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Gait determination and activity measurement in horses using an accelerometer

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ABSTRACT

The observation of locomotor activity and resting behaviour is used to determine time budgets, which may give some indication for the assessment of horses' welfare concerning management and housing. As an alternative to time-consuming direct observations, a common automatic measuring method is the use of pedometers. One disadvantage of pedometers is the loss of information due to pooling of data, which also disallows the distinction of different gaits. In this study, the suitability of an accelerometer (MSR145 data logger) for automatic gait determination was tested. The aims of the study were to define acceleration value ranges for stand, walk, trot and gallop and to compare acceleration data with a commonly used pedometer (ALT-Pedometer). For the validation, 20 horses of different breeds and height at withers were all exercised in stand, walk, trot and gallop for 5 min each with both measuring devices attached to the left foreleg. Acceleration of the vertical leg movement was measured at a sampling rate of 10 Hz. Acceleration data was calculated per second and averaged over the entire 5 min interval to obtain acceleration values. Steps measured by the pedometer were accumulated during minimum sampling intervals of 1 min. For gait determination, breed classes Horse (>148 cm), Pony (⩽148 cm) and Icelandic horse were analysed separately. Results revealed a significant influence of gait on mean acceleration values without overlap between the different gaits, when Icelandic horses were considered separately from other horses and ponies. Therefore, data allowed the determination of gaits by definition of distinct acceleration value ranges for stand, walk, trot and gallop. A positive correlation between acceleration values measured by MSR145 data logger and step activity measured by ALT-Pedometer was found for stand and walk; trot and gallop could not be distinguished by the pedometer.

The validation revealed a clear suitability of the MSR145 accelerometer for gait determination in horses. The MSR145 was shown to be a high-precision measuring device that appeared to be an advantageous alternative to pedometers for measurements of locomotor activity in horses.

1. Introduction

Locomotor activity and resting behaviour are considered to be reliable indicators in the process of evaluating horse welfare concerning management and housing (McCall et al., 1985; Christensen et al., 2002; Heleski et al., 2002; Kurvers et al., 2006; Visser et al., 2008; Werhahn et al., 2012). Direct observations of locomotor activity and resting behaviour, however, require a great effort that is mostly practiced only in studies on feral horses (Duncan, 1980; Boyd et al., 1988; Souris et al., 2007; Ransom et al., 2010). In studies on domestic horses, automatic monitoring of activity by means of pedometers is frequently applied (Holland et al., 1996; Hoffmann et al., 2009; Aguirre and Orihuela, 2010; Warren-Smith and McGreevy, 2010). Such automatic monitoring systems represent an objective and non-invasive method for obtaining information and reduce the potential of a possible observer influence. Pedometers are measuring devices that count single steps and sometimes also recognise lying positions. Data is usually recorded continuously but stored periodically after certain time intervals. One disadvantage of these devices, therefore, is the loss of information due to pooling of data, which also disallows the distinction of individual gaits.

In recent years, more versatile skilled measuring devices were available. Global Positioning Systems (GPS) are frequently used for the acquisition of locomotion data on distance travelled and speed (Kingston et al., 2006; Aerts et al., 2008; Hampson et al., 2010; Von Peinen et al., 2013). Unfortunately, GPS is neither applicable for measurements inside stables due to signal loss under roofing (Johansson, 2009), nor for measurements of individual limb movements (e.g. restlessness in place). Accelerometers seem a promising alternative in the field of gait analysis. Accelerations of the hoof at impact on the ground were studied for different track

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surfaces (Ryan et al., 2006; Thomason and Peterson, 2008; Setterbo et al., 2009) and horseshoeing (Dyhre-Poulsen et al., 1994; Back et al., 2006; Schaer et al., 2006) in order to recognize their potentials for musculoskeletal injuries in different gaits. Objective detection and quantification of lameness was evaluated using correlation of head and pelvic acceleration (Keegan et al., 2002; McCracken et al., 2012) and symmetry of leg movements (Thomsen et al., 2010; Starke et al., 2012). Barrey and Galloux (1997) analysed the equine jumping technique by measuring acceleration peaks of the fore- and hindlimbs at take-off and landing. Stride parameters, such as stride frequency, stance and propulsion duration, were studied in trotting racehorses to estimate racing abilities (Barrey et al., 1995; Leleu et al., 2005), in galloping racehorses to optimize training at different speeds (Witte et al., 2006) and inclines (Parsons et al., 2008) or in Warmblood horses to monitor habituation to treadmill locomotion (Buchner et al., 1994). López-Sanromán et al. (2012) compared stride frequency, stance and regularities as well as dorsoventral, propulsion and mediolateral force of acceleration in non-sedated and sedated horses to determine the effects of sedation on movement patterns in walk. Robilliard et al. (2007) compared walk, tolt, trot, pace, canter and gallop in Icelandic horses by measuring foot-on and foot-off events from all limbs, gait identification was made on a stride-to-stride basis, including limb stance times and speed (measured with GPS). However, no references were available on gait determination and measurement of locomotor activity depending on acceleration values on the forelimbs. For these reasons, the suitability of the MSR145 data logger (MSR Electronics GmbH, Seuzach, Switzerland), an accelerometer including three-axis acceleration sensors (*x*-, *y*-, *z*-axes), was tested in the present study.

The MSR145 data logger has been employed e.g. to record measurements of respiration rate (Reefmann et al., 2009a), body surface temperature and humidity (Reefmann et al., 2009b) in sheep, rumination and feeding activity in cows (Nydegger et al., 2010) or lying behaviour in cows (Helmreich et al., 2009) and goats (Patt et al., 2012). But, according to our knowledge, it has never been used before in connection with activity measurement in horses. In order to compare acceleration data measured by the MSR145 with data recorded by a customary pedometer, the commonly used ALT-Pedometer was tested simultaneously. The ALT-Pedometer (Activity Lying Temperature Pedometer, Ingenieurbuero Holz, Falkenhagen, Germany) includes sensors for step impulses, ventral and lateral position and temperature. The device was developed for early detection of oestrus (Pache et al., 2005; Brehme et al., 2008) and lameness (Alsaaod and Büscher, 2009) in cows but was also used in various studies on horses. Rose-Meierhöfer et al. (2010) compared activity behaviour of adult horses housed in different open barn systems, while Erber et al. (2012) measured locomotor activity and lying behaviour of foals at different weaning protocols. ALT-Pedometers were also used for comparison of daily activity rhythms in different housing systems (Brehme et al., 2006), to study the influence of an automatic concentrate feeder (Hoffmann et al., 2012) or to record adaptation strategies to seasonal changes in environmental conditions of domesticated Shetland ponies (Brinkmann et al., 2011).

The aim of this study was to determine gaits by means of individual acceleration value ranges, recorded by the MSR145 data logger. In addition, a correlation analysis for acceleration values and step activity measured by ALT-Pedometer was conducted to find out whether MSR data can be compared with literature data measured by ALT-pedometers. For the validation of the MSR145 data logger, horses were exercised in stand, walk, trot and gallop and acceleration of the vertical movement of one foreleg was recorded. Within these objectives, a possible suitability for a further use of the MSR145 data logger as an automatic monitoring system for locomotor activity and resting behaviour should also be clarified.

2. Animals, material and methods

Ethical approval to conduct the study was obtained from the Zurich Cantonal Veterinary Office, Switzerland (Approval No. 169/2011).

2.1. Horses and settings

The study was conducted with 20 adult horses of different breeds, height at withers (125–169 cm) and with varying horseshoeing (5 barefoot, 14 shoed); details are shown in Table 1.

Based on breed and height at withers, three breed classes were defined: Horse (>148 cm), Pony (⩽148 cm) and Icelandic horse (Table 1). All horses belonged to private owners and were used to being exercised. To ensure that the horses' sequence of movements was as normal as possible, exercising for data recording was carried out by the owners or familiar riders at local training arenas. The horses were kept in seven different stables in Switzerland, leading to a variety of arena sizes and track surfaces (Table 1).

2.2. Measuring devices

2.2.1. Accelerometer

Acceleration was measured using the MSR145 data logger, a device for the measurements of different physical parameters, providing integrated temperature, humidity, pressure, light and acceleration sensors (MSR Electronics GmbH, 2011). In this study, the waterproof MSR145W in a silicone tube with a size of 18 × 14 × 62 mm and a weigh of 18 g was used (Fig. 1). The data logger was powered by a 260 mAh lithium–polymer battery (alternatively available: 900 mAh), rechargeable via UBS connection, which enables measurements over several days. Data was recorded on an integrated memory with a capacity of 2 million data points (expendable with optional SD card up to 1 billion). It was transferred to a computer, either during or after recording, via USB connection and stored in a Microsoft CSV-file. MSR-Software was used for data transfer and analysis as well as settings of the data loggers. Sampling rates could be set individually for each sensor within a range from 50 Hz (50 measurements/s) to every 12 h. Acceleration was measurable on *x*-, *y*-, *z*-axes (Fig. 1) with a maximum sensitivity of ±10 g [g = m/s^2].

2.2.2. Pedometer

Step activity was measured using the ALT-Pedometer, a measuring device providing sensors for step impulses, ventral and lateral lying position and temperature (Ingenieurbuero Holz, 2006). The technics were placed in a rectangular plastic box with a size of 60 × 50 × 20 mm and a weight of 125 g (Fig. 2). Data was recorded on an integrated memory with a capacity of 768 datasets and transferred to a computer after recording via a serial interface radio modem and stored in a Microsoft Access database. ALT-Pedometer-Software was used for data transfer as well as settings of the pedometer. Sampling intervals could be set for all sensors within a range from 1 to 60 min. Within this time period, step impulses were continuously recorded with the maximum sampling ability of 0.5 s, resulting in a maximum count of 120 steps per minute that the ALT-Pedometer is technically able to sample. At the end of each sampling interval, the sum of steps was stored in one dataset together with lying time data and ambient temperature.

2.3. Data recording

All 20 horses were exercised in the gaits walk, trot and gallop for 5 min each; exercise was either ridden, longed or both combined (Table 1). Intervals of different gaits were recorded continuously in principle. Depending on the physical condition of the