Walking Acceleration Patterns as a Method for Lameness Detection

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Several methods of automatically recording the behavior of cattle have great potential for detecting lameness (Rajkondawar et al., 2002; Pastell et al., 2006; Rushen et al., 2007). Commercially available 3-dimensional accelerometers attached to the legs can measure time spent lying down, which is usually longer for lame cows (Chapinal et al., 2009). Accelerometers can also detect alterations in walking gait that are indicative of lameness (Pastell et al., in press). The aim of this study was to validate 3-dimensional accelerometers placed on the back and on each leg of cows as a method of lameness detection (Experiment 1), and to assess the effect of flooring surfaces on walking accelerations patterns in dairy cattle (Experiment 2 and 3).

Materials and Methods

Lactating Holstein cows housed in sand bedded free-stalls in groups of 12 to 36 cows were fitted with 5 tri-axial accelerometers (HOBO Pendant G Acceleration Data Logger, Onset Computer Corporation, Pocasset, MA), attached to each leg and to the back. The accelerometers can measure a range of ± 3 g, and were set to sample at 33.3 Hz. Cows were gait scored using the system described by Flower and Weary (2006), which assessed 6 different gait components and assigns a continuous overall gait score on a 1-to-100 analog scale.
In Experiment 1, 10 cows were selected to include some lame and some non-lame cows. Cows were walked down a 13 m long by 1.3 m wide non-grooved concrete passageway. In Experiment 2, 30 cows were walked down a 13 m x 1.3 m passageway with a surface of either non-grooved concrete or rubber. The rubber flooring consisted of a bottom layer of revulcanized rubber mats (1.9 cm thick each; Animat, Saint-Élie d'Orford, Quebec) and an upper layer of anti-slippery rubber (0.6 cm thick each, #125 2-ply; Cobelt Canada Inc., Saint-Laurent, QC, Canada). Cows were walked from 6 to 8 times, alternating the walking surface. In Experiment 3, 15 cows were walked down a 27.4 m X 1.2 m passageway with a surface of either grass pasture or concrete. Cows were walked from 8 to 10 times, alternating the walking surface.

The measurements provided forward, lateral horizontal acceleration and vertical acceleration relative to the cows' legs. We calculated the variance of acceleration for each axis and the sum vector of acceleration for each leg. We analyzed the symmetry of gait by calculating the symmetry of acceleration between the front pair and the hind pair of legs, dividing the variance of the leg with lesser variance by the variance of the leg with greater variance. The differences in acceleration features for different treatments in each trial were tested with a linear mixed model with cow included as the random effect. R 2.90 (R Development Core Team, 2008) with nlme package was used in the statistical analysis.

Results

In Experiment 1, we found overall differences between sound and lame animals in the patterns of acceleration when walking. There was a negative linear relationship between the overall gait

score and the symmetry of variance for forward ($p < 0.05$), vertical ($p < 0.05$) and the summed acceleration ($p < 0.05$) of the hind legs and symmetry of variance of the summed acceleration of the front legs ($p < 0.05$). No relationship was found between any acceleration parameter on the back and overall gait score.

In Experiment 2, the gait of the front legs was more symmetric ($p < 0.05$) on concrete than rubber for the vertical axis (84.7% ± 2.1% versus (80.8% ± 1.6%) and summed acceleration (88.2% ± 2.0% versus 84.3% ± 1.5%). There was no difference between the flooring surfaces in the symmetry of acceleration for the hind legs or the back accelerometer.
In Experiment 3, the variance of acceleration for the back accelerometer was higher ($p < 0.05$) on pasture than on concrete for all three axes and the summed acceleration. The gait of the front legs was more symmetric ($p < 0.001$) on pasture than on concrete for the forward axis (91.6% ± 1.8% versus 85.7 ± 2.4%) and sum acceleration (94.3% ± 2.7% versus 84.9% ± 3.5%). There was no difference between the surfaces in the symmetry of acceleration the hind legs.

Discussion

We were able to correlate the symmetry of acceleration to the overall gait score, which indicates that accelerometers attached to the legs measure the same differences in gait of sound and lame animals that are visible to human observers. This is in agreement with findings of Pastell et al. (in press.) Accelerometers produce repeatable measurements and are therefore an appealing option e.g. for measuring the effect of treatment of lameness.

The gait of the animals also differed between surfaces. The gait of the front legs was more symmetric on pasture than on concrete and more symmetric on concrete than rubber. These results contradict our initial hypotheses. We hypothesized, based on other studies such as Flower et al. (2007), that gait would be more symmetric on rubber than on concrete. We can only conclude that accelerometers can detect differences in gait across flooring surfaces and that further research is needed to understand these differences.

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