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Original Research

Changes of Ground Reaction Force and Timing Variables in the Course of Habituation of Horses to the Treadmill

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ABSTRACT

In studies of equine locomotion, treadmills and accompanying measuring systems have become a widely used tool. Before any reliable data can be collected, horses have to habituate to treadmill locomotion. The aim of the present study was to investigate this process of habituation to an instrumented treadmill by analyzing kinetic data and heart rate (HR) at walk and trot and to determine the minimal number of training sessions needed to perform reliable numerical gait analysis. Fourteen Warmblood horses were assigned to two groups of seven subjects each, performing either a simple training of 10 minutes or a more demanding training of 20 minutes. Horses passed 10 consecutive training sessions within 6 days. Before and after each training session, measurements of vertical ground reaction forces, contact times, hoof position, and HR were made. Separately, for each variable and for each gait, the consecutive measurements of the two training regimes were compared with the data of the 10th training session using two-factor repeated measures analysis of variance. The number of sessions needed for habituation was determined accordingly ($P < .05$). At the trot, objective lameness assessment for clinical use is reliable after a minimum of four training sessions, whereas corresponding investigations at the walk demand four to five training sessions. For longitudinal studies or before and after treatment investigations, a minimum of five sessions is necessary to ensure results that are unbiased from ongoing treadmill experience at both gaits.

1. Introduction

Lameness has the highest annual incidence of all medical problems in horses [1]. Consequently, early recognition and reliable examination of lameness is an important and challenging part of daily work in equine veterinary practice. This is done by presenting the horse to a clinician at walk and trot, in a straight line or on a circle and on different surfaces. Another option is to evaluate the horse's gait on a treadmill. Evaluating the gait pattern on a treadmill using constant and reproducible velocities enables a more standardized way of assessment over numerous strides as well as at higher speeds. In the last decades, the treadmill and accompanying measuring systems have become an essential tool for numerous kinematic and kinetic studies in horses worldwide [2–5]. As moving on a treadmill presents a challenge to horses, they have to be habituated to treadmill locomotion before any reliable data can be collected. In humans, the process of treadmill familiarization was described as lasting longer than 15 minutes at walk [6], 10 minutes of walk for clinical use [7], or 6 minutes at a run in young healthy adults [8]. In dogs, habituation was achieved after 1 day of treadmill exercise, regardless of the temporal workload per day [9,10]. In horses however, habituation is described as "a few minutes of rather tense or nervous running" [3] or "one or two exposures to the treadmill at the trot" [11]. Only Buchner et al. [12] has assessed the process of treadmill habituation objectively and revealed that the process of habituation lasted up to three sessions at the trot and that for some variables at walk, a final steady state was never achieved. These authors also showed that well-habituated horses moved with longer, more regular strides and shorter stride-standardized stance durations (duty factor) than novices moving on the treadmill.

Animal welfare/ethical statement: The Animal Health and Welfare Commission of the Canton of Zurich (Switzerland) approved the experimental protocol (TVB-Nr 27/2004).

Conflict of interest statement: No competing interests have been declared.

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At the Equine Department of the Vetsuisse Faculty University of Zurich numerical gait analysis is performed on a treadmill instrumented with a force-measuring system [2]. This system allows determination of the vertical ground reaction forces (GRFs) of all four limbs simultaneously as well as numerous limb timing and positional variables over many consecutive strides. So far, no information is available on how these data depend on the horse's level of habituation to the treadmill. The aims of the present study were:

1) To observe kinetic data during the process of habituating horses to treadmill locomotion over 10 training sessions;
2) To evaluate the effect of two training protocols of differing length and complexity;
3) To determine the minimal number of training sessions needed to allow reliable numerical gait analysis; and
4) To simultaneously monitor the heart rate (HR) as an intrinsic indicator of physical activity but also of stress level.

It is hypothesized that with increasing treadmill experience, horses will show a more relaxed movement characterized by a decrease in stride rate, a pronounced double peak force profile at walk, and a lower, more constant HR. Furthermore, it was expected that kinetic gait variables would approach asymptotically a stable final value as it was described in previous studies on temporo-spatial variables [10,12]. A further hypothesis was that the application of a longer and more challenging training protocol, involving changes in gait, velocity, and treadmill incline, would speedup the habituation process and improve gait regularity.

2. Material and Methods

2.1. Horses

Fourteen Swiss Warmblood riding horses were recruited for this study. The 13 geldings and one mare were 4–12 years old (5.5 ± 2.6 years; mean ± standard deviation [s.d.]), had a body mass of 490–634 kg (562 ± 44 kg), and a height at the withers of 1.56–1.73 m (1.66 ± 0.06 m). None of them had any previous treadmill experience. All horses were subjected to a thorough orthopedic examination and were judged clinically sound.

2.2. Experimental Design

To habituate the horses to treadmill locomotion, 10 repeated training sessions (T_1–T_{10}) were performed: twice a day during the first 4 days and then once a day on the fifth and sixth day. Horses were randomly allocated to two different training protocols (Fig. 1). One protocol lasted 10 minutes and consisted of 5 minutes walk and 5 minutes trot; the other protocol lasted 20 minutes, including walking and trotting sequences, halts, and changes in treadmill incline and velocity. Horses allocated to the short protocol were named as the simple training group (STG) and horses allocated to the longer more demanding protocol as the extended training group (ETG).

On each day, horses were weighed and subjected to a brief clinical and orthopedic re-examination. Ground reaction forces were recorded ante (aT_i) and post (pT_i) every training session (i) at the walk and subsequently at the trot (Fig. 1). During every training session, HR was recorded continuously.

Immediately before the very first training session, each horse was led onto the treadmill and the treadmill belt was started for a few seconds to prepare the horses for the first training session. Thereafter, the treadmill was started again and the first measurement was carried out.

2.3. Data Acquisition and Analysis

Vertical GRF, contact time, and hoof position during ground contact of each limb were measured using a treadmill (Mustang 2200; Kagra-Graber AG, Fahrwangen, Switzerland) instrumented with a force measuring system (TiF, [2]). Data records of 30 seconds were sampled at 433 Hz, thus including around 24 consecutive strides at walk and 37 at trot. For each stride, various discrete variables were automatically determined using the custom made TiF analysis software (HP2; University of Zurich, Zurich, Switzerland) and further analyzed in Microsoft Excel (Microsoft Corporation, Redmond, WA). Force and impulse variables were standardized to the horse's body mass. Hoof–ground contact timing variables were standardized as percentage of stride duration (%SD), the time of force events (peaks, dip) as percentage of stance duration (%StD) of the respective limb. For each variable, the values from the multiple strides within a record were averaged to a representative value. The corresponding inter-stride s.d. ($IS_{s.d.}$) served as measure of the variables' variability. As walk and trot are both symmetrical gaits, data of contralateral limbs or corresponding support phases of the half-cycles were pooled. Because left–right asymmetry is an important criterion in lameness diagnostics, an asymmetry index ASI (%) = 100% (Y_{left}–Y_{right})/mean (Y_{left}, Y_{right}) was calculated for most of the variables (Y). Asymmetry index is zero for perfect symmetry, negative for a left-sided deficit and positive for a right-sided deficit. At this point, it has to be stressed that ASI in this study describes the natural asymmetry as the horses were

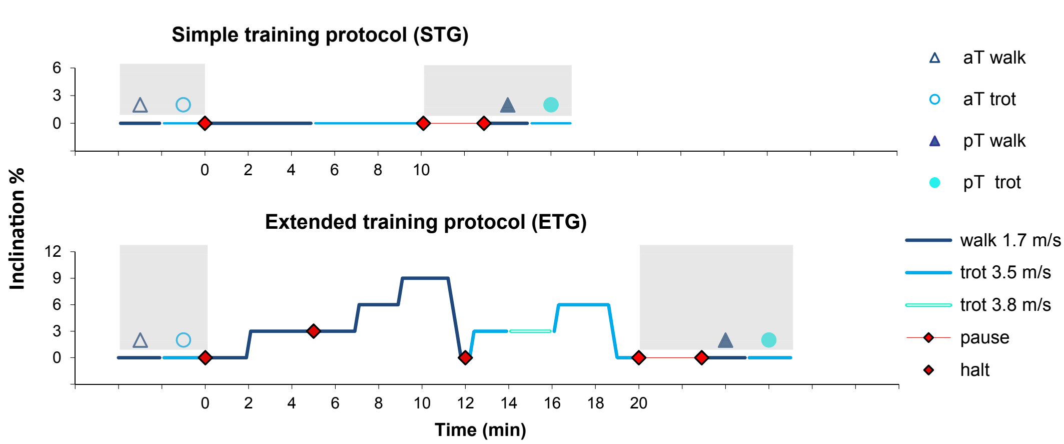

Fig. 1. Illustration of the different training protocols of the two horse groups (STG, ETG). Shown are the time courses of the various sequences regarding gait, speed, and treadmill inclination (y-axis). Intermittently, the treadmill was brought to a brief halt. Additionally indicated are the time points of the measurements before and after the training session. Before pT horses stepped off the treadmill and the force measuring system was reset to zero. STG, simple training group; ETG, extended training group; aT, ante training; pT, post training.