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Impact of walking surface on the range of motion of equine distal limb joints for rehabilitation purposes

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ABSTRACT

The aim of this study was to evaluate the effect of three footing surfaces on the flexion/extension, and range of motion (ROM) of the carpus, tarsus and fetlocks in the horse. The percentage of stride spent in the stance phase of sound horses at the walk was also measured. Nine sound horses were walked on hard ground (HD), soft ground (SF) and a land treadmill (LT), and five complete gait cycles were recorded by a digital video camera. Retro-reflective markers were placed on the skin at four anatomical locations on the left fore and hind limbs, and data were analyzed using two-dimensional (2D) motion-analysis software. Maximal flexion/extension angles and range of motion were calculated for each joint, and the percentage of the stride spent in stance phase was determined for each stride.

Maximal flexion of the tarsus and hind fetlock was greater on LT and SF compared to HD, while maximal flexion of the carpus was greater on LT compared to HD and SF. Maximal extension of the carpus was greater on HD compared to SF and LT, maximal extension of the tarsus was greater on HD and SF compared to LT, and maximal extension of the forelimb and hind limb fetlocks was greater on LT compared to HD and SF. The greatest overall ROM of the carpus and fetlocks was achieved on LT, while the greatest overall ROM of the tarsus was achieved on SF. The stance percentage of the stride for the hind limb was significantly different between all surfaces. In conclusion, walking surface influences flexion/extension of the carpus, tarsus and fetlocks in healthy horses, which should be considered when walking equine rehabilitation cases.

Introduction

Musculoskeletal lesions are a common health problem in horses. Performance horses are frequently affected and the type of lesion varies with the discipline (Smith et al., 2003). In some cases, these pathologies may even mean the end of a performance career in equine athletes, so intensive physical therapy is often required to give these animals the best chance of returning to competition (Bromiley, 2007; Goff and Stubbs, 2007). Exercises designed to promote joint range of motion (ROM) are particularly useful in preventing joint contracture and soft tissue adaptive shortening, reducing pain, enhancing blood and lymphatic flow and improving synovial fluid production and diffusion (Millis et al., 2004). A wide variety of therapeutic exercises and rehabilitation modalities are currently available (Bromiley, 2007) but the selection of therapeutic procedures is often based on individual experience or extrapolation from human or small animal rehabilitation studies, since scientific data on equine therapeutic modalities are scarce.

Hand walking on hard or soft surfaces at increasing intervals is often recommended by equine clinicians in the early rehabilitation period (first few weeks after an injury or surgery) to provide low intensity exercise, but the increase in joint ROM is relatively limited (Goff and Stubbs, 2007), so clinicians often recommend walking on alternating surfaces (soft and hard ground), walking over poles or cavalletti, or attachment of tactile stimulators and/or weights to the pasterns in order to encourage further increases in joint ROM (Bromiley, 2007; Clayton et al., 2010, 2011). Additionally, the use of a land treadmill has been suggested as an alternative to in-hand walking because it provides a non-slip surface with minimum concussion at a controllable speed (Bromiley, 2007). However, to the authors' knowledge, there is no objective data on what walking horses on different conventional surfaces will do to the ROM of joints of the distal limb.

Determination of the effect of walking surface on the flexion and extension of the distal limb joints would help clinicians in designing a rehabilitation program. Therefore, the objectives of this study were: (1) to calculate maximal flexion and extension angles, and ROM of carpal, tarsal and fetlock (fore and hind) joints of sound horses walking on three conventional footing surfaces,

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namely hard ground (HD), soft ground (SF) and a land treadmill (LT); (2) to calculate the percent of stride spent in the stance phase; and (3) to determine which surface provides the greatest flexion, extension and overall ROM for each joint. We hypothesized that walking surface (HD, SF and LT) would affect flexion, extension and ROM of the distal limb joints, as well as the percentage of the stride spent in the stance phase differently.

Materials and methods

Horses

Nine clinically sound horses (eight Quarter horses and one Thoroughbred) were included in the study. Mean ± standard deviation (SD) age of the horses was 8.1 ± 4.3 years; bodyweight (BW) was 486.6 ± 26.3 kg and height at the withers was 150.1 ± 3.2 cm. It was determined that horses were healthy and not lame, based on a thorough physical examination and results of routine subjective lameness evaluation. The study was performed with approval of the Institutional Animal Care and Use Committee.

Data collection

All horses had previous treadmill experience from an unrelated study and were acclimated to the other walking surfaces (HD and SF) by walking back and forth on an asphalt surface used for lameness evaluation (HD) and in arena footing (SF). The arena footing was a combination of fine washed sand mixed with loam (50%–50%) treated with magnesium chloride and packed to a depth of 10 cm. The same area of the arena was used to walk all horses and was manually levelled with a garden rake before collection of data from each horse. Horses were always walked from the left side by the same experienced handler. During data collection, walking speeds were calculated using three light-beam sensors, (Polaris Wireless Timer, FarmTek) spaced at 1.5 m intervals across the data collection area for HD and SF; measurement of the amount of time it took a horse to break each beam allowed for objective measurements of velocity and acceleration. Trials were only considered acceptable if horses walked between 1.0 and 1.4 m/s, with acceleration variation between −0.2 and 0.2 m/s^2. The speed of the treadmill (Säto) was maintained at 1.2 m/s (as measured by treadmill controls) for data collection.

In order to track movement of the limbs, four retro-reflective spherical markers (3 cm in diameter) were taped to the skin over the center of rotation of each joint (lateral aspect), in defined anatomical locations on the left forelimb and left hind limb of each horse. Forelimb markers were placed at the level of: (1) proximal interphalangeal joint; (2) lateral condyle of the distal third metacarpus; (3) ulnar carpal bone; and (4) 15 cm proximal to the ulnar carpal bone on the groove between the common and lateral digital extensor muscles on the radius (Fig. 1A). Hind limb markers were placed at the level of: (1) proximal interphalangeal joint; (2) lateral condyle of the distal third metatarsus; (3) mid talus; and (4) 10 cm proximal to the tuber calcanei on the groove between the long and lateral extensor muscles on the tibia (Fig. 1B).

Locations of the skin markers were chosen based on previous recommendations for gait analysis (Clayton and Schamhardt, 2001), with slight modifications to mimic data collected in a related underwater treadmill (UWTM) study (i.e. distal marker at the level of the proximal interphalangeal joint instead of at the hoof, and proximal marker in the middle of the tibia or radius instead of at the proximal aspect of the bone; Mendez-Angulo et al., 2013). A small area of hair (2 cm × 2 cm) was clipped at these locations to ensure consistent marker placement throughout the study.

Two-dimensional (2-D) movement was recorded from the left side of the horses using a digital video camera (6.0 mm lens; IDS Imaging Development Systems) at 60 frames/s while the horse was walked on HD, SF and LT. Camera resolution was 640 × 480 pixels, shutter speed was set up 1/240 s, and the camera field of view was 3 m in our settings. Data were collected using the same camera settings for all footing surfaces over three consecutive days (one for each surface). Skin markers were taped to the skin on the clipped area immediately before data collection for each surface and removed thereafter. Markers were always taped on all locations on all horses for all surfaces by the same person (JLMA) to ensure consistency throughout the study.

The digital video camera was positioned on a tripod perpendicular to the plane of motion for each footing surface (at 152 cm from the ground and 300 cm away). The camera was tilted 30° down to be able to compare results with data obtained in a related UWTM study (Mendez-Angulo et al., 2013). Retro-reflective skin markers were illuminated by four 300 W halogen lamps positioned close to the camera's field of view. Five complete strides of the left fore and hind limbs of each horse were videotaped for each surface. Additionally, one horse was videotaped using the same conditions (camera position, angle and distance from the plane of motion) at three different occasions on the same surface (hard ground) to evaluate the variability of placement of markers. On this horse, the markers were repositioned by the same person before data collection each time.

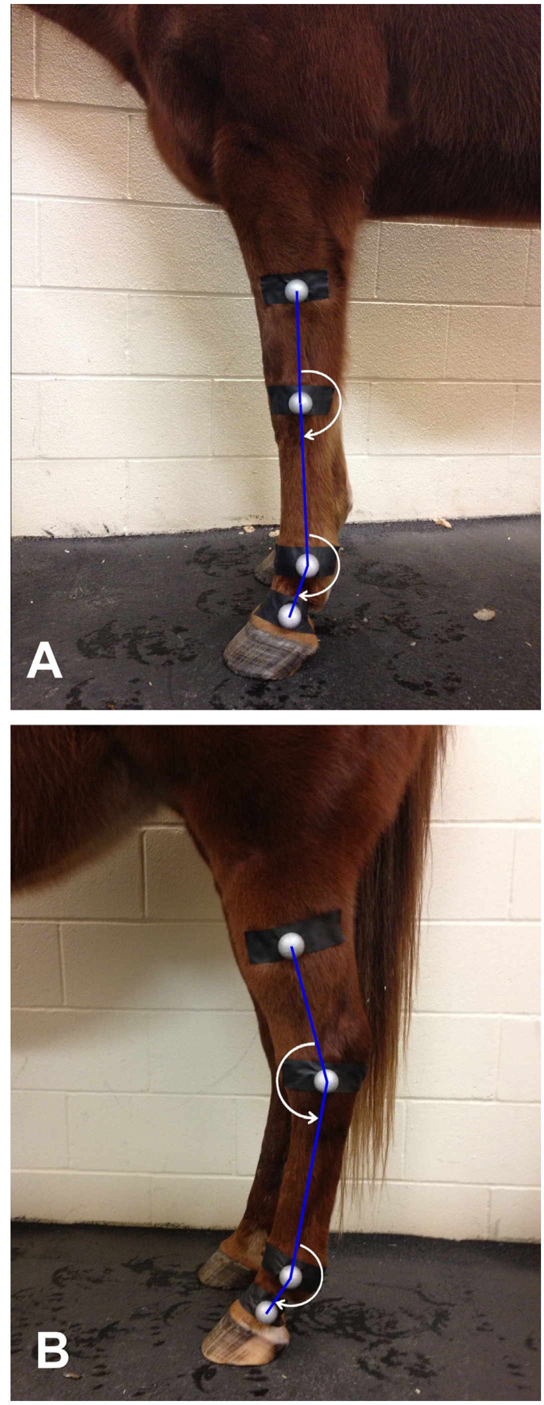

Fig. 1. Photographs of a horse instrumented for data collection. Observe the locations of the skin markers on the fore (A) and hind (B) limbs used to determine the body segments (blue lines) used to calculate the joint angles. Measured angles of each joint are represented by a white line and an arrow.

Data analysis

2-D kinematic analysis was performed using the DMAS Equine Gait Trax system (Motion Imaging Corporation). Calibration was performed at the beginning of each session by marking on the ground a known distance (2 m perpendicular to the tripod and camera) within the camera's field of view. One stride was defined as the distance from complete foot contact (heel and toe) with the ground to subsequent contact of the same limb. For soft ground, complete foot contact was determined when the heel and toe contacted the ground completely and there was no further sinking of the foot in the arena in the following frame. Within a stride, stance duration was defined as the number of frames within a stride in which there was contact