Management characteristics, lameness, and body injuries of dairy cattle housed in high-performance dairy herds in Wisconsin

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ABSTRACT

The objective of this study was to benchmark the prevalence of lameness, hock and knee injuries, and neck and back injuries among high-performance, freestall-housed dairy herds in Wisconsin. A random selection of 66 herds with 200 or more cows was derived from herds that clustered with high performance in year 2011 Dairy Herd Improvement records for milk production, udder health, reproduction, and other health parameters. Herds were surveyed to collect information about management, facilities, and well-being. Well-being measures were obtained through direct observation of the high-producing mature cow group, surveying 9,690 cows in total. Total herd size averaged (mean $\pm$ standard deviation) 851 ± 717 cows, ranging 203 to 2,966 cows, with an energy-corrected milk production of 40.1 ± 4.4 kg/cow per day. Prevalence of clinical lameness (5-point scale, locomotion score ≥ 3) and severe lameness (locomotion score ≥ 4) averaged 13.2 ± 7.3 and $2.5 \pm 2.7\%$, respectively. The prevalence of all hock and knee injuries, including hair loss, swelling, and ulceration, was similar at 50.3 ± 28.3 and $53.0 \pm 24.0\%$, respectively. Severe (swelling and ulceration) hock and knee injury prevalence were 12.2 ± 15.3 and $6.2 \pm 5.5\%$, respectively. The prevalence of all neck injuries (including hair loss, swelling and ulceration) was $8.6 \pm 16.3\%$; whereas the prevalence of swollen or abraded necks was low, averaging $2.0 \pm 4.1\%$. Back injuries (proportion of cows with missing or abraded spinous processes, hooks, or pins) followed a similar trend with a low mean prevalence of $3.6 \pm 3.4\%$. Overall, physical well-being characteristics of this selection of high-producing, freestall-housed dairy herds provide evidence that lameness and injury are not inevitable consequences of the confinement housing of large numbers of dairy cattle. In particular, lameness prevalence rivals that of lower-production grazing systems. However, hock and other injury risk remains a concern

that can be addressed through a choice in stall surface type. Use of deep, loose bedding yielded significant advantages over a mat or mattress type surface in terms of lameness, hock and knee injury, and proportion of cows with dirty udders (distinct demarcated to confluent plaques of manure). The performance benchmarks achieved by these herds may be used to set standards by which similarly managed herds may be judged using welfare audit tools.

Key words: lameness, injury, freestall housing, dairy herd management

INTRODUCTION

The dairy industry continues to expand and consolidate across North America, with more milk being sourced from fewer larger confinement-housed dairy herds (USDA NASS, 2012). In an effort to improve efficiency, milk production per cow has been increased through breeding, feeding, increased milking frequency, and the use of production enhancing technologies such as bST and monensin sodium. With this approach, the US dairy industry now produces more than twice as much milk from two-thirds of the number of cows compared with the 1940s, reducing its carbon footprint and the consumption of food and water (Capper et al., 2009).

However, the sustainability of the industry is a complex problem that has recently received attention from a panel of experts who not only examined environmental and economic facets to their definition of sustainability, but also included a societal perspective (von Keyserlingk et al., 2013). This has relevance when one realizes that the urban shift in the US population has been coupled with increased scrutiny of many dairy practices, such as a move from grazing to confinement housing. Nonfarming respondents to a recent US survey most often indicated that animal well-being is of primary concern in considering the practice of dairy farming (Cardoso et al., 2016).

Consumers carry an expectation that cows should graze and appear to place considerable value on cattle having access to the outdoors, where they have fresh air and freedom to roam (Ellis et al., 2009; Boogaard et al.,

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2011; Cardoso et al., 2016). In stark contrast to these expectations, two-thirds of US dairy herds practice a conventional confinement-housed management strategy (USDA NASS, 2010; von Keyserlingk et al., 2012). Whereas tiestalls continue to be the main form of housing for 49% of all herds in the United States, freestalls are emerging as the dominant form of housing in larger herds, representing 68% of herds with 100 to 499 cows and 73% of herds with 500 or more cows (USDA NASS, 2010). The sustainability of the dairy industry is therefore threatened when society learns that animal welfare may be compromised in high-producing cattle, managed not on pasture, but kept in large freestall-housed dairy herds. Recent benchmarking work of such herds in North America suggests that dairy cows managed in this manner are at significant risk for injury and lameness (von Keyserlingk et al., 2012). Indeed, the United States is not alone in confronting lameness and injury issues in its dairy industry. The worldwide prevalence of lameness in dairy herds is approximately 25% across studies based in Austria, Canada, China, Finland, Germany, Italy, Netherlands, New Zealand, Norway, the United Kingdom, and the United States (e.g., Amory et al., 2006; Dippel et al., 2009; Kielland et al., 2009; Barker et al., 2010; von Keyserlingk et al., 2012; Sarjokari et al., 2013; Chapinal et al., 2014; Fabian et al., 2014; Popescu et al., 2014), with a trend toward lower prevalence in grazing or mixed housing and grazing systems (e.g., 16.5% in Amory et al., 2006; 15% in Haskell et al., 2006; and 8.3% in Fabian et al., 2014), and a higher prevalence in confinement-housed freestall herds (e.g., 54.8% in northeast US dairy herds in von Keyserlingk et al., 2013; 31% in Chapinal et al., 2014). Even more worrisome is a mean prevalence of around 48% for hock injury in a similar global range of housed dairy herds (e.g., Kielland et al., 2009; Lombard et al., 2010; Potterton et al., 2011; von Keyserlingk et al., 2012; Brenninkmeyer et al., 2013; Zaffino Heyerhoff et al., 2014).

The question has therefore been raised as to whether or not lameness, injury, and poor physical well-being are an inevitable consequence of higher milk production and herd size expansion in confinement freestall facilities, or whether they are a consequence of the decisions being made in the construction and management of these larger dairies. Poor animal welfare will be identified by the increasing number of audits and assessments that dairy farms are being exposed to, and public scrutiny will only increase. With this backdrop, it is essential that we develop science-based benchmarks for a variety of well-being outcomes that can be used to compare herd performance within the industry. Given their importance, it is surprising that to date, very few

published articles are available to describe these standards in US dairy herds (e.g., Espejo et al., 2006; von Keyserlingk et al., 2012).

The Wisconsin dairy industry is a microcosm of the changes taking place in the United States as a whole, with a shift from tiestall to freestall housing accompanied by an increase in herd size from an average of 34 cows in 1975 to 152 cows per herd in 2012 (USDA NASS, 2013). As this shift has been made in housing and management, dairy producers in the state have been the recipients of outreach and advice from numerous sources, including University of Wisconsin Extension, producer-led programs through the Professional Dairy Producers of Wisconsin and Dairy Business Association, and through The Dairyland Initiative since 2010 (a web-based program designed to promote the construction of welfare friendly facilities for dairy cattle; <https://thedairylandinitiative.vetmed.wisc.edu/index.htm>). These outreach efforts were focused on creating environments which sustain well-being in high-producing dairy cows housed in freestall facilities.

Recently, Brotzman et al. (2015a) performed a cluster analysis of freestall-housed dairy herds with more than 200 cows in the Upper Midwest, using DHIA parameters to classify herds into groupings based on similar performance characteristics. The previous analysis identified herds where high production was accompanied by above average performance in other variables such as reproductive and fresh cow performance and udder health. The objective of our study was therefore to assess the prevalence of lameness and body injuries in the identified high-performance, larger freestall-housed dairy herds, to determine whether this management approach was compatible with high standards of physical well-being and provide benchmarks for animal observations included in animal welfare audits.

MATERIALS AND METHODS

Farm Selection and Description

Previously, principal component analysis and cluster analysis were successfully used to discover groups of dairy herds with similar performance characteristics on multiple DHI production and performance variables (Brotzman et al., 2015a). This process was applied to year 2011 DHI mean test day data for 557 Upper Midwest dairy herds of ≥ 200 cows on test, creating 6 cluster groups. A follow-up survey of management practices revealed relationships between management practices and overall group DHI performance for milk production, udder health, reproduction, and health (Brotzman et al., 2015b). For the current survey, 66 herds from the

3 groups with highest overall DHI performance were chosen. Herds in the high-performance groups were randomly selected using a random number generator (Microsoft Excel 2010, Microsoft Corporation, Redmond, WA) and telephoned by random order number until each of the 3 groups were equally represented. Visits were conducted once at each of the consenting farms during the available study period, June through August 2012. Limited resources also restricted the location of eligible herds to a region of high density of dairy farms in the state, from southwestern to northeastern Wisconsin, generally along the corridor created by State Highways 18 and 151 (Figure 1). Surveyed herds consisted of a total of 56,131 cows based on year 2011 test-day data, and observations were directly made on 9,690 cows.

Data Collection and Analysis

Survey data were collected using direct observation of the high-producing mature (multiparous) cow group and their environment, from management records and from interviewing the herd manager. On larger farms with more than one pen designated for high-producing mature cows, multiple pens were measured to ensure that at least 30% of the at-risk population was represented (Endres et al., 2014). The pen or pens on each farm to be assessed were identified by interview with the herd manager and confirmed through the use of available on-farm records for mean pen milk production, age, and DIM at the time of the visit. Two trained observers visited the farms. One observer scored knees, hocks, and udder hygiene in the parlor, whereas the second observer scored back and neck injuries as cows entered the holding area and locomotion scored cows as they exited the parlor and returned to their pens. The observers were initially trained using online tutorials, followed by continuous training in live observation throughout the study. Data were statistically summarized with SAS version 9.2 (SAS Institute Inc., Cary, NC), considering the assessment group within each herd as the experimental unit.

Animal-Based Measures

Back injuries included a count of cows with missing or abraded spinous processes, hooks, or pins. Neck injuries were assessed on a scale of 1 to 3 with 1 = normal, 2 = hair loss (defined as any size area clearly devoid of normal hair covering), and 3 = swelling or abrasion. Cows were locomotion scored using a 5-point scale, where 1 = normal locomotion, 2 = mildly lame, 3 = moderately lame, 4 = lame, and 5 = severely lame (Sprecher et al.,

1997). Prevalence of clinical and severe lameness for each herd were calculated as the number of cows with locomotion score ≥ 3 and ≥ 4 , respectively, divided by the total number of cows scored. Hocks were scored according to the Hock Assessment Chart for Cattle developed by the Cornell Cooperative Extension (Cornell University, Ithaca, NY; <https://ahdc.vet.cornell.edu/programs/NYSCHAP/docs/HockScoringChart-NYSCHAP-4-04.pdf>), where 1 = normal, 2 = hair loss (any size area clearly devoid of normal hair covering), and 3 = swollen or abrasion. If more than one lesion was recorded on a cow, the worst hock lesion was recorded. The prevalence of hock injury was calculated as the number of cows with a hock score >1 , and severe hock injuries on each farm were calculated as the number of cows with a hock score = 3, both divided by the total number of cows scored. Knees (carpi) were scored and documented in a similar manner on a 3-point scoring system, where 1 = normal, 2 = hair loss (any size area clearly devoid of normal hair covering), and 3 = swollen or abrasion. If more than one lesion was recorded on a cow, the worst lesion was recorded. Udder hygiene was scored based on the system developed by Cook (2002) with 1 = clean with little or no evidence of manure, 2 = clean with only slight manure splashing, 3 = dirty with distinct demarcated plaques of manure, and 4 = filthy with confluent plaques of manure. Udder hygiene was reported as the proportion of cows scored with an udder score >2 .

Facility- and Management-Based Measures

Time away from the pen (min/milking) was recorded as the time from when the first cow left the high-producing mature cow pen for milking until the last cow returned to the pen on the day of the visit. The total walking distance for milking (m/d) was calculated as the total distance to and from the center of the pen to the holding area, multiplied by the daily milking frequency. Holding area space per cow (m^2/cow ; total area of holding area divided by number of cows in the largest group) was determined and footbath dimensions recorded.

Multiple stocking density indicators were calculated for the day of the visit, including linear feedbunk space per cow (m/cow ; total linear feedbunk space divided by number of cows in the pen), cows per stall (number of cows in the pen divided by number of stalls in the pen), pen space per cow (m^2/cow ; total area of the pen divided by number of cows in the pen), linear water space per cow (cm/cow ; total accessible water trough length in the pen divided by number of cows in the pen), and feed alley space per cow (m^2/cow ; feed alley

Figure 1. Map of high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test. Targets indicate herds visited and surveyed for management, facilities, and measures of well-being. Color version available online.

area divided by number of cows in the pen). Ventilation method of the housing facility, heat abatement method in the pen of natural- and tunnel-ventilated facilities, and heat abatement method within the holding area

were recorded. Type of feed barrier and stall surface were recorded. Pen floor type was recorded, as well as the location of any rubber flooring throughout the dairy facility.

Figure 2. Stall dimensions measured included (A) stall width, measured as the on-center distance between adjacent stalls; (B) stall length, measured from the rear edge of the rear curb to the front barrier; (C) stall bed length, distance from rear edge of the rear curb to the brisket locator; (D) height of the brisket locator above the top edge of the rear curb; (E) neck rail height, distance from the stall surface to the bottom of the rail; (F) neck rail position, horizontal distance from the rear edge of the rear curb to the rear point of the rail; (G) interior diameter of stall divider loop, vertical distance from the top of the lower rail of the stall divider to the bottom of the upper rail of the stall divider; (H) lower rail of stall divider height, distance from the stall surface to the top edge of the lower rail of the stall divider; (I) position of stall divider angle, distance from the rear edge of the rear curb to the upward angle in the lower rail of the stall divider; and (J) curb height, distance from the alley surface to the top of rear curb.

Details regarding freestall characteristics were measured and recorded, including stall surface, bedding type, and stall dimensions, as shown in Figure 2 and Table 2. Freestall dimensions were measured on 3 randomly selected stalls (one available stall in each of the first, second, and last one-third of each row of stalls) and the average was recorded. A forward lunge obstruction was recorded as any obstruction in the front of the stall between 10 to 100 cm above the stall surface or top of the rear curb in loose-bedded stalls. For herds requiring multiple pens of cows to be observed, a single, mean value weighted by number of cows in each pen was calculated for the herd to describe spatial and temporal facility characteristics and freestall dimensions.

To estimate the number of 50-h per week full-time equivalent (**FTE**) workers at each dairy, producers were asked questions to determine the number of people and hours per day were spent in direct contact with the herd (e.g., calf care, milking, mixing and delivering feed, cleaning, management, manure hauling, and so on), not including feed production. Cows per

FTE was calculated as the total number of cows in the herd divided by the total FTE. Producers were asked if calves or heifers were sent to a custom raiser at any point during their rearing. Information about the footbath regimen (frequency and chemicals used), hoof-care program (frequency of trimming, trimming of heifers before first calving, and pasture access), and use of production-enhancing technologies were recorded. Method of freestall barn alley cleaning was also determined.

Statistical Analysis

Obvious differences were observed in the outcome measures by stall surface type. To more accurately represent the data, boxplots by stall surface type (Figure 3) were prepared using R version 3.0.1 (R Foundation for Statistical Computing, Vienna, Austria). A nonparametric method was required to statistically compare these measures, as the assumption of normality was not met in the data distributions. A Wilcoxon

Figure 3. Boxplots of measures of lameness and body injury for the mature, high-producing cows on 66 high-performance Wisconsin dairy herds by stall surface type (46 herds with a deep, loose stall surface and 20 herds with a mat or mattress surface), where the bold center line represents the 50th percentile, the boundaries of the box demarcate the 75th and 25th percentiles, and the whiskers reach to the 5th and 95th percentiles. The diamond marks the mean, and the dots represent outliers. Wilcoxon sum-rank results are indicated by P -values, means are indicated by the diamond and accompanying value.

rank-sum test was performed, with a null hypothesis of similar proportion of high-producing mature cows affected between herds with deep, loose stall surfaces and herds with mat or mattress type stall surfaces, versus the alternative hypothesis that the proportion

affected in these 2 groups was different. Proc NPAR-1WAY in SAS was used to assess potential differences in the prevalences of clinical and severe lameness, severe hock, knee and neck injuries, back injuries, and udder hygiene score >2 .

Table 1. Herd and assessment group characteristics of 66 surveyed dairy herds selected from high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test¹

Variable	Mean $\pm$ SD	Range
Total herd size (no. of cows)	851 $\pm$ 717	203–2,966
ECM (kg/cow per day)	40.1 $\pm$ 4.4	26.7–48.5
Weighted average SCC (1,000/mL)	197.3 $\pm$ 52.5	103.5–332.1
Herd average DIM	180.5 $\pm$ 9.8	159.5–201.4
Assessment group (no. of cows)	131 $\pm$ 60	63–329
Assessment group, mean age (mo; n = 63)	54.3 $\pm$ 6.7	41–75
Assessment group, mean DIM (n = 63)	169 $\pm$ 43	66–257

¹Assessed group on each dairy included the mature, high-producing cows. Three farms did not have data available at the time of the survey visit regarding the assessment group age and DIM.

RESULTS AND DISCUSSION

Cows in all of the visited herds were housed in freestalls and were managed in conventional (nonorganic) production systems, with 93.9% of herds consisting of primarily Holsteins. A large proportion of herds used performance- and production-enhancement technologies, including a hormonal reproductive synchronization program for the first breeding in most cows (87.9%), recombinant bST (66.7%), in-feed monensin sodium (87.9%), and two-thirds of herds milked 3 times daily. Mean ($\pm$ SD) cows/FTE was 62.0 ± 17.7 and custom heifer rearing was used by 53.0% of herds.

Herd-level ECM production and weighted average SCC are summarized in Table 1, along with assessment group size, age, and mean DIM. Herd size ranged from 203 to 2,966 cows with a mean of 851 ± 717 cows. Herd-level ECM production was 40.1 ± 4.4 kg/cow per day and DIM was 180.5 ± 9.8 d. Mean age of the assessment group on the visited dairies was 54.3 ± 6.7 mo, and groups overall had a mean DIM of 160 ± 43 d. Survey continuous variables are summarized in Table 2 and categorical variables in Table 3. Freestall dimensions are summarized in Table 4.

Lameness and Injury Benchmarks

Lameness and injury prevalences are summarized in Table 5, with clinically important measures depicted as boxplots by stall surface type in Figure 3. The prevalence of clinical lameness averaged 13.2%, and varied from 2.8 to 36.1% from herd to herd. This mean is consistent with the 17.1% clinical lameness prevalence found by Husfeldt and Endres (2012) in similar herds in the Midwest, and would rival the degree of lameness identified in grazing herds (e.g., 8.3% as reported by Fabian et al., 2014) and mixed housing and grazing or organic management systems elsewhere (e.g., 16.5% in Amory et al., 2006; 17.2% in Rutherford et al., 2008). Interestingly, it is lower than the prevalence found in similar herds in the Midwest a decade or more ago (e.g., 22.5% in Cook, 2003; 24.6% in Espejo et al., 2006), suggesting that the overall degree of lameness in the region may be improving. The prevalence is also lower than the lameness found in other freestall facilities in other regions of North America (28–55% in von Keyserlingk et al., 2012). The low prevalence of lameness may partially explain why these farms have good production, reproduction, and health records, as lameness can be

Table 2. Summary of continuous management and facility survey variables for the high-producing, mature cows assessed on 66 dairy herds selected from high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test, where N = number of herds assessed

Variable	N	Mean $\pm$ SD	Range
Footbath length (m)	65	2.3 $\pm$ 0.6	1.5–4.1
Footbath frequency (times/wk)	66	4.5 $\pm$ 2.2	0–14
Time away from pen milking (min/d)	66	238 $\pm$ 70	120–480
Total walking distance for milking (m/d)	66	559.5 $\pm$ 316.5	111.8–1,473.1
Time allowed at pasture or dirt lot (h/d)	6	13.3 $\pm$ 7.4	2.0–21.5
Feedbunk space per cow (m/cow)	66	0.52 $\pm$ 0.09	0.30–0.77
Feed alley area per cow (m ² /cow)	64	2.1 $\pm$ 0.5	1.4–4.7
Cows per freestall (cows/stall)	66	1.2 $\pm$ 0.1	0.7–1.5
Total pen area, confined facilities (m ² /cow)	64	6.9 $\pm$ 1.1	4.3–12
Water trough perimeter space per cow (cm/cow)	66	7.8 $\pm$ 2.4	3–13.3
Water troughs per pen (no./pen)	66	3.2 $\pm$ 1.3	2–8
Number of milking units in the parlor (no. of units)	66	28.7 $\pm$ 18.2	10–88
Cows per full time equivalent herd worker	66	62.0 $\pm$ 17.7	28.9–103.4

Table 3. Frequency of categorical management and facility variables surveyed on 66 dairy herds selected from high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test, where N = number of herds in each category¹

Variable	Category	N	%
General management characteristics			
Primary breed of herd	Holstein	62	93.9
	Other	4.0	6.1
Herd is managed under organic regulations	Yes	0	0.0
Times milked per day, high-producing mature cows	2	22	33.3
	3	44	66.7
Calves or heifers are sent to a custom raiser	Yes	35	53.0
Individual pens are used for calvings	Yes	23	34.9
Pharmaceutical, production-enhancing technology use			
Reproductive synchronization program used for the first breeding in most cows	Yes	58	87.9
Recombinant bST used on the dairy	Yes	44	66.7
Monensin is used on the dairy	Yes	58	87.9
Dry cow antibiotic therapy is used	Yes	65	98.5
Orbeseal internal teat sealant is used ²	Yes	58	87.9
Hoof care			
Hoof bath frequency, no. of milkings per week	0	1	1.5
	2 to 3	23	34.8
	4 to 5	28	42.4
	6 to 7	12	18.2
	14	2	3.0
Copper sulfate used in footbath (n = 65)	Yes	65	100
Formalin used in footbath (n = 65)	Yes	5	7.7
Antibiotics used in footbath (n = 65)	Yes	11	16.9
Cows receive hoof trimming on a scheduled basis	Yes	58	87.9
No. of scheduled hoof trims for cows, per lactation (n = 56)	1	20	34.5
	2	36	62.1
	3	2	3.4
Heifers receive regularly scheduled hoof trimming	Yes	32	48.5
Pasture access for the mature high-producing cows	Yes	6	9.1
Rubber flooring in the pens	Yes	3	4.6
Rubber flooring in the transfer lane from the pens to the milking center	Yes	10	15.2
Rubber flooring in the holding area	Yes	27	40.9
Rubber flooring on the parlor cow deck	Yes	45	68.2
Heat abatement			
Fans used in the holding area	Yes	65	98.5
Soaking used in the holding area	Yes	41	62.1
Ventilation method of the housing facility	Natural	57	86.4
	Tunnel	6	9.1
	Cross	3	4.6
Fans used in the pens, natural, and tunnel-ventilated barns (n = 63)	Yes	53	84.1
Fans used over the resting area (n = 53)	Yes	51	96.2
Fans used over the feed bunk (n = 53)	Yes	11	20.8
Soakers used over the feed alley, natural, and tunnel-ventilated barns (n = 63)	Yes	50	79.4
Feed delivery			
Type of feedbunk barrier	Headlocks	55	83.3
	Feedrail	8	12.1
	Both	3	4.6
Times per day fresh feed is delivered	1	38	57.6
	2	24	36.4
	≥ 3	4	6.1
Housing characteristics			
Alley floor construction, solid vs. slatted	Solid	66	100.0
Method of alley cleaning	Skid loader, tractor or vacuum truck	48	72.7
	Automatic alley scrapers	18	27.3
Stall layout	Two-row	40	60.6
	Three-row	24	36.4
	Four-row or more	2	3.0
Stall surface type	Deep, loose surface	46	69.7
	Mat/mattress	20	30.3
Bedding type	Sand	41	62.1
	Straw, stalks or hulls	11	16.7
	Wood shavings or sawdust	8	12.1
	Manure solids	3	4.6
	Paper product	3	4.6

Continued

Table 3 (Continued). Frequency of categorical management and facility variables surveyed on 66 dairy herds selected from high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test, where N = number of herds in each category¹

Variable	Category	N	%
Sand is recycled (n = 41)	Yes	15	36.6
Sand recycling method (n = 41)	Mechanical separation	7	46.7
	Settling lanes	7	46.7
	Both	1	6.7
Brisket locator is used	Yes	49	74.2
Presence of a forward lunge obstruction	Yes	39	59.1

¹Data describe the management and housing of the high-producing, mature cows on each farm, unless otherwise indicated.

²Orbeseal (Zoetis, Florham Park, NJ).

detrimental to all 3 (Warnick et al., 2001; Garbarino et al., 2004; Bicalho et al., 2007, respectively).

Severe lameness was uncommon at a mean of $2.5 \pm 2.7\%$ with a range from 0.0 to 15.7%. This average is lower than that found in the majority of previous freestall surveys (e.g., 16% in Dippel et al., 2009; 5.3% in Barker et al., 2010; 4.8% in Husfeldt and Endres, 2012) and much less than that found in similarly sized large freestall-housed dairy herds in the northeast region of the United States (8.2% in von Keyserlingk et al., 2012).

The mean farm-level prevalence of injured hocks was $50.3 \pm 28.3\%$, similar to several other previous surveys of freestall-housed dairy cattle (e.g., 40.1% in Potterton et al., 2011; 50% in Brenninkmeyer et al., 2013; 40% in Chapinal et al., 2014; 47% in Zaffino Heyerhoff et al., 2014). Severely injured hock prevalence (with swelling or ulceration) was 12.2%, with a wide range from 0.0 to 80.9% between herds. With no standard existing for scoring hock lesions, it is difficult to compare findings between studies; however, our observations are consistent with that of Husfeldt and Endres (2012) in similar herds using a similar scoring system (6.4 and 13.2% severe hock injury on deep-bedded stalls and mattresses, respectively). Thus, this may be an area of animal well-being needing improvement, as the lesions

are obvious to the consumer, and it is included as an outcome assessment in the majority of welfare audits.

The mean prevalence of knee injuries was similar to that of hock injuries overall at $53.0 \pm 24.0\%$, whereas the prevalence of severely injured knees was half as common compared with similar injuries to the hock ($6.2 \pm 5.5\%$). Few benchmarks exist for knee injuries and comparisons are again complicated by the lack of a standardized scoring system. Our overall findings were higher than the 24 and 35.3% reported by Zaffino Heyerhoff et al. (2014) and Kielland et al. (2009), respectively, and our severe knee injury prevalence was higher than that recently found in California (0.3% in von Keyserlingk et al., 2012), but one-quarter of the prevalence observed in the northeast United States (23.1% in von Keyserlingk et al., 2012). Similarly, few studies have documented neck or back injuries. The prevalence of neck injuries was $8.6 \pm 16.3\%$, identical to the 9% reported in the group of Canadian herds studied by Zaffino Heyerhoff et al. (2014). The prevalence of swollen or abraded necks was low at $2.0 \pm 4.1\%$ in the current study, but individual herds were identified with significant issues (range = 0 to 19.3%), whereas back injuries followed a similar trend with a mean of $3.6 \pm 3.4\%$. The average farm prevalence of poor udder hygiene was $12.1 \pm 14.8\%$ with a range

Table 4. Mean stall dimensions for the high-producing, mature cow group assessed on 66 dairy herds selected from high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test, where N = number of herds¹

Variable	N	Mean $\pm$ SD	Range
Stall width, on center (A; cm)	66	120 ± 5	102–127
Stall length (B; cm)	66	252 ± 18	206–309
Stall bed length (C; cm)	66	196 ± 34	146–277
Brisket locator height (D; cm)	49	12 ± 6	1–24
Neck rail height (E; cm)	66	119 ± 7	96–134
Neck rail position (F; cm)	66	167 ± 12	136–227
Interior diameter of stall divider loop (G; cm)	66	81 ± 8	52–93
Lower rail of stall divider height (H; cm)	66	33 ± 9	15–66
Rear distance to upward bend in stall divider lower rail (I; cm)	66	116 ± 25	0–193
Curb height (J; cm)	66	25 ± 3	19–36

¹Letters for each variable correspond to Figure 2.

Table 5. Summary of measures of lameness, body injury, and hygiene for the high-producing mature cows on 66 dairy herds selected from high-performance herds in Wisconsin as determined by cluster analysis of year 2011 DHI data for Upper Midwest herds of ≥ 200 cows on test

Variable ¹ (%, unless otherwise noted)	Mean	SD	Minimum	Maximum	Quartile 1	Median	Quartile 3
No. of cows scored	147	93	63	657	90	112	171
Locomotion score 3	10.7	5.3	2.7	23.4	6.6	9.7	14.7
Locomotion score 4	2.2	2.2	0.0	13.3	0.9	1.9	2.8
Locomotion score 5	0.3	0.7	0.0	3.2	0.0	0.0	0.0
Clinically lame	13.2	7.3	2.8	36.1	7.7	11.3	17.2
Severely lame	2.5	2.7	0.0	15.7	0.9	2.0	3.3
Hock injury score 2 and 3	50.3	28.3	3.7	97.2	27.3	48.3	74.0
Hock injury score 3	12.2	15.3	0.0	80.9	2.2	5.6	14.8
Knee injury score 2 and 3	53.0	24.0	7.0	100.0	34.3	55.4	68.3
Knee injury score 3	6.2	5.5	0.0	35.1	3.2	4.7	7.5
Neck injury score 2 and 3	8.6	16.3	0.0	74.3	0.7	2.2	5.9
Neck injury score 3	2.0	4.1	0.0	19.3	0.0	0.5	1.6
Back, hook or pin injury	3.6	3.4	0.0	22.0	1.6	2.9	4.6
Udder hygiene score 3 and 4	12.1	14.8	0.0	94.3	3.6	6.7	15.2
Udder hygiene score 4	0.3	1.2	0.0	7.1	0.0	0.0	0.0

¹Locomotion scores: 1 = normal locomotion, 2 = mildly lame, 3 = moderately lame, 4 = lame, and 5 = severely lame (Sprecher et al., 1997). Hock injury scores: 1 = normal, 2 = hair loss, 3 = swelling or abrasion. If more than one lesion recorded on a cow, the worst hock lesion per cow was recorded ("Hock Assessment Chart for Cattle" by Cornell Cooperative Extension, <https://ahdc.vet.cornell.edu/programs/NYSCHAP/docs/HockScoringChart-NYSCHAP-4-04.pdf>). Knee injury scores: 1 = normal, 2 = hair loss, 3 = swelling or abrasion. If more than one lesion recorded on a cow, the worst hock lesion per cow was recorded. Udder hygiene scores: 1 = clean with little or no evidence of manure, 2 = clean with only slight manure splashing, 3 = dirty with distinct demarcated plaques of manure, and 4 = filthy with confluent plaques of manure (Cook, 2002). Back, hook or pin injury: proportion of cows with missing or abraded spinous processes, hooks, and pins. Neck injury scores: 1 = normal, 2 = hair loss, 3 = swelling or abrasion.

from 0.0 to 94.3% on farms, lower than the 22.4% found by Schreiner and Ruegg (2003) using a similar scoring system in 8 Wisconsin herds.

Herd Facility and Management Characteristics

Common to previous surveys of multiple outcomes of well-being was the wide variation observed between herds. An obvious source of variation in this survey were differences based on stall surface type, with contrasts in the prevalence of lameness and hock lesions on deep-bedded versus mattress-type surfaces being particularly well-documented (e.g., Barrientos et al., 2013; Cook, 2003; Chapinal et al., 2013; Husfeldt and Endres, 2012; Weary and Taszkun, 2000). Deep, loose bedding was the predominant stall surface used by 70% of herds, with the majority using sand bedding (62.1%). This stands in contrast to the lower percentage of sand stall users nationally across all herd sizes at 45% (USDA APHIS VS, 2010) and much higher than the 26% of herds in British Columbia and 23% herds in the northeast United States surveyed by von Keyserlingk et al. (2012). Sand bedding was used on 52% of Wisconsin dairy farms in a 2008 survey of expanding dairies by Mayer and Kammel (2008), and our findings are consistent with the recent survey of 325 large Wisconsin dairies by Rowbotham and Ruegg (2015), where 60% used inorganic bedding (sand or lime), suggesting increasing use of sand over time as herds expand. Use of deep, loose bedding has long been associated with

beneficial effects on lameness (Cook et al., 2004; Espejo et al., 2006), and the body of evidence is growing, demonstrating a highly significant effect on hock and other injuries (Weary and Taszkun, 2000; Barrientos et al., 2013; Zaffino Heyerhoff et al., 2014). The influence of deep, loose bedding in the current study is demonstrated in Figure 3, where significant beneficial effects were identified for clinically lame cows, severe hock and knee injuries, and udder hygiene. Of the greatest importance in the context of our study was the difference in severe hock injury. Whereas $29.3 \pm 17.3\%$ of cows had hocks that were swollen or ulcerated in man-made rubber mat or mattress stalls, only $4.7 \pm 4.9\%$ of cows on deep, loose-bedded stalls were similarly afflicted ($P < 0.0001$). Similarly, whereas mat or mattress stall herds averaged $17.4 \pm 9.0\%$ clinical lameness, deep, loose-bedded herds were at $11.4 \pm 5.6\%$ ($P = 0.0096$). This difference in well-being likely contributes to the higher production levels observed in herds using inorganic bedding reported by Rowbotham and Ruegg (2015) and the sand users examined by Andreasen and Forkman (2012). Of herds using sand in the current study, 36.6% recycled sand, with an even distribution of mechanical and settling lane systems used. Other aspects of stall design were similar to those reported by von Keyserlingk et al. (2012), with similar dimensions and a high percentage of front lunge obstructions (59.1%).

Many of the study herds demonstrated significant attention to hoof care, with 87.9% of herds operating

a hoof-trimming schedule for adult cows, and 65.5% of trimming herds doing so at least twice per lactation, similar to the rate of trimming found in a previous survey of large, progeny-testing herds in the United States (Caraviello et al., 2006). In addition, 48.5% of herds routinely trimmed heifers before first calving. All but one of the herds operated a footbath program, with a mean frequency of 4.5 ± 2.2 passes per week, with the majority of herds utilizing copper sulfate as the chemical of choice, similar to the survey findings of Cook et al., (2012).

Pasture access for the high-producing, mature cows was allowed on 9.1% of herds for a mean of 13.3 ± 7.4 h/d. Allowing lactating cows access to pasture can improve locomotion scores (Haskell et al., 2006; Hernandez-Mendo et al., 2007), but has also been associated with lower milk production (Bargo et al., 2002). Nevertheless, it is interesting to see this management approach being adopted by some high-producing dairy herds. All herds used a solid floor construction for their high-producing, mature cow groups. Although rubber flooring was found on approximately two-thirds of the parlor cow decks, it was not as commonly used in holding areas (40.9%) or transfer lanes to the milking center (15.2%), and rarely used in the pen (4.6%). Whereas rubber flooring may have benefit in reducing hoof trauma and wear (Cook and Nordlund, 2009), use of this type of flooring in freestall pens was not a significant component of the hoof-care program in these herds. A strong majority of herds used a nonautomatic method of cleaning manure from freestall alleys (72.7%), similar to a previous survey of Wisconsin dairies which found automatic alley scrapers used on only 11% of farms (Bewley et al., 2001).

Freestall barns were predominantly naturally ventilated (86.4%), but heat abatement measures were a focus of attention for these herds. 84.1% of herds in natural- or tunnel-ventilated barns used circulation fans in the freestall pens, primarily over the freestalls, and all but one herd used them in the holding area. Soakers were used in the high-producing, mature cow pens in 79.4% of barns that also used natural or tunnel ventilation and 62.1% of holding areas. Accessible water trough perimeter length per cow was 7.8 ± 2.4 cm. All these findings are similar to those by Caraviello et al., (2006), confirming that owners of large freestall facilities are taking the challenge of ameliorating the deleterious effects of heat stress very seriously.

Distance walked for milking from the pen to the holding area per day varied widely, with a mean of 559.5 ± 316.5 m/d, which was further than the distance reported in the herds surveyed by von Keyserlingk et al. (2012). However, the time away from the pens for milking of 238

± 70 min/d in our study was similar to those herds, but exceeded the 3 h/d compatible with adequate resting time (Gomez and Cook, 2010). Although 61% of herds favored a 2-row stall layout, more than the 46% found in a previous survey of expanding Wisconsin dairies (Bewley et al., 2001), cows were overstocked relative to stalls (1.2 ± 0.1 cows/stall) and feed space (0.52 ± 0.09 m/cow). Lying times are affected by overstocking (Friend et al., 1977; Fregonesi et al., 2007), and limited feed space has the potential to limit intakes, especially in low-rank cows (DeVries et al., 2004; Huzzey et al., 2006). Apparently, these high-performing herds found ways to limit the potential for these negative effects on performance, which did not include multiple fresh feed deliveries, as 57% of herds delivered fresh feed only once per day. However, 83.3% of herds used headlocks at the feedbunk, compared with the 22.2% of medium (100–499 cows) and 79.6% of large (≥ 500 cows) dairies using headlocks nationally in 2007 (USDA APHIS VS, 2010). Headlocks have been shown to decrease aggressive displacements of cows from feeding, compared with a post and rail feed barrier (Endres et al., 2005; Huzzey et al., 2006), and provide a means for handling cattle.

CONCLUSIONS

Overall, lameness and body injury characteristics of this selection of high-producing, freestall-housed dairy herds provide evidence that poor welfare is not an inevitable consequence of the confinement housing of large numbers of dairy cattle. In particular, lameness prevalence rivals that of lower-production grazing systems. However, hock and other injury risk remains a concern that can be addressed through a choice in stall surface type. Use of deep, loose bedding rather than a mat or mattress-type surface yielded significant advantages in terms of lameness, hock and knee injury, and udder hygiene. The lameness and injury benchmarks achieved by these herds may be used to set standards by which similarly managed herds may be judged using welfare audit tools.

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