The influence of head and neck position on the kinematics of the back in riding horses

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Introduction

Back pain is a common problem in riding horses (Jeffcott 1979). The background for back problems of the horse is multifactorial. One factor, which might be important, is the effect of training techniques on the mechanics of the thoracolumbar spine. There is little knowledge about the interplay between the activity of the muscle groups of the back and the movement of the back during training. A common opinion among riders and in the literature is that the attitude of the head and neck influences the back of the horse but this has not been measured objectively. It has been shown that changes in head and neck attitude, caused by the reins, influence the kinetic variables most significantly in the forelimbs, while less significantly in the hindlimbs (Biau et al 2002). The use of draw reins combined with normal reins has been shown to result in shifting the weight of the horse caudally (Roepstorff et al 2002). It is generally believed that the back activity is improved by lowering the head and the neck of the horse. What this means with regard to the movement of the back is, however, unclear. Furthermore, if the horse is forced to lower its head and neck with side reins, the effect is sometimes the opposite: a decrease in back activity as the horse goes on the forehand (Hölzel, Hölzel & Plewa 1995).

The aim of this study was to evaluate the effect of head and neck position on the kinematics of the back. The hypothesis was that the kinematics of the cranial back (T10- T17) would change when the head and neck was lowered or raised with the help of side reins in comparison to when the head and neck were in a free position.

Anatomy of the equine back

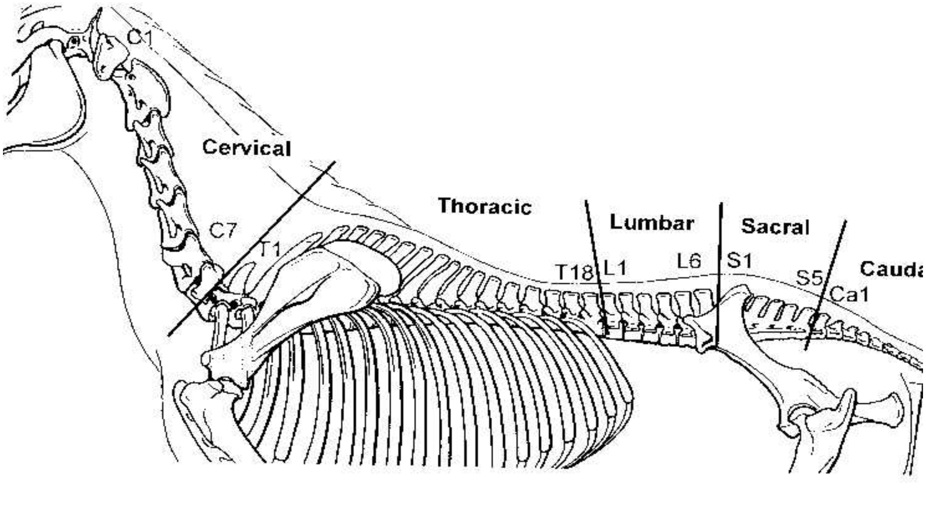

Fig. 1. The vertebral column of the horse.

The vertebral column consists of 7 cervical (C), 18 thoracic (T), 6 lumbar (L), 5 sacral (S) and 15-21 caudal (Ca) vertebrae. The number of vertebrae can vary between horses. The sacral vertebrae are fused and therefore sacrum often is described as a single bone. Each typical vertebrae has a body, an arch around the vertebral foramen, two pairs of articular processes, two transverse processes and one dorsal spinous process, but the appearance of the vertebrae differ according to their position in the vertebral column. They vary in size and form. There are two types of articulations between the vertebrae, those formed by the bodies and those formed by the articular processes.

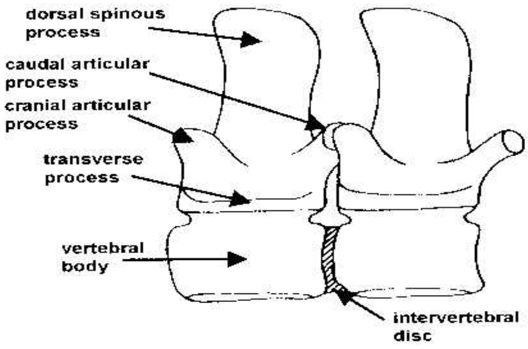

Fig. 2. Two schematic vertebrae.

Atlas (C1) and axis (C2) are highly modified in conformity with the special functions of support and movements of the head (Sisson & Grossman 1975). The cervical vertebrae are longer than the other vertebrae. The cranial articular processes present dorsally concave surfaces for articulation with the caudal pair of the preceding vertebra. In the neck the articular processes are large and wide apart, greatly reduced and much closer together in the dorsum, and in the lumbar region they are larger again. The transverse processes are large in the neck and are short and have facets for the ribs in the thoracic region. In the lumbar region they have an elongated plate-like form and in the sacral part they are fused to form the wings and lateral parts of the sacrum. The dorsal spinous processes in the midline are low ridges in the cervical region except for C2 and C7. They reach their maximum height at the fourth and fifth thoracic vertebrae, form the withers at T3 to T8 and fade out about Ca3. Cranially the spinous processes are inclined caudally but at T16, which is vertical and is termed the anticlinal or diaphragmatic vertebra, the inclination changes to cranial. At S1 there is an abrupt change to the caudal inclination again which contributes to the big space between L6 and S1, which can easily be palpated.

Viewed laterally, the column presents a series of curves. When the head and neck are in the ordinary neutral position, the cranial part of the cervical spine forms a gentle curve, concave ventrally, that does not correspond to the top line of the neck of the horse. The curves formed by the summits of the spines from the withers to the tail correspond to the top line of the horse but not to the curves formed by the bodies of the vertebrae (Sisson & Grossman 1975). Intervertebral discs are placed in the space between the bodies of two adjacent vertebrae, to which the disc is intimately attached. The discs are thinnest in the midthoracic region and become thicker in the caudal region (Sisson & Grossman 1975). The nuchal ligament extends from the occipital bone to the withers from where it continues as the supraspinous ligament, which stretches between the spinous processes, except L6 and S1. The function of the elastic nuchal ligament is to support the head and neck. The vertebral bodies and intervertebral discs are ventrally attached to the ventral longitudinal ligament, and on the floor of the vertebral canal, from axis to the sacrum, the dorsal longitudinal ligament is attached. In the lumbar region there are intertransverse ligaments between the transverse processes (Sisson & Grossman 1975).

The muscles of the back.

The muscles of the back can be divided into three main groups:

Superficial layer	cutaneous muscles
	trapezius muscle
Deeper layer	serratus dorsalis cranialis
	serratus dorsalis caudalis
	longissimus dorsi
	multifidus dorsi
	iliocostalis dorsalis
	intertransversales lumborum
Sublumbar and middle gluteal muscles	psoas minor
	psoas major
	iliacus
	quadratus lumborum
	middle gluteal

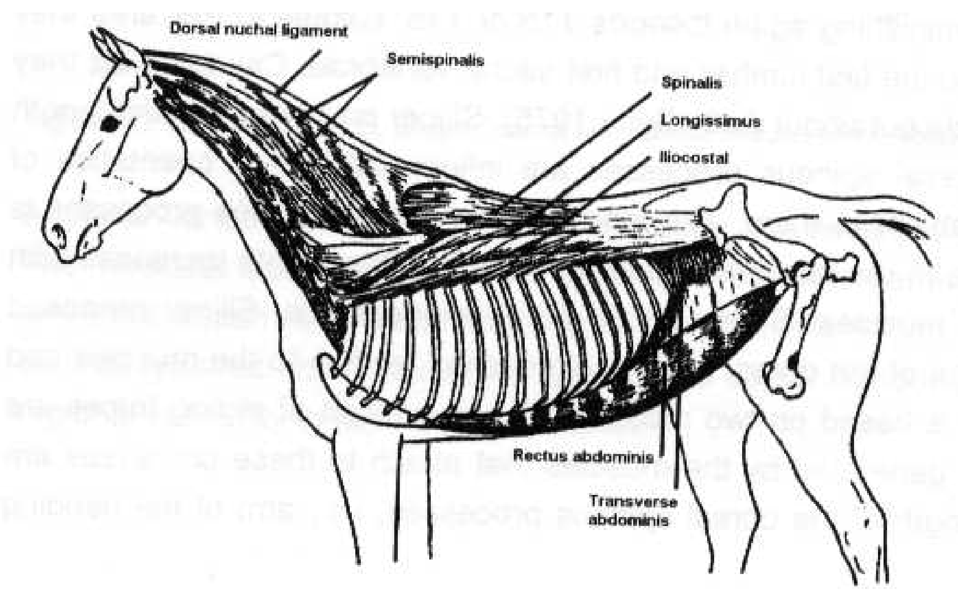

Fig. 3. The superficial muscles of the back.

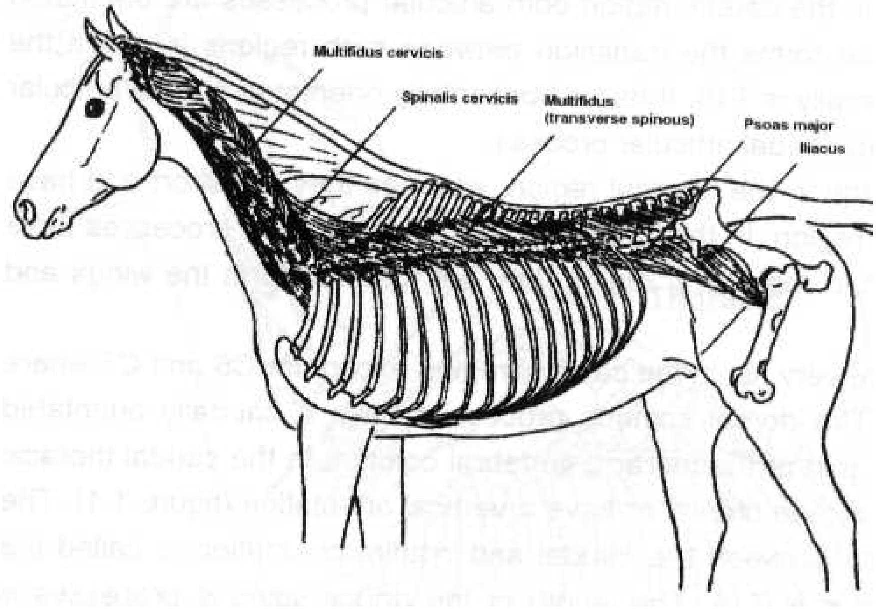

Fig.4. Deep muscles of the back.

Longissimus dorsi is a very important muscle of the back. It is the most powerful extensor of the back and loins and when only acting on one side it flexes the spine laterally and assists in extending the neck. The primary role of the muscles of the back is to control the stiffness of the back rather than to induce movement (Jeffcott 1980; Robert et al 2001), therefore when the back extend rectus abdominis is active and when the back is flexed longissimus dorsi is active (Robert et al 2001).

Functional models of the vertebral column

Each vertebrae can rotate in three planes and this causes three kinds of movements of the spine: extension/ flexion, lateral bending and axial rotation.

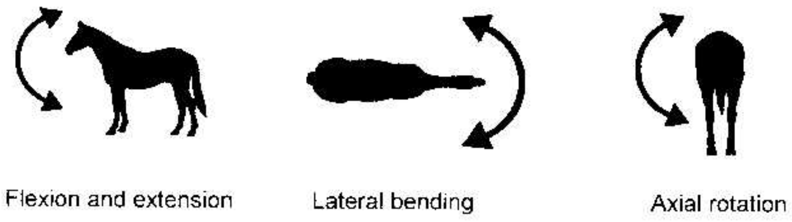

Fig. 5. Illustration of the three rotations in the vertebral column.

The horse has a rigid spine during locomotion compared to other mammals such as cats and dogs. The two most important functions of the vertebral column in quadrupeds are 1) to carry part of the body mass and 2) to transmit the forward-directed propulsive forces. This has resulted in a complex structure. In the “bow-and string theory” (Slijper 1946), the body-axis (vertebral column and spinal musculature), is seen as part of the construction of the whole trunk-skeleton. The construction is formed by an elastic bow (pelvis and body-axis) that is kept rigid and under tension by a string (sternum, ventral abdominal musculature and the linea alba). The ribs and the oblique and transverse abdominal muscles connect the bow and string. The limb muscles can influence the curvature of the bow, i.e., the amount of flexion and extension. The protractor muscles of the forelimb and the retractors of the hindlimb (e.g. m. biceps femoris) will tend to bend the bow, just as the abdominal muscles. The retractors of the forelimb (e.g. latissimus dorsi) and the protractors of the hindlimb (e.g. m psoas) will tend to stretch the bow, just as the epaxial musculature (Gray 1944). Excessive flexion of the bow is prevented by the dorsal spinous processes with their ligaments. Over-extension of the bow is prevented by the abdominal musculature and to some extent by the ventral longitudinal ligament of the vertebral column. Between these two extreme positions, the tension on the bow and string is constantly adjusted to the external circumstances.

In the functional model described above, neither rotation nor lateral movement of the spine are considered. For axial rotation and lateral bending, Townsend et al (1983) showed that the greatest amount of movement is in the mid-thoraco-lumbar spine T11-T13. The least mobile parts of the spine are the caudal thoracic and lumbar regions. The greatest amount of dorsoventral movement of the thoracolumbar spine occurs at the lumbosacral articulation (Slijper 1946; Gambaryan 1974; Jeffcott 1980). Studies on cadavers showed that lowering of the neck causes the thorax to flex (Denoix 1987).

Materials and methods

Horses

Eight sound Swedish Warmblood riding horses (mean age 10 years, mean height 165 cm and mean weight 589 kg) were included in the study according to the following criteria:

History:
- Warmblooded riding horse between 5-15 years old
- No history of back pain or lameness the last three months
- Trained regularly and in competitive condition
- All horses included were already accustomed to treadmill work since they had earlier participated in another study.

On clinical examination:
- No initial lameness or response on flexion test of more than 1/5 degrees of lameness on any leg.
- No significant pain on back palpation

Table 1. Distribution of horses included in the study.

Horse No	Sex	Age (years)	Main use	Level	Height at withers (cm)	Weight (kg)
1	gelding	11	dressage	advance	161	573
2	stallion	10	dressage	advance	162	530
3	gelding	11	show jumping	intermediate	164	600
4	gelding	11	dressage	advance	163	590
5	mare	10	show jumping	intermediate	158	540
6	gelding	7	dressage	intermediate	176	640
7	mare	14	show jumping	intermediate	163	603
8	mare	6	mixed	novice	170	635

Clinical examination.

At visual inspection deviations in the conformation of the extremities or the back were noted. Palpation of all limbs and the back was performed. The horses were observed at walk and trot at hand on a hard surface and at lunging at each rein. Flexion tests of the entire limb of all four legs were made. The horses were lunged at a walk and a trot with the head in the three different positions studied, before they went on the treadmill.

Experimental set-up

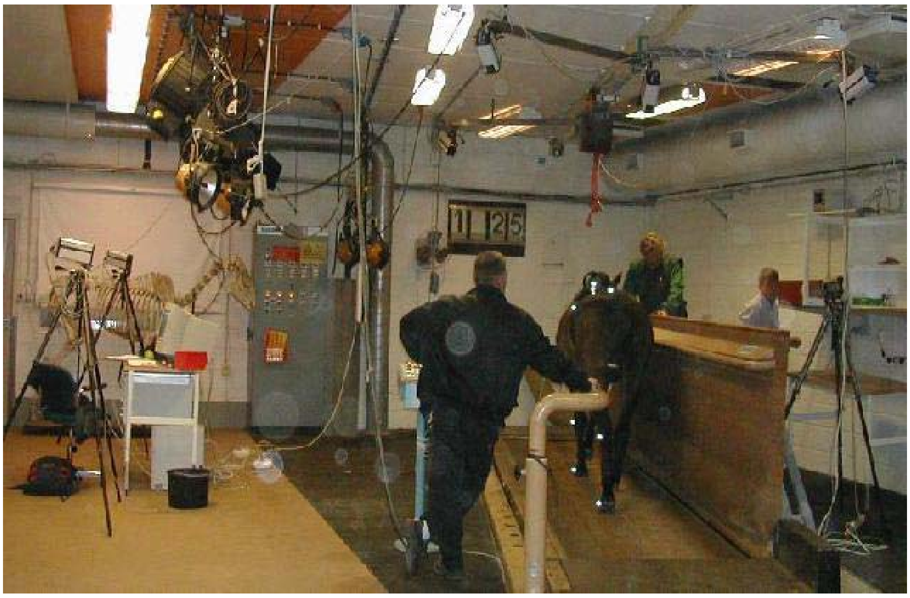

Fig. 6. The horse on the treadmill with the six cameras positioned around it.

Seventeen spherical reflective markers with a diameter of 12 mm were placed on the horse, on the skin above the dorsal spinous processes defined with palpation technique of T6, T10, T13, T17, L1, L3, L5 and S3. Additionally markers were placed on left and right tuber coxae. On the left side of the horse markers were also placed on the wing of the atlas, the regio zygomaticus, the lower part of crista facialis, the carpus, the tarsus and the lateral hoof walls of the front and hind limb. The markers were fixed with quick-drying glue. The equine locomotion analysis was made on a horisontal coir mat treadmill according to Fredricson et al (1983). Since the horses were already accustomed treadmill work they were only trained a two additional times before the measurements were made. On the first of these two occasions, they were if needed sedated (acepromazin, Plegicil®, 1 ml, im.) and wore a safety harness. The horses were examined on the treadmill at two different speeds - walk at 1,7 m/s and trot at 3,8 m/s -with the head and neck in three different positions at each speed. The three positions were as follows:

1. Free position. (Fig.7)
2. Elevation of the neck and with the bridge of the nose near the vertical position (high position) corresponding to the position described in the FEI dressage rules (Anon 1999). (Fig.8)
3. Lowering of the head with the neck close to the level of the withers (low position). (Fig.9)

Fig. 7. The free position.

Fig. 8. The high position.

Fig. 9. The low position.

The two pre-determined positions, low and high, were achieved with side reins attached to the bit and to an anti-cast roller. The examination of the head positions was made in random order at each speed. For collecting the position data of the markers, a modern commercially available motion analysis system (ProReflex®, Qualysis, Sävedalen, Sweden) consisting of six cameras was used. The system is based on passive markers and infrared cameras. The measurements were made in three planes. The y-axis was orientated parallel to the treadmill, the positive z-axis was orientated upwards and the x-axis was perpendicular to the y- and z-axis. In this paper only the results from the movements of the vertebrae in the sagittal plane (z-axis) are presented. The orientation of each segment was identified by a set of three markers. The orientation of the axes of rotation was calculated based on the average position of the markers during one stride-cycle (Faber et al 1999). Data was collected for 10 seconds during walk and during trot respectively, at a sampling rate of 240 Hz. A detailed description of the recording equipment and registration technique has earlier been published by Johnston et al 2002.

Statistical method

The differences between observations were tested by Wilcoxon matched pair test, a non parametic test for paired observations. Level of significance was chosen to be at $p<0.05$.

Results

Range of movement for flexion-extension with the head and neck in three positions at walk and trot.

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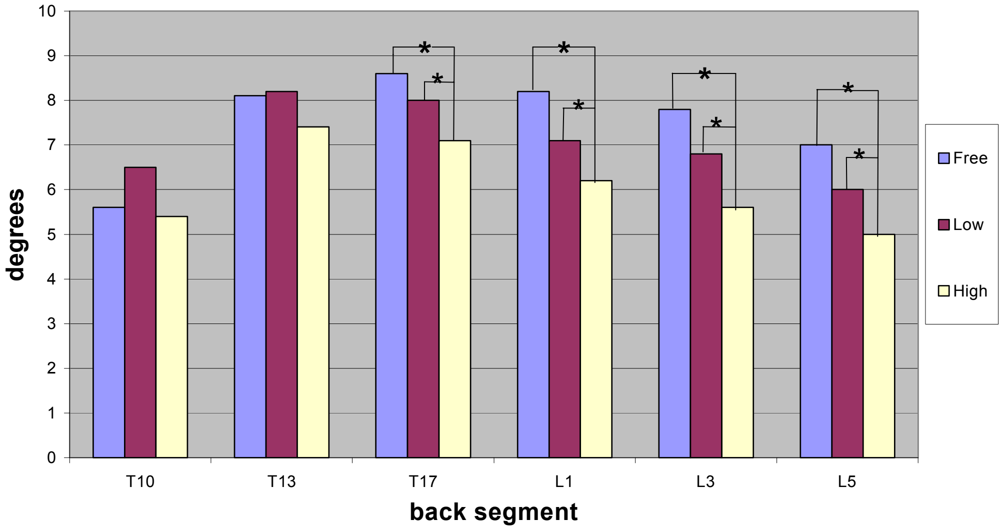

Fig. 10. The diagram shows the range of flexion-extension movement at walk with the head and neck in the different positions. Significant differences ($p< 0.05$) are shown *.

The flexion-extension movement of the back with the head and neck in the high position was at walk significantly lower ($p< 0.05$) as compared to the movement with the head and neck in a free or in a low position at T17, L1, L3 and L5.

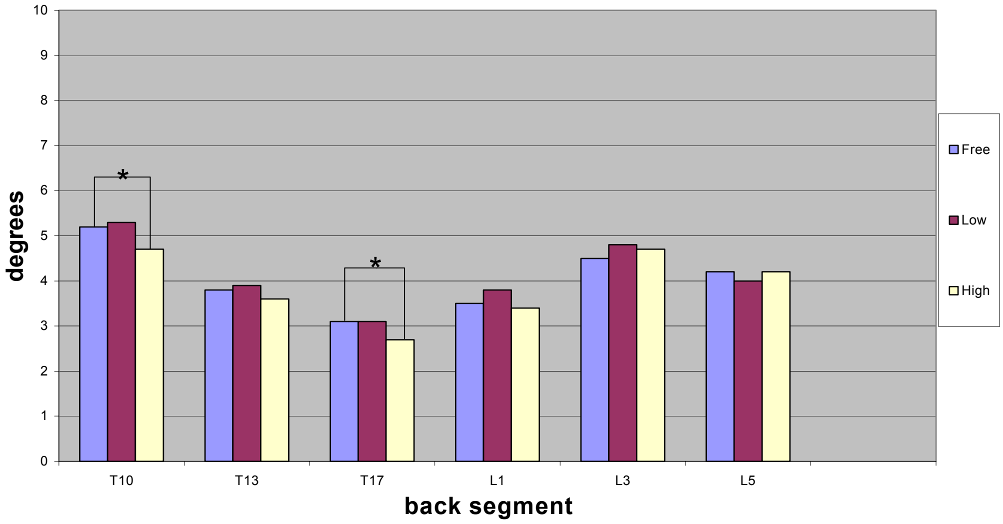

Fig. 11. The diagram shows the range of flexion-extension movement at trot with the head and neck in the three different positions. Significant differences ($p < 0.05$) are shown *.

At trot the flexion-extension movement at segment T10 and segment T17 was significantly lower ($p < 0.05$) in the high position as compared to the free position. At the other segments there was no significant difference in flexion-extension movement as regards the head and neck position.

Stride length in the three head positions at walk and trot.

The stride length at walk with the head and neck in a free position (mean 1.94 m) was significantly longer ($p<0.05$) than for the low (mean 1,89 m) and the high position (mean 1,80 m). The stride length in the low position was significantly longer ($p<0.05$) than for the high position. At trot there was no significant difference in stride length as regards the head and neck position .

Discussion

Understanding the pathophysiology of equine back problems for clinical evaluation, treatment or injury prevention requires understanding of the normal three-dimensional motion characteristics of the vertebral column (Haussler et al 2001). Each vertebrae can rotate in three planes and this causes three kinds of movements of the spine: extension/ flexion, lateral bending and axial rotation. In this study the three types of movements of the spine were measured at segment T10, T13, T17, L1, L3 and L5 with the head and neck in three different positions at walk and trot. Only the flexion-extension movement is presented in this paper.

The interesting findings were that the head and neck in a high position significantly reduced the flexion-extension movement in the lumbar back (T17, L1, L3 and L5) at walk. This was not found at trot where only flexion-extension movement of segment T17 was lower at the high position. At walk the stride length was shortest with the head in the high position but this was not seen at trot where the stride length was constant. It is, however, known that the movement of the back is related to stride length. Horses with longer strides extend and flex their backs in the caudal saddle region to a greater extent at walk (Johnston et al 2002). This is in accordance with our findings but the stride length was also associated with the head and neck position.

The different results at walk and trot may be due to the different characteristics of the gaits. At walk the horse moves the head and neck to a greater extent as compared to at trot, where the head and neck position is more constant. When the head and neck are fixed, as with side reins, this impedes the natural movement at walk more than at trot. At trot speed influences movement of the back (Robert et al 2001), but in this study the speed at trot was constant. To our knowledge there is no previous study published on the relationship between the head and neck position and the movement of the back. It seems probable that the decreased flexion-extension movement of the back at the high head position is directly caused by the shorter stride length, which in turn is caused by the head and neck position. It might also be a smaller but direct influence of the head and neck position on the movement of the back but this remains to be proven.

In this experimental set-up we did not have the possibility to encourage the horses forward and thereby affect the hind limbs. If a constant stride length could be achieved, for example by long reining, together with variable head and neck positions the causal relationship between the head and neck position and the flexion-extension movement of the back could be proven.

The limb movements are closely related to the spinal kinematics and most likely this is a causal correlation in which the spine follows the movement of the limbs. The direct linkage between the hind limbs and vertebral column (i.e., sacroiliac joint) only allows for a small amount of mobility (Faber et al 2000). A close relation seems to exist between the kinematics and the muscular activity in the vertebral column. Both muscular dysfunction and asymmetrical limb-function will therefore lead to altered movement patterns of the vertebral column (Faber et al 2001a).

Faber et al (2001b) showed that skin-fixed markers can be used to quantify kinematics of the thoracolumbar spine and the sacrum in horses under certain conditions, even though they do not represent the true movements of the vertebral column. Skin displacement artefacts did not influence the results for flexion-extension at the walk and trot. The standardised protocol for locomotion analyses on the treadmill provides highly repeatable data, which is obligatory for objective clinical determination of back movements (Faber et al 2002).

Sammanfattning

Ryggömhet är ett vanligt problem hos ridhästar. Orsaken är ofta multifaktoriell men en faktor som kan vara viktig är hur hästen tränas. En vanlig åsikt hos ryttare och tränare är att hästens form, d.v.s. huvud- och halspositionen, påverkar ryggen men detta har aldrig bevisats. Tidigare studier har visat att hästens form påverkar frambenen och att en gramantygel kombinerad med en vanlig tygel kan förskjuta hästens vikt bakåt. Syftet med den här studien var att undersöka hur ryggens rörelse påverkades av tre olika huvud- och halspositioner. De tre olika positionerna var låg, hög ("på tygeln") samt fri position där hästen gick med halsen framsträckt i valfri höjd.

Åtta friska ridhästar ingick i försöket. De försågs med 17 reflektoriska hudmarkörer placerade på huvudet, ovanför tornutskotten längs ryggraden, på bäckenet samt på benen. Hästarna fick skritta och trava på en rullande matta. Huvud-halspositionerna varierades med hjälp av inspänningstyglar fästa till en gjord. Sex kameror registrerade markörernas tredimensionella rörelse. Varje ryggkota kan rotera i tre plan och det ger upphov till tre typer av rörelser: dorsoventral flexion och extension, lateral böjning samt axial rotation. Alla tre typer av rörelse mättes, men endast dorsoventral flexion och extension presenteras här.

I skritt minskade rörelsen i ländryggen när hästen spändes in lågt och rörelsen minskade ännu mer när hästen gick på tygeln jämfört med den fria formen. I trav var skillnaden inte så stor förutom vid ryggsegment T10 och T17 där rörelsen minskade när hästen gick på tygeln jämfört med den fria formen. I skritt påverkade inspänningen även steglängden som kortades, mest vid den höga inspänningen men även vid den låga inspänningen. I trav påverkades inte steglängden av huvud-halspositionen. En förklaring till det kan vara att hästen naturligt rör sig olika i skritt och trav. I skritt rör den huvudet mer och en fixering av huvudet medför att rörelsen hämmas. I trav håller hästen huvudet mer stilla och påverkas inte på samma sätt av fixeringen. Tidigare studier visar att steglängden har en direkt inverkan på ryggens rörelse och för att ta reda på om det är ett direkt samband mellan hästens form och ryggens rörelse skulle man behöva ha steglängden konstant. Ett sätt kan vara att tömköra hästen där man kan driva hästen framåt och därigenom kanske påverka steglängden.

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