Comparison of the calving-to-conception interval in dairy cows with different degrees of lameness during the prebreeding postpartum period

Jorge A. Hernandez, DVM, MPVM, PhD; Eduardo J. Garbarino, DVM, MS; Jan K. Shearer, DVM, MS; Carlos A. Risco, DVM; William W. Thatcher, PhD

Objective—To compare calving-to-conception intervals among cows classified as nonlame, moderately lame, or lame during the prebreeding postpartum period and to examine the relationship between severity of lameness and time to conception in cows that were classified as lame.

Design—Longitudinal study.

Animals—499 Holstein cows.

Procedure—Cows in the prebreeding postpartum period were classified as nonlame, moderately lame, or lame by use of a 6-point locomotion scoring system. Time to conception (days) was compared among cows. A low, medium, or high cumulative locomotion score was assigned to lame cows, and time to conception among those cows was compared. Cows classified as lame were examined on a tilt table for diagnosis and treatment of lameness.

Results—154 (31%), 214 (43%), and 131 (26%) cows were classified as nonlame, moderately lame, and lame, respectively. Most cows classified as lame had laminitis (54%) or disorders of the claw (33%). Median time to conception was 36 to 50 days longer in lame cows than in nonlame cows. Among lame cows, the median time to conception was 66 days longer in cows with high cumulative locomotion scores than in cows with low scores.

Conclusion and Clinical Relevance—Nonlame cows became pregnant more quickly than lame cows. Lame cows with low cumulative locomotion scores during the prebreeding postpartum period became pregnant sooner than lame cows with high scores. Early diagnosis and intervention may mitigate the effects of lameness and improve reproductive performance in lame dairy cows. (*J Am Vet Med Assoc* 2005;227:1284–1291)

Lameness is an important disorder affecting dairy cows in the United States. In the 1996 National Animal Health Monitoring System report,[1] lameness was the reason for culling in 15% of dairy cows that were sent to slaughter. Ten percent of the cows in the report had been lame in the previous 12 months. The economic importance of lameness is attributable to decreased milk yield,[2-5] loss from culling,[6,7] impaired reproductive performance,[6-11] and costs of treatment and control.[12-19] Lameness in dairy cows is also an issue of animal welfare because of the prevalence of this disorder and the associated pain and discomfort in affected cows.

The relationship between lameness and the calving-to-conception interval in US dairy herds has been examined. In a study[9] conducted in 5 Pennsylvania dairy herds, cows affected with lameness had a calving-to-conception interval that was 28 days longer than the interval in nonlame cows.[9] In Michigan, a scoring system[7] was developed to identify lameness and predict future reproductive performance in dairy cows; in that study, time to conception was longer in cows with an abnormal gait than in cows with a normal gait. More recently, in 2 studies[10,11] conducted in Florida, claw lesions were the most important causes of lameness and a prolonged calving-to-conception interval.

Although results of previous studies have established an association between lameness and prolonged calving-to-conception intervals, the relationship between severity of lameness and time to conception has not been investigated. A linear relationship has been observed between an increasing degree of lameness and delayed estrous cycling in postpartum dairy cows.[20] We hypothesized that an increasing degree of lameness would result in a longer calving-to-conception interval. Under field conditions, diagnosis of an increasing or decreasing degree of lameness in cows can be accomplished by use of a locomotion scoring system.[7,20] The objectives of the study reported here were to compare the calving-to-conception interval between cows classified as nonlame, moderately lame, or lame during the prebreeding postpartum period and to examine the relationship between severity of lameness and the time to conception in cows classified as lame.

Materials and Methods

Cows and herd management—Cows were from a high-producing herd (rolling herd average milk production, approx 11,818 kg [26,000 lb]/y) of approximately 600 Holstein cows in Florida. The herd was selected on the basis of the prevalence of lameness, quality of veterinary records, and owner willingness to participate in the study. Cows were milked and fed a total mixed ration 3 times/d. Cows were housed on dirt (dry) lots equipped with sprinklers, fans, and shade cloths over the feed bunks to reduce the effects of heat stress. On this farm, cows were enrolled in a program to presynchronize the stage of the estrous cycle and synchronize ovulation and artificial insemination.[21] The program

From the Department of Large Animal Clinical Sciences, College of Veterinary Medicine (Hernandez, Garbarino, Shearer, Risco), and Department of Animal Sciences, Institute of Food and Agricultural Sciences (Thatcher), University of Florida, Gainesville, FL 32610-0136.

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Address correspondence to Dr. Hernandez.

involved 2 injections of **prostaglandin (PG)**$F_{2\alpha}$, with the first injection given 30 to 37 days postpartum and the second administered 44 to 51 days postpartum. Fourteen days later (ie, 58 to 63 days postpartum), cows received an injection of **gonadotropin releasing hormone (GnRH)**; 7 days after that, cows received an injection of $PGF_{2\alpha}$; and 2 days later, they received a second injection of GnRH. The second GnRH injection was followed by artificial insemination 16 to 18 hours later (68 to 73 days postpartum). Pregnancy diagnosis was performed by the herd veterinarian via palpation of the uterus and its contents per rectum, 42 to 49 days after insemination.

Study design—The study was designed as a longitudinal study. Five hundred sixty-three cows that calved from June 1, 2002 through May 31, 2003 were considered for inclusion; of those, 499 (89%) cows had complete records and were used in the study. To accomplish the first objective, cows were classified into 1 of 3 lameness categories during the first 8 weeks postpartum by use of a 6-point locomotion scoring system.[20] Time to conception (days) was compared among cows classified as nonlame, moderately lame, and lame. In cows classified as lame, time to conception was compared among cows that were classified as lame with low (12 to 24), medium (25 to 26), or high (28 to 35) cumulative locomotion scores. The period of 8 weeks postpartum was chosen as the interval of interest because the incidence (60%) of lameness was highest during that time period (**Figure 1**) and because the synchronization program protocol was initiated at 58 to 63 days postpartum, the end of the voluntary waiting period on the study farm.

Data collection—The following data were collected from the farm records for each cow: lactation number, calving date, calving season (winter months, January to April and October to December; summer months, May to September), dystocia (yes or no), retained placenta (yes or no), metritis (yes or no), mastitis (yes or no), ketosis (yes or no), and 305-day **mature equivalent (ME)** milk yield. Cows with retained placenta were defined as calving cows that failed to expel all fetal membranes within 24 hours after parturition. Cows with metritis were defined as cows with fetid discharge from the uterus. Cows with mastitis were defined as cows with a deviation from their previous 10-day average milk conductivity as assessed by a computer dairy farmer management system[a] and later confirmed via foremilk stripping by the attending farm employee. Cows with ketosis were defined as cows with ketonuria as detected by use of a reagent strip[b] that detects acetoacetate. From records maintained by use of commercially available dairy management software,[c] projected 305-day ME milk yield data were collected on the basis of production at the time of dry-off (cessation of lactation) or culling. Levels of milk yield were defined as low (305-day ME, 5,422 to 10,786 kg [11,928 to 23,729 lb]), medium (305-day ME, 10,787 to 13,102 kg [23,731 to 28,824 lb]), or high (305-day ME, 13,103 to 16,353 kg [28,827 to 35,977 lb]) on the basis of the frequency of distribution (first, second and third, and fourth quartiles, respectively).

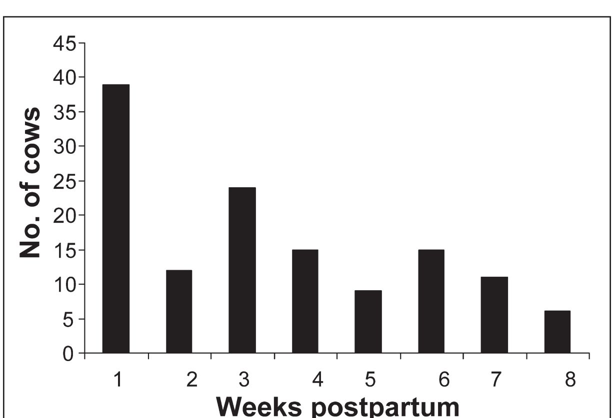

Figure 1—Time of onset of lameness (weeks postpartum) in cows classified as lame (ie, locomotion score of 4 or 5) during the prebreeding postpartum period.

Diagnosis of lameness—During the first 8 weeks postpartum, cows were examined weekly (on Tuesdays) for lameness and scored on the basis of a 6-point locomotion scoring system first described by Sprecher et al[7] and later modified by Garbarino et al.[20] Briefly, cows with a score of 0 were those that stood and walked with a level-back posture and clinically normal gait. Cows with a score of 1 stood with a level-back posture but developed an arched-back posture during walking, although the gait remained clinically normal. Cows with a score of 2 had an arched-back posture that was evident when the cow was standing or walking, but the gait remained clinically normal. Cows with a score of 3 had an arched-back posture that was evident during standing or walking and a short-strided gait in 1 or more limbs (ie, moderately lame). Cows with a score of 4 had an arched-back posture that was always evident and a gait characterized by taking 1 deliberate step at a time; these cows favored 1 or more limbs or feet (ie, were lame). Cows with a score of 5 were unable or extremely reluctant to bear weight on 1 or more limbs or feet (ie, were severely lame). Cows were observed and scored by the same veterinarian as they walked out of the washing pen to the holding area before milking. Cows with a locomotion score of 4 or 5 were further examined on a tilt table for diagnosis and treatment of lameness; observed lesions and date of occurrence were recorded. Lame cows with problems involving the claw had white line lesions or sole ulcers, and those conditions were treated with corrective foot trimming techniques, including the use of foot blocks.[22] Lame cows with laminitis had yellow and red discoloration of the sole and white line and, in most cases, had thin soles and were sensitive when examined with hoof testers.[23] Lame cows with interdigital dermatitis had inflammation and, in some cases, hyperkeratosis that was confined to the epidermis, creating a roughened appearance to the interdigital skin[24]; there was a fetid serous exudate in some instances as well as mild sensitivity to manual pressure. This condition was frequently accompanied by heel and erosions of the horn of the heel, with underrunning of the heel horn.[25]

Statistical analyses—The proportions of cows that left the herd during lactation were compared among nonlame cows, moderately lame cows, and lame cows, as well as between lame cows with low, medium, and high cumulative locomotion scores during the first 8 weeks postpartum, by use of a χ^2 test. Proportions of cows that recovered or had improved locomotion scores after diagnosis or treatment were compared among lame cows with low, medium, and high scores by use of a χ^2 test. Median time-to-conception (days) was compared among nonlame, moderately lame, and lame cows and among lame cows with low, medium, and high scores; median number of weeks of lameness was compared among lame cows with low, medium, and high scores by use of the Kruskal-Wallis test for nonparametric data.

Cox proportional hazards regression analysis[26] was used to test the hypotheses that time to conception was longer in cows classified as lame or moderately lame, compared with nonlame cows, during the first 8 weeks postpartum and that time to conception was longer in lame cows with high or medium cumulative locomotion scores, compared with lame cows with low scores. In a first analysis (model 1), nonlame cows (n = 154) were those with a score of 3 for 1 week only

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or with scores ≤ 2. The rationale for classifying cows with scores ≤ 2 as nonlame in the analysis was that the cows' gait was normal. Cows classified as moderately lame (n = 214) were designated as those with a score of 3 for 2 consecutive weeks to reduce the risk of misclassification. Lame cows were those classified at least once with a locomotion score of 4 or 5 (n = 131). In a second analysis (model 2), the first hypothesis was additionally tested by excluding 23 of 154 (15%) cows that were classified as nonlame during the prebreeding postpartum period but that became lame later before conception. We identified this group of cows by visual examination of weekly locomotion scores of all cows included in the study from calving to the time of conception.

To test the second hypothesis (relationship of severity of lameness to days to conception), lame cows (n = 131) were further classified into 1 of 3 groups: cows with low (12 to 24), medium (25 to 26), or high (28 to 35) cumulative locomotion scores on the basis of frequency of distribution (low, middle, and high 33rd percentiles). Additional independent variables (ie, lactation number, calving season, milk yield, dystocia, retained placenta, metritis, ketosis, displaced abomasum, and mastitis) were examined in the analysis to evaluate possible modifying or confounding effects that these factors might have had on conception. Cows that were culled or inseminated before day 60 postpartum were excluded from the analysis. Cows contributed a maximum of 200 days to the analysis because cows were at risk of not being bred, according to standard reproductive herd procedures on the farm. Cows that had not conceived at the time of culling were right censored. Stepwise forward regression was used, and variables entering the model had to be significant at a value of $P = 0.20$. Variables remained in the model if $P \leq 0.10$. Variables for lactation number and calving season were forced into the model. In the final model, adjusted **hazard ratios (HRs)** and 95% **confidence intervals (CIs)** were reported. The HR was used as an epidemiologic measure of the association between a variable (eg, lameness) and the outcome of interest (eg, time to conception). In each variable, the reference category had an HR of 1. An HR > 1.0 indicated that the probability of conception failure was increased, compared with cows in the reference category. Values of $P \leq 0.05$ were considered significant.

Results

Lameness—One hundred fifty-four (31%), 214 (43%), and 131 (26%) of 499 cows were classified as nonlame, moderately lame, or lame, respectively **(Table 1)**. The proportion of cows that left the herd during lactation was not different among nonlame cows (27%), moderately lame cows (28%), and lame cows (27%; $P = 0.97$). Most cows classified as lame had laminitis (54%) or disorders of the claw (33%; **Table 2**).

Most (50/71 [70%]) cows with laminitis were primiparous. Twelve of the 50 (24%) primiparous cows with laminitis were classified as lame (score, 4) during the first week postpartum. Thirty (60%) cows were classified as moderately lame (score, 3) during the first week postpartum and, later, as lame during the next 7 weeks postpartum.

Time from calving to conception in cows classified as nonlame, moderately lame, or lame—In the univariate analysis, median time to conception was similar in cows classified as nonlame (144 days), moderately lame (135 days), or lame (135 days; $P = 0.74$; Table 1).

In the multivariate analysis, 26 of 499 (5%) cows left the herd within 200 days after calving and 170

Table 1—Distribution (No. of cows [%]) of reproduction-related variables in cows classified as nonlame, moderately lame, or lame during the prebreeding postpartum period.

Variable	Nonlame	Moderately lame	Lame
Cows	154 (100)	214 (100)	131 (100)
Lactation			
1	25 (16)	86 (40)	66 (50)
2+	129 (84)	128 (60)	65 (50)
Calving season			
Winter	77 (50)	138 (64)	77 (59)
Summer	77 (50)	76 (36)	54 (41)
Milk yield			
Low	44 (29)	46 (21)	34 (26)
Medium	70 (45)	112 (52)	66 (50)
High	38 (25)	55 (26)	30 (23)
Dystocia			
No	133 (92)	178 (87)	117 (93)
Yes	12 (8)	26 (13)	9 (7)
Retained placenta			
No	135 (88)	182 (85)	112 (85)
Yes	9 (12)	32 (15)	19 (15)
Metritis			
No	123 (80)	162 (76)	101 (77)
Yes	31 (20)	50 (24)	30 (23)
Ketosis			
No	130 (84)	151 (71)	99 (76)
Yes	24 (16)	63 (29)	32 (24)
Displaced abomasum			
No	149 (97)	210 (98)	126 (96)
Yes	5 (3)	4 (2)	5 (4)
Mastitis			
No	143 (93)	197 (92)	118 (90)
Yes	11 (7)	17 (8)	13 (10)
Culled cows during current lactation			
No	113 (73)	155 (72)	95 (73)
Yes	41 (27)	59 (28)	36 (27)
Cows pregnant 100 days after calving			
No	105 (67)	134 (63)	87 (66)
Yes	49 (33)	80 (37)	44 (34)
Time to conception (days)*	144 (81–200)	135 (72–200)	135 (82–200)

Among nonlame cows, information regarding milk yield, dystocia, and retained placenta was not available in 2, 9, and 10 cows, respectively. Among moderately lame cows, information regarding milk yield, dystocia, and metritis was not available in 1, 10, and 2 cows, respectively. Among lame cows, information regarding milk yield and dystocia was not available in 1 and 5 cows, respectively.

*Values are reported as median (first and third quartiles).

Table 2—Clinical diagnosis in 131 cows classified as lame (ie, locomotion score of 4 or 5) during the prebreeding postpartum period. Cows were scored with a 6-point scoring system.

Diagnosis	No. of cows (%)
Laminitis	71 (54.1)
Imbalanced claws	15 (11.4)
Thin soles	10 (7.6)
White line disease	7 (5.3)
Abscess	6 (4.5)
Ulcers	5 (3.8)
Heel erosion	5 (3.8)
Long toes	3 (2.2)
Interdigital dermatitis	2 (1.5)
Double sole	2 (1.5)
Ulcers, double sole	2 (1.5)
Abscess, thin soles	1 (0.7)
Ulcers, thin soles	1 (0.7)
Broken toe	1 (0.7)
Total	**131**

(34%) did not conceive within 200 days after calving; the pregnancy status of those cows was unknown, and they were classified as right censored. Milk yield, dystocia, metritis, ketosis, displacement of the abomasum, and mastitis were not significantly associated with time from calving to conception and were removed from the model ($P > 0.20$). Lameness, lactation number, season, and retained placenta were retained in the final modeling process (**Table 3**). In model 1, lame cows had an increased risk of conception failure, compared with nonlame cows, but the difference was not significant (HR, 1.21; 95% CI, 0.93 to 1.58; $P = 0.11$). Lame cows became pregnant later than nonlame cows. Median time to conception was 36 days longer in lame cows (180 days) than in nonlame cows (144 days; $P = 0.11$; **Figure 2**), but the difference was not significant.

In model 2, 23 of 154 (15%) cows classified as nonlame during the prebreeding postpartum period became lame later (before conception) and were not included in the analysis (Table 3). Most (14/23 [61%]) cows were classified as lame 133 days after calving. Four (17%) cows were in the first lactation, 12 (52%) calved in the summer months, and 3 (13%) had retained placenta. Median time to conception in this group of 23 cows was 185 days. When these cows were removed from the model derived from the full data set and the model was refit to the remaining cows, the adjusted HRs of the variable for lameness moved away from the null. The risk of conception failure was 1.35 times as high in lame cows as in nonlame cows (HR, 1.35; 95% CI, 1.03 to 1.76; $P = 0.03$). Median time to conception was 50 days longer in lame cows (180 days) than in nonlame cows (130 days; $P = 0.03$; **Figure 3**).

Severity of lameness—Lame cows (n = 131) were further classified into 1 of 3 groups: cows with low (12 to 24; n = 38), medium (25 to 26; n = 53), or high (28 to 35; n = 40) cumulative locomotion scores during the prebreeding postpartum period (**Table 4**). The proportions of lame cows that recovered or had improved locomotion scores after diagnosis or treat-

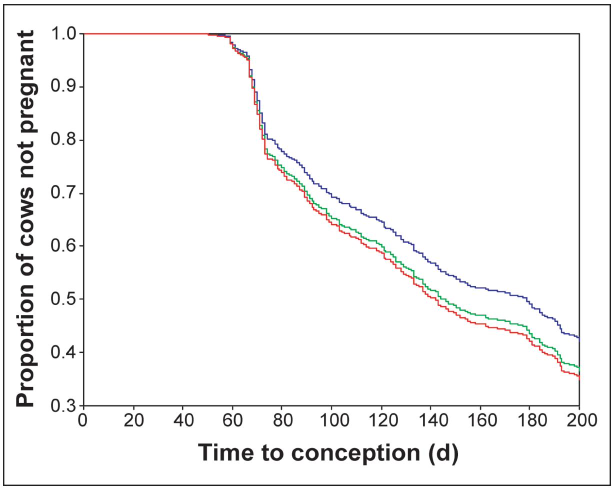

Figure 2—Time to conception in 154 nonlame cows (blue line), 214 moderately lame cows (green line), and 131 lame cows (red line) during the prebreeding postpartum period.

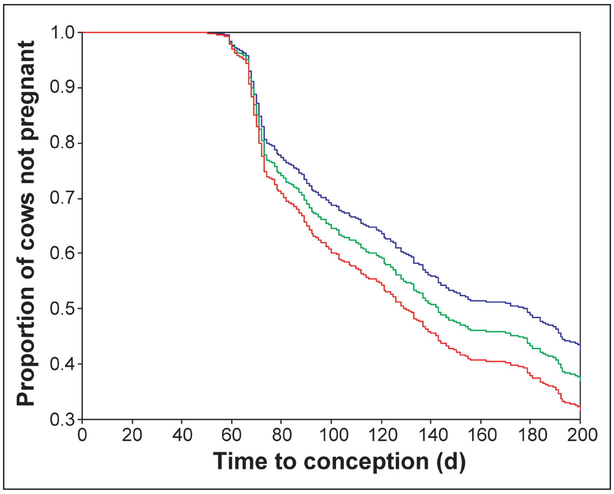

Figure 3—Time to conception in the same cows as in Figure 2, excluding 23 cows that were nonlame during the prebreeding postpartum period but that became lame later, before conception. *See* Figure 2 for key.

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Table 3—Cox proportional hazards ratios (HRs) and 95% confidence intervals (CIs) for conception failure in cows classified as nonlame, moderately lame, or lame during the prebreeding postpartum period.

	Model 1			Model 2		
Variable	HR	95% CI	*P* value	HR	95% CI	*P* value
Lameness group						
Nonlame	1.00	Reference	NA	1.00	Reference	NA
Moderately lame	1.04	0.83–1.30	0.38	1.15	0.91–1.46	0.15
Lame	1.21	0.93–1.58	0.11	1.35	1.03–1.76	0.03
Lactation						
1	1.00	Reference	NA	1.00	Reference	NA
2+	1.33	1.08–1.62	< 0.01	1.30	1.06–1.60	0.01
Season						
Winter	1.00	Reference	NA	1.00	Reference	NA
Summer	0.91	0.75–1.10	0.22	0.91	0.89–1.32	0.23
Retained placenta						
No	1.00	Reference	NA	1.00	Reference	NA
Yes	2.29	1.65–3.17	< 0.01	2.43	1.71– 3.37	< 0.01

Model 1 included 154 nonlame cows, 214 moderately lame cows, and 131 lame cows. Model 2 excluded 23 of the 154 cows classified as nonlame during the prebreeding postpartum period because they became lame later (before conception).

NA = Not applicable.

Table 4—Distribution (No. of cows [%]) of reproduction-related variables in 131 cows classified as lame and with low, medium, or high cumulative locomotion scores during the preservice postpartum period.

Variable	Low score	Medium score	High score
Cows	38 (100)	53 (100)	40 (100)
Lactation			
1	18 (47)	31 (58)	17 (42)
2+	20 (53)	22 (42)	23 (58)
Calving season			
Winter	21 (55)	31 (58)	25 (62)
Summer	17 (45)	22 (42)	15 (38)
Milk yield			
Low	11 (29)	14 (26)	11 (28)
Medium	21 (55)	26 (49)	17 (44)
High	6 (16)	13 (25)	11 (28)
Dystocia			
No	36 (95)	49 (92)	37 (93)
Yes	2 (5)	4 (8)	3 (7)
Retained placenta			
No	31 (82)	46 (87)	35 (88)
Yes	7 (8)	7 (13)	5 (12)
Metritis			
No	33 (87)	39 (74)	29 (73)
Yes	5 (13)	14 (26)	11 (27)
Ketosis			
No	32 (84)	37 (70)	30 (75)
Yes	6 (16)	16 (30)	10 (25)
Displaced abomasum			
No	36 (95)	53 (100)	37 (93)
Yes	2 (5)	0 (0)	3 (7)
Mastitis			
No	34 (89)	48 (91)	36 (90)
Yes	4 (11)	5 (9)	4 (10)
Culled cows during current lactation			
No	31 (82)	40 (75)	24 (60)
Yes	7 (18)	13 (25)	16 (40)
Cows pregnant 100 days after calving			
No	20 (53)	34 (64)	33 (82)
Yes	18 (47)	19 (36)	7 (18)
Lameness improved after treatment*			
No	3 (9)	10 (20)	30 (75)
Yes	31 (91)	41 (80)	10 (25)
Cows with claw lesions			
Yes	16 (42)	18 (34)	26 (65)
No†	22 (58)	35 (66)	14 (35)
Weeks lame (locomotion score of 4 or 5)‡	1 (1–1)	2 (1–2)	5 (4–6)
Time to conception (days)‡	109 (75–200)	142 (80–200)	156 (103–200)

*Lame cows with locomotion scores < 4 after treatment. †Lame cows with subacute laminitis. ‡Values are reported as median (first and third quartiles).

Data from 4 cows with low cumulative locomotion scores and 2 cows with medium scores classified as lame on week 8 were not included.

ment were different among cows with low (91%), medium (80%), and high scores (25%; *P* = 0.01). The number of weeks lame was significantly (*P* = 0.01) different among lame cows with low (1 week), medium (2 weeks), and high (5 weeks) scores. The number of lame cows that left the herd during lactation increased from 18% to 25% to 40% in cows with low, medium, and high scores, respectively (*P* = 0.08). Finally, the number of weeks lame was higher (3 weeks) in lame cows with claw lesions than in cows with laminitis (2 weeks; *P* = 0.01).

Table 5—Cox proportional HRs and 95% CIs for conception failure in 131 cows classified as lame and with low, medium, or high cumulative locomotion scores during the prebreeding postpartum period.

Variable	HR	95% CI	*P* value
8-week-cumulative locomotion score			
Low: 12–24 (n = 38)	1.00	Reference	NA
Medium: 25–26 (n = 53)	1.29	0.82–2.02	0.17
High: 27–35 (n = 40)	1.58	0.94–2.65	0.07
Lactation			
1	1.00	Reference	NA
2+	1.41	0.88–1.14	0.16
Season			
Winter	1.00	Reference	NA
Summer	0.72	0.45–1.14	0.16
Retained placenta			
No	1.00	Reference	NA
Yes	3.27	1.30–8.09	0.01

See Table 3 for remainder of key.

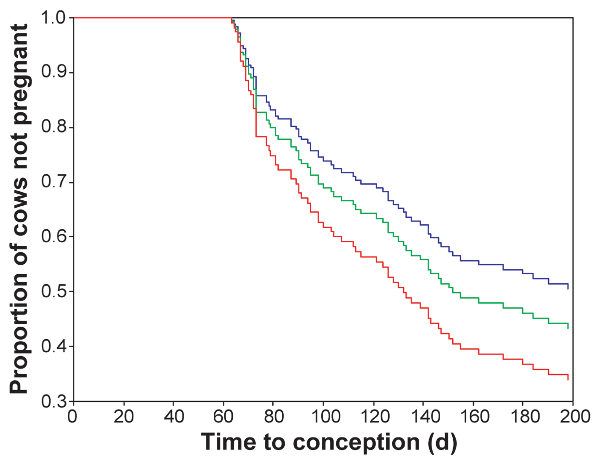

Figure 4—Time to conception in 131 lame cows with low (blue line), medium (green), or high (red) cumulative locomotion scores during the prebreeding postpartum period.

Time from calving to conception in lame cows with different degrees (severity) of lameness—In the univariable analysis, median time to conception was higher in lame cows with high cumulative locomotion scores (156 days), compared with lame cows with low (109 days) or medium scores (142 days), but the difference was not significant (*P* = 0.25; Table 4).

In the multivariate analysis, lameness, lactation number, season, and retained placenta were retained in the final modeling process (**Table 5**). The risk of conception failure appeared to increase in lame cows with high scores, compared with cows with low scores, but the difference was not significant (*P* = 0.07). Lame cows with high scores became pregnant later than lame cows with low scores. Median time to conception was 66 days longer in lame cows with high scores (200 days), compared with lame cows with low scores (134 days; **Figure 4**).

Discussion

Previous knowledge regarding the relationship between lameness and the calving-to-conception interval in US dairy cows is limited.[7,9-11] In each of those studies, the calving-to-conception interval was longer in lame cows, compared with nonlame cows, but the effect of severity of lameness on conception failure was not investigated. The studies in Pennsylvania[9] and Florida[10,11] were retrospective, and inclusion of study animals was made on the basis of cows with or without a history of lameness as determined by examination of herd records. In the studies in Pennsylvania[9] and Michigan,[7] foot lesions or diseases in cows affected with lameness were not reported. In the 2 studies[10,11] in Florida, claw lesions were identified as the most important cause of lameness and impaired reproductive performance in dairy cows, as indicated by a higher incidence of affected cows and a longer time from calving to conception, compared with nonlame cows. In the study[7] in Michigan, a 5-point locomotion scoring system that assessed gait and back posture was used for diagnosis of lameness and to predict future reproductive performance in dairy cows. That study included 66 cows and compared the time to conception in cows with a normal gait (scores 1 or 2) versus cows with an abnormal gait (scores 3, 4, or 5). An assessment of a possible linear association between different degrees or severity of lameness and time to conception in lame cows was difficult because of sample-size limitations.

In our study, most cows classified as lame had laminitis. Although it is known that hoof lesions such as white line disease and sole ulcers can cause clinical lameness,[10,11,22,25] lesions associated with laminitis (such as yellow or red discoloration of the sole and white line) do not cause lameness.[27] Possible explanations for the association between laminitis and lameness during the first 8 weeks postpartum include cows being in the initial (painful) phase of laminitis, lactation number and husbandry factors, and early diagnosis of lameness. Because most lame cows with laminitis had thin soles and were sensitive to hoof testers at the time of examination, it is possible that these cows had laminitis in the intial or acute phase and thus had signs of severe pain and lameness. This phase of laminitis has been associated with acidosis.[28] Rumen acidosis may lead to a decrease in systemic pH, thereby activating vasoactive processes that increase digital pulse intensity and total digital blood flow. Endotoxin and histamine are released, resulting in vasoconstriction, vasodilation, and, consequently, the development of nonphysiologic arteriovenous shunts, which further increase blood pressure. Vessel walls become damaged and exude serum, which results in the formation of edema, thrombosis, and internal hemorrhage in the solar corium and expansion of the corium. Expansion of the corium inside the hoof wall leads to signs of severe pain in affected cows. This metabolic insult is most likely to occur during the early postpartum period, when cows are fed transition diets (ie, changing from a low- to a high-energy diet) for optimal milk production during the early portion of lactation.[29] The early postpartum period was coincident with the exposure (lameness) period of interest in our study.

Most cows with laminitis were also primiparous and classified as lame during the first postpartum 8 weeks. In addition to the role of diet in the development of laminitis, primiparous cows may be at higher risk for laminitis because of stress induced by husbandry factors such as introduction to groups of mature cows around the time of calving, inadequate bedding, or poor stall design such that cows spend more time standing.[30] We believe that the unusually high prevalence of laminitis as the cause of lameness at this dairy may also be explained by the fact that the dairy adopted a surveillance system for early detection of lameness via weekly examinations and use of a locomotion scoring system. Without this surveillance system, it is possible that the number of lame cows detected with laminitis would be lower and other claw lesions or disorders would be equally or more frequently detected.

In this study, cows classified as lame during the prebreeding postpartum period had a longer calving-to-conception interval than nonlame cows. In model 1, lame cows had an increased risk of conception failure after controlling for lactation number, season, and retained placenta, although the difference was not significant (odds ratio, 1.21; 95% CI, 0.93 to 1.58). The time-to-conception interval was 36 days longer in lame cows than in nonlame cows. The effects of lameness on ovarian activity in postpartum cows have been described; in a previous study[20] conducted in the same herd used in this study, cows that were lame during the first 35 days postpartum had 3.5 times the odds of delayed ovarian cyclicity as nonlame cows. In that study, we hypothesized that because lame cows lose more body condition (and hence remain in a prolonged state of negative energy balance) during the early postpartum period, they are at higher risk of delayed resumption of estrous cycling than nonlame cows. Although we observed an association between lameness and delayed cycling, loss of body condition was not a significant risk factor for delayed cycling. However, ketosis was a risk factor for delayed resumption of ovarian cycling; thus, it is possible that there are interactions between the effects of lameness and ketosis that increase the risk of delayed cycling. Lameness may suppress dry-matter intake,[31,32] resulting in a negative energy balance and promoting increased ketone body formation, which delays the onset of ovarian activity.[33] A negative postpartum energy balance not only increases ketogenesis but also delays the resumption of ovarian cycling, especially if the energy-deficient state is prolonged.[34-36] Lame cows with delayed ovarian cycling during the prebreeding postpartum period would be expected to have a longer calving-to-conception interval if lameness is not resolved. An increase of 36 days open (not pregnant)/cow resulted in an economic loss of $144/cow (assuming a mean cost of $4/d) in 1 study.[37,38]

Twenty-three of 154 (15%) cows were classified as nonlame during the prebreeding postpartum period but became lame (ie, had a locomotion score of 4 or 5) later (a mean of 133 days after calving), before conception. When this group of cows was removed from the analysis, the adjusted HR for lameness moved away from the null. The risk of conception failure was 1.35 times as high in lame cows as in nonlame cows (HR, 1.35; 95% CI, 1.03 to 1.76; $P = 0.03$), and the time-to-conception interval was 50 days longer in lame cows than in nonlame cows. This suggests that the model formed on the basis of the full data set yielded conser-

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vative odds of lameness during the prebreeding postpartum period as a risk factor for a prolonged calving-to-conception interval. We examined the frequency distribution of cows in their first lactation, cows that calved in the summer months, and cows with retained placenta between the 23 lame cows (17%, 50%, and 13%, respectively) and 131 nonlame cows (16%, 50%, and 5%, respectively); the differences were not significant. The last result suggests that the observed effect of lameness after the prebreeding postpartum period in this group of cows was not masked by lactation number, calving season, or retained placenta and that lameness after the prebreeding postpartum period had an effect on time to conception in this group of cows. An increase of 50 days open/cow represented an economic loss of \$200/cow.[37,38]

The risk of conception failure in lame cows with high locomotion scores was greater than that in lame cows with low scores, although the difference was not significant ($P = 0.07$). Among cows classified as lame, the time-to-conception interval was 66 days longer in cows with high cumulative locomotion scores than in cows with low scores. Possible explanations for the longer time to conception in lame cows with high locomotion scores include the duration of lameness, time to recovery from lameness, and cause of lameness. The median number of weeks of lameness was significantly higher (5 weeks) in cows with high scores than in cows with low scores (1 week). The number of lame cows that improved their locomotion score after diagnosis or treatment of lameness was significantly lower in cows with high scores (25%), compared with cows with low scores (91%). Most lame cows with low scores had laminitis and did not develop more severe lesions, such as sole ulcers. In contrast, most lame cows with high scores had claw lesions, including thin soles, white line disease, abscesses, or sole ulcers. Lame cows with laminitis were monitored weekly and were treated only if claw lesions developed after laminitis was diagnosed. Lame cows with claw lesions were treated immediately after diagnosis. An increase of 66 days open/cow represented a loss of \$264/cow.[37,b] We are not aware of other studies that examined the relationship between different degrees of lameness and the calving-to-conception interval in lame cows.

The results revealed a linear association between an increasing degree of lameness and time to conception. Cows classified as nonlame became pregnant sooner than cows classified as moderately lame or lame. In addition, among cows classified as lame, cows with low cumulative locomotion scores became pregnant sooner than cows with medium or high scores. The number of weeks of lameness increased from 1 to 2 to 5 in cows with low, medium, and high scores, respectively. Finally, the number of lame cows that left the herd during lactation increased from 18% to 25% to 40% in cows with low, medium, and high scores, respectively. These results underscore the importance of early detection of lameness and, if necessary, use of adequate treatment strategies, such as corrective foot trimming[22] in lame cows with claw lesions or disorders. The locomotion scoring system used in this study was a useful management tool that veterinarians and dairy farmers can adopt for early detection of lameness in dairy cows.

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a. AFIMILK, Kibbutz Afikim, Israel.
b. KETOSTIX, Bayer, Elkhart, Ind.
c. PCDART, Dairy Records Management Systems, Raleigh, NC.

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