ELSEVIER

A LAMENESS SCORING SYSTEM THAT USES POSTURE AND GAIT TO PREDICT DAIRY CATTLE REPRODUCTIVE PERFORMANCE

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ABSTRACT

Lameness has contributed to reproductive inefficiency and increased the risk of culling in dairy cows. We developed a 5-point lameness scoring system that assessed gait and placed a novel emphasis on back posture. Our objective was to determine if this system predicted future reproductive performance and the risk of culling. The study was conducted at a commercial dairy farm with a history of declining reproductive efficiency and an increasing prevalence of lameness. A total of 66 primipara and pluripara calved, received an initial lameness score, and completed their 60-d voluntary waiting period. The overall prevalence of lameness (mean lameness score >2) was 65.2%. Scoring continued at 4-wk intervals and ceased with conception or culling. The percentage of cows confirmed pregnant and culled was 77.3 and 22.7, respectively.

For each reproductive endpoint, a 2 x 2 table was constructed with lameness score >2 as the positive risk factor and either performance greater than the endpoint mean or being culled as the positive disease or condition. Positive and negative predictive values, relative risk, Chi-square statistic and regression analysis were used to evaluate the data. The positive predictive values for days to first service, days open, breeding herd days, services per pregnancy and being culled were 58, 68, 65, 39 and 35%, respectively. Similarly, the negative predictive values were 79, 96, 100, 96 and 100%, respectively. Except for one reproductive endpoint, the total number of services, all linear regressions were significant at $P < 0.01$. Having a lameness score >2 predicted that a cow would have extended intervals from calving to first service and to conception, spend or be assigned to (explained herein) more total days in the breeding herd, require more services per pregnancy and be 8.4 times more likely to be culled. We believe that this lameness scoring system effectively identifies lame cows. Observation of the arched-back posture in a standing cow (≥LS 3) should trigger corrective interventions.

Key words: bovine, lameness, posture, gait, reproductive efficiency

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INTRODUCTION

Lameness negatively impacts dairy herds by contributing to reproductive inefficiency (10) and causing economic losses (2,3). Cows that became clinically lame prior to completion of their voluntary waiting period demonstrated estrus less frequently and required longer intervals from calving to first service and to conception (1,3,7). Conception rate declined in cows treated by veterinarians for lameness within 63 d of breeding (3). Lameness increased the risk of culling, especially as the duration of the condition increased (1).

Previous investigations gradated the seriousness of lameness by observing selected attributes of lame cows. Wells and his coworkers described a system for scoring lameness by assessing gait (11). Based on a more detailed method (4), they scored gait abnormality by observing cows at a walk for a minimum of 10 meters. Another system (3) factored duration of lameness into a formula that required estimating the percentage of weight-bearing by the affected limb. As early as 1966, an arched-back posture was associated with acute and chronic laminitis (6). The simplicity of the Wells system (11) and the importance of posture influenced development of our experimental methods.

Our lameness scoring system emphasized posture and gait. The basic objective of this study was to determine if lameness score predicted future reproductive performance and the risk of culling. By demonstrating its use with a range of normal to severely lame cattle under farm conditions, we hoped to gain clinical acceptance for our system. Clinical acceptance would depend on the system's ability to predict poor reproductive performance, provide early recognition of lame cattle, and integrate into routine reproductive examinations.

MATERIALS AND METHODS

Lameness Scoring System

Table 1 lists the clinical description and assessment criteria for each lameness score within a 5-point system. Posture and gait assessments require a level location that provides the cow with secure footing. Cows that match lameness Score 4 and 5 criteria are typically recognized as clinically lame by producers because of their abnormal gait (4,11). Lameness Score 3 is unique and was based upon a clinical estimate utilized by the first author to survey lameness within cow production or management groups. Prior to developing this lameness scoring system, the percentage of cattle within each group that demonstrated an arched-back posture while standing was used as an indication of the prevalence of lameness. Lameness Score 2 is a subtle variation of normal (lameness Score 1). Note that observation of an arched-back posture in a standing animal results in a lameness score of at least 3.

Study Herd

Since 1990, the first author visited the study herd on a bi-weekly basis to determine the reproductive and pregnancy status of select cows. Herd reproductive efficiency was monitored

by calculating reproductive indices using cow data maintained in a modification of a previously described spreadsheet (5). Several clinical trends led to selecting this herd for the initial testing of our lameness scoring system. During the 1.5-yr period preceding experimentation, the effectiveness of estrus detection declined while the overall conception rate remained relatively constant at about 50 to 55%. As a result, the average number of days to first service and days open (calving to conception interval) increased from about 80 and 115 to 90 and 125 d, respectively. Only the owner performed estrus detection and AI; cows were artificially inseminated at the first observed estrus following completion of a 60-d voluntary waiting period. Historically, hoof trimming was performed on each cow at least once per year; lame cows were often trimmed 2 to 3 times per year. Beginning 2 yr prior to our study and continuing throughout the period of our study, financial difficulties restricted hoof trimming to a single day per year and to the most severely lame cows. Additionally, the veterinary examination of individual feet on lame cows ceased. The only treatment records maintained by the owner related to the systemic administration of antibiotics.

Table 1. Criteria used to assign a lameness score and clinical description to cattle

Lameness score	Clinical description	Assessment criteria
1	Normal	The cow stands and walks with a level-back posture. Her gait is normal.
2	Mildly lame	The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal.
3	Moderately lame	An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs.
4	Lame	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favors one or more limbs/feet.
5	Severely lame	The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.

Concrete surfaces, space limitations, and nutrition during the transition from non-lactation to lactation were diagnosed as the primary factors contributing to lameness (10). A large concrete lot provided all lactating cows access to their free-stall barn, milking parlor, single feed bunk, and a building with maternity and treatment pens. Non-lactating primipara and pluripara (dry cows) and gestating nullipara had separate housing and similar concrete lots.

Space limitations changed the system for adjusting heifers to the lactation diet. Beginning about 2 yr prior to this study, heifers were commingled with the lactating herd for the last 3 to 6 wk (typically 4 wk) of gestation. Similarly, dry cows commingled with the lactating herd for 2 wk pre-partum. Clinical lameness became a major limitation to reproductive efficiency.

Experimental Methods

All cows received an initial lameness score during the bi-weekly visit preceding completion of their 60-d voluntary waiting period. Cows were enrolled in the experiment if their voluntary waiting period was completed without the owner declaring an intention to cull. Lameness scoring continued at 4-wk intervals and ceased with conception or culling. Since conception date was determined retrospectively by transrectal palpation, lameness scores that occurred after conception had to be deleted. Reproductive examinations and lameness scoring were conducted at different times using different data sheets. The investigators did not have knowledge of previous lameness scores at the time of scoring, and the owner did not participate in the scoring. Diestral cows not inseminated within 80 d after calving received prostaglandin $F_2\alpha$ (25 mg, im Lutalyse)[a]. Cases of cystic ovarian degeneration were treated with GnRH (100 μg, im Cystorelin)[b] followed in 10 d with prostaglandin F2α (9).

Individual cow reproductive data included lactation number, calving date, lameness score(s), date of each lameness score, first service date, last service date, number of services, and reproductive status (not serviced, recently bred, diagnosed open, pregnant, and culled after the voluntary waiting period). Calculated reproductive indices (experimental endpoints) included the number of days to first service, days open, services per pregnancy, breeding herd days, number of lameness scores prior to first service, average lameness score prior to first service, total number of lameness scores, and average of all lameness scores. Since lameness was likely to decrease reproductive efficiency and increase the probability of culling, we created an endpoint called breeding herd days. Based upon the concept of average penalty days (5), breeding herd days equaled the interval, in days, from the voluntary waiting period to either the date of conception or 305 d past calving. Assigned because of the standard 305-d lactation length, breeding herd days debited culling, that occurred after a cow completed her voluntary waiting period, by mathematically insisting that she complete the lactation. As a result, culled cows could be included in the breeding herd days calculation even after they had left the farm.

Statistical Analysis

This prospective cohort study investigated the clinical applicability and relevance of our lameness scoring system within a single problem herd. After creating the 5-point system, we hypothesized that a lameness score of >2 would increase the risk of reproductive inefficiency and, therefore, culling. To test our hypothesis, positive and negative predictive values and relative risk (including their 95% confidence intervals) were computed. A Chi-square test of

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[a] Lutalyse®, the Upjohn Company, Kalamazoo, MI 49001, USA.

[b] Cystorelin®, Sanofi Animal Health, Inc., Overland Park, KS.

independence was used to determine if lameness significantly influenced categories of days to first service, days open, breeding herd days and services per pregnancy. Categories were defined as individual cow performance greater than the mean versus equal to or less than the mean for each endpoint. The endpoint reproductive cull was similarly tested after coding as either yes or no. The program used[c] required insertion of a single case into any cell when a value of zero was encountered. Even though reproductive data are right skewed because of the voluntary waiting period, we chose to use the mean instead of the median, because the reproductive record systems used by veterinarians rarely report other than the mean value for reproductive indices. Note that the days to first service calculations used only lameness scores accrued prior to the date of first service to compute the mean. Further analysis of our hypothesis utilized linear regression to test if lameness score influenced days to first service, days open, breeding herd days and the number of services.

RESULTS

From January 22, 1995 through February 24, 1996 (calving dates from November 23, 1994 through December 26, 1995), a total of 66 primipara and pluripara completed their voluntary waiting period. Among those enrolled cows, 51 (77.3%) became pregnant and 15 (22.7%) were culled. Most of the culled cows (73.3%) were never serviced. Table 2 describes the reproductive performance of all enrolled cows. Lameness, defined as lameness score >2, was prevalent. The number and percentage of cows with mean lameness score >3.0 at first service and in total were 14 (24.5%) and 24 (36.4%), respectively. The number and percentage of cows with mean lameness score >2.0 at first service and in total were 27 (49.1%) and 43 (65.2%). At first service, the lameness score mean, standard deviation, median, and range were 2.50, 1.05, 2.00, and 1 through 3, respectively.

Table 2. Reproductive performance of the enrolled cows

Reproductive endpoint	No. of cows	Mean	SD	Range
Days to first service	55	96.22	27.70	62-171
Days open[a]	51	131.90	65.78	62-304
Breeding herd days[b]	66	111.17	93.09	2-245
Total number of services	55	1.82	1.12	1-5
Services/pregnancy	51	1.78	1.12	1-5

[a] Calving to conception interval.

[b] Endpoint equals the interval from the voluntary waiting period to either conception or 305 days of lactation and includes all cows culled after completion of their voluntary waiting period.

[c] Epi Info Version 5, Centers for disease Control, Atlanta, GA.

Overall, the lameness score mean, standard deviation, median and range were 2.80, 1.06, 2.67, and 1 through 9, respectively. Only 3 cows had successive lameness scores that fell from ≥4 to ≤2 and implied successful treatment or resolution. When dramatic change occurred, the increase or decrease tended to happen over a range of 2 or more scores.

For each reproductive endpoint (Table 3), analysis required a 2 x 2 table with lameness Score >2 as the positive risk factor and performance greater than the endpoint mean as the positive disease or condition. The probability of having an interval greater than the mean for days to first service, days open, and breeding herd days given a cow with mean lameness Score >2 was moderately high (positive predictive values ranging from 58 to 68). The probability of requiring greater than the mean number of services per pregnancy or being culled given a cow with mean lameness Score >2 was moderately low (positive predictive values of 39 and 35, respectively). The probability of having an interval less than or equal to the mean for days to first service given a cow with mean lameness Score ≤2 was high (negative predictive value of 79) and for days open and breeding herd days was very high (negative predictive values of 96 and 100, respectively). The probability of requiring less than or equal to the mean number of services per pregnancy or not being culled given a cow with mean lameness Score ≤2 was also very high (negative predictive values of 96 and 100, respectively). A cow with a mean lameness Score >2 was 2.8, 15.6, 15.6, and 9.0 times more likely (relative risk) to require an interval greater than the mean for days to first service; days open; and breeding herd days, or greater than the mean number of services per pregnancy, respectively. Similarly, she was 8.4 times more likely to be culled than herdmates with mean lameness Score ≤2. All 2 x 2 table associations were significant at $P \leq 0.01$.

The relationship between the values for each reproductive endpoint (dependent variable) and the mean lameness score (independent variable) was described using simple linear regression statistics. The R-squared equaled 0.15, 0.23, 0.38, and 0.05 for mean lameness score versus days to first service, days open, breeding herd days, and number of services, respectively. Only the mean lameness score versus number of services linear regression analysis was not significant at $P < 0.01$.

DISCUSSION

Our lameness scoring system effectively categorized cows into normal or mildly lame versus moderately to severely lame groups (Table 1). Having a mean lameness Score >2 predicted that a cow would experience extended intervals from calving to first service and to conception. She would also spend or be assigned (breeding herd days calculation) more total days in the breeding herd, require additional services to become pregnant, and be 8.4 times more likely to be culled. Linear regression did not demonstrate a significant relationship between mean lameness score and the total number of services. We concluded that lameness negatively affected the ability of cows to express or the herd manager to recognize estrus without dramatically reducing the accuracy of estrous detection. In general, herds with prevalent lameness (1,3) experience a decline in both the rate and accuracy of estrous detection. The latter

Table 3. The ability of lameness score to predict various reproductive endpoints

Reproductive endpoint	2x2 Table cells Number of cases				Lameness score-associated		
	a	b	c	d	Positive predictive value (%)	Negative predictive value (%)	Relative risk
Days to first service[a]	15	11	6	23	58	79	2.8[g]
Days open[b]	19	9	1	22	68	96	15.6[h]
Breeding herd days[c]	28	15	0	23	65	100[f]	15.6[i]
Services/pregnancy[d]	11	17	1	22	39	96	9.0[j]
Reproductive cull[e]	15	28	0	23	35	100[f]	8.4[k]

[a] Mean lameness score prior to first service >2 or ≤2 (risk factor) versus Days to first service >mean (96.2) or ≤mean (disease or condition).

[b] Mean lameness score >2 or ≤2 (risk factor) versus Days open >mean (131.9) or ≤mean (disease or condition).

[c] Mean lameness score >2 or ≤2 (risk factor) versus Breeding herd days >mean (111.2) or ≤mean (disease or condition).

[d] Mean lameness score >2 or ≤2 (risk factor) versus Services/pregnancy >mean (1.8) or ≤mean (disease or condition).

[e] Mean lameness score >2 or ≤2 (risk factor) versus culled or not culled (became pregnant).

[f] Because of the zero encountered in cell c, a value of 1 had to be substituted to compute the statistics.

[g] 95 % confidence intervals of RR 1.3-6.1, P <0.01

[h] 95 % confidence intervals of RR 2.3-108.0, P <0.001

[i] 95 % confidence intervals of RR 2.3-107.8, P <0.001

[j] 95 % confidence intervals of RR 1.3-64.9, P <0.01

[k] 95 % confidence intervals of RR 1.2-59.6, P <0.01

reduces conception rate because breeding managers are more likely to time AI after observing only secondary signs of estrus.

Calculation of predictive value and relative risk was selected as the analysis method to mimic clinical decision-making while allowing data collection to conform with the pre-existing examination schedule. We averaged lameness scores instead of considering number of days lame (1) to avoid relying on data generated by the herd owner. A previous study demonstrated that researchers identify more lame cows than herd managers (11). As a result of our experimental design, any cow with an initial lameness Score ≥ 3 that subsequently experienced a resolution to the condition could have been serviced without a lengthy delay. Even with that source of false positives, regression analysis explained as much as 15 to 38% of the variation in days to first service, days open, and breeding herd days. Since reproductive inefficiency represents a multi-factorial situation in most herds (10), finding a source of up to one-third of the variation is clinically important. Subsequent studies should utilize multivariable regression modeling methods to explore interactions between lameness score and factors like season, lactation number, prostaglandin treatment, and cystic ovarian degeneration. Given more numbers of cows and herds, we suspect that nonlinear regression methods might better describe the relationship between lameness score and endpoints with very high negative predictive values. If true, such suspicions would only advance the perceived clinical value of lameness scoring.

Transrectal examinations were performed in the milking parlor. Had we not separated reproductive examinations and lameness scoring for the purpose of experimentation, cows could have been scored while standing in the holding area and walking into the parlor. When available, parlors create a convenient opportunity to score cows and include lameness scoring in the process of making reproductive decisions.

We believe that our lameness scoring system effectively recognizes and gradates lame cattle in both commercial dairy production and dairy research settings. Adoption of the system would augment the veterinary management of dairy herd reproduction. Since a lameness Score >2 predicted future reproductive inefficiency, observation of the arched-back posture in a standing cow should trigger interventions like examination of the feet, corrective foot trimming, or synchronization of ovulation (8) to avoid the necessity of estrus detection and any inaccuracy in the timing of AI.

REFERENCES

1. Collick DW, Ward WR, Dobson H. Associations between types of lameness and fertility. Vet Rec 1989; 125: 103-106.
2. Lee LA, Ferguson JD, Galligan DT. Effects of disease on days open assessed by survival analysis. J Dairy Sci 1989; 72: 1020-1026.
3. Lucey S, Rowlands GJ, Russell AM. The association between lameness and fertility in dairy cows. Vet Rec 1986; 118: 628-631.
4. Manson FJ, Leaver JD. The influence of concentrate amount on locomotion and clinical lameness in dairy cattle. Anim Prod 1988; 47: 185-190.

5. Martineau R, Cardyn P. JMR: A current reproductive monitor. Proc Society for Theriogenology; 1990: 33-44.
6. Morrow DA. Laminitis in cattle. Vet Med/Small Anim Clin 1966; February: 138-146.
7. Peller EJ, Otte MJ, Esslemont RJ. Inter-relationships of periparturient diseases in dairy cows. Vet Rec 1994; 134: 120-132.
8. Pursley JR, Mee MO, Wiltbank MC. Synchronization of ovulation in dairy cows using $PGF_2\alpha$ and GnRH. Theriogenology 1995; 44: 915-923.
9. Sprecher DJ, Ax RL. Hormonal and economic strategies for the treatment of dairy cows with cystic ovaries. In: Pope LS (ed), Dairy Science Handbook, Vol 18. Bryan, TX: Lang Printing Co, 1988; 224-231.
10. Sprecher DJ, Farmer JA, Nebel RL, Mather EC. The educational implications of reproductive problems identified during investigations at Michigan dairy farms. Theriogenology 1995; 43: 373-380.
11. Wells SJ, Trent AM, Marsh WE, Robinson RA. Prevalence and severity of lameness in lactating dairy cows in a sample of Minnesota and Wisconsin herds. JAVMA 1993; 202: 78-82.