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Effect of following recommendations for tiestall configuration on neck and leg lesions, lameness, cleanliness, and lying time in dairy cows

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ABSTRACT

Cow comfort in tiestalls is directly affected by stall dimensions, for which some recommendations exist. To evaluate how well Canadian dairy farms with tiestalls complied with recommendations for stall dimensions, as well as the effect of compliance on cow comfort and cleanliness, we assessed lactating Holstein cows (n = 3,485) on 100 tiestall dairy farms for neck and leg lesions, lameness, and cleanliness and measured time spent lying down. Data on stall dimensions (width and length of the stall, position and height of the tie rail, length of the chain, and height of the manger curb) were recorded for each cow. The majority of cows were housed in stalls smaller than recommended. The prevalence of lesions and lameness was high (neck, 33%; knee, 44%; hock; 58%, lameness, 25%) and the prevalence of dirtiness was low (udder, 4%; flank, 11%; legs, 4%). Chains shorter than recommended increased the risk of neck, knee, and hock lesions. A tie rail further back in the stall than recommended increased the risk of neck, knee, and hock lesions and reduced the frequency of lying bouts and the risk of a dirty udder. A tie rail set lower than recommended decreased the risk of neck lesions and lameness and increased lying time and lying bout frequency. Stalls narrower in width than recommended increased the risk of neck injuries and lameness and reduced the daily duration of lying time and the risk of a dirty flank and legs. Stalls shorter in length than recommended increased the risk of knee lesions and reduced lying bout frequency and the risk of a dirty udder. The majority of farms do not follow recommendations for stall dimensions (with the exception of tie rail height), and the lack of compliance is associated with increased risk of lesions and lameness and can affect lying time. Recommended stall dimensions tend to reduce cleanliness, but the prevalence of dirty cows remains very low.

Key words: dairy cow, tiestall, stall dimensions, cow comfort, welfare

INTRODUCTION

Due to the increasing need to assure consumers and food retailers that animal welfare is being respected on commercial dairy farms, several animal welfare-assurance schemes have been developed. These often contain recommendations or requirements for the dimensions and configuration of stalls. However, although these recommendations are often loosely based on the results of experimental research, the assumption that farms that follow these recommendations will have measurable improvements in cow welfare is not often verified. Many dairy cows are still kept in tiestalls; for example, in the United States nearly 40% of dairy farms use tiestalls for lactating cows (USDA, 2016). However, the use of this method of housing dairy cattle is being increasingly questioned (e.g., European Food Safety Authority, 2009). The comfort and welfare of dairy cows kept in tiestalls is likely to be affected by the dimensions of the stall, and recommendations for stall design have been proposed, often based on observations of cows′ movements when standing up or lying down (e.g., Anderson, 2008; Table 1). Some recommendations have been adopted into welfare standards for dairy cattle (e.g., Dairy Farmers of Canada, 2009). However, little is known about how well these recommendations are being followed on commercial dairy farms, or if they do improve cow comfort.

Although much research has been done on the comfort of cows in loose housing, a dearth of information exists regarding cow comfort in tiestalls (Rushen et al., 2008). Among the rare studies done on tiestall systems, 3 epidemiological studies found high prevalence of neck and leg lesions and that the great majority of farms had stalls that were too small compared with recommendations (Zurbrigg et al., 2005a; Lapointe et al., 2010;

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Nash et al., 2016); one study found that narrow stalls and short chains were risk factors for leg lesions (Nash et al., 2016). A fourth study found a high prevalence of lameness among cows in tiestalls, but did not relate these to stall dimensions (Charlton et al., 2016). Those authors also found a large variation in lying times between farms, and in freestall systems lying time is affected by the dimensions of the stalls (e.g., Tucker et al., 2004).

Considerably more research has been done on stall design in freestall herds, and stall dimensions reportedly have an effect on several measures of cow comfort, such as the presence of leg lesions, lameness, and time spent lying down (reviewed in Rushen et al., 2008); for example, narrow stalls increase the risk of lameness (Westin et al., 2016). Unfortunately, we know little about how stall dimensions affect these measures for cows in tiestall systems. Thus, our objectives were to describe the extent that Canadian dairy farms do follow recommendations for tiestall dimensions (Dairy Farmers of Canada, 2009) and examine whether meeting these recommendations results in measurable improvements in cow comfort by reducing neck and leg lesions and lameness and increasing time spent lying down.

MATERIALS AND METHODS

The Institutional Animal Care Committees of the Universities of Laval and of Guelph approved the study following the guidelines of the Canadian Council for Animal Care (2009).

Herd and Cow Selection

We visited 100 commercial tiestall dairy farms in the Canadian provinces of Quebec (n = 60) and Ontario (n = 40), using criteria and methods described by Vasseur et al. (2015). To be included in the study, the herds had to be on the dairy recording system of either Valacta Inc. (Sainte-Anne-de-Bellevue, QC, Canada) or CanWest DHI (Guelph, ON, Canada), have Holstein cows, and a mean annual milk production of at least 7,000 kg/cow. Letters were sent to farms meeting these criteria, inviting them to participate in the study. The number of letters sent was calculated assuming a positive response of 20 to 25%. Those interested and willing to participate in the study were then contacted by telephone and interviewed to determine whether they met further study criteria, including a herd size of at least 40 lactating cows, barns that had been in use for a minimum of 1 yr, and lactating cows reported as not having access to pasture or a loafing area during the course of the study. Furthermore, the herds were selected to have variation in average cow longevity as measured by the percentage of cows in third lactation or higher (mean ± SD; 39.7 ± 8.5%, range = 15–59%) and the annual farm turnover rate (36.5 ± 10.9%, range = 17–79%).

We found that a variety of stall types were used on the farms (Nash et al., 2016); however, the majority of stalls (n = 3485; 88%) had a single horizontal tie rail with a chain, and so we restricted our analysis to these stalls. The current paper describes this subset of farms described by Nash et al., (2016).

A purposive sample of 40 lactating Holstein-Friesian cows (Ito et al., 2009) between 10 and 120 DIM was selected on each farm. If the herd had <40 cows between 10 and 120 DIM, cows were first selected by continuously increasing the DIM until reaching 40 cows. In contrast, if >40 cows between 10 and 120 DIM, the sample of study cows was balanced to reflect the distribution over parities in the herd and cows were randomly selected within the 3 parity groups, 1, 2, and 3+. The characteristics of the cows are shown in Table 2.

Table 1. Recommendations for tiestall dimensions

Dimension	Recommendation[1]
Stall width	2× width of the cow at the hook bone
Bed length	1.2× height of cow at rump
Tie rail height	0.80× height of cow at rump
Tie rail position	35 cm more than stall length, from the back of the stall
Chain length	Height of tie rail = 20 cm
Manger wall height	<20 cm

[1]From Anderson (2008).

Data Collection

All measures were collected using standard operating procedures described previously (Gibbons et al., 2014; Vasseur et al., 2015; www.dairyresearch.ca/animal-comfort-tool.php). Each farm was visited twice at an interval of 5 to 10 d. During the first visit, data were collected on the cows and on the stall in which each cow was housed. During the second visit, equipment was removed and the farmers were debriefed. Personnel responsible for data collection underwent an intensive 2-wk training program, and the repeatability for each trainee was assessed as described in Gibbons et al. (2012). Only those who attained the target Kendall's W ≥0.6 during training were used. There were never more than 2 observers per farm, and each observer would take the same measure on all cows on a farm.

Lesion Scoring. Cows were scored for lesions on the tarsus (hock) and carpus joints (knee) and neck according to the method described by Gibbons et al. (2012; Table 3). Nash et al. (2016) provides descriptive data

Table 2. Characteristics of the cows in the sample (mean ± SD)

Item	All cows[1]	Parity 1	Parity 2	Parity 3+[1]
No. of cows	3,436	1,236	883	1,317
DIM	156 ± 93	160 ± 95	154 ± 91	152 ± 92
Height at rump, cm	150.6 ± 4.25	150.5 ± 4.16	151.3 ± 4.18	150.3 ± 4.31
Width at hook bone, cm	66.4 ± 4.25	63.6 ± 3.38	66.8 ± 3.48	68.9 ± 3.83
305-d yield, kg				
Milk	9,996 ± 1,780	8,869 ± 1,322	10,342 ± 1,591	10,827 ± 1,726
Fat	386 ± 74	343 ± 54	399 ± 69	417 ± 74
Protein	320 ± 54	285 ± 39	333 ± 47	344 ± 53
Mean SSC ($\times 10^3$)	309 ± 97	282 ± 86	318 ± 97	328 ± 102

[1]Mean parity: all cows = 2.46 ± 1.6; Parity 3+ cows = 4.1 ± 1.2.

on the prevalence of the lesions and on the principal risk factors for each type. For hock and knee lesions, a score of 0 to 3 was assigned for both the left and right legs. A cow was scored as having a hock lesion or a knee lesion if it had a score of 2 or more on either leg, and a neck lesion if it had a score of 2 or more.

Lameness. Each cow was filmed, and the video was later watched twice by the same assessor to determine lameness. Twenty percent of the videos (n = 800) were also scored a second time by 1 of 2 trained observers to check for interobserver repeatability (92.0%). The method used to score the cows for lameness in the stall was developed by Leach et al. (2009) and adapted by Gibbons et al. (2014), who showed that this stall lameness-scoring method is strongly correlated with that obtained from gait scoring. Scoring involved observing the cows in the tiestall for 4 behaviors: (1) edge, standing on the edge of the step when stationary, presumed to be done to relieve pressure on one part of the claw; (2) weight shift, assessed laterally by regular, repeated transfer of weight from one hoof to another; (3) rest, repeatedly avoiding putting full weight on one foot and lifting it more than the other; and (4) uneven, uneven weight bearing between feet when encouraged to move from side to side, demonstrated by a more rapid movement by one foot than the other or by an evident reluctance to bear weight on a particular foot. A cow was scored as lame if she exhibited 2 or more of the above behaviors (Gibbons et al., 2014).

Dirtiness. Cows were scored (0–3; Table 4) for dirtiness either on the flank (defined from middle tarsal joint to a virtual line between pin and hook bones on the right side), leg (defined as from the top of the claw (coronary band to the middle of the hock on the rear right leg), or udder (defined as the lower 50% of the udder excluding the 4 teats). An area was scored as dirty if the cow had a score of 2 or more.

Lying Time. To record the time the cows spent lying down, electronic data loggers (HOBO Pendant G Acceleration Data Loggers, Onset Computer Corporation, Pocasset, MA) were attached to the hind leg of each cow using Vet-Wrap (CoFlex, Andover Coated Products Inc., Salisbury, MA) and programmed to record the position of the cow (lying or standing) at 1-min intervals for 4 consecutive days (Vasseur et al., 2012). Recording was set to begin at 2350 h on the day of the first farm visit. During the second farm visit, all of the data loggers were removed and the data were downloaded. Excel macros (Microsoft Corp., Redmond, WA) were used to calculate, for each cow, the total duration of lying time and lying bout frequency over 4 d. Descriptive data on lying time are provided in Charlton et al. (2016).

Stall Measures. The stall holding each of the focus cows was measured for the following dimensions: stall width, bed length, tie rail height, tie rail position, chain length, and manger curb height (Vasseur et al., 2015; www.dairyresearch.ca/animal-comfort-tool.php).

Table 3. Scoring criteria for lesions (illustrated in Gibbons et al., 2012)

Lesion	Score 0	Score 1	Score 2	Score 3
Hock (tarsus)	No swelling; no hair is missing or broken hair	Bald area on hock with no swelling or swelling <1 cm high.	Swelling, 1–2.5 cm high, or broken skin or scab on bald area	Swelling, >2.5 cm high; may have bald area, broken skin, or scab
Knee (carpus)	No swelling; no hair is missing or slight hair loss or broken hair	No swelling; bald area	Broken skin or scab or swelling (<2.5 cm high); may have bald area	Swelling ≥2.5 cm high; may have bald area or lesion
Neck	No swelling; no hair is missing or slight hair loss or broken hair	No swelling; bald area visible	Broken skin or scab or swelling; may have bald area	Not available

Statistical Analysis

Data were analyzed using SAS Version 9.4 (SAS Institute Inc., Cary, NC). The unit of analysis was the cow and the likelihood that the cow was lame, had a neck, hock, or knee lesion, or a dirty udder, flank, or leg was analyzed separately for each dependent variable using PROC GLIMMIX (binomial distribution) with the independent variables. As our interest was on the effect of following or not following recommendations, we expressed each variable (stall width, bed length, tie rail height, tie rail position, chain length, manger curb height, and stall cleanliness) as the extent that it deviated from the recommendation based on the size of the cow that occupied the stall (Table 1; Anderson, 2008). The recommendation for each (derived from Anderson, 2008) was based on stall width being 2× the width of cow at hook bone; bed length being 1.2× the height of the cow at the rump; tie rail height being 0.8× the height of the cow at the rump; tie rail position from rear of the bed being bed length plus 35 cm; chain length being height of chain rail minus 20 cm; and height of manger curb being <20 cm from top of lying surface. For each dimension, we subtracted the recommendation from the actual measure obtained so that a positive value indicated the measure was larger than the recommendation, whereas a negative number indicated that the measure was smaller than the recommendation.

We forced the model to include DIM and parity as covariables, because previous research (Nash et al., 2016) showed that these have an effect on all outcomes, and included a variable stall management, which combined the variables for bedding type, wetness score, and depth of bedding to account for the effect of these on our measures (Nash et al., 2016). Herd identification was used as random variable in all models. Independent variables were then tested together in a multivariate model, after having tested for the presence of a correlation between the independent variables. If 2 variables had an intercorrelation greater than 0.6, the variable that had the least biologically plausible relationship was removed. Two-way interactions between stall width × bed length, tie rail position × tie rail height, and tie rail position × chain length variables were also included in the model. All independent variables or interactions that were not significantly ($P > 0.10$) related to the dependent variable were removed from the final model using a backward elimination. Continuous variables (daily duration of lying time and bout frequency of lying down) were analyzed in the same way as above but using PROC MIXED.

RESULTS

Table 5 shows the dimensions of the stalls (relative to the recommendations) in each province. Overall, only a minority of stalls met the recommendations, but some numerical differences were noted between the provinces. Table 6 shows the prevalence of lameness, lesions, and dirtiness among all cows and in each province. We found notable differences between the provinces, with Quebec having more cows that were lame or had leg or neck lesions than Ontario and Ontario having more dirty cows than Quebec.

The results of the analysis of risk of certain welfare outcomes associated with following the recommendation for each stall dimension are shown in Table 7. None of the interactions analyzed were significant. Cows in stalls that met or exceeded the recommendations for chain length had a reduced risk of a neck, knee, and hock lesion (negative coefficients). Cows in stalls that met or exceeded the recommendation for tie rail position had reduced risk of a neck and knee lesion and of being lame and lay down more frequently and in longer

Table 4. Scoring criteria for dirtiness of udder, leg or flank of cows

	Score			
Area	0	1	2	3
Udder	Light: Contamination of fresh splashes of manure for <50% of the area	Moderate: contamination of fresh splashes of manure for >50% of the area	Heavy: contamination of dried and caked, and fresh manure for >50% of the area	Very heavy: contamination of entire area with dried, caked manure
Leg	Light: Contamination of fresh splashes of manure for <50% of the area	Moderate: contamination of fresh splashes of manure for >50% of the area	Heavy: contamination of dried and caked, and fresh manure for >50% of the area	Very heavy: contamination of entire area with dried, caked manure
Flank	Light: Contamination of fresh splashes of manure for <50% of the area	Moderate: contamination of fresh splashes of manure for >50% of the area (may have some caked spots)	Heavy: contamination of dried and caked, and fresh manure for >50% of the area	Very heavy: contamination of entire flank area and belly with dried, caked manure

Table 5. Mean (±SD) of the dimensions of the stalls in each province expressed in the same measure as the recommendations[1] and the percentage of stalls meeting each recommendation in each province

	Measure[2]		% Stalls	
Dimension	Quebec	Ontario	Quebec	Ontario
Stall width	1.93 ± 0.18	1.86 ± 0.17	35	22
Bed length	1.19 ± 0.06	1.18 ± 0.06	46	43
Tie rail height	0.74 ± 0.08	0.70 ± 0.09	23	16
Tie rail position	5.2 ± 11.2	32.1 ± 8.9	2	54
Chain length	−45.9 ± 18.1	−25.1 ± 15.4	7	39
Manger wall height	21.3 ± 9.2	19.2 ± 6.6	44	62

[1]Stall width = 2× width of the cow at the hook bone; bed length = 1.2× height of cow at rump; tie rail height = 0.80× height of cow at rump; tie rail position = 35 cm more than stall length, from the back of the stall; chain length = height of tie rail (20 cm); manger wall height <20 cm. From Anderson (2008).

[2]Measure expressed in the same ratio as the recommendation.

bouts, but had an increased risk of having a dirty udder (positive coefficient). Cows in stalls that met or exceeded recommendations for tie rail height had an increased risk of neck lesion and of being lame and lay down for less time in fewer bouts. Cows in stalls that met or exceeded recommendations for stall width had a reduced risk of neck lesions and of being lame and lay down for longer, but were more at risk of having dirty flanks and dirty legs. Cows in stalls that met or exceeded recommendations for bed length had a reduced risk of knee lesions and more frequently lay down in bouts, but were more at risk of having a dirty udder.

DISCUSSION

Our results show that the majority of tiestalls on Canadian dairy farms do not meet the recommendations for most stall dimensions, given the size of the cows. Furthermore, cows that are in stalls that do not meet the majority of recommendations are at higher risk of having a leg and neck lesions, being lame, and of having an altered pattern of lying down compared with cows that are in stalls that do meet the majority of recommendations. Increasing the dimensions of stalls (or decreasing the size of cows in them) to meet the recommendations will likely reduce the prevalence of these welfare issues and improve cow comfort, but may result in a slight increase in the prevalence of dirtiness of the cows.

The lack of compliance with the recommendations corresponds with the results of an earlier study of 317 tiestall farms in Ontario, which found that 90% of the farms did not meet recommendations for stall dimensions (Zurbrigg et al., 2005a). The fact that considerably more than 10% of stalls in our study in Ontario did meet the recommendations suggests that some progress has been made over the last 10 yr. However, the notable differences between the neighboring provinces, both in the extent of compliance with the recommendations and in the prevalence of the expected outcomes, suggest an important role of local information sources in affecting how dairy barns are built. In summary, the design of tiestalls in Quebec appears to be aimed more at improving cleanliness, whereas in Ontario the focus appears to be more on improving cow comfort. Having more consistent information provided to dairy producers would probably be advantageous.

A failure to follow recommendations for the length of the chain was most clearly related to an increased risk of lesions, had little effect on cow cleanliness, and was one of the recommendations that was least respected.

Table 6. Prevalence (% of cows) in total sample and in each province of lesions to the neck, knee, and hock; lameness; and dirtiness of the udder, side, and leg

	All cows		Quebec		Ontario	
Item	No.	%	No.	%	No.	%
Neck lesions	3,370	33.4	2,109	47.5	1,261	9.8
Knee lesions	3,302	43.8	2,050	54.1	1,252	26.9
Hock lesions	3,103	58.3	1,949	64.4	1,154	48.1
Lameness	3,278	25.0	2,077	32.9	1,201	11.4
Dirty udder	3,378	4.0	2,118	3.2	1,260	5.4
Dirty side	3,378	10.6	2,118	8.7	1,260	13.8
Dirty legs	3,378	4.1	2,118	3.0	1,260	5.7

Increasing the length of the chain by 10 cm was found to be associated with an 8 to 10% reduction in the odds of a neck lesion, in the risk of a knee lesion, and in the risk of a hock lesion. These results corroborate the earlier findings of Zurbrigg et al. (2005b) and Nash et al. (2016), who found a reduction in the risk of hock lesions with a longer chain. We found a substantial difference between the 2 provinces, with short chains being more common in Quebec than in Ontario, which corresponds to the difference between the 2 provinces in the prevalence of neck and leg lesions. In addition, if a chain is sufficiently short, it may constrain the cow's behavior (e.g., by increasing the difficulty of adopting some lying positions, grooming, or reaching the feed comfortably). Fortunately, lengthening the chain is probably one of the easiest and least costly changes to implement in stalls, although it would be helpful to understand why producers opt to use short chains.

For cows in tiestalls, the position of the tie rail has a large effect on the comfort of the cow. If the tie rail is not sufficiently forward of the front of the stall, the chance that the cows will hit the rail while getting up, lying down, or feeding is higher. Moving the tie rail forward to meet the recommendations will likely result in a reduction in the risk of neck lesions, of knee lesions, and of lameness. Bernardi et al. (2009) noticed a similar effect of the position of the neck rail on lameness in freestalls. The most plausible explanation for the effect on neck and knee lesions is that an improperly placed tie rail forces the cow to press against the tie rail while eating or else to kneel down to eat. Moving the tie rail forward increased the risk of a dirty udder, but the actual prevalence of dirty udders was low; only 4% of the cows in our sample had a dirty udder. The position of the tie rail also had a small effect on the time that cows spent lying down. We found that for every increase of 10 cm in the forward position of the tie rail, lying time increased by 4 min/d due to a slight increase (+0.14 bouts/d) in the frequency of lying bouts. The latter finding suggests that a tie rail too far back increases the difficulty for the cow to lie down or stand up. These results show the importance of sensitizing dairy producers and advisors to the necessity of respecting the recommendations for the placement of the tie rail. The horizontal position of the tie rail in the stall was a noticeable problem in Quebec farms in particular, with the great majority placing the tie rail further back in the stall than recommended. This was less of a problem on farms in Ontario where a small majority of farms did meet or exceed the recommendation.

Table 7. Likelihood of welfare outcomes associated with following or not following recommendations for measures of tiestall configuration

Stall measure[1]	Outcome[2]	Coefficient	SE	OR[3]	95% CL[4]		*P*-value
Stall width	Neck lesion	−0.123	0.046	0.884	0.808	0.968	0.008
	Lameness	−0.157	0.043	0.854	0.785	0.930	<0.001
	Dirty flank	0.189	0.056	1.208	1.083	1.347	0.001
	Dirty leg	0.153	0.076	1.166	1.005	1.352	0.043
	Daily lying time (h/d)	0.107	0.037	NA[5]	NA	NA	0.004
Bed length	Knee lesion	−0.107	0.062	0.899	0.796	1.014	0.084
	Dirty udder	0.305	0.133	1.356	1.046	1.759	0.022
	Lying bout frequency	0.325	0.098	NA	NA	NA	0.001
Tie rail height	Neck lesion	0.198	0.074	1.219	1.054	1.410	0.008
	Lameness	0.100	0.057	1.105	0.989	1.234	0.078
	Daily lying time	−0.114	0.054	NA	NA	NA	0.034
	Lying bout frequency	−0.212	0.086	NA	NA	NA	0.014
Tie rail position[6]	Neck lesion	−0.541	0.064	0.582	0.514	0.660	<0.001
	Knee lesion	−0.181	0.050	0.834	0.757	0.920	<0.001
	Lameness	−0.275	0.044	0.760	0.697	0.829	<0.001
	Dirty udder	0.184	0.086	1.202	1.016	1.423	0.032
	Daily lying time	0.067	0.045	NA	NA	NA	0.072
	Lying bout frequency	0.145	0.065	NA	NA	NA	0.027
Chain length	Neck lesion	−0.087	0.039	0.917	0.850	0.989	0.024
	Knee lesion	−0.105	0.033	0.900	0.845	0.959	0.001
	Hock lesion	−0.089	0.029	0.915	0.864	0.968	0.002
Feeder curb height	Dirty udder	0.036	0.016	1.037	1.006	1.069	0.020

[1]Observed size − recommended size (10-cm increment).

[2]df for neck lesion = 3,029; knee lesion = 2,972; hock lesion = 2,783; dirty leg, udder, or flank = 2,977; daily lying time and lying bout frequency = 3,077.

[3]OR = odds ratio. This demonstrates how the probability of a cow to be scored as being lame or dirty or having a lesion changes with each 10-cm change in the dimension in the direction of meeting the recommendation.

[4]95% confidence limits.

[5]NA = not applicable.

[6]A positive value for this variable indicates that the tie rail was further forward in the stall.

Our results are surprising in that they show that meeting recommendations for the height of the tie rail seemed to reduce cow comfort. The majority of stalls in both provinces were lower than recommended, but an increase in height of the tie rail increased the risk of neck lesions and of lameness. This is the opposite effect noted for the height of the feed rail in freestall systems (Zaffino-Heyerhoff et al., 2014). We also found that an increase in the height of the tie rail reduced daily lying time and the frequency of bouts of lying down, which is the opposite found for the neck rail in freestalls (Tucker et al., 2005). We cannot explain this effect, and it is clearly important to do more research into the optimum height of the tie rail. Although we expected that the effects of the height and position of the tie rail and the length of the chain would be interdependent, we found no interactions between these 3.

Stall size is the most obvious factor that could affect cow comfort. Stalls that are too small could be expected to reduce the comfort of the cows in making it difficult for them to perform normal behaviors, especially in tiestalls where the cows spend nearly the whole of their daily lives. The effect of these spatial constraints would most likely be apparent when the cow is getting up or lying down, as small stalls increase the chance of the cow hitting the stall. We found that the majority of stalls were both too short and too narrow, given the size of the cows in them, although this was most evident in stall width, which also had the greatest association with lesions and lameness (Nash et al., 2016). Stall sizes are often chosen to improve cow cleanliness by reducing the chance that feces will be deposited in the stall. An increase in the width of the stalls reduced the risk of neck lesions and of lameness, but increased the risk of a dirty flank and of a dirty leg. Again, the prevalence of both dirty flanks (10.6%) and dirty legs (4.1%) was much lower than the prevalence of neck lesions (30–60%) and lameness (25%). Narrow stalls have also been associated with an increased prevalence of lameness in freestall barns (Solano et al., 2015), but not with the prevalence of leg lesions (Kielland et al., 2009; Zaffino-Heyerhoff et al., 2014).

Stalls shorter than the recommendations were less common, but an increase in bed length resulted in a reduction in the risk of a knee lesion but an increase in the risk of a dirty udder. An increase in the risk of leg lesions with short tiestalls was found by Busato et al. (2000) and Keil et al., (2006). An increase in bed length was found to increase the risk of a dirty udder, but the actual prevalence of dirty udders was low. Previously, Zurbrigg et al. (2005b) found an increase in the risk of dirty legs as stall length increased, but we did not find this effect.

The effects of not meeting recommendations for stall width on lying time were as expected from previous results from freestalls by Tucker et al. (2004), who found lower lying times in narrower stalls, which appeared to be a result of longer duration bouts of lying down, as the frequency of bouts did not differ. This finding corresponds to our lack of an effect of stall width on bout frequency.

The recommendations for stall length and width were derived by measuring the amount of space a cows uses when lying down, and are cited in Canada by extension services and national standards (Anderson 2008, Dussault and Leblanc, 2008; Dairy Farmers of Canada, 2009). These result in similar dimension recommendations as used in some US states when adjusted for cow size (Graves et al., 2011). Kinematic studies of how much space cows use when in the process of standing up and lying down provide some further support for the recommendations for the width of the stall; Ceballos et al. (2004) found that the lateral space occupied by the cow was about 181% of the width at the hips, which is smaller than the 200% recommended, so following the recommendations should provide adequate horizontal space. However, Ceballos et al. (2004) found that cows occupied 300 cm of longitudinal space, suggesting that the recommendations for stall length may be shorter than optimal. As the average size of dairy cows has continuously increased in the last 30 yr (Valacta, 2009), and many dairy barns have not recently been renovated, it seems that dairy producers are increasingly likely to have to choose between providing substantially larger stalls or selecting for smaller cows, possibly even switching to smaller breeds.

The opposite effect of changing stall dimensions on lesions and lameness, in contrast to the effect on cow cleanliness, illustrate the stall design paradox described by Bernardi et al. (2009) for freestalls, where the current design of stalls essentially forces producers to choose between cow cleanliness and cow comfort. However, it is important to emphasize that the actual prevalence of lameness and lesions was substantially higher than of dirty cows, even if the recommendations for stalls was met. For example, the prevalence of a dirty udder (which would be most likely to lead to mastitis) was only 4%. A 10-cm increase in the forward position of the tie rail would increase this by 20%, leading to a prevalence of still less than 5%. At the same time, the prevalence of neck lesions would decrease from 33 to 19%. We concluded that the slight risk of having dirtier cows does not justify the use of stalls that substantially increase lesions and lameness. Other means of keeping cows clean need to be explored, such as grooming the cows, cleaning stalls more often, and so on.

At present, dairy producers are very sensitive to the importance of cow cleanliness to reduce risks of mastitis and have a ready tool in SCC to monitor the risk of mastitis on their farms. Unfortunately, they are much less able to identify cows with lesions or lameness (e.g., Espejo et al., 2006) and lack a simple tool for monitoring cow comfort on their farms, although these are becoming available (see Vasseur et al., 2015).

Concern about the effects of tiestalls on cow welfare has largely focused on behavioral issues, such as the lack of exercise and social contact, with the assumption that tiestalls are superior to freestalls for minimizing cow injury and lameness (European Food Safety Authority 2009; Rushen and de Passille, 2015). In contrast, our study found prevalence of lameness and lesions that were as high, if not higher than in freestalls. For example, the prevalence of lameness of 25% in our study is higher than that of 21% reported in freestalls (Solano et al., 2015), whereas our prevalences of 33, 44, and 58% for neck, knee, and hock lesions, respectively, are greater than the prevalences of 16, 24, and 47% reported in freestall herds (Zaffino-Heyerhoff et al., 2014). However, large variability was observed between farms in the prevalence of lesions, and the prevalence is higher on farms using stalls that do not comply with recommendations.

CONCLUSIONS

The majority of tiestalls on Canadian dairy farms do not meet recommendations for stall dimensions. With the exception of tie rail height, making changes to meet the recommendations will likely lead to improvements in cow comfort and welfare, although this may result in a small reduction in cleanliness. Most extension effort needs to be made to sensitize dairy producers, engineers, and equipment suppliers of the importance of meeting recommendations for tiestall dimensions.

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