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Benchmarking cow comfort on North American freestall dairies: Lameness, leg injuries, lying time, facility design, and management for high-producing Holstein dairy cows

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ABSTRACT

In this paper, we describe a novel approach to corporate involvement in on-farm assessment, driven by the desire to provide a service for dairy producers and to create a vehicle for engagement on issues of dairy cow welfare. This program provides producers with feedback on animal-based (including gait score, leg injuries, and lying time) and facility-based (including freestall design, bedding practices, feed bunk design and management, and stocking density) measures that can be used to better address their management goals. The aim of this paper is to describe variation in the prevalence of lameness and leg injuries, lying behavior, facility design, and management practices for high-producing cows on freestall dairy farms in 3 regions of North America: British Columbia (BC; n = 42); California (CA; n = 39); and the northeastern United States (NE-US; n = 40). Prevalence of clinical lameness averaged (mean ± SD) 27.9 ± 14.1% in BC, 30.8 ± 15.5% in CA, and 54.8 ± 16.7% in NE-US; prevalence of severe lameness averaged 7.1 ± 5.4% in BC, 3.6 ± 4.2% in CA, and 8.2 ± 5.6% in NE-US. Overall prevalence of hock injuries was 42.3 ± 26.2% in BC, 56.2 ± 21.6% in CA, and 81.2 ± 22.5% in NE-US; prevalence of severe injuries was 3.7 ± 5.2% in BC, 1.8 ± 3.1% in CA, 5.4 ± 5.9% in NE-US. Prevalence of swollen knees was minimal in CA (0.3 ± 0.6%) but high (23.1 ± 16.3%) in NE-US (not scored in BC). Lying times were similar across regions (11.0 ± 0.7 h/d in BC, 10.4 ± 0.8 h/d in CA, 10.6 ± 0.9 h/d in NE-US), but individual lying times among cows assessed varied (4.2 to 19.5 h/d, 3.7 to 17.5 h/d, and 2.8 to 20.5 h/d in BC, CA, and NE-US, respectively). These results showed considerable variation in lameness and leg injury prevalence as well as facility design and management among freestall farms in North America. Each of the 3 regions had farms with a very low prevalence of lameness and injuries, suggesting great opportunities for improvement on other farms within the region.

Key words: animal welfare, stall design, gait, hock injury

INTRODUCTION

The term benchmarking can be traced back to the shoemaking industry in the 19th century, when cobblers would measure the feet of their clients for hand-made shoes. The cobbler would place each foot on a bench and mark out the pattern for the new shoes. This pattern became a reference point for the cobbler and helped ensure a better fit. This concept has now been adopted by businesses to refer to a process of learning, exchanging ideas, and adopting best practices (Camp, 1989). In this sense, benchmarking may allow dairy producers to evaluate their current performance relative to others and to highlight opportunities for improvement.

Lameness is one of the most important animal welfare and production concerns facing the dairy industry today (von Keyserlingk et al., 2009). Research to date has shown that facility design and management can affect lameness (e.g., Espejo and Endres, 2007; Bernardi et al., 2009), which in turn affects cow welfare and longevity (Whay et al., 2003; Bicalho et al., 2007). Interest in cow comfort and its link to lameness has also been growing (e.g., Cook and Nordlund, 2009). Despite the increasing knowledge in these areas, practical application of research findings requires additional work. For instance, it is now well established that lying behavior is a sensitive measure of cow comfort; however, a reliable assessment of lying behavior requires detailed observation of individual cows for extended periods of time (Ito et al., 2009). Furthermore, lameness detection on commercial farms has been a challenge. Prevalence of lameness reported by herd managers was found to be only one-third of that estimated by trained assessors (8.3% compared with 24.6%) for the same groups of cows (Espejo et al., 2006). These results suggest that

most producers currently lack good data on cow comfort and lameness on their farms and suggest that much scope exists for benchmarking performance relative to colleagues in their region.

Here we describe the results of an on-farm benchmarking project focused on animal-based (including gait score, leg injuries, and lying time) and facility-based (including stall dimensions, bedding practices, feed bunk design, and stocking density) measures of cow comfort. Participating dairy farmers were provided with individual reports they could use to reduce lameness and injuries, and to improve cow comfort. The data collected throughout this study provide a comprehensive data set describing the freestall farms in North America. The objectives of this paper were to describe the prevalence of lameness, hock and knee injuries, and lying behavior as measures of cow comfort among high-producing cows on freestall farms and to describe the variation in facility design and cow management thought to affect these measures.

MATERIALS AND METHODS

Farm Selection and Description

The on-farm assessment protocol was originally developed by the University of British Columbia and piloted on 43 commercial dairy farms in the Fraser Valley region of British Columbia (**BC**), Canada, between November 2007 and June 2008. Data collection from the BC study is described in Ito et al. (2009, 2010), but the present study reports the benchmarking results that have not been reported previously. On the basis of this initial success, The University of British Columbia partnered with Novus International Inc. to create the C.O.W.S. program (http://www.novusint.com/en/Market-Segments/Dairy/COWS), which enabled us to collect additional data in California (**CA**) and the northeastern United States (**NE-US**; New York, Pennsylvania, Vermont).

In BC, 3 local feed suppliers selected 15 of their clients that met the following criteria: freestall housing, TMR or partially mixed ration with supplemental grain, and milking >70 cows (Ito et al., 2009); 42 of these farms were included in the present study. In the United States, 39 herds in CA were assessed between March and May 2010, and 40 herds in NE-US (n = 28 in New York; n = 8 in Pennsylvania; and n = 4 in Vermont) were assessed from July to October 2010. These herds were selected by consulting nutritionists (n = 8 in CA; n = 24 in NE-US) using the same criteria as in BC. The farms were nominated as randomly as possible among dairies that met the criteria and gave consent to participate in the study; no previous knowledge of lameness and leg injuries status affected selection of the farms. The mean, standard deviation, and range in the age of the facility and herd characteristics for the farms visited in each of the regions are described in Table 1. Although all farms used freestall housing, they varied in several housing characteristics, including barn layout (i.e., number of rows), stall type, outdoor access (i.e., exercise corral or pasture), and feed bunk structure (i.e., post-and-rail, feed trough, or headlocks). All methods used to collect data were approved by the University of British Columbia's Animal Care Committee, which follows the standards outlined by the Canadian Council on Animal Care (2009).

Data Collection

Each farm was visited twice, with approximately 3 to 5 d between visits. The same 2 trained observers performed all animal- and facility-based measures on all farms in the 3 regions. On each farm, the producer was asked to identify one high-production pen housing primarily multiparous cows as the assessment group.

Table 1. Herd characteristics for 121 freestall-housed Holstein herds across 3 regions of North America: British Columbia (BC), California (CA), and the northeastern United States (NE-US)

Management variable	BC (n = 42)		CA (n = 39)		NE-US (n = 40)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Age of facility (yr)	12 ± 9	1–48	16 ± 12	0–50	13 ± 10	2–40
Herd size (no. of milking cows)	170 ± 80	71–511	1,796 ± 1,277	450–5,832	826 ± 549	190–2,820
Herd milk production[1] (305ME,[2] kg)	11,734 ± 851	10,133–13,322	12,029 ± 1,030	9,609–14,503	12,238 ± 967	10,434–13,809
Herd lactation no.[3]	2.2 ± 0.2	1.8–2.6	2.2 ± 0.2	1.7–2.6	2.2 ± 0.3	1.7–3.8
Assessment group[4] size (no. of cows)	94 ± 31	32–187	208 ± 122	85–746	150 ± 72	49–330

[1]n = 34 for BC, 31 for CA, and 39 for NE-US.

[2]305ME = projected 305-d mature-equivalent milk production from DairyComp 305 (Valley Agricultural Software, Tulare, CA).

[3]n = 34 for BC, 35 for CA, and 40 for NE-US.

[4]High-production group selected for assessment.

The mean, standard deviation, and range in assessment group size on farms in each region are reported in Table 1. The assessment groups consisted of [mean ± SD (range)] 2.9 ± 0.6 (1.6–4.2) lactations and 115 ± 26 (71–162) DIM in CA, and 2.7 ± 0.4 (1.9–3.6) lactations and 137 ± 41 (73–238) DIM in NE-US. These data were not available for BC, but the focal cows described below were representative of the assessment group. Herd characteristics, including herd size, group size, milk production, and lactation number, were obtained from DHIA records. Age of the facility was reported by the herd manager.

Animal-Based Measures

Lameness. All cows housed in the assessment group were gait scored as they exited the parlor by using a 5-point numerical rating system (**NRS**), where 1 = sound and 5 = severely lame (Flower and Weary, 2006). For descriptive analysis, lameness was categorized as clinical lameness (prevalence of cows scored as NRS ≥3) and severe lameness (prevalence of cows scored as NRS ≥4). The observers were initially trained to gait score by using recorded videos of cows walking in a straight line on a concrete alley (described by Chapinal et al., 2009), followed by extensive training in live observation, as used in this study.

Leg Injuries. During the first visit, the same focal cows selected for lying time assessment (described in the section below) were also scored for hock (tarsal joint) condition on a 3-point scale, where 1 = healthy hock and 3 = swollen hock, open wound, or both, according to the Hock Assessment Chart for Cattle developed by the Cornell Cooperative Extension (http://www.ansci.cornell.edu/prodairy/pdf/hockscore.pdf). Only 1 limb per animal was considered for this assessment because of difficulty in examining the opposite side in some types of parlors (i.e., herringbone parlor). Two measures of hock injuries were calculated: hock injury (prevalence of cows scored ≥2) and severe hock injury (prevalence of cows scored = 3). All cows housed in the assessment group were scored for swollen knees (carpal joint); injuries were recorded as the presence (evidently swollen joint with or without skin damage) or absence of severe injury. Knee injury was not scored on farms in BC.

Lying Behavior. On average, 40 cows from the assessment group, ranging from 26 to 50 across all farms (40.9 ± 5, mean ± SD), were systematically selected as focal cows based on the number of units in the milking parlor. For example, if the parlor had 20 units and the group had 100 cows, 8 cows per milking turn were selected (to have a final sample size of approximately 40 cows selected throughout milking). This systematic selection was done to remove any effect of milking order because previous studies have shown an association between order of milking and lameness (e.g., Main et al., 2010). The sample size was decided based on the method of Ito et al. (2009), who found reliable estimates of lying behavior on commercial dairy farms when using at least 3 d of continuous recordings (at 1-min intervals) from 30 focal cows per group. The focal cows consisted of [mean ± SD (range)] 2.5 ± 0.5 (1.8–3.4) lactations and 149 ± 37 (71–224) DIM in BC, 3.1 ± 0.5 (2.0–4.3) lactations and 132 ± 37 (69–218) DIM in CA, and 2.8 ± 0.4 (1.6–3.6) lactations and 143 ± 42 (68–241) DIM in NE-US. Lying behavior was recorded with electronic data loggers (Hobo Pendant G Acceleration Data Loggers, Onset Computer Corp., Pocasset, MA) at 1-min intervals for 3 d (72 h) as described by Ito et al. (2009) and validated by Ledgerwood et al. (2010). Durations of individual daily lying times were computed using Excel macros (Microsoft Corp., Redmond, WA), from which a mean daily lying time (h/d) and standard deviation were calculated for each farm.

Facility-Based Measures

Management Practices. Management practices, such as daily milking and feeding frequencies, were obtained through an interview with the herd manager. The total number of cows housed in the assessment pen was counted as the cows came through the parlor at the time of assessment. Time away from the pen (min/d) was calculated as the time since cows from the assessment pen left for milking until the time when all cows returned to the pen (measured during assessment) multiplied by daily milking frequency. The distance between the assessment pen and the milking parlor was measured and was multiplied by 2 times the milking frequency to calculate the total mandatory walking distance from pen to parlor (m/d).

Pen Measurements. Total water trough length from all accessible sides was measured to determine the linear water space (cm) per cow. Overall available pen area (m²) per cow was calculated as the total length × width of the pen (including stalls, alleys, and crossovers) divided by the number of cows in the pen at the time of assessment. Feed bunk density (%) was calculated as the number of cows per 60 cm of feed bunk (i.e., width of a standard headlock) multiplied by 100. Stall stocking density (%) was calculated as the number of cows per usable stall (excluding stalls with visible barriers preventing cows from lying down) multiplied by 100.

Stall Design and Bedding Maintenance. On average, 3 stalls (ranging from 2 to 7 stalls, depend-
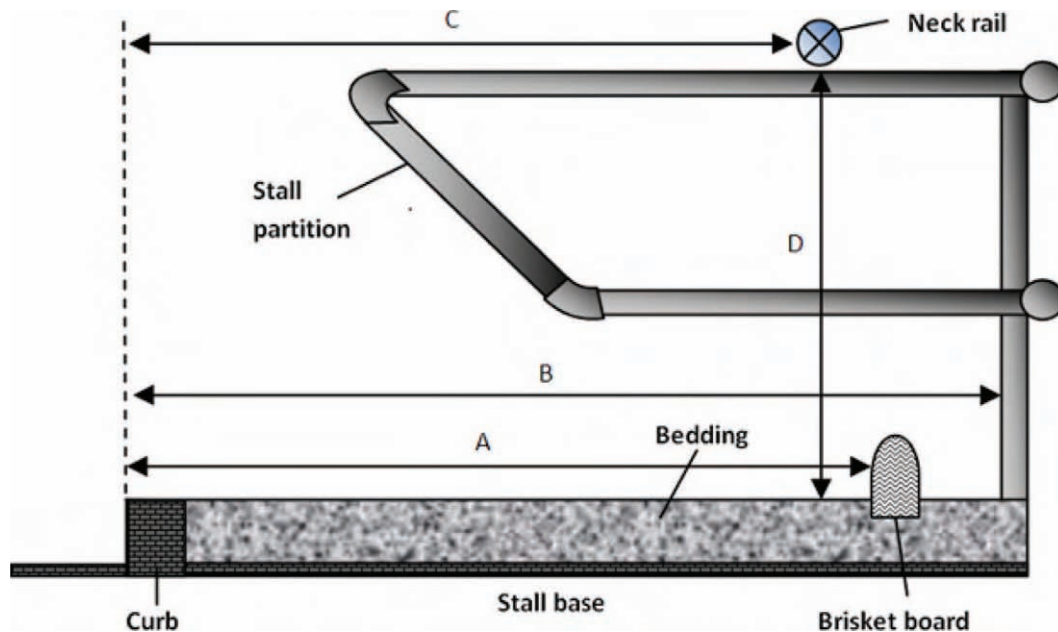
Figure 1. Stall dimensions measured included (A) bed length from the rear curb to the brisket locator, measured from the external side of the curb to the internal side of the brisket board; (B) total stall length, as the distance from the external side of the curb to the front barrier or wall; (C) neck rail position, distance from the vertical plane above the rear curb to the internal side of the rail; and (D) neck rail height, distance from the bedding surface to the bottom of the rail. Color figure available in the online PDF.

ing on the uniformity of the stall design throughout the pen) from each assessment pen were sampled to measure stall dimensions, including bed length from the rear curb to the brisket locator, total stall length, stall width (measured as the distance center-to-center between adjacent stall partitions), neck rail distance from the rear curb, and neck rail height from the bedding, as shown in Figure 1. Stall lengths for single-row stalls (facing a wall or an alley) and double-row stalls (facing another stall head-to-head) were measured and reported separately; 23, 5, and 31 farms in BC, CA, and NE-US, respectively, had both types. Neck rail type (i.e., stationary or adjustable), stall base (e.g., deep-bedded, mattress), brisket locator presence, and bedding material were recorded through direct observation. Bedding characteristics (i.e., quantity and DM content) were scored on 10 systematically selected stalls per pen; for example, if the pen had 100 stalls, every 10th stall was sampled. For non-deep-bedded stalls, bedding quantity was scored as bedding coverage on a 3-point scale: (1) stall base completely covered, (2) <50% of stall base exposed, and (3) >50% of stall base exposed; scoring was done before stalls were raked and cleaned during milking. In addition, a sample of approximately 50 mL of bedding was taken from the back one-third of each sample stall and pooled together into 1 sample per farm for DM analysis; these samples were taken on each visit to avoid bias caused by addition of fresh bedding. Samples were analyzed at Agriculture and Agri-Food Canada (Agassiz, BC, Canada) for BC, Rock River Laboratory West Inc. (Visalia, CA) for CA, and Dairy One Inc. (Ithaca, NY) for NE-US.

Data Analysis

The data analysis undertaken in this study was for descriptive purposes only, and all results are presented as the mean ± standard deviation. Interobserver reliabilities were determined by the 2 trained observers scoring the same cows for gait (n = 228), hock (n = 318), and knee (n = 278) injuries, using prevalence-adjusted, bias-adjusted kappa (Byrt et al., 1993; Thomsen and Baadsgaard, 2006).

RESULTS

Interobserver Reliabilities

The prevalence-adjusted, bias-adjusted kappa was 0.84 (95% CI = 0.77–0.90; $P < 0.001$) for gait, 0.93 (95% CI = 0.88–0.99; $P < 0.001$) for hock injury, and 0.83 (95% CI = 0.76–0.89; $P < 0.001$) for knee injury. According to the scale described by Landis and Koch (1977), interobserver agreement was almost perfect (0.81–1.00) in all cases.

Farm Characteristics

Herd size (number of milking cows) varied across and within region, with farms in BC having on average far fewer milking cows than farms in CA or NE-US (Table 1). We noted very little difference in the average age of the facility or overall herd milk production across regions (Table 1).

Animal-Based Measures

Despite differences in farm size and management, the prevalence of clinical lameness averaged about 30% in both BC and CA, but rates of lameness were considerably higher in NE-US, averaging 55% (Figure 2A). Cases of severe lameness were less common in all regions, averaging only 4% in CA and approximately 8% in both BC and NE-US (Figure 2B). Hock injuries were common in all regions, with farm-level prevalence averaging 42% in BC, 56% in CA, and 81% in NE-US (Figure 3A). The prevalence of severe cases was again lower, averaging only 2% in CA, 4% in BC, and 5% in NE-US (Figure 3B). Swollen knees were rarely observed (less than 1% of cows affected) in CA, but relatively common (23% prevalence) in NE-US (Figure 3C). Average lying times were close to 11 h/d in all 3 regions (Figure 4) but varied greatly among cows (from 4.2 to 19.5 h/d, 3.7 to 17.5 h/d, and 2.8 to 20.5 h/d in BC, CA, and NE-US, respectively).

Categorical Management Variables

Across regions, approximately 60% of the farms visited milked their cows twice a day, with the remainder milking 3 times per day (Table 2). We noted regional differences in milking frequency, with the majority of farms in NE-US milking 3 times a day compared with the majority of farms in BC and CA milking twice a day. Across regions, farms were split evenly in terms of feeding once or twice a day, with only 2.5% of the farms feeding 3 times a day. However, marked regional differences were observed, with the majority (81%) of farms in BC feeding once a day compared with the majority of farms in CA (59%) and NE-US (58%) feeding twice a day.

Deep bedding was the most common type of stall base, especially in CA, where all farms used deep-bedded stalls and 90% of these used dried or composted manure as bedding. In both BC and NE-US, approximately half of the farms used mattresses, often with little bedding. Across regions, the most popular bedding material was sawdust, with more than one-third of the farms using this material, although a wide variety of bedding materials were being used, including straw,
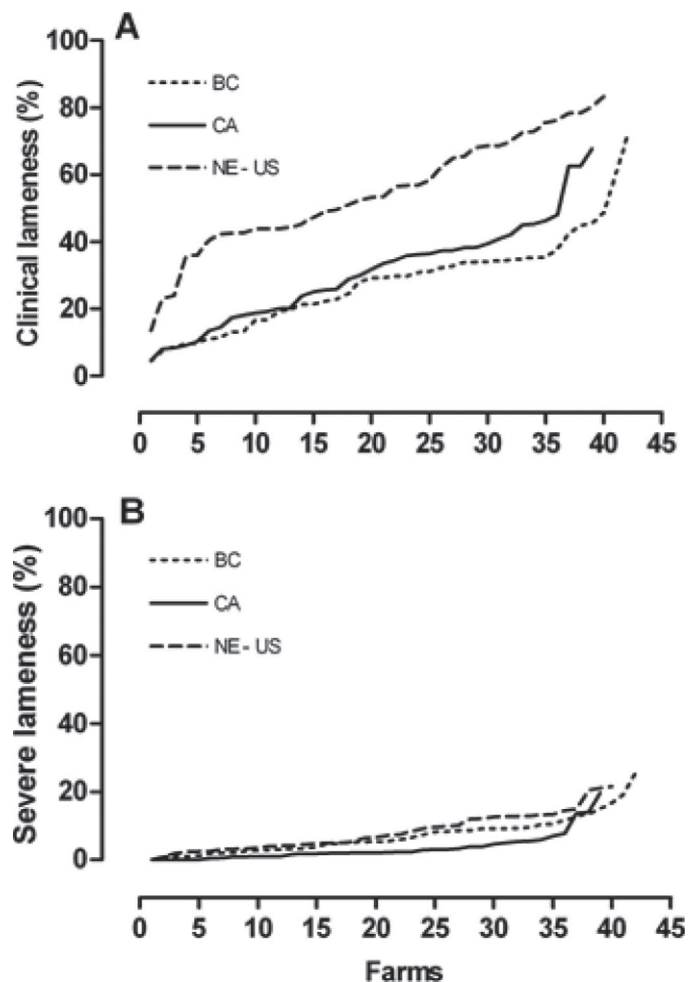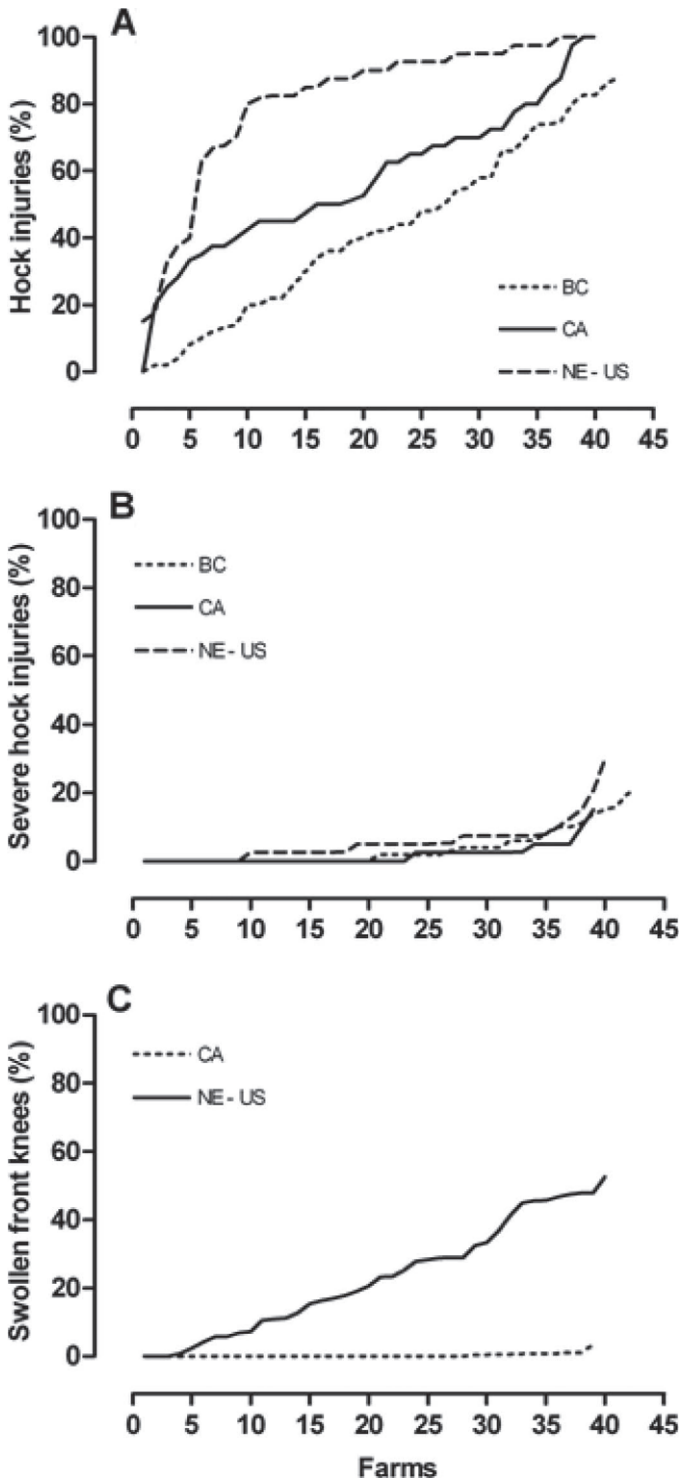

Figure 2. Distributions of the prevalence of (A) clinical lameness [numerical rating system (NRS) ≥3] and (B) severe lameness (NRS ≥4) across the high-production group assessed on farms in British Columbia (BC; n = 42), California (CA; n = 39), and the northeastern United States (NE-US; n = 40). Farms are sorted on the basis of prevalence, from lowest to highest.

shredded newspaper, shredded construction material (e.g., drywall, cardboard, etc.), and shavings. Most (88%) of the farms used relatively dry bedding (greater than 60% DM).

Overall, farms were split evenly in terms of whether they used brisket locators, and this was also the case in BC. None of the farms assessed in CA had brisket locators, but these were used in almost all the farms in NE-US. The majority of the facilities used stationary neck rails, except in CA, where hanging or other adjustable rails were most common.

Continuous Management Variables

Facility design and management varied within region and across regions (Table 3). For example, stalls in CA

and NE-US were on average 10 cm wider than those in BC, but stall width varied by approximately 20 cm within each region. Similarly, stall length varied considerably within each region. For instance, NE-US had ranges of 45 cm and 49 cm, for single-row and double-row stalls, respectively. Although the neck rail position (i.e., horizontal distance from the rear curb) was also highly variable within and across regions, the neck rail height was relatively consistent.
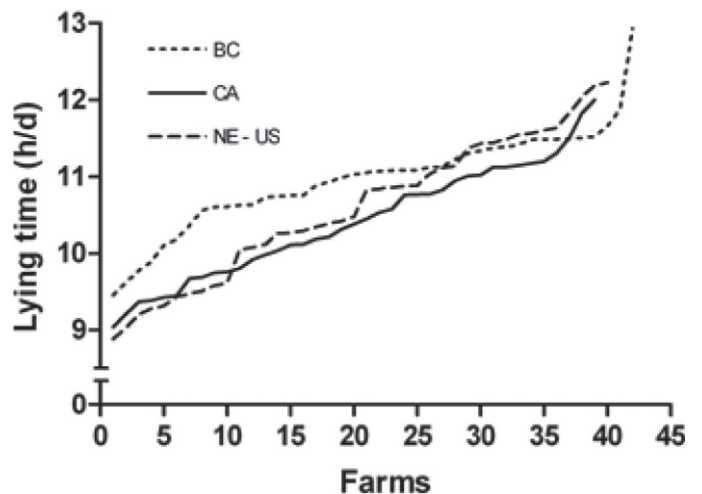
The overall pen area available per cow ranged from 4 to 14 m^2, with farms in BC and CA having on average 8 m^2 and those in NE-US having on average 6 m^2. The average amount of time cows spent away from the pen for milking each day was approximately 249 min, but it varied from 90 to 459 min. Walking distance to the parlor was also highly variable, with some cows having to walk in excess of 1 km each day and others housed immediately adjacent to the parlor.

Feed bunk stocking density ranged from 58 to 228% across regions, but averaged 116% in BC, 94% in CA, and 142% in NE-US (Figure 5A). On the other hand, stall stocking ranged from 71 to 197% (Figure 5B), with the majority of the high-producing groups assessed (60%) having densities over 100% across regions (23, 18, and 32 farms in BC, CA, and NE-US, respectively).

DISCUSSION

Lameness

Lameness compromises the welfare of the affected animals (Whay et al., 2003) and can result in reduced

Figure 3. Distributions of the prevalence of leg injuries across the high-production group assessed on farms in British Columbia (BC; n = 42), California (CA; n = 39), and the northeastern United States (NE-US; n = 40): (A) prevalence of cows with hock injuries (hock score ≥2), (B) prevalence of cows with severe hock injuries (hock score = 3), and (C) prevalence of cows having 1 or more swollen front knees (carpal joint). Farms are sorted on the basis of prevalence, from lowest to highest.

Figure 4. Distribution of average lying times (h/d) across the high-production group assessed on farms in British Columbia (BC; n = 42), California (CA; n = 39), and the northeastern United States (NE-US; n = 40). Farms are sorted on the basis of average lying tine, from lowest to highest.

Table 2. Overall and regional frequencies (% of farms) for categorical management variables across dairies in British Columbia (BC), California (CA), and the northeastern United States (NE-US) assessed using 1 high-production group on each farm

Management variable	Level	Overall frequency	Farms (%)		
			BC (n = 42)	CA (n = 39)	NE-US (n = 40)
Milking frequency	Twice a day	59.5	85.7	79.5	12.5
	3 times a day	40.5	14.3	20.5	87.5
Feeding frequency	Once a day	52.9	80.9	35.9	40.0
	Twice a day	44.6	19.1	59.0	57.5
	3 times a day	2.5	0	5.1	2.5
Stall base	Deep-bedded	48.8	26.2	100	22.5
	Mattress	29.8	40.5	0	47.5
	Other[1]	21.5	33.4	0	30.0
Bedding material	Dried or composted manure	33.0	0	89.8	12.5
	Fine or course sand	17.4	21.4	10.2	20.0
	Sawdust	38.0	76.2	0	35.0
	Straw	1.7	2.4	0	2.5
	Other[2]	9.9	0	0	30.0
Bedding quantity[3]	Deep-bedded	50.4	29.0	100	22.5
	Stall base covered	7.7	18.4	0	5.0
	Stall base <50% exposed	15.4	28.9	0	17.5
	Stall base >50% exposed	26.5	23.7	0	55.0
Bedding DM content[4]	≤60%	12.5	14.3	2.5	20.5
	>60%	87.5	85.7	97.5	79.5
Brisket locator presence	Yes	43.8	47.6	0	82.5
	No	56.2	52.4	100	17.5
Neck rail type	Stationary	70.3	81.0	28.2	100
	Adjustable	29.7	19.0	71.8	0

[1]Other: concrete, rubber mat, waterbed, rubber tire, and mixed stall base.

[2]Other: shredded newspaper, shredded construction material, and shavings.

[3]n = 38 for BC, 39 for CA, and 40 for NE-US.

[4]n = 42 for BC, 39 for CA, and 39 for NE-US.

milk yield (Warnick et al., 2001; Green et al., 2002; Bicalho et al., 2008), reduced fertility, and increased risk of premature culling (Garbarino et al., 2004; Bicalho et al., 2007). Estimates of the rate of clinical lameness on farms in Wisconsin and Minnesota (Cook, 2003; Espejo et al., 2006) agree with the findings for BC and CA presented here. Rates of clinical lameness in the NE-US were much higher and were similar to values

Table 3. Mean, SD, and range of continuous management variables across dairies in British Columbia (BC), California (CA), and the northeastern United States (NE-US) assessed using 1 high-production group on each farm

Management variable	BC (n = 42)		CA (n = 39)		NE-US (n = 40)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Stall dimension						
Length from the rear curb to brisket locator[1] (cm)	180 ± 4	174–187	NA	NA	177 ± 5	166–187
Total stall length, single stalls[2] (cm)	239 ± 17	205–273	232 ± 12	214–258	235 ± 15	205–259
Total stall length, double stalls[3] (cm)	231 ± 14	99–260	237 ± 8	222–259	225 ± 13	204–261
Stall width (cm)	112 ± 4	103–122	121 ± 2	117–124	120 ± 3	115–127
Neck rail distance from the rear curb (cm)	163 ± 12	135–200	160 ± 12	139–183	175 ± 7	161–188
Neck rail height from bedding (cm)	113 ± 8	99–128	112 ± 11	93–129	112 ± 7	91–126
Management						
Linear water space (cm/cow)	6 ± 4	2–24	8 ± 3	2–17	6 ± 3	1–15
Overall pen area[4] (m²/cow)	8 ± 2	4–14	8 ± 1	6–13	6 ± 2	4–13
Time away from pen[5] (min/d)	227 ± 77	90–450	234 ± 79	140–459	286 ± 65	180–459
Walking distance from pen to milking parlor (m/d)	88 ± 110	0–540	319 ± 274	14–1,232	367 ± 303	10–1,470

[1]n = 18 for BC, not applicable (NA) for CA (absence of brisket locator in all assessment groups), and 24 for NE-US.
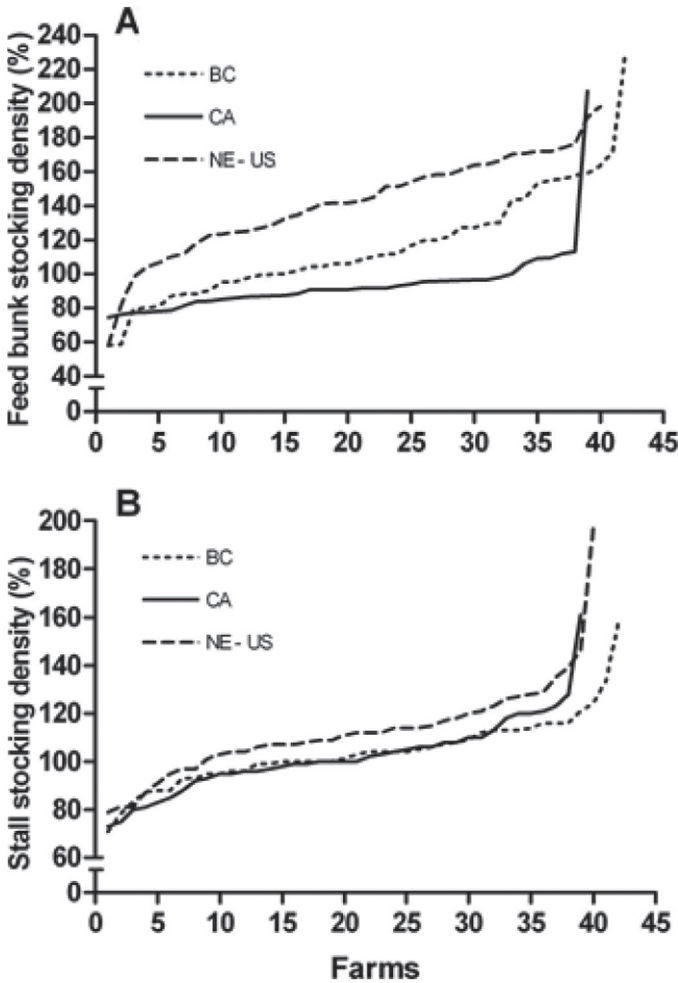
[2]n = 38 for BC, 12 for CA, and 37 for NE-US; single-row stalls facing a wall or an alley.

[3]n = 27 for BC, 32 for CA, and 34 for NE-US; double-row stalls facing another stall head-to-head.

[4]n = 40 for BC, 37 for CA, and 38 for NE-US; available pen area including stalls, alleys, and crossovers.

[5]n = 40 for BC, 38 for CA, and 40 for NE-US.

Figure 5. (A) Feed bunk density, calculated as (number of cows/60 cm) × 100, and (B) stall stocking density, calculated as (number of cows/stall) × 100, across the high-production group assessed on farms in British Columbia (BC; n = 42), California (CA; n = 39), and the northeastern United States (NE-US; n = 40). Farms are sorted from lowest to highest based on density.

reported for freestall herds in central Europe (Dippel et al., 2009). Although our results show considerable variation in lameness among high-producing cows on freestall farms in each of the regions we assessed, it is encouraging that some farms within each of the 3 regions had low rates of lameness, showing that success is achievable.

Few studies to date have reported the prevalence of severe lameness separately from clinical or overall lameness. Espejo et al. (2006) reported approximately 6% severe lameness (locomotion score ≥4 on a similar 5-point scale as used in this study) among high-producing cows housed in freestall barns in Minnesota, which is similar to the midway point of our observations across regions in our study. In the study by Espejo et al. (2006) as well

as in the current study, severe lameness accounted for only a small portion of clinical lameness. Of interest is that the patterns of severe lameness across regions did not match those of clinical lameness; for example, some farms with a low prevalence of severe lameness had a high prevalence of clinical lameness, and vice versa. Causes of mild versus severe cases of lameness are likely different and may not always be progressive, but more research is required to further our understanding in this area. We also suggest that the prevalence of severe lameness in the high-production group (as measured in the current study) is at least partly influenced by the use of a sick or lame pen for these cows, where they are more likely to be identified by the farm workers and moved or treated.

The prevalence of lameness can provide valuable information about the functionality of the stall design, and several studies have shown a link between features of the freestall and the incidence of hoof problems (Leonard et al., 1994; Faull et al., 1996). However, this relationship is complex, and limitations exist in using lameness or hoof health to assess stall design per se. In freestall systems, the link between stall design and lameness is most likely due to uncomfortable stalls resulting in cows spending more time standing (Cook and Nordlund, 2009), but the effect also depends on the nature of the surface that cows use for standing. Cows provided with freestalls with no neck rail, where they could stand fully inside the stall on ample sand, had improved gait scores even though total standing time was unchanged (Bernardi et al., 2009).

Leg Injuries

Differences among and within regions in the prevalence of hock injuries and swollen knees were more extreme than those for lameness. This is surprising because these injuries are relatively easy to recognize and prevent. For more than a decade, we have known that the use of poorly bedded mattresses greatly increases the risk of hock lesions (Weary and Taszkun, 2000; Fulwider et al., 2007). Stall features that restrict the normal rising and lying down movements (i.e., small stalls, presence of obstructions, hard lying surface, etc.) may aggravate the risk of injury as cows try to adapt to restricted space (e.g., Zurbrigg et al., 2005). In addition, concrete stalls (or similarly hard surfaces) are known to cause swollen knees resulting from impact as cows lie down (Rushen et al., 2007). On farms where these injuries are common, dairy producers may come to believe that these are normal and thus fail to manage the problem. The comparative data provided by our benchmarking process may help address this issue.

Lying Time

Compared with the lameness and injury measures, we found much less variation among lying times for farms. The average lying time of approximately 11 h/d is consistent with many other studies of lying times on commercial farms (Wechsler et al., 2000; Cook et al., 2005). Previous work has shown that lying time in free-stall barns increases with deep bedding, especially if it is dry and well maintained (Tucker et al., 2003; Drissler et al., 2005; Fregonesi et al., 2007b). Lying times also increase in larger stalls (Tucker et al., 2004, 2006) and decrease with overstocking (Fregonesi et al., 2007a).

A cow-based analysis of the data from the BC farms found that high lying times were associated with lameness (Ito et al., 2010). However, the relative consistency of lying times across farms in all 3 regions considered in the current study suggests that differences in lying time are unlikely to fully explain differences in lameness and leg injuries.

Study Design

Nutritionists and consultants within each region were asked to select farms as randomly as possible within the criteria provided, but farm selection was ultimately at their discretion and was therefore subject to sampling bias. A certain degree of selection bias is also likely given that our study required farmers' consent. Factors that we did not measure, including seasonality and facilities and management practices, may also have affected our measures of the prevalence. As in any cross-sectional study, prevalence measures should be considered only representative of the data collection period.

Similarly to previous studies (Espejo and Endres, 2007; Ito et al., 2010), our assessment targeted high-producing cows. This cohort, composed mostly of multiparous cows in early or midlactation, is at high risk for new cases of lameness. High-producing cows are the cohort in which the effects on lameness of inappropriate facility design and management are more likely to surface. This sampling method may underestimate or overestimate the overall herd prevalence of lameness depending on management and grouping strategies on each farm, but the high group likely serves as a sentinel for lameness detection.

Benchmarking

One outcome of this field study was to provide individual farms with their own data and with averages from other farms in their region to allow benchmarking of their own performance. Each farm received a confidential report that was often used as a basis for discussion (involving, for example, the owner, herd manager, nutritionist, veterinarian, hoof trimmer, and others with expertise in managing these issues). Our intention was that the reports provided producers and their advisors with an opportunity to make better informed decisions and develop tailored strategies for improving the care and management of cows on their farm. Anecdotal feedback from participants has been positive, but research is required to assess how producers use these data and whether benchmarking results in changes to practices and sustained improvements on farms. Dairy producers in general are concerned about the health and welfare of their animals; for instance, a sense of pride in a healthy herd was identified as one of the most important motivators for lameness control (Leach et al., 2010). Benchmarking may provide information that is either reassuring (if herd performance was high) or that helps to motivate change (if a major opportunity for improvement was identified).

CONCLUSIONS

Considerable variation exists among farms in rates of lameness and leg injuries, with relatively little variation in lying time. In each of the 3 regions, some farms had a low prevalence of injuries, suggesting great opportunities for other farms to benefit from benchmarking and other activities that promote the sharing of best practices among peers.

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