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Evaluation of the force acting on the back of the horse with an English saddle and a side saddle at walk, trot and canter

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Summary

Reasons for performing study: **Force transmission under an English saddle (ES) at walk, trot and canter is commonly evaluated, but the influence of a side saddle (SS) on the equine back has not been documented.**

Hypothesis: **Force transmission under a SS, with its asymmetric construction, is different from an ES in walk, trot and canter, expressed in maximum overall force (MOF), force in the quarters of the saddle mat, and centre of pressure (COP). The biomechanics of the equine back are different under a SS compared to ES.**

Methods: **Thirteen horses without clinical signs of back pain ridden in an indoor riding school with both saddles were measured using an electronic saddle sensor pad. Synchronous kinematic measurements were carried out with tracing markers placed along the back in front of (withers, W) and behind the saddle (4th lumbar vertebra, L4). At least 6 motion cycles at walk, trot and canter with both saddles (ES, SS) were measured. Out of the pressure distribution the maximum overall force (MOF) and the location of the centre of pressure (COP) were calculated.**

Results: **Under the SS the centre of pressure was located to the right of the median and slightly caudal compared to the COP under the ES in all gaits. The MOF was significantly different ($P<0.01$) between saddles. At walk, L4 showed significantly larger ($P<0.01$) vertical excursions under the ES. Under the SS relative horizontal movement of W was significantly reduced ($P<0.01$) at trot, and at canter the transversal movement was significantly reduced ($P<0.01$) . In both trot and canter, no significant differences in the movement of L4 were documented.**

Conclusions and potential relevance: **The results demonstrate that the load under a SS creates asymmetric force transmission under the saddle, and also influences back movement. To change the load distribution on the back of horses with potential back pain and as a training variation, a combination of both riding styles is suitable.**

Introduction

Besides the common use of the English saddle (ES) in various equestrian sport disciplines, an increasing interest in historic forms of riding has emerged in recent years, particularly in riding using a side saddle (SS). The most conspicuous difference between the SS and ES is the dissimilar leg position. In the SS both rider's legs are on the left side of the saddle with the right leg positioned around the fixated horn in front of the left leg. The left leg remains in a similar position as in the ES.

Asymmetric sitting in the SS leads one to assume that the forces acting on the equine back differ considerably from those of an ES and it is particularly interesting to consider whether a SS causes changes in the motion of the equine back.

From an historical point of view, the SS (Figs 1 and 2) was used only by women, because they were not allowed to ride on an ES.

Several studies have previously been published investigating the force transmission under an ES (Harman 1994, 1995, 1997, 1999; Jeffcott *et al.* 1999; Werner *et al.* 2002; Frühwirth 2004; Meschan 2004). The measurements were accomplished using an electronic saddle sensor mat. To the authors' knowledge, no corresponding studies examining the force transmission under a SS at the natural gaits have been undertaken.

The aim of this study, therefore, was to investigate the load on the equine back under the SS at the natural gaits in terms of total force and centre of pressure, with their exact location and peak concentrations, in comparison to a regular ES. Movement of the back with the different saddles was also investigated.

Materials and methods

Horses, riders and saddles

Thirteen horses (age 7–25 years, of various breeds and at different training levels) without clinical signs of back pain (Licka and Peham 1998) or lameness were ridden with an individual accustomed saddle, a well-fitting English dressage saddle and a SS. The horses were examined by a veterinarian, and saddle fit assessed by both a professional saddle maker and a veterinarian.

The riders were all of high quality and able to sit on their horses in the correct way. They rode in dressage competitions in ES and SS, and were members of the Austrian Association of Historical riding (SS riders). The trainer was an instructor for dressage riding in SS and ES at the highest level.

Bodyweight of the riders was mean ± s.d. 67.8 ± 10.2 kg. The horses (n = 13) were ridden by their accustomed riders, 7 women and 6 men. The same rider rode one horse with the 2 different saddles enabling them to compare the effect of SS and ES.

Data collection

The kinetic data were recorded via pressure measuring pad[1] placed under the saddle, using a sampling rate of 30 Hz. The pad

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consisted of 224 sensors (3.2 x 2.5 cm each) arranged in 14 columns and 16 rows and was divided into 2 distinct halves, left and right. Directly above the midline of the horse, the pad had no sensors. The 2 halves were fastened together with adhesive tape. and the pad enclosed with neoprene, total thickness 2.6 mm.

The saddle mat was positioned on the horse's back in such a way that the midline of the saddle mat was accurately placed over the midline of the back. Prior to measuring, the pad was initialised to zero after placing the saddle on the horse and tightening the girth.

The horse was ridden on a 12 m long pressed sand track in an indoor riding arena. Six cameras (sample rate 120 Hz, resolution 240 x 833 pixels), were placed along the right side of the measurement track, and the marker positions recorded using the ExpertVision System[2]. The riders were asked to choose a uniform speed typical for each horse in all gaits and, in canter, the right limbs were the leading limbs. Data were collected for at least 6 motion cycles in walk, sitting trot and canter when ridden with an ES and with a SS.

Data analysis

Kinetic data were processed using Matlab software. Motion cycles were separated using synchronous kinematic data of the right fore hoof. The speed of the horizontal motion of the hoof marker was the reference to determine the beginning and end of each motion cycle as described in Peham *et al.* (1999). The duration of each motion cycle was then normalised to 100% for all kinetic and kinematic data. We determined the range of back motion using the maximal horizontal, transversal and vertical displacement of markers placed on the midline at the withers and above L4 (4th lumbar vertebra).

At every measured time step (sample) the sum of all segment forces was calculated. Out of this time series (force) maximum overall force (MOF) was determined. The same procedure was used for the force in the quarters of the saddle mat (cranial-right, cranial-left, caudal-right, caudal-left). In addition to the MOF, the centre of pressure (COP) of the overall force was determined (Equation 1).

$$MOF = \max\{OF_1, OF_2, \ldots, OF_{100}\}; \qquad OF = \sum_{Seg=1}^{224} F_{Seg}$$

$$COP_x = \frac{\sum_{Seg=1}^{224} F_{Seg} \cdot x_{Seg}}{\sum_{Seg=1}^{224} F_{Seg}}; \qquad COP_y = \frac{\sum_{Seg=1}^{224} F_{Seg} \cdot y_{Seg}}{\sum_{Seg=1}^{224} F_{Seg}};$$

$$F_{Seg} = Pressure_{Seg} \cdot Area_{Seg}$$

The force was normalised to the individual body mass of rider.

Statistics

MOF and motion data were tested for normal distribution in SPSS using the Kolmogorov-Smirnov test. As normal distribution was present, we used a general linear model for repeated measurements (analysis of variance) to check for significant differences between the gaits in MOF and between being ridden with an ES and a SS in the motions of the withers and the fourth lumbar vertebra.

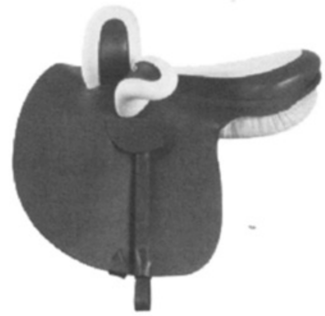

Fig 1a: Side Saddle.

Fig 1b: Sitting on a side saddle.

TABLE 1: Mean ± s.d. maximal overall force (MOF) at walk, trot and canter, comparing ES and SS [N]; the MOF is significantly different between saddles

	SS (N)	ES (N)
Walk	641 ± 124	816 ± 8
Trot	1384 ± 243	1757 ± 338
Canter	1516 ± 273	1840 ± 191

Significant differences were found between all SS and ES measurements ($P<0.01$).

Results

There was no significant difference in speed in both groups in the same gait. Area of contact was greater (mean = 150 cm^2) in the SS, because the SS were longer (mean = 5 cm) than the ES. We found no significant differences between the measurements of women and men riding on the SS. The measurements yielded highly congruent force and COP curves for all 3 gaits and both saddles (Figs 2–5). There was a highly significant difference ($P<0.01$) between MOF under both saddle types at all three gaits (Table 1). The division of the mat into 4 quarters and analysis of partial forces made the distinct differences between both saddle types even more apparent (Table 2). The partial forces were distributed uniformly among the 4 quarters under the ES; the SS, however, showed a pronounced maximum force in the caudal left quarter and an equally pronounced minimum force in the cranial left quarter.

Typical characteristics of the total force were found in both saddle types. At walk, total and partial forces showed the typical 'M'-like shape during one motion cycle. The greatest forces were found in the caudal quarters, the force maximum of the SS being particularly concentrated in the left caudal quarter. At the point of maximum force the right foreleg reached the end of its stance phase,

TABLE 2: Mean ± s.d. maximum of the 4 partial forces (N) for each quarter of the sensor mat

	Cranial-left		Cranial-right		Caudal-left		Caudal-right	
Gait	SS	ES	SS	ES	SS	ES	SS	ES
Walk	119.8 ± 29.9**	229.4 ± 49.1**	181.6 ± 61.3	173.1 ± 41.2	279.7 ± 48.6	273.4 ± 44.2	228.1 ± 64.2	256.5 ± 64.6
Trot	273.3 ± 79.0**	462.3 ± 105.9**	388.2 ± 104.8	407.1 ± 79.3	473.6 ± 113.8	498.8 ± 220.8	390.2 ± 101.1	440.7 ± 96.0
Canter	256.0 ± 73.9**	417.2 ± 85.4**	388.2 ± 119.8	391.0 ± 87.4	496.1 ± 125.2	505.3 ± 128.8	404.3 ± 113.5	466.5 ± 89.8

**Significant differences between SS and ES measurements ($P<0.01$).

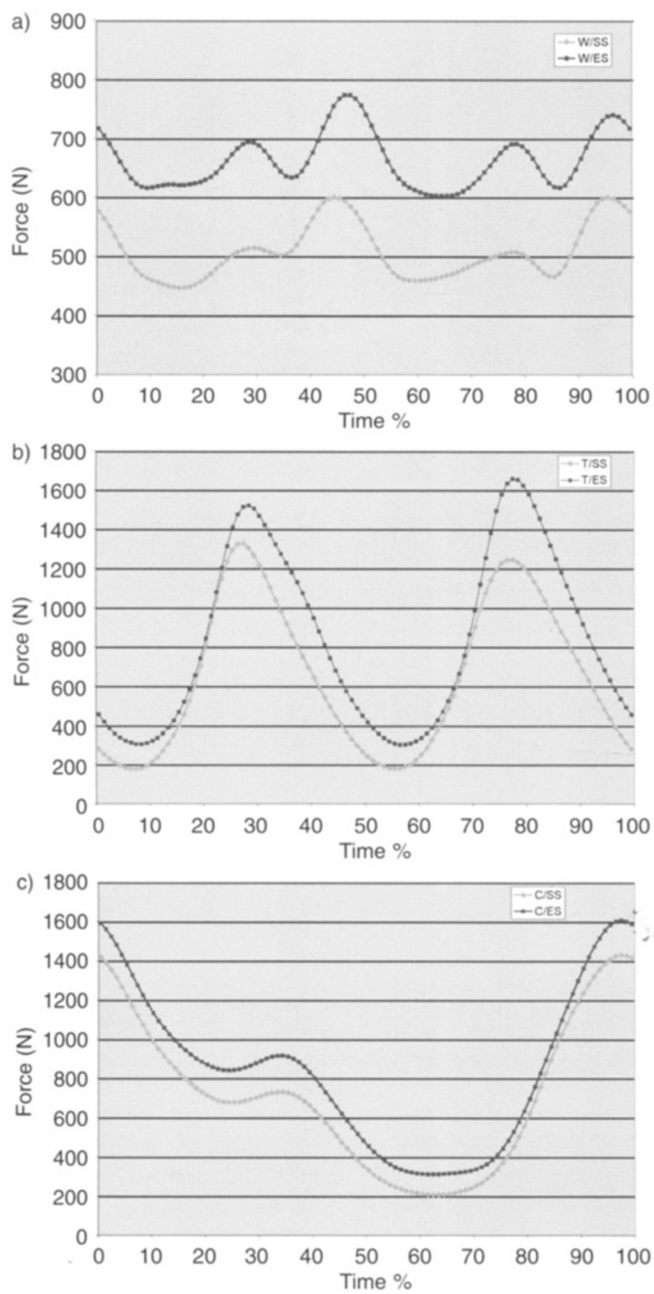

Fig 2: Mean overall force during one motion cycle at a) walk, b) trot and c) canter. The curves start with the beginning of the stance phase of the right fore hoof. C/SS = canter with SS, C/ES = canter with ES, T/SS = trot with SS, T/ES = trot with ES, W/SS = walk with SS, W/ES = walk with ES.

whilst the left hindlimb and left forelimb were in mid-stance phase.

At trot, both saddles exhibited 2 distinct force maxima during one motion cycle occurring in the second half of the stance phase of the respective diagonal leg pair. The force maxima of the caudal quarters trail those of the cranial quarters. In the SS, force maximum occured in the left caudal quarter, force minimum in the left cranial quarter. Force maximum coincided with the stance phase of the ipsilateral leg. In the ES the forces were distributed uniformly among the quarters.

At canter, the shape of the force curve showed 2 typical force maxima and one distinct force minimum. The smaller force maximum was prominently located in the left cranial quarter in the ES; however, in the SS total force was distributed evenly among both cranial quarters. At this time, the right leg was at the end of its stance phase, at the onset of its suspension phase.

The displacement of the COP, which also served as an indicator of the motion stability of the horse and rider system, was larger in the SS than in the ES at all 3 gaits (Figs 3–5). The markers on the back, however, showed smaller excursions in the SS than in the ES. At walk, vertical displacement of the L4 marker was significantly smaller (P<0.05) in the SS than in the ES (5.5 cm vs. 6.3 cm). At trot the cranio-caudal displacement of the marker at the withers was significantly smaller (P<0.01) in the SS (3.3 cm vs. 4.2 cm), and at canter the same was found for the transversal displacement of the same marker (P<0.01) (2.2 cm vs. 3.1 cm). There were no other significant differences found in the kinematics of the horse.

Discussion

Breathing patterns, muscle tension and all other changes of body posture of the horse and rider during separate parts of the movement cycle all influenced the pressure pattern obtained. Only intra-individual differences were therefore analysed, and did not guarantee that breathing patterns for example, were actually similar under both saddles.

We calculated the force acting between the horse's back and the saddle. Force is generated by the acceleration or deceleration of a mass (force = mass x acceleration/deceleration). As body mass of the rider, speed and gait were the same for each comparison (ES, SS) these differences were caused by varying accelerations. Acceleration depends on the mechanic characteristics (rigidity) and dynamics of the bodies acting on each other - e.g. body position, different angle of the centre of gravity of the rider.

Even if there were any small differences because of pelvis shape, for example, this would not influence our results because the same rider rode the same horse with both saddles.

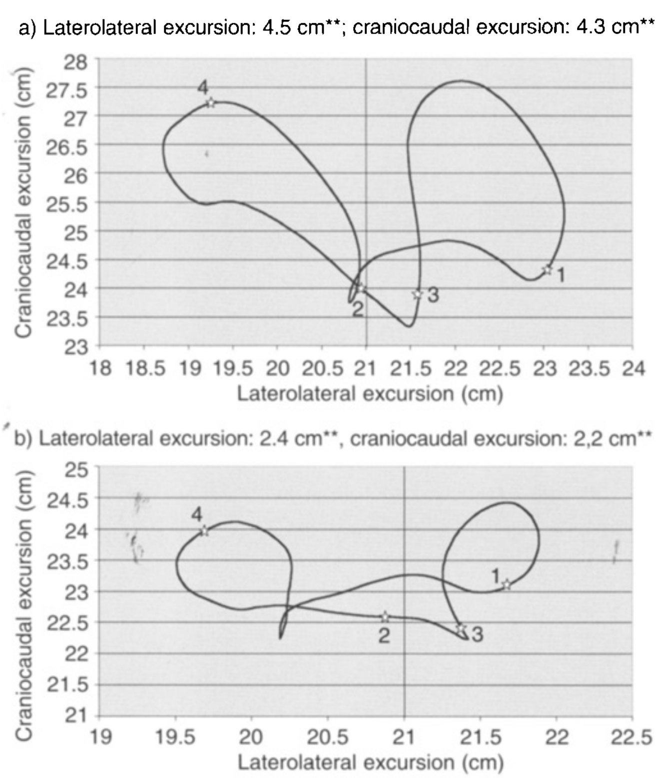

*Fig 3: Excursions of the mean centre of pressure (COP) during walk from top view. a) with SS and b) with ES. The duration of the stance phase of the right forelimb is from 1 to 2, the stance phase of the right hindlimb from 3 to 4. The origin of the saddle coordinate system is situated on the left rear corner of the sensor array. The vertical line at 21 cm indicates the midline of the mat. **Significant differences between SS and ES measurements (P<0.01).*

Walk

The localisation of the force maxima and minima in the SS correspond to those under an ES. However, the absolute force values were smaller in the SS, and their distribution among the four quarters of the sensor mat differed. A possible explanation for the reduced forces might be the occurrence of a force-'bypass' evoked by the specific structure of the SS. This structure may have introduced an altered distribution of the force under the sensor mat. One reason for the force increase in the left caudal quarter may have been the way in which the rider was seated or an increased muscle contraction. The rather unvarying shape of the force curve in the right caudal quarter may have been caused by a contraction of the long back muscle, resulting in a better fixation of the spine (König *et al.* 2002). Licka *et al.* (2004) confirmed the stabilising effect of the contraction of the long back muscle against dynamic forces occurring during the motion cycle at trot. The asymmetric sitting shifts the load of the rider to more caudal positions, which explains the differences of both saddle types in force distribution among the quarters. Further evidence for this shift might be found by the smaller force increase in the left cranial quarter. Furthermore, it appeared that the left-sided saddle showed an increased adhesion to the right side of the horse, because the pressure increase in the right cranial quarter was higher in the SS than in the ES, when the withers move forward to the forelimb, which is in suspension phase at this moment (Licka *et al.* 2001).

The displacement of the COP had a very similar shape at walk for both saddle types. However, there were significant differences in the latero-lateral and the cranio-caudal excursions. The larger excursions of the COP under the SS confirmed the greater instability of the horse-rider system compared to the ES. Jeffcott *et al.* (1999) reported that unbalanced horses and riders (i.e. moving out of harmony) caused large lateral excursions of the COP. Licka *et al.* (2001) showed that the equine back moves away from the hindlimb during its stance phase. In this study we detected a restricted mobility of the fourth lumbar vertebra in cranial direction under the SS. It is possible that the hindlimbs develop less thrust in forward direction under the SS.

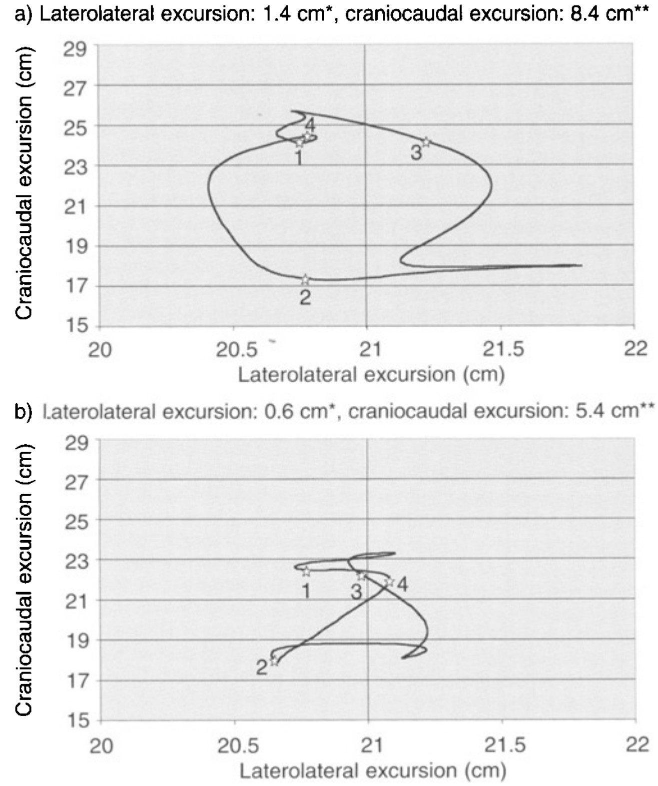

*Fig. 5: Excursion of the mean centre of pressure (COP) during canter from the top view, a) with SS and b) with ES. *Significant differences between SS and ES measurements (P<0.05); **Significant differences between SS and ES measurements (P<0.01).*

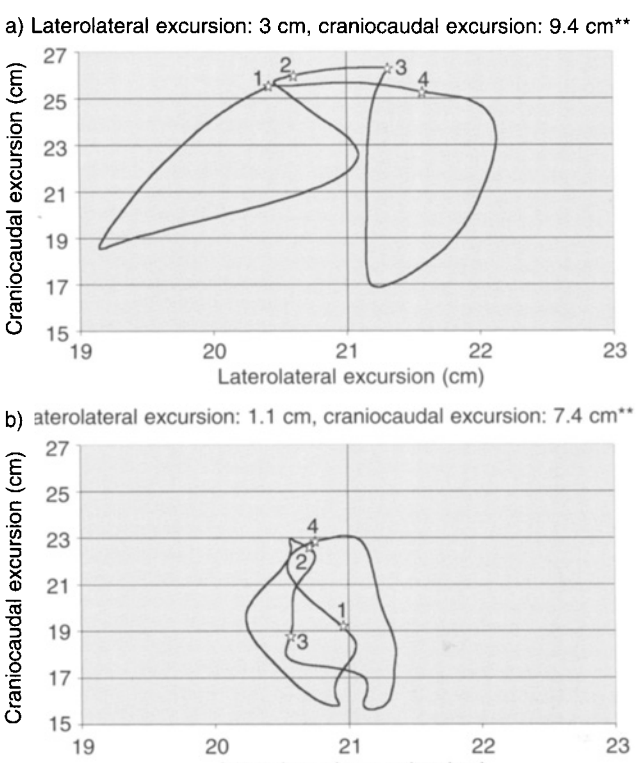

*Fig 4: Excursion of the mean centre of pressure (COP) during trot from the top view, a) with SS and b) with ES **Significant differences between SS and ES measurements (P<0.01).*

Trot

The force trajectories show a maximum in the second half of one motion cycle under both saddle types, at the moment when the respective diagonal leg pair is in stance phase. The SS showed a higher maximum during the stance phase of the right fore and the left hind leg. This force peak was located in the left caudal quarter, while the force minimum is found in the left cranial quarter. Presumably, the rider shifts his/her weight further backwards by this type of sitting.

The back flexes and extends in a similar fashion under both saddles. This study confirms the finding that the back extends during the first half and flexes during the second half of the stance phase of the diagonal leg pair. The specific motion of the back starts in the thoracic region and moves onto the thoracolumbar and lumbosacral regions (Audigie *et al.* 1999).

The force curves display a larger maximum in the cranial quarters when the ipsilateral leg is in suspension phase. EMG recordings by Licka *et al.* (2004) revealed that at the end of the stance phase of the right fore leg the left long back muscle develops a very high activity.

As at the walk, excursion of the COP at trot revealed a higher instability under the SS than under the ES. The displacement of the marker at the withers was also significantly smaller in the cranio-caudal direction in the SS. Presumably the increased contraction of the long back muscle gives better fixation of the back.

Canter

Force trajectories again displayed similar characteristics under both types of saddles. Total force was significantly smaller under the SS. In the caudal quarters the higher values were found in the left quarter. The second characteristic maximum at the end of the stance phase of the leading foreleg was caused by a force increase in the both cranial quarters under the SS. The increased force in the right cranial quarter, not found under the ES, may stem from an increased pressure of the right front of the saddle tree. It is also possible that in the SS the rider slips a little out of place.

In our study we evaluated only right lead canter. In a follow-up study it would be interesting to see the differences between right and left lead canter under ES and SS. Lateral motion of the withers is significantly ($P<0.01$) smaller under the SS than under the ES, in particular in cases when the withers shift caudally and to the right, the latero-lateral motion becomes restricted.

Conclusions

These results demonstrate that the load under a SS leads to significant changes in load and motion patterns and also influences back movement. For horses prone to, or convalescing from back pain, a combination of both riding styles with variation of load distribution is recommended following this study.

Manufacturers' addresses

[1]Pliance System, Novel, Munich, Germany.
[2]Motion Analysis Corporation, Santa Rosa, California, USA.

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