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Insights into Lameness in Dairy Cattle: The Role of Body Condition Score and Lactation Dynamics

Süt Sığırlarında Topallık Üzerine İçgörüler: Vücut Kondisyon Skoru ve Laktasyon Dinamiklerinin Rolü

Yalçın Alper ÖZTURAN[1]
İbrahim AKIN[1]

[1]Aydın Adnan Menderes University, Faculty of Veterinary Medicine, Department of, Surgery, Aydın, Türkiye

ABSTRACT

Lameness is a significant welfare and economic issue in dairy farms, resulting in reduced milk yield, increased treatment costs, and higher culling rates. The present study aimed to investigate the relationships between lameness and animal-level factors including body condition score (BCS), lactation period (LP), and lactation number (LN) in 370 lactating Holstein cows. Lameness and BCS were assessed by observation, while LP and LN were obtained from farm records. Data were analyzed using chi-square and Fisher's-Freeman-Halton exact test to examine relationships between lameness scores and animal-level factors, and logistic regression was performed to reveal risk factors. Chi-square analysis revealed significant associations between lameness scores and both BCS (P = .010) and LN (P = .039), but not with LP (P > 0.05). Consistent with these results, logistic regression identified BCS as a significant predictor (P =.012); cows with a BCS of 4 had 3.72 times higher odds of lameness compared to those with a BCS of 2 (P = .037). Although LN was not significant overall (P = .195), cows in their second lactation showed significantly lower odds of lameness compared to first-lactation cows (P = .045). LP was not a significant predictor in the multivariate model (P = .746). Present findings emphasize the importance of monitoring BCS and LN to reduce lameness risks and improve herd health. Further studies are required to clarify the role of animal level factors in lameness.

Keywords: Body condition score, dairy cows, days in milk, lactation number, lameness

ÖZ

Topallık süt çiftliklerinde süt veriminde azalma, tedavi maliyetlerinde artış ve kesim oranlarında yükselmeye neden olan önemli bir refah ve ekonomik sorundur. Sunulan çalışmada 370 sağmal Holstein inekte topallık ile vücut kondisyon skoru (VKS), laktasyon periyodu (LP) ve laktasyon sayısı (LS) gibi hayvan düzeyindeki faktörler arasındaki ilişkilerin değerlendirilmesi amaçlandı. Topallık ve vücut kondisyon skorları gözlem yoluyla değerlendirilirken, laktasyon sayısı ve periyodu çiftlik kayıtlarından elde edildi. Topallık skorları ile hayvan düzeyindeki faktörler arasındaki ilişkileri incelemek için veriler ki-kare ve Fisher's-Freeman-Halton kesin testi kullanılarak analiz edildi ve risk faktörlerini belirlemek için ise lojistik regresyon uygulandı. Ki-kare analizinde, topallık skorları ile hem VKS (P = 0,010) hem de LS (P = 0,039) arasında anlamlı ilişkiler bulundu; LP ile ise anlamlı bir ilişki saptanmadı (P > 0,05). Bu sonuçlarla tutarlı olarak, lojistik regresyon analizinde VKS'nin anlamlı bir belirleyici olduğu saptandı (P = 0,012); VKS'si 4 olan ineklerin, VKS'si 2 olanlara kıyasla topallık görülme olasılığının 3,72 kat daha yüksek olduğu belirlendi (P = 0,037). LS genel olarak anlamlı bulunmamakla birlikte (P = 0,195), ikinci laktasyondaki ineklerde topallık görülme olasılığı, birinci laktasyondakilere göre anlamlı düzeyde daha düşük bulundu (P = 0,045). LP ise çok değişkenli modelde anlamlı bir risk faktörü olarak bulunmadı (P = 0,746). Mevcut bulgular, topallık risklerini azaltmak ve sürü sağlığını iyileştirmek için BCS ve LN'nin izlenmesinin önemini vurgulamaktadır. Hayvan düzeyindeki faktörlerin topallıktaki rolünü açıklığa kavuşturmak için daha ileri çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Laktasyon sayısı, sığır, süt verim gün sayısı, topallık, vücut kondisyon skoru

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Corresponding author/Sorumlu Yazar:
Yalçın Alper ÖZTURAN
E-mail: y.alper.ozturan@adu.edu.tr.

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INTRODUCTION

Lameness is widely recognized as one of the three most costly diseases affecting dairy herds, alongside mastitis and infertility.[1-4] The economic losses associated with lameness arise from decreased milk yield, reduced fertility, treatment costs, premature culling, and compromised cow welfare.[5-7] It is also associated with high treatment expenses and prolonged recovery periods.[7,8] Numerous studies have investigated methods to understand and mitigate the adverse effects of lameness in dairy cattle.[9-13]

Identifying the factors contributing to the high incidence of lameness, as well as the associated risk factors, is crucial for developing effective intervention strategies on dairy farms.[14] Previous studies have linked both animal- and farm-level risk factors to an increased incidence of lameness, with animal-level risks including parity, BCS, hock injuries, and milk yield, and farm-level risks encompassing management practices such as trimming intervals, footbath usage, herd size, flooring, and lying surface.[15-17]

In previous studies BCS is closely related to lameness incidence in dairy farms.[18,19] It has been hypothesized that low BCS contributes to claw horn lesions, potentially due to reduced digital cushion thickness, which is associated with poor body condition.[18] A BCS of ≤ 2 on a 0-to-5 scale is considered a significant risk factor, markedly increasing the likelihood of lameness.[19] Similarly, high-yielding cows are claimed to be more prone to lameness, which can lead to significant milk yield losses, estimated at approximately 350 kg over a 305-day LP.[20,21] While most research emphasizes the role of parity[22,23] and BCS[24,25] in lameness, there is a lack of detailed information on whether LP is an independent risk factor for lameness after adjusting for other variables such as BCS and LN. This issue is addressed in the present study.

This study aimed to investigate the relationships between lameness and BCS, LN, and LP in dairy cows, while also utilizing logistic regression analysis to identify significant risk factors and their contribution to lameness.

MATERIALS AND METHODS

Animals and Farm

The study included 370 lactating cows (n = 370) from a herd of 500 Holstein cattle. The cows were milked twice daily in a double herringbone milking parlor. They were housed in free-stall barns equipped with concrete stalls covered with mattresses in the lying areas. The walking alleys within the pens had grooved concrete floors and were cleaned by automatic scrapers. All walkways leading to and from the milking barn and holding pen, spanning approximately 75-85 meters, were covered with rubber mats. The cows were fed a total mixed ration comprising 45% concentrate (including soybean meal, cornmeal, cottonseed, and canola) and 55% forage (wheat straw, alfalfa hay, haylage, and corn silage). Routine claw trimming interval was once in 7 months according to the farm protocol by a claw trimmer, and all cows underwent claw trimming during their dry-off period. Although the routine claw trimming interval was 7 months—longer than the commonly recommended 3-6 months—this may have influenced the lameness prevalence observed in this study. The study was approved by the Adnan Menderes University Local Ethics Committee (Date: February 6, 2025, Approval number: 64583101/2025/034).

Body Condition Score Assessment and Lactation Related Data Collection

Body condition scoring was performed from the rear view of the cows while they were feeding in their pens. The BCS was determined as outlined in a previous study, where a score of 1 indicated an undercondition cow, 3 ideal condition and a score of 5 indicated an overcondition.[26] Data on LN and days in milk (DIM) were obtained from the farm's records.

Lameness Assessment

Lameness assessments were conducted on all cows following the afternoon milking session as they exited the milking parlor through an alley, enabling individual observation. The lameness scoring system was adapted from the Agriculture and Horticulture Development Board (AHDB) guidelines, where a score of 0 indicated a cow with no signs of lameness.[27] Lameness scores (LS) from 1 to 3 represented increasing levels of lameness severity, categorized as follows: LS1 for mild lame cows, LS2 for moderate lame cows, and LS3 for severe lame cows.

Categorization of Lactation Period and Lactation Number

Cows' DIM were classified into three categories based on their lactation cycle: early lactation (0-120 DIM), mid-lactation (121-240 DIM), and late lactation (241-360 DIM), as described in a previous study.[28] Lactation numbers equal to or greater than 5 were categorized as one group, while cows with LN smaller than 5 were left uncategorized.

Statistical Analysis

Statistical analyses were performed using SPSS® 22 statistical software (IBM SPSS Corp., Armonk, NY, USA). The relationships between lameness scores and BCS, LP, and LN were analyzed using the chi-square test. When the assumptions of the chi-square test were not met, the Monte Carlo simulation method was employed to provide more accurate p-values with 95% confidence intervals (CI). Fisher's-Freeman-Halton exact test was applied when the expected count for any cell was less than 5. Binary logistic regression analysis was performed to evaluate the association between lameness status (lame vs. not lame) and potential predictor variables, including BCS, LN, and LP. Lameness scores were dichotomized, with cows classified as either not lame (score = 0; reference category) or lame

(scores = 1, 2, or 3). All predictor variables were treated as categorical and were dummy coded for inclusion in the model. The clinically relevant category was designated as the reference group: BCS = 2, LN = 1, and LN = Early lactation. Odds ratios (Exp(β)) were used to interpret the strength and direction of associations. The overall significance of each factor was assessed using the likelihood ratio test, and a *P*-value < .05 was considered statistically significant. Prior to analysis, all predictor variables were assessed for multicollinearity using the variance inflation factor (VIF), with values < 2.0 considered acceptable. The model's fit was evaluated using the Hosmer-Lemeshow goodness-of-fit statistic, with a *P*-value of > 0.05 considered statistically significant.

RESULTS

The incidence of lameness in lactating cows in our study was 31.08% (115 out of 370 cows), which is higher than the prevalence reported in comparable freestall-housed Holstein herds, where previous studies have documented rates ranging from 21% to 25%.[22,23] The relationships between lameness and animal-level factors, including BCS, LN, and LP, are detailed in Tables 1, 2, and 3, respectively. The results of the logistic regression analysis for these animal-level predictors are provided in Table 4.

Table 1. Relationship Between Body Condition Scores and Lameness Scores.

		LS (%)				Total (%)
		0	1	2	3	
BCS	2	40 (15.7)[a,b]	4 (5)[a]	8 (29.6)[b]	2 (25)[a,b]	54 (14.6)
	3	199 (78.1)[a]	74 (92.5)[b]	17 (63)[a]	6 (75)[a,b]	296 (80)
	4	16 (6.3)	2 (2.5)	2 (7.4)	0	20 (5.4)
Total		255 (68.9)	80 (21.6)	27 (7.3)	8 (2.2)	370 (100)

BCS: Body condition score; LS: Lameness score. Different lowercase letters (a, b) within the same row indicate statistically significant differences between groups (*P* = .010; .008-.013 95% Confidence Interval).

Table 2. Relationship Between Lactation Number and Lameness Score of Cows.

		LS (%)				Total (%)
		0	1	2	3	
LN	1	102 (40)	26 (32.5)	4 (14.8)	2 (25)	134 (36.2)
	2	70 (27.4)	22 (27.5)	8 (29.6)	4 (50)	104 (28.1)
	3	40 (15.7)	16 (20)	4 (14.8)	0	60 (16.2)
	4	29 (11.4)[a]	10 (12.5)[a,b]	9 (33.4)[b]	0[a,b]	48 (13)
	≥ 5	14 (5.5)	6 (7.5)	2 (7.4)	2 (25)	24 (6.5)
Total		255 (68.9)	80 (21.6)	27 (7.4)	8 (2.1)	370 (100)

LN: Lactation number; LS: Lameness score. Different lowercase letters (a, b) within the same row indicate statistically significant differences between groups (*P* = .039; .034-.044 95% Confidence Interval).

Table 3. Relationship Between Lactation Period and Lameness Score of Cows.

		LS (%)				Total (%)
		0	1	2	3	
LP	Early	55 (21.6)	14 (17.5)	11 (40.7)	2 (25)	82 (22.2)
	Mid	54 (21.2)	16 (20)	4 (14.8)	2 (25)	76 (20.5)
	Late	146 (57.2)	50 (62.5)	12 (44.5)	4 (50)	212 (57.3)
Total		255 (68.9)	80 (21.6)	27 (7.3)	8 (2.2)	370 (100)

LP: Lactation period; LS: Lameness score (*P* = .354; .342-.366 95% Confidence Interval).

Table 4. Logistic Regression Analysis of Lameness Scores Based on Body Condition Score, Lactation Number, and Lactation Period.

Factors	no.	*P*	β	SE	Exp (β)
BCS:		.012			
2	290		0.000	0.000	1.000
3	60	.492	0.409	0.596	1.505
4	20	.037	1.314	0.630	3.723
LN:		.195			
1	134		0.000	0.000	1.000
2	104	.045	-.862	0.467	0.422
3	60	.156	-.689	0.486	0.502
4	48	.479	-.356	0.503	0.701
5	24	.677	-.216	0.518	0.806
LP:		.746			
Early	82		0.000	0.000	1.000
Mid	76	.570	0.168	0.296	1.183
Late	212	.752	-0.097	0.306	0.908

BCS: Body condition score; LN: Lactation number; LP: Lactation period; β: Estimated coefficient; SE: Standard error; Exp (β): Odds ratio.

Relationship Between Body Condition Score and Lameness Score

In all BCS groups, cows with lameness score of 0 were the most prevalent (n: 40, 199, and 16 for BCS 2, 3, and 4, respectively). Among lameness score groups, cows with BCS 3 were predominant (LS0: 199, LS1: 74, LS2: 17, LS3: 6). A statistically significant difference was identified between mild lame (LS1) and moderate lame (LS2) cows within the BCS 2 group. Similarly, within the BCS 3 group, a significant difference was observed between mild lame (LS1) and moderate lame (LS2) cows (*P* = .010; .008-.013 95%CI; Table 1).

Relationship Between Lactation Number and Lameness Score

Cows classified as not lame (LS0, 255 cows) comprised the largest group across all lactation numbers (Table 2). Specifically, cows in their first lactation (LN1) were the most represented in both the not lame (LS0, 102 cows) and mild lame (LS1, 26 cows) groups. Among lame cows (LS2), the highest proportions were observed in cows in their fourth (LN4, 9 cows) lactations. For severe lame cows (LS3), cows in their second lactation (LN2, 4 cows) had the highest proportion (Table 2).

In cows in their fourth lactation, a significant difference was observed between non-lame (LS0, 29 cows) and moderately lame cows (LS2, 9 cows) (*P* = .039; .034-.044 95%CI; Table 2).

Relationship Between Lactation Period and Lameness Score

In all lactation periods (early, mid, and late), cows with lameness score of 0 had the highest proportions (n: 55, 54, and 146, respectively). Late-lactation cows had the highest proportion across all lameness scores (LS0: 146, LS1: 50, LS2: 12, LS3: 8 cows). No statistically significant differences were observed between lameness scores and lactation periods (*P* > .05; Table 3).

Logistic Regression Analysis of Animal Level Risk Factors for Lameness

Logistic regression analysis was conducted to determine the association between lameness and animal-level factors including BCS, LN, and LP. Among these, BCS emerged as a significant predictor of lameness (*P* = .012). Cows with a BCS of 4 had 3.72 times greater odds of being lame compared to those with a BCS of 2 (*P* = .037), while the difference between BCS 3 and BCS 2 was not statistically significant (*P* = .492). Although LN was not statistically significant overall (*P* = .195), cows in their second lactation demonstrated a significantly reduced likelihood of lameness compared to first-lactation cows (OR = 0.422; *P* = .045). No significant associations were found for higher lactation numbers. Similarly, LP was not significantly associated with lameness (*P* = .746), and comparisons between mid or late lactation and early lactation did not yield significant differences (*P* > .05; Table 4).

DISCUSSION

The findings of this study provide valuable insights into the relationships between lameness and animal-level factors, including BCS, LN, and LP in dairy cows. These results highlight key predictors of lameness, offering valuable guidance for targeted management strategies to mitigate its occurrence and associated economic losses.

Previous studies have demonstrated that maintaining a BCS above 2.5 out of 5 significantly reduces the risk of claw horn lesions requiring treatment.[19] An 8-year longitudinal study similarly reported a higher likelihood of lameness in cattle with a BCS below 2.[29] Both studies suggested a positive association between BCS and digital cushion thickness, with higher BCS linked to thicker digital cushions that help dissipate concussive forces during claw strikes, thereby reducing the risk of claw horn lesions.[18] In our study, significant differences were observed between mildly and moderately lame cows with a BCS of 2 (Table 1), supporting the notion that underconditioned cows are more predisposed to lameness. Consistent with this, earlier research also reported a higher prevalence of claw diseases in cows with a BCS of 3-4, whereas non-infectious claw disorders were less common in cows with a BCS below 3.[30] Importantly, logistic regression analysis revealed that BCS was a significant predictor of lameness. Cows with a BCS of 4 had significantly greater odds of being lame compared to

those with a BCS of 2, indicating that overconditioning may also elevate lameness risk (Table 4). This association may be influenced by farm-specific management or environmental conditions that impact hoof health in overconditioned animals. These findings emphasize the importance of maintaining cows within an optimal BCS range, as both underconditioning and overconditioning appear detrimental to locomotor health. Further research should aim to clarify the pathophysiological mechanisms linking high BCS to lameness, particularly in relation to biomechanical load distribution, altered locomotion, and subclinical claw pathology. A limitation of this study is the lack of specific records on the causes of lameness or the association between claw diseases and BCS. Future research should aim to investigate this relationship to provide a more comprehensive understanding of the interplay between BCS, claw diseases, and lameness.

Lactation number has been previously associated with lameness, with several studies reporting increased lameness risk in cows with higher parity, particularly during the fourth lactation.[17,31,32] In our study, descriptive comparisons revealed differences in lameness prevalence across lactation numbers (Table 2); however, logistic regression analysis did not identify LN as a statistically significant predictor overall (Table 4). Notably, cows in their second lactation had significantly lower odds of lameness compared to first-lactation cows, while no significant associations were observed for higher lactation numbers (Table 4). This finding may suggest that younger, primiparous cows face unique physiological or management-related stressors that predispose them to lameness, whereas more mature cows in their second lactation may benefit from improved metabolic stability or hoof resilience. Future studies with larger sample sizes and a more balanced distribution of cows across lactation numbers are warranted to clarify the relationship between parity and lameness risk.

Lactation period is closely intertwined with BCS dynamics. BCS fluctuates during lactation, with Holsteins in early lactation averaging a BCS of 3, followed by an increase during mid-lactation, and stabilizing at approximately 3.5 during late lactation.[33] Most prior studies investigating the relationship between lameness and LP have focused on the dry period.[25,34] However, our study examined early, mid, and late lactation periods to assess their association with lameness cases. No statistically significant differences were found between LP and lameness, either through chi-square or logistic regression analyses (Tables 3 and 4). While LP can influence physical stress and metabolic demands, its effect on lameness may be less direct compared to other factors such as farm management protocols.[35] A notable limitation of this study is that the results are derived from a single dairy farm. Expanding the sample size and incorporating multi-farm data could yield more robust conclusions.

To further clarify whether BCS, LN, and LP are associated with differences in lameness prevalence, we examined the percentage of lame cows within each category. Chi-square analysis revealed significant differences in lameness distribution across BCS categories. Specifically, the prevalence of lameness was higher in cows with BCS 3 and 4 compared to those with BCS 2. For LN, a significant difference was observed between not lame and moderately lame cows in the fourth lactation group, suggesting parity may influence lameness occurrence. In contrast, the distribution of lameness was not significantly different across lactation period groups. These results demonstrate that both BCS and LN are associated with variation in lameness prevalence and highlight the importance of monitoring these animal-level factors for early detection and prevention.

In this study, we employed both chi-square tests and logistic regression to investigate the relationships between lameness and animal-level factors such as BCS, LN, and LP. Chi-square tests were used to identify simple associations and detect statistically significant differences between categorical variables, such as lameness scores and BCS and LN categories, providing an overview of potential relationships. To address these limitations, in this study, logistic regression analysis was utilized to evaluate the significant predictors of lameness while adjusting for other factors in the model. The complementary use of these statistical methods ensures a robust analysis and a more comprehensive understanding of the factors influencing lameness in dairy cows. A limitation of this study is the relatively small number of animals in certain categories, particularly cows with a BCS of 4 and those in the ≥5 LN group. While statistically significant findings were observed in these subgroups, the limited sample sizes may reduce the generalizability and robustness of these associations. Combining categories was avoided to preserve the biological relevance of each classification. Future studies with larger and more balanced sample distributions are warranted to confirm and expand upon these findings. One potential factor influencing the overall lameness prevalence observed in this study may be the relatively long claw trimming interval of 7 months. Routine trimming at shorter intervals (3–6 months) is typically recommended to prevent claw overgrowth and reduce lameness prevalence.[36] As all cows were managed under the same schedule, this limitation applies uniformly to the study population but should be considered in interpreting the present study findings.

As a result, this study highlights the complex interplay between lameness and key animal-level factors such as BCS, LN, and LP in dairy cows. While significant associations were observed between BCS and lameness in certain categories, logistic regression confirmed BCS as a significant predictor only for cows with a BCS of 4. In contrast, higher lactation numbers were significantly associated with increased lameness severity, emphasizing the need for targeted management strategies for older and multiparous cows. Although no significant relationship was found between LP and lameness, future studies involving larger sample sizes and multi-farm settings are warranted to explore this association further. These findings underscore the importance of individualized and stage-specific interventions in managing lameness, particularly for cows with specific BCS and in late lactation. Incorporating preventive measures and refining farm management practices may mitigate the impact of lameness, improve animal welfare, and enhance the economic sustainability of dairy farms. Additionally, longitudinal follow-up and multi-farm or regional studies are recommended to improve the generalizability of the findings.

Ethics Committee Approval: The study was approved by the Animal Experiments Local Ethics Committee of Aydin Adnan Menderes University (Date: February 6, 2025, Approval number: 64583101/2025/034).

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