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# Effect of repeated therapeutic horse riding sessions on the trunk movement of the rider

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**Abstract**

**OBJECTIVE:** To assess the rider's movement during walking the horse in repeated therapeutic horse riding sessions and to determine the relationship between movements of the horse's back and the rider's trunk.

**METHOD:** A total of 12 healthy females (age: 23.3±2.8 years; height: 167.3±4.2 cm; weight: 59.2±5.3 kg) participated in 10 therapeutic horse riding sessions. Two English Thoroughbreds with similar body constitution (aged 19 and 14 years) were used in the experiment. Nine markers were placed on the rider's body and the horse's back, and four video cameras with a 25 Hz frequency were used. Collected data were processed with APAS software.

**RESULTS:** The mediolateral displacements of C7, Th12, and L5 were gradually decreasing in each of the first three sessions. Statistically significant differences ($p<0.05$) were found between individual sessions in the displacement of C7, Th12 and L5 in the mediolateral and vertical directions as well as in the shoulder and pelvic lateral tilt and rotation. These differences did not show any general tendencies regarding the riders' increasing experiences with riding. The relationships between the displacement of C7, Th12, and L5 and the sacral tuber on the horse's back in the vertical direction were statistically significant ($p<0.01$) during all sessions.

**CONCLUSIONS:** The displacement of C7, Th12 and L5 in the mediolateral direction decreased during riding sessions. A significant relationship was found between the vertical movement of the horse's back and the rider's trunk. These relationships differed between the horses.

ORIGINAL ARTICLE

## INTRODUCTION

Hippotherapy is a treatment strategy that uses equine movement as part of an integrated intervention program for achieving functional outcomes in human patients (Kwon *et al.* 2011). This proprioceptive neuromuscular facilitation method (Engel 2003) can lead to improvements in balance and postural control at the pelvis and trunk. Improvements are often exhibited in a range of motion, muscle tension, and coordination (Whalen & Case-Smith 2012). Hippotherapy acts primarily on the central nervous system, from the lowest spinal level (reflex effects) to the highest cortical level. It can also have major psychological benefits (Kendall *et al.* 2015). Multiple authors have observed this therapy's efficacy, especially in the fields of cerebral palsy (Fizková *et al.* 2013; Kwon *et al.* 2011; Lee *et al.* 2014; Zadnikar & Kastrin 2011), multiple sclerosis (Bronson *et al.* 2010; Long 2013), geriatrics (De Araújo *et al.* 2013; Kim & Lee 2014), and Down syndrome (Champagne & Dugas, 2010; Copetti *et al.* 2007).

Typical gait mechanics of the horse are used during hippotherapy to which the patient adapts (Wheeler 2003). The locomotor impulses from a horse's back while the horse is walking are transferred to the patient/rider at a frequency of 1.5–1.8 Hz in three basic movement planes (Tauffkirchen 2000). The rider learns to anticipate movement as the horse walks in a repetitive, rhythmic pattern. The patient can produce compensatory mechanisms to counteract the horse's movement, such that his or her centre of gravity remains fairly neutral (Long 2013). Furthermore, the 3-dimensional (3D) reciprocal movements of the walking horse produce normalized pelvic movement in the patient, closely resembling pelvic movement during human walking (Bertoti 1988).

A rider and horse are two independent biological systems. To understand the influence of the horse's back movements on the rider's body during hippotherapy, the movement of these two living systems and their mutual interaction must be analysed (Janura *et al.* 2004). In contrast to horseback riding, in hippotherapy the patient is a passive element and the movement of his or her body fully adapts to the horse's movement.

Each horse has a genetically determined physique and characteristic walk, which are manifested in individual variation in the horse's back impulses. An essential prerequisite for this treatment's success method is the selection of a suitable horse for a given patient. The movement of the horse's back can be influenced by head and neck carriage positions (Rhodin *et al.* 2005), as well as the horse's age, gender, and occupational usage (Johnston *et al.* 2004).

To assess the course of therapy, it is necessary to know how the position of the patient's body changes while sitting on the horse. Therefore, this study aimed to find those changes using a kinematic analysis of the rider's body during a series of therapeutic horse riding sessions carried out in a similar manner as hippotherapy sessions.

## METHODS

### Participants

Twelve healthy females without any musculoskeletal or neurological deficiencies (age: 23.3±2.8 years; weight: 59.2±5.3 kg; height: 167.3±4.2 cm) and without any previous horse-riding volunteered to participate in the study. The participants were randomly divided into two groups, and the measurements from each group were taken using the same horse. All participants underwent a series of 10 therapeutic horse riding sessions, conducted on a large asphalt oval (commonly used for hippotherapy), twice a week for a period of 30 minutes each session. Each participant became familiar with the measurement procedures, along with the possible risks involved in the activity, and provided written informed consent before data collection started. The study's protocol was approved by the ethical committee of the Faculty of Physical Culture, Palacký University Olomouc.

### Therapeutic horse characteristics

Therapeutic riding carried out in a similar manner as hippotherapy was conducted on two English Thoroughbreds (19 years old gelding and 15 years old mare) with a similar conformation (mass 530 kg and 487 kg, wither height 165 cm both). Both horses were trained for a longer period of time for quiet mastery of difficult situations, as well as tolerating people and disturbing objects. The horses participated in hippotherapy for 8 and 9 years, respectively

### Measuring instrumentation and procedures

The participant were familiarized with the environment and measurement timetable. Before data collection, each participant was allowed to have a practice ride for approximately 10 minutes until she felt comfortable. In the next phase, the participant mounted the horse, and markers of contrasting colours were attached to specific anatomical locations on the rider's body (palpated by the researcher). The markers were placed on the following anatomical locations: acromion – bilaterally; anterior superior iliac spine – bilaterally; and spinous processes C7, Th12, and L5. We also marked the points on the horse's body (sacral tuber, base of tail) to analyse the movement of the horse's back (Robert *et al.* 2001).

Data were collected from four synchronized video cameras (JVC GR-DVL9800 and SONY DCR-TRV900E) with a sampling frequency of 25 Hz. The global coordinate (reference) system was defined as a right-handed orthogonal system (X, Y, Z), where the axes were defined as: +X pointing anteriorly (forward) along the horse's direction of motion, +Z pointing superiorly (vertical, upward), and +Y perpendicular to both the X and Z directions.

During each session the riders completed 10 rounds on a large asphalt oval. Data were collected only during sessions 1, 2, 3, 5, 7, and 9 (out of 10 sessions in total), always in the 3rd, 6th, and 9th rounds.

During each session, a physical therapist who had completed specialized hippotherapy training actively corrected the position of the participant's body when needed.

*Data processing, measured parameters, statistical analyses*

The video records were divided into the horse's individual sequential stride cycles, synchronized and analysed using the Ariel Performance Analysis System (APAS) (Ariel Dynamics Inc., Trabuco Canyon, CA, USA). The obtained 3D coordinates were used to establish 3D kinematic parameters of the rider's body: displacement of the C7, Th12, and L5 in the vertical and mediolateral directions; and rotation and lateral tilt of the shoulders and pelvis. Stride duration and length were obtained from the video record of the horse's movement.

A one-way ANOVA for repeated measurements with an LSD Fisher's post hoc test was computed using the Statistica programme (Version 9; StatSoft, Inc., Tulsa, OK, USA). Spearman's correlation coefficient was used to assess the relationship between the selected points on the rider's body and the horse's back. The level of significance was set at $\alpha<0.05$.

## RESULTS

*Spatiotemporal parameters of the horses' movements*

The spatial and temporal values of gait parameters of the observed horses are shown in Table 1. The values are presented as the means of all sessions because there were no significant differences in the measurements among the individual sessions. There were significant differences ($p<0.05$) between the values of spatiotemporal parameters measured in both horses, so we evaluated the results for each horse individually.

**Tab. 1.** Spatiotemporal gait parameters of horses (Mean ± SD)

| Parameter | Horse H1 | Horse H2 |
|---|---|---|
| Gait speed (m.s$^{-1}$) | 1.46±0.061 | 1.38±0.059 |
| Step length (m) | 1.76±0.040 | 1.79±0.030 |
| Step frequency (Hz) | 0.83±0.030 | 0.77±0.020 |

*Comparison of kinematic parameters of riders' trunk between individual rounds in first three sessions*

Because the individuals observed in the study were exposed to a new balance situation, we focused on the riders' movement changes during the first three sessions (measured parameters compared at rounds 3, 6, and 9).

Horse H1

The mediolateral displacement of C7 in the first three sessions was smaller in the 6$^{th}$ round in comparison to the 3$^{rd}$ round (Table 2), the difference was statistically significant in the 1$^{st}$ ($p$=0.015) and 3$^{rd}$ session ($p$=0.036). Similarly, a statistically significant difference was seen in the 1$^{st}$ session between the 3$^{rd}$ and 6$^{th}$ round for the mediolateral displacements of Th12 ($p$=0.036) and L5 ($p$=0.048). We did not find any statistically significant differences for the vertical displacements of the monitored points on the rider's back or for the movement of shoulders and pelvis between individual rounds in any of the first three sessions.

Horse H2

The mediolateral displacements of C7 and Th12 during the 3$^{rd}$, 6$^{th}$ and 9$^{th}$ rounds of the first three sessions were gradually decreasing (Table 3). The difference between the 3$^{rd}$ and 9$^{th}$ round in the 3$^{rd}$ session was statistically significant (C7: $p$=0.033, Th12: $p$=0.031). The mediolateral displacement of L5 was gradually decreasing as well, with statistically significant differences in the 3$^{rd}$ session between 3$^{rd}$ and 9$^{th}$ round ($p$=0.024) and

**Tab. 2.** Mean (± SD) of kinematic parameters obtained during first three sessions with horse H1.

| | Session 1 | | | Session 2 | | | Session 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Round 3 | Round 6 | Round 9 | Round 3 | Round 6 | Round 9 | Round 3 | Round 6 | Round 9 |
| C7 mediolateral displacement (cm) | 8.6±4.7 | 4.9±2.3 | 5.7±2.4 | 5.9±2.7 | 4.6±1.9 | 7.0±3.2 | 9.7±4.8 | 6.2±5.0 | 6.9±3.4 |
| C7 vertical displacement (cm) | 2.5±1.1 | 2.7±1.0 | 2.7±0.9 | 1.9±0.4 | 2.0±0.8 | 1.9±0.6 | 2.9±0.7 | 2.5±1.1 | 2.3±1.0 |
| Th12 mediolateral displacement (cm) | 9.1±4.9 | 5.7±2.3 | 6.9±2.3 | 6.8±2.7 | 5.9±2.2 | 7.4±3.5 | 9.0±6.3 | 6.1±4.8 | 6.6±3.4 |
| Th12 vertical displacement (cm) | 3.0±1.0 | 3.1±1.3 | 3.1±0.8 | 1.9±0.7 | 2.1±0.7 | 2.0±0.8 | 3.2±0.9 | 2.9±0.8 | 2.5±0.6 |
| L5 mediolateral displacement (cm) | 9.5±4.2 | 6.4±2.4 | 7.5±2.5 | 7.6±2.7 | 5.8±2.0 | 7.3±3.3 | 9.4±6.5 | 7.0±4.5 | 6.7±3.1 |
| L5 vertical displacement (cm) | 2.9±1.1 | 3.3±1.1 | 2.8±1.3 | 2.1±0.7 | 2.3±0.8 | 2.0±1.2 | 3.1±1.2 | 2.9±1.2 | 2.8±0.7 |
| Shoulders lateral tilt (deg) | 5.0±0.9 | 5.3±1.3 | 4.9±1.5 | 4.6±1.4 | 3.9±0.8 | 4.5±1.4 | 5.3±1.9 | 6.4±1.4 | 5.5±1.7 |
| Shoulders rotation (deg) | 10.0±2.7 | 9.4±2.6 | 8.2±2.1 | 11.7±5.1 | 12.7±6.3 | 12.0±3.4 | 16.7±7.0 | 15.4±5.0 | 18.5±4.1 |
| Pelvic lateral tilt (deg) | 6.1±1.9 | 6.0±2.2 | 6.4±1.6 | 4.8±1.2 | 6.3±3.0 | 5.9±1.6 | 5.7±1.2 | 5.3±1.3 | 5.8±0.9 |
| Pelvic rotation (deg) | 11.6±4.3 | 11.3±1.6 | 12.6±2.8 | 9.8±4.0 | 12.2±4.6 | 12.2±5.5 | 20.1±9.2 | 15.2±4.9 | 20.2±7.8 |

**Tab. 3.** Mean (± SD) of kinematic parameters obtained during first three sessions with horse H2.

| | Session 1 | | | Session 2 | | | Session 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Round 3 | Round 6 | Round 9 | Round 3 | Round 6 | Round 9 | Round 3 | Round 6 | Round 9 |
| C7 mediolateral displacement (cm) | 6.8±5.0 | 6.6±2.2 | 5.3±2.8 | 6.7±3.7 | 7.2±3.7 | 4.5±2.0 | 8.5±5.0 | 7.3±4.0 | 4.9±1.5 |
| C7 vertical displacement (cm) | 3.3±0.5 | 3.4±0.6 | 3.5±0.9 | 3.0±0.7 | 3.2±0.6 | 3.5±0.5 | 2.6±0.6 | 2.7±1.0 | 2.6±0.7 |
| Th12 mediolateral displacement (cm) | 6.7±5.1 | 6.3±2.5 | 5.3±2.4 | 7.2±4.2 | 6.6±4.2 | 4.4±1.8 | 7.8±5.5 | 6.8±3.4 | 4.1±1.6 |
| Th12 vertical displacement (cm) | 3.4±0.8 | 3.7±0.9 | 3.5±1.2 | 3.4±0.7 | 3.5±0.7 | 4.1±0.7 | 2.7±0.6 | 3.1±0.5 | 3.3±1.1 |
| L5 mediolateral displacement (cm) | 7.2±4.8 | 6.6±2.7 | 5.1±2.6 | 8.1±4.0 | 7.0±3.6 | 5.0±1.7 | 7.8±5.4 | 7.2±3.2 | 4.1±1.3 |
| L5 vertical displacement (cm) | 2.9±0.5 | 3.4±0.6 | 3.0±0.8 | 2.5±0.4 | 2.8±0.7 | 3.0±0.8 | 2.2±1.1 | 2.3±0.3 | 2.4±0.6 |
| Shoulders lateral tilt (deg) | 4.4±1.3 | 5.5±2.4 | 5.3±1.5 | 3.2±0.8 | 3.3±1.1 | 4.9±1.6 | 4.0±1.3 | 3.7±1.5 | 4.8±1.7 |
| Shoulders rotation (deg) | 7.8±2.9 | 8.6±4.9 | 6.9±1.7 | 7.7±3.9 | 8.3±2.6 | 7.9±2.2 | 10.7±4.2 | 8.7±3.0 | 10.7±4.3 |
| Pelvic lateral tilt (deg) | 5.2±1.5 | 5.8±1.6 | 4.7±1.4 | 4.6±1.5 | 4.0±1.2 | 4.8±1.3 | 3.5±0.9 | 4.2±1.1 | 3.7±1.3 |
| Pelvic rotation (deg) | 8.5±3.3 | 8.5±2.9 | 8.2±2.1 | 9.1±2.7 | 9.6±2.5 | 10.0±2.6 | 11.9±3.0 | 11.4±4.1 | 10.6±3.9 |

between 6$^{th}$ and 9$^{th}$ round ($p$=0.045). Similarly as with horse H1, we did not find any statistically significant differences for the vertical displacements of the monitored points on the rider's back or for the movement of shoulders and pelvis between individual rounds in any of the first three sessions.

*Comparison of kinematic parameters of riders' trunk in all measured sessions*

Horse H1

The mean displacement in the mediolateral direction during the six measured sessions was between 4.4–7.6 cm for C7, 5.1–7.3 cm for Th12, and 6.2–8.1 cm for L5 (Figure 1). With the exception of the differences between the smallest (7$^{th}$ session for all of the points) and largest (3$^{rd}$ session for points C7 and Th12 and 5$^{th}$ session for L5) values, there were no statistically significant differences.

The mean displacement in the vertical direction during the six measured sessions was between 1.9–3.2 cm for C7, 2.0–3.5 cm for Th12, and 2.1–3.9 cm for L5. The difference between the measured values of point C7 did not exceed 0.6 cm, with the exception of the smallest value measured during the 2$^{nd}$ session. The differences between the 2$^{nd}$ and other sessions were statistically significant ($p$<0.05) for the displacement of C7 and Th12. There was a statistically significant difference for L5 displacement ($p$<0.01) between the smallest (2$^{nd}$ session) and largest (7$^{th}$ session) values.

The lateral tilt of the shoulders ranged from 4.2 to 5.7°, and the differences between the 3$^{rd}$ and other sessions were statistically significant ($p$<0.05) (Figure 1). The rotation of the shoulders ranged from 9.2 to 16.9°, and the differences between the individual sessions were statistically significant ($p$<0.05).

The lateral tilt of the pelvis ranged from 5.1 to 6.6°, and there were statistically significant differences between the 7$^{th}$ session (largest tilt) and all other sessions ($p$<0.05). The rotation of the pelvis was between 11.4 and 18.5°, and the differences between the individual sessions were statistically significant ($p$<0.05).

Horse H2

The mean displacement in the mediolateral direction during six measured sessions was between 5.5–7.1 cm for C5, 5.4–7.0 cm for Th12, and 5.9–7.4 cm for L5 (Figure 2). The differences among the individual sessions were not statistically significant for any of the above-mentioned vertebral points.

The mean displacement for the vertical direction during the six sessions was between 2.6–3.4 cm for C7, 3.0–3.8 cm for Th12, and 2.3–3.1 cm for L5. With the exception of the differences between the smallest and largest values, there were no statistically significant differences among the individual sessions for any of the above-mentioned vertebral points.

The shoulder tilt ranged from 3.9 to 5.0°, and there were significant differences between the 1$^{st}$ and 2$^{nd}$ sessions ($p$<0.01). The shoulder rotation ranged from 7.7 to 11.8°. The differences between the 5$^{th}$ session and all other sessions were statistically significant ($p$<0.05).

The pelvic tilt ranged from 3.7 to 5.2°. Statistically significant differences were found between the 1$^{st}$ session and 3$^{rd}$, 5$^{th}$, and 9$^{th}$ sessions ($p$<0.01). The pelvic rotation in the transverse plane ranged between 8.4 and 11.9°. Statistically significant differences existed between the 1$^{st}$ session and all other sessions ($p$<0.05).

*The interaction of the movement between the rider and a horse during the course of hippotherapy*

The dependency of the movement of the rider's trunk in relation to the vertical displacement of sacral tuber (vST) on the horse's back was used to evaluate effect of therapeutic horse riding on the rider's motor response (Table 4).

**Tab. 4.** Correlation coefficients between kinematic parameters of the rider's trunk movement and the vertical displacement of sacral tuber on the horse's back.

| | Sessions with horse H1 | | | | | | Sessions with horse H2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 7 | 9 | 1 | 2 | 3 | 5 | 7 | 9 |
| C7 vertical displacement | 0.56 ** | 0.52** | 0.48** | 0.72** | 0.68** | 0.66** | 0.77** | 0.82** | 0.67** | 0.74** | 0.70** | 0.79** |
| Th12 vertical displacement | 0.63** | 0.51** | 0.52** | 0.77** | 0.74** | 0.74** | 0.74** | 0.85** | 0.75** | 0.78** | 0.77** | 0.82** |
| Shoulders lateral tilt | 0.69** | 0.54** | 0.61** | 0.78** | 0.78** | 0.72** | 0.73** | 0.74** | 0.63** | 0.73** | 0.66** | 0.77** |
| Shoulders rotation | 0.34* | 0.34* | 0.21 | 0.30 | 0.38* | 0.28 | 0.27 | 0.32 | 0.17 | 0.28 | 0.26 | 0.06 |
| Pelvic lateral tilt | 0.33 | 0.28 | 0.33* | 0.29 | 0.40* | 0.35* | 0.29 | 0.29 | 0.34* | 0.20 | 0.25 | 0.11 |
| Pelvic rotation | 0.45** | 0.29 | 0.39* | 0.38* | 0.40* | 0.28 | 0.33* | 0.33 | 0.13 | 0.35* | 0.32 | 0.32 |
| Shoulders lateral tilt | 0.22 | 0.30 | 0.32 | 0.19 | 0.44** | 0.17 | 0.24 | 0.24 | 0.30 | 0.10 | 0.26 | 0.11 |

*$p<0.05$, **$p<0.01$

Horse H1

The relationship between the vertical displacement of C7 and vST was statistically significant ($p<0.01$) during all sessions. This dependency increased during the last three measured sessions. We also noticed similar tendencies for the displacement of Th12 and L5. There was a statistically significant correlation for the shoulder lateral tilt in the 1st, 2nd, and 7th sessions ($p<0.05$) and the shoulder rotation in the 3rd, 7th, and 9th sessions ($p<0.05$). The strongest relationship between the pelvic lateral tilt and vST was found in the 1st session ($p<0.01$); other statistically significant relationships were found in the 3rd, 5th, and 7th sessions ($p<0.05$). The relationship between the pelvic rotation and vST was the statistically significant only in the 5th session ($p<0.01$).

Horse 2

The relationships between the displacement of C7, Th12, and L5 and vST were statistically significant ($p<0.01$) during all hippotherapy sessions. In contrast with horse H1, the correlation coefficients for horse H2 did not show large differences during the six measured

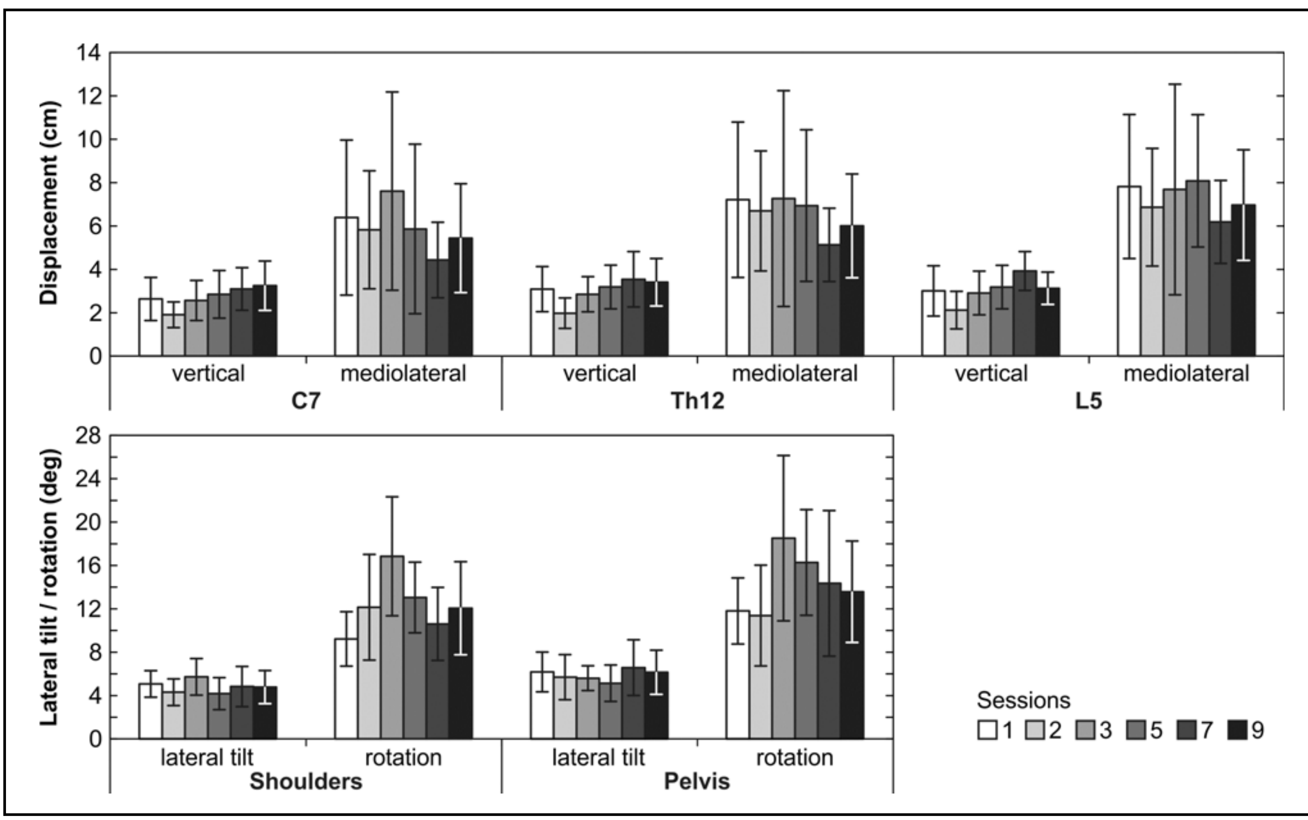


**Fig. 1.** Mean (± SD) of kinematic parameters obtained during all measured sessions with horse H1.

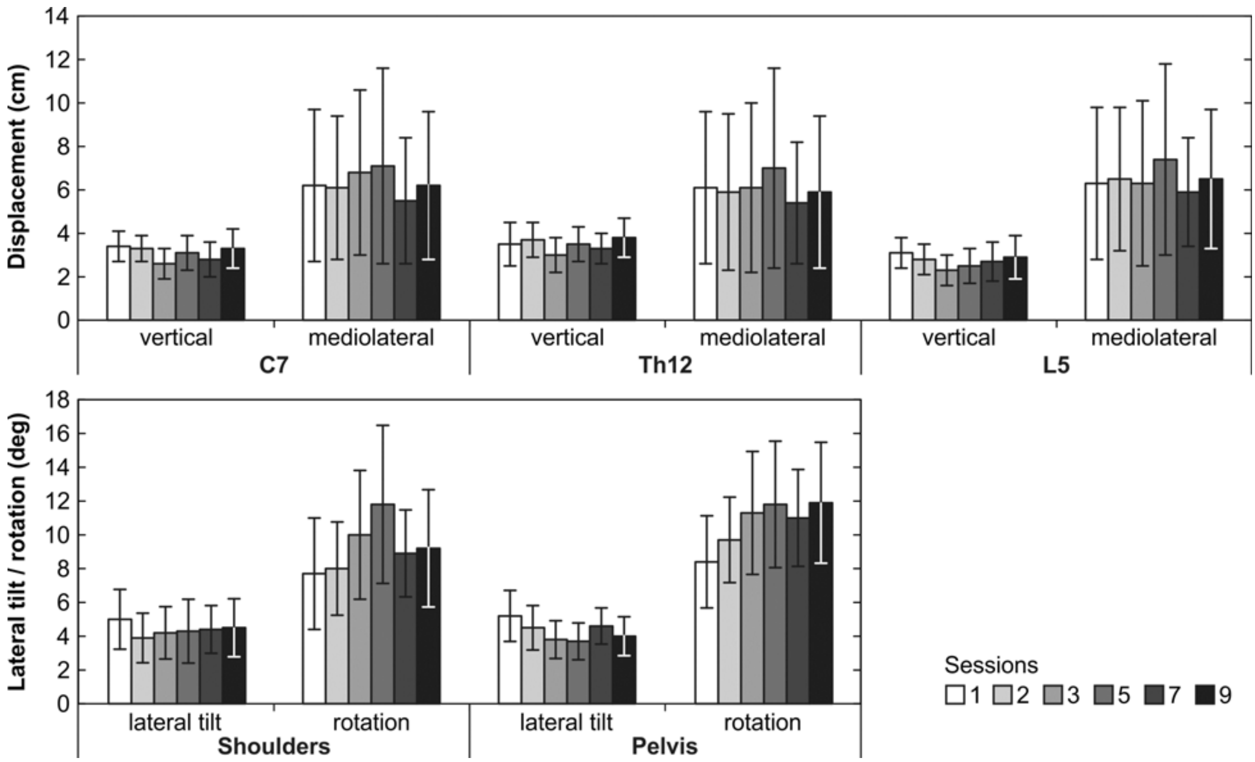


**Fig. 2.** Mean (± SD) of kinematic parameters obtained during all measured sessions with horse H2.

sessions. We did not find any significant relationship between the shoulder lateral tilt or rotation and vST, except for rotation in the 3rd session ($p<0.05$). Pelvic lateral tilt showed similar correlation coefficients in all measured sessions, with the exception of the 3rd session, but a significant correlation ($p<0.05$) was found only in the 1st and 5th sessions.

## DISCUSSION

Effect of hippotherapy is demonstrated in the changes in patients' neuromusculoskeletal systems. Hippotherapy is important for the integration of motor afference and activation of one muscle facilitating other muscles in a given locomotion chain (Holly & Hornacek 2005). Proper neuromuscular activity is necessary for joint protection (Stastny *et al.* 2014). Adaptation to the rhythm of three-dimensional movements of the horse's back is one of the key factors of hippotherapy (Beinotti *et al.* 2010). The experience of the learning reaction to the rhythmic movement of the horse is crucial for motor learning and control (Casady & Nichols-Larsen 2004). To assess this relationship in our pilot study we used results of able-bodied persons during repeated riding sessions on the therapeutic horse.

The horse's walk in hippotherapy consists of accurate, smooth, rhythmic, and repetitive movements (McGee & Reese 2009). Stability of the horse's movement as a "tool" used for rehabilitation purposes is a necessary prerequisite for achieving an adequate therapeutic effect. It is necessary that the horse is well relaxed to secure stability of the horse's movement (Knopfhart 2002). For this reason, both horses were walked for approximately 15 minutes in the field before beginning data collection.

The basic spatiotemporal parameters of the horses' walk during repeated sessions, obtained as a part of our study, did not vary significantly. Walk frequency (50 resp. 46 strides per minute) was smaller than claimed by Clayton (2002) (55 strides per minute) for a medium speed walk. Values of mean stride length (1.76 and 1.79 m) were similar to those (1.82 m) in the study by Faber *et al.* (2002). Stability in the basic spatiotemporal parameters was achieved, despite the fact that the variability in velocity and acceleration in a forward direction is significantly higher in the un-ridden horse than in the ridden horse (Peham *et al.* 2004). In hippotherapy, in contrast to equitation, the rider is rather a passive element, only stimulated by mechanical impulses produced by the moving horse's back.

It is important to assess the horse-rider interaction during the walk (horse's walk speed ranged from 1.45 to 1.47 $m \cdot s^{-1}$) because the rider's influence on the horse's movements seems to be maximal at low walk speeds (Byström *et al.* 2010). Rider movements during the walk are more likely to relate to the alternating level difference between the horse's croup and withers than to deviations and accelerations of the horse's trunk in trot (Byström *et al.* 2009). During the walk, the horse's movement pattern is most sensitive to an influence from an unskilled rider (Collins 2006). In hippotherapy, the patient sitting on the walking horse only maintains his or her balance while the leader controls the horse's movement.

Hippotherapy is implemented by several representatives from different disciplines (All & Loving 1999), who form a multidisciplinary team (Gabrielová & Velemínský 2014). Measuring able-bodied persons allowed us to use a smaller team than what would be required to carry out and measure a regular hippotherapy session.

A faster adaptation phase to movement impulses transmitted from the back of a horse can be expected in able-bodied persons (Janura *et al.* 2009), resulting in fewer problems with the riders' balance. Therefore, we decided to address adaptation of the rider in more detail during the first three sessions.

There was a gradual reduction of displacement of the points on the rider's spine (C7, Th12, and L5) in the mediolateral direction during each of the first three sessions. We believe this change was caused by the rider's adjustment to the horse's movement. There is a correlation between the rider's skill and the consistency of motion of the ridden horse. Movement of the rider's trunk is influenced by the horse's walking mechanism. The horse's step length affects the size of the lateral bending of the horse's trunk and the swing amplitude of the horse's barrel (Harris 1993). The lateral movement of the horse's abdomen produces deviations in the mediolateral direction, which are followed by the rider's pelvic movement.

At the beginning of riding sessions, there is an accompanying higher muscle tension of the individual, similar to that experienced when learning a new locomotor activity (Peham *et al.* 2001). Skilled riders exhibit flexible motion, absorbing the horse's movements, whereas less-skilled riders are stiff and tense in their adjustments and unable to follow the horse's movements (Lagarde *et al.* 2005). Larger muscle activity results in a higher position of the rider's COM above the horse's back at the beginning of therapy. Gradual relaxation leads to the rider adjusting to the horse's movement when fully "seated" on its back.

For both groups (horses H1 and H2), the displacement of the points on the rider's spine in the vertical direction was smaller than in the mediolateral direction. A similar trend was also found for the lateral tilt in comparison with the rotation of the rider's shoulders and pelvis. The horse's movement affects these changes when the range of motion of the rear part of the horse's trunk in the mediolateral direction is greater in comparison with the vertical movement (Jeffcott *et al.* 1999). During walking, the horse's trunk rotates about the mediolateral axis, resulting from the alternating up-and-down motion of the cranial and caudal parts of the trunk (Hübener 2004), and the rider passively follows this movement.

The results for horses H1 and H2 were different. The magnitude of shoulder and pelvic lateral tilt and rotation, as well as the variability of these parameters, was larger for horse H1. These differences might have been caused by the riders' groups where these specific parameters were measured. The higher average walking speed of horse H1 was more important; because the increased speed indicates a greater rotation of the shoulders and pelvis (Münz *et al.* 2014). We did not find generally valid trends related to the rider's increasing experience with riding to identify statistically significant differences among the individual therapeutic horse riding sessions. The differences in the points' displacements were, in most cases, approximately 1 cm, and we do not consider them sufficiently large to prove the effect of the repeated riding sessions.

Dependency of the vertical displacement of the rider's spinal points on the vertical displacement of the horse's back (sacral tuber point) was statistically significant during all measured sessions. While there were not any noticeable differences in the strength of correlation in the observed parameters with horse H2 in between individual sessions, there was a stronger relationship between those parameters in horse H1 in last three measured sessions. We assume that this change, among others, could be caused by a rider's response to a body position correction by a physical therapist. This change repeatedly took place during the first sessions, in accordance with the hippotherapy methodology, and was more frequent in horse H1.

The number of statistically significant dependencies for the pelvic rotation was smaller. This outcome is probably because the movement of the horse's back was represented only by one point. Münz *et al.* (2014) also suggested a stronger coupling for pelvic rotation than for pelvic tilt.

The number of significant dependencies for shoulder rotation was comparable to the number of dependencies for pelvic rotation. This finding was not surprising, even though the distance from the rider's shoulders to the horse's back is greater. The impulses from the back of the horse to the rider's shoulders are transmitted via a kinematic chain which consists of the individual spinal segments. Thus, the rider's upper body movements during walking seem to be individual and dependent on the rider's skill level (Byström *et al.* 2010).

## LIMITATION OF THE STUDY

Although the horse is one of the key factors involved in hippotherapy's resultant effect, we used two horses, which was necessary to avoid potential overloading of the horses. The magnitude of movement impulses from the horse's back can also be influenced by equine conformation (Matsuura *et al.* 2008). Faber *et al.* (2002)

mentioned that, in general, back-movement variability between horses is greater than variability between strides and testing days. Both horses in our study were of the same breed and had similar conformation, which helped to minimize differences in motion between the horses.

Six experienced handlers led the horses during data collection and they were acquainted with the measurement objectives. Nevertheless, it is possible that their movement and thus the walking speed of the horses were influenced by the external environment and their immediate status.

Variable weather conditions may have been another factor affecting the horses' movement. During the study, weather conditions varied from windy with slight rain and temperatures around 15 °C to warm summer weather with temperatures around 25 °C.

Healthy individuals who were not hippotherapy patients participated in the study. Actual hippotherapy patients typically hold the horse's reins during therapy; however, our study participants did not hold the reins in order to challenge their balance. The narrow backs of the Thoroughbred increased the level of stimulation of balance functions. We believe that by increasing these balance requirements for our participants, the conclusions we obtained can be applied to other groups of persons, including those undertaking hippotherapy.

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