Journal of Equine Veterinary Science 61 (2018) 1–6

Contents lists available at ScienceDirect

Journal of Equine Veterinary Science

journal homepage: www.j-evs.com

Original Research

Proof of Concept on Energy Expenditure Assessment Using Heart Rate Monitoring and Inertial Platforms in Show-jumping and Riding School Horses

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ARTICLE INFO

Article history:
Received 13 September 2017
Received in revised form 16 October 2017
Accepted 16 October 2017
Available online 28 October 2017

Keywords:
Acceleration
Energy expenditure
Heart rate
Horse
Inertial platform

ABSTRACT

Currently, the most accurate and noninvasive method used to assess energy expenditure (EE) in sport horses is based on heart rate (HR) monitoring. However, EE assessment using inertial platforms has been lately discussed in human sports medicine. The objective of this study was to evaluate whether inertial platforms would be useful tools to assess EE in horses. Six show-jumping and riding school horses (Thoroughbred and warmblood) were equipped with a HR monitoring system and a wireless inertial platform. Acceleration, HR, and speed were measured during the exercise protocol that included walk, trot, canter, and a sequence of four jumps. Stride maximum and minimum acceleration, and acceleration amplitude and root mean squares (RMSs) were determined. Energy expenditure and oxygen uptake (VO_2) were calculated using HR and speed, respectively. Bivariate correlations (nonparametric Spearman's ρ correlation) between EE, VO_2, and acceleration variables were tested. Spearman's ρ correlation was positive between both EE and VO_2, and maximum acceleration, acceleration amplitude, and RMS and negative for minimum acceleration. Acceleration variables of vertical and lateral movement were generally better correlated with EE and VO_2 ($P < .001$) than those of forward movement ($P < .01$). The results of this innovative approach reveal that the determination of EE in horses could be assessed using inertial platforms. Moreover, vertical and lateral movements appear to influence more EE than forward movement.

1. Introduction

Energy requirements of horses have been studied since many centuries, but the first scientific approaches that can be considered the basis of our present knowledge were developed mostly in the 90s [1]. However, there are some difficulties in the precise statement of the work required to horse today: this work in fact is deeply changing from one day to another, variable in intensity and duration, sustained by different cell energy sources. All these aspects are very difficult to study in field conditions without interfering with the normal activity because measurements are "normally" based on invasive techniques (e.g. use of gas exchange measurement masks). Moreover, riders frequently do not understand exactly the importance of a precise definition of the energy requirements. The result is a generalized overestimation of these requirements and the possible onset of disturbances linked to energy excess, such as endocrine and metabolic disorders [2–4].

Animal welfare/ethical statement: This study was carried out in accordance with the EU Directive 2010/63/EU for animal experiments. Only non-invasive methods were used to determine energy expenditure; in particular equine belt for HR sensor was used to monitor HR, and inertial platforms were attached to the saddle pad. This article complies with the Uniform Requirements for manuscripts submitted to Biomedical journals ICMJE 2006.

Conflicts of interest statement: Free loan inertial platforms were provided by BTS bioengineering, Garbagnate Milanese, Italy.

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0737-0806/$ – see front matter
https://doi.org/10.1016/j.jevs.2017.10.014

The development of noninvasive tools for the assessment of energy requirement during exercise, using new technologies understandable also for riders, is one of the ways to safeguard and improve horse welfare, fitness, and even consciousness of the rider in correct exploitation of the athletic potentiality of the horse, as already demonstrated in human field.

One of the new technologies that can be used to define energy requirements (both in humans and in animals) with noninvasive tools is the use of heart rate (HR) monitoring systems, on one hand, and accelerometers (or—more precisely—inertial platforms containing accelerometers) on the other. Such devices are widely accessible to a large part of riders (an accelerometer is present in the largest part of commercially available Smartphone), but no software is developed to study horse athletic activity at present.

Among all methods proposed in international literature for the calculation of energy expenditure (EE) for exercise in horses [5], in particular, the German system is strictly linked with indirect measurements, through HR monitoring.

The German method, in fact, introduces an indirect evaluation of metabolizable energy based on the relationship between HR (beats per minute) and oxygen uptake (VO_2), allowing for estimation of anaerobic energy production at higher exercise level, based on the following equation:

$$EE\left(J\ kg^{-1} BW min^{-1}\right) = 0.0566 \times HR^{1.9955}$$

where HR in beats $\times$ min^{-1}.

Heart rate monitoring is based on the application of two electrodes on the horse's skin, with some discomfort for the adjustment of the brides and saddle, and some problems for the accuracy of measurements. For this reason, the use of inertial platform has been considered for the studies of horse's EE. These devices have been used for several purposes in humans, to study physical activity in older men [6], bodyweight, and EE [7–9]. Unfortunately, very few papers are on the contrary available in international literature about accelerometric measurements applied to animal science. One of the first was about cormorants migration [10].

As to horses, pressure-based accelerometer was used for the definition of horse biomechanics at the end of 19th century [11], while modern devices have been used, in recent years, to study hoof acceleration in the exercising horse [12], biomechanical and energetic determinants of the walk–trot transition in horses [13], and in particular horse's biomechanics, symmetry, lameness, and gait analysis [14–16].

Very few papers and data are available on the use of accelerometers for the estimation of EE in horses. Two of the latest were proposed by Kubus et al [17,18], the more recent investigating the relationships between HR monitoring and accelerometry.

Today, triaxial devices working at 100 Hz and more are the bases for modern studies. Our group developed, in the recent years, some competences in this area based on previous experiences [19–21].

In this paper, we started from field measurements of indirect EE, coupled with accelerometric measurements, in riding school horses; the preliminary relationship between the two methods is discussed.

2. Material and Methods

This study was carried out in accordance with the EU Directive 2010/63/EU for animal experiments. Only noninvasive methods were used to determine EE; in particular, equine belt for HR sensor was used to monitor HR, and inertial platforms were attached to the saddle pad. This article complies with the uniform requirements for manuscripts submitted to biomedical journals [22].

2.1. Animals

Three warmblood competing in show-jumping (Selle Français, Sella Italiano, and Holsteiner; two females and one gelding) and three riding school (Thoroughbred and Lippizan crossbreed, and warmblood; one female and two geldings) horses (12.7 $\pm$ 1.6 years old) were equipped with Polar Equine RS800 G3 HR monitoring system (Polar Electro Inc, Lake Success, NY) and BTS Bioengineering wireless inertial platform (BTS Bioengineering Corp., Brooklyn, NY).

2.2. Exercise Program

Horses were ridden by different experienced riders. Each exercise was monitored for 1 minute. The exercise program included linear, right and left walk and trot, and right and left canter, and right and left canter with a sequence of four jumps (height 40 cm). Each horse was monitored once for each exercise. Horses were ridden in sand indoor arena.

2.3. HR and Speed Monitoring

Heart rate and speed were recorded every 5 seconds for the entire duration of the exercise program. Mean and minimum HR and mean speed during each exercise (walk, trot, canter, and jump) were calculated using Polar Equine Software.

2.4. Acceleration Measurement

Inertial platform wireless sensors (BTS Bioengineering, Garbagnate Milanese, Italy) were placed at withers level, attached to the saddle pad under the saddle pommel. Acceleration was measured at 100 Hz during each exercise. Collected data included acceleration in forward (x), lateral (y), and vertical (z) directions.

2.5. Determination of EE and Oxygen Uptake (VO_2)

Minimum and mean EE were calculated using HR (bps) during each gait (walk, trot, canter, and jump) using the method proposed by Coenen [23], EE (J kg BW^{-1} $minute^{-1}$) $= 0.0566 \times HR^{1.9955}$.

Mean oxygen uptake was determined using speed (S; m/s) during each exercise according to Coenen [24], VO_2 (mL O_2 kg BW^{-1} $minute^{-1}$) $= 4.515 + 9.14S + 0.726S^2 - 0.00452S^3$ during each exercise.