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Stepping behavior and muscle activity of dairy cows on uncomfortable standing surfaces presented under 1 or 4 legs

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ABSTRACT

The comfort of dairy cattle while standing has important implications for housing design. Research has examined how cattle respond to standing surfaces by presenting options under all 4 legs or under a single leg, but no work, to date, has compared presentation methods. This study examined behavior and muscle activity when cows stood on rough floors under all 4 legs or just 1 hind leg. Three treatments were tested: smooth concrete under all 4 legs (0-ROUGH), a rough surface under all 4 legs [2 cm × 2 cm × 4 cm trapezoidal protrusions (4-ROUGH)], and a rough surface only under 1 hind leg, with other legs on smooth concrete (1-ROUGH). Twenty-four healthy Holstein cows stood on each surface for 1 h/d in a repeated-measures design. Surface electromyograms (SEMG) were used to evaluate muscle fatigue and total activity. Muscle fatigue was measured using SEMG to evaluate (1) static contractions when cows were continuously weight bearing on each hind leg, before and after 1 h of standing, and (2) dynamic contractions associated with steps during 1 h of standing. Behavioral measures included steps per minute, time between each consecutive step, and the latency to lie down after testing. The number of legs affected by roughness influenced both behavioral and physiological responses to flooring. Cows on 1-ROUGH stepped twice as often with the rough-treated leg and one-half as much with the hind leg on smooth concrete compared with other surfaces. Similarly, on the 1-ROUGH surface, total muscle activity was reduced in the leg on the rough surface, and muscle activity was more sustained (3× higher) in the other hind leg, suggesting that cows avoid possible discomfort under 1 leg by using muscles in the other. In the 4-ROUGH treatment, time between steps was more variable than on the other 2 treatments (coefficient of variation, 4-ROUGH: 245; 1-ROUGH: 208; 0-ROUGH: 190 ± 5.8%), likely because cows could not move away from this uneven flooring. Thus, the method of presentation of stimuli used to evaluate comfort while standing altered the response. Stepping rate and SEMG changed when roughness was under a single leg, whereas timing between consecutive steps was more variable with rough flooring under all 4 legs. These results have implications for the design of experiments evaluating standing comfort in the future.
Key words: behavior, electromyogram, muscle fatigue, flooring

INTRODUCTION

Flooring surface is an important feature of housing design. Concrete is used in 56% of US dairy operations (USDA, 2009). However, concrete flooring has been identified as a risk factor for development of hoof and leg lesions (Vokey et al., 2001; Somers et al., 2003) and lameness in cattle (Cook, 2003; Vanegas et al., 2006). When concrete floors were compared with a more compressible surface, such as rubber, cows spent more time standing on (Platz et al., 2008; Haufe et al., 2009; Ouweltjes et al., 2009) and showed preferences for (Tucker et al., 2006; Telezhenko et al., 2007) rubber, indicating that concrete may be uncomfortable. Although cows stand on concrete for 11 to 15 h/d in most freestall barns (Ito et al., 2009), only a few studies have attempted to investigate responses while exclusively standing (Cooper et al., 2007; Krebs et al., 2011; Chapinal and Tucker, 2012).

The research on responses to standing can be divided into 2 methods of presentation: evaluation of flooring features where all 4 legs are on standard surfaces (e.g., concrete or rubber), and where only 1 leg experienced something different, such as pain or exposure to alternative flooring. Experiments that present treatments under all 4 legs have used stepping rate to examine the effect of standing time (Cooper et al., 2007), floor slope (Rajapaksha and Tucker, 2014), or surface compressibility (Krebs et al., 2011; Chapinal and Tucker, 2012). In all of these experiments, steps increased over time, but no differences were observed between flooring treatments. Thus, to date, it is unclear whether increased stepping rates reflect discomfort associated with standing surfaces. In experiments that present alternative flooring or pain under a single hoof, weight shifting

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from 1 leg to the other and number of steps increased with lameness (Pastell and Kujala, 2007; Rushen et al., 2007; Chapinal et al., 2010) or when a single hind leg of a healthy cow was placed on protruding rocks or screws (Neveux et al., 2006). When animals were given pain relief (Rushen et al., 2007; Chapinal et al., 2010), weight shifting and stepping were reduced. Thus, when pain or alternative surfaces are presented under a single hoof, stepping behavior distinguishes among treatments and provides insight into animal welfare. To date, work that compares the 2 methods of presentation (under a single vs. all 4 legs) with an adequate sample size is limited.

In addition to the stepping and weight shifting measured in previous work, other tools could provide additional insight into comfort while standing. Evaluation of skeletal muscle activity and muscle fatigue play a key role in understanding human responses to standing and correspond to verbal reports of discomfort (Kim et al., 1994). Skeletal muscle activity can be measured in healthy cattle (Ternman et al., 2012; Rajapaksha and Tucker, 2014). In addition, weight-bearing correlates with muscle activity in animals (De Leon et al., 1998; Gregor et al., 2006); thus, muscle activity and fatigue captured by surface electromyograms (**SEMG**) may provide insight into the effects of rough standing surfaces that is similar to data collected with load cells. For example, cows standing with 1 hind leg on a surface with rocks or screws reduce weight-bearing on that leg and transfer the weight to the contralateral leg (Neveux et al., 2006). In addition, it is known that neither weight distribution among legs (Chapinal et al., 2010) nor muscle activity (Rajapaksha and Tucker, 2014) is correlated with visually observable stepping behavior. Thus, evaluating both stepping behavior concurrently with SEMG may provide additional information about responses to standing.

The objective of this study was to compare 2 methods of presentation of rough standing surfaces (1 or all 4 legs on rough concrete surface) in terms of stepping behavior and skeletal muscle activity. We hypothesized that cows would show increased stepping rate, total muscle activity, and indicators of muscle fatigue on rough flooring, and that the most marked response would occur when all 4 legs were on this surface. We also hypothesized that presenting the rough flooring under a single hind leg would reduce muscle activity and increase steps taken for that leg.

MATERIALS AND METHODS

General Information

This experiment was conducted at the University of California, Davis, dairy facility between September and November of 2011. All procedures were approved by the Institutional Animal Care and Use Committee.

Animals and Housing

Twenty-four lactating Holstein-Friesian dairy cows were tested in groups of 6. All were clinically sound, with a gait score ≤ 2 (Flower and Weary, 2006). Cows had an average BW of 661 $\pm$ 53 kg, BCS of 2.8 $\pm$ 0.3; DIM of 161 $\pm$ 64, and daily milk production of 35.5 $\pm$ 5.5 kg (mean $\pm$ SD). Cows were housed in a pen with 24 head-to-head freestalls (1.2 m $\times$ 2.4 m; 1 cow/freestall) that were deep-bedded with sand and had a neck rail located 106 $\pm$ 2 cm above the stall surface. The cows were milked at 0600 and 1700 h, had ad libitum access to water, and were fed a total mixed ration consisting of 37% alfalfa hay, 36% grain mix, 10% whole cottonseed, 12% almond hulls, 2% soybean meal, and 3% mineral mix (DM basis) at 0400, 1100, and 1600 h.

Experimental Procedures

During the experiment, animals were moved to a test area located 20 m away from the home pen. The testing area contained 3 standing areas (stalls) each 2.4 m $\times$ 1.2 m wide and separated by steel panels (Powder River Inc., Provo, UT). Each stall had (1) a smooth poured concrete surface under all legs (**0-ROUGH**), (2) roughened concrete surface under all legs (**4-ROUGH**), or (3) the same rough surface under 1 hind quarter (**1-ROUGH**) while other legs were on smooth concrete (Figure 1). All floors were created by closely aligning 8 square (30 $\times$ 30 cm) concrete slabs that were 7.6 cm thick and placed on level ground. Rough surfaces were these same concrete slabs, but with 49 equally distributed 4-sided trapezoidal prism-shaped protrusions from the top of each slab, created with a concrete mold. This rough treatment was chosen to create discomfort, similar to the protruding rocks or screws treatments used by Neveux et al. (2006), but not to cause injury during 1 h of standing.

In a crossover design, each cow was tested once on each treatment for 1 h/d, with the order of exposure balanced across the study. The location of the floors in the testing area relative to one another and placement (right or left hind leg) of 1-ROUGH treatment was balanced over the course of the study and switched between every group of cows. Cows were tested in groups of 6 to provide resting time between test days; at least 46 h of resting time was provided between each treatment. During the 1 h of testing, 2 horizontal metal bars were placed on the back end of the stall to confine the cows. They were able to move their heads, look sideways,