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Impact of Calving Difficulty on Lameness in Dairy Cows

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Simple Summary: Our study aimed to evaluate the relationship between calving difficulty and lameness and association with milk composition. Calving scores were recorded in Lithuania between 2018 and 2020 with Lithuanian black and white cows. A total of 4723 calving cases were evaluated using a 4-point scoring system. Lameness was diagnosed by training staff, and this was followed from 1 to 30 days after calving in 333 fresh dairy cows. Lameness was scored twice a week using a locomotion scoring system from 1 to 30 days after calving. Cows were divided into two groups: non-lame cows and lame cows. Milk yield, milk electrical conductivity and composition parameters—fat, protein, lactose, urea—were recorded using Lely Astronaut® A3 milking robots. In the lame cow group, we observed 14.2% more animals with calving difficulty as compared with non-lame cows. On average, non-lame cows increased their daily milk yield by 1.24 kg, had higher milk protein by 0.04% and produced 0.10% more milk lactose as compared with lame cows. The cell counts for non-lame animals were lower than for lame animals, but both groups had relatively low cell counts, and thus, the difference would seem to be unimportant from a biological perspective. Calving difficulty carried a 2.09-fold higher risk of lameness in cows.

Abstract: The aims of our study were to evaluate the associations between calving difficulty and lameness and their effects on milk yield and quality traits. A total of 4723 calving cases were evaluated for calving difficulty using a 4-point scoring system. Lameness was diagnosed with a visual locomotion score system from 1 to 30 days after calving in 333 fresh dairy cows. Cows were divided into non-lame cows and lame cows. Milk quality traits were registered using Lely Astronaut® A3 milking robots. The normal distribution of all indicators was assessed using the Shapiro–Wilk normality test. Normally distributed milk indicators were expressed as mean ± standard error of the mean. Differences between the mean values of their groups were determined using the Fisher's least significant difference test. We categorized cows by health status, i.e., lame (LA) and non-lame (HL) cows, and according to calving difficulty (CD) (on a 4-point scale: 1—no problem, 2—slight problem, 3—problems requiring assistance, 4—considerable force and extreme difficulty). In the present study, calving difficulty increased the risk of lameness in cows by 2.09-fold (95% CI = 1.644–2.650, $p < 0.001$). It was found that the mean standard milk yield in fresh dairy cows with calving difficulty was lower (−6.14 kg, $p < 0.001$) than in the group where no assistance was required at calving. Similarly, herd affected milk fat (%) and the calving process—herd and the interaction between calving difficulty and herd—and lameness impacted the quantity of milk protein and lactose in cows. We found that

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severe lameness (3–4 points) (3.88–5.92% of cows) became more prevalent in those cows that had dystocia than those that did not (0.27–2.37% of cows).

Keywords: calving difficulty; fresh dairy cows; lameness; milk composition

1. Introduction

The impact of calving difficulty (CD) on lameness in dairy cows is a global problem because CD in dairy cattle leads to important economic losses for producers due to calf or dam mortality, decreased milk yields, reduced fertility and increased veterinary costs [1]. CD or dystocia is defined as "a birth that reduces calf viability, causes maternal injury and requires assistance" [2]. Atashi et al. (2012) reported that CD can have long-term effects on the survival of calves into adulthood and the subsequent lactation production both from the calf and the dam. CD incidence also causes animal welfare issues [3]. Studies indicate that CD has a negative influence on milk yield [4]. In contrast, other studies report shorter-term effects that disappear after 14 days in milk (DIM) [5], 90 DIM [6] or 6 months postpartum [3]. Dystocia can deteriorate cow negative energy status during the postpartum period [7]. Valde et al. [8] and Washburn et al. [9] reported that there were adverse associations between CD and negative energy balance, mastitis and metabolic disorders related to reproductive performance in high-producing cows after calving. Data from several studies also indicate that dystocia may decrease milk protein, fat and lactose and increase somatic cell counts [3]. It has been demonstrated that there is a link between milk lactose % and cow fertility [10]. Changes in milk lactose levels have been proven to be an accurate predictor of first and second post-calving ovulation [11]. Lactose levels beyond a certain threshold are linked to an increased likelihood of pregnancy [12]. Furthermore, a close relationship between lactose levels and postpartum luteal function recovery has been documented [13]. Milk electrical conductivity and lactose concentration have been identified as two of the most helpful markers for monitoring and diagnosing subclinical and clinical mastitis [14]. As calving difficulty score increased from 1 to 4 (using a 4-point scale system: 1—easy, unassisted; 2—easy, assisted; 3—difficult, assisted; 4—difficult, requiring veterinary assistance), the average productivity of cows decreased by 6.77 kg/day.

In addition, with increasing CD scores (using a 4-point scale system), a regular increase in milk EC and milk somatic cell count was observed. Research indicates that dystocia significantly increases milk SCC. Dystocia had a significant effect on mastitis incidence in cows, particularly on mastitis caused by *S. aureus* and *S. agalactiae* [7]. The change in resting behavior observed when cows transition may have implications for the risk of lameness onset in early lactation [8]. An effect of lameness is superimposed on behavioral changes that can be regarded as a typical element of the parturition process [9]. Calving issues are connected with decreased survival, fertility and milk output [10].

As part of calving, changes in the pelvic ligaments allow the calf to be born more easily. These changes are not limited to the pelvis but affect the whole body, including the feet. These changes mean a calving cow is at increased risk of developing clinical lameness [15]. The typical lying and rising behavior of cattle is hampered by severe discomfort in lame cows. Mastitis is more likely in lame cows who spend more time lying down [16]. Bacterial contamination of the bedding might result in tarsal and udder infection [17]. Lameness in cows is associated with lower milk yield [18–22] and a worsening in their welfare [20]. The effects of lameness on a decrease in milk production and fertility have been fairly well described in the literature; however, little is known of their impact on somatic cell counts and milk composition [23,24].

In our past studies, we found that cows that did not experience calving problems had greater milk lactose concentrations, whereas higher-yielding cows had more calving problems than less productive ones [10].

While researching the literature, we discovered a scarcity of information on how calving difficulty affects cow lameness. We hypothesized that calving difficulty impacts the lameness status of cows and milk quality traits after calving. The aims of our study were to evaluate the associations between calving difficulty and lameness and their effects on milk yield and quality traits in fresh dairy cows.

2. Materials and Methods

2.1. Location and Animals

The experiment took place on 10 commercial Lithuanian dairy farms (each with approximately 450–500 Lithuanian black and white breed cows). The research was performed following the Law's Provisions on Animal Welfare and Protection of the Republic of Lithuania (study approval number: PK016965). A total of 4723 cows were kept in free housing system farms, without access to pasture. Milking was performed with Lely Astronaut A3 milking robots (Lely Campus, Maassluis, The Netherlands). Milking occurred 2.5–3 times a day on average, and this varied on parity. The milk yield and calving intervals were 35–45 kg/day and 390–400 days, respectively. In the study, milk yield (MY), milk lactose (ML), milk fat (MF), milk protein (MP), milk electrical conductivity (EC) and somatic cell count (SCC) from all quarters of the udders were registered with the help of Lely Astronaut® A3 milking robots each time the cow was milked. For the data analysis, we used the daily average of each parameter calculated from all milkings. These parameters were registered for fresh dairy cows (from day 1 to day 30 after calving).

All cows fed on a total mixed ration (TMR) simultaneously each day, balanced according to their physiological requirements. TMR was composed of 25% corn silage, 4% grass hay, 15% grass silage and 50% grain concentrate. The main nutritional characteristics are shown in Table 1.

Table 1. The characteristics of total mixed ration.

Dry Matter	48.8
Neutral detergent fiber (% of DM)	28.2%
Acid detergent fiber (% of DM)	19.8%
Non-fiber carbohydrates (% of DM)	38.7%
Crude protein (% of DM)	15.8%

2.2. Measurements

In the study, the calving status was scored between 2018 and 2020, as described by Jensen [25] in the herds of the Lithuanian Black and White Cattle Breeders Association.

A total of 4723 calving cases were assessed. The start of calving was identified based on the three-stage methodology for all cows, as described by Saint-Dizier and Chastant-Maillard (2015) [26]. The calving difficulty was evaluated using a 4-point scale system: (1) easy, unassisted; (2) easy, assisted; (3) difficult, assisted; (4) difficult, requiring veterinary assistance. The lactation number of the cows was $\geq$2 (2.9 $\pm$ 0.01). The different degrees of lameness in 333 fresh dairy cows (from 4723 cows in total) over the 2 years were diagnosed by staff based on the standard farm procedures. Lameness was scored twice a week using a locomotion scoring system from 1 to 30 days after calving. Cows in which signs of lameness were observed before calving were excluded from the study due to their low number. On each farm, lameness diagnoses were performed using the visual locomotion scale (VLS) by experienced staff, according to the standard procedure described by Sprecher et al. [27]: (1) Normal: The cow walks normally; (2) Uneven gait: The cow walks (almost) normally. In most cases, the back is flat when the cow is standing but arched when walking; (3) Mild lameness: Abnormal gait with short strides on 1 or more legs; (4) Lameness: the cow is obviously lame on 1 or more legs. Experienced staff involved the assessor observing a walking cow from the side and back twice a week until 30 days after calving.

In consequence, cows were classified into two groups—the HL group: non-lame cows; and the LA group: lame cows. No cows were lame at calving. All fresh dairy cows

(1–30 days after calving) were included in the study. The study included cows with severe calving that were later diagnosed with lameness. Other cows were excluded if they showed other signs of diseases, such as ketosis, metritis, "milk fever", retention placenta, etc.

2.3. Data Analysis and Statistics

The statistical assay was carried out using the SPSS 25.0 software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY, USA: IBM Corp.). The normal distribution of all indicators, such as MF, MP, ML, SCC and EC, was assessed using the Shapiro–Wilk normality test. Analysis of SCC was carried out with the logarithmic expression of this indicator: SCS = (log2 (SCC/100)) + 3. Normally distributed milk indicators were expressed as mean ± standard error of the mean (M ± SEM). Differences between the mean values of study groups were determined using Fisher's least significant difference (LSD) test.

We categorized cows by health status, i.e., lame (LA) and non-lame (HL) cows, and according to calving difficulty (CD) (on a 4-point scale: 1—no problem, 2—slight problem, 3—problems requiring assistance, 4—considerable force and extreme difficulty).

Chi-square test (χ^2) of independence was used to assess the relationship between the state of health of the cows and the classes of these indicators in milk. A probability of less than 0.05 was considered significant. Binary logistic regression was used to predict the risk of lameness in cows and the possible association with calving difficulty (calving difficulty = CD score 3–4; no assistance needed = CD score 1–2). The obtained results are presented as the odds ratio (OR) and at a 95% confidence interval (CI).

The effects of calving ease, lameness, herd and interactions on milk yield and quality traits were evaluated using the following linear model:

$$y_{ijkl} = \mu + Ci + Lj + Hk + CLij + CHik + LHjk + CLHijk + eijkl \quad (1)$$

where y_{ijkl} denotes the milk yield/fat/protein/lactose/urea/electrical conductivity/SCS on CD score *i*, lameness status of the cows *j* and herd *h* for cows *l*; μ denotes the population mean; *C* denotes the CD score; *L* denotes the lameness status of cows (lame or non-lame); H denotes the herd; *CL* denotes the interaction between *C* and *L*; *CH* denotes the interaction between *C* and *H*; *LH* denotes the interaction between *L* and *H*; *CLH* the denotes interaction between *C*, *L* and *H*; and e denotes a random effect.

Data on the productivity of cows were analyzed from day 1 to day 30 after calving. The tables and figures show the average values for 30 days for the groups of cows.

In our dataset, one animal had 1 calving record (total 4723 records in all herds) and an average of 78 records of milk parameters tested over 30 days (total 368,394 records).

3. Results

Lameness was diagnosed in 7.1% of the 4723 fresh dairy cows tested. Among the farms, this indicator ranged from 5.22 to 8.49 percent. (Figure 1).

The results from individual farms show that lameness was more common in farms with a higher percentage of calving difficulty (Figure 1). In the present study, calving difficulty was associated with a 2.09-fold higher risk of lameness in cows (95% CI = 1.644–2.650, $p < 0.001$).

The data in the second table confirm that severe lameness (3–4 points) (3.88–5.92% of cows) was more prevalent in those cows that had dystocia than in those that did not (0.27–2.37% of cows) (Table 2).

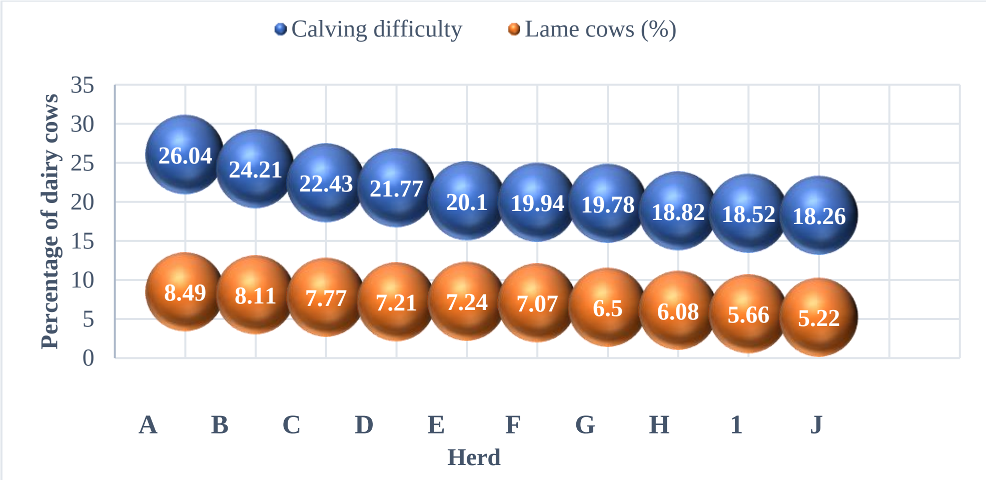

Figure 1. Percentage of dairy cows with dystocia at calving and lameness from 1 to 30 days after calving in different herds. A–J—Herd.

Table 2. Distribution of cows by lameness and calving difficulty.

Lameness Score	CD = 1		CD = 2		CD = 3		CD = 4	
	n	%	*n*	%	*n*	%	*n*	%
1	2116	93.46	1407	95.13	428	87.35	439	89.59
2	94	4.15	25	1.69	8	1.63	9	1.84
3	48	2.12	35	2.37	29	5.92	19	3.88
4	6	0.27	12	0.81	25	5.10	23	4.69

CD—calving difficulty; *n*—number of cows; Lameness score—(1) Normal: The cow walks normally; (2) Uneven gait: The cow walks (almost) normally. In most cases, the back is flat when the cow is standing but arched when walking; (3) Mild lameness: Abnormal gait with short strides on 1 or more legs; (4) Lameness: the cow is obviously lame on 1 or more legs [14].

It was found that the mean standard milk yield value was lower in fresh dairy cows with calving difficulty (−6.14 kg, $p < 0.001$) than in the group where no assistance was required at calving (Table 3). The data in Figure 2 confirm that the standard milk yields in all analyzed herds were significantly higher in cows where no assistance was required at calving.

Table 3. Milk yield and composition and somatic cell count in cows with calving difficulty and with no assistance needed at calving.

Trait	No Assistance Needed at Calving	Calving Difficulty	*p*
	M ± SEM	M ± SEM	
MY (kg)	32.19 ± 0.25	27.25 ± 0.13	<0.001
MF (%)	4.03 ± 0.01	4.27 ± 0.30	<0.001
MP (%)	3.52 ± 0.01	3.34 ± 0.01	<0.001
SMY	33.25 ± 0.25	27.11 ± 0.13	<0.001
ML (%)	4.68 ± 0.00	4.53 ± 0.01	<0.001
MU (mg/dL)	24.08 ± 0.14	24.47 ± 0.27	0.202
SCS *	1.89 ± 0.01	1.94 ± 0.02	0.002
EC (mS/cm)	4.84 ± 0.01	5.33 ± 0.02	<0.001

p and n.s. indicates the significance levels of the difference between the groups. MY: milk yield; MF: milk fat; MP: milk protein; SMY: standard milk yield (0.4 × MY + 15 × MF × MY); ML: milk lactose; MU: milk urea; EC: milk electric conductivity; SCS *: the logarithmic expression of somatic cell count in milk (SCC): SCS = (log2 (SCC/100)) + 3. No assistance needed at calving—cows without dystocia; Calving difficulty—cows with dystocia.

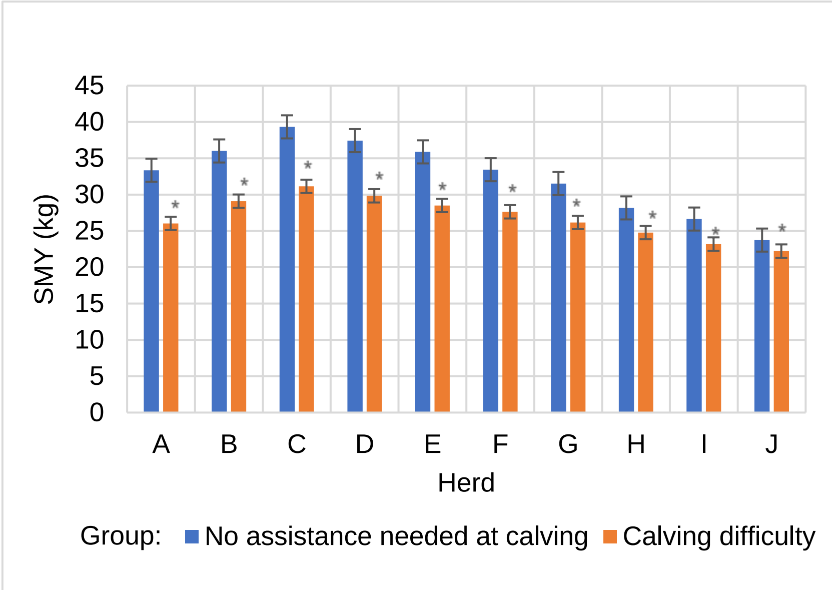

Figure 2. Standard milk yield of cows with and without assistance needed at calving from 1 to 30 days after calving in different herds. SMY: standard milk yield (0.4 × MY + 15 × MF × MY); Means within a herd that are marked with an * differ by $p < 0.05$. A–J—Herd.

On average, the daily milk yield was higher by 1.24 kg ($p = 0.007$), milk protein ($p = 0.044$) was higher by 0.04%, milk lactose was higher by 2.1% ($p < 0.001$) in non-lame cows as compared with lame cows, whereas no differences were observed in the mean fat content value between the groups. The number of somatic cells, CD, was lower in non-lame cows (Table 4).

Table 4. Milk yield and composition and somatic cell count in non-lame and lame cows.

Trait	Non-Lame Cows	Lame Cows	*p*
	M ± SEM	M ± SEM	
MY (kg)	28.36 ± 0.12	27.12 ± 0.44	0.007
MF (%)	4.08 ± 0.01	4.08 ± 0.05	0.070
MP (%)	3.48 ± 0.01	3.44 ± 0.02	0.044
SMY	28.485 ± 0.12	27.076 ± 0.45	0.003
ML (%)	4.67 ± 0.00	4.57 ± 0.01	<0.001
MU (mg/dL)	24.23 ± 0.13	23.30 ± 0.47	0.070
SCS *	1.89 ± 0.01	1.96 ± 0.03	0.021
EC (mS/cm)	4.921 ± 0.009	5.194 ± 0.031	<0.001

p indicates the reliability of the difference between the groups, and n.s. indicates that the difference is unreliable. MY: milk yield; MF: milk fat; MP: milk protein; MU: milk urea; SMY: standard milk yield (0.4 × MY + 15 × MF × MY); ML: milk lactose; EC: milk electric conductivity; SCS *: the logarithmic expression of somatic cell count in milk (SCC): SCS = (log2 (SCC/100)) + 3. The average milk lactose concentration in non-lame cows in the current study was 0.1% higher than in lame cows ($p = 0.04$). In the group of healthy cows, 8.2% more animals with ML ≥ 4.6% were observed.

In the current study, no significant differences were observed between non-lame and lame cows with regard to the level of MU, although the group of non-lame cows contained more (1.06%) animals with the lowest urea level (12.57% of cows with MU < 15 mg/dL) and fewer cows (3.34%) with the highest urea level (25.26% of cows with MU > 30 mg/dL).

We found that in the non-lame cow group, the electrical conductivity of the milk (EC) in all animals was 4−6 mS/cm; in the lame cow group, 45.35% of cows had EC < 4 mS/cm, and 54.65% of cows had EC > 6 mS/cm.

With regard to the effects of calving difficulty, lameness and herd on the quality traits of milk in cows (according to the results of the linear model), the ease of calving and lameness-related health status indicators were associated with the quality traits of the milk studied, except for the milk fat value (%). The impact of the herd factor was not significant for milk urea. The studied fixed factors exerted the most significant influence on milk protein, milk lactose and milk electrical conductivity (Table 5).

Table 5. Assessment of the statistical significance (*p*) of the effects of calving ease, lameness-related health status, herd and interactions on milk yield and quality traits in cows.

Milk Quality	Significance of Effects			Significance of Interactions				Model	
	CD	L	H	CD × L	CD× H	L ×H	CD × L × H	R^2	*p*
MY (kg)	<0.001	0.049	<0.001	<0.001	<0.001	0.033	0.154	0.957	<0.001
MF %	0.062	0.078	<0.001	0.003	0.232	0.993	0.695	0.962	<0.001
MP %	<0.001	<0.001	<0.001	<0.001	0.812	0.544	0.706	0.991	<0.001
ML %	<0.001	<0.001	<0.001	<0.001	0.203	0.632	0.123	0.998	<0.001
MU (mg/dL)	0.027	0.042	0.167	0.963	0.928	0.901	0.843	0.889	<0.001
SCS *	0.015	0.030	<0.001	0.038	0.006	0.868	0.621	0.944	<0.001
EC (mS/cm)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.990	<0.001

MY: milk yield; MF: milk fat; MP: milk protein; ML: milk lactose; MU: milk urea; SCS *: the logarithmic expression of somatic cell count in milk (SCC): SCS = (log2 (SCC/100)) + 3. C: milk electrical conductivity; CD: calving difficulty score (4 classes, fixed effect), L: health status of cows (healthy or lame cows, fixed effect), H: herd (10 herds, fixed effect). *p* = the significance of the influence of the effects (CD, L, H and their interaction) or the model (1). R^2 is the coefficient of determination of the model for the milk indicators.

The interaction between calving difficulty and cow health according to lameness had a significant influence ($p < 0.001$) on all milk quality traits, except for milk urea. This confirms the findings in Figures 1 and 2 that lameness events were likely to be more common in cows that had difficulty calving. The obtained results also confirm the data of Tables 1 and 2 that the milk yield and quality of the easily calved and non-lame cows were better. The interaction between calving difficulty and herd was significant for milk yield, milk somatic cells and electrical conductivity; the interaction between herd and lameness was significant for the cow's milk yield and electrical conductivity, and the interaction of all three factors was significant for the electrical conductivity of milk.

The milk yield of cows was mainly associated with the assessment of the calving process, herd and the interaction of calving difficulty × herd and calving difficulty × lameness ($p < 0.001$); fat content of milk (%)—with the herd ($p < 0.001$); milk protein (%) and milk lactose (%)—with the calving process, lameness, herd and the interaction between calving difficulty of milk with all the studied factors and their interactions ($p < 0.001$).

4. Discussion

According to the results of our study, lameness occurred in 3.88–5.92% of cows with dystocia and 0.27–2.37% of cows without dystocia.

Calving is a trigger where lameness was shown to be substantially more prevalent in the early stages of lactation than in the later stages of lactation [28]. Glucose production by hepatic gluconeogenesis and reduced oxidation of glucose in peripheral tissues are the key physiological alterations during early lactation. During this time, keeping cows on a high-concentrate diet leads to hyperinsulinemia and hyperglycemia, conditions in which insulin resistance develops, leading to blockage of glucose and amino acid intake, resulting in poor-quality hoof horn [28]. However, Hendry et al. (1999) discovered that additional variables, such as epidermal growth factor (EGF), relaxin, prolactin and cortisol levels during late gestation, cause the formation of poor-quality keratin, increasing the chance of lameness during late lactation [29].

According to the results of our study, we found that lameness is more common in calving difficulty. Lameness is a symptom of pain caused by an injury or disease of the feet or legs [30]. The transition phase, which occurs around the time of calving, has been identified as an essential risk period, with higher stress due to physiological changes, social variables and changes in housing that influence the chance of lameness occurring (Bergsten et al., 2015) [31]. Lameness is a matter requiring attention due to its high prevalence and link to pain [30]. The observed shift in resting behavior pattern when cows transition may have implications for the probability of lameness onset in early lactation. Non-inflammatory alterations in the connective tissue of the corium of the foot occur in periparturient cattle, impairing their resilience to external stressors at this key time [32]. Any decrease in rest may contribute to the loading stress that the hoof is subjected to, hence exacerbating the severity of the lesion that develops. Lameness may be a cause of central sensitization and central nervous system winding-up, and the observed behavioral response is consistent with the hypothesis that lame cows are actually susceptible to painful stimuli [30]. According to Calderon et al. (2011) [33], lame cows had longer lying periods during the transition period, and they had considerably more lying bouts per day for 3 days before and after calving than non-lame cows.

According to our results, the daily milk yield average was higher by 1.24 kg, milk protein) was higher by 0.04%, milk lactose was higher by 2.1% in non-lame cows as compared with lame cows. These data imply that lameness during early lactation may have a negative impact on the milk supply during that lactation. The fact that there is a positive relationship between lameness and milk output during early lactation shows that high production is a risk factor for lameness [34].

We found that the milk quality, according to the number of somatic cells, was better in non-lame fresh dairy cows (from day 1 to day 30 after calving) ($p < 0.05$). Lame cows exhibited a higher milk somatic cell count (SCC) than non-lame cows, indicating a higher risk of mastitis. Due to the close vicinity of underfloor sludge, increased lying time in lame cows may have exposed their udders to numerous intramammary illnesses [35]. The immune system's response to a mammary gland infection is critical for the health of the dairy cow. Harmon (1994) [36] discovered that an increase in milk SCC is caused by the migration of polymorphonuclear cells from blood arteries to the mammary gland in response to inflammatory mediator release. According to research, this mechanism may be comparable in animals suffering from subclinical mastitis, which causes low reproductive performance [37]. Dystocia also has a negative impact on milk quality. When the calving difficulty score was 4 or higher, the somatic cell count in milk samples increased by 3–3.5-fold [7]. Similarly, Olechnowicz and Jacekowski (2010) [38] showed that elevated milk SCC counts in clinically or severely lame cows were most likely caused by subclinical mastitis or lameness, as well as their synergistic stressful effect. However, in a following investigation, lameness was found to alter milk composition in crossbred dairy cattle. Olechnowicz and Jacekowski (2010) found a substantial decrease in mean monthly milk output, as well as fat, protein and lactose production, in cows with clinical lameness compared to non-lame cows [38]. Ref. [38] observed considerably decreased mean monthly fat, protein and lactose production in lame cows compared to non-lame cows, owing to stress, pain, increased oxidative agents and poor absorption and assimilation of various nutrients from the daily food due to lameness. Olechnowicz and Jacekowski (2010 [38] discovered that clinically lame animals had considerably lower milk protein content than healthy cows in their subsequent testing.

In the study of Refaai et al. (2017) [39], infectious claw disorders, such as digital dermatitis (DD), heel horn erosion (HHE) and interdigital dermatitis (IDD), were significantly associated with the occurrence of subclinical intramammary infections (IMI), which are diagnosed by CMT in dairy cows and may influence the chance of IMI. Their findings were in accordance with those of Hagiya et al. [40] who found positive genetic correlations between SCC with mastitis and the incidence of claw disorders, suggesting that reducing SCC in the early stages of lactation would decrease the quantity of both mastitis and claw disorder cases. Similar findings were reported by Sato et al. [41], who described that clinical mastitis was associated with claw problems. Sogstad et al. [16] came to a similar conclusion, i.e., that claw and hock lesions are associated with poorer reproductive performance and certain production diseases, such as mastitis. On the other hand, various clinical findings showed that non-infectious claw disorders have no significant association with subclinical IMI. This is in agreement with Hultgren et al. [42] who were unable to find a significant association between SU and various reproductive disorders, such as clinical mastitis and high milk somatic cell counts. One of the possible explanations is that non-infectious claw disorders have non-infectious causes, such as mechanical, chemical or physical triggers [43]. On the other hand, infectious claw disorders, such as DD, are infectious in nature and are caused by infectious pathogens, such as Bacteroides and Treponema species or *Fusobacterium necrophorum*. Such pathogens activate the cow's immune system response to a greater extent than non-infectious claw disorders. Thus, in the case of infectious claw disorders, the immune system may suppress the general immune response, which subsequently provides favorable conditions for pathogens in the udder, causing subclinical IMI [43].

It is also hypothesized that a higher locomotor score (a more severe degree of lameness) is related to a worsening overall health status and a weaker immune system, making the cow more susceptible to additional infections. Furthermore, it was discovered that the forelimbs were less impacted by claw problems than the hind limbs. Because claw lesions in the rear limbs are closer to the mammary tissue than claw lesions in the forelimbs, they are hypothesized to cause a higher prevalence of mastitis [39].

The average concentration of lactose in milk in the non-lame cow group was 0.10% higher than in the lame cow group ($p < 0.05$). Milk lactose concentration decreases during inflammation. In many cases, this can be useful for the detection of mastitis and certain metabolic disorders [44]. In general, the term lameness describes a systemic disease affecting the hooves and the general condition of the animal. Research data indicate that the inflammation is primarily associated with a dysfunction of the digital vasculature system, resulting in hypoxia and malnutrition of the vulnerable laminar structure in the hoof wall [45]. In equine experimental models, lameness can be easily provoked by supplementing the feed with excess carbohydrates, whether it be fed voluntarily or infused. The same methods have not been successfully adapted in bovine experiments, but challenging diets have been used to provoke lameness symptoms and claw horn lesions (in an approximate sense). Researchers have used claw horn lesions as retrospective tools to estimate the influence of various lameness risk factors [46]. In one paper, a separate diet with restricted forage resulted in 68% of the cows developing clinical lameness symptoms at calving, followed by 64% of them developing sole ulcers in the subsequent 2–3 months [47].

5. Conclusions

Our study investigated the relationship between ease of calving and lameness and its influence on milk quality traits in fresh dairy cows. We found that lameness occurred in 3.88–5.92% of cows with dystocia and 0.27–2.37% of cows without dystocia.

Lame cows had a greater incidence of dystocia than non-lame cows. Dystocia was more common in fresh dairy cows with more severe (3–4 points) lameness than in cows with easy calving. We found that severe lameness (3–4 points) was more prevalent in those cows that had calving difficulty than in those that did not. In the present study, calving difficulty increased the risk of lameness in cows by 2.09-fold. It was confirmed that the standard milk yields in all analyzed herds were significantly higher in cows with calving difficulty. The average milk lactose concentration in non-lame cows in the current study was higher (0.10%) than in lame cows. As was observed in almost all the analyzed herds, the milk yield of lame cows was lower than that of non-lame cows. With regard to the effect of ease of calving, lameness and herd on milk quality traits, the indicators of ease of calving and lameness-related health status affected the quality traits of the milk studied, except for the milk fat value (%). The studied fixed factors exerted the most significant influence on milk protein, milk lactose and milk electrical conductivity. According to lameness, the interaction between calving difficulty and cow health significantly influenced ($p < 0.001$) all milk quality traits, except for milk urea. From a practical point, we can suggest that with identification and treatment of lameness, we can decrease dystocia and improve milk quality. It can be a great advantage for the farmers to improve the health of their herds.

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References

1. Barrier, A.C.; Haskell, M.J. Calving difficulty in dairy cows has a longer effect on sale able milk yield than on estimated milk production. *J. Dairy Sci.* **2011**, *94*, 1804–1812. [CrossRef]
2. Lombard, J.E.; Garry, F.B.; Tomlinson, S.M.; Garber, L.P. Impacts of dystocia on health and survival of dairy calves. *J. Dairy Sci.* **2007**, *90*, 1751–1760. [CrossRef] [PubMed]
3. Atashi, H.; Abdolmohammadi, A.; Dadpasand, M.; Asaadi, A. Prevalence, risk factors and consequent effect of dystocia in Holstein dairy cows in Iran. *J. Anim. Sci.* **2012**, *25*, 447. [CrossRef] [PubMed]
4. Tenhagen, B.A.; Helmbold, A.; Heuwieser, W. Effect of various degrees of dystocia in dairy cattle on calf viability, milk production, fertility and culling. *J. Vet. Med.* **2007**, *54*, 98–102. [CrossRef] [PubMed]
5. Dematawewa, C.M.B.; Berger, P.J. Effect of dystocia on yield, fertility, and cow losses and an economic evaluation of dystocia scores for Holsteins. *J. Dairy Sci.* **1997**, *80*, 754–761. [CrossRef]
6. Rajala, P.J.; Grohn, Y.T. Effects of dystocia, retained placenta, and metritis on milk yield in dairy cows. *J. Dairy Sci.* **1998**, *81*, 3172–3181. [CrossRef]
7. Thompson, J.R.; Pollak, E.J.; Pelissier, C.L. Interrelationships of parturition problems, production of subsequent lactation, reproduction, and age at first calving. *J. Dairy Sci.* **1983**, *66*, 1119–1127. [CrossRef]
8. Valde, J.P.; Hird, D.W.; Thurmond, M.C.; Østerås, O. Comparison of ketosis, clinical mastitis, somatic cell count, and reproductive performance between free stall and tie stall barns in Norwegian dairy herds with automatic feeding. *Acta Vet. Scand.* **1997**, *38*, 181–192. [CrossRef]
9. Washburn, S.P.; White, S.L.; Green, J.T., Jr.; Benson, G.A. Reproduction, mastitis, and body condition of seasonally calved Holstein and Jersey cows in confinement or pasture systems. *J. Dairy Sci.* **2002**, *85*, 105–111. [CrossRef]
10. Antanaitis, R.; Juozaitienė, V.; Malašauskienė, D.; Televičius, M.; Urbutis, M.; Baumgartner, W. Influence of Calving Ease on In-Line Milk Lactose and Other Milk Components. *Animals* **2021**, *11*, 842. [CrossRef]
11. Taylor, V.J.; Beever, D.E.; Wathes, D.C. *Physiological Adaptations to Milk Production That Affect the Fertility of High Yielding Dairy Cows*; British Society of Animal Science Occasional Publication No. 29; Nottingham University Press: Nottingham, UK, 2004; pp. 33–71.
12. Wathes, D. Mechanisms linking metabolic status and disease with reproductive outcome in the dairy cow. *Reprod. Dom. Anim.* **2012**, *47*, 304–312. [CrossRef] [PubMed]
13. Leroy, J.L.; Vanholder, T.; van Knegsel, A.T.; Garcia-Ispierto, I.; Bols, P.E. Nutrient prioritization in dairy cows early postpartum: Mismatch between metabolism and fertility? *Reprod. Domest. Anim.* **2008**, *43*, 96–103. [CrossRef] [PubMed]
14. Pyörälä, S. Indicators of inflammation in the diagnosis of mastitis. *Vet. Res.* **2003**, *34*, 565–578. [CrossRef] [PubMed]
15. Lean, I.J.; Westwood, C.T.; Golder, H.M.; Vermunt, J.J. Impact of nutrition on lameness and claw health in cattle. *Livest. Sci.* **2013**, *156*, 71–87. [CrossRef]
16. Sogstad, A.M.; Osteras, O.; Fjeldaas, T. Bovine claw and limb disorders related to reproductive performance and production diseases. *J. Dairy Sci.* **2006**, *89*, 2519–2528. [CrossRef]
17. McPherson, S. Making stall beds more comfortable: The effect of longitudinal space and deep-bedding on the comfort and welfare of tie-stall-housed dairy cows. *J. Dairy Sci.* **2020**, *103*, 10940–10950. [CrossRef]
18. Archer, S.C.; Green, M.J.; Huxley, J.N. Association between milk yield and serial locomotion score assessments in UK dairy cows. *J. Dairy Sci.* **2010**, *93*, 4045–4053. [CrossRef]
19. Ettema, J.F.; Capion, N.; Hill, A.E. The association of hoof lesions at claw trimming with test-day milk yield in Danish Holsteins. *Prev. Vet. Med.* **2007**, *79*, 224–243. [CrossRef]

20. Green, L.E.; Borkert, J.; Monti, G.; Tadich, N. Associations between lesion-specific lameness and the milk yield of 1635 dairy cows from seven herds in the Xth region of Chile and implications for management of lame dairy cows worldwide. *Anim. Welfare* **2010**, *19*, 419–427.
21. Reader, J.D.; Green, M.J.; Kaler, J.; Mason, S.A.; Green, L.E. Effect of mobility score on milk yield and activity in dairy cattle. *J. Dairy Sci.* **2011**, *94*, 5045–5052. [CrossRef]
22. Singh, Y.; Lathwall, S.S.; Chakravarty, A.K. Effect of lameness (hoof dis-orders) on productivity of Karan Fries crossbred cows. *Anim. Sci. J.* **2011**, *82*, 169–174. [CrossRef] [PubMed]
23. Archer, S.C.; Green, M.J.; Madouasse, A.; Huxley, J.N. Association between somatic cell count and serial locomotion score assessments in UK dairy cows. *J. Dairy Sci.* **2011**, *94*, 4383–4388. [CrossRef] [PubMed]
24. Pavlenko, A.; Bergsten, C.; Ekesbo, I.; Kaart, T.; Aland, A.; Lidfors, L. Influence of digital dermatitis and sole ulcer on dairy cow behaviour and milk pro-duction. *Animal* **2011**, *5*, 1259–1269. [CrossRef] [PubMed]
25. Jensen, M.B. Behaviour around the time of calving in dairy cows. *Appl. Anim. Behav. Sci.* **2012**, *139*, 195–202. [CrossRef]
26. Saint-Dizier, M.; Chastant-Maillard, S. Methods and on-farm devices to predict calving time in cattle. *Vet. J.* **2015**, *205*, 349–356. [CrossRef]
27. Sprecher, D.E.A.; Hostetler, D.E.; Kaneene, J.B. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. *Theriogenology* **1997**, *47*, 1179–1187. [CrossRef]
28. Green, L.E.; Huxley, J.N.; Banks, C.; Green, M.J. Temporal associations between low body condition, lameness and milk yield in a UK dairy herd. *Prev. Vet. Med.* **2014**, *11*, 63–71. [CrossRef]
29. Hendry, K.A.; Maccallum, A.J.; Knight, C.H.; Wilde, C.J. Effect of endocrine and paracrine factors on protein synthesis and cell proliferation in bovine hoof tissue culture. *J. Dairy Res.* **1999**, *66*, 23–33. [CrossRef]
30. Whay, H.R.; Jan, K.S. The impact of lameness on welfare of the dairy cow. *Vet. Clin. N. Am. Food Anim. Pract.* **2017**, *33*, 153–164. [CrossRef]
31. Bergsten, C.; Telezhenko, E.; Ventorp, M. Influence of Soft or Hard Floors before and after First Calving on Dairy Heifer Locomotion, Claw and Leg Health. *Animals* **2015**, *5*, 662–686. [CrossRef]
32. Knott, L.; Tarlton, J.F.; Craft, H.; Webster, A.J.F. Effects of housing, parturition and diet change on the biochemistry and biomechanics of the support structures of the hoof of dairy heifers. *Vet. J.* **2007**, *174*, 277–287. [CrossRef] [PubMed]
33. Calderon, D.F.; Cook, N.B. The effect of lameness on the resting behavior and metabolic status of dairy cattle during the transition period in a freestall-housed dairy herd. *J. Dairy Sci.* **2011**, *94*, 2883–2894. [CrossRef] [PubMed]
34. Ristevski, M.; Toholj, B.; Cincović, M.; Trojačanec, P.; Starič, J.; Smolec, O. Milk production, body condition score and metabolic parameters at the peak of lactation as risk factors for chronic lameness in dairy cows. *Kafkas Üniv. Vet. Fak. Derg.* **2017**, *23*, 721–727.
35. Ekesbo, I. The impact of feeding and drinking management, and bedding and waste management, on animal health, welfare and performance. In *Livestock Housing: Modern Management to Ensure Optimal Health and Welfare of Farm Animals*; Wageningen Academic Publishers: Wageningen, The Netherlands, 2013; p. 115.
36. Harmon, R.J. Physiology of mastitis and factors affecting somatic cell counts. *J. Dairy Sci.* **1994**, *77*, 2103–2112. [CrossRef]
37. Rainard, P.; Riollet, C. Mobilization of neutrophils and defense of the bovine mammary gland. *Reprod. Nutr. Dev.* **2003**, *43*, 439–457. [CrossRef]
38. Olechnowicz, J.; Jaskowski, J.M. Impact of clinical lameness, calving season, parity, and month of lactation on milk, fat, protein, and lactose yields during early lactation of dairy cows. *Bull Vet. Inst. Pulawy* **2010**, *54*, 605–610.
39. Refaai, W.; Gad, M.; Mahmmod, Y. Association of claw disorders with subclinical intramammary infections in Egyptian dairy cows. *Vet. World* **2017**, *10*, 358. [CrossRef]
40. Hagiya, K.; Yamazaki, T.; Nagamine, Y.; Togashi, K.; Yamaguchi, S.; Gotoh, Y.; Kawahara, T.; Masuda, Y.; Suzuki, M. Genetic correlations between production and disease traits during first lactation in Holstein cows. *Animal* **2014**, *8*, 217–223. [CrossRef]
41. Sato, K.; Bartlett, P.C.; Alban, L.; Agger, J.F.; Houe, H. Managerial and environmental determinants of clinical mastitis in Danish dairy herds. *Acta Vet. Scand.* **2008**, *50*, 4. [CrossRef]
42. Hultgren, J.; Manske, T.; Bergsten, C. Associations of sole ulcer at claw trimming with reproductive performance, udder health, milk yield, and culling in Swedish dairy cattle. *Prev. Vet. Med.* **2004**, *62*, 233–251. [CrossRef]
43. Bay, V. *A Study on the Role of the Foot Skin Microbiome and the Host's Genetics in the Development of Lameness Causing Foot Lesions in Dairy Cattle*; The University of Liverpool: Liverpool, UK, 2018.
44. Bansal, B.K.; Hamann, J.; Grabowski, N.T.; Singh, K.B. Variation in the composition of selected milk fraction samples from healthy and mastitic quarters, and its significance for mastitis diagnosis. *J. Dairy Res.* **2005**, *72*, 144–152. [CrossRef] [PubMed]
45. Bergsten, C. Causes, risk factors, and prevention of laminitis and related claw lesions. *Acta Vet. Scand.* **2003**, *44*, 1–10. [CrossRef] [PubMed]
46. Faye, B.; Lescourret, F. Environmental factors associated with lameness in dairy cattle. *Prev. Vet. Med.* **1989**, *7*, 267–287. [CrossRef]
47. Mason, W.A.; Laven, L.J.; Laven, R.A. An outbreak of toe ulcers, sole ulcers and white line disease in a group of dairy heifers immediately after calving. *N. Z. Vet. J.* **2012**, *60*, 76–81. [CrossRef]