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The stall-design paradox: Neck rails increase lameness but improve udder and stall hygiene

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ABSTRACT

Housing conditions for dairy cows are thought to affect lameness, but almost no experimental work has addressed this link. The aim was to assess the effect of one feature of free-stall design, the position of the neck rail, testing the prediction that cows will be more likely to become lame if using pens with the neck rail positioned such that it prevents standing fully inside the stall. Cows (n = 32) were housed in 8 pens. Treatments were tested using a crossover design; treatments were allocated alternately to pens at the beginning of the experiment and switched halfway through the 10-wk experiment. Cows spent 27 ± 3 min/d standing with all 4 feet in stalls with less restrictive neck rails. In contrast, cows averaged just 1 ± 3 min/d when the neck rail was positioned restrictively. Cows spent less time standing with only the front 2 feet in the stall with less restrictive neck rails (33 vs. 49 ± 6 min/d). Gait scores improved when cows were kept in the less restrictive stalls and worsened when cows were kept in pens with the restrictive neck rail (median score 2.5 vs. 3.5 after 5 wk on treatment). Of 13 new cases of lameness, 11 occurred in pens with the restrictive neck-rail position. Similarly, of the 16 new cases of sole lesions, 15 occurred during the period when cows were housed in pens with a restrictive neck rail. Stalls with the neck rail positioned less restrictively had higher contamination scores than stalls with the restrictive neck rails (3.7 vs. 0.4 ± 0.2), and cows using those stalls had dirtier udders and longer teat-cleaning times (8.3 vs. 7.0 ± 0.2 min for 12 cows). This study provides the first experimental evidence that aspects of stall design can reduce the risk of lameness and hoof disease. The results illustrated that changes in design that resulted in improvements in cow comfort and hoof health came at the expense of cow and stall cleanliness.

Key words: cow comfort, lameness, udder cleanliness, stall design

INTRODUCTION

Lameness is one of the major problems of intensive dairy production, as well as a cause of pain and discomfort for dairy cows (Whay et al., 1997). Economic losses associated with lameness include decreased milk production, weight loss, reduced fertility, treatment costs, involuntary culling, and decreased slaughter value (Sprecher et al., 1997; Warnick et al., 2001).

A growing body of research has demonstrated that the lying surface provided for cows is one of the most important factors affecting the incidence of lameness and injuries in intensively housed dairy cows. For example, cows on farms with mattresses and little bedding had more severe hock lesions than did cows on farms that used deep-bedded stalls (Weary and Taszkun, 2000; Wechsler et al., 2000; Fulwider et al., 2007). Cows housed on mattresses had a higher incidence of clinical lameness (24%) than those housed in deep-bedded sand stalls (11%; Cook et al., 2004). Stall size and configuration affected standing and lying times. For example, Tucker et al. (2004) showed that providing cows with wider free stalls improved lying times, likely because they had less contact with the partitions in the larger stalls. Cows spent more time standing with all 4 legs in the wider stalls, reducing the time spent standing partially in the stall (i.e., perching with only the front 2 feet in the stall and the back feet in the alley) or standing on the concrete flooring elsewhere in the barn.

In most barns, the surface for standing outside of the stall is wet concrete, a risk factor for problems with hoof health (Somers et al., 2003). Cows can use the stall as a refuge, accessing the dry, softer surface for standing. Nevertheless, free stalls are typically configured with a neck rail that prevents cows from standing fully in the stall, with the intention of preventing feces and urine from contaminating the stall and ultimately improving udder health. However, both the height of the neck rail

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and its distance from the curb affected standing; more restrictive neck-rail placements, lower and closer to the rear of the stall, prevented cows from standing fully in the stall (Tucker et al., 2005). Thus, designing stalls that stay clean may have the unintended effects of increasing standing time outside of the stall and, hence, increasing the risks of lameness and hoof disease.

Hernandez-Mendo et al. (2007) reported that gait scores used to assess lameness improved with increased time on pasture, but gait scores of cows kept indoors remained stable or worsened. They suggested that a period of access to pasture could help lame cattle recover and could potentially have longer term benefits for milk production and fertility. However, moving cows onto pasture may not be a practical solution for some producers, and pasture availability is typically seasonal. Thus, the objective was to test if a simple modification to existing free stalls, moving the neck rail ahead such that it is less restrictive, could improve the gait of lame cows. Specifically, we predicted that cows would spend more time standing fully in stalls with less restrictive neck rails, would spend less time standing partially in these stalls, and would show improvements in gait. We also predicted that stalls with less restrictive neck rails would become more contaminated with fecal matter, reducing udder cleanliness and increasing the risk of IMI.

MATERIALS AND METHODS

Cows and Treatments

This experiment was conducted at the University of British Columbia Dairy Education and Research Centre—Agassiz (British Columbia, Canada) beginning in April 2007 and ending in July 2007. Eight groups of 4 focal Holstein cows (i.e., 32 cows; parity = 2.6 ± 1.4; BW = 630 ± 163 kg; mean ± SD) were cared for according to a protocol approved by the university's Animal Care Committee. Cows averaged 111 ± 24 DIM and had a milk yield of 40.2 ± 1.3 kg/d at the beginning of the study.

Before starting the experiment, cows were gait scored (Flower and Weary, 2006). Cows were visually assessed and scored using a numerical rating system score (**NRS**) ranging from 1 to 5 in 0.5-point increments. A score of 1 reflected sound cows, namely those with a flat back and steady head carriage, hind hooves falling in or near the tracks left by the front hooves, joints flexing freely, symmetrical gait, and all legs seeming to bear weight equally. A score of 5 reflected severely lame cows, showing a distinct back arch and head bob, reduced tracking up and joint flexion, asymmetric gait, and an obvious limp (i.e., a reluctance to bear weight equally on all limbs).

Cows were randomly assigned to 1 of 8 groups, within the constraint that each group contained at least one cow with a score of 2.5, 3.0, and 3.5 and that groups did not differ in parity, DIM, milk yield, BW, and BCS. Pens were assigned alternately to the 2 treatments, with the neck rail positioned either at 130 or 190 cm from the vertical plane above the rear curb. The 130- and 190-cm positions were intentionally near the extremes of the range found on commercial farms in the United States (2007 NAHMS Dairy survey; Jason Lombard, USDA, Fort Collins, CO; personal communication); the 130-cm position was more aggressive and 190 cm more generous than what is typically recommended (Nordlund and Cook, 2003). In both treatments, the height of the neck rail was fixed at 118 cm above the stall surface. Following 5 wk of observation, each pen was switched to the alternate treatment condition such that the effect of neck-rail position was tested within pen. Before the experiment, all cows had been housed in this same free-stall barn with the neck rail positioned at the same height and 140 cm from the vertical plane above the rear curb.

Housing and Management

Each group of cows was kept in a pen together with 8 nonexperimental cows. Pens had a total of 6 m of accessible feed-alley space and 12 free stalls filled with 40 cm of washed river sand raked level twice daily. In each pen, the 12 stalls were configured in 3 rows: 2 rows faced one another, were open at the front, and had a length of 240 cm, and the back row faced a cement wall and had a length of 270 cm. All stalls were 120 cm wide (center to center of divider pipes). The crossover alleys were scraped manually twice daily, and all other alleys were cleaned 6 times daily with automatic scrapers. All flooring outside the free-stall area was grooved concrete. Cows were milked twice daily in a double 12-parallel milking parlor; cows were away from their pens for 30 min, with the morning milking starting between 0530 and 0700 h and the afternoon milking between 1600 and 1700 h.

Cows were given ad libitum access to a TMR consisting of 30.5% corn silage, 6.4% grass silage, 6.6% grass hay, 5.5% alfalfa hay, and 51% concentrate on a DM basis. The composition of the TMR was 48.4% DM and contained (on a DM basis) 17.8% CP, 35.9% NDF, 21.1% ADF, 0.9% Ca, and 0.45% P. Fresh feed was provided twice daily at 0500 and 1500 h, and feed was pushed up at 1100, 1900, and 2200 h. Water was available ad libitum from a self-filling trough located in the crossover alley of each pen. Cows were walked 120 to 160 m on grooved concrete from their pens to the milking parlor, with the distance depending on the location of the home pen.

Measurements

All cows were locomotion scored weekly immediately after the morning milking. Cows were walked down a 1.2-m wide and 40-m long grooved concrete corridor. Individual cows were assigned an NRS as described previously. Cows were gait scored live by a single observer. This observer and one other observer blind to treatment also scored cows from video. Interobserver reliability was assessed by Pearson correlation coefficients between the 2 scores of the 2 observers ($r = 0.71$). Scores taken from video and those assessed live showed a reasonable level of agreement ($r = 0.76$). All analyses presented in the following are based on the live scores, but the conclusions from these analyses would have been unchanged if using the video score from either observer.

Udder cleanliness was recorded twice weekly during the morning and afternoon milking using a hygiene score described by Cook et al. (2004). The udder was visually inspected from the rear and the side and assigned a score from 1 to 4: 1 = no manure present, 2 = minor splashing of manure near the teats, 3 = distinct plaques of manure on the lower half of the udder, and 4 = confluent plaques of manure encrusted on and around the teats. To provide an indication of the practical consequences of any differences in udder cleanliness, the time required to clean the teats in preparation for milking was measured. Before attaching the milking cluster, each teat was dipped with iodine and then wiped with a clean paper towel. The time was measured from when the first teat was dipped until the last cluster was attached for the entire group of 12 cows.

Stall cleanliness was scored twice a day when cows were in the milking parlor and before the stalls were raked. A grid measuring 120 × 160 cm and consisting of 240 equal-sized (8 × 10 cm) partitions was placed over the bedding in each stall. A cleanliness score was allocated by counting the number of grid squares contaminated with fecal matter or wet with urine.

Hoof pathologies were scored at the beginning, before the crossover, and at the end of the trial. Cows were elevated in a trimming chute, claws were cleaned and scraped, and the location and severity of hoof horn injuries (sole hemorrhages, sole ulcers, and white line hemorrhages) were recorded for each claw using a foot map that divided each claw into 6 zones (adapted from Greenough and Vermunt, 1991). Sole hemorrhages and ulcers were scored by one observer using a validated 8-point scoring system in which sole hemorrhages were assigned a 1 to 5 score based on color intensity, and sole-ulcer severity was assigned a 6 to 8 score based on the degree of corium exposure and the presence of infection (Leach et al., 1998). Presence or absence of digital or interdigital dermatitis or both, heel erosion, and interdigital hyperplasia was recorded at each scoring session.

Behavior was video recorded for 24 h, 3 d/wk using a Panasonic WV-GP-470 camera positioned 5 m above each experimental pen. The cameras were attached to a video multiplexer (Panasonic WJ FS 416) and time-lapse recorder (Panasonic AG 6540; Panasonic, Mississauga, Ontario, Canada). Two red lights (100 W) hung 10 m above each experimental pen to facilitate video recording at night. Cows were marked with unique symbols and letters using hair dye to identify individuals, and pens were numbered for identification. Video recordings were scanned at 5-min intervals to assess stall usage (standing with 2 or 4 feet in the stalls). A standing bout was defined as the interval between 2 lying events. Data loggers (Gemini Dataloggers Ltd., Chichester, UK), validated by O'Driscoll et al. (2008), were used to quantify the number of standing bouts, as well as the total time spent standing and lying per day. The data logger used a mercury switch to determine leg orientation (standing vs. lying) and was programmed to record position every 1 min. The device was placed into a fabric pouch and attached to either hind leg of each cow with vet-wrap (CoFlex, Andover Coated Products Inc., Salisbury, MA). The data logger was removed for approximately 8 h between the morning and afternoon milking every 7 d to download data and was switched to the contra-lateral leg. Cows were never observed lying down outside of the stall.

Milk samples were analyzed for SCC at the end of each phase of the experiment. Counts >200,000 cells/mL were considered indicative of subclinical IMI.

Statistical Analysis

Responses measured using an interval scale (time standing with 2 or 4 feet in the stall, time lying in the stall, number of lying bouts, stall cleanliness score, and teat cleaning time) were averaged by calculating a mean for each pen on each of the 2 treatments. These treatment averages were subtracted to calculate a between-treatment difference for each pen. A one-sample *t*-test with 7 df was used to determine if these differed from zero.

The analysis of the 2 ordinal response measures (gait score and udder-cleanliness score) was identical, except pen by treatment averages were calculated as medians rather than means, and the difference between treatments was tested using a Wilcoxon signed-rank test. Unlike all the other response measures, gait was expected to change in relation to week of treatment, so analysis for this measure was done separately for week of treatment. Cows started the experiment with different gait scores. The hypothesis that initial gait score affected response to treatment was tested using a Spearman rank correlation ($\mathbf{r}_s$) across cows (30 df), comparing the baseline gait score with the change in gait score after 5 wk on each treatment (i.e., after the entire treatment period).

The numbers of new cases of lameness (NRS $\geq$3), severe sole lesions, digital dermatitis, mastitis, and subclinical IMI (SCC >200,000 cells/mL) that developed in each treatment condition were compared using a binomial test with the null expectation that the frequency of new cases would be equal in the 2 groups. Each test considered only those animals that were not already affected at the beginning of the experiment.

RESULTS

Cows spent less time standing with all 4 feet in the stall when the neck rail was positioned restrictively ($P < 0.001$). Cows spent approximately 30 min/d standing fully in the stalls with the less restrictive neck-rail placement, but this time reduced to near zero when the neck rail was positioned more restrictively (Figure 1). This difference in standing time can be accounted for by the increased time cows spent standing with 2 feet in the stall ($P < 0.02$). Cows spent approximately 30 min/d standing with 2 feet in stalls without the restrictive neck rails, but this increased to almost 50 min/d when cows were housed in pens with the restrictive neck-rail placement. Cows spent 12.3 ± 0.6 (SD) h/d lying down regardless of neck-rail position. This lying time was divided into fewer bouts when the neck rail was positioned more restrictively ($P < 0.01$); cows had 10.4 ± 0.2 lying bouts/d without the restrictive neck rail versus 9.6 ± 0.2 bouts/d with the neck rail positioned restrictively.

Gait scores were lowered in pens without the restrictive neck rail relative to pens equipped with the neck barrier (Figure 2). This difference between treatments was significant in wk 3, 4, and 5 ($P < 0.02$). The gait score at the beginning of the experiment was correlated with response to treatment after 5 wk both without the restrictive neck rail ($r_s = 0.87$, $P < 0.001$) and with the neck rail positioned restrictively ($r_s = -0.66$, $P < 0.001$).

These results for gait can be considered in terms of the number of new cases of lameness. Thirteen cows not lame at the beginning of the study (i.e., NRS <3) became lame over the course of the experiment; 11 of these cases appeared in pens when the neck rail was positioned restrictively versus 2 new cases in pens without

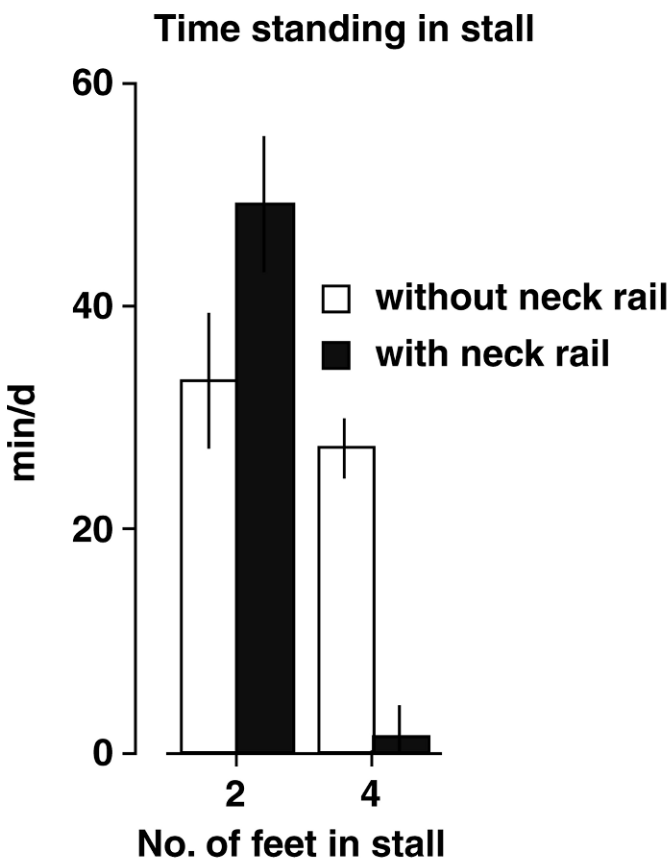

Figure 1. Mean (±SE) time (min) cows spent standing with either the front 2 feet in the stall or with all 4 feet in the stall. Results are shown separately for cows kept in pens (n = 8) with and without the neck rail positioned restrictively.

the restrictive placement (binomial test; $P = 0.01$). A similar pattern was observed for sole lesions. Of the 16 new cases of sole lesions that developed, 15 occurred during the period when cows were housed in pens with the restrictive neck-rail placement versus 1 case when housed with less restrictive neck rails (binomial test; $P < 0.001$). Of 9 new cases of digital dermatitis identified over the course of the experiment, 6 developed while cows were housed in pens with the restrictive neck rails versus 3 new cases in pens without the restrictive neck barrier ($P > 0.05$).

Stalls with the neck rail positioned more restrictively were less contaminated with fecal matter and urine. In addition, cows using those stalls had cleaner udders, and less time was required to clean the teats in preparation for milking ($P < 0.001$). Stalls in pens with the less restrictive neck rails averaged 4 of 240 grid locations with feces or urine on the bedding versus <1 grid location for stalls with the more restrictive neck rails (Figure 3). The median udder contamination score tended to be lower in pens with the more restrictive

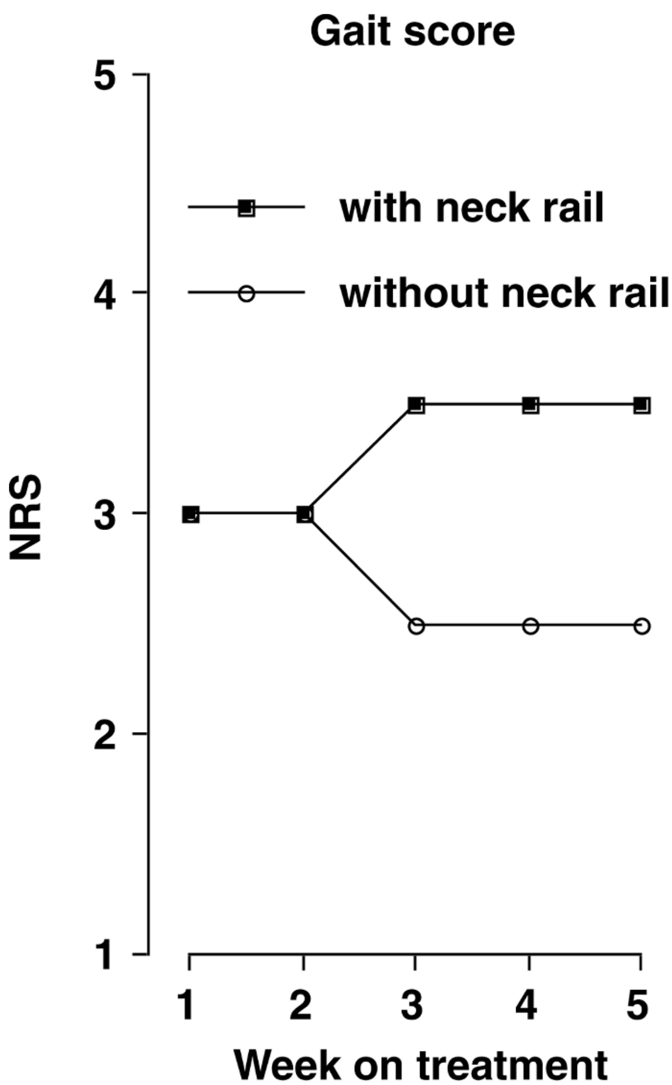

Figure 2. Median gait score [measured with a numerical rating system score (NRS); 1 = sound, 5 = severely lame] when cows were kept in pens (n = 8) with or without the neck rail positioned restrictively. Results are illustrated for the 5 wk cows were kept on each treatment. Gait scores improved (i.e., decreased) when using the less restrictive neck-rail positioning. The interquartile range for each treatment and each of the 5 wk was 0.5.

neck rails (2.0 vs. 2.5 on a 5-point scale; interquartile range = 1; $P = 0.10$). Groups of 12 cows housed in pens with the more restrictive neck rails required less time for teat cleaning before milking ($P = 0.002$): 7 min per group versus more than 8 min for groups with less restrictive neck rails.

There was one new case of subclinical IMI (SCC >200,000 cells/mL) in each of the treatments ($P > 0.05$). No cases of clinical mastitis occurred in either housing treatment.

DISCUSSION

Moving the neck rail affected both standing and lying behavior. Cows spent about 30 min/d standing fully in the stall when neck rails were positioned restrictively, but almost never stood completely in the stall when the neck rails were moved well forward in the stall. The increase in 4-foot standing in the stall may be explained by the stall surface being softer and more comfortable than the alternative available in the alley. Telezhenko et al. (2007) reported that a higher proportion of cows stood in areas with soft and extra-soft rubber mats than on solid concrete. Also, time spent standing on soft rubber increased when the concrete slatted floor had been partially replaced with rubber mats (Platz et al., 2007). Furthermore, cows provided with a softer floor in front of the feed bunk spent more time standing near the feed bunk without eating (Tucker et al., 2006).

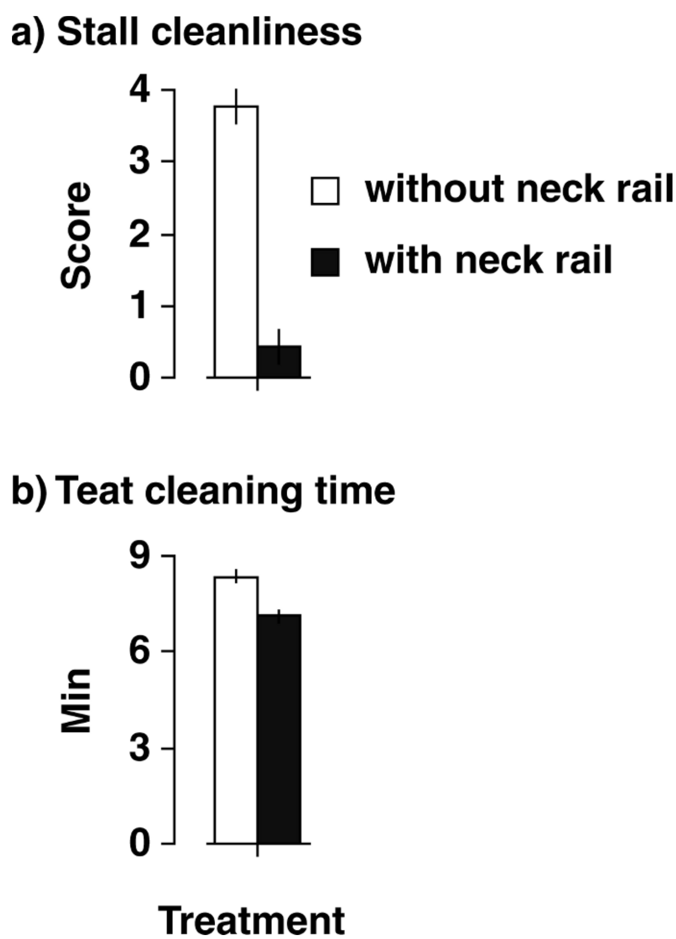

Figure 3. Mean (±SE) stall cleanliness score (a) and udder preparation time per pen of 12 cows (b). Results are shown separately for cows kept in pens (n = 8) with and without the neck rail positioned restrictively.

In contrast, time spent standing with just the front 2 feet in the stall increased by almost 30 min/d when the neck rail was positioned restrictively. These results support the findings of Tucker et al. (2005), who showed that neck rails interfere with the ability to stand fully in the stall, increasing time spent standing with the front feet in the stall and the rear feet in the alley. Similar to Tucker et al. (2005), the current study showed that total lying time did not vary with neck-rail placement. However, moving the neck rail increased the number of lying bouts from 9.6 to 10.4 bouts/d, probably because the lying down and standing up movements were less restricted. Our data support Tucker et al. (2005), who found a similar trend in the number of lying bouts, but their difference was not significant, perhaps because of a shorter sampling period (4 d for each treatment versus 15 d over 5 wk in the current study).

Gait scores declined (i.e., improved) when cows were kept in pens with the less restrictive neck rail. Comfortable housing may reduce lameness by providing a more appropriate surface for cows to stand on (Somers et al., 2003; Vanegas et al., 2006) or by providing cows a more comfortable surface on which to lie down (Cook, 2003; Cook et al., 2004; Espejo et al., 2006). The only previous experimental test of the effects of housing condition on gait was Hernandez-Mendo et al. (2007) comparing access to pasture and free-stall housing. They found that a period of time away from conventionally designed stalls had dramatic effects on cow gait; over just 4 wk on pasture, gait score (again assessed using a 1 to 5 NRS) improved by more than a whole unit relative to cows kept in the free-stall barn. Interestingly, cows actually spent less time lying down when kept on pasture. These results combined with those of the current study indicate that improved gait is not simply the result of longer lying times. Hernandez-Mendo et al. (2007) suggested that the improvement in gait was the result of the pasture providing a more comfortable standing surface than the concrete flooring inside the barn. Their greater improvement in gait, relative to the current study, may have been the result of the longer period away from concrete or other differences between the housing systems, including the higher forage intakes and extra exercise of cows on pasture.

The current study was designed to assess effects on gait rather than on measures of hoof health. Treatments were applied for only 5 wk, but sole hemorrhages typically become visible only weeks after corium damage occurs (Bergsten and Frank, 1996). Despite this limitation, 15 of the 16 new cases of sole lesions recorded occurred during the period when cows were housed in stalls with neck rails. This result supports an earlier experiment showing that transition cows housed on deep straw packs experienced fewer sole lesions than cows kept in free-stall housing (Webster, 2002).

Stalls without restrictive neck rails had contamination levels 9 times higher than stalls with the neck rails. Tucker et al. (2005) found that stalls without neck rails were much more contaminated with feces, in part because the animals spent more time standing in the stall. The current study showed that the udders of cows using stalls without restrictive neck rails were more contaminated with fecal matter. One might expect some link between udder cleanliness and udder health, and some empirical work supports this link (Zdanowicz et al., 2004). We found no effect of the neck-rail treatment on clinical or subclinical measures of udder health, but this study was not designed to assess the effects on udder health, and cows were housed on carefully maintained sand bedding. Longer term work using a larger sample of cows housed under less favorable management conditions might show some benefit of the neck rail in terms of udder health.

In this study, the neck rail was positioned 130 cm from the rear curb. The use of an aggressive placement provides a proof of principle; the neck rail can affect lameness. In a recent study, Fregonesi et al. (2009) tested neck rails positioned at 130, 145, 160, 175, and 190 cm and found that the behavior and hygiene responses varied in a near-linear fashion over the range of positions. Given the intermediate behavioral effects of the intermediate placements, we predict that these would have intermediate effects on lameness. Future research to test these effects is encouraged.

For producers, these results represent a paradox in terms of stall design. Using a neck rail, as positioned in the current study, promoted stall cleanliness and cow cleanliness and may have reduced the risk of IMI, but using a neck rail interfered with cow comfort by preventing the use of the stall as a refuge from wet concrete flooring elsewhere in the barn, increasing the risk of lameness and hoof disease. How dairy farmers choose to configure their stalls on the basis of these results will depend on how they view the relative risks. In our facility, the clear negative effects on clinical measures of gait and hoof health outweighed the hypothetical improvements in udder health, and on this basis, we recommend using stalls without neck rails that interfere with the ability to stand fully in the stall. We advocate the development of housing systems that provide both a suitable environment for the cow to stand and a clean, dry lying surface that promotes cow comfort and udder health.

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