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Associations between hoof lesions and locomotion score in 1098 unsound dairy cows

Néstor Tadich^{a,*}, Efrén Flor^b, Laura Green^c

^a Department of Veterinary Clinical Sciences, Faculty of Veterinary Science, University Austral of Chile, P.O. Box 567, Valdivia, Chile

^b Master of Science Programme, Faculty of Veterinary Science, University Austral of Chile, Chile

^c Department of Biological Sciences, University of Warwick, Coventry, England CV4 7AL, UK

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ABSTRACT

To investigate the association between locomotion score and types of hoof lesion, cows from 91 selected dairy herds in southern Chile were studied. The locomotion score was recorded for all of the lactating cows ($n = 10,699$). The mean prevalence of lame cows, when all locomotion scores >1 were included was 33.2% in large herds and 28.7% in small herds. There were 39.7%, 42%, 17.9% and 0.4% cows with locomotion scores of 2, 3, 4 and 5, respectively. Feet (with locomotion scores representative of all severities of lameness) were examined on 676 cows from 34 large herds and 422 cows from 57 small herds. The prevalence of lesions by type ranged from 65% of cattle with at least one white line lesion to 2% of cattle with an interdigital growth.

The lesions linked with increasingly poor locomotion were sole ulcer, double sole and interdigital purulent inflammation. There was correlation between claw skin lesions and also between sole ulcer and double sole within cows. It was concluded that the presence of a lesion does not imply that it is necessarily associated with increasing locomotion score. The lack of association between certain lesions and poor locomotion scores indicates either that these lesions are causing different severities of lameness, or that the case definitions used were not sufficiently precise. Locomotion score may not be sensitive enough to detect all lesions (and possibly discomfort).

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Introduction

Lameness in dairy cows is a serious welfare issue. It is a painful condition and causes economic losses (Esslemont and Kossaibati, 1997) through early culling (Booth et al., 2004) and reduced milk yield (Amory et al., 2008). A useful research and practitioner tool for monitoring herd and individual lameness is locomotion scoring. Routine scoring of locomotion in a dairy herd fulfils a number of functions: (1) it identifies cows that require treatment, (2) it provides a baseline of the current estimate of prevalence of lame cows on the farm and (3) it raises awareness of the number of lame cows on the farm (Whay, 2002). Almost all scoring systems emphasise leg placement and back posture of the cow and have five grades, where 1 is sound and 5 is very lame (Manson and Leaver, 1988; Tranter and Morris, 1991; Whay et al., 1997; Sprecher et al., 1997; Whay, 2002). The usefulness of any assessment method is limited by its validity, reliability and sensitivity (Flower and Weary, 2006).

There are a number of studies on the prevalence and incidence of lameness in dairy cows (Whitaker et al., 1983; Alban et al., 1995; Clarkson et al., 1996; Bargai, 2000; Warnick et al., 2001; Manske

et al., 2002; Cook, 2003; Espejo et al., 2006). The prevalence estimates range from 8% to 60%. In a recent study carried out on 91 dairy farms in Southern Chile, the mean prevalence of lame cows was found to be 33.2% in large herds and 28.7% in small herds when locomotion scores (Sprecher et al., 1997) >1 were considered lame. When a score >2 was taken as the cut off point to define lameness, the mean prevalence of lameness decreased to 16.7% in large herds and 13.3% in small herds (Flor and Tadich, 2008).

There have also been studies on the types of lesions that affect cows' claws (Petersen and Nelson, 1984; Murray et al., 1996; Shearer, 1998; Enevoldsen et al., 1991a,b). However, there are few publications that have investigated the relationship between locomotion score and the types of foot lesion present (Logue et al., 1994; Manske et al., 2002; O'Callaghan et al., 2003; Flower and Weary, 2006). It is possible that only certain foot lesions are associated with poor locomotion; for example, Flower and Weary (2006) reported that cows with sole haemorrhage did not have a different locomotion from sound cows. Also, it could be that only at certain severities are some types of foot lesion associated with poor locomotion; for example, Berry (2006) reported that only certain stages of digital dermatitis cause pain. Moreover locomotion scoring may not be sufficiently sensitive to detect all claw lesions, even if they are painful.

* Corresponding author. Tel.: +56 63 221214; fax: +56 63 221480.
E-mail address: ntadich@uach.cl (N. Tadich).

The hypothesis addressed in the current paper is that whilst veterinarians and hoof trimmers might assume that the presence of lesions in a lame cow is the cause of lameness, this is not necessarily correct. The aim of the study was to determine which hoof lesions were associated with increasing lameness and so likely to be causally associated with lameness. Using the Sprecher et al. (1997) scale, we used a stratified sample of unsound cattle with a range of locomotion scores from very mild (1) to severely lame (5) in cattle in 91 dairy herds.

Material and methods

Ninety-one dairy herds from the Xth Region of southern Chile were studied between August and November 2004. Thirty-four herds were large dairy herds with a milk production of >1 million L/farm/year (22.6 ± 4.1 L/cow/day) and where cows were milked twice a day. In these large herds, cows were housed partially or totally during autumn and winter and are at pasture partially or totally during the spring and summer. Fifty-seven herds were small dairy herds that produced <100,000 L/year/farm (16 ± 6.1 L/cow/day), with cows milked once or twice per day; many of these cows were hand milked but some were machine milked. These cows were at pasture all year round.

Farms were accessed via their veterinarian. Herds were convenience sampled, based on (1) the willingness of the owner to participate, (2) the distance between the farm and the university, (3) appropriate roads to access the farms, (4) easy access to the cows, (5) available facilities to examine the feet, (6) herd size and (7) milk production. Dairy farms were visited once during the study.

The number of herds examined was calculated assuming a within herd lameness prevalence of 10% (Tadich et al., 2005) with a confidence level of 95% and a precision of 5%. At the visits, the locomotion scores of all of the lactating cows ($n = 10,699$) were recorded. The locomotion score was determined by two observers working together, as the cow exited the milking parlour. Each animal was observed standing and walking (on a concrete surface whenever possible) using the Sprecher et al. (1997) scoring system. A list of all cows with a locomotion score >1 was made: 20 cows were randomly selected from this list proportional to the number of cows with each locomotion score in the herd.

Twenty cows formed the maximum number of cattle that it was possible to examine in a crush in 1 day without interfering with the routine management of the farm. In large dairy herds the selected cows ($n = 676$) were examined the day following selection. There were 6/57 small dairy farmers with >20 cows where cows were selected for examination as above; on the remaining 51 farms with <20 cows, all cows ($n = 422$) were examined on the day of the visit.

The lesions were recorded by observation of all four feet with the cow standing in a metal crush. The data from each cow were recorded on an individual recording sheet, and included the name of the owner, date of the visit, identification of the herd, identification of the cow, locomotion score, foot and claw affected, and type and location of the lesion. The definition of the hoof lesions is presented in Table 1 (Greenough and Weaver, 1997). Data were entered into a spread sheet (Microsoft Excel 2002) and checked for outlying or incorrect data values.

Statistical analysis

The number of lesions, the number of different types of lesion and the sum of each type was calculated per cow. Each cow's feet were examined and compared with the locomotion score of all cows. The pattern of correlation of lesions within cow was investigated and those correlated at $P < 0.05$ and $r > 0.2$ were noted. A hierarchical model MLwiN version 2.01 (Rasbash et al., 2000) with the continuous outcome variable locomotion score was used to investigate the association between

lesion presence and number and locomotion score adjusted for between farm variability and within farm correlation to investigate which lesions were associated with increasing locomotion score (i.e. poorer locomotion). The model took the form:

$$Y_{ij} = \alpha + \beta_{x_{ij}} + v_j + \epsilon_{ij}$$

where Y_{ij} is the locomotion score of cow i in herd j , α is the intercept, the mean locomotion score across farms and cattle and $\beta_{x_{ij}}$ is a series of vectors of lesion types for cow ij . The between herd variance was v and residual error ϵ .

Results

There were 39.7%, 42%, 17.9% and 0.4% cows examined that had locomotion scores of 2, 3, 4 and 5, respectively. Cattle had between 0 and 8 lesion types (median 3) across all four feet. The prevalence of lesion type ranged from 2% of cattle with an interdigital growth to 65% of cattle with at least one white line lesion. The most prevalent lesions are illustrated in Fig. 1. The number of feet with each lesion varied from 1 to 4 but was generally <3.

The presence of a lesion was not always associated with increasing locomotion score (Table 2, Fig. 1). For example, the percentage of cattle with locomotion scores of 2 and 4 with at least one white line disease lesion was 64% and 55%, respectively. In contrast, for sole ulcer, the respective figures were 11% and 58%, indicating a closer association between the presence of sole ulcer and poorer locomotion.

From the multivariable model, the mean (SE) locomotion of cattle with a score >1 after adjusting for lesions observed was 2.58 (0.06). Cattle with at least one white line lesion, haemorrhage, heel erosion or interdigital dermatitis did not differ significantly in their locomotion from this mean score (CI included 0), as shown in Table 4. However, cattle with at least one sole ulcer, double sole or interdigital purulent inflammation lesion had significantly poorer locomotion with a mean increase in locomotion score of 0.51, 0.17 and 1.06, respectively.

There were significant correlations between heel horn erosion/interdigital dermatitis and heel horn erosion; between interdigital hyperplasia and interdigital dermatitis and between sole ulcer and double sole. No other coefficients were >0.20 (Table 3).

Discussion

A key finding from this study was that when the feet from a representative proportion of cows with varying severities of locomotion score were examined, only some of the many lesions observed were linked with an increasing severity of lameness. Other authors have reported that non-lame cows have hoof lesions (Manske et al., 2002; O'Callaghan et al., 2003) and it is unfortunate that, due to time restrictions, cows with normal locomotion were not examined in the current study. However, there is no reason to think that the pattern between a locomotion score of 2 and

Table 1

Definitions of hoof lesions as recorded at claw examination in 91 dairy herds ($n = 1098$ feet observed).

White line disease	Separation of the abaxial sole from the wall; disrupted continuity of white line with the presence of necrosis. Presence of organic material or an abscess
Haemorrhage of the sole	Haemorrhagic discolouration covering $\geq 50\%$ of the sole or a smaller area with deep intense colour
Heel horn erosions	Pits and pockmarks, with parallel horizontal grooves on the bulb of the heel. Sometimes the horn is separated forming flaps
Interdigital dermatitis	Inflammation of the interdigital skin without extension to deeper tissues
Heel horn erosions/interdigital dermatitis	Heel erosion extending towards the interdigital space causing inflammation of the interdigital skin
Digital dermatitis	Proliferative inflammation of the dorsal or plantar – palmar skin. Commonly found adjacent to the heels or less commonly in the proximal part of the interdigital space
Sole ulcers	Circumscribed loss of the horny sole exposing the corium of the solar surface, located in the region of the sole-bulb junction, usually nearer the axial margin with or without additional affection of deeper structures of the claw
Double sole	Under run of the sole horn, two soles separated by a space
Interdigital hyperplasia (tyloma)	Fibrous proliferation of the interdigital skin causing a mass that protruded between the claws; which could be inflamed or not
Interdigital purulent inflammation (interdigital phlegmon/foul)	Acute necrotising inflammation of the interdigital skin and underlying tissues, with swelling above the coronary band and in the interdigital space

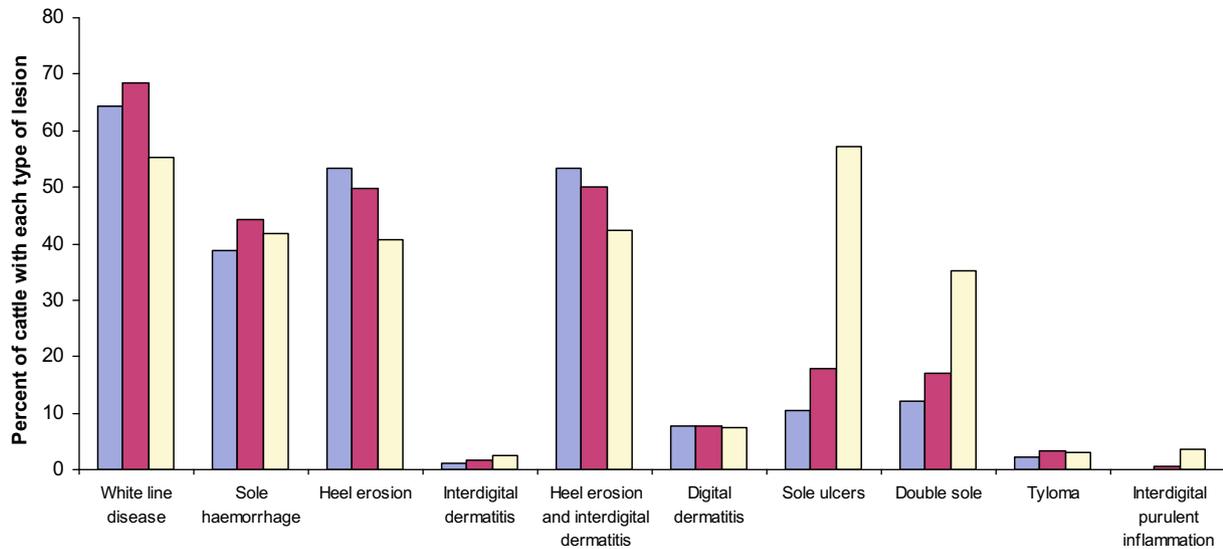


Fig. 1. The percent of cattle by lesion type for locomotion scores 2 (blue, first column), 3 (red, second column) and 4 or 5 (yellow, third column). (For interpretation to colors in the figure legend, the reader is referred to the web version of this paper.)

Table 2

Number and percent of cattle by number of each lesion type by locomotion scores 2–4.

Lesion type	Number of lesions/cow	Number of cows	(% Cows)	(% Locomotion score)		
				2	3	4
White line disease	0	391	36	36	32	45
	1	305	28	27	26	34
	2	402	37	36	41	20
Haemorrhage of the sole	0	641	58	61	56	59
	1	265	24	21	24	30
	2	99	9	18	20	11
Heel horn erosion	0	554	51	47	50	58
	1	274	25	26	26	21
	2	270	25	27	23	17
Interdigital dermatitis	0	1081	99	99	98	97
	1	17	2	1	2	3
Heel horn erosion/interdigital dermatitis	0	550	50	47	50	57
	1	279	25	26	26	23
	2	269	25	27	23	17
Digital dermatitis	0	1013	92	92	92	93
	1	66	6	6	6	5
	2	19	2	2	2	2
Sole ulcer	0	854	78	89	82	42
	1	179	16	9	15	38
	2	65	6	2	3	20
Double sole	0	896	82	88	83	65
	1	177	16	11	16	29
	2	25	2	2	1	6
Interdigital hyperplasia (tyloma)	0	1067	97	98	97	97
	1	26	2	2	2	3
	2	5	1	0	1	0
Interdigital purulent inflammation	0	1089	99	100	100	96
	1	9	1	0	0	4

the lesion observed would be very different from that using a locomotion score of 1 (sound) as the baseline, because cattle with scores 1 and 2 are not usually considered lame.

Many feet had more than one type of lesion, highlighting that the cause of lameness might be one or all of the many lesions present. The correlation between sole ulcer and double sole (0.22) was similar to the correlation between these two lesions (0.26) reported by Capion et al. (2008). According to Ossent and Lischer

(1998), these conditions have laminitis as a common aetiology and have been associated with pain and discomfort (Enevoldsen et al., 1991a,b; Berry, 2001) and poor locomotion (Flower and Weary, 2006).

Double sole was the fourth most prevalent claw lesion in a study in 50 dairy farms of the South of Chile where the authors concluded that it was associated with a lack of a routine functional claw trimming (Hettich et al., 2007). In the current study, double

Table 3

Correlation coefficient between lesions within cow (first row = correlation coefficient, second row = probability value), 1089 cows, 91 dairy cow farms in Chile.

Lesion code		1	2	3	4	5	6	7	8	9
1	White line disease	1.000								
2	Haemorrhage of the sole	−0.086								
		<0.01								
3	Heel horn erosions	0.003	−0.083							
		0.92	0.01							
4	Interdigital dermatitis	0.032	−0.046	0.023						
		0.32	0.09	0.45						
5	Heel Erosion/interdigital dermatitis	0.004	−0.089	0.982	0.126					
		0.92	<0.01	<0.01	<0.01					
6	Digital dermatitis	−0.155	−0.044	0.081	0.102	0.086				
		<0.01	0.18	0.01	<0.01	<0.01				
7	Sole ulcer	−0.042	0.020	−0.096	−0.032	−0.100	−0.007			
		0.16	0.5	<0.01	0.74	<0.01	0.74			
8	Double sole	0.009	0.028	−0.043	−0.041	−0.051	−0.006	0.227		
		0.74	0.32	0.16	0.16	0.09	0.74	<0.01		
9	Interdigital hyperplasia (Tyloma)	−0.011	−0.010	0.007	0.246	0.039	0.074	−0.025	0.004	
		0.74	0.74	0.74	<0.01	0.16	0.01	0.35	0.92	
10	Interdigital purulent inflammation	−0.059	−0.015	−0.029	0.152	0.010	0.049	−0.049	0.009	−0.015
		0.05	0.16	0.62	<0.01	0.74	0.09	0.09	0.92	0.5

1–9 Corresponds to the lesion names in the rows.

Table 4

Hierarchical model of association between locomotion score and lesion adjusted for farm variability.

Variable	Mean	SE	Lower 95% CI	Upper 95% CI
Intercept	2.58	0.06	1.47	1.69
White line disease	0.06	0.05	−0.03	0.15
Haemorrhage of the sole	−0.02	0.04	−0.10	0.06
Heel horn erosion	−0.39	0.24	−0.88	0.09
Interdigital dermatitis	0.08	0.19	−0.31	0.46
Heel horn erosion/interdigital dermatitis	0.33	0.24	−0.16	0.82
Digital dermatitis	−0.06	0.08	−0.21	0.10
Sole ulcer	0.51	0.05	0.41	0.61 ^a
Double sole	0.17	0.05	0.07	0.27 ^a
Interdigital hyperplasia (Tyloma)	0.14	0.12	−0.10	0.38
Interdigital purulent inflammation	1.06	0.22	0.62	1.50 ^a

Between farm variance 0.06 SE 0.01.

Between cow variance 0.39 SE 0.01.

^a Confidence intervals do not include zero.

sole was rarely present in cows with a locomotion score of 2 (Table 2) and was associated with an increasing locomotion score in the final model independent of sole ulcer (Table 4). Sole ulcer has recently been reported to cause the greatest drop in milk yield of all common foot lesions in a study investigating lesion specific causes of lameness and reduction in milk yield (Amory et al., 2008) and has been associated with longer calving intervals, longer intervals from calving to first service (Sogstad et al., 2006) and the greatest risk of failure to conceive at first service, and longer calving intervals (Hultgren et al., 2004). These poor production indices indicate that the presence of sole ulcer on a bovine hoof strongly suggests that they are causing pain even though some (11%) sole ulcers did not cause definite lameness (Table 2).

In contrast to sole ulcers, heel horn erosion, white line disease and sole haemorrhage were not significantly associated with increasing locomotion score. Flower and Weary (2006) reported that sole haemorrhage was not associated with poor locomotion and Logue et al. (1994) reported no correlation between the presence of heel erosion and the locomotion score of cows. However, white line lesions are a commonly attributed cause of lameness (Hedges et al., 2001; Barker et al., 2007) and associated with milk loss (Amory et al., 2008). It is therefore interesting that white line lesions were observed as commonly in cows with a locomotion score of 2 as in those with scores of 4 or 5. This might explain why studies that investigated risks of white line disease appear unfruitful as perhaps it is only when the white

line lesion includes the sensitive laminae (through trauma or infection) that it causes pain and therefore lameness. However, ignoring non-lame cows with white line disease might reduce the probability of detecting risks for white line lesion development through misclassifying as unaffected non-lame cows with white line disease.

Interdigital purulent inflammation, with a 4% prevalence, impacted significantly on cows' locomotion scores, whilst digital dermatitis (approximately 10% prevalence) was not significantly associated with increasing locomotion score. Berry (2001, 2006) suggested that whereas herd lameness was higher in those herds with a high prevalence of digital dermatitis, not all affected cattle were lame and the size and maturity of digital dermatitis lesions may well have affected their association with lameness. Other authors have proposed that the severity of lameness is related to the severity of the clinical presentation of the lesion (Leach et al., 1997), how long it has been present (O'Callaghan et al., 2003) and whether the lesion is infected (Petersen and Nelson, 1984). A more refined definition for lesions such as heel erosion, white line disease and digital dermatitis (Table 1) may be required to investigate their role in dairy cow lameness but investigation of non-lame cows with these lesions might assist in determining the aetiology.

This approach might be particularly important for the claw skin associated lesions, namely heel horn erosion, digital and interdigital dermatitis, that were correlated in the current study and have been reported to be correlated in various combinations by Petersen

and Nelson (1984), Manske et al. (2002) and Berry (2001) The associations between heel and interdigital skin lesions might occur because these areas are in contact with the floor surface and are likely to be affected by adverse conditions (e.g. wetness or slurry) which have an important infectious or environmental component (Capion et al., 2008).

Our results highlight that inferences made on hoof lesions observed only from lame cattle (typically defined as locomotion 3+) will underestimate the prevalence of some lesions, such as white line disease and digital dermatitis, and might overestimate the association of these lesions with lameness. Moreover, the use of locomotion scoring to identify poor foot health in herds will highlight an increase in the presence of lesions such as sole ulcer but not necessarily a high prevalence of lesions such as white line disease or digital dermatitis. This could be important for management. In addition, research studies of management risks and higher locomotion score (see, for example, Barker et al., 2007; Amory et al., 2006) will not have detected risks for the presence of digital dermatitis or white line disease lesions, but rather risks associated with these lesions in lame cows so influencing the management recommendations that might prevent these lesions occurring.

Does it matter if a cow has a lesion and is not lame? Is the presence of any lesion an abnormality? Lesions may resolve and never cause lameness and there is no need to concern ourselves with lesions that do not cause lameness. However, it may be that treatment of lesions in non-lame cows prevents them from becoming lame. It might also be that the locomotion score is insufficiently sensitive and that these lesions are causing the cows discomfort, but not sufficient discomfort to change their gait (it takes effort and energy to walk abnormally and so a change in gait will only be made when it is less costly than maintaining normal gait). Until longitudinal studies monitor the development of lesions and lameness these questions remain unanswered but are very important for herd health.

Conclusions

The presence of sole ulcer, double sole and interdigital purulent inflammation was associated with increasing locomotion score and recording the presence of these lesions was sufficient to capture this relationship. In contrast, the presence of other lesions was not associated with increasing locomotion score suggesting that the purpose of the measurement of lesions and locomotion score need to be carefully considered before a research study or health programme is implemented. More information is required on the importance of foot lesions that are not associated with poor locomotion and the likelihood that they are currently affecting a cow's health or will affect a cow's locomotion in the future.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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