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The cow pedogram—Analysis of the gait cycle variables allows the detection of lameness and foot pathologies

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ABSTRACT

Changes in gait characteristics are important indicators in assessing the health and welfare of cattle. The aim of this study was to detect unilateral hind limb lameness and foot pathologies in dairy cows using 2 high-frequency accelerometers (400 Hz). The extracted gait cycle variables included temporal events (kinematic outcome = gait cycle, stance phase, and swing phase duration) and several peaks (kinetic outcome = foot load, toe-off). The study consisted of 2 independent experiments. Experiment 1 was carried out to compare the pedogram variables between the lateral claw and respective metatarsus (MT; n = 12) in sound cows (numerical rating system <3, n = 12) and the differences of pedogram variables across limbs within cows between lame cows (numerical rating system ≥3, n = 5) and sound cows (n = 12) using pedogram data that were visually compared with the synchronized cinematographic data. Experiment 2 was carried out to determine the differences across limbs within cows between cows with foot lesions (n = 12) and without foot lesions (n = 12) using only pedogram data. A receiver operator characteristic analysis was used to determine the performance of selected pedogram variables at the cow level. The pedogram of the lateral claw of sound cows revealed similarities of temporal events (gait cycle duration, stance and swing phases) but higher peaks (toe-off and foot load) as compared with the pedogram of the respective MT. In both experiments, comparison of the values between groups showed significantly higher values in lame cows and cows with foot lesions for all gait cycle variables. The optimal cutoff value of the relative stance phase duration for identifying lame cows was 14.79% and for cows with foot lesions was 2.53% with (both 100% sensitivity and 100% specificity) in experiments 1 and 2, respectively. The use of accelerometers with a high sampling rate (400 Hz) at the level of the MT is a promising tool to indirectly measure the kinematic variables of the lateral claw and to detect unilateral hind limb lameness and hind limb pathologies in dairy cows and is highly accurate.
Key words: dairy cows, gait cycle, accelerometer, lameness

INTRODUCTION

Lameness and foot pathologies in cattle are among the most important welfare problems and are responsible for significant economic losses in the dairy industry (Bicalho et al., 2008; Schearer et al., 2013); lameness in cattle is an expression of pain. The etiologies and pathogeneses of some foot disorders are still relatively poorly understood (Huxley, 2012). Early lameness detection and prompt treatment reduce the duration and prevalence of lameness and thus improve cow welfare (Leach et al., 2012; Thomas et al., 2016). Change in an animal′s behavior is one of the most important criteria in assessing animal welfare and health. For example, pain associated with claw or limb disorders causes alterations in gait characteristics and a decreased daily overall activity level (Thorup et al., 2014; Nechanitzky et al., 2016; Beer et al., 2016). The current gold standard for the detection of lameness in dairy cows is the clinical observation by a trained professional. The degree of lameness is described using a validated clinical gait-scoring system (Sprecher et al., 1997; Flower and Weary, 2006), this being a subjective method for assessing lameness. However, locomotion scoring requires observer training and may not be sensitive enough to detect slight gait alterations (Engel et al., 2003; Tadich et al., 2010). The difficulties in evaluating the stride and postural characteristics as well as the reproducibility of scoring mildly lame cows are most challenging (Engel et al., 2003; Holzhauer et al., 2005; Flower and Weary, 2006). In addition, cows showing impaired locomotion may not always express all traits described by

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a certain locomotion-scoring method (Schlageter-Tello et al., 2015). Automated and objective methods of lameness detection are an attempt to mimic locomotion scoring by measuring different traits using different types of sensors (Alsaaod et al., 2012; Van Hertem et al., 2014; Beer et al., 2016). Consequently, methods that objectively analyze cattle locomotion could provide useful information for (1) early and more accurate lameness detection, (2) early foot pathology detection, (3) improved intra- and interobserver agreement of gait scoring, (4) monitoring the effect of treatment strategies, and (5) assessing the influence of environmental conditions on locomotion.

The objective measurement of gait patterns in research studies is mainly based on 2 methods: (1) kinematic (changes in the position of the body segments during a specified time) gait analysis (Flower et al., 2005), such as high-speed cinematography with the cow on a treadmill (Schmid et al., 2009), image-processing techniques (Poursaberi et al., 2010; Viazzi et al., 2013), or accelerometers (Pastell et al., 2009; Alsaaod et al., 2015); and (2) kinetic (force applied to the body) gait analysis using 1- or 3-dimensional ground reaction force systems (Rajkondawar et al., 2006; Walker et al., 2010; Thorup et al., 2014) or pressure-sensitive walkways (Van Nuffel et al., 2009; Maertens et al., 2011). One of the drawbacks of some of these methods is that they are expensive or difficult to apply in clinical settings. Furthermore, data acquired from the use of high-frequency accelerometers to detect and characterize gait cycle patterns (such as characteristics of swing and stance phases) in cattle is still not available. To date, these sensors are partially used in equine medicine (Olsen et al., 2012) and for a broad range of applications in human movement science, sport science, and rehabilitation medicine (e.g., Lee et al., 2010; Mariani et al., 2013; Lugade et al., 2014). In human movement science, quantitative analysis of temporal events using inertial measurement units (**IMU**) provided a promising tool to assess normal and pathological ambulatory gaits. Consequently, investigating the gait cycle, as proposed in human movement research, might improve lameness detection in cattle movement research. The aim of our study was to determine whether measurements from accelerometers with high frequency (400 Hz) would allow us (1) to describe the gait pattern of nonlame cows while walking, (2) to compare the acceleration between lateral claw and metatarsus (**MT**) of the same limb, (3) to determine the differences between hind limbs in nonlame and lame cows, and, finally, (4) to estimate the differences between both hind limbs in cows with unilateral foot pathologies as compared with cows without foot lesions.

MATERIALS AND METHODS

Ethics Statement

The study protocol was approved by the animal experimentation committee of the canton of Bern, Switzerland (permission # 25601).

Animals and Experimental Procedures

The study consisted of 2 independent experiments, both carried out at the Clinic for Ruminants, Vetsuisse-Faculty, University of Bern. The cows of both experiments were submitted to a thorough orthopedic, radiographic, or ultrasonographic examination, if indicated (Dirksen et al., 2012). In experiment 1, 5 cows [group lame (**L1**)] that had been referred to the clinic for evaluation of a lameness problem in the area of the hind limbs and 12 dairy cows without any signs of lameness [group nonlame (**C1**)] were used. The lame group included cows with one of each of the following unilateral pathologies: bulb abscess, double sole, osteitis of P3, septic tendovaginitis of the common digital flexor tendon sheath, or septic arthritis of the tibiotarsal joint. In group C1, the mean (±SD) lactation number was 2.58 (±1.31) with a mean daily milk yield of 30.5 (±8.87) kg and a mean BW of 632.36 (±94.01) kg. The breeds involved were Holstein-Friesian (n = 2), Red Holstein (n = 4), Swiss Fleckvieh (n = 5), and Rhätisches Grauvieh (n = 1). In group L1, the mean lactation number was 1.2 (±0.45) with a mean daily milk yield of 25.5 kg (±3.32) and a mean BW of 546.75 (±77.95) kg. The breeds involved were Holstein-Friesian (n = 2), Red Holstein (n = 1), Brown Swiss (n = 1), and Eringer (n = 1). In experiment 2, 12 dairy cows with no signs of orthopedic pathologies [no lesion group (**C2**)] and 12 dairy cows with unilateral claw pathologies [lesion group (**L2**)] were included. The lesion group included cows with the following pathologies [double sole (n = 1), osteitis of P3 (n = 3), fracture of P3 (n = 2), Rusterholz ulcer (n = 1), septic arthritis of the distal interphalangeal joint (n = 1), claw horn fissure (n = 1), interdigital phlegmon (n = 1), and white-line abscess (n = 2)]. In group C2, the mean (±SD) lactation of the cows was 4.08 (±2.71) with a mean daily milk yield of 24.22 kg (±6.65) and a mean BW of 660.83 kg (±84.36). The breeds involved were Holstein-Friesian (n = 4), Red Holstein (n = 1), Swiss Fleckvieh (n = 4), Simmental (n = 1), Rhätisches Grauvieh (n = 1), and Montbéliard (n = 1). In group L2, the mean lactation of the cows was 2.67 (±2.35) with a mean daily milk yield of 25.54 (±7.05) kg and a mean BW of 648.75 (±114.57) kg. The breeds involved were Holstein-Friesian (n = 4), Swiss Fleckvieh (n = 3),