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Risk Factors Associated with Lameness, Subclinical Mastitis and Hock Wounds in Tie-Stall Dairy Cows across Four Production Regions of Sri Lanka

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Abstract

Identifying risk factors associated with major welfare problems is essential for improving dairy productivity under diverse management systems. This study investigated risk factors for lameness, subclinical mastitis (SCM) and hock wounds in tie-stall dairy farms across four major agro-ecological areas of Sri Lanka: Up-Country, Mid-Country Coconut Triangle and Western Province. Data were collected from 597 farms involving 1,240 Friesian crossbred cows through structured questionnaires and standardized animal-based welfare assessments. Assessments included animal-based (cleanliness, California Mastitis Test (CMT), lameness, hock wounds) and facility-related factors (flooring, bedding, stall design) were evaluated. Statistical analyses were performed using IBM SPSS Statistics version 23. and multivariable binary logistic regression models were used to identify significant risk factors and interaction effects. The overall prevalence of lameness was 15.4%, with considerable regional variation: 27.7% in the Up-Country, 17.6% in the Mid-Country, 5.9% in the Coconut Triangle and 10.3% in the Western Province. Flooring characteristics, including dirtiness, slipperiness, cracks, floor type and moisture level, were significantly associated with lameness ($p < 0.05$). Subclinical mastitis was significantly associated with cow cleanliness, particularly flank, limb and udder cleanliness. Very slippery floors increased hock-wound prevalence by 52.1%, whereas dry flooring reduced prevalence by 53.3%. Interaction analysis indicated that improved flooring and hygiene management could reduce the predicted probability of lameness by up to 96.9% under optimal conditions. Overall, welfare disorders were influenced by interacting environmental and management factors, highlighting the need for region-specific housing and management interventions to improve dairy-cow welfare and support sustainable milk production in tropical production systems.

Key Words: Hock Wounds, Lameness, Risk Factors, Subclinical Mastitis

Introduction

Animal welfare is distinguished as a core component and receives great attention ~~(Rao et al. 2014)~~ on enhancing milk production (Rao et al. 2014). According to five freedom concept, diseases and suffering could be considered as a significant welfare indicator because it negatively associate with pain, discomfort or distress (Sutherland et al. 2013). Lameness, Subclinical mastitis and Hock wounds are severe welfare issues which dramatically affect cow comfort and production (Levison et al. 2016). Lameness ranks third loss from the diseases on dairy farms and has been defined as a clinical incident of painful disorders. Mastitis is the most prevalent, expensive animal health problem among high yielding dairy cows (Sutherland et al. 2013). Hock wounds are relatively common in dairy cows and can range from hair loss to open sores and inflammation of the tarsal joint (Haskell et al. 2006). According to previous research, lameness (Von Keyserlingk et al. 2012), mastitis (Tucker et al. 2003, Lobeck et al. 2011, Tongel et al. 2016) and hock wounds (Haskell et al. 2006, Proudfoot et al. 2010) of dairy cows were affected by the housing design and management practices. Hence, risk factors for these welfare issues cannot be identified as single factors. Therefore, current study focused to investigate the relationship of herd characteristics and management practices with the prevalence of subclinical mastitis, lameness and hock wounds of dairy cows in tie-stall farms of four regions in Sri Lanka [(Up-Country (UP), Mid-Country (MC), Coconut Triangle (CT) and Western Province (WP)].

Method

The study was conducted in four regions (UP/MC/WP/CT) of Sri Lanka which are considered as potential milk production zones. Different climatic conditions were observed in these areas where UP has a very low temperature with an average of 16 °C to 20 °C, followed by MC (20 °C to 28 °C), CT (20 °C to 30 °C) and WP (24 °C to 31

°C) (Department of Meteorology, 2016). Data were gathered from 597 tie-stall dairy farms (UP = 151, MC = 155, CT = 134, WP = 157) with a total of 1240 Friesian crossbred dairy cows (UP = 254, MC = 382, CT = 217 and WP = 387) using an open structured questionnaire survey (Weerasinghe et al. 2020). Data related to animal-based parameters including cow cleanliness (0–2 scoring system: Krebs et al. 2001), severity of sub-clinical mastitis (California Mastitis Test (CMT) - 0-3 scoring system - Kandeel et al. 2018) and lameness (Tie-stall lameness - 0-4 scoring system - Winckler and Willen, 2001) were measured using scoring systems while Infrared Thermography (IRT) camera (Weerasinghe et al. 2021) was used to detect the presence of hock wounds. All four legs were captured by FLIR T420 Infrared Thermography (IRT) camera and the thermal images were analysed using FLIR Tool+ software to calculate the number of wounds and their temperature. Facility-based parameters (floor cleanliness, slipperiness, cracks, floor type, bedding type and the given space allocations of cow bed) were collected according to a previous experiment of Weerasinghe et al. 2025.

Statistical analysis

The data were entered in Microsoft Excel and then imported into IBM SPSS Statistics for analysis. The outcome variable was lameness status, coded as a binary variable (0 = not lame, 1 = lame) and categorical predictors such as floor type, hoof damage, slipperiness, cleanliness, humidity condition, and other management or environmental factors were treated as nominal or ordinal variables and continuous variables such as skin temperature, hoof temperature, dimensions and difference scores were treated as scale variables. The prevalence of lameness was calculated as the proportion of animals classified as lame out of the total number examined, with 95% confidence intervals where appropriate.

Bivariate analysis was performed to assess the association between factors and lameness prevalence. Chi-square tests or Fisher's exact tests were used for categorical variables and independent-samples t tests or non-parametric equivalents were used for continuous variables. Variables showing evidence of association at the bivariate level, together with variables considered biologically important, were retained for multivariable modelling. Multivariable binary logistic regression analysis was performed to evaluate the independent effect of all parameters with the prevalence of lameness. The model estimated adjusted odds ratios (AORs) with 95% confidence intervals and corresponding p-values, allowing the probability of being lame to be assessed according to the level or presence of each factor. Categorical predictors were entered as dummy variables, and reference categories were selected based on biological relevance or the lowest-risk category. For continuous predictors, linearity in the logit was assessed, and transformations or categorical grouping were considered if required.

Interaction effects were observed and were retained in the final model only if they were statistically and biologically meaningful. The probability of lameness was estimated from the fitted binary logistic regression model. The linear predictor (Y) was calculated using the intercept (β_0) and the regression coefficients (β)

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k$$

For models containing an interaction, the relevant product term was included:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 (X_1 X_2)$$

The predicted probability of lameness was then calculated using the inverse-logit transformation(P - Predicted probability of lameness, β - Regression coefficients)

$$P = \frac{e^Y}{1 + e^Y}$$

All statistical tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant.

Results

This study is a secondary analysis of the dataset previously used to describe the prevalence of welfare issues in Sri Lankan dairy cows (Weerasinghe et al., 2025). The previous publication quantified prevalence, whereas the present study focuses on identifying animal- and farm-level risk factors associated with lameness, subclinical mastitis and hock wounds using multivariable regression modelling Region wise significant factors ($P<0.05$) for the prevalence of lameness was tabulated in Table 1.

Table 1: Factors affected on the prevalence of lameness in dairy cows ($P<0.05$).

Parameter	UP	MC	CT	WP
Prevalence of Lameness	-Floor Dirtiness -Floor Slipperiness -Floor Cracks	- Floor Dirtiness -Floor Slipperiness -Floor Cracks -Wound Score -Floor Type -Floor Gradient -Limb Cleanliness	-Floor Dirtiness	-Floor Dirtiness -Floor Cracks -Wound Score -Floor Dryness

UP- Up-Country, MC- Mid-Country, CT- Coconut Triangle, WP- Western Province

Accordingly, several flooring characters were individually significant and multivariable binary logistic regression analysis was continued to discover the interaction effects. Out of the variables in univariable step, seven were retained in the multivariable model. Factors which affect on the prevalence of lameness were varied in region wise and an interaction effect was observed. In UP, interaction effect was observed among floor cracks x floor slipperiness x limb cleanliness x wounds' prevalence and in MC and WP, floor cracks and floor dirtiness had interaction effect on lameness where as in CT it resulted with no interaction effect due to the significance of just one factor. With those results, probability of being lameness was calculated and obtained as follows (Table 2).

Table 2: Interaction effect of each factor on prevalence of lameness

Region	Interaction effect	Percentage (%) of reducing lameness by maintaining optimum conditions
UP	Cracks (-), Grip, Clean limb, Wounds (-) : 0.01 %	96.9 %
	Cracks (-), Slip, Dirty limb, Wounds (-) : 0.04 %	
	Cracks (+), Grip, Clean limb, Wounds (-) : 0.08 %	
	Cracks (-), Slip, Clean limb, Wounds (-) : 9.91 %	
	Cracks (-), Slip, Clean limb, Wounds (+) : 37.42 %	
	Cracks (+), Slip, Clean limb, Wounds (-) : 63.20 %	
	Cracks (+), Slip, Dirty limb, Wounds (-) : 85.80 %	
	Cracks (+), Slip, Dirty limb, Wounds (+) : 96.90 %	
MC	Cracks (-), Clean flooring : 15.6 %	45.4 %
	Cracks (+), Dirty flooring : 61.0 %	
WP	Clean, dry flooring : 1.1 %	46.2 %
	Dirty, Wet flooring: 47.3 %	

UP- Up-Country, MC- Mid-Country, CT- Coconut Triangle, WP- Western Province

According to table 2, different animal and facility-based factors were resulted with different contribution percentages to minimize the prevalence of lameness in four different regions.

In current study subclinical mastitis was significantly ($P<0.05$) affected by the cleanliness of dairy cows (flank, limb and udder) in UP ($P = 0.011$, $P = 0.010$, $P = 0.024$, respectively) and CT ($P = 0.004$, $P = 0.016$, $P = 0.002$, respectively). In addition, significant ($P<0.05$) risk factors of hock wounds were identified as floor type, floor dryness, floor slipperiness and prevalence of lameness. Floors with high slipperiness (very slippery) enhanced wounds prevalence by 52.1% and dry floors reduced wounds by 53.3%. Ordinal logistic regression analysis revealed an interaction effect of floor slipperiness x prevalence of lameness towards wound prevalence of cows in UP. Probability of being wounded of cows in UP area was 0.08 % when floor was in good grip with the absence of lameness. Lame cows on very slippery flooring had higher probability (2.9 %) of wounds' prevalence. There was no interaction effect for cows to be wounded in other regions, however, significant ($P<0.05$) consequence of floor dirtiness, dryness and cracks was obtained. Further, extra length of bedding area significantly augmented wounds' prevalence in WP ($P = 0.01$) and CT ($P = 0.04$).

Discussion

This study identified uncomfortable stall design as a primary contributor, along with management practices, housing and sanitation for the prevalence of lameness, sub clinical mastitis and hock wounds.

Risk factors of Lameness

Dirty flooring emerged as a significant risk factor across all four regions (Table 1), aligning with findings that infrequent floor cleaning and slurry accumulation in hooves resulted claw lesions and lameness (Abdelouahed et al. 2023; Chaplin et al. 2000). In addition, hoof damageable floors, slipperiness, wetness, prevalence of wounds, limb cleanliness and floor type (concrete) were also identified as risk factors of lameness in the current study. Slipperiness alters the gait of cows' movement and wet flooring reasoned for less abrasive and restrict the locomotion of cows. Barker et al. (2010) discovered that damaged concrete surfaces increase the risk of lameness due to pressure on the sensitive tissues of claws when cows try to shift their weight away from the limb in uncomfortable floors.

According to the results of this study (Table 2), wounds positive cows with dirty limbs in hoof damageable, very slippery floors of UP farms have higher probability for being positive to lameness. The lameness probability is 0.01% in UP region, when cows are free from wounds and dirty-limbs, and housed in crack free, good grip sheds. It indicates that proper management practices can minimize lameness prevalence by 96.9%. In MC, 61.0% of cows were lamed, due to the interaction effect of floor dirtiness and cracks. It could be reduced up to 15.6%, with the use of crack free clean floors. In WP, cows in dirty and wet floors, had 47.3% of probability for being lamed while proper flooring management (clean and dry) minimized the lameness probability to 1.10%. In CT, floor dirtiness was observed as a significant factor for the lameness. Therefore, in overall, factors that affect on lameness were varied according to the region wise and Dippel et al. (2009) had also stated that lameness prevalence significantly varied across farms and regions. Thus, according to these findings proper management practices could minimize the probability of lameness of tie-stall dairy cows.

Prevalence of Subclinical Mastitis

In Sri Lanka, few studies had reported with regard to prevalence and risk factors of Subclinical Mastitis. The overall incidence of 27.3% of subclinical mastitis had been reported in Sri Lanka (Ranasighe et al. 2021) and this value had a slight variation in region wise. A recent study (Weerasinghe et al. 2025) had discovered that

prevalence of subclinical mastitis was higher in UP (42.9 %) and followed by other regions (MC, CT and WP) with percentages of 17.9 %, 6.7 % and 1.3 % respectively. The present study resulted that cow dirtiness (flank, limb and udder) had significantly affected on prevalence of subclinical mastitis in UP and CT. According to a previous study, risk of mastitis was high in slurry accumulated unhygienic floors particularly when the cows lie on it (Zdanowicz et al. 2004). Udder dirtiness considered to be a source of bacteria for mastitis (Nóbrega and Langoni, 2011) and dirty limbs also increased udder infections when they were lying down. Thus, the floor of the cattle shed should be as clean and dry as possible to minimize the prevalence of mastitis.

Prevalence of Hock Wounds

The present study highlighted some flooring characters (type, dryness, slipperiness) and prevalence of lameness as key factors of hock wounds. Animal has to kneel on bare abrasive concrete floors during the standing up behaviour and that may course injuries to the carpal area (Barker et al. 2010). In conformity to present findings, Livesey et al. (2002) also had reported that sharp, hard and abrasive floors increased wounds' prevalence and another experiment concluded that comfortable bedded area can minimize cows being wounded rather than using bare concrete or cements (Weary and Taszkun, 2000; Weerasinghe et al., 2021). Floor slipperiness was also identified as a significant factor for the prevalence of hock wounds by Norberg, (2012). According to the results of current study, the interaction effect of floor slipperiness and lameness increased wound prevalence. This was further confirmed through the results of a previous study in Sri Lanka (Weerasinghe et al. 2021) which identified lower percentage of hock wounds in non-lamed cows on rubber mat beds (less floor slipperiness) compared to concrete floor. Therefore, to reduce hock wounds, a suitable bedding and a comfortable lying area could be recommended. Additionally, bed length was also positively significant on wound prevalence in WP and CT thus, more bedding length increased prevalence of wounds. Therefore, appropriate design and dimensions of bedding areas are critical for minimizing injuries. The present study resulted prevalence of hock wounds of dairy cows was varied with regional level being compatible to the findings of Freigang et al. (2023) which also find out a regional variation of the risk factors for the prevalence of hock wounds of dairy cows in Germany.

In conclusion, this study identified key animal and facility-based risk factors associated with major welfare issues of dairy cows in Sri Lankan tie-stall systems, highlighting significant regional variations. Flooring characteristics, cow cleanliness and stall management practices, were found to strongly influence welfare outcomes. Interaction effects resulted a combined effect of environmental and management factors and clean, dry, well-designed and non-slippery housing can reduce these problems. Overall, these findings demonstrated that relatively simple, region-specific improvements in housing designs and management practices can significantly enhance dairy cow welfare and support more sustainable and productive dairy systems in Sri Lanka, emphasizing the importance of targeted extension programs and evidence-based welfare guidelines.

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