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The influence of walking speed on equine back motion in relation to hippotherapy

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Summary

Hippotherapy is a method of treatment used by physiotherapists, which involves horses as treatment tools. Kinematic analyses of the horse's back are usually carried out on a treadmill. However, for the requirements of hippotherapy, an assessment of the movement in overground conditions is necessary. This study investigates the relationship between the walking speed of the horse and the vertical and horizontal displacements of chosen points on the horse's back. Our hypothesis is that the vertical and horizontal displacements of the equine back are influenced by the speed of the movement of the horse when walking.

7 horses (age 13.1 ± 2.6 years) took part in the study. Hemispheric markers were attached to selected points on the horse's back (top of the withers, a point at a quarter distance from the top of the withers to the sacral tuber, a point halfway between the distance from the top of the withers to the sacral tuber, the sacral tuber, the left and right proximal scapular spine, and the left and right coxal tuber) and were tracked semi-automatically while walking at 3 different speeds of movement (slow: 1.07 ± 0.08 $m.s^{-1}$, regular: 1.38 ± 0.09 $m.s^{-1}$, fast: 1.59 ± 0.13 $m.s^{-1}$). The range of movement of the selected points in the vertical and laterolateral directions was determined and evaluated in relation to the speed of the movement. Data were statistically analysed using the Friedman test and sign test.

With increasing speed, there is an increase of both the stride length and stride frequency. In the central part of the back and at the pelvic end, the increasing walking speed led to an increase in vertical and, in the case of the pelvic area, horizontal (laterolateral) displacement. In the thoracic area there was a tendency towards a decrease in lateromotion and an increase in axial rotation with increasing speed.

The length of the step, the vertical displacement of the pelvic parts of the back and the stride frequency were greater during the fast walk in comparison with the slow walk. This is of clinical relevance, as substantial movement of the pelvic part of the back can influence the patients during hippotherapy in the cases when they are lying on their stomach, with their elbows in the region of the coxal tuber of the horse's back.

Schlüsselwörter: Pferd, Pferderücken, Hippotherapie, Geschwindigkeit, Kinematik, Verschiebung**.**

Zusammenfassung

Der Einfluß der Schrittgeschwindigkeit auf die Rückenbewegung des Pferdes in Bezug auf die hippotherapeutische Anwendung

Hippotherapie ist eine physiotherapeutische Behandlung, die als ein Rehabilitationshilfsmittel das Pferd benützt. Heutzutage ist die kinematische Analysen von Pferden auf einem Laufband "state of the art". Hippotherapie ist jedoch auf einem Laufband nicht möglich.

Ziel dieser Studie war es, die Rückenbewegung des Pferdes in verschiedenen Schrittgeschwindigkeiten zu im Hinblick auf die Hippotherapie zu dokumentieren.

7 Pferde (Alter von 13,1   2,6 Jahre) nahmen an der Studie teil. Reflektierende Marker wurden am Pferderücken (höchster Punkt des Widerrists, 2 Marker in der Sattellage, ein Marker über der Lendenwirbelsäule und ein Marker am Kreuzbein) angebracht. Die Pferde wurden in 3 Geschwindigkeit (langsam: 1,07 ± 0,08 m.s-1, natürlich: 1,38 ± 0,09 m.s-1, schnell: 1,59 ± 0,13 m.s-1) vorgeführt und die Bewegung der Marker 2-dimensional aufgezeichnet. Die Daten wurden mit Hilfe von nichtparametrischen Tests (Friedman Test, Vorzeichen Test) auf Unterschiede überprüft.

Mit zunehmender Geschwindigkeit nahm die Auslenkung der Marker sowohl in vertikaler als auch in horizontaler Richtung in der Satteliage zu. Dies ist auf die vergrößerte Schrittlänge und erhöhte Schrittfrequenz zurückzuführen.

Diese Erkenntnisse liefern wichtige Basisdaten für die Hippotherapeuten, die die Pferdegeschwindigkeit individuell auf den Patient damit anpassen können.

Abbreviations: APAS = Ariel Performance Analysis System; LCS = local coordinate system; p = statistical significance; P0 = point at a quarter distance from the top of the withers and sacral tuber; P1 = point halfway between the top of the withers and sacral tuber; P2 = sacral tuber; PSS = proximal scapular spine; SD = standard deviation; TC = coxal tuber; TW = top of the withers

Introduction

Hippotherapy can be defined as a method of treatment for patients with movement dysfunctions and/or neurological disorders used by physiotherapists trained in using horses as treatment tools (ENGEL, 2001). It uses the rhythmically moving back of a horse while walking (WHEELER, 2003).

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Most authors who were engaged in the area of hippotherapy have observed the benefits of this therapy. STERBA et al. (2002) found that horseback riding therapy may improve gross motor function in children with cerebral palsy. KUCZYNSKI and SLONKA (1999) mentioned that artificial saddle riding has a beneficial effect on the stability posture of these children.

LECHNER et al. (2007) observed patients with spinal cord injuries. They suggested that hippotherapy is more efficient in temporarily reducing spasticity in comparison with sitting astride a Bobath roll or on a rocking seat. In addition, hippotherapy had a positive short-term effect on the subjects' mental well being. These studies have described the therapeutic effects of hippotherapy. However, there is a need to describe the movements of the equine back and the influences thereon for the optimal use of the horse in hippotherapy as a "rehabilitation tool".

The kinematic variables of equine locomotion can be influenced by many factors. BUCHNER et al. (1994) found that lameness influences head and trunk movement. At walk, horses with back dysfunctions have a smaller range of axial rotation of the pelvis in comparison with sound horses (WENNERSTRAND et al., 2004). The movement of the back can also be influenced by the head and neck position (RHODIN et al., 2005). They showed that when the head was fixed in a high position while walking the flexion-extension movement, lateral bending and axial rotation were reduced in comparison with the head free or in a low position. JOHNSTON et al. (2004) found that the horse's age, gender and usage influence the kinematics of back movement. Knowledge of these changes of movement in the area of the horse's back, which take place as a reaction to the mechanics of the movement of the horse's limbs while walking, is invaluable knowledge for the physiotherapist in terms of being able to choose a specific type of horse and select optimal speed for a specific client.

The basic force impulses on the horse's limbs are produced by the muscles in the pelvic and shoulder girdles. The lower part of the limb "passively follows" its upper part (BACK, 2002).

Modifying the speed of the horse can be an important tool for modifying the movement of the horse's back (KÜNZLE, 2000). The effect of speed on the mechanics of the back was investigated by ROBERT et al. (2001a). They observed horses on a treadmill while trotting and found that the amplitude of the vertical movement of the trunk and maximal angles of flexion decreased with increasing speed. The extension angles remained unchanged.

The aim of this study was to describe the relationship between the speed of the horse's walk and the vertical and horizontal displacement of selected points on the back.

Materials and methods

Horses

7 horses participated in the experiment (age 13.1 ± 2.6 years, withers height of 161.3 ± 4.43 cm). All horses had regularly undergone hippotherapy lessons (therapeutic practice of 8.6 ± 3.74 years) and worked regularly. The experiment was carried out at the Bohnice Hippo-rehabilitation Centre located in Prague.

Experimental set-up and data collection

The horses were walked in hand for 15 minutes before the start of the experiment. Afterwards, contrast hemispheric markers (4 cm in diameter) were attached at sites previously described by ROBERT et al. (2001b). Points P0 and P1 were thought to be the relevant points for studying the effect of back movement on patients undergoing hippotherapy. The top of the withers served as a point for the determination of the other points (P0 and P1) and was not analyzed (Fig. 1). The horses were first twice led from the front over an 8 m long asphalt track for testing purposes. 3 attempts at high speed followed (the highest speed, during which the fluent step cycle was maintained without a tendency to slip into a trot), a further 3 at the most often used walking speed (regular) and another 3 at a slow walking speed at the end (the slowest speed, but without a tendency of the horse to stop). The varying speeds were set according to the individual possibilities of each animal.

The movement was captured using 4 synchronized digital video cameras (50 Hz). The recorded data was processed using the APAS system (Ariel Dynamics Inc, Trabuco Canyon, CA, USA).

Data analysis

The local coordinate system (LCS) was constructed from markers at the points of the coxal tuber (or proximal scapular spine). The origin of the LCS was located at a point midway between both coxal tubers. The "y" axis was a vector running in the direction of the movement. The "x" axis was calculated as the vector perpendicular to the y-axis in the horizontal plane. The "z" axis was calculated as a vector perpendicular to both x- and y-axes that was positive in an upward direction. An upward movement of the right coxal tuber in the frontal plane (rotation around Y-axis) was assigned a positive value. Similarly, the cranial movement of the right coxal tuber in the horizontal plane (rotation around the z-axis) was regarded as positive.

The walking speed was measured by photocells. The other spatial and temporal variables were derived from kinematic analysis. Stride time was calculated as the period between the moment when the right hind limb contacted the ground and the moment when the next contact of the same limb occurred. The stride length was measured as the displacement of the right hind hoof during one stride cycle.

The data derived from one stride in 3 trials at each velocity were combined and a mean curve for each horse was constructed to represent the horse's movement pattern. The observed variables were: P0_ll = laterolateral displacement of P0, P1_ll = laterolateral displacement of P1, P2_ll = laterolateral displacement of P2, P0_v = vertical displacement of P0, P1_v = vertical displacement of P1, P2_v = vertical displacement of P2, PSSc_h = proximal scapular spine angle in the horizontal plane, TCc_h = coxal tuber angle in the horizontal plane, PSSc_f = proximal scapular spine angle in the frontal plane, and TCc_f = coxal tuber angle in the frontal plane.

The statistical analysis of the entire dataset (Friedman test, sign test) was done using STATISTICA (Stat-Soft, Inc., Tulsa, OK, USA) software (Version 6). p-Values less than 0.05 were deemed significant throughout.

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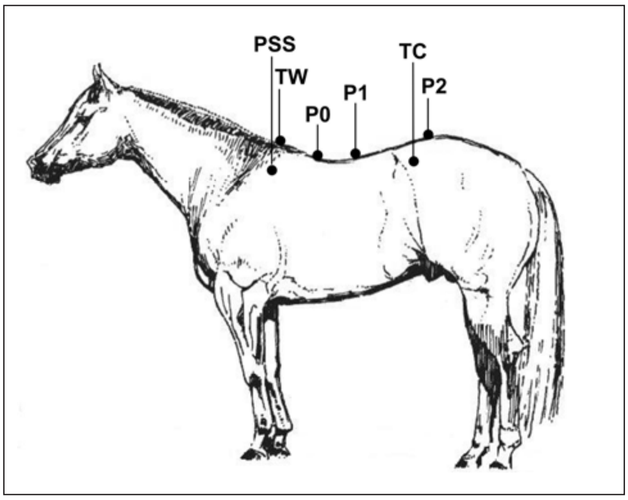

Fig 1: Evaluated points on the horse's body; TW - top of the withers; P0 - point at a quarter distance from the top of the withers and sacral tuber; P1 - point halfway between the top of the withers and sacral tuber; P2 - sacral tuber, PSS - proximal scapular spine (bilateral); TC - coxal tuber (bilateral)

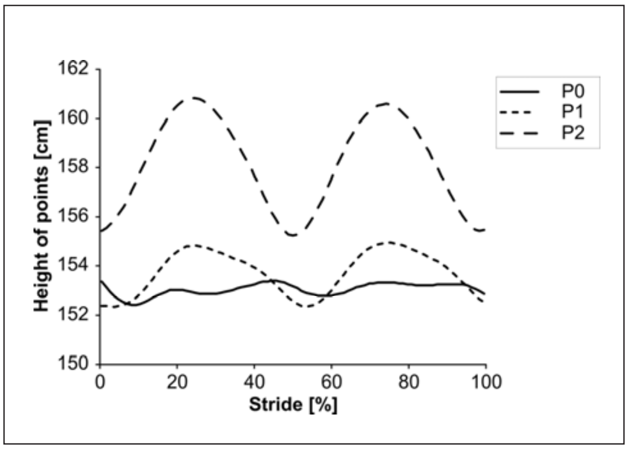

Fig 2: Vertical movement of the selected points on the horse's back during one stride at a regular walking speed

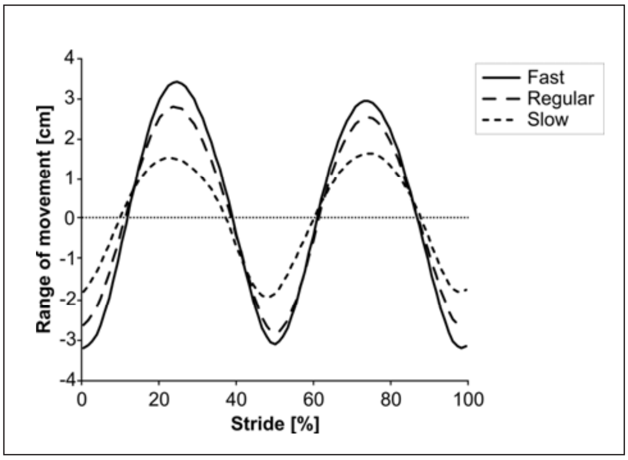

Fig 3: Range of movement in point P2 during a stride at slow, regular and fast walking speeds

Results

The mean values of the basic parameters of the stride at various speeds of the horse movements are presented in Tab. 1. The increase in speed was achieved through a combination of increases in stride frequency and stride length. In terms of the stride frequency, there were differences (for the whole group) among speeds of movement ($p<0.001$). In terms of the stride length, a difference between regular and slow walk ($p=0.023$) was noted.

The vertical displacement of the horse's back increases ($p=0.023$) in the pelvic area (point P2, Fig. 2). The horizontal displacement of the horse's back is greater in the central part (point P1); in caudal direction the range of movement decreases ($p=0.046$). These observations apply to all evaluated speeds.

When the speed of the walk increases, the observed parameters on the horse's back are subject to change (Tab. 2). The biggest differences were seen in the range of movements in the vertical direction at the pelvic end of the back (point P2). The increasing speed of movement leads to an increase in the displacement of point P2 in the vertical direction ($p=0.004$, Fig. 3), as is the case for point P1 ($p=0.042$). A change in the horse's speed was evident in the difference in the range of movement in point P2 in the laterolateral direction ($p=0.060$). When the regular walk and fast walk were compared, the difference was found to be of statistical significance ($p=0.041$).

When determining the influence of speed on the range of movement in the thoracic and pelvic areas, a trend towards a difference in movement in the frontal plane ($p=0.096$) was discovered during a slow and fast walk. The range of movement of these areas in a regular walk was found among the variables relating to slow and fast walking. In terms of the movement in the pelvic area in the horizontal plane, a trend towards a difference ($p=0.096$) between the size of the angle during a regular and fast walk and during slow and fast walk could be noted.

Discussion

This study aimed at obtaining information about the movement of the horse's back and the possibilities of modifying this movement through manipulation of the speed of the horse's walk in hippotherapy.

This influences the efficacy of hippotherapy, as variations in the horse's speed influence the intensity and frequency of the impulses transmitted by the back of the horse to the patient. It is presumed that a decrease of the horse's speed and frequency will affect the facilitation of co-ordination, the process of motor control and result in a lower level of muscle tension (HERMANNOVA, 2002).

The points on the middle part of the horse's back were chosen in such a way that it was possible to investigate the whole therapeutical area of the horse's back that is relevant in relation to the different positions of the patients as used in hippotherapy. In special cases the patient lies on the horse's back in the opposite direction to the horse's movement with their elbows resting on the coxal tuber, in contrast to the position where the patient is sitting in the area behind the withers.

BUCHNER et al. (1994) found differences in equine movement on a treadmill in the laboratory compared to the

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Tab 1: Mean values of speed, stride length and stride frequency at slow, regular and fast walk (n=7)

Variables	Slow		Regular		Fast		p (Friedman test)
	Mean	SD	Mean	SD	Mean	SD	
Speed (m.s^{-1})	1.06	0.081	1.36	0.087	1.69	0.137	<0.001
Stride length (m)	1.54	0.079	1.77	0.043	1.85	0.155	0.005
Stride frequency (Hz)	0.69	0.029	0.77	0.043	0.85	0.046	<0.001

p = statistical significance

Tab 2: Means of the observed variables at slow, regular and fast walk (n=7)

Variables	Slow		Regular		Fast		p (Friedman test)	Sign test
	Mean	SD	Mean	SD	Mean	SD		
P0_ll (cm)	6.4	1.08	6.1	1.05	5.5	0.93	0.241	S-F+
P1_ll (cm)	6.4	0.86	6.1	0.73	6	0.71	0.223	S-F*
P2_ll (cm)	4.4	0.62	4.1	0.86	5	1.07	0.060	R-F*
P0_v (cm)	2.5	0.46	2.8	0.92	2.9	0.74	0. 538	
P1_v (cm)	3.1	0.58	3.9	0.74	4.6	1.88	0.042	S-R*, S-F+
P2_v (cm)	4.2	0.46	6.6	0.99	7.6	1.42	0.004	S-R*, S-F*
PSSc_h (°)	14.3	3.73	13.9	6.04	13.4	4.34	0.432	
TCc_h (°)	9.6	2.5	9.3	2.37	8.4	1.99	0.061	S-F+, R-F+
PSSc_f (°)	20.1	7.43	20.1	7.55	21.6	6.97	0.326	
TCc_f (°)	8.4	0.98	9.9	1.96	10.4	2.06	0.076	S-F+

p = statistical significance; +p<0.1; *p<0.05; S-R = difference between slow and regular walk; S-F = difference between slow and fast walk; R-F = difference between regular and fast walk; P0 = point at a quarter distance from the top of the withers to the sacral tuber; P1 = point halfway between the top of the withers and sacral tuber; P2 = sacral tuber; PSSc = connection of points of proximal scapular spine; TCc = connection of points of coxal tuber; ll = laterolateral direction; v = vertical direction; h = horizontal plane; f = frontal plane; SD = standard deviation

outside environment. These differences should be kept in mind when data obtained during treadmill locomotion have to be transferred to overground conditions. Due to the fact that we wanted to approximate real hippotherapy conditions, we chose outside overground measurements.

The movement of the points on the horse's back has the shape of a sine curve in the vertical direction (MATSUURA et al., 2003). The displacement of points on the back (P0, P1, P2) is largest in the pelvic part of the back. This can be caused by the gradual transfer of impulses from the hind limbs of the horse, where they are generated in a forward direction. These movements are smallest in the P0 area, where the range is limited by the opposing impulse coming from the contact of the horse's front limbs. LICKA et al. (2001) found that the range of movement in the laterolateral direction at walk was 3.6 - 5.7 cm. In another study the value of this movement of the sacral tuber was established at 2.7 cm (MATSUURA et al., 2003). The smaller values reported by these authors, in comparison with ours, may be attributed to the fact that their studies were performed on a treadmill. It has been shown that the vertical displacement of the fore hoof and hind hoof at trot is significantly greater on an asphalt track than on a treadmill (BUCHNER et al., 1994).

Changing the speed of the horse's walk is one of the basic procedures employed in hippotherapy. A slow walk is considered to be less stimulating in comparison with a fast walk.

The results of our study indicate that particularly the length of the stride, the vertical displacement of the pelvic parts of the back and the stride frequency increases when the horse goes faster.

Knowledge of the differences in movement of the horse's back at various walking speeds is important for the therapist. Increasing the range of movement can be unsuitable in cases where children are positioned lying on their stomachs with their heads placed on the horse's back, as there is a danger of the cervical spine overloading in Morbus Down patients (PUESCHEL, 1990). On the other hand, a more intensive movement in the pelvic area of a horse can be more beneficial when the patients are lying on their stomachs in a more active position, with their forearms supporting their upper body (3-month age pattern of child verticalisation).

Further research should be focused on confirming results in groups of patients.

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