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# Relationships among clinical mastitis test-day records, somatic cell counts, and linear udder conformation traits in Czech dairy cows

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**Abstract:** This study evaluated test-day records of clinical mastitis (CM), somatic cell count, and nine udder conformation traits. Somatic cell count was log-transformed into somatic cell score (SCS) in 10 periods, each 30 days long and overall, for the first lactation. CM is a complex disease closely connected with somatic cell count. The optimum udder conformation traits significantly affect dairy cattle health. The CM binary trait was monitored in seven periods throughout lactation, each 50 days long, and for the whole lactation. A logistic regression model was used to estimate the risk of CM. The model included a fixed effect of herd-year-season, age at first calving, and a fixed effect of the linear type traits of the random effect of the animal. The phenotypic correlations for udder conformation traits, CM, and SCS ranged from −0.13 to 0.69 and standard errors were 0.01–0.99. The highest CM incidence and SCS were observed for the medial ligament scores 1–2: convex base of the udder. According to the logistic regression assessment, the medial ligament scores 1–2: convex base of the udder and the CM incidence to 50 days in milk reported a 3.79 times higher probability of the CM incidence at the reference level (extremely deep medial ligament) at the same stage of the lactation. CM incidence and SCS significantly decreased with decreasing udder depth. Udder depth below the hock was associated with the highest risk of CM. For udder depth and the whole lactation, the CM ODDS ratio was 1.00–2.56, CM least squares means were 0.18–0.44, and SCS least squares means were 3.20–4.10. Our study confirmed that the start of lactation is critical for the onset of CM, and somatic cell count is manifested throughout lactation. The effect of the udder conformation is then observable in somatic cell count and CM during the whole lactation.

**Keywords:** dairy farming; Holstein; phenotypic relationship; udder health

Clinical mastitis (CM) is a complex disease defined as an inflammation of the mammary gland resulting from introducing and multiplying pathogenic microorganisms (Heringstad et al. 2000). CM is characterised by swelling or pain in the udder, milk with abnormal appearance, and, in some

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cases, increased rectal temperature, lethargy, loss of appetite, and even death (Harmon 1994). Milk yields were dramatically affected (Seegers et al. 2003) and did not return to the previous level after treatment (Rajala-Schultz et al. 1999). If mastitis was not cured, it had a long-lasting effect overlapping to the next lactation. CM is the main reason for using antimicrobials on dairy farms (Ferronatto et al. 2018). A current animal breeding program has to face several challenges, including the sustainability of livestock production and its impact on climate change, animal welfare, and the quality of animal products (Gross and Bruckmaier 2019). The European Commission will aim to reduce sales of antimicrobials for farmed animals and in aquaculture by 50% by 2030 (European Commission 2020).

Intensive selection for high milk yields caused a higher risk of udder health problems (Bertulat et al. 2017). Cows with high milk yields are more susceptible to health disorders and intramammary infections (Zavadilova et al. 2015). The breeding program in Czech Holstein cows included selection for better resistance to mastitis through somatic cell score (SCS) and several udder conformation traits by a multilinear animal model (Zavadilova et al. 2021). The index combines relative breeding values for the CM incidence in the first parity cows, CM for cows in the other lactations, and SCS elevated across the first three lactations (Zavadilova et al. 2021). The selection for CM and improving udder health is difficult because of weak heritability 0.01–0.09 (Martin et al. 2018). This trait is under polygene control (Sender et al. 2013), and improving udder health based on finding and selecting genes related to CM resistance is a long-term goal with cumulative and permanent effects (Dube et al. 2009). Udder depth and the other udder conformation traits were moderately correlated with a maximum of 0.44 and a minimum of –0.23 (Nemcova et al. 2011). Cows with genetically weak fore udder attachment had a high risk of CM because of deep udders. Estimated phenotypic correlations were 0.44 between fore udder attachment and udder depth and 0.46 between rear udder height and rear udder width (Nemcova et al. 2011). Phenotypic correlations of udder disorders were from –0.13 (for CM and rear udder height) to 0.05 (SCS and teat width) (Lund et al. 1994). CM could be linked with increased SCS, but the opposite is true. On the other hand, a negative phenotypic correlation was found between lactation mean SCS and milk yield, which was –0.08 (Castillo-Juarez et al. 2002). Somatic cell count and milk yields were low or moderately correlated after and before the CM case (Koivula et al. 2005).

As apparent from the literature overview, mastitis is a big problem in modern dairy farming, and prevention measures such as correct udder conformation might be an effective way to improve udder health in general populations. The study aimed to analyse the phenotypic relationship between clinical mastitis incidences and somatic cell scores to udder conformation traits and body condition scores based on linear models and logistic regression.

## MATERIAL AND METHODS

The study was conducted in accordance with the Czech legislation for the protection of animals against cruelty (Act No. 246/1992) and with the Directive 2010/63/EU on the protection of animals used for scientific purposes. The data were collected as part of a routine milk recording system. It applies that this type of research does not impact animal welfare because procedures do not stress or hurt the animals and there was no additional interaction with the animal caused by the experiment. It was supported by the Ministry of Education, Youth and Sports (Project No. SV24-14-21360) and Ministry of Agriculture of the Czech Republic (Project No. QK1910320), and Institutional Support (Support No. MZe-RO0723).

### Animals and management

The dataset included 17 622 Czech Holstein primiparous cows and crossbreds with 75% or more of Holstein breed. The source of data on clinical mastitis (CM) was the long-term cooperation between the Institute of Animal Science in Prague and agricultural enterprises. The continually created dataset on health traits was used to estimate genetic parameters for CM and economic weights of CM in several analyses (Wolfova et al. 2006; Wolf et al. 2010; Zavadilova et al. 2015). CM was defined as the veterinary treatment of udder diseases with antibiotics. CM was recorded in six herds from the Czech Republic from 1993 to 2020. These farms were included in the study because of detailed CM

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monitoring on farms and they were not randomly chosen. The number of cows on farms differed, and the farms were from various regions in the Czech Republic. All farms had feeding a total mixed ration, straw bedding, and milking twice a day.

## Experimental design

The somatic cell count (SCC) data source was the official animal recording on dairy farms in the Czech Republic. The scoring of udder conformation traits on a nine-point scale was evaluated based on a methodology published by the Holstein Cattle Breeders Association of the Czech Republic (Holstein Cattle Breeders Association of the Czech Republic 2009). It involves fore udder attachment, front teat placement, teat length, udder depth, rear udder height, medial ligament, rear teat placement, udder width, and body condition.

The exterior traits were evaluated on a nine-point scale using the linear description system. Cows were evaluated from 30 to 210 days after the first calving. SCC was log-transformed into somatic cell score (SCS) using a formula:

$$\text{SCS} = \log_2(\text{SCC}/100) + 3 \quad (1)$$

where:
SCS – somatic cell score;
SCC – somatic cell count.

SCS was observed in 10 periods in the first lactations, 30 days long. The logarithmic mean of somatic cell score (LSCS) for the lactation was used. LSCS is based on the values of the number of somatic cells measured for individual lactations on control days, minimally from five values.

## Statistical analysis

Clinical mastitis (CM) was considered an all-or-none trait with 0 (no CM case) and 1 (at least 1 CM case). CM was assessed in seven periods throughout lactation, 50 days long, and for the whole lactation. Each CM record was characterised by the beginning and the end of CM, including data on the cow. A linear animal model was used to estimate the effects of udder conformation traits on SCS. A logistic regression model was used to estimate the levels of effects on CM. The evaluation of the data, the least squares means (LSMEANS) and correlations for CM and SCS were performed in SAS software v9.4 (SAS/STAT; SAS Institute Inc. Cary, NC, USA) by GLM and CORR procedures. Datasets were analysed using the DMU package (Maia et al. 2013) for the logistic regression model.

## Model equations

The generalised linear model:

$$Y_{ijk} = \text{HYS}_i + \text{AGE-CLASSES}_j + \text{EXTERIOR}_k + e_{ijk} \quad (2)$$

where:
$Y_{ijk}$ – CM incidence and SCS;
$\text{HYS}_i$ – fixed effect of the herd-year-season [created by merging the effects of 6 herds, 17 years of calving (1993–2020) and 4 seasons of calving, which was divided into four categories according to the months of January–March, April–June, July–August, October–December];
$\text{AGE-CLASSES}_j$ – fixed effect of the first calving (divided into six categories by one hundred days from 550 to 1 250 days);
$\text{EXTERIOR}_k$ – FUA (fore udder attachment); FTP (front teat placement); TL (teat length); UD (udder depth); RUH (rear udder height); ML (medial ligament); RTP (rear teat placement); UW (udder width); BCS (body condition score);
$e_{ijk}$ – residual error.

Significance levels $P < 0.01$ and $P < 0.05$ were used to evaluate statistical significance.

The logistic regression model:

$$\text{Log}\frac{\pi_{ijkl}}{1-\pi_{ijkl}} = \text{HYS}_i + \text{AGE-CLASSES}_j + \text{EXTERIOR}_k + \text{individual}_l + e_{ijkl} \quad (3)$$

where:
$\pi_{ijkl}$ – odds ratio for CM incidence;
$\text{individual}_l$ – a random effect considering the pedigree (the pedigree used in the estimation involved 24 499 animals);
$e_{ijkl}$ – residual error.

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For the description of effects see Equation (1). Significance levels $P < 0.01$ and $P < 0.05$ were used to evaluate statistical significance.

### Score definition and description of udder conformation traits

Fore udder attachment – score 2: weak and loose fore udder attachment with bulging fore quarters (combined score one and score two), score 3: weak fore udder attachment, score 4: intermediate acceptable fore udder attachment, the attachment to the abdominal wall is not smooth, score 5: intermediate proper fore udder attachment, score 6: intermediate adequate fore udder attachment, score 7: strong and tight fore udder attachment tightly adjacent to the abdominal wall and score 8: extremely strong and tight, significantly flat attachment to the abdominal wall (combined score eight and score nine).

Front teat placement – score 2: front teats outside the quarter on the lateral side (combined score one and score two), score 3: front teats outside the quarter, score 4: front teats in the middle of the quarter, score 5: front teats in the middle of the quarter, score 6: front teats in the middle of the quarter, score 7: front teats inside the quarter closer to the intermammary groove (medial ligament) and score 8: front teats inside the quarter very close to the intermammary groove (combined score eight and score nine).

Teat length – score 2: very short front teats (combined score one and score two), score 3: short front teats, score 4: short front teats, score 5: intermediate front teats, score 6: intermediate front teats, score 7: longer front teats and score 8: very long front teats (combined score eight and score nine).

Udder depth – score 2: the lowest part of the udder below the hock (combined score one and score two), score 3: bottom line 3 cm below the hock, score 4: bottom line 6 cm below the hock, score 5: bottom line 9 cm below the hock, score 6: bottom line 11.5 cm below the hock, score 7: bottom line 15 cm below the hock and score 8: bottom line 21 cm below the hock – shallow udder (combined score eight and score nine).

Rear udder height – score 2: very low rear udder height (combined score one and score two), score 3: very low rear udder height, score 4: intermediate rear udder height (udder attachment at reference point), score 5: intermediate rear udder height, score 6: intermediate rear udder height, score 7: higher rear udder height, score 8: high rear udder height and score 9: very high rear udder height.

Medial ligament – score 2: convex to the flat floor from +1 cm to +0.5 cm, score 3: convex to the flat bottom +0 cm, score 4: slight definition –1 cm, score 5: slight definition –2 cm, score 6: slight definition –3 cm, score 7: deep definition –4 cm, score 8: deep definition –5 cm, score 9: deep definition –6 cm.

Rear teat placement – score 2: rear teats outside the quarter (combined score one and score two), score 4: rear teats in the middle of the quarter, score 5: rear teats in the middle of the quarter, score 6: rear teats in the middle of the quarter, score 7: rear teats inside the quarter (touching teats), score 8: rear teats inside the quarter (crossing teats) (combined score eight and score nine).

Udder width – score 3: udder width 6–8 cm (combined score one, score two and score three), score 4: udder width 8–9 cm, score 5: udder width 9–9.5 cm, score 6: udder width 10 cm, score 7: udder width 10.5 cm, score 8: udder width 11 cm and score 9: udder width 12 cm (combined score eight and score nine).

Body condition – score 3: body condition score 1–2 (combined score one, score two and score three), score 4: body condition score 2–2.5, score 5: body condition score 2.5–3, score 6: body condition score 3–3.5, score 7: body condition score 3.5–4 and score 8: body condition score 5 (combined score eight and score nine).

## RESULTS AND DISCUSSION

The clinical mastitis (CM) incidence was the highest immediately after calving, at 0.10 (Table 1). The CM incidence for the whole lactation was 0.23. The highest phenotypic correlation with the whole lactation ($r = 0.59$, $P < 0.01$) occurred for the CM incidence in the first period after calving (Table 1). Phenotypic correlations among the CM incidences in different lactation stages were from –0.01 to 0.15 (Table 2). It agrees with common knowledge that dairy cows are often more susceptible to mastitis during the post-partum period (Gasparik et al. 2022). The average somatic cell score (SCS) [Electronic Supplementary Material (ESM) Table S1] did not show a significant trend

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Table 1. Clinical mastitis (CM) incidence and phenotypic correlations between CM incidence in different lactation stages in days in milk and CM incidence for the whole lactation

| Days in milk | *n* | Cases of CM | CM incidence | Phenotypic correlations |
|---|---|---|---|---|
| to 50 | 17 544 | 1 678 | 0.10 | 0.59 |
| 51–100 | 17 314 | 546 | 0.03 | 0.38 |
| 101–150 | 16 999 | 455 | 0.03 | 0.36 |
| 151–200 | 16 671 | 387 | 0.02 | 0.35 |
| 201–250 | 16 237 | 359 | 0.02 | 0.35 |
| 251–300 | 12 666 | 270 | 0.02 | 0.34 |
| 301–350 | 6 345 | 266 | 0.04 | 0.35 |

All correlations are significant at $P < 0.01$

Table 2. Phenotypic correlations for the clinical mastitis incidence in different lactation stages by 50 days in milk

| Days in milk | 51–100 | 101–150 | 151–200 | 201–250 | 251–300 | 251–300 |
|---|---|---|---|---|---|---|
| to 50 | 0.10 | 0.06 | 0.05 | 0.03 | 0.02* | –0.01 |
| 51–100 | – | 0.14 | 0.10 | 0.04 | 0.03 | 0.01$^{ns}$ |
| 101–150 | – | – | 0.14 | 0.08 | 0.09 | 0.03* |
| 151–200 | – | – | – | 0.15 | 0.08 | 0.05 |
| 201–250 | – | – | – | – | 0.13 | 0.07 |
| 251–300 | – | – | – | – | – | 0.13 |

All correlations are significant at $P < 0.01$, except $^*P < 0.05$
ns = not significant

during lactation. The highest SCS value during lactation stages was at the end of lactation (3.31). The logarithmic mean of somatic cell counts for the whole lactation (LSCS) was 3.38. Phenotypic correlations between SCS in different lactation stages and LSCS were from 0.48 to 0.69 (ESM Table S1). SCS correlations among lactation stages, 30 days long, ranged from 0.18 to 0.59 (ESM Table S2). Higher correlations were observed for SCS between consecutive lactation stages and LSCS.

Phenotypic correlations for CM and SCS were low and ranged from 0.01 to 0.29 (ESM Table S3). The highest correlations occurred between CM and SCS at the beginning of lactation (0.24) and for the whole lactation ($r$ = 0.29, $P$ < 0.01). The phenotypic correlation between CM to 50 days in milk (DIM) and SCS between 30 and 60 was 0.17. Stronger correlations were found between CM values for the whole lactation or LSCS and separate lactation stages. The higher phenotypic correlations ($r$ = 0.20, $P$ < 0.01) occurred between LSCS and CM in three periods between 50 and 200 DIM, while the correlations between the CM incidence in the whole lactation and SCS in the lactation stages were in the range from 0.17 to 0.20 without a noticeable trend.

The phenotypic correlations among the udder conformation traits are in ESM Table S4. They were low or moderate and ranged from –0.13 to 0.45 (ESM Table S4). These values were consistent with (Nemcova et al. 2011) and reflected the udder biological proportions. The highest value was found between fore and rear teat placement ($r$ = 0.45, $P$ < 0.01). There was a correlation of 0.44 between rear udder height and udder width, which means that a cow with a narrow udder probably had a low-attached udder. Between fore udder attachment and udder depth, there was a correlation of 0.38. Between fore udder attachment and rear udder height, there was a correlation of 0.3. Phenotypic correlations between conformation traits and CM ranged from –0.1 to 0.04 (ESM Table S5). ESM Tables S6 and S7–S15 show the estimated least squares means (LSMEANS) for CM and udder conformation traits. The resulting LSMEANS for CM incidence were high at the beginning of lactation. CM decreased between 51 and 100 DIM, then it was the same and slowly increased after

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100 DIM. The highest values (0.44) of LSMEANS were observed for scoring udder depth 1–2 (below the hock) and for the whole lactation. The lowest CM incidence was observed for the seventh score of udder depth and the case of CM between 201 and 250 DIM. The increasing score of udder depth, fore udder attachment, rear udder height, and medial ligament meant decreased CM incidences. For teat placement, teat length, udder width, and body condition score were observed as the lowest incidence for middle scoring of udder conformation traits. This would indicate that considering CM, the middle rating is the most optimal for these characters, and the extremes are undesirable.

ESM Tables S16 and S17–S25 show the estimated odds ratios for CM. Odds ratios were high at the beginning of lactation. Udders below the hock had a 2.56 higher probability of CM than udders with a bottom line of 21 cm below the hock-shallow udder (ESM Table S16). The highest value was 4.27 for the last period of lactation (301–350 DIM) and cows with the udder below the hock (ESM Table S20). At the end of lactation, it rapidly increased again, especially for scoring 1–2. It was also monitored that decreasing udder depth and medial ligament had consequences with the increasing odds ratio for CM. Analyses proved that CM incidence and SCS increased with decreasing udder depth.

LSMEANS were estimated for SCS characteristics and udder conformation traits (ESM Tables S26 and S27–S35). Estimated LSMEANS for SCS were high at the beginning of lactation, then they decreased to 90 DIM. After that, LSMEANS strongly increased until 270 DIM. The highest LSMEANS of SCS (4.10) were observed for udder depth below the hock and in the whole lactation (ESM Table S26). Increasing scores of all udder conformation traits were linked with decreasing SCS except for scores 8, where SCS slightly increased. Progresses of CM and SCS were identical to the CM odds ratio and the LSMEANS for CM and SCS. The CM incidence and the average SCS were high at the beginning of lactation, around 100–150 DIM; it slightly decreased and then it increased until the end of lactation for all udder conformation traits.

Fore udder attachment significantly affected CM and SCS. The worst conformation was weak and loose fore udder attachment with bulging fore quarters (ESM Tables S5, S6, S7, S16, S17, S26 and S27). Strong and tight fore udder attachment adjacent to the abdominal wall and score positively affected low CM and SCS. Cows with tightly attached udders had a lower CM incidence and SCS, which agrees with (Nash et al. 2002).

Front teats outside the quarter on the lateral side and front teats inside the quarter very close to the intermammary groove negatively affected CM incidence and SCS (ESM Tables S5, S6, S8, S16, S18, S26 and S28). Front teats in the middle of the quarter can be an appropriate selection criterion.

Very short and long front teats were linked with a high CM incidence and SCS, which is in accordance with scientific literature (Singh et al. 2014).

Intermediate teats had the lowest CM incidence and SCS (ESM Tables S5, S6, S9, S16, S19, S26 and S29). We found that the increase in SCS occurred for short teats compared to long teats. However, shorter teats could decrease the CM incidence during the first lactations (Nash et al. 2003). On the other hand, results of our and Nemcova et al. (2007) study found lower SCS for longer teats. The negative effect of long teats, i.e. the higher risk of CM, is more pronounced at the beginning of lactation than the CM incidence for the whole lactation. Cows with shorter teats were associated with low CM incidence (Sorensen et al. 2010; Nakov et al. 2014). The same trends are observable also for SCS.

Udder depth significantly affected CM and SCS (ESM Tables S5, S6, S10, S16, S20, S26 and S30). Increasing scores of udder depth were linked with decreasing incidences of CM and SCS. The lowest CM incidence and SCS were monitored for udders with a bottom line of 21 cm under the hock-shallow udder. Increasing CM by increasing udder depth was proved in the scientific literature (Rogers et al. 1998; Singh et al. 2014).

Very low rear udder height significantly affected CM and SCS similarly to udder depth and fore udder attachment. An appropriate selection criterion can be high rear udder height (ESM Tables S5, S6, S11, S16, S21, S26 and S31).

Medial ligament significantly affected CM and SCS (ESM Tables S5, S6, S12, S16, S22, S26 and S32). The highest CM incidence and SCS reported udders with convex to the flat floor from +1 cm to +0.5 cm. This conformation had a probability of CM for the first lactation period by 3.79 higher than the reference baseline: score 2, convex to the flat floor deep definition –6 cm (ESM Table S24). There was a high risk of CM and increased SCS at the beginning of lactation. The highest CM incidence and SCS for the medial ligament belonged

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to scores 1–2: convex base of the udder. Medial ligament had a weak negative correlation ($r = -0.1$, $P < 0.5$) with the CM incidence at the first lactation period (ESM Table S5).

Rear teats outside the quarter on the lateral side and rear teats inside the quarter negatively affected CM incidence and SCS (ESM Tables S5, S6, S13, S16, S23, S26 and S33). Rear teats in the middle of the quarter can be an appropriate selection criterion.

Udder width of 12 cm increases the incidence of CM and SCS. The middle scoring of udder width can be an appropriate selection criterion. Udder width of 9–10 cm was linked with the lowest SCS and 10–10.5 cm with the lowest CM incidence (ESM Tables S5, S6, S14, S16, S24, S26 and S34).

The middle body condition scores (BCS 2.5–4) were associated with the lowest incidence of CM and SCS. Optimum BCS corresponds to good health. Thin and fat cows also had problems with CM and high SCS (ESM Tables S5, S6, S15, S16, S25, S26 and S35).

In the present study, we evaluated the phenotypic associations between CM and SCS, particularly emphasising the linear type traits of the udder because those udder conformation traits are the first possible indicators of future CM incidence in a cow (Bobbo et al. 2019).

Both SCC and CM were analysed throughout the whole first lactation. As shown in agreement with Koivula et al. (2005), Gasparik et al. (2022) and Negussie et al. (2010), CM occurs most frequently at the beginning of lactation, and then its incidence decreases. Cows are the most susceptible to CM and high SCC after calving. This start of lactation accounted for 60% of the total incidence of CM during lactation. Therefore, scoring the cow's udder in this lactation phase is especially suitable for assessing the CM susceptibility due to the udder exterior.

There is undeniably a phenotypic and genetic relationship between the two main characteristics of udder health: CM and SCC. The genetic relationship for SCC, usually expressed in logarithms as SCS, is quite strong: 0.80–0.90 (Martin et al. 2018). The phenotypic correlation is smaller than the genetic one because the increase in SCC is connected not only with CM incidence but also with subclinical mastitis cases (Lund et al. 1994). This fact that SCS was associated not only with CM caused SCS values not to show a trend similar to the CM incidence during lactation. It can be concluded that increased SCC is a consequence of mastitis. Still, at the same time, it is necessary to note that lower SCS does not indicate a lower genetic predisposition to CM (Koivula et al. 2005). However, lactation SCS values are used to select for increased genetic resistance to CM in cows, as they are a retrospective indicator of the CM incidence.

The CM phenotypic correlations with the udder linear type traits were from –1.00 to 0.04 (ESM Table S5). It agrees with Samore and Groen (2006), who found low environmental correlations from –0.05 to –0.07 between LSCS and udder depth, medial ligament, fore udder attachment, and rear udder height. A low phenotypic correlation of –0.02 was found between SCS and BCS (Kadarmideen 2004). As a rule, genetic correlations were ten times higher, with values from –0.35 to 0.36 (Samore and Groen 2006). Udder conformation had a strong genetic relationship with CM (Nash et al. 2002). Deeper udders are genetically related with a high CM incidence (Rogers et al. 1998; Singh et al. 2014; Khan and Khan 2016). Cows with tight udder attachment and deep medial ligaments had the low CM incidence (Sorensen et al. 2010; Nakov et al. 2014).

Udder conformation traits are highly heritable and genetically associated with CM, which is why these traits are included in the selection index of dairy cows (Sorensen et al. 2010). Selection for low SCS, longevity, and shorter and slightly inside-quarters teats could decrease the CM incidence during the first lactations (Nash et al. 2002). Due to the trend of CM incidence during lactation, the highest and, therefore, the most significant values of LSMEANS for CM occurred at the beginning of lactation. SCS LSMEANS evolve in line with the trends of SCS values. The trends of CM odds ratios do not follow the tendencies in CM incidence. The odds ratios for CM can better capture the effects associated with the linear type traits.

The facts obtained in this study show that those characteristics associated with the udder depth, the strength of its attachment, and the length and position of the teats are essential for the probability of CM and, by extension, the level of SCS in each cow. Our study showed that udders below the hook had the highest CM incidence. These udders are usually dirtier and more exposed to the farm floor environment, which could increase the infection rate. The udder below the hock line could lead

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to health problems in the cow, such as accidental loss of a teat by stepping on it or through mastitis, leading to increased premature culling (Khan and Khan 2016). Deep udders, loose attachments, weak ligaments, and long teats are connected with high SCC in milk (Bobbo et al. 2019). In Czech Holstein cows, higher values of SCS were linked with deep udders, very low rear udder height, weak medial ligament, weak udder attachment, and teat placement outside or inside the quarters (Nemcova et al. 2007). Similarly, the low SCS is related to higher and narrower udders (Samore and Groen 2006). Cows with tight udder attachment had the low CM incidence (Nash et al. 2002). For teats, a medium length is optimal for the low incidence of CM and low SCC (Singh et al. 2014).

The most noteworthy linear type traits were those connected with udder attachment, size, and depth. The exterior classification of udders can be employed for negative phenotypic selection of cows to decrease the mastitis incidence in herds. A linear description score of udder depth can be helpful where the CM incidence is not routinely monitored (Rogers et al. 1998). Phenotypic negative preselection of cows with a score for high udder depth could help decrease subsequent intramammary infections in herds. The phenotypic scoring of the udder can be used similarly to the clinical examination procedure proposed by (Klaas et al. 2004), where the udder and teat characteristics, the degree of soiling with manure, CM incidence, etc., are examined and used as criteria for mastitis herd management (Klaas et al. 2004).

## CONCLUSION

The clinical mastitis (CM) incidence and somatic cell score (SCS) varied in different lactation stages, focusing on udder conformation and body condition scores. The CM and SCS were high at the beginning of lactation, decreased after 50 days in milk, and then they increased. The optimum score of the udder conformation traits for low CM incidence mostly coincided with the optimum score of low SCS in milk. The best udder health was observed for strong and tight fore udder attachment, intermediate and shallower udder depth, high rear udder height, deep medial ligament, intermediate udder width, front teat placement in the middle of the quarter, intermediate teat length, midpoint rear teat placement, and intermediate body condition score. The findings of this study could be used to improve breeding and phenotypic selection for negative phenotypic selection of young cows against the risk of CM and high somatic cell count in milk.

## Conflict of interest

The authors declare no conflict of interest.

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