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Biomechanical responses of the back of riding horses to water treadmill exercise

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ABSTRACT

There is a lack of evidence for the presumed beneficial effects of water treadmills on the movement of the horse's back. The aim of the study was to evaluate the effects of water treadmill exercise on axial rotation (AR), lateral bending (LB) and pelvic flexion (PF) in horses. The back kinematics of a group of riding horses were studied at the walk in a water treadmill at different depths of water (hoof, fetlock, carpus, elbow and shoulder joint levels) over a period of 10 days. Skin markers were placed at anatomical locations on the back. AR, LB and PF were measured on days 1 and 10 using two high-speed video cameras. There was a significant increase in AR compared to baseline at the level of the carpus and at higher water levels, whereas LB was significantly lower than baseline values at water levels that reached the elbow and shoulder joints. PF was significantly higher than baseline values at each water depth other than hoof water depth. At increasing water depths, there were significant increases in flexion and rotation of the back. At the highest water levels, there was reduced bending of the back. After 10 days, horses exhibited more bending of the back.

Introduction

Water treadmills are used widely in rehabilitation centres for horses with poor performance caused by a stiffened back. Water provides buoyancy and assists the horse in lifting the limbs in the vertical plane, but it may also create resistance to movement of the limbs in the sagittal plane (King et al., 2013). Scott et al. (2010) showed that stride frequency decreases and stride length increases as horses are trained in a water treadmill at increasing water depths.

Biomechanical responses of the back to training include axial rotation (AR), lateral bending (LB) and pelvic flexion (PF). AR is rotation around the craniocaudal axis, LB is rotation around the dorsoventral axis and PF is rotation around an axis perpendicular to the sagittal plane (Fig. 1). Each horse uses an individual triangular combination of AR, LB and PF (Pourcelot et al., 1998; Audigié et al., 1999; Van Weeren, 2009; Warner et al., 2010). In kinematic studies, the degree of motion of the horse's back in flexion and extension is usually visualised using a bow and string analogy (Fig. 2; Van Weeren, 2009). Often a treadmill is used for these kinematic studies, since this device offers a stable and controlled scenario (Sloet van Oldruitenborgh-Oosterbaan and Clayton, 1999; Weishaupt et al., 2002; Gómez Alvarez et al., 2009; Back and Clayton, 2013). Vertebral column kinematic studies have also been conducted over ground (Pourcelot et al., 1998; Audigié et al., 1999; Warner et al., 2010).

In the present study, the biomechanical responses of the back and pelvis of horses were examined by measuring changes in the range of AR, LB and PF of the back and pelvis during water treadmill exercise at different depths of water using the hoof as a baseline and control level.

Materials and methods

Horses

Twelve riding horses with no previous experience of water treadmill training were used in this study. They comprised five mares, six geldings and one stallion (10 Warmblood and 2 Baroque horses) with a mean (± standard deviation, SD) age of 7.4 (± 2.1) years (range 5–11 years) and a mean (± SD) height at the withers of 1.66 (± 0.08) m (range 1.51–1.86 m). The horses were all routine patients of a privately owned clinic, using the water treadmill at the request of and with informed consent of the owners. It was considered that there was no need for Animal Care and Ethics Committee approval according to Dutch law.

Experimental design and data collection

Horses were trained four times over 10 days on a water treadmill (Bogenhard; Fig. 3) at different depths of water (Scott et al., 2010). Recordings were made on days 1 and 10 while the horses walked in the water treadmill at a belt speed of 0.8 m/s at a range of depths of water (Peham et al., 2001). For each

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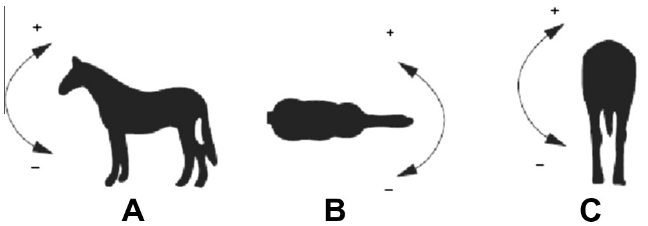

Fig. 1. The three planes of movement of the back. (A) Pelvic flexion (PF): rotation around an axis perpendicular to the sagittal plane. (B) Lateral bending (LB): rotation around the dorsoventral axis. (C) Axial rotation (AR): rotation around the craniocaudal axis (Van Weeren, 2009).

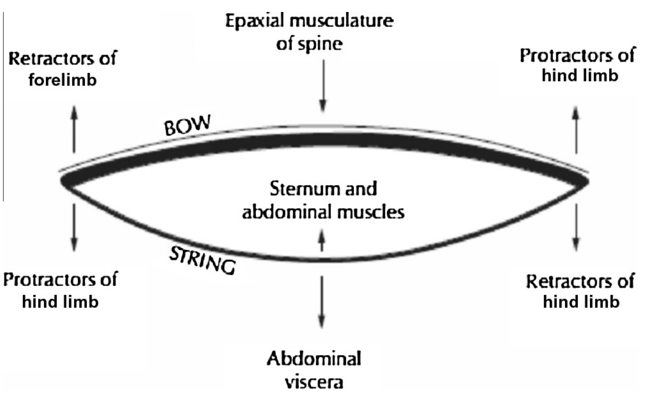

Fig. 2. The 'bow and string' analogy. The bow is the thoracolumbar vertebral column and the string is formed by the linea alba, rectus abdominis and related structures (Van Weeren, 2009).

Table 1
Marginal means (± standard errors and *P* values) for the effect of water height on the range of motion of axial rotation, lateral bending and pelvic flexion of horses walking in a water treadmill.

Water level	Axial rotation (cm)	Lateral bending (°)	Pelvic flexion (cm)
Hoof (control)	4.5 ± 0.3	9.1 ± 0.5	13.6 ± 0.6
Fetlock	5.2 ± 0.3*	8.8 ± 0.5	14.4 ± 0.6*
Carpus	5.9 ± 0.3*	8.4 ± 0.5	15.2 ± 0.6*
Elbow	5.4 ± 0.3*	7.6 ± 0.5*	16.2 ± 0.6*
Shoulder	5.5 ± 0.3*	6.4 ± 0.5*	17.7 ± 0.6*

* Values that are significantly different from the control (baseline value) at the hoof water level: $P < 0.05$.

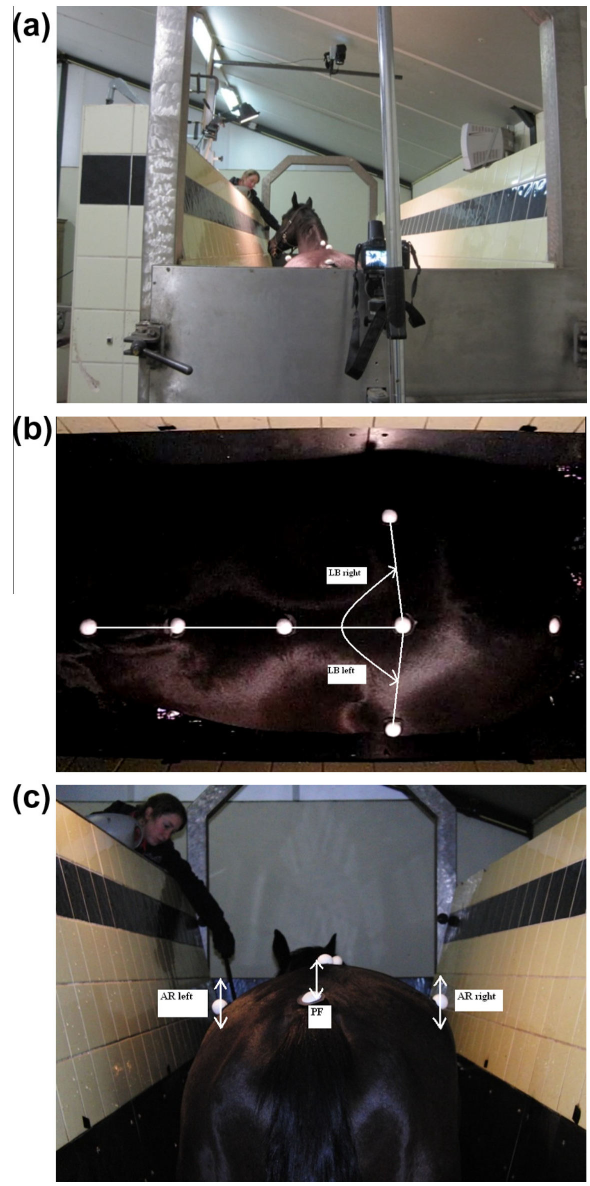

Fig. 3. (a) Recordings with both cameras were performed simultaneously when the horse was walking in a steady state. (b) Schematic representation of the calculation of the left and right lateral bending (LB) angles using the camera from above the treadmill. (c) Schematic representation of the calculation of the left and right axial rotation (AR) and the pelvic flexion (PF) distances using the camera from behind the treadmill.

recording, white spherical markers (diameter 40 mm) were glued to a piece of black paper, which was attached to the skin using double-sided adhesive tape at seven defined locations along the vertebral column. These shaved areas were identified by digital palpation and were defined as the highest point of the withers (T5–6), lowest point of the withers (T10–T11), thoracolumbar junction, tuber sacrale, left tuber coxae, right tuber coxae and tail base.

The water treadmill was filled with water to the level of the shoulder joint and recordings were made over a period of 20 min as the water level increased, with the water level being held constant for 2 min at each of five selected depths: midline of the shoulder, elbow, carpus and fetlock joints and at the level of the coronary band of the hoof. Recording was performed over a period of 1 min at each water depth using two high speed (300 frames/s) video cameras (Casio) and an artificial light source. The lighting was controlled to provide sufficient contrast between the edge of the markers and the surroundings. The cameras were aligned perpendicular to each other, whereby one camera was placed 3 m above the water treadmill to record the LB of the horse's back and the other camera was placed behind the water treadmill to record the AR and PF (Fig. 3). Twenty strides were analysed at each water depth on days 1 and 10.

Data analysis

To process the captured data, the vertical and horizontal axes of the field of view were defined and quantified, and external calibration files were created. For the camera that was placed behind the treadmill, the distance between the two sidewalls of the treadmill was measured at a fixed point in the treadmill for the horizontal axis. For the vertical axis, a wooden stick with a known size was measured at a fixed point in the treadmill for the camera that was placed above the treadmill. These external calibration files were then analysed using standard analysis software (Quintic) in which the markers were tracked automatically into frames recorded during 1 min at each water depth and converted into spreadsheet files (MsExcel, Microsoft) after data smoothing using a Butterworth filter. The vertical ranges of motion (ROM) of the left and right tuber coxae were calculated during 20 strides at each water depth. The AR of the pelvis is given by the mean left and right values during these 20 strides recorded with the camera behind the treadmill (Fig. 3c). The ROM of the angle between the craniocaudal axis, tuber sacrale and tuber coxae on the left or right indicates the LB of the back. This was calculated from recordings of the camera placed above the treadmill (Fig. 3b). The camera behind the treadmill was also used to record the distance between the tuber sacrale marker and the tail base marker, representing the PF of the back (Fig. 3c).