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Changes in movement symmetry over the stages of the shoeing process in Military Working Horses

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Abstract

Military working horses perform a high proportion of work on road surfaces and are shod frequently to deal with high attrition rates. We investigate the influence of shoeing on movement symmetry as an indirect indicator of mechanical differences affecting force production between contralateral limbs.

In this quantitative observational study, inertial sensor gait analysis was performed in 23 Irish Sport type horses (4-21 years, 1.58-1.85m) in full ceremonial work at the King's Troop, Royal Horse Artillery. Changes in two movement symmetry measures (SI: symmetry index; MinDiff: difference between displacement minima) for head and pelvic movement were assessed at four stages of routine shoeing: 'old shoes', 'shoes removed', 'trimmed', 'reshod'. Horses were assessed applying shoes to the front limbs (N=10), to the hind limbs (N=10) or both (N=3).

Changes in head movement symmetry between conditions were small and inconsistent. Changes in pelvic movement symmetry were small and showed significant differences between shoeing stages (SI: P=0.013, MinDiff: P=0.04) with most symmetrical pelvic movement after trimming.

In military working horses with high frequency shoeing small changes in movement symmetry were measured. All significant changes involved trimming and which indicates that future studies should in particular assess changes before/after trimming and investigate longer shoeing intervals.

Keywords: military working horses, road surface, shoeing, trimming, movement symmetry

INTRODUCTION

Farriery techniques have evolved from the requirements of protection and preventing excessive hoof wear to improving performance, prophylaxis and corrective techniques dealing with injuries (Hickman and Humphrey 2004). It is well documented where forces are acting under the hoof and how they are transmitted through the foot (Willemen and others 1999; Hood and others 2001), how angles of trimming and shoeing affect the structures inside the foot (van Heel and others 2004; Kummer and others 2006; Moleman and others 2006) and how attaching a shoe affects a horse's gait quality (Willemen and others 1997). However, comparatively little is known about the immediate effect of shoeing on movement symmetry (MS), a lack of which – either between stride halves or between movement of the left and right side of the horse – is often used to characterize lameness (May and Wyn-Jones 1987; Buchner and others 1996; Kramer and others 2004). This is in analogy to visual indicators such as head nod and hip hike, which are intrinsically linked to the underlying mechanical changes (Buchner and others 1996). Here, we assess quantitatively with inertial sensor gait analysis how shoeing affects MS in a group of military working horses. These horses perform large amounts of their exercise on hard surfaces and recently a similar population of military working horses has been reported to commonly show lameness and among the top three reasons "foot/shoeing problems" (Putnam and others 2014).

The application of a shoe alters both limb kinematics and kinetics. The increase in inertia (Willemen and others 1994; Singleton and others 2003) mostly affects the swing phase. Small significant differences in movement and loading of the distal limb also exist (Roepstorff and others 1999). Crucial, in terms of the limb joint torques, is the point of force application, a sensitive parameter in the discrimination between orthopaedic deficits (Williams and others 1999). Point of force application is only minimally affected by a standard steel shoe applied to a balanced foot, but alterations to the applied shoes (wedges) alter point of force application significantly (Wilson and others 1998). Shoeing also affects the dampening characteristics of the hoof and the distal limb leading to an increase in vibrations transferred through the hoof (Dyhre-Poulsen and others 1994). Proximal to the fetlock, only minimal differences in vibration are observed (Willemen and others 1999). It has been hypothesized that in order to maintain a constant slip time and distance with different types of shoes, horses adapt their gait pattern (Pardoe and others 2001).

The ideal standard for trimming of a horse's hoof is controversial (Eliashar 2007). It is generally accepted that trimming affects the hoof and the structures within it (Kummer and others 2006). Trimming is usually undertaken with the aim to leave the foot with a conformation that maximizes the mechanical efficiency (Hood and others 2001) and the foot is deemed balanced when done so, either 'geometrically', 'dynamically' or 'naturally' in balance (O'Grady and Poupard 2001).Feet are often trimmed to gain a straight hoof pastern axis (Willemen and others 1997; Hood and others 2001; van Heel and others 2004) and so that the hoof and phalanges are approximately symmetrical with respect to a line bisecting the metacarpal region (Butler and others 2000, Hickman and Humphrey 2004). Trimming also reduces the differences between left and right feet resulting in a more symmetrical landing pattern and, with a reduced four week shoeing cycle, trimming seemingly only affects temporal components of the hoof-ground interaction (van Heel and others 2004).

Quickly applicable to the horse, sensor based gait analysis can be used to study the effects of standard procedures of lameness exams, e.g. flexion tests (Marshall and others 2012; Starke and others 2012a), or lungeing (Starke and others 2011; Pfau and others 2012; Rhodin and others 2013) by quantifying the amount of movement symmetry (MS) analogous to visual lameness indicators such as hip hike and head nod. Here we make use of MS of poll and pelvis as measurable indicators mechanically linked to force distribution between contra-lateral limbs via Newtonian physics (Pfau and others, 2015). In particular, we assess the immediate effects of the different stages of the shoeing process on these mechanically relevant parameters indirectly showing difference in force production between contralateral limbs. This addresses the question to what extent a horse is prompted to alter force production in reaction to small changes in foot balance, distal limb inertia and point of force application. We hypothesize that horses are able to immediately adapt their limb movement patterns and will hence show no changes in MS of poll and pelvis over the four stages of the shoeing process.

MATERIALS AND METHODS

Ethics

The project was approved by the Royal Veterinary College's Ethics and Welfare Committee.

Horses

Thirty Irish Sport type horses (age: 4 years to 15 years, body height: 1.58 m to 1.85 m) owned by the King's Troop, Royal Horse Artillery, were convenience sampled and quantitatively assessed for movement symmetry during routine trimming and shoeing. Horses were deemed suitable if considered fit for work by the regiment Veterinarian (NH) and in normal work and training. Due to the high amount of work performed on road surfaces, these horses undergo a high frequency shoeing regimen (every 2-3 weeks) and new shoes are fitted as seen fit by the farrier at different time points for front and hind limbs. Ten horses were assessed before/after routine shoeing of front limbs, ten horses before/after shoeing of hind limbs and three horses before/after shoeing of both front and hind limbs. Seven horses had to be excluded from the study due to technical issues or behavioral problems during at least one of the four data collection stages.

Training and Shoeing Regime

All horses underwent the same training regime and were on a short shoeing cycle due to the high proportion of work conducted on road surfaces and the high attrition rates seen on these. As a result, front and hind shoes were changed independently when required as assessed by the head farrier (AB). Steel manufactured shoes[1,2] (concave fullered, toe clips in front, quarter clips in hind legs) were changed every two to three weeks. Trimming and shoeing was undertaken by experienced farriers, under the supervision of an Associate of the Worshipful Company of Farriers (AB), visually aiming to achieve a straight hoof pastern axis, mediolateral foot symmetry and symmetrical heel height. Shoes were fitted through hot shoeing technique and the foot dressed.

Equipment Setup

Two MTx inertial sensors[3] were attached to each horse. One sensor was attached to the head with a customised Velcro attachment to the highest point on the head collar (poll) to quantify head nod; a second sensor was placed on the os sacrum using adhesive padding[4] to measure pelvic hike. Sensors were attached by cables to an Xbus wireless transmitter unit[3] mounted in an elastic surcingle sending calibrated inertial sensor data at a sample rate of 100 Hz per individual data channel to a laptop computer running MTManager software[3].

Data collection

Horses were trotted in hand in a straight line (approximately 50m) twice aiming to gather a minimum of 25 strides (judged by counting strides) for each of the following four conditions:

1 with old shoes
2 after removal of old shoes, before trimming
3 fully trimmed and balanced
4 after application of new shoes.

The horses were trotted over a hard (tarmac), flat, straight surface by an experienced handler (from the left side) and were allowed to set their own preferred speed at the initial trotup (old shoes). A metronome[5] was adjusted to the stride frequency observed during the initial trotup to ensure consistency of speed between trot ups to minimize variation of trotting speed affecting results (Peham and others 2000, Starke and others 2013). For each horse, all recordings were completed within approximately 1.5 hours.

Data analysis

Data was processed with custom written MATLAB[6] scripts following published protocols for rotation, double integration and stride segmentation (Pfau and others 2005; Starke and others 2012b). Based on vertical displacement data of poll and os sacrum, symmetry index (SI_{poll}, SI_{pelvis}) (Starke and others 2011) and difference between displacement minima observed during the stance phases of the two diagonal pairs of limbs ($MinDiff_{poll}$, $MinDiff_{pelvis}$) (Keegan and others 2011) were determined for each stride (see Figure 1A). Median and interquartile ranges across all available strides were calculated for each condition of each horse.

In order to minimize the influence of differences in MS between left and right ‘sided’ horses, normalized MS measures were calculated for condition 1 (old shoes) following the procedure illustrated in Figure 1B: MS measures of horses with negative MinDiff values, observed for condition 1, were inverted for all four shoeing conditions. As a consequence, the variation in movement symmetry between horses due to sidedness was reduced in the baseline condition while maintaining the ability to study directional changes in asymmetry. Changes in normalized MS between consecutive stages (1to2, 2to3, 3to4) as well as overall (1to4) and between old shoes and after trimming (1to3) and between shoes off and new shoes (2to4) were calculated as the difference in normalized MS values (ΔSI_{poll}, $\Delta MinDiff_{poll}$, ΔSI_{pelvis}, $\Delta MinDiff_{pelvis}$).

Statistical analysis

Statistical analysis was carried out in SPSS[7]. Stride-by-stride median SI and median MinDiff values were tested for normality using a Shapiro-Wilk test. For normally distributed data, repeated measures ANOVA tests were used to compare normalized MS between the four conditions and ANOVA to compare the differences between the conditions. For non-normally distributed data, a Friedman test investigated the differences in normalized MS between the four conditions and a Kruskal Wallis test assessed the changes in the differences between the conditions. Posthoc pairwise comparisons were conducted applying Bonferroni's correction method. P values of <0.05 were considered significant.

RESULTS

On average, median normalized MS values were calculated from 40 strides per condition and horse. All median normalized MS values except for $\text{MinDiff}_{\text{pelvis}}$ were found to be normally distributed ($\text{SI}_{\text{pelvis}}$ P=0.95, $\text{MinDiff}_{\text{pelvis}}$ P=0.02, SI_{poll} P=0.20, $\text{MinDiff}_{\text{poll}}$ P=0.22). Table 1 summarizes normalized MS values for poll and pelvis for the 23 horses. Across all horses, a mean of 0.17 was found for SI_{poll}, 7 mm for $\text{MinDiff}_{\text{poll}}$, 0.10 for $\text{SI}_{\text{pelvis}}$ and 3.8 mm for $\text{MinDiff}_{\text{pelvis}}$.

MS of poll and pelvis over the stages of the shoeing cycle.

Both SI and MinDiff values generally showed little variation over the four stages of the shoeing cycle (Figure 2). Head movement was found to be most symmetrical (lowest median value) after removal of the old shoes (SI_{poll}) respectively after trimming and with new shoes ($\text{MinDiff}_{\text{poll}}$). Across all horses, both $\text{MinDiff}_{\text{pelvis}}$ and $\text{SI}_{\text{pelvis}}$ appear to be most symmetrical after trimming (Figure 2, condition 3). However, no statistically significant difference between the four conditions (SI_{poll} P= 0.703, $\text{MinDiff}_{\text{poll}}$: P= 0.491, $\text{SI}_{\text{pelvis}}$: P = 0.378, $\text{MinDiff}_{\text{pelvis}}$ P = 0.385) was found.

Changes in MS between conditions.

Intra-individual changes in normalized MS between the different stages of the shoeing process (Figure 3) show changes close to zero between all conditions for head movement with interquartile ranges including zero for $\Delta\text{SI}_{\text{poll}}$ and $\Delta\text{MinDiff}_{\text{poll}}$. Changes in normalized MS of the poll did not reveal any significant differences between shoeing/trimming conditions. The largest variation between horses was found for the change from condition 3 (trimming) to condition 4 (new shoes) for $\Delta\text{SI}_{\text{poll}}$.

Changes in normalized pelvic MS reveal that in particular for changes involving condition 3 (trimming, e.g. 2to3 and 3to4) values deviating from zero are measurable. For both $\Delta\text{SI}_{\text{pelvis}}$ and $\Delta\text{MinDiff}_{\text{pelvis}}$ small negative changes are found between condition 2 (shoes removed) and condition 3 (trimmed) indicating an increase in symmetry after trimming. This is then counteracted (for both ΔSI_{pelvis} and $\Delta MinDiff_{pelvis}$) by small positive changes in the following step (3to4) after fitting of the new shoes. ANOVA indicates a significant difference ($P = 0.013$) for ΔSI_{pelvis} and $\Delta MinDiff_{pelvis}$ ($P=0.04$). Bonferroni post hoc tests for ΔSI_{pelvis} show significant differences between condition 2to3 and 3to4 ($P = 0.018$). Significant differences for $\Delta MinDiff_{pelvis}$ were found between condition 1to2 and 3to4 ($P = 0.025$), condition 1to3 and 1to4 $P = 0.033$), condition 1to3 and 3to4 ($P = 0.003$), condition 2to3 and 2to4 ($P = 0.031$) and condition 2to3 and 3to4 ($P = 0.004$). All pairwise significant changes for ΔSI_{pelvis} and $\Delta MinDiff_{pelvis}$ included changes from or to condition 3.

DISCUSSION

In this study we have investigated with quantitative gait analysis the immediate effects of the shoeing process on normalized MS of poll and pelvis in a group of military working horses. These horses typically undergo a high frequency shoeing cycle (2-3 weeks) and are often independently shod in front and behind as a result of the high attrition rates on the road surfaces they work on. A similar population of horses has recently been shown to commonly show lameness and a considerable proportion is related to foot/shoeing problems (Putnam and others 2014). Here, we have shown that MS showed overall little difference between the four stages of shoeing. The significant differences found for changes in normalized pelvic MS between the conditions – but not for the actual normalized MS values – indicate that even after normalizing MS data with respect to the direction of asymmetry inter-individual variation in the amount of MS, i.e. the baseline level of asymmetry, has a masking effect which is removed by investigating differences between conditions.

It seems interesting to note, that in particular trimming – which affects both foot balance and distal limb inertia (compared to the baseline condition with the old shoes) and which has been found to result in more symmetrical foot placement between contra-lateral limbs interaction (van Heel and others 2004) – is involved in all significant pairwise comparisons for pelvic MS. No significant changes were found for head movement, despite the fact that the forelimbs support more than half the body weight of a horse (Merkens and others 1993; Dutto and others 2004; Witte and others 2004). However, the large variation between horses for ΔSI_{poll} may indicate that individual horses adopt different strategies to deal with changes in foot balance and inertia when the new shoes are applied. It would be interesting to follow this up several days after shoeing and to investigate the effect of shoeing on MS in horses with clinically diagnosed lameness. In this study it was practically not feasible to implement a control assessment mimicking the shoeing process (without actually performing the trim and the shoeing) to investigate whether the changes measured here could be simply related to repeated trotting.

All horses were deemed fit for regular work by the regiment Veterinarian. However, there was some variation in baseline MS values between horses when assessed quantitatively with gait analysis. The average number of strides of 40 per condition suggests that the objective measurements are likely a good representation of the amount of MS and its stride-by-stride variation (Keegan and others 2011). When applying our current thresholds of deviating from ‘perfect symmetry’ by more than +/-0.18 for head SI and +/-0.17 for pelvic SI (Buchner and others 1996; Starke and others 2011), eleven horses would have been classified lame, a similar percentage of general sports horses has recently been reported to show gait abnormalities (Greve and Dyson 2013). It is important to mention that it is not possible to relate the recorded movement asymmetries exclusively to pain related lameness, which would require a full clinical lameness examination including diagnostic analgesia. However, similar changes in MS (head nod and hip hike) are observed clinically and have been linked to the underlying mechanics (Buchner and others 1996) and an uneven force distribution between contralateral limbs (Keegan and others 2012, Bell and others, 2016). It hence seems reasonable to argue that the horses classified outside normal limits show differences in force production between contra-lateral limbs. Many of the changes measured here between the four stages of shoeing would be hard to appreciate by eye, since human perception of movement asymmetry appears to be limited (Parkes and others 2009).

The documented variation in MS between horses further supports our attempts to minimize the effect of baseline MS by inverting values (normalized MS) of horses with negative SI values for condition 1. Only when investigating changes – i.e. differences in normalized MS within each horse between each stage – significant differences were revealed between the shoeing stages – effectively removing the masking effect of baseline MS. All significant differences included a change from or to condition 3 (trimming and balancing) the one stage of the shoeing process that has a combined effect on foot balance and distal limb inertia when compared to the baseline condition with the old shoes.

While changes in pelvic MS show significant pairwise differences, no significant changes were found for changes in head MS. $\text{MinDiff}_{\text{pelvis}}$ in particular quantifies the differences between the minima of pelvic displacement observed during the left and right hind limb stance phase. The minimum position of the pelvis in mid stance is closely related to the amount of fetlock hyperextension and hence the amount of force exerted onto the ground – an indicator of weight support. Interestingly $\Delta\text{MinDiff}_{\text{pelvis}}$ shows a higher number of significant changes than $\Delta\text{SI}_{\text{pelvis}}$, the latter in addition also influenced by the propulsive effort generated during the second half of the stance phase (and normalized to the range of motion).

Changes to the foot with trimming and shoeing imply that the differences are restricted to specific parts of the stride cycle and affect either the stance or the swing phase but not both at the same time (Roepstorff and others 1999; Keegan and others 2005). The compensatory mechanism of the distal limb during stance (Riemersma and others 1996) is expressed in its ability to absorb the increase of concussive effects from applying a shoe (Dyhre-Poulsen and others 1994). Alongside this instant absorption, the distal limb has also been shown to compensate for gradual changes of foot conformation by altering joint angles, especially of the metatarsophalangeal joint at initial contact and toe off (van Heel and others 2006). Our study indicates that horses instantaneously adopt compensatory mechanisms as a reaction to changes in foot conformation and inertia and overall successfully aim to move symmetrically. This adaptation appears to be more successful for the thoracic limbs where no significant influence on MS can be shown.

The horses used in this study underwent a fairly unique shoeing regime: due to the high amount of ‘roadwork’ their shoeing cycle (two to three weeks) is shorter than the usually expected cycle of six to eight weeks. Hoof growth in two to three weeks is much reduced: if on average the dorsal wall grows by 0.14cm a week (Kummer and others 2006), this extrapolates to 0.28cm growth over two weeks compared to 1.12cm growth over eight weeks, or a 2.5% increase in length rather than 10%. The reported effects of changes with hoof growth (van Heel and others 2005) or trimming (van Heel and others 2004) over six to eight weeks are hence not directly applicable to our study horses. The results of our study provide evidence that is useful for the design of future studies and in particular suggest that when investigating the mechanical effects of the stages of the shoeing process in horses with longer (6-8 week intervals) it is crucial to assess horses before/after trimming as well as at the end of the shoeing process. In addition, given the unique 2-3 weeks shoeing cycle in our horses here, the changes in MS as a function of the length of the shoeing cycle appear to be of interest and again should concentrate on intra-individual changes between shoeing stages (in particular involving trimming).

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Manufacturer details

[1] Richard Ash Horseshoes, Witherleigh Farm, Mill Road, Somerset, UK
[2] Stromsholm, Wood Court, Milton Keynes, UK
[3] Xsens, Enschede, the Netherlands.
[4] Animal Polster, Snogg, Boks 5444 Strai, NO-4671 Kristiansand, Norway
[5] Metronome, marketwall.com, developer Keaka Jackson.
[6] MATLAB; The Mathworks INC, Natick, Massachusetts, USA.
[7] SPSS Inc, Chicago, Illinois, USA.

Figure legends and Tables

Figure 1: A: Example vertical displacement of the pelvis over a stride cycle for a horse in trot. Shown here is pelvic displacement of a horse showing reduced movement amplitude during the right hind (RH) stance phase compared to the left hind (LH) stance phase. As a consequence of the asymmetry between displacement during and after LH and during and after RH stance, in this case MinDiff shows a negative value and SI a positive value. The blue line represents the average vertical displacement, the thin light blue lines represent individual strides and the grey bars indicate approximate timing of LH and RH mid stance. B: Flow diagram explaining the procedure to minimize the influence of differences in MS between left and right 'sided' horses.

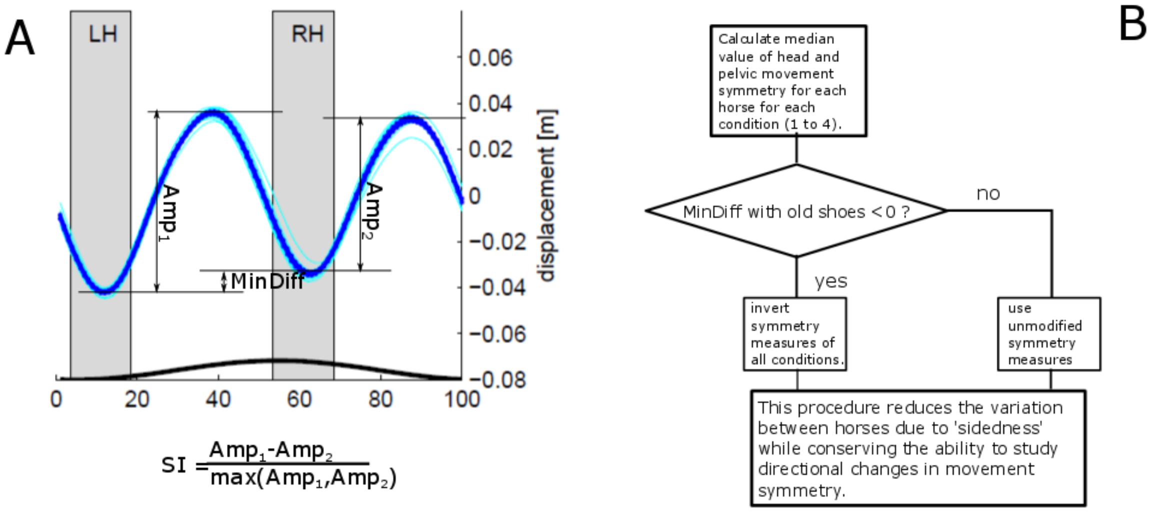

Figure 2: Symmetry Index (SI) and difference in minima of vertical displacement between the two halves of a stride cycle (MinDiff) for head and pelvic movement for the four stages of the shoeing process. A: SI_{poll}, B: $MinDiff_{poll}$, C: SI_{pelvis}, D: $MinDiff_{pelvis}$. Generally small differences can be observed between the individual stages. 1: old shoes, 2: shoes off, 3: trimmed and balanced, 4: new shoes. SI values unitless, MinDiff values in mm.

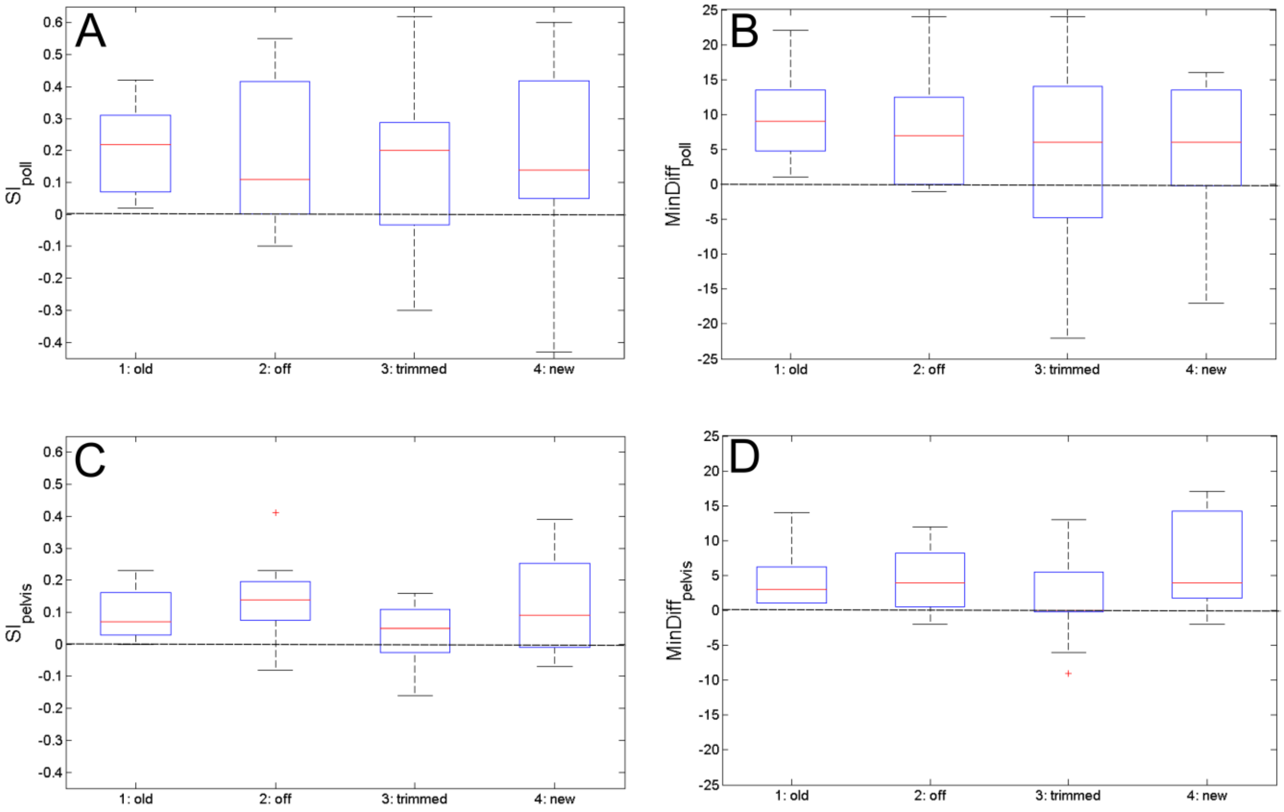

Figure 3: Changes in normalized movement symmetry between the stages of the shoeing process. Changes within horse between the four conditions are shown. A: ΔSI_{poll}, B: $\Delta MinDiff_{poll}$, C: ΔSI_{pelvis}, D: $\Delta MinDiff_{pelvis}$. Pairwise significant differences (at $P<0.05$ after Bonferroni correction) are illustrated by the black bars: these show that all pairwise significant differences include a change from or to condition 3 (trimming and balancing).

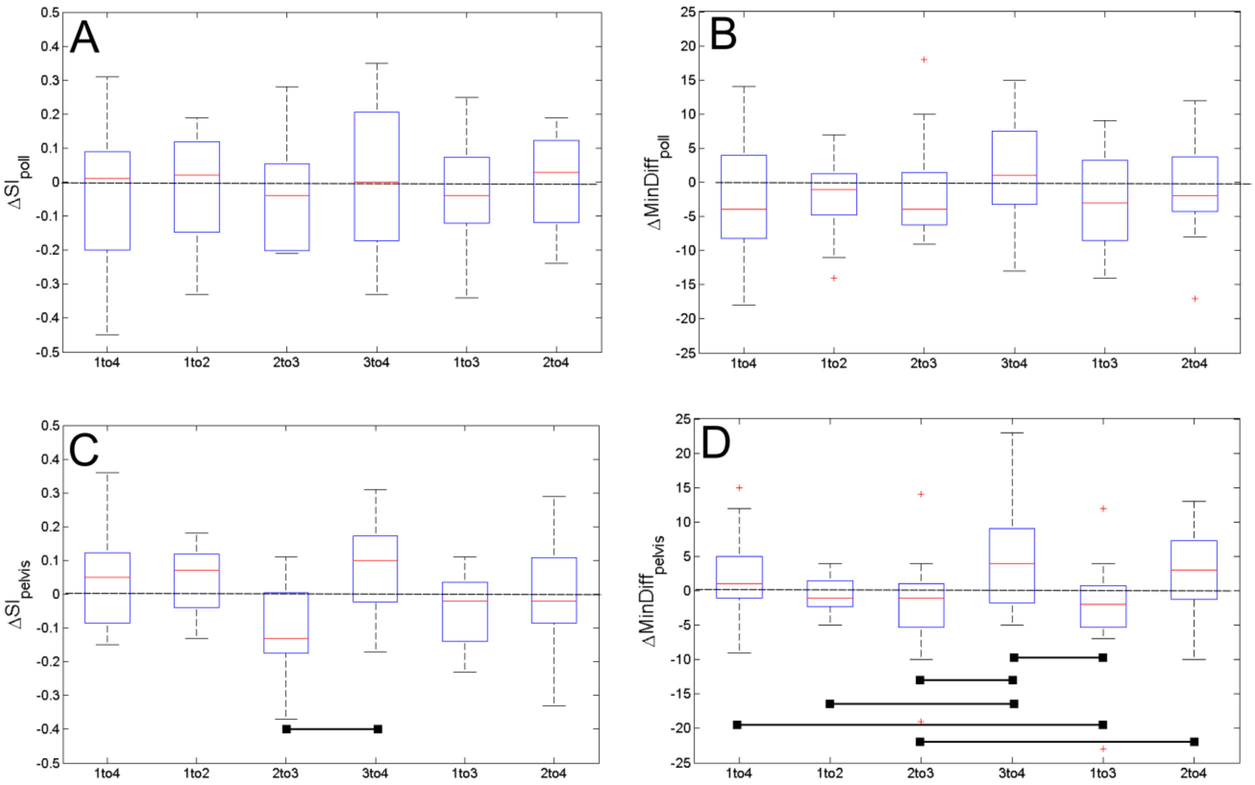

Table 1: Symmetry index (SI) and difference in minima of vertical displacement between the two halves of a stride cycle (MinDiff) for all study horses for poll and pelvic movement.

		Stage 1				Stage 2				Stage 3				Stage 4			
No.	G	SI_F	SI_H	MD_F	MD_H	SI_F	SI_H	MD_F	MD_H	SI_F	SI_H	MD_F	MD_H	SI_F	SI_H	MD_F	MD_H
1	F	0.08	0.01	4	2	0.02	0.01	0	2	-0.01	-0.02	-3	0	-0.22	0.03	-4	-3
3	F	0.37	0.12	15	2	0.55	0.08	14	0	0.62	0.02	24	3	0.45	0.13	11	-3
4	H	0.52	0.07	11	1	0.29	0.21	7	4	0.31	-0.16	9	-6	0.30	-0.01	5	2
7	B	0.29	0.04	12	1	0.46	0.14	14	2	0.25	-0.01	9	0	0.41	0.09	16	4
8	H	0.66	0.20	5	5	0.66	0.23	4	4	0.61	0.09	5	5	0.65	0.33	17	17
9	H	0.05	0.03	3	3	-0.01	0.12	-2	-2	0.04	0.02	-1	-1	0.18	-0.01	3	4
10	H	0.06	0.07	1	1	0.03	0.00	1	1	-0.02	0.10	5	5	0.10	-0.07	0	0
11	F	0.14	0.01	5	1	0.24	-0.11	6	-6	0.20	-0.15	6	-1	0.20	0.07	4	-3
12	F	0.04	0.17	3	1	0.06	0.02	2	7	0.16	0.13	-7	5	0.09	0.12	-6	4
14	F	0.12	0.03	9	5	-0.05	0.14	7	2	0.00	0.11	1	-2	0.05	0.02	4	2
16	H	0.3	0.03	16	1	0.40	0.10	18	5	0.29	0.08	13	0	0.33	0.39	16	16
17	H	0.02	0.03	4	6	-0.21	0.14	11	9	-0.10	0.14	-1	9	0.18	0.12	2	5
18	H	0.03	0.17	0	2	0.03	0.14	2	-1	0.06	0.16	1	0	0.06	0.29	-2	4
19	H	0.02	0.09	4	3	-0.27	0.00	-1	1	-0.19	-0.14	1	0	-0.09	-0.01	4	1
20	F	0.04	0.39	6	14	-0.10	0.30	-1	11	-0.30	0.39	-8	15	0.05	0.25	1	9
21	F	0.22	0.09	13	10	-0.05	0.07	-1	4	0.23	0.02	17	14	0.14	0.17	10	13
22	B	0.4	0.23	9	7	0.40	0.41	7	8	0.41	0.16	13	2	0.23	0.08	13	-2
24	H	0.08	0.16	3	14	0.21	0.19	-1	10	-0.47	-0.07	-10	-9	0.24	0.24	3	14
25	H	0.1	0.05	4	1	-0.47	-0.08	26	-1	-0.64	0.03	33	13	-0.40	0.05	20	12
27	B	0.42	0.00	22	13	0.09	0.18	11	12	-0.76	0.05	-22	7	0.13	0.15	6	15
28	F	0.02	0.03	1	1	0.11	-0.09	0	-4	-0.10	-0.10	-4	-3	-0.43	0.14	-17	1
29	F	0.29	0.02	22	3	0.48	-0.06	24	7	0.40	0.020	21	5	0.60	-0.10	36	6
30	F	0.26	0.11	5	3	0.31	0.04	12	-2	0.22	-0.04	8	-1	0.44	0.11	15	6

(Stage 1: Old Shoes On, Stage 2:Shoes off, Stage 3: Trimmed, Stage 4: New Shoes On, No.: Horse identification number, G: Group with F: new shoes on fore feet, H: new shoes on hind feet, B: both fore and hind new shoes.

Symmetry measures: SI_F: SI_{poll}, SI_H: SI_{pelvis}, MD_F:$MinDiff_{poll}$, MD_H:$MinDiff_{pelvis}$)

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