In horseback riding, the rider's kinematics was usually measured through visual observation. Today, 3D optical motion capture on treadmills is the golden standard method. However, there are differences between the horse's treadmill locomotion and the overground locomotion. The aim of this study was to investigate and compare the motion of the rider's pelvis in walk, trot, and canter under field conditions by using a full body inertial measurement system. Ten professional riders rode their own horses wearing a full body inertial sensor system. Gait-dependent characteristics of pelvis rotation in riding under field conditions could be found. The possibility to characterize kinematic data of horse and rider under field conditions using a full body inertial sensor system seems to promising for researchers and horsemen.

KEY WORDS: horse riding, human pelvis, kinematics, inertial motion capturing, equine gait

INTRODUCTION: A good riding performance is mainly based on a correct rider sitting position. At present, three-dimensional (3D) optical motion capture on treadmills is the gold standard method to quantify and analyse the rider's and horse's movements. Recent treadmill studies of Byström et al. (2009; 2010) describe the kinematics of the rider's upper body, the saddle, and the horse trunk in walk and sitting trot. However, there are differences between the locomotion of a horse on a treadmill and overground locomotion. Previous video-based studies on rider kinematics are limited in field of view (Schils et al. 1993; Lovett et al. 2004) or the expenditure of time and cost (Greve et al. 2013). Many researches compared the kinematics and motor skills of novice and expert riders (Schils et al. 1993; Münz et al. 2013). It was found, that good riders have a more upright upper body position during sitting trot (Schils et al. 1993), move more in phase with the horse (Lagarde et al. 2005), and have less variable movements (Peham et al. 2001). The pelvis is considered as the “center” of movement that determines the synchronisation between upper body and legs. The movement of the pelvis is said to play the key role in controlling a horse as it connects the rider’s body weight with the horse’s trunk. In a preliminary study Münz et al. (2013) found gait dependent characteristics of pelvis rotation in dressage riding in field test. Following the research of Münz et al. (2013) the aim of this study was to characterize the motion of the rider’s pelvis in different equine gaits by using a full body inertial measurement system under field conditions.

METHODS: Ten professional riders (PRO: age: 23.4 ± 5.25 years, training hours/week: 33.9±11.89) participated in the study. They rode their own horses in walk (W), sitting trot (ST), and in right (CR) as well as left lead canter (CL) four times on a 30 m long track. Kinematic data from the rider’s segments were collected using a full body inertial measurement system (MVN, Xsens). For the calibration of the MVN the subjects had to stand upright with arms stretched out horizontally and the thumbs pointing forward (Xsens, standard T-Pose). Two sensors were mounted to the horse in order to collect its motions and steps: One single inertial sensor was next to the horses’ sternum and one single acceleration sensor on the horses’ left cannon bone. A complete stride was defined as the time between two successive ground contacts of the left front limb of the horse. Afterwards, strides were normalized to 101 samples (MATLAB, 2012b) and the averaged pelvis’ (the mean of ten riders over 30 strides) waveform parameters for Roll (transversal axis) and Pitch (lateral axis) were calculated and plotted.
RESULTS: Figure 1 shows the greatest rotations of the riders’ pelvis and horses’ trunk in CL, followed by CR, W, and ST. Compared to the range of motion of Roll angles in CL (24.0°) and CR (23.6°), it is approximately half the amount in ST (11.5°) and W (14.6°), respectively. Pitch angles decreased also from CL (5.5°), CR (5.3°) to W (5.0°), and ST (4.0°). In W the maximal cranially rotation of the pelvis and the maximal caudally rotation of the horse was at about 30% and 80% of the stride. In contrast to W, in ST the pelvis and horse shows a smaller range of motion and the rider’s posture is featured by a more forward tilt pelvis. In ST as in W a forward- backward motion of the pelvis in opposite to the horse could be found. In CL, the pelvis tilts maximal dorsally at about 25% and maximal cranially at 75% opposite to the horse. In CR, the pelvis is maximal dorsally flexed at about 50%. In Pitch, the pelvis tilts maximal to the left at about 50 % in CL and maximal to the right at about 75 % in CR. Further, between CL and CR almost the same range of motion with a time lag about 25% (Roll and Pitch) was found.

Figure 1: Average of time-normalized anterior-posterior angles (Roll) for the pelvis (solid lines) and the horse’s trunk (dotted lines) of ten riders across 30 strides in different gaits.

For Pitch angles, differences between the gaits are less prominent than for Roll angles. Further, the pelvis of the rider ran out-of-phase for all investigated gaits in Roll. Generally, the pelvis tilts more backwards in Roll and more to the right in Pitch.
Figure 2: Average of time-normalized lateral angles (Pitch) for the pelvis (solid lines) and the horse’s trunk (dotted lines) of ten riders across 30 strides in different gaits.

DISCUSSION: Differences and tendencies could be found for pelvis rotation in Roll between all selected gaits. However, this could not be found in Pitch. Qualitative differences between gaits and characteristic patterns in the angle-time courses of the riders' pelvis and horses' trunk could be demonstrated. The Pelvis rotated more about the mediolateral axis (Roll) than about the sagittal axis (Pitch), respectively (Figs. 1 and 2). The two-beat rhythm in ST was qualitatively well represented in the waveform of Roll angles. However, we could not find a similar correspondence for the three-beat rhythm of CL and CR and for the four-beat rhythm of W. In Pitch, we could not find any rhythm of the selected gaits. The movements of the rider’s pelvis in Pitch displayed smaller values than in Roll. The time series of pelvis (Fig 1 and Fig. 2) corresponds to those of Münz et al (2013) and emphasizes the key role for the communication between rider and horse. The Roll angles were diametrically opposed in W, ST, CL and CR. These results might be caused by the riders’ attempts to keep their seat balanced. Throughout the whole gait cycle of W, ST, CL and CR, the rider’s pelvis is leant backwards. These results have to be interpreted with caution because of the circumstance that all kinematic data were measured with respect to the calibrated T-Pose. Anatomic changes from a standing position to a sitting position are supposed to have taken place. Further, the pelvis showed a slight tilt to the right. Rider asymmetry could have been caused by the horses’ anatomy or the rider’s musculoskeletal system (Symes et al. 2009). It could not be pointed out clearly why the rider’s segments tilt more to the right than to the left. According to the research of Lovett et al. 2005 the greatest rotation could be found in canter. A comparison of these objective findings with the subjective analyses by riding judges would be sensible. Nonetheless, there are problems and limitations of subjective methods that are
pointed out by Blokhuis et al 2009. The pelvis in riding is very important, because all aids (weight, rein, legs) enables the rider to lead a horse sensitively. Further research, however, can contribute to deeper understanding of the complexity of interactions between a horse and its rider. By using a full body inertial measurement system, there is a possibility to obtain several objective information of the riders’ kinematics in different equine gaits and skill levels.

CONCLUSION: This study demonstrated the application of a full-body inertial measurement in horseback riding under field conditions. Previous studies under field conditions have a small sample size and are limited in field of view. In treadmill studies, the rider’s and horse’s kinematics cannot be collected under realistic conditions. This study should describe a method to characterize the kinematic of the pelvis of high-level dressage riders. Based on these findings, it could be possible to obtain a multitude of objective information of whole-body kinematics and horse-rider interactions in different equine gaits by using a full body inertial measurement system. Especially in canter, this setup offers the possibility to assess riders’ movements under realistic conditions. This knowledge offers new perspectives in equine research and helps better understanding the movements of riders during horseback riding and the horse–rider interaction in different equine gaits.

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