

Effect of lameness on milk yield in dairy cows

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Objective—To examine the relationship between lameness and milk yield in dairy cows.

Design—Cohort study.

Animals—531 dairy cows.

Procedure—Cows affected with lameness were classified into 1 of 3 groups on the basis of type of diseases or lesions observed, including interdigital phlegmon (foot rot), papillomatous digital dermatitis (foot warts), or claw lesions. Cows not affected with lameness were classified as healthy. From Dairy Herd Improvement Association records, 305-day mature equivalent milk yield data were collected at the end of lactation or when the cow left the herd. Milk yield was compared between cows affected with lameness and healthy cows.

Results—167 (31%) cows were affected with lameness during lactation. Lameness was associated with claw lesions (60%), papillomatous digital dermatitis (31%), or interdigital phlegmon (9%). Milk yield in lame cows with interdigital phlegmon (mean, 17,122 lb) was significantly less, compared with healthy cows (19,007 lb).

Conclusions and Clinical Relevance—In this herd, interdigital phlegmon was associated with a 10% decrease in milk production. Lameness was associated with claw lesions or papillomatous digital dermatitis produced less milk than healthy cows, but the difference was not significant. (*J Am Vet Med Assoc* 2002;220:640–644)

Lameness is an important disorder affecting dairy cows in the United States. In the National Animal Health Monitoring System Dairy '96 Study, lameness was reported as the reason for culling 15% of dairy cows sent to slaughter.¹ Overall, 10% of cows were reported affected with lameness in the preceding 12 months.¹ The economic importance of lameness is reportedly attributable to cost of treatment and control methods,²⁻⁹ impaired reproductive performance,¹⁰⁻¹⁴ decreased milk yield,^{15a} and increased number of culled cows.^{11,12} In addition, because of the pain, discomfort, and high incidence of lameness in dairy cows, this disorder is an animal welfare issue of concern.

Two studies have examined the relationship between lameness and milk production in US dairy herds. In 1 study¹⁵ conducted in California, lameness was more common in high-producing cows. In another study^a conducted in New York, cows with lameness produced less milk 2 weeks before and 3 weeks after the diagnosis. Detection of cows affected with lame-

ness may trigger interventions such as parental administration of antimicrobials (eg, interdigital phlegmon),^{10,16,17} topical administration of antimicrobials or nonantimicrobials (eg, papillomatous digital dermatitis),^{2-9,17} or corrective foot trimming (eg, claw lesions).^{10,11,18} Treatment failure, prolonged incapacitation, and withdrawal time of antimicrobials may affect energy balance, body condition, and milk yield in dairy cows affected with lameness. The effect of lameness attributable to different diseases or foot lesions on milk yield has not been investigated. We hypothesized that the effect of lameness on milk yield is different among lame cows with interdigital phlegmon (foot rot), papillomatous digital dermatitis (foot warts), or claw lesions, compared with healthy cows. The purpose of the study reported here was to examine the relationship between lameness and milk yield in dairy cows.

Materials and Methods

Cows and herd management—Cows in this study were from a medium-producing dairy herd of approximately 500 Holstein cows located in Florida. Cows were milked 3 times/d (rolling herd average milk production, approx 19,000 lb). Beginning 60 to 70 days after calving, bovine somatotropin (500 mg)^b was administered every 2 weeks to all cows. This herd was selected for the study on the basis of a history of lameness, the veterinarian and hoof trimmer's knowledge and ability to recognize different types of lesions associated with lameness (eg, interdigital phlegmon, papillomatous digital dermatitis, and claw lesions), and quality of veterinary records.¹⁰

Data collection—Herd records from 868 cows that calved during 1997 to 1998 were initially considered for inclusion in the study. Records of 50 cows with missing data (ie, milk yield or days in lactation) and 31 cows with multiple foot lesions (eg, papillomatous digital dermatitis and claw lesions) were not included. Records of 51 cows that were culled before day 60 post partum because of low milk production were not included (1 cow was reported affected with lameness attributable to claw lesions). Records of 205 cows with > 400 days in lactation were not included, because it was not considered within normal managerial limits (eg, the calving interval in the study herd is 15 months); 75% of all lactating cows in the herd remained in lactation ≤ 400 days. Five hundred thirty-one cows were included in the study. For each cow, the following data were collected: lactation number (1, 2, 3, 4+), calving date, calving season (Jan to Mar, Apr to Jun, Jul to Sep, Oct to Dec), dystocia (yes, no), retained placenta (yes, no), metritis (yes, no), ketosis (yes, no), clinical mastitis (yes, no), days in lactation, and milk yield. From Dairy Herd Improvement Association records, 305-day mature equivalent milk yield data were collected at the end of lactation or when the cow left the herd.

Lameness—Clinical diagnosis of lameness was made by farm personnel and confirmed by the same attending veterinarian or herd's hoof trimmer during the study period.¹⁰ Cows affected with lameness had an arched-back posture while standing and walking and an abnormal gait. Cows examined and treated for lameness were recorded, noting lesions

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Supported in part by the USDA Current Research Information System (grant No. FLAV-CO-00209).

The authors thank Shawn Ward for technical assistance.

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observed and date of occurrence. On the basis of type of lesions observed, lame cows were classified into 1 of 3 groups: interdigital phlegmon, papillomatous digital dermatitis, or claw lesions. Lame cows with interdigital phlegmon had an interdigital lesion, swelling of the entire foot above the dewclaws, and separation of the digits; they were treated by use of parenterally administered antimicrobials. Lame cows with papillomatous digital dermatitis had early lesions (round to oval, flat or concave, raw, moist, red-yellow-gray, with tufted or granular strawberry-like surfaces) or mature lesions (raised, with surfaces covered by small filiform papillae) on the interdigital cleft, heels, or dewclaw.^{4,6} Lame cows with papillomatous digital dermatitis were treated by use of topical administration of antimicrobials. Lame cows with claw lesions had white line lesions or sole ulcers and were treated by use of corrective foot trimming techniques¹⁸; however, herd records did not allow for identification of type of claw lesions in lame cows. After a cow was counted as lame, that cow remained in that category for the entire lactation because of the damage that these diseases may cause and the long recovery period typically observed in dairy cows.^{2-10,17-23} Herd records did not permit an estimation of duration of lameness. Cows that were not affected with lameness were classified as healthy.

Statistical analyses—The hypothesis that lame cows with interdigital phlegmon, papillomatous digital dermatitis, or claw lesions produce less milk than healthy cows was tested by use of a 1-way ANOVA for the dependent variable of 305-day mature equivalent milk yield. Differences in distribution of cows by lactation number, calving season, dystocia, retained placenta, metritis, ketosis, clinical mastitis, and culled cows during lactation were compared between lame and healthy cows by use of a χ^2 test. Among lame cows, proportions of cows in each group with lameness diagnosed ≤ 100 days in lactation were compared among groups by use of the Fisher exact test. Mean days in lactation were compared between groups by use of a 1-way ANOVA. Multiple regression analysis was performed to determine the effect of lameness on milk yield while simultaneously adjusting for variables related to milk yield.²⁴ A model with a hierarchical structure was specified by adding terms for interactions between independent variables. In the analysis, lameness sta-

tus was coded as a 4-category variable (healthy, interdigital phlegmon, papillomatous digital dermatitis, or claw lesions). Variables for lameness, lactation number, calving season, clinical mastitis, days in lactation, and year of calving were forced into the model. The final model was selected on the basis of biological criteria in addition to adjusted correlation coefficient (R^2). Significance was set at $P \leq 0.05$.

Results

Lameness—One hundred sixty-seven (31%) cows were affected with lameness (Table 1). Most lame cows had claw lesions (60%), followed by papillomatous digital dermatitis (31%) or interdigital phlegmon (9%). Differences in distribution of cows by lactation number, clinical mastitis, and days in lactation were significantly different between lame and healthy cows. The distributions of cows by calving season, dystocia, retained placenta, metritis, and ketosis were not significantly different between lame and healthy cows ($P \geq 0.28$). The proportion of cows with lameness diagnosed ≤ 100 days in lactation was significantly different in cows with interdigital phlegmon (80%), compared with cows with papillomatous digital dermatitis (44%) or claw lesions (29%). Proportions of cows that left the herd during lactation were significantly different among cows with interdigital phlegmon (60%) or cows with claw lesions (45%), compared with healthy cows (33%) or cows with papillomatous digital dermatitis (21%).

Milk production—Milk yield in lame cows with interdigital phlegmon (mean, 15,737 lb) was significantly lower, compared with healthy cows (19,250 lb; Table 1). In the regression analysis, interaction terms did not significantly contribute to the final regression model for milk yield and were removed from the model. Terms for lameness, lactation number, calving season, clinical mastitis, days in lactation, and year of calving were retained (Table 2). In the final model, mean milk yield values reported for cows affected with

Table 1—Distribution of milk production-related variables (number [%] of affected cows) in healthy cows and cows with lameness caused by interdigital phlegmon (IP), papillomatous digital dermatitis (PDD), or claw lesions

Variable	Healthy	IP	PDD	Claw lesions
Cows (n)	364	15	52	100
Lactation				
1	183 (50)	7 (50)	28 (54)	36 (36)
2	93 (26)	3 (30)	12 (23)	20 (20)
3	44 (12)	3 (10)	8 (15)	15 (15)
4+	44 (12)	2 (10)	4 (8)	29 (29)
Calving season				
Jan–Mar	75 (21)	4 (27)	15 (29)	26 (26)
Apr–Jun	56 (15)	4 (27)	5 (10)	13 (13)
Jul–Sep	92 (25)	3 (20)	9 (17)	22 (22)
Oct–Dec	141 (39)	4 (26)	23 (44)	39 (39)
Dystocia	16 (4)	0 (0)	0 (0)	6 (6)
Retained placenta	31 (9)	0 (0)	4 (8)	8 (8)
Metritis	17 (5)	0 (0)	4 (8)	6 (6)
Ketosis	5 (1)	0 (0)	0 (0)	3 (3)
Clinical mastitis	92 (25)	4 (27)	8 (15)	37 (37)
Cows lame ≤ 100 d*	NA	12 (80)	23 (44)	29 (29)
Culled cows during lactation	121 (33)	9 (60)	11 (21)	45 (45)
Days in lactation†	283 \pm 81	224 \pm 112	301 \pm 63	302 \pm 78
305-d milk yield (lb)†	19,250 \pm 4,047	15,737 \pm 4,962	19,318 \pm 3,104	18,890 \pm 3,749

*Cows lame ≤ 100 days in lactation. †Data are reported as mean \pm SD.

Table 2—Multiple regression model for mean milk yield (lb) in cows affected with lameness caused by IP, PDD, or claw lesions

Variable	Milk yield	Coefficient	Standard error	P value
Lameness				
Healthy	19,007	Reference	NA	NA
IP	17,122	-1,885	870	0.03
PDD	18,669	-338	488	0.48
Claw lesions	18,554	-453	381	0.24
Lactation				
1	18,230	Reference	NA	NA
2	18,545	315	388	0.42
3	18,913	683	481	0.16
4+	17,665	-565	472	0.23
Calving season				
Jan–Mar	16,980	Reference	NA	NA
Apr–Jun	18,254	1,274	489	< 0.01
Jul–Sep	19,432	2,452	430	< 0.01
Oct–Dec	18,687	1,707	379	< 0.01
Clinical mastitis				
No	18,921	Reference	NA	NA
Yes	17,755	-1,166	330	< 0.01
Days in lactation	NA	23	2	< 0.01
Year				
1997	18,066	Reference	NA	NA
1998	18,611	545	341	0.11

NA = Not applicable.

lameness were adjusted for lactation, calving season, clinical mastitis, and days in lactation. Negative coefficients indicate production losses associated with the study variable, relative to the reference class. Lameness cows with interdigital phlegmon produced a mean of 1,885 lb less milk than healthy cows did ($P < 0.05$). Lameness cows with papillomatous digital dermatitis or claw lesions produced less milk (338 and 453 lb, respectively) than healthy cows did, but these differences were not significant ($P \geq 0.24$). Variables included in the final regression model explained 34% of the variation in milk yield ($R^2 = 0.34$).

Discussion

Analysis of results of the study reported here indicated that cows with lameness attributable to interdigital phlegmon had significantly lower milk production, after adjusting for variables biologically related to milk production, than healthy cows did. This represented a decrease in mean milk production of approximately 10%. This decrease in milk production of 1,885 lb/cow represented a loss of \$301/cow (assuming a milk value of \$16/100 lb). Amoxicillin, ceftiofur, erythromycin, oxytetracycline, penicillin G, sulfadimethoxine, sulfamethazine, and tylosin are antimicrobials labeled for treatment of pododermatitis interdigitale in lame cattle.^{16,17} In our study, most lame cows with interdigital phlegmon (73%) were treated with penicillin G or sulfadimethoxine. It is known that chronic interdigital phlegmon is likely to involve tendon and bone tissues, long-standing infection, and failure to respond to antimicrobial treatment.¹⁶ Furthermore, most lame cows with interdigital phlegmon (80%) were affected during early lactation, when cows reach peak yields, and 60% were culled during lactation. These findings may suggest that lame cows with interdigital phlegmon during early lactation may be so severely affected that

they cannot achieve their milk-yield potential during that lactation.

Only cows that were lame were examined by the veterinarian or herd's hoof trimmer. Cows classified as affected with lameness had an arched-back posture while standing and walking and an abnormal gait. Thus, it is possible that cows with mild signs of lameness (eg, a cow that stands with a level-back posture but develops an arched-back posture while walking)⁵ or moderate signs of lameness (eg, an arched-back posture is evident while standing and walking, but the cow's gait remains normal)⁵ may have been classified as healthy. Assuming that cows with mild or moderate signs of lameness attributable to interdigital phlegmon were misclassified as healthy, the detrimental effect on milk yield may have been underestimated. Because duration of lameness data was not available, we did not assess the effect of duration of lameness on milk yield.

This study was designed as an observational cohort study. Thus, misclassification of lame cows with interdigital phlegmon, papillomatous digital dermatitis, or claw lesions was a potential source of bias. We minimized this source of systematic error by selecting a dairy herd associated with a veterinarian and a hoof trimmer who had the knowledge and ability to recognize and diagnose different diseases and lesions associated with lameness. On the basis of differences in anatomic location and morphologic characteristics, it is possible to make a clinical diagnosis of interdigital phlegmon, papillomatous digital dermatitis, or claw lesions in cows affected with lameness. In this study, classification of cows with interdigital phlegmon, papillomatous digital dermatitis, or claw lesions was confirmed by examination of treatment codes in veterinary records (ie, parental administration of treatments [interdigital phlegmon], topical administration of treatments [papillomatous digital dermatitis], or corrective foot trimming [claw lesions]).¹⁰

The effect of lameness on milk yield in dairy cows has been investigated.^{15,19,25-27,a} However, results from those studies are difficult to compare with results of our study because of differences in exposure and outcome definitions, incidence of lameness, herd size, breed, herd management, and statistical methods. In 3 studies, a positive or negative effect of lameness on milk yield has been reported.^{25,26,a} In 1 study²⁵ conducted in 2,008 Holstein-Friesian cows from 32 herds in Ontario, Canada, cows affected with lameness produced more milk (1.6%) than healthy cows. In another study conducted in 23,416 Finish Ayrshire cows,²⁶ milk loss of cows with foot and leg disorders varied between 3.3 and 4.6 lb/d during the first 2 weeks after the diagnosis; incidence of lameness during lactation was 2.1%. Finally, in 1 study conducted in 1,224 cows in New York,^a milk loss of cows with lameness varied between 0.3 and 4.8 lb 2 weeks before and 3 weeks after diagnosis, respectively; incidence of lameness was 35%. In all 3 studies, diseases or foot lesions associated with lameness were not reported. In our study, because mean weekly or monthly milk yield data were not available, we did not assess the effect of lameness at different stages of lactation.

In this study, lame cows with papillomatous digi-

tal dermatitis produced less milk (338 lb) than healthy cows did, but the difference was not significant. Our data support results from 1 study conducted on a 600-cow dairy in Mexico,¹⁹ where cows with papillomatous digital dermatitis produced a mean of 268 lb less milk than healthy cows did, but the difference was not significant; a possible explanation for the detrimental effect of this disease on milk yield was not reported. No further studies have examined the relationship between papillomatous digital dermatitis and milk yield in dairy cows. The cause of papillomatous digital dermatitis is not known. However, the marked susceptibility of lesions to parental or topical administration of antimicrobials and detection of spirochetes invading the stratum spinosum and dermal papillae suggest that bacteria may play an important role in the pathogenesis of the disease.⁴ In our study, lame cows with papillomatous digital dermatitis may have recovered sufficiently after treatment with a topically administered oxytetracycline followed by bandaging of the affected foot. Alternatively, our failure to detect a significant effect on milk yield may have been attributable to low statistical power (11%).

In this study, lame cows with claw lesions produced less milk (453 lb) than healthy cows did, but the difference was not significant. In 2 studies, a positive or negative effect of lameness on milk yield attributable to claw lesions was reported. In 1 study conducted on a 500-cow dairy in California,¹⁵ cows with lameness within 49 days after calving had higher milk yield up to 21 days and 49 to 119 days post partum; lameness was mostly attributable to sole and white line lesions. During diagnosis and treatment of lameness, milk yield was reduced and increased again thereafter.¹⁵ The positive association of lameness and milk yield during early lactation suggested that high production was a risk factor for lameness. Higher production is associated with higher feed intake, which may increase the risk of rumen acidosis and cause lameness as a result of histamine release.¹⁵ Increase feed intake may also result in more time spent walking and standing and increased risk of feet problems.¹⁵ In another study conducted in 732 British Friesian, Ayrshire, and Holstein crossbred cows,²⁷ cases of lameness were more common in cows that had higher than mean peak milk yields. However, examination of lameness attributable to different foot lesions revealed that lame cows with heel lesions (presumably heel or sole ulcers) produced less milk (7.3%) than healthy cows did. The authors suggested that this difference was attributable to decreased lactation length in lame cows affected with heel lesions. However, other diseases such as mastitis or number of days in lactation were not taken into account in the analysis. In our study, it is possible that lame cows with claw lesions recovered sufficiently after corrective foot trimming. The application of corrective trimming procedures can help relieve weight bearing and promote recovery of claw lesions.¹⁸ Alternatively, our failure to detect a significant effect on milk yield may have been attributable to low statistical power (22%).

To our knowledge, this is only the third study that has examined the relationship between lameness and milk production in US dairy cows. In previous studies,

diseases or foot lesions associated with lameness were not reported.^{15,a} Our study results support the hypothesis that interdigital phlegmon has a significant detrimental effect on milk production in dairy cows.

^aWarnick LD, Guard CL, Grohn YT. The effect of lameness on milk production in dairy cattle (abstr), in *Proceedings. Annu Meet Am Assoc Bovine Pract* 1998;182.

^bPosilac, Monsanto Co, St Louis, Mo.

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