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Original Research

Application of a Full Body Inertial Measurement System in Dressage Riding

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ABSTRACT

With the steady further development of microelectromechanical systems, nowadays, it is possible to measure various specific kinematics of riders with inertial sensors. The aim of the study was to quantify the rider's posture on the horse with a full-body inertial measurement system (Xsens MVN) under field conditions. Ten high-level riders from the German National Equestrian Federation participated in this study. The measurements were performed in sitting trot (ST) in an indoor riding hall. Kinematic data from the riders' segments (head, trunk, and pelvis) and joint angles (elbow and knee) were collected. Qualitative analyses of the waveform parameters and statistical analyses were applied to the data. In addition, the coefficient of multiple correlations (CMCs) was calculated between angle-time courses to quantify the waveform similarities and intertrial repeatability for each rider. All analyzed CMCs ranged from moderate (0.65) to very good (0.92). The two-beat rhythm of the ST was qualitatively represented in the waveform data of the head, trunk, and pelvis about the rotation of the mediolateral axes (Roll). The Roll of the riders' pelvis was significantly greater than the Roll of the riders' trunk. In general, the movements of the riders' segments about the sagittal axes (Pitch) show smaller values than about the mediolateral axes. In conclusion, this setup seems to be suitable to quantify riders' kinematics under certain field conditions. Based on these findings, there is a possibility to obtain several objective information of the riders' kinematics in different equine gaits and skill levels.

1. Introduction

A good performance in dressage riding is mainly based on a correct rider sitting position. In BC 365, Xenophon already dealt with the question how the rider should move on a horse. Xenophon describes an upright sitting position and emphasizes the importance of a well-balanced and elastic seat of the rider [1]. These rules are still acknowledged across all equestrian disciplines down to the present day.

In the guidelines of the German National Equestrian Federation (2012), the dressage seat is defined as balanced, elastic, and upright. The requirements of a good posture are described as a vertical line between the rider's shoulder-hip-heel and a central position of the rider [2,3]. However, these theoretical considerations are difficult to grasp for researchers and horsemen [4]. It would be an improvement if more objective criteria could be developed. Biomechanical measurements could be beneficial in this matter.

At present, three-dimensional (3D) optical motion capture in gait laboratories (treadmill) is the gold standard method to quantify and analyze the rider's [5,6] and horse's movements [7–9]. Recent treadmill studies of Byström et al [5,6] and Peinen et al [10] present a comprehensive kinematic description of the rider's upper body, the saddle, and the horse trunk in walk and sitting trot (ST). However, there are differences between the locomotion of a horse on a

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treadmill and overground locomotion [11–15]. In several studies, the posture, joint angles, and kinematics of riders were investigated with camera-based measurements [16–19]. However, video-based measurement techniques show a number of disadvantages with respect to the application in horseback riding: a limited field of view, limitations concerning the acceleration measurements, and the expenditure of time and cost [20–23].

The steady development of microelectromechanical systems and inertial measurement units (IMUs) results in decreasing costs, enhanced performance, and portability [24].

The application of full-body inertial measurement systems in human movement research is becoming increasingly practicable. There are a few studies in the usage of such systems in alpine sports [25–28], clinical gait analysis [29–31], human movement research [32,33], and other sport sciences [34,35].

This new age of data capturing allows performance analyzes in horseback riding outside gait laboratories with a big sample size and high accuracy [22]. In recent years, there is a great interest in veterinary studies to collect the equine movement with IMUs [9,36–38]. The investigations of Münz et al [39,40] are one of the first who describe an inertial sensor-based method attached on rider's pelvis and horse's trunk. They found that the IMUs are suitable to collect the kinematics of human pelvis in the different equine gaits. Distinctions between the horse–rider interaction of professional riders and beginners have also been demonstrated with these methods. Wolframm et al [41] found characteristics of motor coordination between horse and rider in walk, trot, and canter based on two single triaxial wireless accelerometers. Investigations regarding the acceleration of head movement and muscular activity also point out differences depending on the gait and performance levels [42]. However, there are no publications available considering the rider's whole-body movement. It is hypothesized that a full-body kinematic analysis could contribute for a better understanding of the horse–rider interaction [20].

Hence, the aim of the current study was to evaluate the application and performance of a full-body inertial system in dressage riding and additionally to investigate the selected rider kinematics in ST.

2. Material and Methods

2.1. Riders and Horses

Ten professional dressage riders (eight females and two males; mean age ± standard deviation, 23.4 ± 5.3 years) with a body mass index of 21.5 ± 2.5 kg/m^2 and at least 17 years of experience participated in the study. All of them had worked as riding instructors at the German Federation Equestrian National (FN). The participants rode with their own dressage saddles and bits. The eight geldings and two mares (mean age ± SD: 7.9 ± 4.2 years; mean height ± SD at withers: 170 ± 3.5 cm) had been trained by the FN and did not show any sign of lameness. The experimental protocol was approved by the Ethical Board of the Otto-von-Guericke-University Magdeburg.

2.2. Experimental Design

2.2.1. Motion Capture

The kinematic data of each rider were collected with a six DOF full-body inertial measurement system (MVN; Xsens Technologies BV, Enschede, The Netherlands). The MVN consists of 17 inertial sensor modules (MTx orientation tracker; Xsens Technologies BV) and two wireless transmission units (Xbus Masters). The MTx units were attached to the riders head, hands, forearms, upper arms, shoulders, pelvis, upper and lower legs, and boots with straps (Fig. 1) and measured the position and orientation of the segments in a global coordinate system by 3D magnetometers, 3D accelerometers, and 3D rate gyroscopes [43]. Before the measurements, the MVN had to be calibrated and participants' anthropometric data (eight parameters) were raised and entered manually to a graphical user interface (Moven Studio V3.1; Xsens

Fig. 1. Experimental setup: rider (MVN suit) and horse (acceleration sensor on the cannon bone) with the applied measurement systems: rotation axes of the riders' segments are shown as arrows: red arrows indicating Roll angles and green arrows indicating Pitch angles.