An investigation of the relationship between hindlimb lameness and saddle slip

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Summary

Reasons for performing study: We have observed saddle slip consistently to one side because of a crooked rider, an ill-fitting saddle, asymmetry in a horse's thoracolumbar shape and lameness. Currently, there are no objective data to permit assessment of the relative importance of each factor.

Objectives: To document the frequency of occurrence of saddle slip in horses with hindlimb lameness compared with other horses. To describe the effect of lameness characteristics and grade, the abolition of lameness by diagnostic analgesia, breed, size, thoracolumbar shape and symmetry and the rider's weight.

Methods: One hundred and twenty-eight horses were assessed prospectively, and lameness and saddle slip were assigned a grade before and after diagnostic analgesia. The thoracolumbar shape and symmetry were measured objectively. In 3 horses, the force distribution and magnitude underneath the saddle were measured before and after diagnostic analgesia.

Results: The saddle consistently slipped to one side in 38 of 71 horses (54%) with hindlimb lameness, compared with one of 26 horses (4%) with forelimb lameness, none of 20 (0%) with back pain and/or sacroiliac joint region pain and none of 11 sound horses (0%). The association between saddle slip and hindlimb lameness was significant (Spearman's rank correlation coefficient, \( p = 0.548, P<0.001 \)). Diagnostic analgesia abolishing the hindlimb lameness eliminated the saddle slip in 37 of 38 horses (97%). In 2 horses, the saddle continued to slip after resolution of lameness; one horse had bilateral forelimb lameness and the other horse had concurrent hindlimb and forelimb lameness. The saddle of both these horses was asymmetrically flocked. The saddle slipped to the side of the lamer hindlimb in most horses (32 of 37 [86%]). No horse with saddle slip had significant left-right asymmetry of the back at 4 predetermined sites.

Conclusions and clinical relevance: Hindlimb lameness is an important factor in inducing saddle slip. Saddle slip may be an indicator of the presence of hindlimb lameness.

Keywords: horse; saddle; back movement; pressure measurements

Introduction

Saddle slip in sports horses is a well-recognised problem that can occur for a variety of reasons, including asymmetry in the shape of the horse's back [1], riders sitting crookedly [2–4], ill-fitting saddles [5,6] and hindlimb lameness [7,8]. A pilot study revealed altered force distribution underneath the saddle in horses with hindlimb lameness and back pain [9]. Symmetrical thoracolumbar movement in sound horses has been demonstrated using kinematic analysis [10,11]. However, symmetry and amplitude of the movement of the back are influenced either by experimentally induced transient forelimb or hindlimb lameness [12–15] or by experimentally induced back pain [16,17]. These studies did not induce concurrent back pain and lameness, although their coexistence is commonly recognised clinically [18]. The majority of published information on thoracolumbar kinematics is from treadmill studies [11,16,17], and there are limited data on ridden sound [19–22] and lame horses [9] in 'real-life' conditions.

It has been observed in ridden horses that in association with hindlimb lameness saddles may slip consistently to one side. This has encouraged owners to try multiple saddles and additional padding to try to diminish the saddle slip, but this has generally been ineffective [7]. Saddle slip may be influenced by the rider's weight and the back shape of the horse, with greater slip occurring with lighter weight riders and in native-type horses with round back contours [7].

A comprehensive description of the saddle kinematics in ridden sound and lame horses outside gait laboratories has not been reported. Although interface force–distribution data have confirmed that there are a variety of factors that influence the movement of a saddle [6,20,23,24], there is limited knowledge of the interrelationships between the horse, saddle and rider and no objective assessment of saddle slip and gait irregularities in lame horses. By evaluating the response to diagnostic analgesia, we are able objectively to separate out the relative importance of the movement of the horse when ridden and other factors that potentially may induce saddle slip.

The aims of the present study were as follows: 1) to document the frequency of occurrence of saddle slip in horses with hindlimb lameness, compared with horses without hindlimb lameness; 2) to describe the effect of lameness grade, unilateral or bilateral hindlimb lameness, multilimb lameness (≥3 lame limbs) and the coexistence of sacroiliac joint region pain and/or thoracolumbar-sacral pain/stiffness; 3) to document the effect of abolition of lameness by diagnostic analgesia; and 4) to determine the relationships between saddle slip and the horse's thoracolumbar shape and evaluate the influence of rider weight, horse breed, type, body condition score (BCS) and size.

It was hypothesised that saddle slip may be induced by hindlimb lameness, with the saddle slipping most frequently to the side of the lame(r) limb, and that the degree of saddle slip may be reduced by improvement in the lameness by diagnostic analgesia.

Materials and methods

A prospective study was performed at the Animal Health Trust, approved by the Ethics Committee and with informed consent of owners, between August 2011 and August 2012. All horses that were presented for gait assessment and were ridden by at least 2 riders were included. Diagnosis was assigned prospectively based on the results of a comprehensive clinical evaluation, diagnostic analgesia and imaging. The horses were divided into the following 5 categories: Group A, hindlimb lameness; Group B, forelimb lameness; Group C, horses with both forelimb and hindlimb lameness; Group D, poor performance in association with thoracolumbar-sacral and/or sacroiliac joint region pain; and Group E, sound horses.

Horse data

Age, breed, sex, height, bodyweight, BCS [25], work discipline and the presence of hindquarter and epaxial muscle atrophy were recorded. An interobserver repeatability study was carried out on 10 horses for BCS, to confirm that the method could be used practically. In addition, an intraserver repeatability study was performed, with 5 horses assessed 3 times in random order. A variance of less than 1% was obtained.
Assessment of thoracolumbar shape and symmetry

The thoracolumbar shape and symmetry were measured at the level of the 18th (T18), the 13th (T13) and the 8th (T8) thoracic vertebrae, identified by palpation of the ribs, and at a site one-third of the distance between the point of the elbow and the point of the shoulder (shoulder region). A Flexible Curve Ruler was shaped around the dorsum, perpendicular to the dorsal midline, to follow the body contours. The resultant shape was drawn on graph paper. A single investigator (L.G.) performed all the measurements. Repeatability of the measuring technique was tested with a pilot repeatability study on 3 differently shaped and sized horses measured 10 times in random order, followed by 5 measurements in random order of an additional 10 horses (measurement error ±2 mm). The minimal detectable difference outside of the measurement error was established using coefficients of variation (CV) of 4, 8 and 12% (95% confidence interval [CI]) across all horses [26], and the number of horses with asymmetries greater than a CV of 4, 8 and 12% (95% CI) was determined. Asymmetries between left and right sides were confirmed by rotating the Flexible Curve Ruler by 180° in a horizontal plane and comparing it with the predrawn curve. All measurements were performed with the horses standing squarely on a level surface, before exercise. Preliminary data had indicated that alterations in stance could alter measurements slightly and that measurements acquired soon after exercise varied compared with before exercise.

Thoracolumbar shape categories

The thoracolumbar shape at each measurement site was divided into the following 4 categories: type 1, concave; type 2, straight; type 3, convex; and type 4, very convex. The grading system was based on the ratio between the horizontal distances between left and right sides 3 and 15 cm ventral to the dorsal midline (Fig 1). Type 1 back shape was defined as having a ratio ≥0.30 (Fig 1a), type 2 back shape a ratio of 0.31 ≥ 0.35 (Fig 1b), type 3 back shape a ratio of 0.36 ≥ 0.40 (Fig 1c) and type 4 back shape a ratio of ≥0.41 (Fig 1d).

Description of lameness characteristics and saddle slip

All horses were examined by one experienced clinician (S.J.D.) moving in hand, on the lunge and ridden, and the lameness was graded in each circumstance (0 = sound, 2 = mild, 4 = moderate, 6 = severe and 8 = nonweightbearing) [27]. The horses were evaluated when ridden by the owner and at least one experienced rider from the Animal Health Trust. The lameness was graded at sitting and rising trot on both left and right diagonals, on the left and right reins, and when performing specific movements, such as 10 m diameter circles to the left and right. The lameness was graded before and after diagnostic analgesia for each circumstance [27]. Diagnostic analgesia was performed in all lame limbs. Rider straightness, rider weight, the grade of saddle slip, whether it occurred with more than one rider, and whether saddle slip was influenced by the direction of movement or by the diagonal on which the rider was sitting were recorded. Both authors assessed saddle slip by consensus. The same rider rode the horse before and after diagnostic analgesia. The grade of saddle slip after lameness had been abolished was recorded. Photographs and video recordings were obtained.

A pilot study to determine accuracy of detection of saddle slip had previously been performed, which had involved placing markers on horses, saddles and riders. All horses were videoed being ridden in a straight line. The presence or absence of saddle slip was determined without and with markers by 3 people independently. There was complete agreement...
in the thoracolumbar region; 8) concurrent hindlimb lameness and close-impinging spinous processes (improved gait was seen after local analgesia of the spinous processes); 9) unilateral gluteal muscle atrophy and/or epaxial muscle atrophy; and 10) tension in the epaxial musculature.

For horses in Groups A and C, Spearman’s rank correlation was used to test for association between the grade of lameness and the following factors: 1) grade of saddle slip; 2) the tendency of the saddle to slip towards the sound or less lame hindlimb; 3) sex; 4) age; 5) breed; 6) work discipline; 7) BC5; and 8) weight/height ratio.

For all horses in Groups A and C, Spearman’s rank correlation was used to test for association between saddle slip and the following factors: 1) the back shape at the shoulder, T8, T13 and T18; and 2) the effect of having a similar or wider back shape at the level of T13 compared with T18 (horses were selected for inclusion if the back contour at T13 ≥ T18). All statistical analyses were made using SPSS Statistics 20®, with significance set at P<0.05.

Results
There were 11 sound horses and 117 with lameness or poor performance. The horses ranged in age from 5 to 17 years (mean 8.72 years, median 8 years) and comprised 92 geldings and 36 mares. The duration of lameness ranged from 0 to 12 months (mean 1 month, median 1.5 months). Horses were used for dressage (n = 32), showjumping (n = 26), evening (n = 29), general purposes (n = 40); horses used for unaffiliated competitions were classified as general purpose) and endurance (n = 1). Breeds comprised Warmbloods (n = 56), Thoroughbreds (n = 9), Thoroughbred crosses (n = 28), cobs (n = 6), ponies (n = 15) and others (n = 14).

The horses ranged in weight from 286 to 914 kg (mean 568 kg, median 574 kg), in height from 117 to 183 cm (mean 167 cm, median 170 cm) and the weight/height ratio ranged from 1.9 to 4.8 kg/cm (mean 3.4 kg/cm, median 3.4 kg/cm). The BCS was 1 (n = 1), 2 (n = 10), 3 (n = 106) and 4 (n = 11). No horses with a well-fitted saddle had focal areas of reduced sweating in the saddle region. Thirty-nine horses had saddle slip, comprising 34 horses with grade 1 and 5 with grade 2, including 2 induced by an asymmetric saddle. Thirteen of 39 riders (33%) had appreciated the presence of saddle slip prior to the clinical investigation. The lameness groups are summarised in Figure 3, together with the number of horses with saddle slip for each lameness group. Twenty horses had unilateral hindlimb lameness and 51 horses had bilateral hindlimb lameness. The hindlimb lameness grade when ridden ranged from 1 to 6; the most frequent lameness grade was 2 (n = 33). In 3 horses, hindlimb lameness grade was at least one grade different when the rider changed from sitting on one diagonal to the other, irrespective of whether the horse was on the left or right rein, and this influenced the tendency for the saddle to slip.

The weight of the normal rider of horses with saddle slip associated with hindlimb lameness ranged from 47 to 80 kg (mean 63 kg, median 65 kg). Five riders sat crookedly. The weight of the riders (n = 4) from the Animal Health Trust ranged from 43 to 60 kg (mean 56 kg, median 60 kg).

Saddle slip
There was complete consensus between the authors in assessment of saddle slip. Saddle slip occurred with at least 2 riders in all the horses with saddle slip. In horses with saddle slip which was abolished by resolution of hindlimb lameness, saddle slip was consistently greatest with a lighter weight rider (n = 37); however, when saddle slip was related to an asymmetrical saddle, slip was greater with a heavier weight rider (n = 2). In Group A, the saddle consistently slipped to one side in 20 of 36 horses (56%); 18 of 35 horses (51%) had saddle slip in Group C, compared with one of 26 (4%) in Group B, none of 20 (0%) in Group D and none of 11 (0%) in Group E. The association between saddle slip and hindlimb lameness was significant (Spearman’s ρ = 0.548, P<0.001). The association between saddle slip and horses with hindlimb lameness alone (ρ = 0.354, P<0.001) and horses with hindlimb lameness and coexistent forelimb lameness (ρ = 0.254, P = 0.004) was significant.

Objective relationship between saddle slip and lameness
There was a significant difference in the occurrence of saddle slip among Groups A, B, C and D (P<0.001; Fig 3). For all horses, there was a significant disagreement between the clinical assessment of saddle slip and the presence of osseous pathology.
A positive association between the presence of saddle slip and bilateral hindlimb lameness \( (p = 0.344, P < 0.001) \), unilateral hindlimb lameness \( (p = 0.286, P = 0.001) \), concurrent unilateral hindlimb and unilateral forelimb lameness \( (p = 0.222, P = 0.012) \) and concurrent bilateral hindlimb lameness and sacroiliac joint region pain \( (p = 0.220, P = 0.013) \). The association between saddle slip and 3-limb lameness \( (p = 0.116, P = 0.191) \), 4-limb lameness \( (p = 0.098, P = 0.269) \) and coexistent unilateral hindlimb lameness and sacroiliac joint region pain \( p = 0.012, P = 0.089 \) was nonsignificant.

There was a significant association between the presence of saddle slip and tense epaxial muscles in the thoracolumbar region \( (p = 0.358, P < 0.001) \) and between unilateral hindquarter muscle atrophy and/or epaxial muscle atrophy \( (p = 0.274, P = 0.002) \). There were significant associations between the presence of saddle slip and both hindlimb lameness and concurrent osseous pathology in the thoracolumbar region \( (p = 0.436, P < 0.001) \) and hindlimb lameness and improvement in clinical signs after local analgesia of close/impeining spinous processes \( (p = 0.341, P < 0.001) \). Horses with unilateral hindquarter muscle atrophy and/or epaxial muscle atrophy \( p = 0.472, P < 0.001 \) and horses with sacroiliac joint region pain \( p = 0.290, P = 0.001 \) were more likely to have tense epaxial muscles in the thoracolumbar region compared with horses in Group B \( p = 0.250, P = 0.005 \), in which the association was negative.

For all horses in Groups A and C, there was no significant association between the grade of saddle slip and lameness grade \( p = -0.179, P = 0.136 \), nor was there a significant association between the lameness grade and the experience of the saddle to slip towards the sound or less lame hindlimb \( p = -0.136, P = 0.260 \). The causes of hindlimb lameness are summarised in Table 1, together with the number of horses with saddle slip for each cause.

**Objective relationship between saddle slip and horse data**

There was no significant association between saddle slip and breed \( p = -0.069, P = 0.565 \), BCS \( p = 0.069, P = 0.570 \), weight/height ratio \( p = 0.151, P = 0.210 \), work discipline \( p = -0.064, P = 0.596 \), sex \( p = -0.150, P = 0.211 \) or age \( p = 0.087, P = 0.472 \).

**Association between back shape and saddle slip**

Subjectively, only minor asymmetries <2 cm between left and right sides were observed by rotating the Flexible Curve Ruler through 180° in a horizontal plane and comparing it over the predrawn curve. Greater asymmetries were observed in horses without saddle slip than in horses with saddle slip.

The mean typical measurement error for each level (shoulder, T8, T13 and T18) across all horses included in the pilot repeatability study resulting in minimal detectable difference in back shape between left and right sides was 0.6 cm for a CV of 4%, 1.2 cm for a CV of 8% and 1.8 cm for a CV of 12%. All the horses with saddle slip had asymmetries between the left and right sides of less than a CV of 8% (1.2 cm) measured at the level of the shoulder region, T8, T13 and T18. Five horses had asymmetries greater than a CV of 8% (1.2 cm) in the saddle region, and none had saddle slip.

There was no significant association between saddle slip and the type of back shape at the shoulder, T8, T13 or T18 \( p = 0.128, P = 0.289 \), nor was there a significant association having a similar type of back shape at T8, T13 and T18 and saddle slip \( p = 0.112, P = 0.352 \) or having one or less difference in the type of back shape among T8, T13 and T18 \( p = 0.150, P = 0.211 \). However, there was a significant positive association between saddle slip and horses with a wide back shape at T13 (defined as having a back contour at T13 ≥ T18, \( p = 0.340, P = 0.004 \)). There was also a significant positive association between horses having one or less difference in the type of back shape among T8, T13 and T18 and a wide back shape at T13 \( p = 0.288, P = 0.015 \).

**Factors affecting saddle slip associated with hindlimb lameness**

Thirty-seven horses had saddle slip caused by hindlimb lameness. The saddle slipped to the side of the lame or lamer hindlimb when the horse was worked in straight lines, going large around the arena and also in circles of 20 m diameter in most horses (32 of 37 [86%]). The direction of the saddle slip was associated with the rein on which the horse appeared most lame in 18 of 37 horses (49%). However, this was complicated by the fact that some of the horses (13 of 37 [35%]) going large or in a 20 m circle appeared lamer with the lame limb on the outside, whereas on a 10 m circle the horse appeared lamer with the lame limb on the inside. However, the difference in appearance of the lameness did not alter the direction of saddle slip. Saddle slip was present on both reins in 6 of 37 horses (16%) and on only one rein in 31 of 37 (84%).
The causes of hindlimb lameness and other causes of lameness or poor performance | Number of horses with the injury | Number of horses with saddle slip | Percentage with saddle slip
---|---|---|---
Bilateral PSD and FL lameness | 13 | 5 | 38
Bilateral PSD and SI pain | 8 | 4 | 50
Bilateral PSD | 7 | 2 | 29
Unilateral CD and TMT OA | 4 | 2 | 50
Unilateral FT OA and FL lameness | 2 | 2 | 100
Bilateral PSD and impinging/overriding 14th–15th to 16th–17th thoracic SPs (one improved with infiltration of local anaesthetic solution around the impinging/overriding SPs; one was not blocked) ± OA 15th–16th and 16th–17th thoracic APJs | 2 | 2 | 100
Bilateral PSD and SI pain and impinging 10th–15th thoracic SPs (one improved with infiltration of local anaesthetic solution around the impinging SPs; one was not blocked) ± OA 15th–16th and 16th–17th thoracic APJs | 2 | 2 | 100
Bilateral PSD and SI pain and FL lameness | 6 | 1 | 17
Unilateral PSD and FL lameness | 4 | 1 | 25
Unilateral TMT/CD OA and bilateral PSD | 2 | 1 | 50
Unilateral TMT/CD OA and FL lameness | 1 | 1 | 100
Bilateral TMT/CD OA | 1 | 1 | 100
Unilateral FT OA and middle patellar desmitis | 1 | 1 | 100
Unilateral FT OA and bilateral PSD | 1 | 1 | 100
Unilateral CD OA | 1 | 1 | 100
Bilateral TMT/CD OA and OA 15th–16th thoracic APJs | 1 | 1 | 100
Unilateral talocalcaneal joint OA, DDFT injury and old fracture of right tuber coxae and FL lameness | 1 | 1 | 100
Bilateral MTP OA and unilateral lateral oblique sesamoidian desmitis and FL lameness | 1 | 1 | 100
Lateral suspensory branch desmitis, apical sesamoid fracture of lateral PSB and bilateral PSD; close SPs between the 13th and 18th thoracic vertebrae (improved with infiltration of local anaesthetic solution around the close SPs) and OA 16th–17th and 17th–18th thoracic APJs; old fracture of the caudoverentral aspect of the 4th cervical vertebra | 1 | 1 | 100
Unilateral medial collateral desmitis of DIP, unilateral PSD and FL pain | 1 | 1 | 100
Unilateral accessory desmitis of SL, bilateral PSD and FL lameness | 1 | 1 | 100
Unilateral accessory desmitis of SL, bilateral PSD and FL lameness; close/impinging SPs of first to 3rd lumbar vertebrae* | 1 | 1 | 100
Bilateral PSD, SI pain and impinging 10th–15th thoracic SPs (improved with infiltration of local anaesthetic solution around the close SPs) and OA 15th–16th and 16th–17th thoracic APJs and OA caudal cervical APJs | 1 | 1 | 100
Unilateral PSD, SI pain, impinging SPs of the 13th thoracic to 2nd lumbar vertebrae (improved with infiltration of local anaesthetic solution around the impinging SPs) and OA 15th–16th and 16th–17th thoracic APJs | 1 | 1 | 100
Bilateral PSD, SI pain and impinging SPs of the 12th thoracic to 3rd lumbar vertebrae (improved with infiltration of local anaesthetic solution around the impinging SPs) and FL lameness | 1 | 1 | 100
Unilateral PSD | 2 | 0 | 0
Unilateral FT OA and unilateral PSD | 1 | 0 | 0
Unilateral lateral collateral desmitis of MTP | 1 | 0 | 0
Unilateral displaced fractures of the distal aspect of the navicular bone and OA caudal cervical APJs and FL lameness | 1 | 0 | 0
Bilateral PSD, SI pain and asymmetric OA of APJs between the 15th–16th and 16th–17th thoracic vertebrae; supraspinous ligament injury from 15th to 17th thoracic vertebrae* and FL lameness | 1 | 0 | 0
Total | 71 | 37 | 52

Abbreviations: APJ(s) = articular process joint(s); CD = centrodistal joint; DDFT = deep digital flexor tendon; DIP = distal interphalangeal joint; FL = forelimb; FT = femorotibial joint; MTP = metatarsophalangeal joint; OA = osteoarthritis; PSB = proximal sesamoid bone; PSD = proximal suspensory desmitis; SI = sacroiliac joint region; SL = suspensory ligament; SP(s) = spinous process(es); and TMT = tarsometatarsal joint. *Infiltration of local anaesthetic solution around the close/impinging SPs was not performed.

Saddle slip was consistently greater in circles compared with straight lines (37 of 37 horses [100%]), irrespective of the appearance of the lameness (Fig 2). Lameness was worse when the rider sat on the diagonal of the lame(r) limb in the stance phase in 11 of 37 horses (30%), but this was associated with greater saddle slip in only 3 horses. Saddle slip was consistently greater in rising trot compared with sitting trot (37 of 37) and was remarkably reduced when riding without stirrups (4 of 4). In canter, the saddle slip was similar to or greater than in rising trot. The saddle slip was consistently less with a heavier rider in 37 horses ridden by 2 riders (Rider 1 = 43 kg and Rider 2 >60 kg), resulting in >17 kg difference in bodyweight, but the grade (0–2) of saddle slip did not change between riders.

Diagnostic analgesia and ill-fitting saddles
Diagnostic analgesia abolishing the lameness did not eliminate the saddle slip in 2 horses, one with hindlimb lameness and one with forelimb lameness. The causes of hindlimb lameness and other causes of lameness or poor performance were:

- Bilateral PSD and FL lameness
- Unilateral PSD and FL lameness
- Unilateral TMT/CD OA and bilateral PSD
- Unilateral TMT/CD OA and FL lameness
- Bilateral TMT/CD OA
- Unilateral FT OA and middle patellar desmitis
- Unilateral FT OA and bilateral PSD
- Unilateral CD OA
- Bilateral TMT/CD OA and OA 15th–16th thoracic APJs
- Unilateral talocalcaneal joint OA, DDFT injury and old fracture of right tuber coxae and FL lameness
- Bilateral MTP OA and unilateral lateral oblique sesamoidian desmitis and FL lameness
- Lateral suspensory branch desmitis, apical sesamoid fracture of lateral PSB and bilateral PSD; close SPs between the 13th and 18th thoracic vertebrae (improved with infiltration of local anaesthetic solution around the close SPs) and OA 16th–17th and 17th–18th thoracic APJs; old fracture of the caudoverentral aspect of the 4th cervical vertebra
- Unilateral medial collateral desmitis of DIP, unilateral PSD and FL pain
- Unilateral accessory desmitis of SL, bilateral PSD and FL lameness
- Unilateral accessory desmitis of SL, bilateral PSD and FL lameness; close/impinging SPs of first to 3rd lumbar vertebrae*
- Bilateral PSD, SI pain and impinging 10th–15th thoracic SPs (improved with infiltration of local anaesthetic solution around the close SPs) and OA 15th–16th and 16th–17th thoracic APJs and OA caudal cervical APJs
- Unilateral PSD, SI pain, impinging SPs of the 13th thoracic to 2nd lumbar vertebrae (improved with infiltration of local anaesthetic solution around the impinging SPs) and OA 15th–16th and 16th–17th thoracic APJs
- Bilateral PSD, SI pain and impinging SPs of the 12th thoracic to 3rd lumbar vertebrae (improved with infiltration of local anaesthetic solution around the impinging SPs) and FL lameness
- Unilateral PSD
- Unilateral FT OA and unilateral PSD
- Unilateral lateral collateral desmitis of MTP
- Unilateral displaced fractures of the distal aspect of the navicular bone and OA caudal cervical APJs and FL lameness
- Bilateral PSD, SI pain and asymmetric OA of APJs between the 15th–16th and 16th–17th thoracic vertebrae; supraspinous ligament injury from 15th to 17th thoracic vertebrae* and FL lameness

Total | 71 | 37 | 52

Saddle slip was consistently greater in circles compared with straight lines (37 of 37 horses [100%]), irrespective of the appearance of the lameness (Fig 2). Lameness was worse when the rider sat on the diagonal of the lame(r) limb in the stance phase in 11 of 37 horses (30%), but this was associated with greater saddle slip in only 3 horses. Saddle slip was consistently greater in rising trot compared with sitting trot (37 of 37) and was remarkably reduced when riding without stirrups (4 of 4). In canter, the saddle slip was similar to or greater than in rising trot. The saddle slip was consistently less with a heavier rider in 37 horses ridden by 2 riders (Rider 1 = 43 kg and Rider 2 >60 kg), resulting in >17 kg difference in bodyweight, but the grade (0–2) of saddle slip did not change between riders.
lameness; both had an ill-fitting saddle. When ridden with correctly fitting saddles, no saddle slip was apparent.

**Force distribution measurements**

Two horses with lameness and saddle slip that were assessed with a CONFORMat pressure mat exhibited an asymmetric pressure distribution underneath the saddle. The mean pressure in the quadrant of the lamer hindlimb during the lamer diagonal stance phase was significantly lower compared with the corresponding pressure in the quadrant of the sound or less lame hindlimb during the sound or less lame diagonal stance phase. Another horse with bilateral hindlimb lameness exhibited an almost symmetric pressure distribution underneath the saddle; there was no saddle slip.

When the horses with saddle slip were re-evaluated following diagnostic analgesia that abolished the lameness, the difference in pressure underneath the saddle between lame and sound diagonal stance disappeared, the amplitude of the sinusoidal curve increased and the craniocaudal excursion of the centre of pressure (COP) increased, whereas the right–left excursion and sideways movement of the saddle decreased. All findings from the pressure measurements correlated with the clinical assessments.

**Discussion**

In accordance with our hypotheses, saddle slip was induced by hindlimb lameness in 37 of 71 horses (52%). The saddle slip was eliminated when the hindlimb lameness was abolished by diagnostic analgesia in 37 of 38 (97%), verifying a causal relationship. Although no association was found between the severity of lameness and saddle slip, horses with severe lameness when exercised in hand were not evaluated ridden and were therefore not included in the study. To an untrained observer, some of the horses with obvious saddle slip when ridden appeared clinically normal, and only a skilled, experienced clinician recognised subtle lameness. Riders were commonly surprised by the complete abolition of saddle slip and transformation in work quality when lameness was eliminated by diagnostic analgesia, emphasising that saddle slip may highlight the presence of low-grade and subclinical lameness. This indicates that even subtle lameness can influence a horse’s entire way of moving. One horse ridden by an experienced rider, examined 2 months prior to the commencement of the study, had no overt lameness, but had grade 2 saddle slip and was presented for that reason. Although no overt lameness could be seen, the horse’s performance improved substantially following intra-articular analgesia of the tarsometatarsal joint, which abolished the saddle slip completely (S. J. Dyson, unpublished data).

Our findings demonstrated that saddle slip can also occur because of an asymmetrical (or ill-fitting) saddle. In 2 horses, the saddle slip was unchanged after lameness was abolished by diagnostic analgesia, which makes it highly unlikely that it was induced by lameness. Both horses were also ridden with correctly fitting saddles and no saddle slip was apparent. Although saddle slip is often a manifestation of hindlimb lameness, it can also occur due to asymmetrical muscling of the horse’s back, asymmetrical position of the rider [3] or asymmetry of the biomechanical function of the horse, but based on our results these causes are less common than hindlimb lameness.

Only 13 riders of 39 horses with saddle slip had recognised saddle slip prior to the clinical investigation. However, in all except one horse with saddle slip, riders from the Animal Health Trust were able to feel saddle slip. Better education of riders may be required to recognise saddle slip, especially because it may be an important indicator of the presence of lameness. Five of the normal riders in the present study sat crookedly and could have induced saddle slip; however, a similar degree of saddle slip was seen when ridden by riders from the Animal Health Trust, who all sat squarely when riding a variety of different horses without saddle slip.

Some movement of the saddle can potentially be detected in horses free from lameness. In 7 Grand Prix dressage horses free from lameness ridden on a treadmill in rising trot, there was saddle rotation around the vertical axis away from the supporting hindlimb [20]. Alternation of the force between right and left was also seen in the trajectory of the COP [19]. In the present study, the saddle slip caused by hindlimb lameness was obvious and occurred with at least 2 riders. The saddle slip was consistently more pronounced with a lighter weight rider, despite the lameness being less obvious, presumably because a lighter rider is less able to stabilise and maintain a straight position of the saddle. However, when saddle slip was related to an asymmetrical saddle, slip was greater with a heavier weight rider. This observation was based on only 2 horses, but mirrors previous observations (S. J. Dyson, unpublished data). A heavier rider may exacerbate the uneven pressure caused by the unequal thickness and shape of the panels of the saddle. We also observed that the saddle slip associated with lameness was much less in sitting trot or when riding without stirrups compared with rising trot. This may be because in rising trot the rider induces some rotation, which exacerbates sliding of the saddle. Riders impose more force in the stirrups in rising trot compared with sitting trot [31], although there were no significant differences in peak forces under the saddle in rising and sitting trot [32]. However, when forces on the back were calculated using kinematics of a rider, there was a significant difference in peak vertical force between rising and sitting trot [22]. In the present study, a heavier rider was more effective than a lighter rider in maintaining stability of the saddle in sitting trot. However, in canter saddle slip was sometimes greater than in trot, probably related to the asymmetrical 3-beat gait, which impairs the rider’s ability to stabilise the saddle despite sitting.

Saddle slip associated with hindlimb lameness was increased in circles compared with straight lines. Low-grade hindlimb lameness is often accentuated when a horse is ridden, especially in circles of approximately 10 m diameter [8]. Assessment of movement of the trunk and tubera coxae in horses free from lameness was compared in straight lines and in circles on the lunge in unridden horses using inertial measurement units [33]. There were significant repeatable patterns of asymmetry, which potentially may be magnified in the face of lameness and alter forces on the saddle and rider. Based on the results of the present study, there is clearly a complex interaction between the size of a circle and its effect on the degree of hindlimb lameness and its characteristics, and whether the lameness is worse on the outside or inside of a circle, and saddle slip.

We demonstrated that the shape of the horse’s back had an influence on saddle slip, with ‘rounder’ horses at the level of T13 being more at risk. This may reflect greater dorsoventral displacement at T13, which appears to be the site that comes closest to the lowest back line. The maximal range of vertical displacement occurs at this site, where the equine body centre of mass is aligned with the rider’s centre of mass [34,35]. However, there was no association between the BCS and saddle slip. A large proportion of the horses in the study were BCS 3 [25]. Use of a more sensitive method of condition scoring, such as the 9-point scale [36], may have permitted further differentiation among horses within BCS 3.

In our study, the saddle usually slid towards the side of the lamer hindlimb, but sometimes towards the less lame or nonlame limb. When saddle slip occurred towards the side of the lamer limb, this was usually associated with the lamer limb on the outside of a 20 m circle. In contrast, when the saddle slid towards the sound or less lame hindlimb, this was with the lamer limb on the inside of a circle. We need to understand better the biomechanical changes in gait that occur to cause these 2 different patterns of saddle movement and to establish the interrelationship between the symmetry and amplitude of equine in vivo back movement, the saddle movement and lameness in a variety of movement conditions. Combining conventional techniques for lameness assessment with back kinematics data using inertial measurement units mounted on the saddle, the rider and the horse [33] and force measurements under the saddle [37], alongside measurements of back muscle activity using electromyography [38,39] and ultrasonographic evaluation of multifidus [40], may help to improve basic understanding of vertebral biomechanics and the changes that occur with lameness.

The Flexible Curve Ruler is widely used in the saddle-fitting industry and has been considered to be a reliable tool. However, there has been no scientific validation prior to the present study. Our data indicate that using strict consistency in technique (the horse standing squarely on a horizontal, level surface, acquiring measurements before exercise at reliably identified predetermined sites), accurate, repeatable data can be obtained. The ruler is prone to fatigue, and regular replacement is recommended to ensure consistency of results. However, the potential consequences of different patterns of work prior to back shape
measurements have yet to be investigated. We also need to determine the speed with which body shape may change over time, influenced by type and intensity of work, skeletal maturity, work discipline and nutrition.

We have previously demonstrated that hindlimb lameness can cause back stiffness [9]. Following diagnostic analgesia to abolish lameness, there was increased back mobility, assessed both subjectively and objectively using a Pliance pressure mat. The present study provided further evidence that following diagnostic analgesia to eliminate hindlimb lameness, there was an improved range of movement through the horse’s back and abolition of saddle slip. This was also confirmed objectively in 3 horses by using a pressure mat, which demonstrated increased cranial–caudal excursion of the COP and decreased sideways movement of the COP, and the difference in pressure between the lame and sound diagonal stance phases disappeared.

Limitations of the study
This study had some limitations. The horses were a referral population and therefore may not be typical of the general horse population, in which there may be greater occurrence of musculoskeletal asymmetries. The prevalence of crooked riders and saddle-fitting problems may not necessarily reflect the general population. The study was not performed blinded, which could potentially have introduced bias. There were only 39 horses with saddle slip in the study, in 37 of which saddle slip was caused by hindlimb lameness. This was not enough to allow investigation of the relationships between the grade and direction of saddle slip and the source of pain causing lameness. We need to gain a better understanding of the biomechanical changes that occur with lameness that induce saddle slip. Combining clinical diagnosis with inertial measurement unit measurements in a larger number of horses would enable us to establish patterns related to the site of pain causing lameness, back movement and saddle slip. Although there was no relationship between the presence of saddle slip and the degree of lameness in the present study, horses that were severely lame in hand were not ridden and were therefore not included in the study. This may potentially have influenced the results. A large proportion of horses had bilateral hindlimb lameness; it is difficult to grade bilateral lameness accurately [27]. One horse ridden by a professional rider had grade 2 saddle slip towards the lame hindlimb abolished by diagnostic analgesia. However, the horse was assessed by only one rider due to its potentially dangerous behaviour and was not included in the study.

The back shape measurements were obtained in standing horses from predetermined anatomical locations and therefore do not represent the equine back shape in its entirety and in a dynamic situation. By combining the Flexible Curve Ruler measurements with 3-dimensional back shape scanning with Artecd, alongside Horse Weight Measuring Tape, it may be possible to evaluate the back in its entirety and also to measure quantitatively the change in back shape that may occur with work and over time. This was a single-point study; however, most horses were investigated over 2–3 days, and the presence or absence of saddle slip were consistent features. A proportion of horses were re-evaluated during the study period after treatment of lameness. In those horses in which lameness resolved, saddle slip invariably disappeared also. There were only 2 horses in which saddle slip was associated with an ill-fitting saddle, but the findings recorded are consistent with previous observations (S. J. Dyson, unpublished data).

Conclusions
Based on the present study, there is evidence that saddle slip occurs in a high percentage of horses with hindlimb lameness. Moreover, saddle slip may highlight the presence of low-grade and subclinical hindlimb lameness. Saddle slip is usually blamed on saddle fit and horse shape. Our findings emphasise the need for education of owners, veterinarians, physiotherapists, riders and saddle fitters that saddle slip is frequently an indicator of lameness, not necessarily a manifestation of an ill-fitting saddle or asymmetric shape of the horse’s back. It appears that saddle slip as a manifestation of hindlimb lameness has previously been underestimated. In many horses hindlimb lameness goes unrecognised, and early recognition of lameness is important for appropriate treatment and rapid return to work. Detection of saddle slip provides an opportunity for the owner, riders and trainers to detect low-grade and subclinical lameness, with important welfare consequences.

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