scoring systems in the WHS. A score of 2 in the WHS corresponded either to a swollen navel or to a rectal temperature between 38.9 and 39.4 °C. A swollen navel is more likely to indicate a deteriorated health status of the calf than a rectal temperature between 38.9 and 39.4 °C (Renaud et al., 2018). Nevertheless, the WHS values obtained for each of our treatment group were comparable to those reported by Wenker et al. (2022). However, over the period from the 2nd to the 11th week of age, a slightly higher rectal temperature without any signs of illness was recorded in WDC calves compared to NOC calves. According to Bertelsen and Jensen (2023b), a higher rectal temperature in WDC calves may indicate higher metabolized energy usage, thereby supporting the ad libitum milk provision of WDC calves.

5. Conclusion

Allowing calves to visit the cow herd at any time of day or night enhances their growth by probably enabling them to suckle ad libitum without compromising their health. Although calves progressively spent less time with the cow herd as they aged, this reduction did not negatively impact their performance, if they had whole-day access to the cow herd. Additionally, while calves spent more time in the herd with polled cows than with horned cows, this was not associated with any negative effects on their performance or health. The reduction of the time spent within the herd emphasizes the importance of providing calves with a separate area. However, future studies should examine calf behavior in greater detail during contact with the cow herd, in order to determine the factors influencing the time spent in the herd.

Notes

This study is a retrospective study based on the study by Schneider et al. (2024) that received no external fundings.

Ethical approval

No ethical approval was necessary. Data were collected as part of the compulsory monitoring of the calves at the research farm. Data were analyzed retrospectively.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors used DeepL Translate and DeepL Write in the writing process.

CRedit authorship contribution statement

Romane Gillet: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Marie Schneider:** Writing – review & editing, Data curation, Conceptualization. **Kerstin Barth:** Writing – review & editing, Supervision, Conceptualization.

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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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.livsci.2025.105834](https://doi.org/10.1016/j.livsci.2025.105834).

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