Locomotion Score and Postpartum Conception in Jersey Cows Raised Under Hot Humid Tropical Conditions

Karina Viles (vileskarina@gmail.com)  
Agrarian University of Ecuador  
https://orcid.org/0000-0003-0752-1303

Andres García  
Agrarian University of Ecuador

Octavio Rugel  
Agrarian University of Ecuador

Nahim Jorgge  
Agrarian University of Ecuador

Research Article

Keywords: lameness, reproductive performance, dairy cattle, days open, services per pregnancy, fertility

DOI: https://doi.org/10.21203/rs.3.rs-685082/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Reproductive physiology is one of the first systems to be affected when any cause of imbalance is present in an organism, and becomes relevant in tropical dairy farming, where high demands are required to maintain homeostasis and produce. Lameness is a common problem related to reproductive health and postpartum conception seems to be the most affected trait. The locomotion score system has demonstrated to be a reliable tool for the early detection of lameness. In this study, 52 Jersey milking cows, aged from 3 to 14 years, were visually scored once (1: non-lame, 2: slightly-lame, 3: moderately-lame, 4: lame and 5: severely-lame) and lactation, services per conception, and days open was registered. Scores ≥3 were considered as clinical lameness. Healthy, slightly-, moderately- and severely-lame cows required about 3 to 4 inseminations to conceive, whereas it was doubled in cows scored as lame-. Cows scored as moderately-lame, lame, and severely-lame had two to three times greater of days open than that of those scored as healthy and slightly-lame. Besides, the herd’s conception rate was reduced from 45.09% to 21.84% when clinical lame cows were included in the analysis. Days open and number of inseminations are considered hidden costs in dairy herds, therefore, the locomotion score should be considered as a routine analysis to reduce the impact of lameness on reproductive performance, even more so when it comes to humid tropical conditions, where high levels of humidity and temperature could rapidly aggravate lameness, increasing the costs of both, postpartum conception and hoof treatment.

1. Introduction

Lameness is defined as the clinical manifestation of painful disorders, mainly related to the locomotor system, that result in changes of movement or deviation from normal gait or posture, and its severity ranges from stiffness or decreased symmetry of limb movement to inability to bear weight on one limb or even full recline (Flower and Weary, 2009; Randall et al., 2016; Van Nuffel et al., 2015). It is considered the third-costliest health problem and a cause of discard in dairy cattle after reduced fertility and mastitis (Bicalho et al., 2007; Booth et al., 2004), and its importance in relation to welfare, health and profitability has received considerable attention, not only in terms of preventing and treating claudication, but also in terms of detection, since early diagnosis and treatment could decrease the associated direct and indirect costs (Dolecheck and Bewley, 2018; Hernandez et al., 2005; Ózsvárí, 2017). Typically, lame cows are detected by the farmer on the basis of abnormal locomotion or changes in behavior (Grimm et al., 2019; Sadiq et al., 2017; Thomsen et al., 2012; Weigele et al., 2018) and the presence of obvious lesions on the hooves during routine trimming (Van Nuffel et al., 2015). However, a locomotion score (LS) system has been developed to reduce subjectivity associated with individual perceptions that lead to the underestimation of the prevalence of lameness in a herd (Babatunde et al., 2019; Grimm et al., 2019; Leach et al., 2010; Šárová et al., 2011). This qualitative test was first described by Sprecher et al. (1997), and consists of a score from 1 (normal) to 5 (abnormal), that is given by an expert observer, and it can be supported by automated software (Schlageter-Tello et al., 2018). It is based on the degree of alteration of the biomechanics of the movement of the appendicular skeleton and its relationship with the line of the spinal column in standing and walking (gait) positions (Sprecher et al., 1997). The LS evaluation allows
an early detection of foot disorders, monitoring of the prevalence of lameness, accurate comparison of the incidence and severity of it; and the identification of animals that require functional trimming or treatment (Grimm et al., 2019; Thomsen et al., 2012). Moreover, it has proven useful in effectively predicting reproductive performance disorders since Spretcher’s findings (Sprecher et al., 1997) to date (O’Connor et al., 2020). Different studies support the findings of negative effects of cows scored as lame in postpartum reproductive variables, such as an increase of days open (Garcia-Muñoz et al., 2017), along with the need of more inseminations to conceive (Bicalho et al., 2007; Garcia-Bracho et al., 2015; Hernandez et al., 2005; Madushanka et al., 2016; Olechnowicz and Jaśkowski, 2011; Somers et al., 2015) and the delayed ovarian cyclicity due to the presence of ovarian cysts (Garbarino et al., 2004; Melendez et al., 2003; Morris et al., 2011). From a pathophysiological point of view, Melendez et al. (2003) indicates three hypotheses for the negative effect of lameness on fertility. First, histamine and endotoxins released during the decrease in ruminal pH in postpartum cows suffering from ruminal acidosis act indirectly to destroy the microvasculature of the chorion that causes laminitis, and those substances also potentiate their effects on the neuroendocrine and ovarian level, compromising the LH surge. Secondly, cortisol released as a result of stress and pain suffered by lame cows disrupts GnRH and the LH surge system. Lastly, the degree of negative energy balance can be higher in lame cows, affecting the somatotropic axis, inhibiting the growth hormone (GH), growth factors similar to Insulin (IGF-1 and -2) and its associated transporter proteins and receptors that play a key role in the return to cyclicality after calving.

On the other hand, the literature evidences that animals which produce high quantities of milk are more susceptible to lameness (Espejo et al., 2006; Huxley, 2013). Most of the studies on LS and reproductive performance have been carried out on breeds such as Holstein, Brown Swiss, some including Jerseys and crossbreeds (Bahonar et al., 2009; Madushanka et al., 2016; Van Nuffel et al., 2015), but only a few of them have been conducted under tropical conditions (Garcia-Bracho et al., 2015; Mellado et al., 2018). The Jersey breed, originally from the British island of Jersey, is recognized for producing milk with a level of fat higher than that of other breeds with respect to its weight (Chikhi et al., 2004; Huson et al., 2015), and it has been demonstrated to be the most successful in adapting to tropical conditions in comparison to other dairy breeds such as Holstein (Nascimento et al., 2019; Wing-Ching Jones et al., 2008). To our knowledge, no similar studies have been conducted on the Jersey breed reared under hot humid tropical conditions. Therefore, this study aimed to evaluate the effect of LS in Jersey milking cows on reproductive postpartum variables, such as the number of inseminations, the days open - also known as the calving conception interval (CCI) - and the conception rate.

2. Material And Methods

2.1 Animals and management

The study was conducted on a tropical dairy farm located in the Bucay Canton in the Province of Guayas (Ecuador). The herd was mainly constituted by certified Jersey cattle, and the region is within the tropical ecological zone; with an altitude of 300 - 700 m AMSL, average annual temperature of 20 °C, average annual precipitation of 2000 mm, and a relative humidity of 80% with a humid equatorial climate.
(INAMHI, 2019). Fifty two (n = 52) milking Jersey cows aged 3-14 years were included, weighing 300-450 kg, with a body condition score of 2.5 to 3.7 (1-5 scale), producing an average of 2940 kg of milk per lactation. Animals suffering any common postpartum disease in the immediately-preceding calving, such as ketosis, milk fever, mastitis, left abomasum displacement, and dystocia were previously discarded for the study. Selected cows experienced similar management conditions throughout the study, housed in a rotational grazing free-stall, milked two times per day by an automated system, had free access to grass (mainly *Brachiaria decumbens*), clean water, and supplemented during milking with pellets based on their individual requirements. The detection of postpartum oestrus and timed artificial insemination (TAI) were performed after 45 days of a voluntary waiting period. Briefly, the TAI protocol consisted in 2 ml of intramuscular estradiol benzoate (Benzoato de Estradiol 100 mg, Fatro Von Franken, Argentina) with an intravaginal implant of progesterone (Dispocel Max 1.2 g, Fatro Von Franken, Argentina) at day 1; and 2 ml of prostaglandin (Dextrogenol 7.5 mg, Fatro Von Franken, Argentina), 1 ml of estradiol ciprionate (Sincro CP 100 mg, Ourofino, Brazil) and 1.5 ml of chorionic equine gonadothropin (Sincro eCG 6.000 UI, Ourofino, Brazil), all intramuscularly at day 7; following TAI after 48-56 h with one straw of certified frozen-thawed semen containing $2 \times 10^6$ sperm/ml in 0.5 ml (ABS Global, Brazil). Pregnancy diagnoses were performed by ultrasound with a linear transducer of 5MHz (Eco 2 Chison Medical Technologies Co., Ltd. China) at 45 days after TAI, and reconfirmed by rectal palpation after 70 days of TAI.

### 2.2 Study design

All experiments were performed with the consent of the Veterinary Medicine and Zootecnicos Project Evaluation Committee of the Agrarian University of Ecuador. It was a prospective observational cohort study based on the 5-point scale locomotion score (LS) system (Sprecher et al. 1997). To evaluate the patterns of movement in station and gait, animals were visually examined once by a similarly-trained veterinarian on a horizontal, flat, dry, clean and comfortable surface, in accordance with the recommendations of Huxley (2013) and Van Hertem et al. (2014). Additionally, the automated Zinpro® software was used to verify the given score. A scale of 1 (non-lame), 2 (slightly lame), 3 (moderately lame), 4 (lame) and 5 (severely lame) was assigned to each animal. Information of age, milk yield, lactation, body condition and reproductive parameters of each animal was retrieved from the Genus Reproductive Management System (ABS Global, Brazil).

### 2.3 Statistical analysis

Data were analyzed by using Rstudio (Version 1.3.1093; Integrated Development for R. RStudio, PBC, Boston, MA) statistics software. LS was considered as an independent variable, and reproductive variables associated with postpartum conception as dependent variables. The conception rate of the herd was calculated by dividing the number of pregnant cows by the total number of inseminations. In addition, the effect of the number of lactations on LS was analyzed, due to the wide range of age in the sample. Descriptive statistics of LS were expressed in frequencies, percentages, median and mode, and quantitative data of the reproductive variables were expressed in mean (M) with its standard error (SEM). Before comparing the variables, the assumptions of normality and homoscedasticity were verified.
Comparisons were made with one-way ANOVA and a Tukey test in the case of compliance with the assumptions; otherwise, data were compared with the non-parametric Kruskal-Wallis test. A 95% of confidence and a significance of $P< 0.05$ were considered for all tests.

3. Results

3.1 Descriptive statistics of LS

A proportion of 82.68% ($n = 43$) of the total sampled cows ($n = 52$) had any grade of lameness, distributed in the 13.46% ($n = 7$) for slightly lame and 69.22% ($n = 36$) for cows with clinical lameness (scores $\geq 3$); distributed in 44.23% ($n = 23$) for moderately lame, 19.23% ($n = 10$) for lame and 5.76% ($n = 3$) for severely lame, whereas 17.30% ($n = 9$) of cows were scored as sound. Moreover, the herd showed a median and mode of score 3 and a negative asymmetry skewed to the left (Fig. 1) was observed.

3.2 Influence of LS on reproductive variables related with postpartum conception

Significant differences between LS and the number of inseminations and days open - calving conception interval - were observed; $P< 0.001$, $P< 0.0001$, respectively. Cows presented a mean $4.53 \pm 0.42$ lactations with no significant differences between LS and the number of lactations ($P = 0.62$). A total of 238 inseminations with a mean of $4.57 \pm 0.35$ services to conceive were registered, and a conception rate of 21.84% for the entire herd ($n = 52$) was estimated. Cows presenting an LS $\leq 2$ had a conception rate of 45.09%, and clinically-lame cows (scores $\geq 3$) had a conception rate of 19.25%. The number of inseminations was similar in 1-, 2-, 3- and 5-scored cows, with a significant increase of inseminations in 4-scored cows, although there were no differences between 4- and 5-scored animals. The average number of days open (or the CCI) was $225.51 \pm 14.31$, being similar in 1- to 3-scored cows, and significantly increasing in 4- and 5-scored cows, while 3- and 4-scored cows presented similar CCIs (Table 1).

| Reproductive variables | 1       | 2       | 3       | 4       | 5       |
|------------------------|---------|---------|---------|---------|---------|
| Number of inseminations| $3.11 \pm 0.3^b$ | $3.28 \pm 0.60^b$ | $4.39 \pm 0.42^b$ | $7.50 \pm 0.92^a$ | $3.66 \pm 2.18^{ab}$ |
| Days open/CCI          | $142.9 \pm 14.62^c$ | $158.3 \pm 23.38^c$ | $230.7 \pm 19.95^{bc}$ | $287.9 \pm 29.8^{ab}$ | $383 \pm 52.7^a$ |
| Lactation              | $5.11 \pm 1.29^a$ | $5.85 \pm 1.45^a$ | $3.78 \pm 0.53^a$ | $5 \pm 0.89^a$ | $4 \pm 2.08^a$ |

$a, b, c$ Means with different superscripts within the same raw differ ($P\leq 0.05$)

4. Discussion
Lameness in cattle is one of the most important issues in a veterinarian’s daily performance, since it compromises animal welfare and represents an important cause of economic losses in milk and meat productions (Dolecheck and Bewley, 2018; Ettema et al., 2010; Huxley, 2013; Whay et al., 2003). Lameness evaluation using the LS system has become a novel trait of economic relevance in dairy herds (Roveglia et al., 2019). A high proportion of Jersey cows presented any grade of lameness (82.69%), where subclinically-lame cows represented 13.46% of the herd and clinically lame cows 69.22%, moderately lame animals being the most common score, resulting in almost half the dairy herd. Similar results have been reported with respect to the prevalence of subclinically and clinically lame cows (Bicalho et al., 2007; Hernandez et al., 2005; Whay et al., 2003); however, a large variation across herds is described, with ranges varying from one third to more than one-half of the herd, mainly due to varying conditions of the cow and its environment, such as the type of production system, breed, ecology of the area, cow handling, frequency of hoof-trimming, flooring surface and skills of personnel responsible for identifying lame cows, among many other aspects (Barker et al., 2010; Bran et al., 2019; Dippel et al., 2009; Foditsch et al., 2016; Mellado et al., 2018). For instance - and contrary to our results - lactation influenced the presentation of lameness in high-production Holstein cows housed in freestall barns (Espejo et al., 2006), and a very low incidence risk of 15% was reported for clinically-lame cows in a seasonally breeding pasture-based system in New Zealand (Alawneh et al., 2011). Importantly, it was reported that the incidence of lameness usually increased in winter, characterized by rains and a humid environment (Clarkson et al., 1996; Cook, 2003; Espejo et al., 2006), and so the high proportion of cows suffering any grade of lameness in this study was probably due to the amount of constant proportion of water in the hot humid tropical environment. Likewise, a prevalence of up to 76% of lameness was reported under similar tropical conditions in Brazil (Bran et al., 2019). Therefore, even when the Jersey breed has been demonstrated to adapt to the tropics (Nascimento et al., 2019; Smith et al., 2013) and the pasture-based systems seem to decrease the incidence of lameness when compared with confinement systems (Alawneh et al., 2011), not just the management of the animals but the hot humid tropical conditions themselves might increase the prevalence of lameness.

On the other hand, the effect of LS on fertility has been broadly studied in many countries, under different production systems and environmental conditions (Alawneh et al., 2011; Bicalho et al., 2007; Foditsch et al., 2016; Garbarino et al., 2004; Hernandez et al., 2005; Huxley, 2013; Morris et al., 2011; Randall et al., 2016; Somers et al., 2015; Sood and Nanda, 2006; Sprecher et al., 1997). In this study, all postpartum conception variables were related to LS, and values increased within scores, indicating the severity of lameness, as first stated by Sprecher et al. (1997). First, the conception rate of the herd was 21.84%, but when splitting scores under and above 3; non-lame and slightly lame cows presented better values (45.09%) compared with clinically lame cows (LS ≥ 3), which presented a lower conception rate (19.25%). Regarding inseminations, the mean number of services was 4.5, with a range of 3 to 4 services in normal and slightly, moderately and severely lame cows, whereas animals scored as lame (LS= 4) required about 6 to 10 inseminations to conceive. These results indicate that although a normal number of inseminations in dairy cattle should be about 1.65 services (Ball and Peters, 2007), and the mean values in normal to moderately-lame cows were slightly higher than normal, these were doubled in cows
scored as lame. It is to be noted that severely lame cows had a similar number of inseminations to non-
lame, slightly and moderately lame cows, but this could be explained by the low proportion of animals
scored as severely lame (n = 3) ; and thus results could be seen to vary given a greater sample. The
increase in the number of inseminations has been reported for lame Holstein cows (Hernandez et al.,
2005; Shearer et al., 2013) and, similar to our results, one study described more than 3 services needed to
conceive in cows with different causes of lameness, increasing up to 7 services in cows presenting
infectious pododermatitis and digital dermatitis, while non-lame animals required 1.5 to 6 inseminations
to conceive (Mellado et al., 2018). Moreover, non-lame and slightly lame cows had an approximate CCI of
130 to 170 days, showing a slight rise compared to the normal range compared to that defined in the
literature (Ball and Peters, 2007). However, moderately lame, lame and severely lame cows had about 190
to 500 days open or CCI, hence, the number of days from calving to conception was doubled for
moderately lame and lame cows, and tripled for severely lame cows. Since the findings of Sprecher et al.
(1997), who evidenced the negative influence of lameness on days to first service and CCI, subsequent
studies have strengthened the direct relation of lameness with low fertility, mainly due to the increased
number of inseminations and therefore the days open, with ranges that vary from 4 to 50 more days
(Alawneh et al., 2011; Bicalho et al., 2007; Garbarino et al., 2004; Hernandez et al., 2005; Madushanka et
al., 2016; Melendez et al., 2003; Mellado et al., 2018; Orgel et al., 2016; Paiano et al., 2020; Somers et al.,
2015; Willshire and Mr cvs, 2012). In addition, lameness has been reported as the second-
placed production disease responsible for increasing days open after caesarean, and it is rated above
other diseases such as endometritis, placental retention, dystocia, mastitis and milk fever (Dobson et al.,
2020; Walker et al., 2008). Although our results are similar to those described above, the higher increase
of days open due to lameness stands out in this herd; which is probably due to the high proportion of
clinically lame cows that mainly corresponded to evidently lame cows.

Production diseases such as lameness have long-term effects on milking performance, fertility and
culling of dairy cows, all of which are detrimental to the sustainability of dairy herds (Carvalho et al.,
2019). This is a challenging aspect when considering dairy production in the tropics, where not only
factors such as economic restrictions, lack of agricultural politics or sufficient scientific information limit
the ability to sustainably manage a dairy herd's health, but also cattle are subjected to environmental
conditions different to their origins, such as an elevated temperature, solar radiation and high humidity;
and these conditions can compromise management traits as foot health and reproductive efficiency
(Hernández-Castellano et al., 2019; Mellado et al., 2018). Nonetheless, the need to satisfy the increasing
demand for animal-sourced foods and to reduce poverty in the tropics has led it to consider the tropical
livestock production as a relevant discipline within Animal Science, and under this scenario, region-
specific strategies toward sustainable livestock production within the limitations described above, and
integrated into a value chain concept are being developed (Oosting et al., 2014). Among them, lameness,
considered as a critical determinant of animal well-being and directly related with technical efficiency and
thus sustainability at a farm level; might be actively managed to minimize its occurrence (Barnes et al.,
2011). In this context, a routine monitoring of lameness using the LS system should be given more
relevance in the tropics, since it is an economic and easy-to-learn tool that gives valuable information on
the prevalence of lameness and, as such, could also prevent the consequences related to postpartum conception in a hot humid tropical environment being observed as worse than those reported for non-tropical regions.

Fertility is one of the main factors that becomes relevant when discussing economic losses caused by foot diseases in livestock farms. In this study, subclinical lameness did not influence postpartum conception in Jersey cows raised under hot humid tropical conditions; however, a high proportion of clinically-lame cows biased overall postpartum conception variables, and environmental conditions seemed to worsen the effects of lameness on reproduction, doubling and even tripling the values of services per conception and days open compared to normal. Those results were also reflected in a very low conception rate for the herd. A regular evaluation of the movement patterns of cattle through the LS system not only allows an early diagnosis of lameness and maintains a healthy-foot herd, but would also favour sustainable management of the herd by improving the reproductive efficiency related to postpartum conception in dairy cattle raised under hot humid tropical conditions.

Declarations

**Funding:** No funds, grants, or other support was received

**Conflicts of interest:** The authors have no conflicts of interest to declare that are relevant to the content of this article

**Data, material and code availability:** all data, materials as well as software code support this study and comply the scientific standards

**Ethics approval:** Not applicable

**Consent to participate:** Not applicable

**Consent for publication:** Not applicable

**Authors' contributions:** Karina Vilés and Andres García conceived and designed the study. Andres García conducted the experiments and collected information of field. Octavio Rugel ran the statistics and analyzed data. Karina Vilés interpreted data results and wrote the manuscript. Nahim Jorgge reviewed the document and made technical recommendations. All authors read and approved the manuscript.

**Acknowledgements**

We would like to thank Dr. Luis Lalama, who generously volunteered his installations to conduct the study, and to Dr. Washington Yoong, dean of the Faculty of Veterinary and Zootecnics of the Agrarian University of Ecuador, for his gentle collaboration with professional recommendations and administrative duties. We also particularly thank Prof. Paul Lewin Giles, M. Sc. in Creative Writing from the University of Sydney, for his kind collaboration in this article's language revision.
References

1. Alawneh, J.I., Laven, R.A., Stevenson, M.A., 2011. The effect of lameness on the fertility of dairy cattle in a seasonally breeding pasture-based system. J. Dairy Sci. 94, 5487–5493. https://doi.org/10.3168/jds.2011-4395

2. Babatunde, S.M., Ramanoon, S.Z., Shaik Mossadeq, W.M., Mansor, R., Syed Hussain, S.S., 2019. Dairy Farmers’ Perceptions of and Actions in Relation to Lameness Management. Anim. an open access J. from MDPI 9, 270. https://doi.org/10.3390/ani9050270

3. Bahonar, A., Azizzadeh, M., Stevenson, M., Vojgani, M., Mahmoud, M., 2009. Factors Affecting Days Open in Holstein Dairy Cattle in Khorasan Razavi Province, Iran; A Cox Proportional Hazard Model. J. Anim. Vet. Adv. 8.

4. Ball, P.J.H., Peters, A.R., 2007. Reproduction in Cattle: Third Edition, Reproduction in Cattle: Third Edition. Wiley Blackwell. https://doi.org/10.1002/9780470751091

5. Barker, Z.E., Leach, K.A., Whay, H.R., Bell, N.J., Main, D.C.J., 2010. Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. J. Dairy Sci. 93, 932–941. https://doi.org/10.3168/jds.2011-4262

6. Barnes, A.P., Rutherford, K.M.D., Langford, F.M., Haskell, M.J., 2011. The effect of lameness prevalence on technical efficiency at the dairy farm level: An adjusted data envelopment analysis approach. J. Dairy Sci. 94, 5449–5457. https://doi.org/10.3168/jds.2011-4262

7. Bicalho, R.C., Vokey, F., Erb, H.N., Guard, C.L., 2007. Visual locomotion scoring in the first seventy days in milk: Impact on pregnancy and survival. J. Dairy Sci. 90, 4586–4591. https://doi.org/10.3168/jds.2007-0297

8. Booth, C.J., Warnick, L.D., Gröhn, Y.T., Maizon, D.O., Guard, C.L., Janssen, D., 2004. Effect of Lameness on Culling in Dairy Cows. J. Dairy Sci. 87, 4115–4122. https://doi.org/10.3168/jds.S0022-0302(04)73554-7

9. Bran, J.A., Costa, J.H.C., von Keyserlingk, M.A.G., Hötzel, M.J., 2019. Factors associated with lameness prevalence in lactating cows housed in freestall and compost-bedded pack dairy farms in southern Brazil. Prev. Vet. Med. 172, 104773. https://doi.org/10.1016/j.prevetmed.2019.104773

10. Carvalho, M. R., Peñagaricano, F., Santos, J. E. P., DeVries, T. J., McBride, B. W., & Ribeiro, E. S. (2019). Long-term effects of postpartum clinical disease on milk production, reproduction, and culling of dairy cows. Journal of Dairy Science, 102(12), 11701–11717. https://doi.org/10.3168/jds.2019-17025

11. Clarkson, M.J., Downham, D.Y., Faull, W.B., Hughes, J.W., Manson, F.J., Merritt, J.B., Murray, R.D., Russell, W.B., Sutherst, J.E., Ward, W.R., 1996. Incidence and prevalence of lameness in dairy cattle. Vet. Rec. 138, 563–567. https://doi.org/10.1136/vr.138.23.563

12. Cook, N.B., 2003. Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. J. Am. Vet. Med. Assoc. 223, 1324–1328. https://doi.org/10.2460/javma.2003.223.1324
13. Dippel, S., Dolezal, M., Brenninkmeyer, C., Brinkmann, J., March, S., Knierim, U., Winckler, C., 2009. Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries. J. Dairy Sci. 92, 5476–5486. https://doi.org/10.3168/jds.2009-2288

14. Dobson, H., Routly, J.E., Smith, R.F., 2020. Understanding the trade-off between the environment and fertility in cows and ewes. Anim. Reprod. 17, 1–30. https://doi.org/10.1590/1984-3143-AR2020-0017

15. Dolecheck, K., Bewley, J., 2018. Animal board invited review: Dairy cow lameness expenditures, losses and total cost. Animal 12, 1462–1474. https://doi.org/10.1017/S1751731118000575

16. Espejo, L.A., Endres, M.I., Salfer, J.A., 2006. Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. J. Dairy Sci. 89, 3052–3058. https://doi.org/10.3168/jds.S0022-0302(06)72579-6

17. Ettema, J., Østergaard, S., Kristensen, A.R., 2010. Modelling the economic impact of three lameness causing diseases using herd and cow level evidence. Prev. Vet. Med. 95, 64–73. https://doi.org/10.1016/j.prevetmed.2010.03.001

18. Flower, F.C., Weary, D.M., 2009. Gait assessment in dairy cattle. Animal 3, 87–95. https://doi.org/10.1017/S1751731108003194

19. Foditsch, C., Oikonomou, G., Machado, V.S., Bicalho, M.L., Ganda, E.K., Lima, S.F., Rossi, R., Ribeiro, B.L., Kussler, A., Bicalho, R.C., 2016. Lameness prevalence and risk factors in large dairy farms in upstate New York. Model development for the prediction of claw horn disruption lesions. PLoS One 11, 1–15. https://doi.org/10.1371/journal.pone.0146718

20. Garbarino, E.J., Hernandez, J.A., Shearer, J.K., Risco, C.A., Thatcher, W.W., 2004. Effect of lameness on ovarian activity in postpartum Holstein cows. J. Dairy Sci. 87, 4123–4131. https://doi.org/10.3168/jds.S0022-0302(04)73555-9

21. García-Bracho, D., Hahn, M., Pino, D., Soto, E., Leal, M., Aranguren, J., 2015. Efecto de las enfermedades podales sobre los parámetros reproductivos en vacas mestizas doble propósito a pastoreo. Rev. Cient. la Fac. Ciencias Vet. la Univ. del Zulia 25, 300–303.

22. García-Muñoz, A., Singh, N., Leonardi, C., Silva-del-Río, N., 2017. Effect of hoof trimmer intervention in moderately lame cows on lameness progression and milk yield. J. Dairy Sci. 100, 9205–9214. https://doi.org/10.3168/jds.2016-12449

23. Grimm, K., Haidn, B., Erhard, M., Tremblay, M., Döpfer, D., 2019. New insights into the association between lameness, behavior, and performance in Simmental cows. J. Dairy Sci. 102, 2453–2468. https://doi.org/10.3168/jds.2018-15035

24. Hernández-Castellano, L.E., Nally, J.E., Lindahl, J., Wanapat, M., Alhidary, I.A., Fangueiro, D., Grace, D., Ratto, M., Bambou, J.C., de Almeida, A.M., 2019. Dairy science and health in the tropics: challenges and opportunities for the next decades. Trop. Anim. Health Prod. https://doi.org/10.1007/s11250-019-01866-6

25. Hernandez, J.A., Garbarino, E.J., Shearer, J.K., Risco, C.A., Thatcher, W.W., 2005. Comparison of milk yield in dairy cows with different degrees of lameness. J. Am. Vet. Med. Assoc. 227, 1292–1296. https://doi.org/10.2460/javma.2005.227.1292
26. Huxley, J.N., 2013. Impact of lameness and claw lesions in cows on health and production. Livest. Sci. 156, 64–70. https://doi.org/10.1016/j.livsci.2013.06.012

27. Instituto Nacional de Meteorología e Hidrología – IMNAHI. Características climáticas del Canton Bucay. http://www.serviciometeorologico.gob.ec/?s=BUCAy (accessed 16 October 2019)

28. Leach, K.A., Whay, H.R., Maggs, C.M., Barker, Z.E., Paul, E.S., Bell, A.K., Main, D.C.J., 2010. Working towards a reduction in cattle lameness: 1. Understanding barriers to lameness control on dairy farms. Res. Vet. Sci. 89, 311–317. https://doi.org/https://doi.org/10.1016/j.rvsc.2010.02.014

29. Madushanka, D., Ranasingha, V., Bandara, A., Mayurawansha, W., Magamage, M., 2016. Body condition score and locomotion score help to predict reproductive and health performances of dairy cattle. Rumin. Sci. 5, 179–186.

30. Melendez, P., Bartolome, J., Archbald, L.F., Donovan, A., 2003. The association between lameness, ovarian cysts and fertility in lactating dairy cows. Theriogenology 59, 927–937. https://doi.org/10.1016/S0093-691X(02)01152-4

31. Mellado, Miguel, García, J.E., Veliz Deras, F.G., De Los Ángeles de Santiago, M., Mellado, J., Gaytán, L.R., Ángel-García, O., 2018. The effects of periparturient events, mastitis, lameness and ketosis on reproductive performance of Holstein cows in a hot environment. Austral J. Vet. Sci. 50, 1–8. https://doi.org/10.4067/s0719-81322018000100102

32. Mellado, M, Saavedra, E., Gaytán, L., Veliz, F., Macías-Cruz, U., Avendaño-Reyes, L., García, E., 2018. The effect of lameness-causing lesions on milk yield and fertility of primiparous Holstein cows in a hot environment. Livest. Sci. 217, 8–14. https://doi.org/10.1016/j.livsci.2018.09.008

33. Morris, M.J., Kaneko, K., Walker, S.L., Jones, D.N., Routly, J.E., Smith, R.F., Dobson, H., 2011. Influence of lameness on follicular growth, ovulation, reproductive hormone concentrations and estrus behavior in dairy cows. Theriogenology 76, 658–668. https://doi.org/10.1016/j.theriogenology.2011.03.019

34. Nascimento, S.T., Sandro, A., Maia, C., França, V. De, Fonsêca, C., Cardoso, C., Nascimento, N., Carvalho, M.D. De, Pinheiro, G., 2019. Physiological responses and thermal equilibrium of Jersey dairy cows in tropical environment. Int. J. Biometeorol. 1-10.

35. O’Connor, A.H., Bokkers, E.A.M., de Boer, I.J.M., Hogeveen, H., Sayers, R., Byrne, N., Ruelle, E., Shalloo, L., 2020. Associating mobility scores with production and reproductive performance in pasture-based dairy cows. J. Dairy Sci. 103, 9238–9249. https://doi.org/10.3168/jds.2019-17103

36. Olechnowicz, J., Jaśkowski, J.M., 2011. Relation between clinical lameness and reproductive performance in dairy cows. Med. Weter. 67, 5–9.

37. Oosting, S.J., Udo, H.M.J., Viets, T.C., 2014. Development of livestock production in the tropics: Farm and farmers’ perspectives. Animal 8, 1238–1248. https://doi.org/10.1017/S1751731114000548

38. Orgel, C., Ruddat, I., Hoedemaker, M., 2016. Prävalenz von Lahmheiten unterschiedlichen Grades in der Frühlaktation von Milchkühen und deren Einfluss auf Fruchtbarkeitsparameter. Tierärztliche Prax. Ausgabe G Großtiere / Nutztiere 44, 207–217. https://doi.org/10.15653/tpg-150624
39. Ózsvári, L., 2017. Economic Cost of Lameness in Dairy Cattle Herds. J. Dairy, Vet. Anim. Res. 6. https://doi.org/10.15406/jdvar.2017.06.00176

40. Paiano, R.B., Birgel, D.B., Bonilla, J., Birgel Junior, E.H., 2020. Alterations in biochemical profiles and reproduction performance in postpartum dairy cows with metritis. Reprod. Domest. Anim. 55, 1599–1606. https://doi.org/10.1111/rda.13815

41. Randall, L. V., Green, M.J., Chagunda, M.G.G., Mason, C., Green, L.E., Huxley, J.N., 2016. Lameness in dairy heifers; impacts of hoof lesions present around first calving on future lameness, milk yield and culling risk. Prev. Vet. Med. 133, 52–63. https://doi.org/10.1016/j.prevetmed.2016.09.006

42. Roveglia, C., Niero, G., Bobbo, T., Penasa, M., Finocchiaro, R., Visentin, G., Lopez-Villalobos, N., Cassandro, M., 2019. Genetic parameters for linear type traits including locomotion in Italian Jersey cattle breed. Livest. Sci. 229, 131–136. https://doi.org/10.1016/j.livsci.2019.09.023

43. Sadiq, M.B., Ramanoon, S.Z., Mossadeq, W.M.S., Mansor, R., Syed-Hussain, S.S., 2017. Association between lameness and indicators of dairy cow welfare based on locomotion scoring, body and hock condition, leg hygiene and lying behavior. Animals 7. https://doi.org/10.3390/ani7110079

44. Šárová, R., Stěhulová, I., Kratinová, P., Firla, P., Spinka, M., 2011. Farm managers underestimate lameness prevalence in Czech dairy herds. Anim. Welf. 20, 201–204.

45. Schlageter-Tello, A., Van Hertem, T., Bokkers, E.A.M., Viazzi, S., Bahr, C., Lokhorst, K., 2018. Performance of human observers and an automatic 3-dimensional computer-vision-based locomotion scoring method to detect lameness and hoof lesions in dairy cows. J. Dairy Sci. 101, 6322–6335. https://doi.org/10.3168/jds.2017-13768

46. Shearer, J.K., Stock, M.L., Van Amstel, S.R., Coetzee, J.F., 2013. Assessment and Management of Pain Associated with Lameness in Cattle. Vet. Clin. North Am. - Food Anim. Pract. 29, 135–156. https://doi.org/10.1016/j.cvfa.2012.11.012

47. Smith, D.L., Smith, T., Rude, B.J., Ward, S.H., 2013. Short communication: Comparison of the effects of heat stress on milk and component yields and somatic cell score in Holstein and Jersey cows. J. Dairy Sci. 96, 3028–3033. https://doi.org/10.3168/jds.2012-5737

48. Somers, J.R., Huxley, J., Lorenz, I., Doherty, M.L., O’Grady, L., 2015. The effect of Lameness before and during the breeding season on fertility in 10 pasture-based Irish dairy herds. Ir. Vet. J. 68, 1–7. https://doi.org/10.1186/s13620-015-0043-4

49. Sood, P., Nanda, A.S., 2006. Effect of lameness on estrous behavior in crossbred cows. Theriogenology 66, 1375–1380. https://doi.org/10.1016/j.theriogenology.2006.04.031

50. Sprecher, D., Hostetler, D.E., Kaneene, J., 1997. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology 47, 1179–1187. https://doi.org/10.1016/S0093-691X(97)00098-8

51. Thomsen, P.T., Munksgaard, L., Sørensen, J.T., 2012. Locomotion scores and lying behaviour are indicators of hoof lesions in dairy cows. Vet. J. 193, 644–647. https://doi.org/10.1016/j.tvjl.2012.06.046
52. Van Hertem, T., Parmet, Y., Steensels, M., Maltz, E., Antler, A., Schlageter-Tello, A.A., Lokhorst, C., Romanini, C.E.B., Viazzi, S., Bahr, C., Berckmans, D., Halachmi, I., 2014. The effect of routine hoof trimming on locomotion score, ruminating time, activity, and milk yield of dairy cows. J. Dairy Sci. 97, 4852–4863. https://doi.org/10.3168/jds.2013-7576

53. Van Nuffel, A., Zwertvaegher, I., Pluym, L., Van Weyenberg, S., Thorup, V.M., Pastell, M., Sonck, B., Saey, W., 2015. Lameness detection in dairy cows: Part 1. How to distinguish between non-lame and lame cows based on differences in locomotion or behavior. Animals 5, 838–860. https://doi.org/10.3390/ani5030387

54. Walker, S.L., Smith, R.F., Routly, J.E., Jones, D.N., Morris, M.J., Dobson, H., 2008. Lameness, activity time-budgets, and estrus expression in dairy cattle. J. Dairy Sci. 91, 4552–4559. https://doi.org/10.3168/jds.2008-1048

55. Weigele, H.C., Gygax, L., Steiner, A., Wechsler, B., Burla, J.B., 2018. Moderate lameness leads to marked behavioral changes in dairy cows. J. Dairy Sci. 101, 2370–2382. https://doi.org/10.3168/jds.2017-13120

56. Whay, H.R., Main, D.C.J., Green, L.E., Webster, A.J.F., 2003. Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigation of farm records. Vet. Rec. 153, 197–202. https://doi.org/10.1136/vr.153.7.197

57. Willshire, J.A., Mrcvs, B.C., 2012. The use of mobility score to predict dairy cow reproductive performance by.

58. Wing-Ching Jones, R., Pérez, R., Salazar, E., 2008. Condiciones ambientales y producción de leche de un hato de ganado Jersey en el trópico húmedo: El caso del módulo lechero SDA/UCR. Agron. Costarric. 32, 87–94. https://doi.org/10.1002/pola.24127

Figures
Figure 1

Distribution of LS in Jersey milking cows raised in a hot humid tropical dairy farm.