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Effect of Limb Torsion and Distal Asymmetry (LTDA) on Performance and Morphometry of Holstein Cows

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ABSTRACT

Background: The present study was designed to evaluate the correlation of limb torsion and distal asymmetry (LTDA) with respect to zoometric, productive and reproductive variables in Holstein cows.

Methods: A total of 120 cows diagnosed with LTDA in a previous experiment (60 positive and 60 negative) with one or more lactations were randomly selected for measurement. The height at withers (cm), neck length (cm) and head length (cm) of all cows were measured. Records were obtained for the year of the study regarding lactation order, days in milk, mean of milk production in 24 h (kg), number of inseminations per conception, days open and body condition (scale 1-5). The association between LTDA and zoometric measures along with productive and reproductive variables was evaluated by multiple logistic regression.

Result: A statistically significant correlation ($p<0.05$) was observed between the zoometric variable's height at withers and neck length, while no association was found between LTDA and head length ($p>0.05$). The study revealed no effect of LTDA on productive variables ($p = 0.38$), however an effect of LTDA on reproductive variables was significant ($p = 0.01$), primarily on body condition. However, the findings indicate that body condition exerts an influence on the occurrence of LTDA in Holstein cows stabled under intensive systems in other words LTDA can impact certain variables, particularly reproductive ones.

Key words: Animal welfare, Limb torsion and distal asymmetry, Logistic regression, Milk production, Zoometric measurements.

INTRODUCTION

The zoometric or morphometric traits of Holstein cows are characterized by well-defined phenotypic traits, including height at withers, rib cage and head size, which surpass those of other breeds specialized in milk production. (Charfeddine and Pérez-Cabal, 2017; Sadiq *et al.*, 2020) Consequently, these animals support weights greater than 600 kilograms when moving to feeders, milking parlors and handling aisles, which has favored the appearance of locomotion problems, limb twisting and lameness problems that are also associated with the intensive production with which dairy cattle are managed on some farms.

Espejo *et al.* (2006) have indicated that lameness represents the primary issue for animal welfare in intensive dairy farming. This subject has become of significant importance for both society and food production (Arya *et al.*, 2025), It has been observed that, over the years, the topic in question has gained prominence for two main reasons: firstly, commercial and secondly, ethical. This has resulted in the entity receiving recognition from governments, national and international organisations, academic institutions and individuals around the world (Khyalia and Singh, 2023). In intensive dairy farms, cows open the compass of their forelimbs to tilt their heads to reach pasture. In contrast, under natural conditions, the height at the withers of cows has no effect on grazing (Temple and Manteca, 2020). However, in the context of

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intensive housing and feed provision in troughs, a different scenario emerges (Hernández *et al.*, 2017). Animals with low height encounter limitations in accessing feed located near the trough wall and their hooves contact the base of the trough wall. This hinders their ability to access feed located near the trough wall, prompting them to turn their limbs outwards to approach and reach the feed (Delaby *et al.*, 2009). In some cases, animals have been observed to adopt an abnormal posture, characterized by spreading their limbs apart, to reach feed located near the trough wall (Sadiq *et al.*, 2020). These observations are consistent with the prevalence of limb twisting and distal asymmetry (LTDA) in dairy cattle in intensive production systems.

In the Comarca Lagunera, an arid northern area of Mexico where cattle milk production is intensive type, cases of lameness, asymmetry and torsion of the forelimbs have been reported (Bautista-Fernández *et al.*, 2021). Consequently, there has been a decrease in animal comfort and welfare (Solano *et al.*, 2015). In light of these observations, a study was conducted to test the working hypothesis that there is a correlation of the zoometric traits of lactating Holstein cows on LTDA, moreover, this lesion affects productive and reproductive performance of the cattle.

MATERIALS AND METHODS

General

The present study was observational, cross-sectional and comparative in nature. Data were collected from the records of a dairy farm and body measurements were taken from the cows in a study on 2024 (Barrera-Flores *et al.*, 2024). It is important to note that these measurements did not affect the cows' welfare. The animals utilized in this study adhered to the guidelines for the ethical use, care and welfare of research animals at the international (FASS, 2010), national (de Aluja, 2002) and institutional (UAAAN-UL-18-3059) levels.

Location and description of the experimental area

The study was conducted in a dairy complex, which is located at 25°52′39″ N 103°23′39″ W longitude in Tlahualilo, Durango, Mexico. The region is distinguished by a rainy season that extends from June to September, with an annual mean of 266 mm (range 163 to 440 mm) and a dry climate with an average annual temperature of 21°C, ranging from 0°C in winter to 37°C (May-August) (INEGI 2015).

Methodology

From a preliminary LTDA prevalence study conducted in the Comarca Lagunera dairy complex (Barrera-Flores *et al.*, 2024), a total of 60 animals were selected randomly divided into 30 LTDA-positive and 30 LTDA-negative cows for the study (Fig 1 A) LTDA-positive cow in feed bunk, B) LTDA positive cow, C) LTDA-negative cow.

Animal management

The ration for the experimental animals in both barns consisted of corn silage, alfalfa hay, cottonseed, soybean meal, canola, rolled corn, molasses, mineral salts, mycotoxin binder, sodium bicarbonate and free water. The ration offered was balanced according to the nutritional needs based on what is established by the NRC (NRC, 2007). Feed was offered at the rate four times a day. The quantity of feed offered was adjusted based on consumption, with additional feed being provided as per need. The cows were milked three times a day and during the initial 120 days in milk, an additional milking was performed during peak lactation.

Zoometric variables

The selected bovines were measured for the following zoometric variables: Height at the withers (CH; stainless steel ruler), neck length (NM), measured from the shoulder blades to the base of the ear and head length (HM), measured from the base of the ear to the tip of the nose. All measurements were made in centimeters (cm). The latter measurement was made with a flexometer (Trupper FCG-3M retractable, Jilotepec, Edo Mexico, Mexico) (Fig 2).

Productive variables

The following productive variables were measured like 24-hour milk production (PLD), using electronic meters

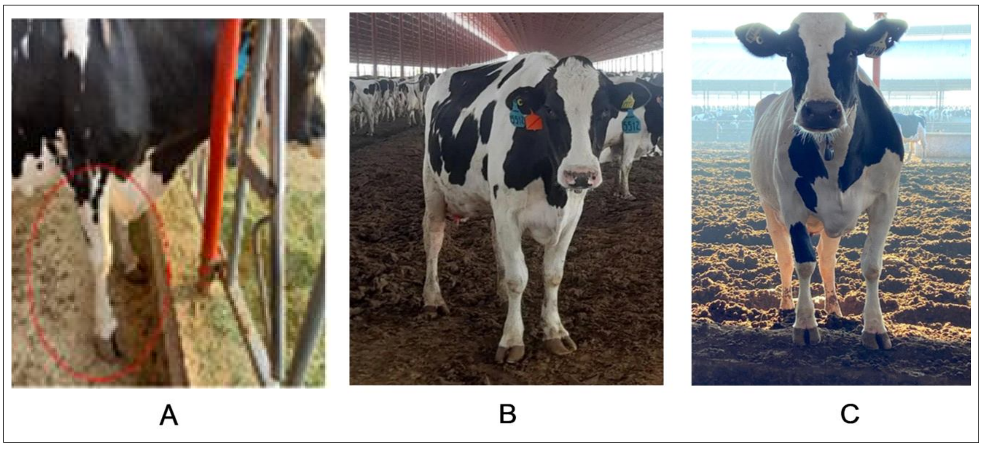


Fig 1: LTDA-positive cow in feed bunk (A), LTDA positive cow in pen B) and LTDA-negative cow in pen (C).

[Metatron Demas, Westfalia-Surge GmbH, Oelde, Germany]), number of lactations (LC) and days in milk (DIM). All these variables were obtained from Herd Management Software Records [Dairy Plan DP21, Westfalia-Surge GmbH, Oelde, Germany]).

Reproductive variables

The reproductive variables documented encompassed the number of inseminations (AI), days open (OD) and body condition score (BCS), in scale one to five (Ferguson *et al.*1994). These data were derived from Herd Management Software Records (Dairy Plan DP21, Westfalia-Surge GmbH, Oelde, Germany).

Statistical analysis

A logistic regression analysis of the observed data was performed to examine the influence of zoometric variables on LTDA, with the data partitioned into two halves (*i.e.*, sample and test). Likewise, a MANOVA was performed to compare cows with and without LTDA on productive and reproductive variables. A value of p<0.05 was defined as statistically significant.

The statistical analyses were executed using R version 4.4. (R Core Team 2024) and the following packages: InformationValue Version 1.3.1 (Prabhakaran, 2016), pscl version 1.5.9 (Jackman, 2024) and caret (Kuhn, 2008) for Logistic Regression and tidyverse (H. Wickham *et al.*, 2019), gridExtra (Auguie, 2017), effectsize (Ben-Shachar *et al.*, 2020), MASS (Venables and Ripley, 2002), rstatix version 0.7.2 (Kassambara, 2023), mvnormalTest version 1.0.0 and ggplot2 (Hadley Wickham, 2017) for MANOVA and plots.

RESULTS AND DISCUSSION

Zoometric variables and LTDA

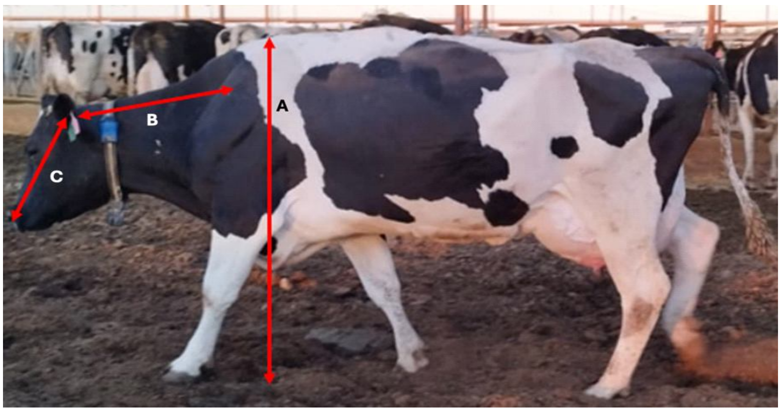
Perusal of predictive model coefficient of the predictive model reflect the mean variation in the logodds of “LTDA”. For instance, an increase of one unit in the variable “Height at withers” (CH) is associated with a mean decrease of 0.2985 in the logodds of “LTDA” presence (p = .003). With respect to neck length, the estimated value of the coefficient was -0.235, which is interpreted as a decrease in log odds (p = .015). With respect to head length, the coefficient was 0.009, however, it was not statistically significant (p = .581) (Table 1). The McFadden pseudo R^2 of the model was 0.220.

Productive variables

Descriptive statistics for Productive variables are shown in Table 2. A One-way MANOVA was conducted to determine whether there is a difference between positive and negative cows to LTDA on productive variables (Number of lactations, Days in milk and Average daily milk production per cow [kg]) (Fig 3). There was non-significant difference in Productive variables based on LTDA, $F(1, 118) = 0.819$, p = 0.486; partial eta squared = 0.02.

Reproductive variables

We fail to reject the null hypothesis and conclude that there is no difference between positive and negative cows to



A: Height at withers (CH). B: Neck length (NM), C: Head length (HM). All the measurements are in cm.

Fig 2: Zoometric variables.

Table 1: Regression coefficient estimates between forelimb torsion and the presence of forelimb torsion and distal asymmetry (LTDA) and zoometric variables in holstein cows.

	Estimate	Std. Error	Z value	Pr(|>z|)
Intercept	53.060	17.540	3.026	.002
Height at withers	-0.298	0.102	-2.931	.003
Neck length	-0.235	0.096	2.441	.015
Head length	0.092	0.166	0.552	.581

LTDA on productive variables (Number of lactations, Days in milk and Average daily milk production per cow [kg]).

Descriptive statistics for the reproductive variables are shown on Table 3. One-way MANOVA was conducted to determine whether there is a difference between positives and negatives cows to LTDA on reproductive variables (Number of inseminations, Open days and Body condition score) (Fig 4). There was significant difference in Reproductive variables based on LTDA, $F(1, 118) = 5.55$, $p = 0.001$; partial eta squared = 0.013.

Table 2: Mean, standard deviation and range of productive variables in Holstein cows positive or negative forelimb torsion and distal asymmetry (LTDA) reared in an intensive dairy farm.

Variable	LTDA	n	Mean	sd	Min	Max
Number of lactations	Negatives	60	3.870	0.724	1	6
	Positives	60	3.620	1.121	1	6
Days in milk	Negatives	60	127.570	34.780	13	172
	Positives	60	129.100	46.005	58	289
Average daily milk production per cow (Kg)	Negatives	60	42.280	7.127	26.000	57.398
	Positives	60	41.240	9.821	23.100	61.315

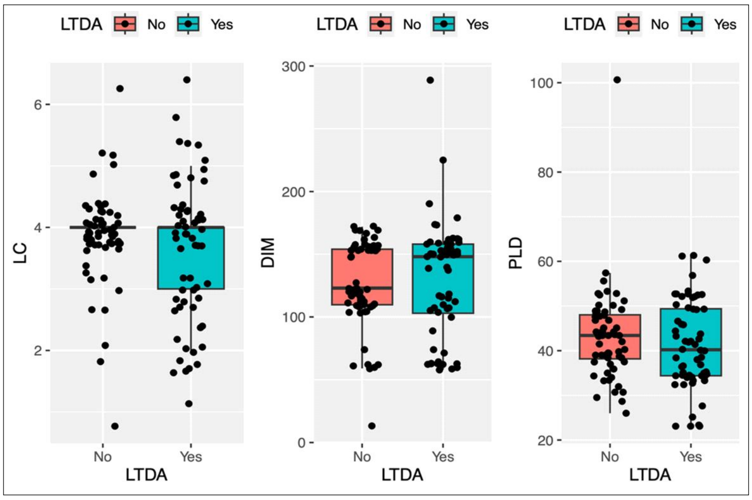


Fig 3: Productive variables: Number of lactations (LC), days in milk (DIM) and average daily milk production per cow (PLD), in cows positive (Yes) and negative (No) to forelimb torsion and distal asymmetry (LTDA) raised an intensive dairy farm.

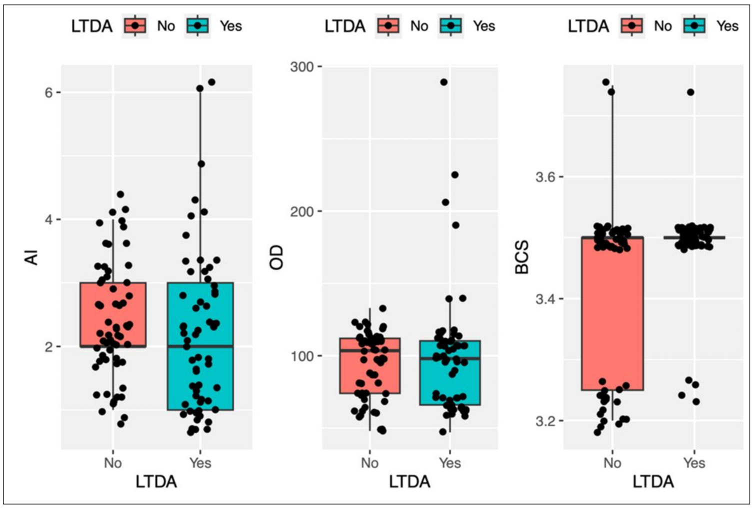


Fig 4: Reproductive variables: Number of artificial inseminations (AI), days open (OD) and body condition (BCS) in cows positive (Yes) and negative (No) to forelimb torsion and distal asymmetry (LTDA) raised in two intensive dairy farms.

We reject the null hypothesis and conclude that there is difference between positive and negative cows to LTDA with respect to Reproductive variables.

This study postulated two hypotheses. The first hypothesis postulated that there exists an association between the zoometric traits of Holstein cows (HC, NM, HM) and LTDA and that this lesion of the anterior train exerts an influence on the productive and reproductive performance of the cattle. Similarly, the second hypothesis postulated that the presence of LTDA impacts both productive (LC, DIM and PLD) and reproductive variables (AI, OD and BCS).

The findings of this study provide evidence to support the initial hypothesis, as demonstrated by the observation that two of the zoometric variables (HC and NM) exhibited an impact on the incidence of LTDA. However, no such effect was detected for HM on LTDA. In this context, the zoometric variables of height at withers and neck length have been found to demonstrate a significant negative association with LTDA. That is, as the height of the cow at the withers increases and its neck length increases, the prevalence of LTDA decreases. The design of the automatic traps' support wall and the presence of a crust of manure adhering to it due to inadequate cleaning of the inner sidewalk area of the pen did not appear to affect the height and neck length of cows (Barrera-Flores *et al.*, 2024, Sadiq *et al.*, 2021). Conversely, cows with a conformation characterized by low height and short neck encounter difficulties in accessing the feed trough. To address this challenge, cows are forced to approach the trough at an angle, resulting in their hooves making contact with the trough's wall. This leads to the stiffening of their forelimbs, which serves as the primary support for their body weight (Temple and Manteca, 2020).

With regard to the second hypothesis, an association between LTDA and productive variables was not observed ($p>0.5$), indicating that foot lesions in dairy cattle do not affect milk production. However, other studies have reported a negative association between milk production and limb diseases. Consequently, in regions where intensive cattle milk production is the norm, a negative impact of locomotion problems on milk production has been observed in response to the demand for high productivity. This phenomenon has been demonstrated to culminate in an augmented risk of hoof disorders (Bell *et al.*, 2009, Leach *et al.*, 2010). Conversely, it has been documented that approximately one-third of Holstein dairy cows in Spain encounter a minimum of one hoof disorder annually (Charfeddine and Pérez-Cabal, 2014a, 2017). Comparable trends have been observed in the United Kingdom, with estimates ranging from 21% (Clarkson *et al.*, 1996) to 36% (Leach *et al.*, 2010). In the Netherlands, more than 70% of dairy cows are affected by at least one hoof disorder (Somers *et al.*, 2003, Van Der Waaij *et al.*, 2005). However, these studies have not examined the potential role of body conformation and trough design as a contributing factor to the observed hoof problems.

A study of dairy cattle was conducted to evaluate the impact of lameness on milk production (Green *et al.*, 2002). The study concluded that cows with high milk yields in a herd may experience a reduction in their potential if they become lame. The authors of the study reported that a decline in milk production was observed from four months before to five months after a cow was diagnosed as clinically lame, resulting in a milk loss of up to 360 kilograms (range 160 to 550 kilograms) during a lactation period. This finding aligns with the conclusions reported by (Huxley *et al.*, 2013), who examined the repercussions of lameness on the health, animal welfare (Arnott *et al.*, 2017) and productivity of dairy cows. The aforementioned findings underscore the necessity of formulating strategies for the timely detection of locomotion problems in cows (Charfeddine and Pérez-Cabal, 2014b), whether due to torsion, asymmetry, or lameness, in order to mitigate losses in milk production (Dolecheck and Bewley, 2018, Huxley, 2013, Mason *et al.*, 2024, Robcis *et al.*, 2023). In contrast, lame cows appear to be more prone to postpartum uterine infections, experience higher levels of negative energy balance, resume ovarian cyclicity at a lower rate during the puerperium and exhibit lower potential to conceive and higher pregnancy losses (Tsousis *et al.*, 2022). In the context of LTDA and reproductive variables ($p<0.01$), an association was observed, primarily with BCS. A high BCS value (>4.0) is indicative of higher body weight, which, when added to advanced gestation, prevents the cow from a comfortable approach to the trough and thus, to an increased occurrence of LTDA (Barker *et al.*, 2010, EFSA, 2009, Sadiq *et al.*, 2021, Weigele *et al.*, 2018). Furthermore, cows with short stature, high body condition and advanced gestation, whether uniparous or multiparous, that inhabit

Table 3: Mean, standard deviation and range of reproductive variables in holstein cows positive and negative forelimb torsion and distal asymmetry (LTDA) reared in two intensive dairy farms.

Variable	LTDA	n	Mean	sd	Min	Max
Number of inseminations	Negatives	60	2.290	1.095	1	6
	Positives	60	2.290	1.095	1	6
Open days	Negatives	60	94.520	22.717	48	133
	Positives	60	99.080	42.409	47	289
Body condition score	Negatives	60	3.420	0.142	3.2	3.75
	Positives	60	3.490	0.072	3.25	3.75

pens with very wide walls and poor cleanliness and manure crust accumulation, are more prone to LTDA (Siachos *et al.*, 2024, Whay and Shearer, 2017). To mitigate the consequences of trough size on LTDA, dairy farms with crossbred populations (Holstein + Jersey), (Holstein + Ashire), (Hu *et al.*, 2021, Van Der Waaij *et al.*, 2005) should consider adjusting the trough floor areas by elevating the trough with an over floor (Somers *et al.*, 2003, Thomsen *et al.*, 2023). Furthermore, as Siachos *et al.* (2024) observe, enhancing the frequency and thoroughness of the approach of the ration to the trough wall is pivotal in preventing LTDA in housed dairy cattle. This approach is thus conducive to the promotion of animal welfare and, by extension, the enhancement of the performance of dairy farms. As Kumar *et al.* (2017) also observe, it was demonstrated that animals receiving adequate care exhibited increased productivity.

The findings of this study could be enhanced by increasing the sample size, incorporating age related variations in LTDA lesions and including the severity of the lesions (mild, moderate, or severe) as a variable. Additionally, measuring the effects on production and reproduction as the animal ages would contribute to a more comprehensive understanding.

CONCLUSION

LTDA in cows in production is associated with the zoometric or morphometric variables such as height at withers and neck length, indicating that cows with lower height and shorter neck length are more prone to LTDA.

Although the productive variables showed no significant effect on the incidence of LTDA, however, the reproductive variables are affected, similarly body condition also affected is significantly, since the heavier cow faces more problem accessing the feeder to feed comfortably.

Consequently, it is recommended that the study of the presence of LTDA, its causes and negative effects on animal welfare and variables of interest to livestock be extended, with the aim of establishing preventive measures to reduce or eliminate its incidence in dairy farms.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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