

Presence of back arch in headlocks: an indicator of lameness and hoof lesions in dairy cattle?

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Abstract

Observation of an arched back while standing and walking is 1 criterion for assessing dairy cow lameness. Objectives of these projects were to evaluate back arch and its association with locomotion score (LS) and hoof lesions. On a single 200-cow farm, digital photographs were taken of cows with locomotion scores >1 while stanchioned and walking, and analyzed for degree of back arch. One pen of cows was observed 5 times while stanchioned to evaluate “time in headlock” effect on presence of back arch. Angle of deviation from flat-back was not significantly associated with LS; however, there was a trend for cows with a score of >2 to have back angles deviating from flat. The proportion of time a cow was observed with a back arch was greater for lame cows vs non-lame cows. In a second herd, back arch data were collected on 233 cows while stanchioned, and hoof lesion data were collected on 141 cows. Cows with a back arch were 2.1 times more likely to have a hoof lesion ($P = 0.04$), and there were more cows with hoof lesions with increasing LS ($P < 0.0001$). Back arch could be used as a screening test for lameness.

Key words: dairy, lameness, hoof lesions

Résumé

Un des critères pour l'évaluation de la boiterie chez les vaches laitières est la courbure du dos lorsque la vache se tient debout et marche. L'objectif du projet était d'évaluer la courbure du dos et son association avec le score de locomotion et les lésions du sabot. Sur une ferme de 200 vaches, des photographies numériques ont été prises sur des vaches avec des scores de locomotion > 1 en stabulation entravée et à la marche et analysées pour déterminer le degré de courbure du dos. Un enclos de vaches en stabulation entravée a été observé à cinq reprises pour évaluer l'effet de la durée de l'entrave de la tête sur la courbure du dos. L'angle de déviation par rapport au dos droit n'était pas statistiquement associé au score de locomotion. Toutefois, chez les vaches avec un score > 2, il y avait une tendance à une plus grande déviation de l'angle par rapport à la normale. La proportion de temps passé par

une vache avec le dos arqué était plus grande chez les vaches qui boitaient que chez les vaches qui ne boitaient pas. Dans un autre troupeau, des données sur la courbure du dos ont été recueillies chez 233 vaches en stabulation entravée et les lésions au sabot ont été évaluées chez 141 vaches. Les vaches avec le dos arqué avaient 2.1 fois plus de chance d'avoir des lésions au sabot ($P = 0.04$) et les lésions au sabot étaient plus fréquentes lorsque le score de locomotion était plus élevé ($P < 0.0001$). La courbure du dos pourrait être utilisée comme test de dépistage pour la boiterie.

Introduction

Currently, most dairy cow welfare audit systems, including the original industry-sponsored Dairy FARM (Farmers Assuring Responsible Management) program, suggest a lameness prevalence of less than 10%, with lameness defined as a locomotion score (LS) of >2.¹⁷ However, previous lameness studies, using the 5-point scale with a score of 1 being sound to 5 being severely lame, suggest the lameness prevalence in US dairy herds is well above 10%, with prevalence reaching 50% in some herds.^{3,4,10,25} Other studies have shown that dairy producers consistently underestimate the number of lame cows on their farms.^{4,20,26}

In addition to the impact on cattle welfare, the cost of lameness can quickly surpass \$200/cow. This monetary amount includes costs associated with treatment as well as money lost in decreased milk production, depending on the cause of the lameness.² Therefore, herds with a high prevalence of lameness can incur large economic consequences. If producers could identify lame cows earlier and remediate before they become severely lame, they could improve animal welfare and reduce the economic burden of dealing with costly treatments or culling.

The most common method of assessing early signs of lameness in dairy cow herds is through locomotion scoring, which requires observation of the cow's gait and posture while both standing and walking. The defining factor for giving a LS score of 3, considered a lame cow, is when a cow is observed to have an arched back while both standing and walking, and a short-stride with 1 or more limbs.²² However, with the increasing size of dairy farms, it is logistically difficult

to observe every cow walking and standing on a regular basis to monitor lameness. Therefore, few veterinarians or farm personnel engage in locomotion scoring on a regular basis.¹³

Simply evaluating the position of the back (arched or not) while cows are standing has been suggested to be a simpler method of determining lameness, and previous studies have indicated that back arch in dairy cows is correlated to locomotion score.^{10,12,13,23} However, 1 investigator found this method only correctly identified about half of truly lame cows,²³ and another study determined that the sensitivity and specificity for the observation of back arch as a test for lameness were only 63% and 64%, respectively.⁹ The high rate of false negatives detected using back arch as the sole diagnostic screening test for lameness means that 36% of lame cows (LS>2) may go undetected; however, few other gait or postural abnormalities (jerky head movement and uneven weighting on the limbs) have been well correlated to early lameness detection.^{6,10} These results suggest that in order to improve the current gold standard, further validation of test characteristics of back arch are needed. Some recent evidence collected in a pilot study using digital images indicated that the curvature of the spine in cows becomes more arched with a higher locomotion score.¹² In addition, the observation of cows with arched backs increases with increasing severity of lameness (higher locomotion score).²³

Although back arch observations in cows have been compared to locomotion scores in the past, there is little work on the association of back arch with the presence of hoof lesions. Previous research has shown that over 90% of hoof lesions are correlated to lameness, which means more than 90% of the causes of lameness are potentially treatable or preventable.²¹ When a cow shifts weight from the hind hooves, where lameness occurs most often, to the front hooves, the weight shift is speculated to be the most likely reason for the appearance of an arched back.¹⁹ Higher posture scores (where posture-scoring used specifics of gait, back and head carriage) tend to be associated with chronic hoof lesions, confirming that the curvature of the spine is a relatively accurate predictor of the presence of a hoof lesion, and suggesting either that chronic hoof lesions cause more pain than acute lesions or that the pain associated with chronic lesions is harder to ignore for these cows.^{18,25} The degree of spine curvature that signifies a lame cow is not known, and while the observation of a back arch while standing is used as a criterion in locomotion scoring to classify a cow as lame (LS>2) or not,²² agreement among observers is not perfect.¹⁰ The objectives of this project were to further evaluate back arch as a screening test for lameness, and assess its ability to predict the presence of hoof lesions in dairy cattle.

Materials and Methods

Locomotion Score and Back Arch – Study 1

Cows observed for this study came from 1 herd of 200 Holsteins. Data were collected from May 2012 to July 2012.

Cows were fed a total mixed ration from a bunk with stanchions and milked twice daily. Water was freely available in multiple locations within the pens. Housing was in compost-bedded free-stalls. Flooring was grooved concrete and fans, sprinklers, and shade were available for cooling.

Cows were locomotion-scored over the course of 3 days as they exited the milking parlor by 1 trained observer using a 5-point scoring system.²² Information on stage of lactation and parity was collected from the herd's computerized records. Training for the observer was provided by a Washington State University College of Veterinary Medicine Extension online training module for locomotion-scoring dairy cows.¹⁴

The day after locomotion scoring, cows that scored ≥ 2 were observed by the same trained observer before milking while in the stanchions. A visual assessment of back arch, body condition score, and time since lockup were recorded. Back arch was assessed only when the cow's head was up and she was not eating, defecating or urinating, as per Thomsen.²³ Cows were then marked with an orange paint stick on the withers and at the base of the tail head as landmarks for image analysis. Lateral view, digital images were collected for each cow as she stood in lockup using a Canon *PowerShot* A560^a.

After milking, video recordings were taken of each marked cow as she walked using a SONY Handycam digital video camera recorder (model number DCR-SR42)^b and tripod. The video camera was positioned approximately 30 feet (9 m) from the grooved concrete alleyway where cows exited the milking parlor to return to their pens. Each video segment was locomotion-scored individually by 3 trained observers, and the cow's final recorded locomotion score reflected the agreement between 2 or more observers. If discrepancies were found between the "in-person" and video assessments of the locomotion scores, scores from the recorded video evaluation were used.

Still images of cows in stanchions as well as still images from the video footage were used to evaluate the angle of back arch present. From each video segment 4 stills were chosen, corresponding to the placement of each foot on the ground. Microsoft Moviemaker^c was used to capture video stills, and Microsoft PowerPoint^d was used for the still images. Using the orange marks at the withers and the base of the tail head, a circle was placed to record the midway point between the withers and the base of the tail, then the degree of back angle was collected using a software program^{d,e} to connect a line based at the midway point to the withers and to the base of the tail head (Figure 1). A back arch measurement was calculated for the video footage by taking the average of each of the 4 video stills. Data points recorded for back arch that were >5 degrees from the other data points were discarded as outliers. A "deviation from flat-back" was calculated from each image, where a flat-back was considered a cow with a measurement of 180 degrees. The number of degrees of spine curvature was assessed for both still and video images. Differences in the average curvature were compared for cows that were observed to be lame (LS >2) and those that were not

lame. The sample size deemed necessary to see a difference of 0.001 degree per cm of curvature with a SD of 0.001, 80% power and $\alpha=0.05$ was calculated to be 15 cows/group (lame vs not lame), based on previous research.¹²

Time spent in lockup was studied to determine its influence on the presence or absence of a back arch. Fifty-two cows were observed in lockups over a time span of 60 minutes before their first milking of the day. One trained observer visually assessed each cow for a back arch as they walked down the line of cows. Cows could not be eating, urinating or defecating at the time when the visual assessment of back arch was made. The observer completed 5 visual assessments for each cow during the 60-minute time period; each observation period lasted approximately 5 to 6 minutes, and cows only remained locked up for as long as it took the barn crew to clean their pens and perform pregnancy examinations.

Data were managed and summarized in a computerized spreadsheet^f. A statistical software program was used for analysis^g. The ANOVA method was used to analyze back-angle differences by locomotion score. Logistic regression was used to assess the probability of making a back arch observation based on the degree of the back angle.

Back Arch and Hoof Lesions – Study 2

Cows used in the second study were from 1 herd of approximately 500 Holstein cows. Data were collected from May 2013 to July 2013. Cows were fed a total mixed ration and milked 3 times daily. Water was freely available in multiple locations within the pens in self-filling troughs. Cows were housed in sawdust-bedded free stalls; elsewhere in the pen flooring was grooved concrete. Fans were used for cooling

and some pens had access to grass turnout. This herd was selected based on an elevated prevalence of lameness from previous herd prevalence estimates using locomotion score, and for having pens with a high percent of lockup spaces available (an adequate number of lockups were needed in order to fulfill part of the study).¹³

Data were collected from cows on 4 separate occasions. A total of 240 cows were locomotion-scored by 1 trained observer as they exited the milking parlor. If time allowed between scoring of individual cows, a specific leg lameness, if present upon observation, was identified and recorded for cows scoring >1 . Once all cows had exited the milking parlor and locomotion scores were collected for each, all cows were encouraged to lock-up in the stanchions. Once the majority of cows from the pen were in stanchions, the same observer walked behind the cows, and made observations of back arch and body condition (<2.75 lacking appropriate body condition, 3 maintaining healthy body condition, or >3.5 slightly over-conditioned).⁵ Cows were evaluated if not eating, urinating or defecating. Cows with and without an arched back in the stanchions were included to correlate the presence of hoof lesions and presence of an arched back in the stanchions. Information on lactation stage and parity was collected from the herd's computerized records.

After collecting back arch and body condition scores (BCS) for all cows that locked up, 141 cows in groups of 10 to 14 cattle were released from the stanchions and herded to a holding pen near the foot-trimming tilt chute. Cows that had a LS of 1 were allowed to bypass the chute. Cows with a LS >1 were evaluated by an experienced hoof trimmer. If the cow's hooves had been trimmed within the previous 8 weeks, and the hooves were found not to be in need of a trim they were visually examined by removing dirt and manure and were then observed for any visible lesions, including lesions around the pasterns, knees, and hocks. If the cow's hooves were recently trimmed but found to be in need of a trim, a maintenance trim was performed such that all 4 hooves were pared minimally to allow the hoof trimmer and recorder to identify the presence or absence of any hoof lesions. A bovine hoof lesion identification and severity score sheet was used.²⁴ If a lesion was discovered, it was recorded using the "abc Foot Record Form".²⁴ Lesions were organized based on both the foot and claw affected, and cows were classified as having a lesion or not. Hoof lesion information was compared to back arch observations to identify factors correlated and potentially useful as predictive indicators for hoof lesions. Data were managed and summarized in a computerized spreadsheet^f. A statistical software program was used for analysis^g. Logistic regression was used to assess the relationship between potential risk factors (including the presence of hoof lesions) and lameness.

Results

Locomotion Score and Back Arch – Study 1

Of 200 cows scored for lameness, 18 (9%) had a loco-

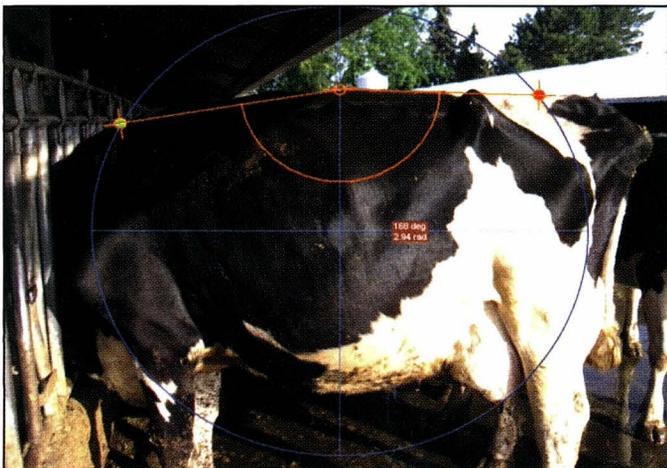


Figure 1. Example of back angle measurement* on a stanchioned cow exhibiting a back arch (angle = 168 degrees).

*Using the orange marks at the withers and the base of the tail head, a circle was placed to record the midway point between the withers and the base of the tail, then the degree of back angle was collected using a software program (VistaMetrix), to connect a line based at the midway point to the withers and to the base of the tail.

motion score of >2 (classified as “lame”), 55 cows (27.5%) had LS= 2, and 127 cows (63.3%) had LS=1. Body condition scores for non-lame cows ranged from 2.5 to 3.5, and BCS for lame cows ranged from 2.5 to 4.0. Days into lactation (DIM) when cows were observed with lameness ranged from 5 to 513 days. The average DIM was 217 days for lame cows, and 203 days for non-lame cows. Thirty-five percent of cows were first parity, 20.6% of cows were in their second lactation, and 44.3% of cows were in their third or greater lactation. Thirty-five of 70 (50%) cows with locomotion scores >1 were observed with an arched back while stanchioned. The 3 observers had perfect agreement on locomotion scores of 87% for cows videoed. They were not significantly different in making back arch determinations on still images of cows ($P = 0.77$).

The average back angle measured from still images of cows in stanchions (range 168 to 188 degrees; mean=176.7) for lame cows (LS > 2) was 176 degrees (SD=5.0), and the average back angle for non-lame cows was 177 degrees (n=52; SD=4.9). No statistically significant difference between back angle while in lockup and locomotion score was found (Table 1; $P = 0.15$). However, when back angle was measured from the video images (mean=174.1), back angle was significantly smaller as locomotion score increased (Table 1; $P < 0.0001$). The average back angle (from lock-up images) was significantly smaller for cows observed with a back arch in the stanchions compared to those without an arch (173.8 vs 179.4 degrees, respectively; $P < 0.001$).

Logistic regression analysis was used to assess the probability of making a back arch observation while observing cows in stanchions based on the degree of back angle, conditional on the total time a cow had been in the stanchion. Back angle significantly influenced the probability of observing a back arch (Table 2). As the measured back angle increased (going to a flat-back at 180 degrees, controlling for time in the stanchion), the probability of making a back arch observation decreased (Figure 2). Out of 68 images with

corresponding back arch observation, an error was made (calling the cow “no back arch”) about 7.4% of the time when the back arch was below 173 degrees.

The average time a cow spent in the stanchion before being evaluated for a back arch (range 10 to 60.5 min; mean=52 min) was not significantly different between cows observed with a back arch or not observed with a back arch (51 vs 52 min; $P = 0.56$). To better evaluate the effect of time spent in the stanchion and the consistency of observing a back arch, 1 pen of cows was observed consecutively several times over 1 hour. Of the 52 cows observed 5 successive times in the stanchions, 26 were identified as having a back arch at least 1 time. However, only 17 of these cows were consistently recorded as having a back arch (3 or more times). The proportion of times a cow displayed an arched back ranged from 0 to 100%, and the average proportion of observations that cows exhibited a back arch was 26%. The proportion of

Table 2. Logistic regression model for back angle influence on the odds of observing a back arch.

Variable	Odds ratio	95% C.I.		Coefficient	P-value
Back angle	0.6531	0.5297	0.8053	-0.426	0.0001
Total time in stanchion	1.0438	0.9798	1.1121	0.0429	0.184

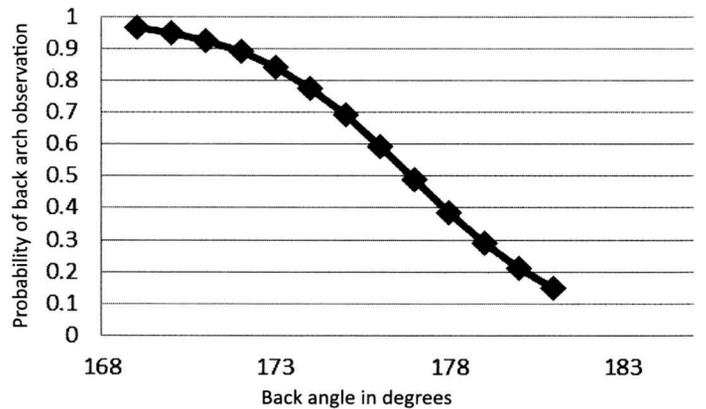


Figure 2. Probability of observing a back arch while dairy cows are stanchioned in head locks for 60 minutes, by measured angle of the back*.

*Time spent in lockup was studied to determine its influence on the presence or absence of a back arch. Fifty-two cows were observed in lockups over a time span of 60 minutes before their first milking of the day. One trained observer visually assessed each cow for a back arch by walking down the line of cows. Cows could not be eating, urinating or defecating at the time the visual assessment of back arch was made. The observer completed 5 visual assessments for each cow during the 60-minute time period, each observation period lasted approximately 5 to 6 minutes, and the cows only remained locked up for as long as it took the barn crew to clean their pen and perform pregnancy examinations.

Table 1. Average measured back angle* of lateral view digital images of cows standing in stanchions and from video images.

Locomotion score	Mean back angle from lockup image	Mean back angle from video image
1	183.5 (n=2)	183.0** (n=2)
2	176.4 (n=50)	174.6 (n=49)
3	175.9 (n=14)	171.5 (n=15)
4	179.0 (n=3)	169.8 (n=3)

*Back angle measured between withers and tail head as measured by the VistaMetrix Program.

**Mean back angle significantly differed by locomotion score; $P < 0.0001$

observations that cows displayed an arched back was significantly greater for lame cows (LS>2) vs non-lame cows (60% vs 20%, respectively; $P = 0.001$).

Lameness prevalence was significantly higher in cows with more than 2 lactations ($P = 0.008$). Using a logistic regression model, the odds of being classified as lame increased with decreasing BCS (Table 3; $P = 0.01$). There was a tendency that the odds of being designated lame increased for each increase in DIM ($P = 0.09$). As parity increased, the odds of being called lame increased ($P = 0.03$). However, there was no significant difference between the presence of an arched back and body condition score or lactation group ($P > 0.05$). The cows' DIM had no effect on the observation of a back arch ($P > 0.05$). As a test to predict lameness, observation of a back arch had a sensitivity and specificity of 0.65 and 0.56, respectively, with 95% confidence intervals ranging from 0.39 to 0.85 for sensitivity and 0.41 to 0.69 for specificity.

Back Arch and Hoof Lesions – Study 2

From the 500-cow Holstein herd, 245 lactating cows were used in the study. Approximately 30% of the cows were pregnant, and DIM ranged from 1 to 200 days. Average milk yield ranged from 0 to 148 lb (0 to 67 kg); about 85% of the 245 cows used in the study had an average milk yield > 75 lb (34 kg). Locomotion scores were collected for 240 of the 245 lactating cows; 43 cows (18%) received a LS >2 and 197 cows (82%) received a LS ≤ 2.

Body condition and back arch observations were made for 233 cows while they were in stanchions. Cow BCS ranged from 2 to 3.5, and 91% of the 245 cows used in the study had a BCS ≥ 3. Median BCS was significantly lower for lame cows vs non-lame cows (2.75 vs 3.0; $P < 0.05$), but there was no difference in median BCS for cows with or without a back arch ($P > 0.40$). Cows identified with a back arch were 7.45 times more likely to be lame (LS > 2) ($P < 0.001$; 95% CI 3.57-15.5) than those without back arch. As a test to predict lameness, observation of a back arch had a sensitivity and specificity of 0.55 and 0.89, respectively.

Hoof lesions were evaluated for 141 cows, and no lesions were observed in 82 (58%) head. Of the 59 cows with a hoof lesion, 8.5% had white line hemorrhages, 15% had white line abscesses, and 20% had sole ulcers. Seventeen percent

of cows had more than 1 hoof affected by a lesion, and 94% of affected cows had a lesion involving a rear hoof. Body condition, DIM, average milk production, and parity were not associated with lameness or presence of hoof lesions ($P > 0.40$). However, there was an increasing proportion of hoof lesions with increasing locomotion score (Figure 3; $P < 0.001$).

Of the 59 cows with a hoof lesion or abnormality recorded, 21 (35.6%) were observed to have an arched back while stanchioned. Cows with a back arch observed in the stanchions were 2.6 times more likely to have a hoof lesion compared to those not observed with a back arch (95% CI 1.4, 5.1; $P = 0.004$), but as a test for detecting cows with hoof lesions, back arch had a sensitivity and specificity of 0.36 and 0.78, respectively.

Discussion

Back angle, measured from cows in stanchions, was not associated with locomotion score. However, a trend existed for greater deviation from flat-back (<180 degrees) with increasing locomotion score, such that the higher the locomotion score the more likely a back arch was to be observed. In 14 cows back angle exceeded 180 degrees (>180 degrees), indicating their back was not flat but actually U-shaped. This observation was made for both lame and non-lame cows. Finding lame cows with U-shaped backs was not expected, and made diagnosing an arched back in lockup for these cows especially difficult. When the back angle was measured from video images of cows mid-stride (as opposed to still images of cows in stanchions), there was a significant relationship

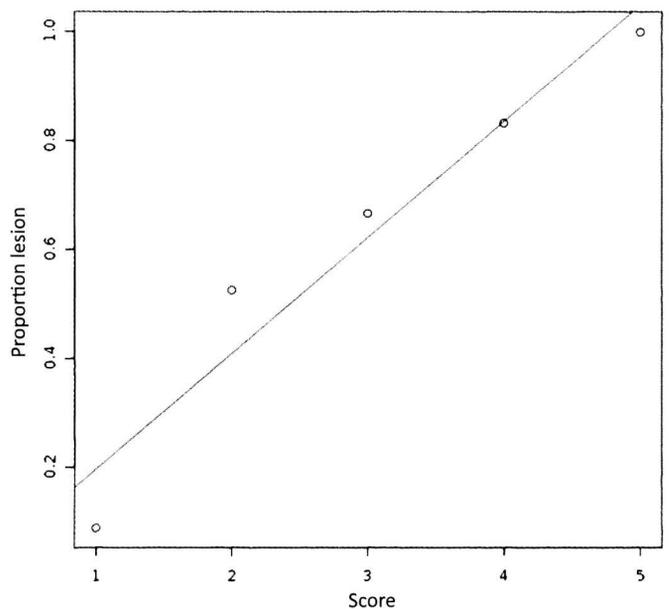


Figure 3. The proportion of cows (n=141) with a hoof lesion by locomotion score. A significant trend was found for increasing proportion of lesions with increasing locomotion score ($P < 0.0001$).

Table 3. Logistic regression model for risk factors associated with lameness (locomotion score >2).

Risk factor	Odds ratio	95% Confidence interval	Coefficient	P-value
BCS*	0.04	0.003, 0.56	-3.13	0.02
DIM**	1.01	1.0, 1.01	0.007	0.09
Group	3.04	1.1, 8.4	2.14	0.03

*BCS = body condition score

**DIM = days-in-milk

between back angle and locomotion score and between back angle and arched back observation. Back angle may be more pronounced as cows are walking, making the association with locomotion score more evident.

Another factor that could explain the low sensitivity of the standing back arch “test” for lameness might be the ability of the human observer to visualize the arch. The ability of an observer to conclude whether or not a cow has an arched back appears to be related to the angle of the cow’s back. The probability of making a back arch observation falls quickly when the angle exceeds 173 degrees (where flat = 180 degrees).

One important finding from the study on lameness and back arch was that the average proportion of times a cow displayed an arched back was significantly higher for lame cows when back arch was observed at multiple time points within 1 hour. This suggests there is increasing sensitivity to observing back arch on truly lame cows as the number of observations increases. An application of this finding could be used by veterinarians during regular herd checks or by trained farm personnel during periods when the cows are already locked up in stanchions for such routine procedures as estrus detection, pregnancy diagnosis, insemination, and preventive health procedures. However, the observation should be performed prior to cow handling because they may show an arched back after rectal palpation or other procedures. Increasing the number of observations could lead to increased detection of lameness within herds as the trained observer makes his or her way down the line of cows in lockup.^{6,10}

The low sensitivity and specificity of back arch observations of stanchioned cows to predict lameness, as defined by a LS >2, might be explained by the fact that some cows are effective at hiding their lameness while standing due to their instinctive stoicism, which would lower the sensitivity.¹⁸ Other reasons for poor sensitivity could include the multifactorial etiology of lameness, potentially causing different levels of pain, behavior of individual cows, genetics of leg and hoof conformation, and flooring or housing. Other reasons a cow might exhibit an arched back include cow conformation, pericardial disease, abomasal ulcers, pleuropneumonia, acute laminitis or any other pathologic process that might cause anterior abdominal pain,¹⁵ which would result in a lower specificity. An additional consideration is the current standard of locomotion scoring, with the inclusion of LS = 3 with “lame” cows in the 5-point scoring system. Because of the frequency with which an error can be made by an observer scoring cows a 2 or 3, the National Dairy FARM program has distilled their welfare assessments for lameness to a 3-point scale.¹⁶

On the second farm, there was a relatively low rate of hoof lesions and lameness present, with the most common hoof lesion category being “no lesion”. Despite this, results indicate that cows presenting with locomotion scores ≥ 3 are more likely to have a hoof lesion present and confirm results

of another study; there is a greater likelihood of detecting cows with hoof pathology among those that stand with an arched back in stanchions than among those that do not.¹

While it may not be economically feasible to examine the hooves of every cow that displays an arched back in stanchions, cows with an arched back could be examined by observing their gait. Frequent monitoring could result in early detection and reduce the impact of lameness on cow performance.^{7,8} One study looked at an “early threshold” protocol for lameness detection and treatment where all cows were monitored bi-monthly, and those found lame were treated within 48 hours. This protocol resulted in a decreased prevalence of lameness compared with groups of cows where current farm lameness protocols were used.¹¹

Conclusions

Despite low sensitivity, observing cows for a back arch while they are stanchioned remains a tool for early lameness screening. The observations could be made during management of cows for other reasons. However, the visual indications of an arched back (such as back angle) still need better definition. Because of the impact of lameness on cattle welfare, reproduction, and production performance, a more rapid method to identify dairy cow lameness is needed.

Endnotes

^aCanon PowerShot A560, Canon Inc., Tokyo Japan

^bSONY Handycam digital video camera recorder (model number DCR-SR42), Sony Ericsson, Tokyo, Japan

^cMicrosoft Moviemaker, Microsoft Corp., 2012. Seattle, WA

^dMicrosoft PowerPoint, Microsoft, Corp., 2012. Seattle, WA

^eVistaMetrix, Skillcrest LLC., Tucson, AZ

^fMicrosoft Office Excel, Microsoft, Corp., 2012. Seattle, WA

^gEpi Info™ Version 3.4, Centers for Disease Control and Prevention, Atlanta, GA

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