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Original Article

A comparison of protraction-retraction of the distal limb during treadmill and water treadmill walking in horses.

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Abstract

The amount of protraction-retraction of the limbs during water treadmill walking has implications for postural and muscular development of horses undertaking this exercise for training and rehabilitation purposes. The objective of this study was to compare protraction-retraction of both forelimbs (FL) and hind limbs (HL) during dry treadmill (DT) and water treadmill (WT) exercise at the typical walking speed of each as used in practice. Inertial motion sensors attached to the metacarpal/metatarsal bones were used to compare maximal protraction (PRO_{MAX}), retraction (RET_{MAX}) and total protraction-retraction range of movement (ROM) across five walking conditions: DT at 1.6 m/s; and WT at 0.8 m/s at four water depths, hoof depth (WT_{HOOF}), fetlock depth (WT_{FET}), hock depth (WT_{HOCK}) and stifle depth (WT_{STIFLE}).

FL ROM was lowest at WT_{STIFLE} and significantly lower than DT ($P<0.001$). HL ROM was highest at WT_{STIFLE} and significantly greater than DT ($P<0.001$). FL PRO_{MAX} was significantly lower at WT_{HOCK} ($P=0.001$) and WT_{STIFLE} ($P<0.001$) than DT. HL RET_{MAX} was higher at WT_{HOCK} ($P=0.001$) than on DT and was significantly greater at WT_{STIFLE} and WT_{HOCK} than WT_{FET} ($P<0.001$ and $P=0.001$ respectively).

Walking slowly (0.8 m/s) on a water treadmill reduces forelimb protraction-retraction ROM and increases hind limb protraction-retraction ROM when compared with walking at normal speed (1.6 m/s) on a dry treadmill. The potential for forelimb protraction to be decreased and hind limb retraction to be increased should be taken into account when designing training and rehabilitation programmes using this exercise modality.

Keywords: Water treadmill; Rehabilitation; Distal limb; Kinematics; Inertial Motion Sensor

1.0: Introduction

Water treadmill exercise is a common modality within training and rehabilitation programmes of horses. For the successful use of water treadmill exercise in both of these applications, it is necessary to understand the effects of water depth and belt speed on the physiology and biomechanics of the horse. Water treadmills are currently used to exercise horses from different disciplines that have a variety of physiological and biomechanical demands. The development of an evidence base regarding the effects of water treadmill exercise will enable informed decisions regarding the use of water treadmills for any given application. When considering using a water treadmill for rehabilitation of horses with limb and/or back pathology, it is essential to understand the effect of water walking on the movement pattern of the horse in order to construct an effective rehabilitation programme and avoid exercise that may exacerbate injury or promote poor movement patterns.

Previous studies [1-2] have compared limb kinematics of walking on a water treadmill in either low water depths (or no water) to walking in higher depths (up to the level of the stifle joint). Increasing water depth has been shown to bring about a decrease in stride frequency compared with the baseline condition (hoof depth) when horses walk on a water treadmill at 0.9 m/s [1]. At the same belt speed, Mendez-Angulo et al. [2] showed an increase in the range of movement for distal limb joints in water depths level with the fetlock, tarsal and stifle joints compared with the baseline condition, primarily due to increases in the range in flexion. Horses adopt differing gait strategies when walking in water dependent upon water depth. Water is more viscous than air resulting in a greater drag force acting on the limbs in comparison to overland walking. The drag force experienced by the moving limb is increased in proportion to the velocity of the limb squared and in proportion to the water depth [3].

Mooij et al. [4] found an increase in axial rotation of the pelvis as water depth increased from baseline up to a depth level with the carpal joints when horses walked at a belt speed of 0.8 m/s. The authors proposed that up to this depth, horses select a gait pattern of increased flexion of the distal limb joints to minimise the influence of drag (as observed by Mendez-Angulo et al. [2]). Once the water depth reached levels that were too high to be accommodated simply by distal limb flexion, the additional response was to increase what these authors described as ‘pelvic’ flexion, synonymous with increased lumbar flexion also seen by Nankervis et al. [5] in greater water depths.

Nankervis et al. [5] demonstrated an increase in total range of flexion-extension of the back and an increase in lumbar flexion as water depth increased up to the level of the stifle in a group of competition horses walking at a belt speed of 0.9 m/s. In Nankervis et al. [5] there was variation between horses in terms of the water depth at which peak pelvic vertical displacement was seen. In both Nankervis et al. [5] and Mooij et al. [4] there was evidence of horses adopting differing gait strategies dependent upon water depth. According to the bow and string model [6] lumbar flexion is brought about by increased hind limb protraction. If lumbar flexion during water walking is associated with increased hind limb protraction, this makes a good case for incorporating this type of exercise into the training programmes of horses such as dressage horses, which require this gait characteristic.

The effect of drag on the forelimb during water walking has been demonstrated by Tokuriki et al. [7]. In this study, electromyography was used to measure forelimb muscle activity in horses during water treadmill walking (at 1.34 m/s) and trotting (at 2.67 m/s) at a water depth of 1.2 m; walking overland (speed not stated) and swimming. Activity of *brachiocephalicus* was higher in walk and trot on the water treadmill than when walking overland, and the *extensor digitorum communis* showed more intense activity whilst walking and trotting in the water treadmill than when swimming. One of the potential perceived negative effects of water treadmill exercise is the propensity to 'overdevelop' forelimb musculature and the tendency for horses to 'pull' with the forehand rather than 'push' with the hind limbs, a tendency which would increase with water depth and the concurrent increase in drag.

Studies reporting reduced stride frequency [1], increased distal limb joint flexion [2] and increased lumbar/pelvic flexion [4,5] with increasing water depth have all been at belt speeds significantly lower than those used by Tokuriki et al. [7]. Many more studies have been conducted on water treadmill exercise in humans than in horses, and the comfortable walking speed for a human walking on a water treadmill is approximately half that on an ordinary dry treadmill [8,9]. Increasing water depth at speeds < 1 m/s may induce increases in ranges of movement of the limb, but unless these are compared to overland walking or walking on a normal treadmill, we cannot draw conclusions about the preferred mode of exercise for any given training or rehabilitation scenario. The extent to which water treadmill exercise at a 'slow walk', i.e. < 1 m/s, decreases or increases limb protraction, retraction and total protraction-retraction range of movement when compared to walking at 'normal' speed is relevant when making decisions about whether to use water treadmill exercise within a rehabilitation programme or to simply walk the horse on an ordinary 'dry' treadmill/exercise it in hand.

The objective of this study was to compare the ranges of movement of the limbs in protraction, retraction and total protraction-retraction range of movement during dry treadmill walking and water treadmill walking at the typical speed of each as used in practice. The angular rotation of the metacarpi/metatarsi within the sagittal plane, equating to protraction and retraction of the limb was compared across five different walking conditions: dry treadmill walking at 1.6 m/s (DT); and walking on a water treadmill at 0.8 m/s at four different water depths, hoof (WT_{HOOF}), fetlock (WT_{FET}), hock (WT_{HOCK}) and stifle (WT_{STIFLE}).

1.1: Hypothesis

Walking in WT_{STIFLE} at 0.8 m/s will result in a decrease in forelimb protraction and in increase in hind limb protraction when compared with DT at 1.6 m/s.

2.0: Materials and methods

2.1: Horses

The study consisted of an experimental, within-subject repeated measured design to test the effect of walking condition (DT, WT_{HOOF}, WT_{FET}, WT_{HOCK} and WT_{STIFLE}) on the angular rotation of the metacarpal/metatarsal angles in the sagittal plane measured using an inertial motion sensor system (IMS). Eight riding horses (3 eventers, 1 dressage, 2 show jumpers and 2 general purpose) comprising 3 Warmbloods, 3 Warmblood x Thoroughbreds and 2 Thoroughbreds, mean age 10 ± 2.8 years, mean height 166.5 ± 4 cm and weight ranging from 520 kg to 580 kg carried out WT exercise at 0.8 m/s and DT exercise at 1.6 m/s within the same session. All horses were fully acclimated to both DT [10] and WT [1, 11] prior to the study. The kinematic acclimation to water treadmill exercise, categorized as a stabilization of gait, has been established as requiring a minimum of four sessions [1]. For the purpose of this study, a minimum of four acclimating runs was required when selecting participants. All horses were judged sound by an experienced equine clinician when observed trotting on a straight line, on a firm surface. The study was approved by the University Centre Hartpury's Research Ethics Committee.

2.2: Protocol

The WT used in this study did not have clear sides, prohibiting the use of video or optoelectronic motion capture of the movement of the limbs. Inertial motion sensor (IMS) units (European Technology for Business Ltd) were used which had previously been compared to an optical based system and deemed suitable for the measurement of movement of the metacarpal/metatarsal bones in the sagittal plane [12]. Each horse was fitted with neoprene brushing boots to which the IMS units were attached. The IMS units were placed in resealable polythene pouches (Aquapac International Ltd. London) before taping securely in position on the lateral central aspect of each metacarpal/metatarsal. The same handler fitted the boots and the IMS to each horse to ensure standardization of placement of the IMS. Each sensor was then turned on and further secured on the horse's leg with tape to minimize movement between the sensor and the limb. All horses stood for a minimum of 10 seconds prior to move off, which was the time period necessary for calibration of the IMS as the sensors measure rotations relative to their initial orientation, with protraction being given by cranial rotation and retraction given by caudal rotation (see Figure 1). Protraction angles were assigned positive values and retraction angles negative values.

At time '0', IMS data collection was started by depressing the button on the unit. At the same time a stopwatch was started to record the time at which each walking condition was started (to within the nearest second). IMS collected metacarpal/metatarsal angle data continuously throughout data collection at a sampling frequency of 102.4 Hz. Horses were randomly assigned to one of two groups, Group A or Group B, which determined the order in which they would run through the data collection process. Group A completed WT exercise first followed by DT and Group B the opposite. Group A horses walked at four water depths in the order WT_{HOOF}, WT_{FET}, WT_{HOCK} and WT_{STIFLE}. Group B horses were put on the DT first, followed by the WT starting at WT_{STIFLE}, WT_{HOCK}, WT_{FET} and finishing with WT_{HOOF}. Transfer between the treadmills took no more than 5 minutes. Horses were held with a handler on the left hand side only on both treadmills. Before beginning either the increasing or decreasing water depth protocol, each horse underwent a 5-minute warm-up at hock depth. Water depth was set to a level just below the coronary band (for WT_{HOOF}) and approximately level with the centre of rotation of each joint for fetlock (WT_{FET}), hock (WT_{HOCK}), and stifle (WT_{STIFLE}) depths. Water temperature was 14 ° C. Data were collected continuously and each horse spent four minutes in each walking condition.

2.3: Data Analysis

Data were downloaded from the inertial motion sensors using Pegasus Poseidon Software and analysed within Excel. Twenty strides of each walking condition from within the last minute of each four-minute recording period were used to calculate the mean and standard deviation of the stride duration, maximal protraction (PRO_{MAX}) (in degrees) and retraction (RET_{MAX}) (in degrees) of each limb (see Fig. 1). The sum of PRO_{MAX} and RET_{MAX} gave the total ROM for each limb. Symmetry of ROM for contralateral limb pairs was expressed as (left forelimb (LF) ROM/right forelimb (RF) ROM and left hind limb (LH)/right hind limb (RH) ROM). Data for LF and RF, and LH and RH were combined to obtain a mean PRO_{MAX}, RET_{MAX} and ROM for each forelimb and hind limb pair. The duration of protraction and retraction as a % of total stride duration was calculated for each limb and then left and right limbs combined as per the maximal protraction and retraction values. Angular velocity (°/sec) for each limb pair was given by the PRO_{MAX}/protraction duration and RET_{MAX}/retraction duration.

Data were tested for normality using SPSS. A Shapiro-Wilks test confirmed that all variables (PRO_{MAX}, RET_{MAX} and ROM) were normally distributed. The ROM of the left and right forelimbs, and left and right hind limbs were compared using *t*-tests. To test for the effect of walking condition on each variable, a series of one-way, repeated measures ANOVA were carried out and the level of statistical significance set at $P<0.05$. In the event of a significant effect of walking condition, a Bonferroni post-hoc test was then applied to determine where the significance lay and the P value for these post-hoc tests was adjusted to take into account the number of pairwise comparisons (10), resulting in an adjusted P value of $P<0.005$. Mann Whitney U tests were carried out to see if there was any effect of the order of exercise, by comparing both mean FL and HL ROMs, and the coefficient of variance ((s.d./mean) x 100) of FL and HL ROMs of Groups A and B (with significance level set at $P=0.05$).

3.0: Results

3.1: Symmetry of total ROM of contralateral limb pairs

Symmetry of LF and RF ranged from a group mean of 0.97 ± 0.07 in WT_{STIFLE} to 1.00 ± 0.05 on both DT and WT_{FET}. Symmetry of LH and RH ranged from 0.97 ± 0.04 on DT to 1.00 ± 0.03 in WT_{FET}. T-tests revealed no significant difference between the ROMs of contralateral limb pairs ($P>0.05$ for both FL and HL pairs in all water depths) and so thereafter data for limb pairs were combined to give a mean for each limb pair.

3.2: PRO_{MAX} , RET_{MAX} and total ROM

All results are shown in Table 1. FL ROM was lowest at WT_{STIFLE} (significantly lower than DT, $P<0.001$) whilst HL ROM was highest at WT_{STIFLE} (significantly greater than DT, $P<0.001$). FL PRO_{MAX} was lower in all WT conditions than DT, decreasing with increasing water depth and was significantly lower at WT_{HOCK} (P=0.001) and WT_{STIFLE} (P<0.001) than DT. HL PRO_{MAX} was higher when walking in water and increased with increasing water depth although there were no significant differences between any of the conditions (P>0.005). HL RET_{MAX} was also higher when walking in water and was significantly greater at WT_{HOCK} (P=0.001) than DT and was significantly greater at WT_{STIFLE} and WT_{HOCK} than WT_{HOOF} (P<0.001 and P=0.001 respectively).

3.3: Protraction-retraction phase as % stride duration

See Table 2. As a % stride duration, forelimb protraction phase was significantly greater in WT_{STIFLE} water compared with WT_{FET} (P=0.004) and WT_{HOOF} (P=0.002) and significantly greater in WT_{HOCK} than in WT_{FET} (P=0.0001), WT_{HOOF} (P=0.0001) and DT (P=0.001). No significant differences existed in either forelimb or hind limb protraction or retraction phases between WT_{FET} and DT (P<0.005).

3.4: Angular velocity of forelimbs and hind limbs

Greater differences in angular velocities between walking conditions were seen in the forelimb compared with the hind limb (see Table 3). Angular velocity of the forelimb during protraction was significantly lower in WT_{STIFLE} than on DT (P=0.0001), on WT_{HOOF} (P=0.0001) or WT_{FET} (P=0.005), and significantly lower in WT_{HOCK} than on DT (P=0.0001) or on WT_{HOOF} (P=0.0001), whilst hind limb angular velocity was relatively unchanged.

3.5: Effect of the order of exercise

Mann Whitney U tests found no significant difference between either FL ROM (P=0.602) or HL ROM (P=0.602), nor between the coefficient of variance of FL ROM (P=0.465) or HL ROM (P=0.754) when Groups A and B were compared.

4.0: Discussion

This study has shown significant differences in peak protraction and retraction of the limbs during walking on a WT and walking on a DT when each are used at speeds typical of those used in practice. Walking in WT_{STIFLE} and WT_{HOCK} at 0.8 m/s reduced peak forelimb protraction and total ROM compared with walking on DT at 1.6 m/s and so part of the hypothesis is supported. There was no significant difference between peak forelimb protraction on DT at 1.6 m/s and WT_{HOOF} at 0.8 m/s, so the reduction in forelimb protraction is not explained by the reduction in speed alone. Peak forelimb protraction in WT_{STIFLE} is approximately 60% of that on DT at 1.6 m/s and can be explained by the increase in drag with increasing water depth which retards the forward movement of the limb. Reduction in walking speed is often used to compensate for the increase in drag encountered during water treadmill walking [8,9]. This study has shown that despite a 50% speed reduction, forelimb protraction is limited on a WT at 0.8 m/s when compared to a DT at 1.6 m/s.

In this study, as in previous [1], stride duration increased with increasing water depth. Forelimb protraction time was also increased when walking in WT_{STIFLE} compared with

DT both in real terms and as a % stride duration. Not only is the range in protraction reduced, but there is also a significant decrease in angular velocity of the forelimb when walking in WT_{STIFLE} at 0.8 m/s compared with DT at 1.6 m/s. It can be seen from Table 3 that between DT and WT_{HOOF}, angular velocity decreased from approximately 70°/sec to 45°/sec (a 36% decrease). However, between WT_{HOOF} and WT_{STIFLE}, angular velocity decreased from 45°/sec to 23°/sec, a 50% decrease in angular velocity. Increasing water depth from hoof depth to stifle depth therefore has a more profound effect on forelimb angular velocity than a 50% reduction in belt speed.

The reduction in forelimb peak protraction and reduction in angular velocity suggests that either there is no compensatory action from the horse to offset the drag force, or that any additional muscle activity recruited to offset drag, is insufficient in its action. The increase in drag during WT walking has been seen to induce an increase in *brachiocephalicus* activity [7] compared with overground walking reflecting the role of *brachiocephalicus* as a major forelimb protractor. The horses in that study walked at a belt speed of 1.34 m/s; which would impose greater drag on the limbs than experienced at 0.8 m/s as per the current study. However, an increase in both amplitude and duration of *brachiocephalicus* activity with increasing water depth has also been observed where horses walked on a water treadmill at 0.9 m/s [13], but unfortunately no direct comparison with the *brachiocephalicus* activity on a DT at 1.6 m/s was made in this instance. Part of the rationale for the present study arose from concerns about WT exercise ‘overdeveloping’ the musculature of the forehand of the horse, as water increases the load in protraction. The results relating to forelimb protraction in this study provide further evidence that these concerns are valid at least for water depths of hock level and above.

The musculature of the forelimb is optimized for support, having a greater role in weight bearing of the trunk than the hind limb [14] a role which is reflected in the volume and architecture of the extrinsic muscles of the forelimb [15]. The thoracic limb extrinsic muscles have limited scope for power production as the muscles are small compared with the total locomotor muscle mass, and are better suited to power absorption [15]. The forelimb therefore, has less scope to respond to an increased load in protraction than the hind limbs, the musculature of which are optimised for propulsion [16].

Hind limb protraction in WT_{STIFLE} is not affected in the same way as the forelimb. This is not entirely surprising given the very different roles of the thoracic and pelvic limb in locomotion. Hind limb ROM is significantly greater in WT_{STIFLE} than on DT at 1.6 m/s, with increases in both protraction and retraction in greater water depths. The second part of the hypothesis, that hind limb protraction would be greater in WT_{STIFLE} than on a DT at 1.6 m/s is not supported, despite the fact that the group mean HL PRO_{MAX} is nearly 10° greater in WT_{STIFLE} than on DT. The standard deviations of the peak hind limb protraction angles and peak hind limb retraction angles also increase with water depth; reflecting an increase in inter-horse variation in movement pattern as water depth increases. So whilst six of the eight horses in this study showed maximal protraction in WT_{STIFLE}, this is not reflected in the statistical results since not all horses responded the same way. The fact that individual horses show peak HL PRO_{MAX} at different depths (either WT_{HOCK} or WT_{STIFLE}) could reflect the ability of the individual horse to flex either the lumbopelvic region or any of the proximal hind limb joints. Horses unable to flex proximal hind limb joints and/or the lumbar/lumbosacral regions of the back due to conformation, stiffness or pathology will be less likely to increase HL protraction at increasing water depths and more likely to show increased HL retraction at increased water depth. Increased HL retraction could be counterproductive within rehabilitation following certain hind limb conditions, for example, proximal suspensory desmitis [17] or deep digital flexor tendon injuries [18]. In this study, peak HL retraction was significantly greater in WT_{HOCK} than on the DT, and significantly greater in WT_{STIFLE} than WT_{HOOF}.

This study has shown that not all horses are able to continue to increase HL protraction when walking in water above the level of the hock, and there is increased HL retraction in high water compared with lower water. According to the bow and string model, increased hind limb retraction would lead to an increase in back extension. However, lumbar flexion (not extension) has previously been observed [5] in horses walking in stifle depth water when compared to horses walking in hoof depth. That study not only had a larger sample size (n=14) but used horses that were generally of a higher level, competition horses (largely show jumpers and dressage horses) than the horses in the present study, some of which were not used for competition at all. The present study, and others [xx] show inter-horse variability in hind limb movement patterns as water depth is increased; variability that may relate to the ability of an individual horse to flex the hind limbs, protract the hind limb, and to flex the lumbar/lumbosacral region of the spine. WT exercise clearly has the potential to induce responses which would be beneficial within many training and rehabilitation programmes, i.e. lumbar flexion and increased hind limb protraction-retraction ROM, but the potential for increases in HL retraction in water of hock depth and above should be noted, particularly when formulating rehabilitation programmes for horses with either hind limb injury, or back injury.

The findings of this study support the caution given by Mendez Angulo et al. [2], that protraction and retraction muscle action should be considered when deciding what depth to use to avoid injury or fatigue in horses that are not trained for exercise in water. Hip joint ROMs during WT exercise have not yet been measured in horses, but it is reasonable to hypothesise that peak hip joint extension would increase as water depth increased, as has been shown in humans. Miyoshi et al. [8] found increased hip joint extension moments during water walking in axilla water depth compared to walking overland.

Inertial motion sensors were used to quantify protraction-retraction movements of the distal limb as we were unable to use videography with our particular model of water treadmill. The actual values of peak protraction and retraction are greater than those typically reported for walk when protraction-retraction of the limb is measured using an optical method tracking markers on the scapula spine and hoof [19]. The values obtained using this method do however compare favourably with those seen by Roepstorff et al. [12] using the same system and with Hodson et al. [19] using a videographic technique to measure rotation of the metacarpals. The IMS itself alters the profile of the metacarpal and metatarsal, and will further contribute to the increase in drag once water was at hock depth and above; but every attempt was made to fit the aqua pack as close to the limb surface as possible, to minimise the increase in surface area presented to the water. Also the horses that went from WT to DT (Group A) had a wet boot on when walking on the DT as compared to Group B; this was one of the reasons for conducting the study as a cross-over, to minimise the influence of any difference in weight of the boot. Whilst weighted boots of 700g have been shown to induce changes in hind limb kinematics (but not forelimb kinematics) [20] the increase in weight of the boot from dry to wet condition in this study was approximately 40 g and therefore highly unlikely to influence the kinematics of the limb.

5.0: Conclusions

Walking slowly (0.8 m/s) on a water treadmill reduces forelimb protraction-retraction range of movement and increases hind limb protraction-retraction range of movement when compared with walking at normal speed (1.6 m/s) on a dry treadmill. The potential for forelimb protraction to be decreased, and hind limb retraction to be increased, should be taken into account when designing training and rehabilitation programmes using this exercise modality.

Conflicts of interest: None.

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Figure 1: Protraction and retraction angles as measured using the inertial motion sensors. The examples of right forelimb retraction and left hindlimb protraction only are shown. The right forelimb in retraction is assigned a negative angle, whilst the left hind limb in protraction is assigned a positive angle.

Table 1: Mean ± s.d. of forelimb and hind limb maximal protraction (PRO_{MAX}), maximal retraction (RET_{MAX}) and total protraction-retraction range of movement (ROM) walking on a dry treadmill (DT) and a water treadmill (WT) in 4 different water depths. WT_{HOOF}, WT_{FET}, WT_{HOCK} and $\text{WT}_{\text{STIFLE}}$ = water at hoof, fetlock, hock and stifle depths respectively. *a* = significantly different to DT, *b* = significantly different to WT_{HOOF}.

	FORELIMBS			HIND LIMBS		
	PRO_{MAX}	RET_{MAX}	ROM	PRO_{MAX}	RET_{MAX}	ROM
DT	21.5 ± 7.1	-50.0 ± 5.7	71.6 ± 4.0	40.0 ± 4.6	-17.8 ± 5.6	57.9 ± 3.5
WT_{HOOF}	16.0 ± 3.9	-46.0 ± 4.2	62.0 ± 5.1[a]	40.0 ± 4.4	-15.7 ± 5.1	55.8 ± 2.7
WT_{FET}	14.1 ± 4.0	-53.5 ± 4.4[b]	67.5 ± 6.0[b]	44.4 ± 6.4	-21.6 ± 7.7	66.0 ± 5.8[b]
WT_{HOCK}	12.9 ± 5.0[a]	-49.6 ± 3.9	62.5 ± 4.0[a]	48.8 ± 9.6	-25.2 ± 6.4[a,b]	74.0 ± 6.9[b]
$\text{WT}_{\text{STIFLE}}$	12.4 ± 5.6[a]	-46.3 ± 3.6	58.6 ± 3.4[a]	49.7 ± 9.1	-24.8 ± 6.4[b]	74.6 ± 5.4[a,b]

Table 2: Mean ± s.d. forelimb protraction duration (FL% PRO), retraction (FL%RET) and hind limb protraction duration (HL% PRO) and retraction (HL%RET) as as % stride duration *a* = significantly different to dry treadmill (DT), *b* = significantly different to WT_{HOOF}, c = significantly different to WT_{FET}

	Stride Duration (secs)	FL % PRO	FL % RET	HL % PRO	HL % RET
DT	1.2 ± 0.1	25.1 ± 1.4	74.9 ± 1.4	34.2 ± 1.5	65.9 ± 1.5
WT_{HOOF}	1.6 ± 0.1	22.5 ± 1.8[a]	77.5 ± 1.8[a]	30.9 ± 1.8[a]	69.1 ± 1.8[a]
WT_{FET}	1.7 ± 0.2	26.5 ± 0.8	73.5 ± 0.8	33.1 ± 1.9	66.9 ± 1.9
WT_{HOCK}	1.8 ± 0.2	29.0 ± 0.7[a,b,c]	71.0 ± 0.7 [a,b,c]	33.5 ± 1.5	66.5 ± 1.5
WT_{STIFLE}	1.8 ± 0.1	29.5 ± 1.3[b,c]	70.5 ± 1.3 [b,c]	33.1 ± 1.6	66.9 ± 1.6

Table 3. Mean ± s.d. angular velocity (°/second) of forelimb during protraction (FL PRO) and retraction (FL RET), and hind limb during protraction (HL PRO) and retraction (HL RET) . *a* = significantly different to dry treadmill (DT), *b* = significantly different to WT_{HOOF}, c = significantly different to WT_{FET}.

Angular velocity (°/sec)	FL PRO	FL RET	HL PRO	HL RET
DT	72.2 ± 22.9	-56.6 ± 8.5	99.0 ± 13.0	-22.7 ± 6.7
WT_{HOOF}	45.5 ± 8.3	-38.4 ± 3.3[a]	83.7 ± 8.0	-15.0 ± 5.7
WT_{FET}	31.8 ± 8.4 [a,b]	-43.9 ± 3.6[b]	81.0 ± 9.9	-19.8 ± 7.6
WT_{HOCK}	24.4 ± 9.5[a,b]	-38.4 ± 3.5[a]	78.8 ± 8.8	-20.9 ± 5.9[b]
WT_{STIFLE}	23.0± 8.9[a,b,c]	-37.0 ± 5.0[a]	83.1 ± 8.7	-20.9 ± 6.2[b]