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Effect of egg-bar shoes on the three-dimensional kinematics of the distal forelimb in horses walking on a sand track

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Introduction

The understanding of the biomechanical effects of egg-bar shoes remains incomplete because kinematics studies are normally performed on hard tracks and with skin markers that do not measure the actual three-dimensional (3D) movements of the 3 digital joints. The objective of the present study was to quantify the effects of egg-bar shoes on the 3D kinematics of the distal forelimb in horses walking on a sand track.

Material and methods

Four healthy horses were equipped with ultrasonic markers surgically fixed to the four distal segments of the left forelimb. The 3D movements of these segments were recorded while the horses were walking on a sand track. Rotations of the digital joints were calculated by use of a “Joint Coordinate System”. Data obtained with egg-bar shoes were compared to those obtained with standard shoes. Mean differences were expressed in a 0.5 confidence interval.

Results

With egg-bar shoes, sinking of the heels into the ground during landing was reduced and the heels were raised by up to 5.1 (3.5-6.7) at mid-stance. Concurrently, maximal flexion of the distal (DIPJ) and proximal (PIPJ) interphalangeal joints was increased by up to respectively 3.2 (2.2-4.2) and 1.8 (1.1-2.5) and extension of the DIPJ at heel-off was reduced by 3.8 (2.6-5.0). In extrasagittal planes of movement, egg-bar shoes induced a decrease of sinking of the medial quarter into the ground that led to a slight decrease of DIPJ medial rotation.

Conclusion

Since egg-bar shoes prevent the heels and the medial side of the hoof from sinking into the ground on a sand track, they contribute to a decrease of DIPJ maximal extension at heel-off and to hoof stabilization in the transversal plane. Such quantitative results are useful to support the clinical indications of egg-bar shoes.
Effects of ground surface on the equine superficial digital flexor tendon load, evaluated by a non-invasive ultrasonic technique

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Introduction

The influence of ground surface on equine locomotion was investigated. However, studies dealing with the impact of the ground on tendon loading are few, because of the invasive nature of the techniques used so far. A non-invasive method to measure tendon loads was developed. This method is based on the measurement of the propagation velocity of ultrasound in the tendon. The objective of this study was to evaluate the effects of two different grounds on the equine superficial digital flexor tendon (SDFT) load using this non-invasive technique.

Material and methods

Ultrasonic measurements were performed on four sound adult horses using an ultrasonic probe (1MHz) and an electronic module. The speed of sound (SOS) was measured using the axial transmission method. The probe was placed in contact with the (depilated) skin facing the left SDFT in the metacarpal area by means of a gaiter. Both front hooves of each horse were equipped with a standard shoe. Two types of ground were evaluated: asphalt and sand. For each ground test, the horses were led at walk then at trot along a 30 m long track. Ultrasonic recordings (100 Hz) were repeated 3 times at each gait. For each recording, a mean pattern of SOS was calculated after time normalization by averaging the SOS data over 10 successive strides. The SOS values at the beginning, the peaks (2 at the walk, 1 at trot) and the end of the stance phase, as well as the corresponding temporal parameters (in % of stride duration) were considered for statistical analysis.

Results

No significant differences in maximal values of SOS (tendon load peaks) could be demonstrated between asphalt and sand. However, the relative duration of tendon loading during the stance phase was significantly higher, and the speed of loading was lesser, on sand compared with asphalt.

Conclusion

The new ultrasonic technique allows the demonstration of significant effects of the ground surface of the SDFT loading at walk and trot. This technique brings new information about tendon loading duration as well as loading speed that may have an impact on tendon lesion occurrence.
Metacarpal strains associated with fast exercise in Thoroughbred racehorses

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Introduction

Bone surface strains exceeding -2500 microstrains are associated with bone modelling and are thought to be the stimulus for the change in bone shape on the midshaft of the third metacarpal bone (MC3) in young thoroughbred racehorses. However microstrains exceeding -5000 have been reported in the literature and it is not clear if such strains are necessarily associated with bone modelling. The peak microstrain at this site at 12m/s \( (\gamma) \) is proportional to a radiographic measure of the relative thickness of the midshaft dorsal cortex (RI = ratio of cortex to medulla*ratio of dorsal to palmar cortex) \[ \gamma = -5985 + 944\text{RI} \] (Davies 2001 Equine Vet J Suppl.33:16-20) and linearly related to exercise speed \( (s) \) \[ \text{strain} = -55 - 244s \] (Davies et al. 1993 Acta Anatomica, 146:148-153) which suggests that microstrains of -3960 may occur in racehorse MC3’s at 16m/s.

Material and methods

RI was measured weekly for between 6 months and 5 years in 40 racehorses (3 to 6 years old) being monitored for soundness and training at racing speed (16 to 19m/s). All horses had previously adapted to fast exercise and had no history of clinical shin soreness.

Results

These 40 horses had no significant change in RI during the study. The mean RI was 3.7 (SE = 0.1), range 2.4 to 5.9. This equated to peak microstrains at 12m/s of -2,488, with a range from -415 to -3719.

Conclusion

The consistency of the RI through months and years of racing (> 16m/s) suggests that the strains associated with very fast exercise may not be sufficient stimulus to induce further bone modelling in these horses. The size of strains required to induce bone modelling may be much greater than the -2,500 to -3,000 microstrains suggested by the Frost mechanostat under some conditions at least. Thanks to Racing Victoria for their recent support.
Change in bone parameters in Thoroughbred horses months after training has ceased

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Introduction

As training stimulus increases, bone mass and bone density are known to increase in thoroughbred horses. There is less knowledge of changes that occur after training is interrupted, despite the assumption that withdrawal from training causes loss of bone mass, and epidemiological evidence of spelling being a risk factor for fracture after training is resumed.

Material and methods

Nineteen horses were raised at pasture. The conditioned group received additional exercise in the form of 1030m exercise on a grass/sand training track 5 days/week from age 10 days to 18months. The horses were trained as two year olds. Bone parameters were determined before (Pre2) and after (Post2) training, and 147 ± 25 days after the training had ceased (Pre3), using peripheral quantitative computed tomography of the third metacarpal diaphysis, with the horse under general anaesthesia.

Results

The diaphysis was larger and more resistant to deformation (6159.81 ± 209.67 mm³ vs. 5769.97 ± 256.79 mm³), and bone mass and area were greater in previously conditioned horses than in controls (822.98 ± 16.78 mg/mm vs. 789.77 ± 20.55 mg/mm and 685.08 ± 14.45 mm² vs. 656.16 ± 17.70 mm²) respectively. Mean apparent volumetric bone mineral density increased by 0.83% by Post2, and had fallen to Pre2 levels by Pre3. Bone density was lower in conditioned than control horses, but not significantly. Fall in bone density (-9.99 ± 13.42 mg/cm³) was accompanied by an increase in bone mass (16.22 ± 14.59 mg/mm) between Post 2 and Pre 3, indicating that bone growth was still occurring.
Effect of exercise and training on markers of cartilage metabolism and synovial inflammation

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Introduction

Synovial inflammation is thought to play a role in the pathogenesis of joint disease. There is evidence that training is associated with low-grade synovitis, but only limited understanding of the relationships between training, cartilage metabolism and markers of inflammation within equine joints. We hypothesised that training and intense exercise induce joint inflammation and alterations to cartilage metabolism in horses.

Material and methods

Six TB horses were studied in a cross-over design; a) 9 weeks of treadmill training, with a strenuous exercise test in week 9 and a 6 week recovery period or b) 15 weeks at pasture. Synovial fluid (carpus and fetlock) was collected before training, after 9 weeks and after 6 weeks at pasture. Samples were also collected in week 9 before, 2 and 24h following intense treadmill exercise. Synovial 8-isoprostane (8-Iso), nitrite, nitrate, keratan sulphate, glycosaminoglycans, total protein (TP) and white blood cells (WBC) were measured.

Results

After cessation of training, carpal nitrite increased ($P < 0.05$). Following the exercise test, carpal 8-Iso increased at 24h post exercise ($P < 0.05$). Synovial and plasma nitrate were correlated before and at 24h post-exercise ($r^2 = 0.44$ to $0.85$, $P < 0.05$). A similar pattern, but with a negative relationship was observed for 8-Iso. Paradoxically, untrained horses had higher TP and WBC than trained horses ($P < 0.05$).

Conclusion

In mature horses, neither nine weeks of treadmill training nor an intense treadmill test produced significant alterations in indicators of cartilage metabolism or synovial inflammation. Synovial nitrate and 8-Iso levels may reflect systemic versus local production, whilst the differences seen in TP and WBC between trained and untrained may reflect lower synovial fluid turnover in the latter.
Effect of head and neck position on temporal and force parameters in the
unridden and ridden horse at trot

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Introduction

The influence of head-neck position (H) on the load distribution between fore- and hindlimbs and the
additional effect of the rider lack objective assessment. It is commonly believed that the higher the H,
the more load is shifted to the rear.

Material and methods

Vertical ground reaction force and time parameters of each limb were measured in 7 high level
dressage horses while trotting on an instrumented treadmill in 6 predetermined Hs: H1–free; H2–
elevated neck, head in front of the vertical; H3–elevated neck, head behind the vertical; H4–rolled up;
H5–extremely high neck; H6–low neck, extended head. The experiment was conducted both with and
without the horses’ experienced riders and judged by a qualified dressage judge. In the unridden
situation, the different Hs were achieved using side-reins. Hs were assessed by comparing the data to a
velocity-matched reference H: H1 in the unridden, H2 in the ridden situation. Differences were tested
using paired t-test (P < 0.05).

Results

In the unridden condition, stride duration (SD) remained unchanged. Relative stance duration (StDrel)
of the forelimbs was shortened and relative suspension duration (SpDrel) prolonged in H2, H3 and H5.
No changes in the distribution of vertical impulse (Iz) between fore- and hindlimbs were observed.
However, peak vertical forces (Fzpeak) in the forelimbs increased in H5 but were reduced in H6. In
the ridden condition, SD increased in H4 and H5. Forelimb StDrel increased in H1 but decreased in
H5. Inversely, SpDrel was shortened in H1 but prolonged in H5. Diagonal Iz shifted to the forelimbs
in H1 but to the rear in H5. On the Contrary, forelimb Fzpeak decreased in H1 but increased
significantly in H5.

Conclusion

In the unridden horse, changes in H affected mainly the forelimb timing. In the ridden horse, H5 had
the biggest impact on limb timing and load distribution and behaved inversely to H1. Shortening of
forelimb StDrel in H5 increases Fzpeak although the diagonal Iz is redistributed to the hindlimb.
Functional anatomy of the thoracolumbar and lumbosacral spine in the horse.

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Introduction

This paper describes the aspects of functional anatomy of the equine thoracolumbar and lumbosacral (LS) spine and potential effects on performance.

Material and methods

Study 1 identified variations in LS vertebral formula by post mortem examination of 114 horses. Midline vertebral transection was carried out on 61 TB, 22 STB and 31 Other (OT) breeds.
Study 2 investigated morphology and biomechanics of the deep stabilising epaxial muscles of 13 horses using MRI (n = 3), anatomical dissection (n = 9), and biomechanical analysis (n = 4). Multifidus fascicle orientation, length and force vectors at thoracic vertebra (T) 14, T18, L3, L5, L6 and sacrum (S) were analysed using specialised software.

Results

LS variations were found in 46% TB, 51% OT, but 0% STB. Sacralisation of lumbar vertebra (L) 6 with LS motion between L5 and L6 occurred in 31% TB and 29% OT.
Five segmental multifidus fascicles were identified originating from spinous processes and vertebral laminae running craniocaudally onto the mammillary processes and lateral border of S, crossing between 1-5 intervertebral discs. Sacrocaudalis dorsalis lateralis mm (SDL) was an extension of multifidus from L4 whereas sacrocaudalis dorsalis medialis mm originated from S3. Both were inserted on caudal vertebrae. Biomechanically, the principal actions of multifidus/SDL were dorso-ventral sagittal rotation, allowing dynamic stabilisation during dorsoventral motion. This action was dependant on vertebral spinous process/body orientation. We hypothesise that equine multifidus and SDL act as posterior sagittal rotators of their vertebra of origin as is the case in humans.

Conclusion

Equine multifidus mm anatomy and biomechanics were comparable to that of humans. The high prevalence of anatomical variations in the lumbosacral spine may affect maximal dorsoventral motion, stability of the lumbosacral joint and therefore athletic performance. Further studies of these structures are warranted in appropriately selected poorly performing horses.
Analysis of horse-rider interaction by accelerometry

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Introduction

The reports of experienced riders indicate that the movements imposed by riding at different gaits are greatly variable according to the locomotion of each horse. Elsewhere it was proposed that rider level influences the horse locomotion pattern. Recent developments in instrumentation have provided new tools for simultaneously studying horse and rider biomechanical parameters with an accelerometric device. The main objective of this study was to compare biomechanical horse-rider interaction.

Material and methods

Three French saddle horses trained in dressage were equipped with a 3D acceleration gait recorder (Equimetrix) fixed over the caudal part of the sternum. Four riders rode each horse equipped with a 3D acceleration recorder system (Locometrix) fixed at the lumbar spine level. These two systems were synchronised to record accelerations during 20 sec at walk, trot and gallop. For each gait the variables recorded and calculated were for the rider the triaxial accelerations and the total mechanical power (TP), for the horses the following variables were also calculated: stride symmetry and regularity.

Results

The mean peak acceleration (g) observed on the rider in the cranio-caudal axis was of 1.2 + 0.7 at walk, 3.73 + 1.6 at trot, 3.2 + 1.2 at gallop. The best competitive horse results impose significant higher TP at trot (102 vs. 75 and 79 W/Kg) and gallop (99 vs. 81 and 84 W/Kg). The comparison between horses according to rider level indicates no difference in TP at walk and trot when one rider induced more TP for one horse at gallop. The rating of gaits indicates that the regularity is influenced by the dressage level of the rider for the three gaits (total score of regularity, walk+trot+gallop for national level rider: 702, for regularly trained dressage rider: 640, for occasionally trained riders: 532 and 502) when the symmetry seems poorly influenced by the differences between riders.

Conclusion

These data confirm that the rider expertise influences horse locomotion. The accelerometry values observed at the lumbar spine level of the rider shown great differences according to the horse.
A pattern recognition approach for the quantification of horse and rider interactions

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Introduction

In riding, the interaction between two moving systems attracts specific interest. The interaction includes the rider’s ability to control the horse and an optimal interaction that comprises the adaptation of the rider to the individual nature of the horse. The purpose of this study was to identify rider-horse interactions by means of artificial neural nets.

Material and methods

Fourteen riding horses were measured trotting in hand, and ridden at working trot with a professional (P) and a leisure rider (L) sitting. 3D-coordinates were calculated from video recordings (120 Hz) and lowpass filtered (5-20Hz). The horse’s movement was described by 2D angles, angular velocities, and angular accelerations of variables of the right body side: hind and front fetlock, head, back, the summation angle of the carpus, elbow, shoulder, the summation angle of the hock, stifle, and hip. The distances between the trajectories of the feature vectors in a N=11x11 Kohonen map were determined and analysed by means of a cluster analysis.

Results

The results of the time courses of the head variables led to one cluster with the trials where the P rode the horses, one with the trials ridden by the L rider, one with the trials without a rider and one of the trials with the L rider and without a rider. The analysis of all variables shows clusters that are dominated by horses and clusters where riders seem to be dominant. The separate clustering of one horse suggests that this does not seem suitable for beginners or for hippotherapy. A clustering of trials-with-rider separated from trials-without-rider leads to the interpretation that these horses were controlled more easily.

Conclusion

Overall, the process oriented analysis by means of ANN can be considered as a supplementary tool for quantifying horse rider interactions.
Pressure distribution and back movement under an English saddle and a sidesaddle at walk, trot and canter

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Introduction
Pressure distribution under an English saddle at walk, trot and canter is commonly evaluated, but the influence of a sidesaddle on the equine back has not been documented. Pressure distribution under an English saddle, with its asymmetric construction, is different to a sidesaddle in walk, trot and canter.

Material and methods
Thirteen horses without clinical signs of back pain were ridden in an indoor riding school with both saddles using a pressure measuring saddle pad. Synchronous kinematic measurements were carried out tracing markers placed along the back in front (withers, W) and behind the saddle (4th lumbar vertebra, L4). At least six motion cycles at walk, trot and canter with both saddles (ES, SS) were measured. 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 between saddles (walk ES 816 ± 85N, SS 641 ± 124N, trot ES 1757 ± 338N, SS 1384 ± 243N, canter ES 1840 ± 191N, SS 1516 ± 273N). At walk, L4 showed significantly larger (0.7cm) vertical excursions under the ES. Under the SS horizontal movement of W was significantly reduced at trot (0.9cm), and at canter the transversal movement was significantly reduced (0.9cm). In both trot and canter, no significant differences in the movement of L4 were documented.

Conclusion
These results demonstrate that the load under a sidesaddle creates asymmetric pressures 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.
Association of type of sport and performance level with anatomical site of orthopaedic injury and injury diagnosis

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Introduction

Although anecdotal reports of orthopaedic injury risk in equine sports exist, there is little scientific evidence to support this. This study tested the hypotheses that horses undertaking a single competitive sport have increased risk of specific injuries than horses used for general purpose riding (GP), and that the injury type would vary with sport category and performance level.

Material and methods

Data from 1069 records of horses undergoing orthopaedic evaluation (1998-2003) meeting inclusion criteria were reviewed, and sport category (GP, showjumping, dressage, eventing, racing), level (non-elite or elite) and diagnosis were recorded. The effects of sport category and level on the probability of a specific diagnosis were assessed using chi-squared tests. Logistic regression was used to determine which competitive sports and levels increased the risk of injury compared with GP.

Results

Overall there was a significant effect of sport category and level on diagnosis ($P < 0.0001$). A significant difference was seen in anatomical site injured between sport categories ($P < 0.0001$). There was a high risk of forelimb SDFT injury in elite eventing ($P < 0.0001$) and elite showjumping ($P < 0.02$); distal DDFT injury in elite showjumping ($P < 0.002$); and hindlimb suspensory ligament injury in elite ($P < 0.0001$) and non-elite ($P < 0.001$) dressage. There was a low risk of tarsal injury in elite eventing ($P < 0.01$) and proximal DDFT injury in dressage ($P = 0.01$).

Conclusion

Horses competing in different sports are predisposed to specific injuries; particular sports may increase the risk of injury at certain anatomical sites; and the type and site of injury may reflect the type and level of performance.
Abnormal radiographic findings in 865 French Standardbred trotters and relation with racing performance

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Introduction

The purpose of this experiment was to study the prevalence and the distribution of developmental orthopaedic lesions in young French Standardbred trotters and to relate them to racing performance.

Material and methods

Feet, fetlocks, tarsus and stifles were x-rayed in 865 two-year-old French Standardbred trotters. For 12 anatomical sites identified in these areas, abnormal radiographic findings (ARF) were evaluated and a gravity index was given. Performance criteria were: success in qualification, maximal and mean index of trot (ITR) which is an annual index calculated on the basis of logarithm of earnings per starts, total earnings at 5 years, placed races compared to starts, longevity of the racing career, and best time. Analysis of variance was calculated to study the relationships between racing performance and the number of ARF or the gravity index. A level of significance of \( P < 0.05 \) was used in all tests.

Results

A total of 363 horses (42.0%) showed ARF. Prevalence of ARF was 17.9% in the plantar aspect of the hind fetlock and 10.6% in the proximal tarsus. Among the total population, 833 horses were considered for performance evaluation. Four-hundred and seventy-eight of them were qualified for racing. The number of ARF significantly affected the racing longevity. However, the number of ARF did not affect performance categories according to maximal ITR. Concerning the distribution of ARF, the number of plantar lesions in the fetlock significantly affected mean ITR. Finally, the index of gravity did not bring more information for prognosis than the number of ARF.

Conclusion

The results of this study show that longevity is the only criteria affected by ARF. Considering sites, only plantar fetlock showed a significant relationship with ITR.
Gait pattern of the ataxic horse compared to the gait pattern of normal and sedated horses

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Introduction
Ataxia is a common problem in equine medicine, and the mechanisms of ataxic gait are still only partially understood. Clinical examination is not specific in determining whether a horse is ataxic. In horses, mild sedation produces reversible ataxia. The aim of this study was to compare the limb coordination of normal horses, ataxic horses, and sedated horses.

Material and methods
Ataxic horses (n = 17) were measured walking and trotting on a treadmill (Mustang 2200 KAGRA, Switzerland) using a 3D high-speed video system with 120 Hz (Motion Analysis, Santa Rosa, CA). From the horizontal movement of the hoof markers, the autocorrelation function (ACF) of the left forelimb and the cross correlation (CCF) between the left forelimb and the three other limbs (CCF flhr, flhl, flfr) were correlated, resulting in a value close to one for high consistency of the motion cycles and a value close to zero for low consistency. The results were compared to data of 17 normal horses prior to and during sedation using the t-test for independent samples.

Results
Comparing normal (NO) and ataxic (AT) horses at walk, highly significant differences for the ACF (AT 0.85 ± 0.02, NO 0.88 ± 0.01) and for all the CCF (AT 0.91-0.92; NO 0.94-0.95) were documented. At trot, ACF and CCF flhr, flhl, flfr were significantly different in the NO and AT groups. Comparing sedated and ataxic horses, only the CCF flfr at walk and trot were significantly different.

Conclusion
Ataxia is best documented and examined at walk. At trot, the pendulum effects may make coordination less relevant. The results of this study may serve as a basic data set for comparison of the gait pattern of questionable ataxic horses with the incoordination of naturally occurring and sedation-induced ataxia.
The influence of raised heels on the hindlimb joint angles (coffin, fetlock and hock) at walk and trot

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Introduction

Raised heels are recommended for a variety of orthopaedic conditions in the hindlimbs. The effects on hindlimb biomechanics have not yet been examined. The aim of this study was to investigate the influence of raised heels on the joint angles of fetlock (FJA), coffin (CJA) and hock (HJA) joints at trot and at walk.

Material and methods

Eight sound horses walking and trotting on a treadmill were used. Data were recorded for each horse in three different measurement settings: barefoot (group0 = G0), with a 2cm raised heel (resulting in 8 hoof angle, group8 = G8); and with a 4cm raised heel (resulting in a 16 hoof angle, group16 = G16). During 15 motion cycles, kinematic measurements of 8 markers per limb were carried out. Mean JA was calculated for each horse in each setting during the normalised stance phase (SP). Groups were compared using multivariate ANOVA analysis for repeated measures with a post hoc test, significance was set at $P < 0.05$.

Results

During the whole SP, CJA was significantly different between the groups at walk and trot. Raised heels led to an increase of the CJA by $11 \pm 2$ at walk and $9 \pm 1$ at trot when comparing G0 and G16. Fetlock extension (FE) was significantly reduced during the first third of SP by $6 \pm 1$ at trot and by $7 \pm 1$ at walk when comparing G0 and G16. HJA was significantly different between groups at walk during all of SP. At trot, the groups were significantly different during the middle third of SP resulting in 5 less extension when comparing G0 ($145 \pm 5$) and G16 ($140 \pm 5$).

Conclusion

Raised heels decrease hind FE, which is different to the effect of raised heels on the fore fetlock. Additionally, raised heels led to a significant reduction of hock extension during stance phase at walk and trot, supporting the reported positive influence of raised heels in horses with spavin.
The effect of gallop training on the hoof angle in Thoroughbred racehorses

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Introduction

Low hoof wall angle at the toe has been associated with a lack of soundness in racehorses. This experiment investigated possible environmental causes of low hoof angles.

Material and methods

Weekly hoof angle measures were taken with a hoof gauge (Ruidoso HG1) from 3 groups of horses: 45 Thoroughbred racehorses, 4 Thoroughbred show horses kept in consistent conditions and shod by the same farrier as some of the racehorses, and 6 unshod free-ranging horses. Fifteen more horses were measured twice in one day to test the repeatability of the method.

Results

Repeatability coefficients were 0.31 degrees (95%CI 0.23 to 0.49) for the left hoof and 0.37 degrees (95%CI 0.27 to 0.59) for the right. Racehorses in training showed a significant decrease in hoof angle over time while free ranging horses and show horses did not. In some racehorses there was a slight increase in hoof angle associated with re-shoeing, but the general trend was for a decrease through training. Free-ranging horses had a significantly lower angle in the winter (wet) compared with the summer (dry) in both left (mean 53.7 dry and 56.8 wet \( P = 0.029 \)) and right (mean 51.5 dry and 55.7 wet \( P = 0.009 \)). Show horses had no significant change in hoof angle. Racehorses that had a period of rest during the experiment (11 horses) showed a decrease in hoof angle during training and an increase over their rest period for both hooves (-0.42 degrees during training versus +0.37 degrees during rest \( P = 0.006 \) for the left hoof, and -0.53 degrees versus +0.36 degrees \( P = 0.001 \) for the right).

Conclusion

These data suggest that training for fast exercise in thoroughbred racehorses is associated with a reduction in hoof angle, and that wet pasture conditions may also be associated with a reduced hoof angle in free-ranging horses.
Vertical frontlimb ground reaction forces of sound and lame Warmbloods differ from those in Quarter horses

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Introduction
Lameness still is a burden to horse owners and veterinarians. In Evidence Based Veterinary Medicine studies to evaluate NSAID therapies, force plates are commonly used to objectively assess improvement of lameness. In literature, however, there is no information available whether breed differences would influence these force plate measurements in sound and lame riding horses.

Material and methods
Kistler force plate measurements of lame \( (n = 20) \) and sound \( (n = 20) \) Warmblood and lame \( (n = 11) \) and sound \( (n = 8) \) Quarter horses were compared. Lameness was visually scored using the grade 0-5 AAEP lameness scale.

Results
It appeared that, at trot, frontlimb lame Warmblood horses showed significantly \( (P < 0.05) \) higher vertical Ground Reaction Force values (grade 2: 89% BodyWeight; grade 3: 69% BW), than frontlimb lame Quarter horses with similar lameness scores (grade 2: 75% BW; grade 3: 63% BW). Furthermore, trotting sound Warmbloods loaded their frontlimbs with 118% BW and their hinds with 104% BW, while Quarters only used 101% BW in the front and 92% BW in the hinds.

Conclusion
Relative peak vertical forces of either lame or sound horses seem to be influenced by breed differences between Warmblood and Quarter riding horses. These possibly conformational differences would enable trotting Quarters to demonstrate lower peak vertical forces, while the estimated absolute decrease caused by lameness is rather similar (Warmbloods 36% vs Quarters 30%). Thus, in studies where objective lameness observations are recorded, breed differences should be taken into account when specific grades of lameness of a group of horses are to be compared to another group.
Equine superficial digital flexor tendon forces at the trot and canter uphill

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Introduction

Injury to the equine superficial digital flexor tendon (SDFT) may be reduced by decreasing the force in the SDFT during running. Strain in the SDFT reportedly decreases with a toe-wedge shoe. The angle of hoof-sole during uphill running is similar to that of the toe-wedge shoe. The purpose of this study was to determine the effects of uphill exercise on the force in the SDFT.

Material and methods

"Arthroscopically Implantable Force Probes" (AIFP) were implanted into the SDFT of the left or right forelimb of seven Thoroughbred horses. AIFP output was recorded during trotting and cantering on a treadmill inclined at slopes of 0%, 3% or 8%, and then 0% again. SDFT force was calculated as a relative value, with the amplitude of AIFP output voltage at an initial 0% slope equal to 100.

Results

Increasing the incline from 0 to 8% tended to decrease peak force in the SDFT in nine successfully analyzed trials at the trot; and in the trailing forelimb at the canter in three successful trials. Statistical significance was not determined at the canter due to the small number of trials.

Conclusion

The force in the SDFT trotting or cantering uphill is unchanged or lower than that generated at the same speed on a flat surface. Because at similar speeds the workload for uphill exercise is greater than on the flat, uphill running increases exercise strength without increasing force in the SDFT.
Morphometrical variations of the carpal bones in Thoroughbreds and ponies

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Introduction
The carpus is a complex region which generally contains seven carpal bones. Although the carpal bones have been described in a general manner, variations between equine breeds have not been identified. The purpose of this study was to identify morphological variations of the carpal bones between thoroughbred horses and ponies.

Material and methods
Four pairs of Thoroughbred carpi and 8 pairs of pony carpi were collected and boiled at 98.5 C for 48 hours. The weight of each carpal bone was measured. At 49.5 C, the bones were heated for 8 hours, and then re-weighed. Measures of width, length and volume were taken, and a full morphological description was made for each bone.

Results
The intermediate carpal bone in these thoroughbreds represented 15.2 to 16.1% of the total volume of the carpal bones, while in the wild pony it represented 16.8 to 19.6%. Medially, the first carpal bones in these thoroughbreds were proportionately smaller than in the ponies. Morphologically, in the ponies, the palmo-medial facet of the distal surface of the fourth carpal bone was oriented considerably more to the medial side. In the thoroughbreds, the palmar tubercle of the ulnar carpal bone was proportionately large and clearly evident, while in the ponies it was very small and hard to distinguish.

Conclusion
There are considerable morphological variations in the carpal bones between thoroughbreds and ponies. Further studies are needed to find the reasons and mechanical effects of these variations.
Determination of mechanical loading components of the equine third metacarpal bone at mid-shaft from in vivo measurements of strain motivation

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Introduction

Measurement of the loading of the third metacarpal bone (MC3) at mid-shaft during locomotion can provide insight into clinical conditions that involve this bone. In addition, direct measurement of loading can be used to validate mathematical (computer) models of the forelimb.

Aims: To describe the time-varying loading at the mid-shaft of the MC3 during walking.

Material and methods

A single Thoroughbred horse (450 kg) was instrumented with 3 triple-gauge rosettes adhered to the dorsal, medial and lateral aspects of the MC3 at mid-shaft, using a technique previously described. Strains were sampled at 40 Hz during walking at 1.4 m/s on a treadmill. Analysis of the strains was performed using a shaft model of the bone to find four stress components that represented a linear decomposition of the mid-shaft loading: a uniform axial stress, torsion, and bending moments in two perpendicular planes.

Results

Uniform axial stress showed two distinct peaks during the stance phase of the stride, reminiscent of the two peaks reported in recordings of the vertical ground reaction force (GRF). Axial torsion showed a pattern similar to previously reported horizontal GRF. Sagittal and transverse plane moments together caused compression of the dorso-medial aspect of the bone during the stance phase.

Conclusion

In addition to axial stress, bending moments and torsion were also observed. Further research will assess how these loads vary with gait, speed and conformation. Comparisons between measured stresses and those predicted by computer models will be performed.
Fetlock landing kinematics on two different arena surfaces

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Introduction

The fetlock joint (MPJ) has a major role in the attenuation of high impact forces produced when landing from a jump, which may be modified due to the resilience of a surface. This study investigated the movement strategies of the MPJ on both the leading and trailing limbs on two different arena surfaces.

Material and methods

Sagittal plane kinematics of the MPJ of four horses were captured by a high speed (250 Hz) digital camera during landing from a two strided double fence onto two arena surfaces: sand and rubber (SR) and sand and fibre (SF). Five trials were digitised using the Ariel Performance Analysis System (APAS) for each horse under each condition. Impact was identified from the vertical velocity of PI. Graphs were plotted for angle and angular velocity versus time. Key points in the landing phase were identified and a repeated measures ANOVA was performed for each limb on each surface.

Results

Significant differences were found between the leading and trailing limbs from the time of impact of each limb to maximum extension of MPJ (mean difference = 0.0235s, $P = 0.005$) and to the McIII reaching the vertical (mean difference = 0.0838s, $P = 0.018$). Ranges of motion (ROM), peak extension velocity, and time to peak extension velocity of MPJ were not significantly different. The effect of the arena surfaces was also found not to be significant.

Conclusion

The peak angular velocity of the MPJ on the leading and trailing limbs shows a similar control during power absorption; however, the timing of this is different showing that different strategies are required. No significant differences between surfaces were found, but work is currently underway looking at more extreme surfaces encountered in training and competition riding.
A high head and neck position reduces back movement in dressage horses compared to a natural position, but the “Rollküür position” increases back mobility.

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Introduction

In dressage competitions, another position of the head and neck than the natural is required. Some training systems use extremely low (“Rollküür”) positions, claiming a positive effect on the gymnastic development of the horse. The effects of these positions are heavily disputed, but little is known about their effect on kinematics. Objectives: To study the influence of different head-neck positions: (p-1) free, (p-2) high with head slightly in front of the vertical, (p-3) Rollküür and (p-4) extremely-high extended head-neck on 3-dimensional back kinematics in dressage horses.

Material and methods

Seven Warm-blooded international level dressage horses were studied walking and trotting on a treadmill with different head-neck positions. Kinematics was measured using reflective markers with 12 infrared cameras. Positions were compared with the free position at the same speed.

Results

Most of the changes in the back were found at p-4: the flexion-extension movement of the thoracic back was reduced at trot (17.6%, \( p < 0.01 \)) and in the lumbosacral junction at walk (17.6%, \( p < 0.05 \)), lateral bending was higher in the thoracic segment at walk (18.1%, \( p < 0.05 \)), axial rotation was reduced at walk (15.7%, \( p < 0.01 \)) and higher at trot (13.4%, \( p < 0.05 \)). Protraction was reduced at walk (6%, \( p < 0.01 \)). No differences were found in protraction or stride duration at trot. At p-2, flexion-extension was reduced in the thoracolumbar area at trot (12.9%, \( p < 0.05 \)). At Rollküür, the whole back flexion-extension was bigger at trot (21.2%, \( p < 0.01 \)).

Conclusion

In unridden horses, some head-neck positions significantly influence back kinematics. A high position reduces normal back mobility, whereas the Rollküür position increases the range of motion at trot.

Potential relevance: This study provides scientific data on the far empirically discussed influence of head-neck position on equine motion. The outcome lends credibility to the theoretical background of the “Rollküür” as a training method and may serve as an argument in the discussion about the ethical acceptability of some training methods.
Effect of head and neck position on limb and back kinematics in the ridden horse at trot

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Introduction

The effect of the rider and equipment alters the horse’s movement and loading to the limbs as well as the metabolic response to exercise. The aim of this study was to describe the effect of head positions on the movement of the limbs and back in the ridden horse.

Material and methods

One Intermediate and six Grand Prix dressage horses trotted on a treadmill while being ridden by their respective riders. The horses were trained to trot with several head and neck positions (H) as helped by their riders and controlled by a dressage judge. H1–free position, loose reins. H2–elevated neck with the head slightly in front of the vertical. H3–elevated neck, head behind the vertical. H4–extremely flexed head and neck with the head behind the vertical (rollkur). H5–extremely high extended head and neck position. The 3-D kinematics of the horse and rider were measured simultaneously with vertical force at the hoof and pressure under the saddle. Limb, head and neck, and back angles of the horse were determined from the kinematic data. Statistical comparisons of the limb and back data were calculated with regards to the H2 position.

Results

In the H5 position, maximal extension of the fetlock joint in the forelimbs and hind limbs increased during the stance, maximal flexion of the carpus increased during the swing, and the back segment angle at L5 was more extended throughout the stride. In the H1 position, maximal extension of the fetlock joint in the forelimb was reduced during stance, maximal flexion of the carpus was decreased during the swing, and hip joint flexion occurred later during the swing phase of the stride.

Conclusion

Head position in the ridden horse has a significant effect on the movement of the limbs and back. While the free and extremely high positions resulted in significant changes in movement, the rollkur position and H3 did not seem to differ from the position that is similar to advanced dressage riding (H2).
Analysis of the rider’s impact on the horse’s locomotion through biomechanical and osteopathic approaches

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Introduction

Ridden horses display modified locomotion biomechanics and may, on the long term, develop musculoskeletal disorders. The present study was aimed firstly at describing the impact of riding on horse locomotion by measuring the stride parameters, and secondly at linking these biomechanical changes with the development of locomotion pathologies by carrying out osteopathic assessments.

Material and methods

Biomechanical data were collected with the Equimetrix® system based on accelerometry. Twenty warmblooded horses of various age and in sound health for daily riding work were recorded at walk and trot before and after riding on a standardised 70 m track, in an outdoor sand arena. Test conditions enabled the comparison between the stride parameters of the loose (no rider/tack) horse and those of the loaded and ridden horse, under a novice rider and an advanced rider of the same weight.

In parallel, osteopathic assessments were carried out on the horses, under blind conditions, by a novice osteopath and an experienced one; manipulations were performed by the experienced osteopath only.

Results

Preliminary results indicate that loading and riding a horse significantly affect some of the stride parameters such as propulsion power, medio-lateral power, dorso-ventral displacement, regularity and symmetry, with different alteration patterns depending on the skills of the rider and whether the horse has received osteopathic treatment. Potential correlations between osteopathic status and stride characteristics are also evaluated and statistically analysed.
Saddle force measurements in relation to ground reaction forces in different head and neck positions in the ridden horse

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Introduction

The influence of the head and neck position (H) on the ridden horse’s motion pattern and on force distribution under the saddle is controversially discussed and has never been investigated.

Materials and methods

Vertical ground reaction forces (GRFz), 3D kinematics and saddle forces (SF) were recorded simultaneously from 7 high level dressage horses, ridden by their own professional rider on an instrumental treadmill at walk and sitting trot in 6 different Hs: H1–free; H2–elevated neck, head in front of the vertical; H3–elevated neck, head behind the vertical; H4–rolled up; H5–extremely high neck; H6–low neck, extended head. Data from all Hs were compared to H2 (reference) at matched treadmill speeds. The differences were tested using a paired t-test (P < 0.05). Synchronised SF and GRFz, both normalised to stride duration (SD), were compared. Saddle contact area was divided into 4 transverse areas and SF distribution (% of total) was analysed.

Results

At trot, horses prolonged their SD from H1 to H5 reaching significance for H4 (mean difference to H2 + 2.0%) and H5 (+ 4.1%). For all Hs, the minimum SF was attained close to, but significantly later than ground contact of the forelimb (mean delay 3.4 ± 1.3% of SD) and its maximum simultaneously with the forelimb GRFz peak (0.4 ± 1.7% of SD). When compared to H2, both the GRFz peak of the forelimbs and the SF peak occurred significantly later in H1 (+ 0.5% of SD), simultaneously in H3 and H4 and earlier in H5 (- 2.4% of SD). The SF minimum shifted in a similar manner. In neck positions lower than H2 (H1, H4, H6), the force was redistributed to the centre of the saddle contact area, most pronouncedly in H6 at walk (P < 0.03). In H3 and H5, no significant force shifts were observed.

Conclusion

The timing of minimum and maximum SF is closely related to ground contact and peak GRFz of the forelimb, respectively. Low neck position (H6) raises the back, supporting the centre of the saddle more.
Influence of draw reins on limb kinematics in relation to kinetics

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Introduction

It has been shown in a previous study that draw reins in combination with normal reins can increase the weight-bearing of the hind limbs (Roepstorff et al. 2002), whereas riding with draw reins only, does not produce the same effect. The present work was based on the analysis of the kinematic data recorded from the same experiment. The aim of this study was to analyse the influence of draw reins on limb kinematics, and, if possible, describe kinematic characteristics of importance for increasing weight bearing of the hindquarters.

Material and methods

The experimental design has been described in detail elsewhere (Roepstorff et al. 2002). Eight sound Swedish warmblooded horses were ridden at trot, 3.0 m/s over a force plate. The kinematics and speed were recoded using a 6-camera ProReflex motion capture system. Three different experimental riding alternatives were evaluated: 1) draw reins only, 2) the combination of draw reins and normal reins and 3) normal reins only.

Results

The draw rein significantly influenced the head and neck angles, but the changes were not found to correlate with kinetics. Changes in weight bearing distribution instead seemed to be more related to decreased hock and stifle joint angles. The decrease of joint angles resulted in a lowering of the hindquarters during the stance phase. Hind hoof pendulation was unaffected.

Conclusion

Lowering of the hindquarters may therefore be important to achieve a shift of weight from fore to hind. The results are important to clinicians working with prophylaxis as well as rehabilitation of sport injuries. It is also important in defining terminology within equestrian sports.
Preliminary studies to investigate in vivo and in vitro sacroiliac movement in the horse

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Introduction
Two experiments were undertaken to evaluate the range of movement between the sacrum and ilium in the horse.

Material and methods
Study 1 recorded the relative motion in vivo between the sacrum and ilium (n = 10 TBs). The cross sectional area (CSA) of the dorsal sacroiliac ligament (DSIL) was measured ultrasonographically and compared before and after manual force application to the ilium at the tuber coxae (TC) and tuber sacrale (TS). Study 2 recorded the relative motion between the sacrum and the ilium in vitro using wireless orientation sensors on a cadaver. Euler angles represented movement during manual force application to the ilium in the transverse, frontal and sagittal planes. Data were collected pre and post pelvic ligament transection (DSIL & sacrotuberous - STL)

Results
Study 1 showed significant decreases (P < 0.05) in CSA of DSIL with force application to TC (mean difference 0.21 ± 0.19 cm²) and TS (mean difference 0.36 ± 0.18 cm²) with a greater difference in CSA with force application to TS. No difference was observed between the left and right DSIL CSA. Study 2 demonstrated motion between the ilium and the sacrum to occur in all 3 planes. The largest motion over 12 trials occurred in the transverse plane (mean 4.55 degrees, SD 0.27, CV 6%). The greatest increase in motion followed transection of STL in the sagittal plane (mean 6.32 degrees; SD 0.04; CV 1%).

Conclusion
The change in DSIL CSA in vivo with application of a manual force may represent lengthening of the ligament and equine sacroiliac joint motion. The motion recorded between the ilium and sacrum in vitro suggests that the greatest sacroiliac motion may occur in the transverse plane. Further pelvic biomechanics research using orientation sensors in vivo is warranted.
Body center of mass movement in horse trotting in a circle

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Introduction

The objective was to develop a methodology for kinematic analysis of horses moving along a circular path and to report preliminary findings describing movements of the body center of mass (COMbody).

Material and methods

Seventy-five skin markers, distributed over the head, neck, trunk and limbs of 5 sound horses were tracked in a global coordinate system at 120Hz as the horses trotted around a small circle. Based on segmental inertial data, 3D positions of the segmental centers of mass and COMbody were calculated. Movements of COMbody were measured relative to the cylindrical sagittal plane, which was defined as a vertical plane defined by a marker overlying the sixteenth thoracic vertebra (T16).

Results

During trotting, COMbody was the highest at the start and end of the diagonal stance phases and lowest in midstance, with a vertical range of 90 ± 6mm. All horses leaned to the inside of the circle, with an average angle of 14.8 ± 2.8o during the entire stride. COMbody swung from side to side with a mediolateral range of 123 ± 18mm, reaching its most inward position around contact of the outside forelimb and its most outward position around contact of the inside forelimb.

Conclusion

Kinematic analysis of horses moving on a circular path can be accomplished by transposing data onto a cylindrical plane defined by the path of T16. Horses leaned to the inside when turning, and the oscillations of COMbody in a horizontal plane were not symmetrical relative to the circle line. The angulation of the horse’s body during circling is likely to be associated with asymmetrical forces on the limbs, which may play a role in the etiology of injuries, in the response to longeing as a diagnostic technique and in the appropriateness of certain training methods during rehabilitation.
Harnessed versus mounted Standardbreds on the track: changes in gait and physiological variables

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Introduction

Based on the analysis of performance in an elite population over the past 20 years, the mean difference of maximal speed between a mounted and a harnessed race is constant and about 2 s per/km, when considering the same population, same distance and the same track. The aim of that study was to compare mounted and harnessed activities in trotters by measuring physiological and biomechanical data to explore that difference.

Material and methods

Fourteen trotters were submitted to two standardized exercise tests one week apart. Randomly, one test was performed harnessed and the other mounted by jockeys of standardized weight. The field test consisted in three steps of 3 min at 8.33, 9.5, 10.66 m/s and finally at maximal speed. During the tests, speed, heart rate, respiratory frequency, blood lactate concentration, and stride characteristics (length, frequency, symmetry, regularity, dorso-ventral displacement, 3D activities) were measured. Statistically, paired two tests were calculated between the two conditions: harnessed or mounted.

Results

Most physiological and biomechanical variables were significantly different between the two conditions. V4 (speed for a blood lactate concentration of 4 mmol/L), V200 (speed for a heart rate of 200 bpm), stride length, and the symmetry of the trot were lower in the mounted condition. Inversely, respiratory frequency, stride frequency, dorso-ventral displacement and 3D activities were significantly higher in mounted compared to harnessed condition.

Conclusion

Those significant changes between harnessed and mounted condition reflect an increase in energetic cost of locomotion in mounted horses compared to harnessed ones. This higher energetic cost is related to the weight loading but might also be due to interactions between horse and jockey movements.
Correlation between routine radiographic findings and racing ability in French Trotters

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Introduction

Many horses are routinely subjected to radiography as part of pre-purchase examinations and those having lesions are usually depreciated. Paradoxically, the relationship between the presence of radiological abnormalities and the subsequent racing performance is still discussed. Performance indeed depends on many factors including horse temper and conformation, training techniques and the racing program. The purpose of the present study was to evaluate the impact of osteoarticular lesions (OAL) on racing ability in French Trotters (FT).

Material and methods

The limbs of 188 FT from 16 breeding farms were radiographed at approximately 18 months of age just before they started training. Radiographic files were analysed by three veterinarians. All the OAL were graded according to a standardised protocol depending on their severity. Racing ability was evaluated through the success to “qualification”, a test that young FT have to pass to be allowed to race. Information was collected from the trainers to know the reasons for non-qualification. The osteoarticular statuses of qualified and non-qualified horses were compared using the Khi-2 test.

Results

The main reason for non-qualification was a “lack of quality” (51.4%) and OAL were responsible for non-qualification in 28.5% of the horses. The presence and location of OAL had little influence on the qualification rate. Nevertheless, the proportion of qualification was significantly lower in horses with one severe OAL, more than 2 moderate OAL or more than 4 mild OAL.

Conclusion

This study confirms that OAL may be compatible with beginning a racing career. Only severe forms of OAL or multiple lesions significantly reduce the ability to compete.