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Research Article

Influence of Body Condition Score and Ultrasound-Determined Thickness of Body Fat Deposit in Holstein-Friesian Cows on the Risk of Lameness Developing

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Abstract

The aim of this study was to examine the correlations between ultrasound measurement of thickness of fat over the tuber ischiadicum (TFT), body condition scoring (BCS) and the risk of lameness developing in Holstein-Friesian dairy cows. The 100 cows were enrolled from a population of dry cows on one farm. TFT was measured with ultrasound, and BCS and locomotion score were determined during lactation. Of the 100 cows, 31% developed lameness during lactation. The highest proportion of lame cows was in cows with BCS≥4.25 (66.7%). The risk of lameness developing was higher in cows with BCS≥4.25 (OR=7) and ≤3.25 (OR=2) than in cows with optimal BCS=3.75. Cows in the lower TFT quartile had a higher proportion of lameness, but not those in the upper quartile. TFT may have some value as a predictor of lameness in thin cows. The best prediction of lameness in both fat and thin cows (ROCAUC=0.8725, P<0.01) occurred when both BCS and TFT values were used together. The risk of developing lameness was positively correlated with BCS, negatively correlated with TFT and negatively correlated with their interaction. For fat cows, BCS assessment is a suitably strong predictor of lameness. In normal or thin cows, lameness prediction required the combination of both BCS and TFT measurements.

Keywords: *Dairy cow, Lameness, Body condition score*

Siyah-Alaca İneklerde Vücut Kondisyon Skoru ve Ultrasonla Belirlenmiş Vücut Yağ Katmanı Kalınlığının Topallık Gelişme Riski Üzerine Etkisi

Özet

Bu çalışmanın amacı, Siyah-Alaca süt ineklerinin tuber ischiadicum üzerindeki yağ kalınlığının (TFT) ultrasonla ölçümü, vücut kondisyonu skorlama (BCS) ve topallık gelişme riski arasındaki korelasyonu incelemekti. Bir çiftlikteki kurudaki inek popülasyonundan 100 baş inek kaydedildi. TFT ultrason ile ölçülürken, BCS ve hareket puanı emzirme döneminde belirlendi. Yüz baş ineğin %31'inde laktasyon döneminde topallık gelişti. En yüksek topal inek oranı BCS≥4.25 (%66.7) ineklerde oldu. Topallık gelişme riski, BCS=3.75 optimum olan ineklere kıyasla BCS ≥4.25 (OR=7) ve ≤3.25 (OR=) olan ineklerde daha yüksekti. Daha düşük TFT çeyrekli inekler, daha yüksek çeyreğe göre daha yüksek bir topallık oranına sahipti. Zayıf ineklerdeki TFT topallığın göstergesi olarak belli bir değere sahip olabilir. Hem yağlı hem de zayıf ineklerdeki topallığın en iyi tahmini (ROCAUC=0.8725, P<0.01), BCS ve TFT değerleri her ikisi birlikte kullanıldığı zaman oluştu. Topallığa yakalanma riski BCS ile pozitif, TFT ile negatif ve bunların etkileşimi ile de negatif korelasyonlu idi. Yağlı inekler için, BCS tayini topallığın uygun şekilde güçlü bir göstergesidir. Normal veya zayıf ineklerde ise, topallık tahmini hem BCS hem de TFT ölçümlerinin kombinasyonunu gerektirdi.

Anahtar sözcükler: *Sütçü inek, Topallık, Vücut kondisyon skoru*

INTRODUCTION

Lameness is one of the most important endemic diseases of cattle, particularly in the dairy sector. It has a significant impact on health and welfare and leads to a range of production losses [1]. Furthermore, it reduces longevity [2] causes pain [3], influences milk production [4,5] and reproductive performance [6,7], and consequently, has

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a great economic effect [8]. Lameness in cattle is not a single condition, but rather is a symptom of a wide range of different diseases. The etiology and pathogenesis of many of these diseases remain relatively poorly understood. Claw horn disruption (CHD) is a common underlying cause of lameness in dairy cattle and leads to compromised animal welfare and production losses [9]. A greater risk of lameness and claw horn disruption lesions developing in cows with lower body condition score (BCS) and lower digital cushion thickness (DCT) has been described in cross sectional study [10]. Cows with low BCS (≤2 on a scale 0 to 5) are more likely to be treated for lameness in the four months following such a score [11]. This supports the hypothesis that low BCS are correlated with reduced digital cushion thickness, which can be associated with claw horn disruption lesions [10-14]. BCS is the most common method to evaluate the subcutaneous adipose tissue depot of the cow [12]. This is a widely accepted management tool to estimate the amount of adipose tissue laid down as energy storage at parturition, but which can be lost after parturition. This data can be used to predict the lactation performance, reproduction, and general health of the cow. As a part of dairy herd management, BCS can be used as an attempt to assess the magnitude of the energy deficit [13]. In a former study [14], we found that ultrasound determination of digital cushion thickness can be used for predicting CHD lesion development. However, ultrasound examination of the cattle acropodium has significant obstacles. First of all, there is a hard horn with moisture content lower than skin and loose layers filled with air. In a preliminary study [15], it was reported that an absolute requirement for ultrasound examination is claw trimming with removal of the air-filled layer of hoof horn and to make a flat surface. This procedure involves restraining the animal in a crush, which is very stressful. Then, BCS is influenced by the experience of the observer and many inter-observer differences can occur.

The purpose of this study was to examine the correlations between ultrasound measurement of thickness of fat over the *tuber ischiadicum* (TFT), BCS scores, and risk of lameness developing.

MATERIAL and METHODS

Animals and Study Design

Altogether, 100 Holstein-Friesian cows were enrolled. The cows were selected from population of dry cows, and were housed on a dairy farm with a cubicle housing system. They were fed a total mixed ration based on alfalfa hay, sugar beet pulp, corn silage, and concentrate. The average milk yield at the previous lactation was 7794±1210 kg/305 days. All cows were under the competent and permanent supervision of an employed veterinarian, with daily veterinary examination.

Ultrasound Measurement

The thickness of fat over the *tuber ischiadicum* (TFT) was measured with ultrasound using a linear probe (8 MHz) and ultrasound device Falco vet (Esaote Pie Medical). The measurement was taken at the point of *tuber ischiadicum (Fig. 1; Fig 2)* during the dry period, 4 to 6 weeks prior to calving.

Body Condition Score

A BCS system 1-5 [16] which incorporates a numerical scale, with thin animals receiving lower scores and fat animals receiving higher scores, was employed. All cows were scored in the dry period, 4 to 6 weeks prior to calving.

Lameness Diagnosis

All cows were scored for locomotion in the dry period

Fig 1. The point of *tuber ischiadicum* measurement

Şekil 1. *Tuber ischiadicum* ölçüm noktası

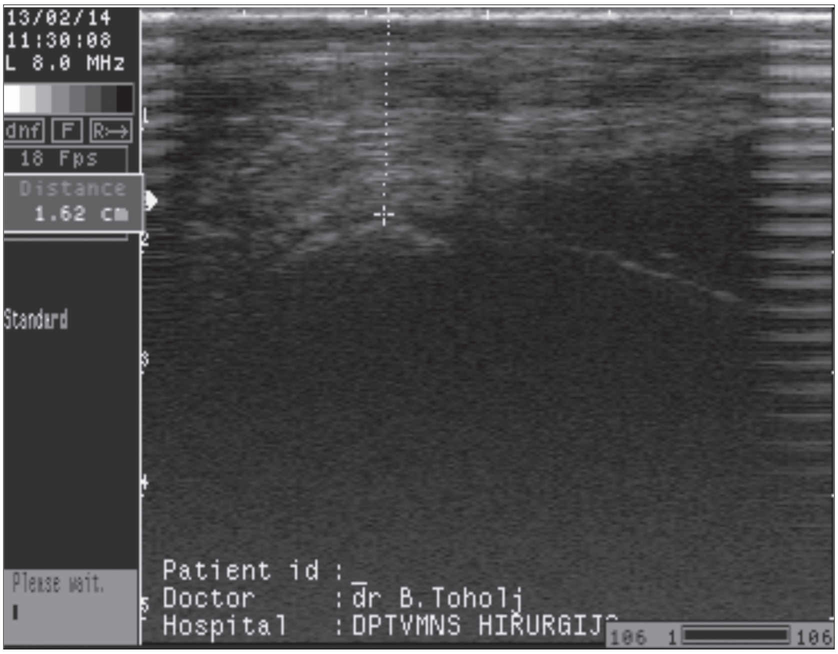

Fig 2. Ultrasound image of a typical *tuber ischiadicum* viewed among the 100 dairy cows

Şekil 2. *Tuber ischiadicum*'un yüz inek arasında gözlemlenen tipik ölçüm noktası

and six month after calving. The locomotion scoring system as developed by [17] using a 1 to 5 score, was employed. A score of 1 and 2 denotes sound locomotion, whereas scores of 3 or higher describe clinical lameness.

Statistical Analyses

The correlation between BCS and TFT was determined using Spearman's coefficient of correlation.

The influence of BCS and TFT on lameness developing was determined using a logistic regression model, separately for BCS, TFT and BCS×TFT interaction.

Risk of lameness development in cows with high or low BCS and TFT, in comparison with the optimal values, was analyzed by calculation of odds ratio using a 2×2 table. Tables contained the proportions of cows with lameness when they were classified into different classes of BCS (BCS≤3.25; BCS 3.5; BCS 3.75; BCS 4; BCS≥4.25) and TFT (lower quartile ≤1.27; lower medial quartile 1.28-1.40; upper medial quartile 1.41-1.54; higher quartile ≥1.54). Differences in proportions were determined using a t-test for proportion.

Prediction capacity of BCS, TFT and BCS×TFT interaction for lameness development was analysed by ROC curve and the area under the ROC curve (AUC ROC). ROC curve is plot that illustrated the relationship between X - true positive cow and Y - false positive cow in logarithmic regression model: $Y = a \times \ln(x) + b$. AUC ROC gives information about correct detection of lameness in cows with different BCS and TFT values, so that correct detection of cows will be estimated as: fail (AUC ROC=0.5-0.6), poor (0.6-0.7), fair (0.7-0.8), good (0.8-0.9) or excellent (0.9-1). We constructed the following ROC curve: 1) true positive cows (lame cows with BCS≥4.25 or ≤3.25) and Y - false positive cows (lame cows with optimal BCS 3.5-4); 2) true positive cows (lame cows with TFT in the lower or upper quartiles) and Y - false positive cows (lame cows with TFT in the optimal-median quartile); 3) true positive cows (lame fat cows BCS≥4.25, TFT ≥1.54; lame thin cows ≤3.25, TFT≤1.27) and Y - false positive cows (lame cows with optimal BCS and optimal TFT).

For this investigation we used a statistical software Statgraphic centurion and Microsoft Office Excel.

RESULTS

BCS and TFT Correlation

Result showed a strong positive correlation between values of TFT and BCS. In 28% of cases, the TFT variation depended on the BCS variation *(Fig. 3)*.

Relationships Between BCS, TFT and Lameness Development

Relationships between BCS and TFT in the dry period with lameness development during lactation were not statistically significant. However, lameness was positively regressed with BCS, but negatively regressed with TFT. Importantly, though, lameness was statistically significantly correlated to both BCS and TFT (BCS×TFT). Models and tests of regression parameters (variables) and intercept are presented in *Table 1*.

Different Level of BCS and TFT and Risk of Lameness Development

Altogether, 31% of cows develop lameness in lactation. The highest proportion of lame cows was in the group of cows with BCS≥4.25 (66.7%), and lowest proportion was found in group with optimal BCS=3.75 (20%) *(Table 2)*. The risk of lameness developing in cows with BCS≤3.25 was

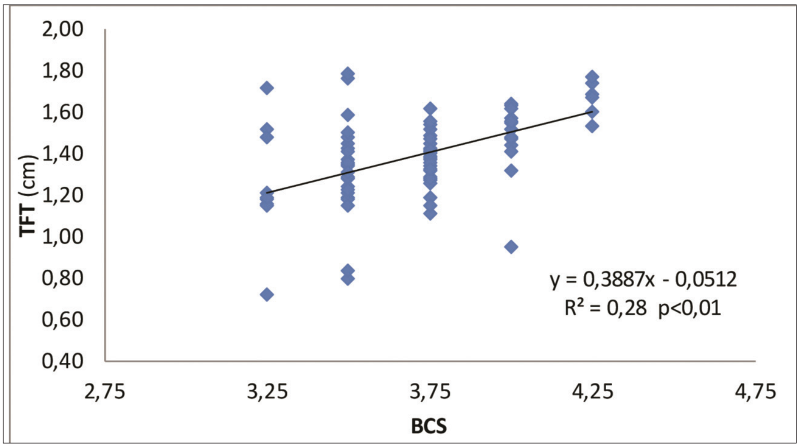

Fig 3. Correlation between TFT and BCS value in dairy cows

Şekil 3. Sütçü ineklerde TFT ve BCS arasındaki korelasyon

Table 1. *Testing of logistic regression model parameters for lameness developing as a function of BCS, TFT and BCS×TFT*
Tablo 1. *BCS, TFT ve BCSxTFT'nin bir işlevi olarak lojistik regresyon modeli parametre testi*

Independet Variable	Regression Formula						
BCS	**Lameness occurrence=1/(1+exp (-(-3.75+0.79×BCS))) Chi Square=0.99; df=1; p=0.31^{ns}**						
	Variable	**Coeff.**	**SE**	**P**	**O.R.**	**Low**	**High**
	BCS	0.79	0.80	0.32	2.22	0.46	10.71
	Intercept	-3.75	3.00	0.21			
TFT	**Lameness occurrence =1/(1+exp (-(1.12-1.38×TFT))) Chi Square=1.67; df=1; p= 0.19^{ns}**						
	Variable	**Coeff.**	**SE**	**P**	**O.R.**	**Low**	**High**
	TFT	-1.38	1.07	0.19	0.25	0.03	2.06
	Intercept	1.12	1.49	0.45			
BCS×TFT	**Lameness occurrence =1/(1+exp (-(-4.55+2.14×BCS-3.05×TFT))) Chi Square= 5.99; df=2; p=0.04**						
	Variable	**Coeff.**	**SE**	**P**	**O.R.**	**Low**	**High**
	BCS	2.14	1.08	0.04	8.53	1.01	72.94
	TFT	-3.05	1.44	0.03	0.047	0.028	0.8
	Intercept	-4.55	3.18	0.15			

^{ns} *Non-significant model P>0.05*

two times higher (O.R.=2) then in the group of cows with BCS=3.75 *(Table 3)*. The cows with BCS≥4.25 were seven times more likely to develop lameness compared with cows with BCS=3.75. The risk of lameness development was not statistically significant from 1 between other groups of BCS.

The highest proportion of lame cows were in the first TFT quartile (42.3%) and the lowest proportion of lame cows were in third quartile (20.8%) *(Table 4)*. The risk of lameness developing in cows in the lower TFT quartile was higher then in cows in the other quartiles. Cows in higher TFT quartiles did not show a statistically significant increased risk of developing lameness *(Table 5)*.

Prognostic Value of BCS, TFT and BCS×TFT in Lameness Development

High BCS≥4.25 in the dry period was a good indicator for lameness development during lactation (AUCROC=0.7556; P<0.05; *Fig. 4*). Prediction of lameness in thin cows (BCS<3.25) was not statistically significant (AUCROC=0.62; P>0.05). The possibility of lameness prediction using TFT was most relevant in the lowest quartiles of TFT values compared with upper quartiles. However, it was impossible to strictly determine a numeric risk (in terms of TFT) for lameness developing (AUCROC 0.57; P>0.05). The best model for predicting lameness in cows was obtained when both BCS and TFT were used in the prediction model for both fat and thin cows (ROCAUC=0.8725, P<0.01; *Fig. 5)*.

DISCUSSION

The mean prevalence of lameness in dairy herds is approximately 20% [18,19]. In our investigation, 31% of enrolled cows develop lameness in lactation. The prevalence of lameness in Europe has been estimated at 1.2% in 34 zero-grazing herds in The Netherlands [20], 5% on 101 farms in Sweden [21], and 22% on 53 farms in England [22]. The

Table 2. *Number or proportion of cows with lameness within each BCS category*

Tablo 2. *Her bir BCS kategorisindeki topal inek sayısı veya oranı*

Parameter	BCS				
	≤3.25	3.5	3.75	4	≥4.25
Lame (n)	4	8	7	8	4
Sound (n)	7	17	28	15	2
Proportion (%)	36[a]	32[a]	20[a]	34.7[a]	66.7[b]

[a,b] Numbers with different superscripts in a row are significantly different; P<0.01

Table 3. *Risk for lameness occurrence (odds ratio; OR) in cows with low BCS≤3.25 or high BCS≥4.25 in comparison with optimal BCS=3.5-4.0*

Tablo 3. *Optimal BCS=3.5-4.0 olanlara kıyasla, düşük BCS≤3.25 veya yüksek BCS≥4.25 ineklerdeki topallık oluşum (odds ratio; OR) riski*

BCS Risk	OR	Low	High
3.25 to 3.50	1.07	0.90	2.20
3.25 to 3.75	2.00*	1.50	3.60
3.25 to 4.00	1.07	0.90	2.20
3.25 to 4.25	0.29	0.11	0.42
4.25 to 3.25	3.50*	2.50	4.20
4.25 to 3.50	3.75*	2.80	4.40
4.25 to 3.75	7.00*	4.90	9.20
4.25 to 4.00	3.75*	2.80	5.10

** Risks that are statistically greater than; **1** = Real, increased risk*

Table 4. *Number or proportion (%) of cows with lameness within each TFT quartile grouping*

Tablo 4. *Her bir TFT çeyrek gruplandırması içindeki topal inek sayısı veya oranı (%)*

Parameter	TFT Quartiles			
	≤1.27	1.28-1.4	1.41-1.54	≥1.54
Lame (n)	11	7	5	8
Sound (n)	15	18	19	17
Proportion (%)	42.3[a]	28[b]	20.8[b]	32[b]

[a, b] Numbers with different superscripts in a row are significantly different; P<0.01

Table 5. *Risk of lameness occurrence (odds ratio; OR) in cows with TFT scores in the lower and upper quartiles in comparison with median quartiles*

Tablo 5. *Median çeyrekli olanlara kıyasla, daha düşük ve daha yüksek çeyrekli TFT skorlu ineklerde topallık oluşum (odds ratio; OR) riski*

TFT Risk	OR	Low	High
0.10-1.27 to 1.28-1.4	1.88	0.90	2.60
0.10-1.27 to 1.41-1.54	3.23*	1.80	4.30
0.10-1.27 to >1.54	1.55	0.74	2.42
>1.54 to 1.28-1.4	1.11	0.60	2.10
>1.54 to 1.41-1.54	1.25	0.55	2.20

** Risks that are statistically greater than; **1** = Real, increased risk*

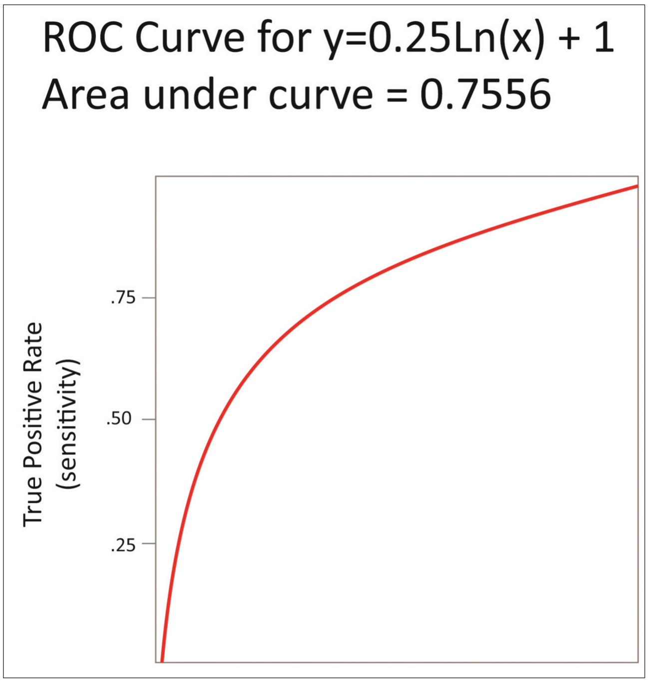

Fig 4. ROC curve and area under curve in prognosis of lameness in cows with high BCS

Şekil 4. Yüksek BCS'li ineklerde topallık prognozunda ROC eğrisi ve eğri-altı alanı

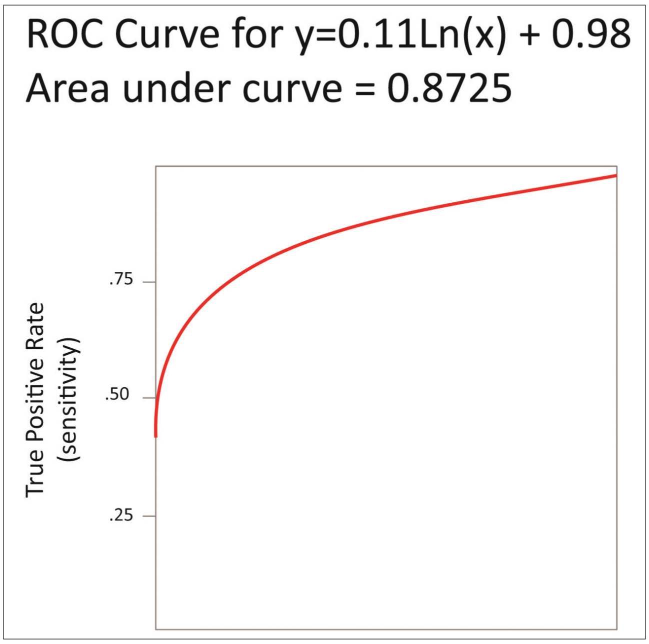

Fig 5. ROC curve and area under curve in prognosis of lameness in cows with BCS×TFT interaction

Şekil 5. BCS × TFT etkileşimli ineklerde topallık prognozunda ROC eğrisi ve eğri-altı alanı

prevalence of dairy cow lameness in our study was even higher, but this could have been a result of us enrolling a lower number of animals from one herd only. This was done because the purpose of our study was to find if there was any possible correlation of BCS and TFT with lameness.

An investigation into the incidence [23] of lameness in the United Kingdom revealed that approximately 50 cases/100 cows were stricken with lameness annually. The poor correlation between lameness incidence rates and records of treatments for lameness on-farm has been highlighted in some research [24], which suggests that the true incidence of lameness is likely to be higher than the rates cited above.

BCS and TFT Correlation

The ideal body condition during each stage of lactation is that which optimizes milk production, minimizes reproductive and health disorders, and maximizes economic returns [25]. A precise assessment of body energy stores is needed to increase the efficiency of milk production. In our investigation, an ultrasound device was used to measure the thickness of fat over the *tuber ischiadicum* (TFT). The image is generated by the sound waves being reflected from boundaries between different tissue densities [26]. In this particular case, the boundaries existed between adipose tissue and bone surface. Our results show a strong positive correlation between TFT values and BCS. This can be easily explained because there is a lot of fat surrounding the cow tail structure and BCS mostly depends on the amount of fat deposits. Ultrasound measurement of back fat thickness has been described earlier as a valuable method for assessing the body fat deposits in cows. The most common place for measuring of back fat thickness was at an imaginary line between the hooks and pins at the sacral examination site [13]. Our method seems to be more easily learned, because there are not a lot of tissue structures at the site where our measurement is taken, and we only measure the distance between skin and bone. If fat thickness in the gluteal region is measured, the examiner needs to distinguish the fat deposits among many other structures, such as superficial and deep gluteal fascia, gluteal muscles, etc.

BCS and Risk for Lameness Developing

Several cow-level factors have been associated with an increased incidence of lameness. BCS has been reported as being a suitable indicator of risk for lameness in several studies [11,27]. In our investigation, the highest proportions of lame cows were in the groups of cows with BCS≤3.25 (64.3%) and BCS≥4.25 (66.7%). Therefore, it seems that BCS, which are not optimal could be associated with an increased risk of lameness developing. One study has shown that cows with low BCS around parturition had 3 to 9 times higher odds of developing lameness compared with cows with higher BCS [29]. Cows with low BCS≤2 (on a scale 0 to 5) are more likely to be treated for lameness in the 2 or >2 to 4 months following such a score [11]. This can be explained by reduced capability of the digital cushion (fat tissue) to serve as shock absorbers during walking, which results in increased pressure on corium and consequently, the development of claw horn disruption lesions. The impaired shock-absorbing properties of the digital cushion seem to be a crucial factor leading to concussions of the corium and developing a claw horn disruption lesions [29]. The digital cushion is a complex structure (composed mostly of adipose tissue) located underneath the distal phalanx and plays an important function of dampening compression of the corium tissue beneath the cushion. The biomechanical importance of the digital cushion in alleviating compression under the *tuberculum flexorum* of the distal phalanx is well known [29]. This finding supports the hypothesis that low BCS is associated with claw horn lesions, possibly due to reduced digital cushion thickness, which has been correlated with low BCS [10]. At the opposite end of the scale, a group of cows with high BCS and an increased proportion of lameness were also noticed. We hypothesize that increased BCS could also mean increased body weight, and therefore, the increased proportion of lame cows in this group may be due to increased body weight pressure on the claws.

TFT and Risk for Lameness Developing

Regardless of the fact that BCS was strongly positively correlated with our ultrasound-determined TFT, this value has limited importance in predicting a lameness event. The highest proportion of lame cows was in the first TFT quartile (42.3%) and the lowest proportion of lame cows was in third quartile (18.5%). The possibility of lameness prediction using TFT would be most relevant in the lowest quartiles. To date, we are not aware of any comparable data from other investigations, which studied the relationship between ultrasound-determined TFT and risk of lameness developing.

In conclusion, the results showed a strong positive correlation between TFT values and BCS. The cows with BCS≥4.25 or below 3.25 were much more likely to develop lameness in comparison with cows with normal BCS. The risk of lameness developing positively correlates with BCS, but negatively correlates with TFT and with their interaction (BCS×TFT). For fat cows, BCS assessment is a suitable predictor of future lameness. In normal or thin cows, lameness prediction requires a combination of BCS and TFT. In further research, the influence of TFT on prediction of lameness in normal and thin cows should be investigated.

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