Neck-rail position in the free stall affects standing behavior and udder and stall cleanliness

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ABSTRACT

This study tested the effect of neck-rail position on stall usage and udder and stall cleanliness. Thirty Holstein lactating cows were tested in groups of 6. Each group was tested with each of 5 neck-rail positions (130, 145, 160, 175, and 190 cm from the rear curb, at a constant height of 125 cm above the bedded surface) for 1 wk, with the order of testing allocated in a 5 × 5 Latin square. When the neck rail was positioned further from the rear curb, cows spent less time standing with their front 2 hooves in the stall (2.2 ± 0.26 h/d at 130 cm vs. 1.7 ± 0.27 h/d at 190 cm, mean $\pm$ SE) and more time standing with all 4 hooves in the stall (0.0 ± 0.02 h/d at 130 cm vs. 0.6 ± 0.07 h/d at 190 cm). These effects of neck-rail position tended to be more marked for smaller cows, perhaps because the standing behavior of larger cows was restricted even in the 190-cm treatment. Cows were more likely to defecate and urinate in the stalls when the neck rail was positioned further from the rear curb. Cows using these stalls tended to have dirtier udders and these stalls required more cleaning time (0.4 ± 0.16 min/d at the 130-cm position vs. 1.6 ± 0.35 min/d at the 190-cm position). In summary, positioning the neck rail further from the curb increased the time that cows spent standing fully in the stall. This change in standing behavior is likely beneficial for hoof health, but reduced udder and stall cleanliness.

Key words: dairy cattle, cow comfort, standing behavior, stall maintenance

INTRODUCTION

Free-stall barns are designed to encourage the cow to lie down in the stall but to defecate and urinate in the alley outside of the stall. For this reason, stalls are typically equipped with a neck rail. Ideally, the rail is positioned to allow the cow to stand in the stall with her hindquarters close to the rear curb such that feces and urine do not contaminate the stall surface. Both the height of the neck rail and its distance from the curb affect standing behavior; more restrictive neck-rail placements (lower and closer to the rear of the stall) prevent cows from standing fully in the stall but help improve stall cleanliness (Tucker et al., 2005). The use of narrow free stalls has a similar effect (Tucker et al., 2004). Restricting the amount of time cows spend standing with all 4 hooves in the stall increases the time cows spend standing on concrete or wet flooring elsewhere in the barn and hence increases the risk of lameness (Colam-Ainsworth et al., 1989; Wells et al., 1995; Faull et al., 1996; Somers et al., 2003). Indeed, Fulwider et al. (2007) found that farms with restrictive neck-rail placements had a higher proportion of lame cows.

Producers are now faced with a wide range of recommendations for neck-rail position. There are risks with positioning the neck rail either too restrictively (increased standing outside of the stall and increased rates of lameness) or too permissively (reduced stall and cow cleanliness). Positioning the neck rail in a way that minimizes these 2 risks is complicated by differences in cow size because both cow height and body length will affect how she contacts the neck rail.

The objectives of the current study were to test the combined effects of neck-rail placement and cow size on 1) stall use, particularly standing behavior; 2) stall cleanliness and maintenance; and 3) cow cleanliness. We predicted that positioning the neck rail closer to the curb would reduce the time cows spent standing with 4 hooves in the stall and increase the time cows spent standing outside the stall or with 2 hooves in the stall, and that this would result in cleaner udders and stalls.

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We also predicted that larger cows would be more affected by restrictive neck-rail positions.

MATERIALS AND METHODS

Animals, Housing, and Diet

Thirty lactating Holstein dairy cows were used in the study, all housed in a free-stall barn located at The University of British Columbia's Dairy Education and Research Centre (Agassiz, British Columbia, Canada). Cows were fed *ad libitum* a TMR consisting of 30.5% corn silage, 6.4% grass silage, 6.6% grass hay, 5.5% alfalfa hay, and 51% concentrate mash 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 4 times per day. Water was freely available from a self-filling trough. Cows were milked twice daily (at 0800 and 1700 h).

Experimental Treatments and Design

The animals were divided into 5 groups of 6 cows each, balanced for parity (2.5 ± 1.0 lactations, mean $\pm$ SD), DIM (160 ± 19.2 d), milk production (38.9 ± 9.8 kg/d), body height (142 ± 3.7 cm, range 134 to 150 cm; measured at the third thoracic vertebra), body length (139 ± 5.8 cm, range 125 to 150 cm; measured between the first cervical vertebra and the most caudal vertebra at the base of the tail), BW (690 ± 64.6 kg, range 570 to 880 kg), and BCS [3.0 ± 0.3 scored from 1 to 5, following Edmonson et al. (1989)].

Groups were randomly assigned to 5 adjacent pens, each fitted with 12 headlocks, spaced at 60 cm center to center. Each experimental pen (width = 9.5 m, length = 12.3 m) contained 12 free stalls (geotextile mattress covered with 0.1 m of sand and a skiff of sawdust) configured in 2 rows that were separated by a 3.0-m alley. The width of the alley between the 6 stalls closest to the feed bunk was 3.5 m. Individual stalls were separated by Y2K (Artex, Langley, British Columbia, Canada) style partitions (1.2 m wide center to center and 2.6 m length) and had a brisket board that was 1.7 m from the internal side of the curb (0.2 m height). The height of the neck rail (from the bedded surface to the bottom of the rail) was fixed at 1.25 m throughout the experiment. The stalls located the furthest from the feed bunk were blocked off to prevent access by cows such that 6 stalls were available for each group of 6 cows. Flooring in the pens was textured rubber, and the alleys were cleaned 6 times/d with automatic scrapers. Groups were housed together for 1 wk before the

experiment began. Groups were then tested with each of 5 neck-rail positions (130, 145, 160, 175, and 190 cm from the rear curb) for 1 wk, with the order of testing allocated using a 5×5 Latin square.

Behavior

Behavior was recorded 24 h/d during the last 3 consecutive days of each experimental week, using 3 cameras/pen (WV-BP334 24V, Panasonic, Mississauga, Ontario, Canada) positioned 10 m above the experimental pen. The cameras were attached to a video multiplexer (model WJ FS416, Panasonic) and time-lapse recorder (model AG 6540, Panasonic). Red lights (100 W) were hung 10 m above the pen to facilitate video recording at night. Cows were marked with unique symbols using hair dye to identify individuals, and stalls were numbered.

Video recordings were scanned at 5-min intervals to quantify stall use (lying, standing with 2 hooves in the stall, or standing with all 4 hooves in the stall). These recordings were also watched continuously to record elimination behavior, specifically whether fecal material and urine touched any part of the stall surface.

Stall and Udder Cleanliness

Stall cleanliness was assessed using a 1.2×1.6 m wire grid, containing 300 equally sized squares, that was placed at the rear section of the stall closest to the alley and centered between the stall partitions. We counted the total number of squares containing any visible fecal material or urine (defined as wet bedding) in each stall 2 d/wk (at the time of both the a.m. and p.m. milkings but before stall maintenance).

An individual unaware of experimental treatments removed fecal matter and leveled the stalls with a rake each day during the morning milking. The time required for this daily stall maintenance was assessed using the video recordings from the last 2 d of each experimental week. Time was measured from the moment the rake came into contact with the first stall until it was lifted from the 6th stall in each pen.

The amount of fecal matter on the udders of all experimental cows was assessed in a double-12 parallel milking parlor, immediately before the beginning of both the a.m. and p.m. milkings on the last 2 d of each experimental week. Cleanliness was assessed using a subjective score from 1 to 4, where 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 (Cook, 2007). Only the rear portion of the udder immediately visible to the milker

Figure 1. Mean $\pm$ standard error time (h/d) standing in the free stall in response to neck-rail position. Results are shown separately for standing with 2 hooves and standing with all 4 hooves in the stall.

was scored from the base of the teats to the rear quarter attachment.

Statistical Analysis

For the overall test of treatment, group means for each week per treatment were calculated. Variance between treatments was unequal; thus, nonparametric tests were used for all tests of treatment means. Page's L was used to assess linear trends in response to treatment (130, 145, 160, 175, and 190 cm; $n = 5$ groups) for all dependent variables (Page, 1963). We tested the effect of cow size on the dependent variables using Spearman's rank correlation ($n = 30$).

Each cow's response to treatment was estimated using the slope from a linear regression between the response variable and treatment (130, 145, 160, 175, and 190 cm; i.e., $n = 5$ data points/cow). The only dependent variables considered in this regression analysis were those that were measured on a ratio scale and that occurred for every cow in every treatment (i.e., time standing and lying). No statistical inferences were drawn from these individual regressions. Instead, we tested the prediction that larger cows would respond more to treatment by correlating the slopes with measures of body size (body length, height, and weight), using Spearman's rank correlation ($n = 30$).

Figure 2. Time spent standing with 4 hooves in the stall (h/d) in relation to BW at 5 different neck-rail positions. Lines were fitted with the linear trend line feature in Microsoft Excel (Microsoft Corp., Redmond, WA).

Table 1. Number of defecation and urination events per 24 h (mean $\pm$ SE) in response to neck-rail placement relative to the curb¹

Item	Neck-rail distance from curb, cm					P-value
	130	145	160	175	190	
Total defecations while in the stall, n	1.7 $\pm$ 0.13	1.7 $\pm$ 0.06	1.6 $\pm$ 0.10	1.9 $\pm$ 0.14	2.1 $\pm$ 0.13	NS
Defecations that contacted the stall surface while						
Standing with front 2 hooves in the stall	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	—
Standing with all 4 hooves in the stall	0.0 $\pm$ 0.01	0.0 $\pm$ 0.01	0.2 $\pm$ 0.01	0.5 $\pm$ 0.05	0.5 $\pm$ 0.06	<0.001
Lying in the stall	0.1 $\pm$ 0.02	0.1 $\pm$ 0.02	0.2 $\pm$ 0.02	0.3 $\pm$ 0.04	0.4 $\pm$ 0.06	<0.001
Total defecations that contacted the stall, sum of 3 postures	0.1 $\pm$ 0.02	0.2 $\pm$ 0.03	0.4 $\pm$ 0.03	0.7 $\pm$ 0.07	0.9 $\pm$ 0.06	<0.001
Total urinations while in the stall, n	1.2 $\pm$ 0.06	1.0 $\pm$ 0.10	1.1 $\pm$ 0.05	1.2 $\pm$ 0.09	1.1 $\pm$ 0.09	NS
Urinations that contacted the stall surface while						
Standing with front 2 hooves in the stall	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.01	—
Standing with all 4 hooves in the stall	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.1 $\pm$ 0.02	0.1 $\pm$ 0.01	0.2 $\pm$ 0.04	<0.001
Lying in the stall	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	—
Total urinations that contacted the stall, sum of 3 postures	0.0 $\pm$ 0.00	0.0 $\pm$ 0.00	0.1 $\pm$ 0.02	0.1 $\pm$ 0.01	0.2 $\pm$ 0.04	<0.001

¹Shown separately is the number of defecation and urination events while the cows were in the stall and the number of these events that contacted the stall surface.

RESULTS

In response to the neck rail being moved further from the rear curb, cows spent less time standing with their front 2 hooves in the stall (Page's $L = 253$, $P < 0.01$; Figure 1) and more time standing with all 4 hooves in the stall ($L = 273$, $P < 0.001$). The mean $\pm$ standard error of lying time was 12.0 ± 0.4 h/d, with no effect of treatment ($L = 218$, NS). Similarly, the time spent standing out of the stall averaged 9.8 ± 0.22 h/d with no difference in treatment levels ($L = 226$, NS).

The response to treatment on standing with 4 hooves in the stall tended to vary with cow BW ($r = -0.31$, $P = 0.093$); as illustrated in Figure 2, cows with lower BW showed the strongest response to the neck-rail treatment. In contrast, we found positive interactions between cow body length and treatment for lying time (lying time: $r = 0.37$, $P = 0.048$). No other interactions between cow size (height, length, and BW) and treatment were statistically significant ($P \geq 0.104$).

Cows were more likely to defecate in the stalls when the neck rail was positioned further from the rear curb (Table 1), both when cows were lying down in the stall ($L = 262$, $P < 0.001$) and when they were standing with all 4 hooves in the stall ($L = 268$, $P < 0.001$). The same pattern was observed for urine soiling the stall bedding while standing fully in the stall ($L = 266$, $P < 0.001$). Cows never urinated when lying down, but $55 \pm 28\%$ (mean $\pm$ SD, cows ranged from 0 to 93%) of defecation events in the stall occurred while lying down.

When the neck rail was positioned further from the curb, fecal material was more likely to land in the stall (6, 12, 25, 37, and 43% defecation events touched the stall in the 130-, 145-, 160-, 175-, and 190-cm treatments, respectively). Thus, stalls were more likely to contain fecal matter ($L = 266$, $P < 0.001$; Figure 3a)

and these pens required more time to maintain ($L = 264$, $P < 0.001$; Figure 3b). Cows using these stalls were somewhat more likely to have dirty udders ($L = 250$, $P < 0.05$), with the udder hygiene score increasing from a mean of 1.2 ± 0.07 at the 130-cm position to 1.4 ± 0.08 at the 190-cm position.

Cow size affected both cow behavior and cow hygiene. Taller cows spent more time standing with the front hooves in the stall (Figure 4a; height: $r = 0.65$, $P < 0.001$; weight: $r = 0.56$, $P = 0.001$; length: $r = 0.35$, $P = 0.058$). Compared with smaller cows, larger cows were more likely to defecate while standing with the front hooves in the stall (weight: $r = 0.33$, $P = 0.076$) and tended to have dirtier udders (height: $r = 0.33$, $P = 0.078$; Figure 4b). No other relationships between cow size (height, length, and BW) and the dependent variables were statistically significant ($P \geq 0.119$).

DISCUSSION

Placement of the neck rail altered how cows stood in the stall. The more permissive neck-rail placement increased the time cows spent with all 4 hooves in the stall and reduced the time cows spent standing with only the front 2 hooves in the stall. These results are consistent with our previous findings (Tucker et al., 2005) and show these effects over a range of neck-rail positions.

The magnitude of changes in standing behavior was dependent on cow size: compared with larger cows, smaller cows showed a greater increase in 4-hoof standing times when neck rails were further from the rear curb. It seems likely that the neck rail was still restrictive for large cows, even at the 190-cm treatment. In previous work, we included a more extreme treatment, 233 cm from the curb, and found that larger cows spent

Figure 3. Mean $\pm$ standard error (a) stall cleanliness score and (b) time required to rake the fecal matter from the pen (min/d), in relation to neck-rail treatment.

more time standing in the stall when the neck rail was placed at this distance (Tucker et al., 2005). An earlier study also showed that standing fully in the stall increased when cows were provided wider stalls (Tucker et al., 2004), suggesting that future work should consider several stall attributes to understand how the neck rail allows or prevents this behavior.

The fact that cows reduced the amount of time spent standing with just the front hooves in the stall, when provided an option that allowed them to stand in the stall with all 4 hooves, suggests that they found the

Figure 4. Relationship between cow height (cm) and (a) time spent standing with the front hooves in the stall (h/d) and (b) udder cleanliness score. The udder cleanliness score ranged from 1 to 4, with 4 being the dirtiest. Cow averages were calculated using all 5 neck-rail placements.

latter posture more comfortable. However, standing partially in the stall was likely more comfortable than standing fully in the alley; when cows were unable to stand in the stall (because the neck rail was too restrictive or the cow was too large), standing partially in the stall increased, but not standing in the alley. This pattern was apparent even though the alley surface used in this study was rubber. Softer surfaces in the free stall (Fregonesi et al., 2004; Tucker et al., 2006a), perhaps

because the stall surface was typically drier and softer than either rubber or concrete flooring available in the alley.

Cow size also affected the time spent standing with only the front hooves in the stall. Larger cows spent more time standing in this position, with more than a 3-h difference between the shortest and tallest cow. This result raises additional questions about the interpretation of standing partially in the stall. It is clear that stall comfort affects this behavior: cows spent more time standing with the front hooves in stalls that had restrictive neck rails or that were narrow or poorly bedded (Tucker and Weary, 2004; Tucker et al., 2004, 2005). Other authors have reported a relationship between time standing with only the front hooves in the stall and hoof lesions and lameness (Galindo and Broom, 2000). Galindo and Broom (2000) suggested that this effect may be mediated by social status. Our results suggest that body size may also have played a role, perhaps because larger cows were more likely to be lame (Wells et al., 1993).

As in previous work on neck-rail placement (Tucker et al., 2005), we found no differences in lying time between any of the treatments; even over a wide range of positions, neck-rail placement had little effect on how much time cows spent lying down. Surprisingly, we found an interaction effect between cow length and neck-rail placement on lying time. We suspect that this interaction was not biologically relevant because the overall treatment effect was not consistent across individuals (i.e., for half the cows, a positive relationship was found between lying time and treatment, and for the other half, a negative relationship was found). One reason why neck rail did not affect lying time was that cows did not touch this part of the stall while resting. The neck rail, however, may have affected cows in the movements associated with lying down and standing up, and could result in injury (Veissier et al., 2004). Larger cows require more space when moving from standing to lying down (Ceballos et al., 2004), and likely also when moving from lying to standing. Future work should consider the number of lying events as a dependent variable, in addition to total lying time.

Not surprisingly, less restrictive neck-rail placements resulted in dirtier stalls; cows were more likely to defecate into the stalls when the neck rail was positioned further from the rear curb. This pattern was apparent both when cows were lying down in the stall and when they were standing with all 4 hooves in the stall. This result indicates that the cows were moving forward in the stall, both while standing and while lying. Cows also moved forward in the stall when other barriers, such as the brisket board, were removed (Tucker et al.,

2006b), suggesting that they preferred to have their body fully supported by the bedded area.

Although stalls were dirtier when the neck rail was less restrictive, elimination in the stall was relatively rare; we observed an average of 1.8 defecation events/d and 1.1 urination event/d for each cow in the stall. The total number of defecations and urinations per 24 h in dairy cows has been reported to be 16 and 9, respectively, with the frequency lowest during resting (Aland et al., 2002). Of the relatively small number of eliminative behaviors that occur in the stall, Tucker et al. (2005) reported that 69% of defecations occurred while cows were lying down, and we found a similar result (on average, 55%). There were, however, individual differences in this behavior. For example, 1 cow never defecated while lying down, whereas 93% of another individual's defecation events in the stall occurred while lying. A better understanding of this individual variation may be useful information in designing the lying area.

Udder cleanliness declined by 17% with the use of the least restrictive neck rail. Other work has shown a link between stall and udder hygiene (e.g., Smith et al., 1985; Hogan et al., 1989; Zdanowicz et al., 2004). Reduced udder hygiene has been associated with intramammary pathogens (Schreiner and Ruegg, 2003), and fecal contamination of stalls is considered a risk factor in the transmission of environmental mastitis (Bakken, 1981). However, we know of no study that has investigated the effects of neck-rail placement on udder health. In addition, the magnitude of the effect of neck-rail placement on udder cleanliness was only half the effect of body size. The udder of the tallest cow was 34% dirtier than the udder of the shortest cow, indicating that udder cleanliness is influenced by factors other than stall design.

Recommendations for neck-rail placement are based on the hope that cows can stand with all 4 hooves in the stall but are indexed within the stall such that any feces or urine falls in the alley. The results of this study suggest that this hope is misplaced. Cows vary considerably in body size, and many cows are unable to use the stall for standing regardless of the neck-rail positions tested. Positioning the neck rail less restrictively, thereby allowing cows to stand with all 4 hooves in the stall, increases the risk that cows will defecate and urinate into the stall and reduces stall and udder hygiene. Producers using free stalls are thus faced with 2 bad choices: to use restrictive neck-rail placement that keeps the stall surface cleaner but that forces cows back onto the wet concrete, or to use more open designs that allow some cows to stand fully in the stall but that reduce stall cleanliness. The former is likely preferable

from the perspective of udder health, and the latter is likely preferable from the perspective of hoof health. In both cases, the cow, and ultimately the producer, suffers the consequences of poor design. We urge new work that provides a solution to this paradox and that leads to the development of barn designs that offer cows soft, clean, and dry surfaces for both lying and standing.

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