EQUESTRIAN RIDER TRUNK-PELVIS STRATEGIES CAN BE IDENTIFIED USING SELF-ORGANISING MAPS

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The purpose of the study was to explore whether equestrian riders can be grouped by their trunk-pelvis movement strategy. Riders (n = 40) with national or international competition experience in dressage were measured using motion capture on a riding simulator for ten seconds of simulated medium and extended trot, respectively. Trunk and pelvic pitch trajectories were filtered, time-normalised to the riding simulator's vertical displacement cycle, and scaled. A self-organising map, with subsequent *k*-means clustering, identified three groups of rider-trunk pelvis movement. These groups related to the relative timing between peak posterior trunk and pelvis pitch. The study identified movement-based classifications of riders for future studies, which may have implications for rider injury risk and training.

KEYWORDS: equestrian, self-organising maps, kinematics.

INTRODUCTION: Studies of the equestrian rider have sought to define optimal technique by analysing experts (Byström et al., 2009) and comparing expert and novice riders (Lagarde et al., 2005; Peham et al., 2001), although this assumes that all experts or novices perform the task similarly and precludes technique analysis within a given level. Particular focus in research and practice has been on the rider's trunk and pelvis, as the trunk is integral to the rider's balance and the pelvis interfaces with the horse through the saddle. Back pain, combined with poor spinal motor control is common within competitive riders (Deckers et al., 2021). Injury, decrements in performance, or the ability to achieve a high level of coordination to the horse may relate to the rider's trunk-pelvis technique, however, in order to investigate this further, an inventory of rider trunk-pelvis techniques during riding should be developed.
Previous studies of the rider have focussed on discrete analyses of the rider's technique in sitting trot (e.g. at one point within the horse's stride cycle) (Eckardt & Witte, 2017) or have presented group averages within an experience level (Byström et al., 2009; Engell et al., 2016). Therefore, little is known about the variety of trunk-pelvis strategies that are employed during sitting trot in competitive riders and whether they are influenced by the level of perturbation within the horse's gait (e.g. medium or extended trot). One approach to generate novel groups based on the features of a time-series, rather than *a priori* categories, is the self-organising map (SOM).The purpose of this study was to identify whether movement-based groupings could be identified in equestrian dressage riders, using a self-organising map (Schöllhorn et al., 2002).The hypothesis was that there would be distinct groups of trunk-pelvis movement within a population of female competitive dressage riders.

METHODS: Forty adult female dressage riders volunteered for the study (mean ± SD age: 32 ± 11 y, 62.6 ± 7.9 kg, 1.67 ± 0.07 m). Riders were included if they had previous competition experience at national or international level dressage. Nine motion capture cameras (Miqus M3, Qualisys AB, Gothenburg, Sweden), sampling at 200Hz were positioned around a riding simulator (Eventing Simulator, Racewood Ltd, Tarporley, UK). Riders wore a vest top and tight riding trousers. Motion capture markers were affixed to the clothing overlying the rider's pelvis (left/right anterior and posterior superior iliac spines and body of the sacrum) and trunk (affixed to skin: left/right acromion processes, C7, affixed to clothing: sternum, T8). Six markers were affixed to the riding simulator. Riders were captured in their seated posture in a standard dressage saddle (Devoucoux, Biarritz, France) for two seconds in a static capture, and then for ten seconds of simulated medium, and extended trot, respectively. Relative to simulated medium trot, simulated extended trot produces 3 cm greater anterior-posterior displacement and 1.3 cm greater vertical displacement while maintaining the same movement frequency (1.73 Hz).

The static capture was used to form rigid bodies for the trunk, pelvis and riding simulator, which were then applied to the motion files in Qualisys Track Manager (v2020, Qualisys AB, Gothenburg, Sweden). Pitch (corresponding to the second Euler rotation) of the rider segments and the vertical displacement of the riding simulator were exported into MATLAB (R2020B, The MathWorks, Natick, Mass., USA).

Data were filtered using a fourth-order Butterworth filter with a cut-off of 15Hz. Rider data were time-normalised to 101 points (minimum-minimum of the vertical displacement of the riding simulator). Cycles were scaled to zero mean and to the range of -1 and 1. Movement cycles containing missing trunk or pelvis pitch data of 100 samples or more were discarded. Ten cycles, from the second valid cycle, were retained for analysis from each rider, except four riders, who due to gaps in the measurements, had seven cycles. An input data matrix was created for the self-organising map (SOM) in each gait. Pelvis and trunk time-series were horizontally concatenated into two 388x202 matrices. A MATLAB toolbox (SOM Toolbox, Vesanto et al., 2000) was used to train two separate SOMs for medium and extended trot with the following settings: 13 x 8 map units, linear initialisation algorithm, batch training algorithm and Gaussian neighbourhood function. Through an iterative, competitive process, the SOM is trained to group similar vectors on the map based on the Euclidean distance between the input vector and the output node (Aljohani & Kipp, 2020). Nodes are grouped based on a neighbourhood function, resulting in a map where all similar input vectors are grouped. The node associated with each input vector is known as the ‘best-matching unit’ (BMU), which is selected according to the similarity between the input values and the nodes in the grid.

K-means clustering was applied to the SOM with a maximum of 10 clusters. The optimal cluster number was the lowest Davies-Bouldin index (Davies & Bouldin, 1979), which calculates the lowest ratio of the average within-cluster centre distance to the average between cluster centre distance. In both medium and extended trot this was three clusters (medium: 0.91; extended 1.09). The assessment rate (Schöllhorn et al., 2002) which is defined as the average ratio of the number of trials for a single subject separated in one cluster and the whole number of trials for the same subject was calculated for each individual. The mean assessment rate ± SD for each of the 40 riders was calculated. The cluster with the greatest assessment rate was deemed as the rider’s group. Group characteristics, including trunk and pelvis mean and range of motion (ROM) were calculated on the un-scaled pitch data.

RESULTS: Visual inspection of the three clusters (Figure 1) indicated that the most significant feature that defined the movement groups was the relative timing of the peak posterior trunk and pelvis pitch. The mean rider assessment rate was 84 ± 20% in medium trot and 83 ± 18% in extended trot. The pelvis pitch trajectories were similar between all groups, reaching peak posterior pitch at around 50% of the movement cycle, corresponding with the simulator’s change of direction from upward to downward displacement. As per the order shown in Figure 1, group 1 had two pitching cycles of the trunk per pitching cycle of the pelvis. These riders’ trunk reached its maximal anterior pitch as the pelvis reached its maximal posterior pitch.

Groups 2 and 3 were similar, with only a single maximum posterior pitch of the trunk per movement cycle. Riders in group 2 had coincident timing between the maximal posterior and anterior pitch of their pelvis and trunk. Riders in group 3 showed some lag during the upward phase of the riding simulator’s movement (0-50% of the cycle) of the trunk posterior pitch relative to the pelvis; the maximal posterior pitch of the trunk occurred after the peak posterior pitch of the pelvis. Marked differences between the shape of the mean trajectories were observed between medium and extended trot in group 1. The error clouds (standard deviation of the mean trajectory) indicate that there was more variability of the timing of the peak anterior pitch of the trunk at around 50% of the movement cycle in extended trot. No similar differences were observed between medium and extended trot for groups 2 and 3.

Table 1 shows the number of riders for each group in medium and extended trot. In medium trot, group 2 represented the most riders' strategy, while in extended trot an identical number of riders were assigned to groups 2 and 3. Group 1 was characterised by greater pelvis than trunk ROM in both gaits. Group 2 had similar trunk-pelvis ROMs in medium trot, but greater trunk ROM in extended trot. Group 3 had greater pelvis ROM in medium trot, but similar ROMs in extended trot.

Figure 1. Mean (bold line) and error cloud normalised trajectories of the trunk (blue) and pelvis (red) pitch during simulated medium and extended trot. Pitch trajectories were normalised to 100% of the period between two subsequent minimum vertical displacements of the riding simulator and the range between 1 and -1 for the analysis.

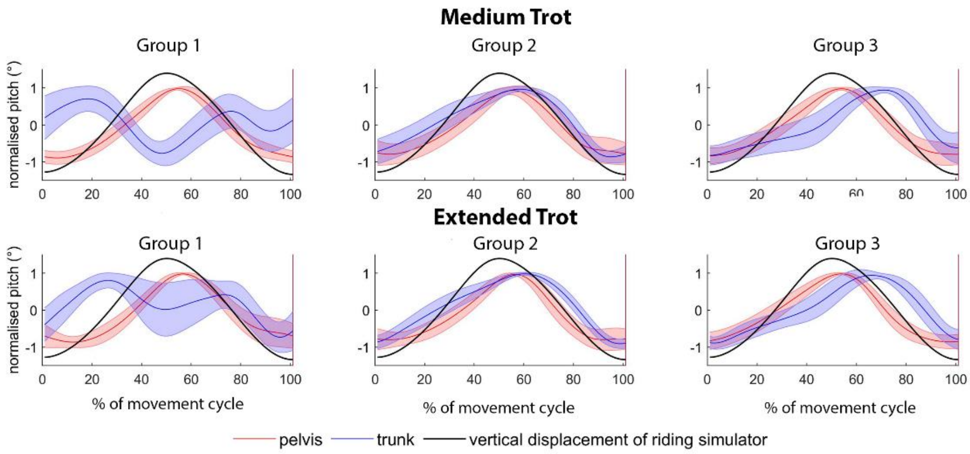

Table 1. Mean (± SD) trunk and pelvis pitch and ROM (degrees) within each group.

Group	Medium trot					Extended trot				
	Number of riders	Pelvis		Trunk		Number of riders	Pelvis		Trunk	
		Mean	ROM	Mean	ROM		Mean	ROM	Mean	ROM
1	5	3.3 ± 1.6°	8.0 ± 2.5°	0.6 ± 2.4°	3.3 ± 1.3°	2	3.6 ± 3.9°	11.9 ± 6.3°	0.7 ± 0.8°	4.6 ± 2.6°
2	25	1.5 ± 3.4°	6.0 ± 1.9°	1.3 ± 3.7°	6.6 ± 2.9°	19	1.8 ± 2.8°	8.6 ± 2.4°	1.5 ± 3.3°	11.3 ± 3.1°
3	10	2.7 ± 5.6°	7.0 ± 2.1°	2.4 ± 3.4°	4.3 ± 1.5°	19	2.6 ± 3.0°	9.6 ± 2.6°	0.8 ± 3.9°	9.2 ± 3.0°

DISCUSSION: Three different trunk-pelvis movement groups were identified in national and internationally competitive dressage riders riding a riding simulator in simulated medium and extended trot by self-organising maps and *k*-means clustering. As all riders were competitors in the national or international levels of dressage, the implication of these results is two-fold: riders within a seemingly homogenous population riding a standardised riding simulator, can show different movement strategies, and therefore, movement-based variables, such as pelvis-trunk technique should be used as a classifier for kinematic studies of the rider when the task variability is low.

The movement groups illustrated how riders pitch their trunk and pelvis to maintain an upright position in the saddle. The plots (Figure 1) show that the classification was based on the rider's trunk pitch, as the pelvis pitched similarly between groups. The majority (medium trot: 84 ± 20%; extended trot:83 ± 18%) of the riders' cycles were assigned to the same group. The most common movement strategies were groups 2 and 3. Riders in these groups pitched trunk and pelvis together (group 2), or with a small temporal separation between peak posterior trunk and pelvis pitch (group 3). Riders in group 1 pitched their trunk in the opposite direction of their pelvis and showed two pitching cycles of the trunk per trot cycle. The ROM provided some context to these strategies that may not be evident due to the scaling of the data that was necessary to perform the SOM. Similar trunk and pelvis ROMs in groups 2 and 3,

combined with similar pitch trajectories, suggest that the riders fixed their trunk and pelvis. This likely resulted in greater movement around the hip joint to follow the movement of the riding simulator, however, this was not measured in this study. Considerably greater pelvis than trunk ROM for group 1 indicates that the rider was predominately rotating the pelvis, while keeping their trunk around neutral, likely accomplished through flexion and extension of the lumbar spine. Three riders in group 1 in medium trot did not maintain membership of the group in extended trot, instead forming part of group 3 in extended trot. This finding would suggest that, for several riders, this movement strategy is not stable as the perturbation increases. Further, greater standard deviation of the group 1 extended trot trunk movement (shown in the error cloud in Figure 1 and values in Table 1) may suggest some instability of the trunk in extended trot.
These findings have implications for rider training and potential risk of injury. Rider back pain is prevalent and associated with the lumbar spine and impaired spinal motor control (Deckers et al., 2021). It is possible that the site of rider injury from repetitive movement cycles experience during riding may relate to their movement strategy. This study may inform further studies of rider technique relative to the incidence of injury.

CONCLUSIONS: Groups of rider trunk-pelvis movement can be identified within the standard task of riding a riding simulator in medium and extended trot using self-organising maps. The individual nature of the rider's movement strategy should be taken into consideration when considering the rider's coaching, off-horse training, and injury risk. Future studies should analyse the aetiology of rider injuries relative to their movement strategy. Riders may be grouped by their strategy, however, within a relatively homogenous cohort of riders, various strategies may exist.

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