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Circumferential hoof clamp method of lameness induction in the horse

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ABSTRACT

A circumferential hoof clamp method to induce controlled and reversible lameness in the forelimbs of eight horses was assessed. Peak vertical forces and vertical impulses were recorded using a force plate to verify induced lameness. Video recordings were used by blinded observers to determine subjective lameness using a 0–5 scale and any residual lameness following clamp loosening. Tightening of clamps resulted in consistent, visible lameness in the selected limbs in all horses. Lameness was confirmed by significant decreases from baseline in the peak vertical force ($P < 0.01$). Lameness was also confirmed subjectively by elevated median scores (0 at baseline and 2 during lameness). Lameness was not immediately reversible after clamp loosening (median score 1.5), but horses were not obviously lame after clamp removal and were no different from initial baseline (median score 0.5) approximately 3 days later.

Introduction

Lameness is one of the most important health issues affecting the equine industry (Kaneene et al., 1997). It is more costly to horse owners and trainers than any other disease, with approximate annual estimates at US $1 billion[1] in 1998[2]. In view of the importance of this problem, researchers have focused on lameness in an effort to improve the accuracy of diagnosis and effects of treatment. Most studies have evaluated diagnostic methods (Dyson and Kidd, 1993; Keegan, 2007) or therapeutic interventions in horses with naturally occurring lameness (Symonds et al., 2006; Back et al., 2009). However, naturally occurring lameness is often complex and adds variability, since it is difficult to enroll multiple horses with the same source and degree of lameness.

A variety of techniques have been used to induce reversible lameness in sound horses to eliminate the variability seen in naturally occurring lameness, each with unique strengths and weaknesses. One of the most commonly used methods of inducing lameness is the creation of synovitis through the intra-articular administration of pro-inflammatory agents (McIlwraith et al., 1979; Bowman et al., 1983; Hamm et al., 1984; Firth et al., 1987), autogenous blood (Judy and Galuppo, 2005) or sterile saline to pressurize the joint (Thomsen et al., 2010). These techniques induce reversible lameness in a particular limb, but all have high variability in the time to onset, degree and duration of lameness achieved.

To better control variability, less invasive induction techniques were developed by applying adjustable pressure on the sole of the foot or frog. One technique uses a screw with nuts welded to the inner rim of the shoe, where screws are tightened to put pressure on the solar corium to create pain (Merkens and Schamhardt, 1988a). Another technique uses a screw to push up a portion of an adjustable heart-bar shoe to put pressure directly on the frog (Foreman and Lawrence, 1991); this was first described in detail as a treatment for laminitis and recognized to worsen lameness when the screw was over-tightened (Goetz and Comstock, 1985).

These solar methods of lameness induction are more easily controlled and reversible than intra-articular techniques (Merkens and Schamhardt, 1988a; Foreman and Lawrence, 1991), but still have some shortcomings. For instance, the frog-pressure method, when used on trotting horses, has been shown to produce an inconsistent lameness pattern over time (Keegan et al., 2000; Kelmer et al., 2005). In addition, residual lameness has been reported with the solar pressure technique, with most being in studies where the nuts and screws are placed closer to the toe than the quarter (Deuel et al., 1995; Schumacher et al., 2000, 2001a, 2001b). The type of screw used may also affect induction of lameness; for example, researchers found greater residual lameness when using flat-tipped screws when compared to pointed screws and it has been speculated that additional pressure and repeated placement may lead to solar bruising (Schumacher et al., 2000, 2001a).

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[1] US $1 = approximately GBR £0.64 and €0.80 at 29 November 2014.
[2] See: http://www.aphis.usda.gov/animal_health/nahms/equine/downloads/equine98/Equine98_is_EconCost.pdf (accessed 4 March 2013).

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An alternative method of inducing lameness has been described using a circumferential pipe clamp (Stick and Caron, 1994). This technique uses an adjustable clamp that can be tightened to tailor the amount of pressure placed around the hoof. Using incremental clamp tightening, researchers were able to create repeatable lameness that immediately resolved with clamp loosening. However, a detailed description of this technique has been lacking and further study is required to determine if this method creates a predictable, consistent lameness that can be repeated throughout a study.

The aim of our study was to refine the circumferential clamp method of inducing lameness and to validate its use. Both subjective (observational gait scoring) and objective (force plate analysis) measures were used to verify the successful induction of lameness and to evaluate the return to baseline. Our hypothesis was that controlled lameness of an American Association of Equine Practitioners (AAEP) grade 2 could be created by applying a clamp to a given limb, and that the lameness would be reversible, thereby providing the potential for multiple data collections on the same horses without interfering with subsequent induction of lameness. We further hypothesized that the resulting lameness could be confirmed by decreased ground reaction forces and elevated subjective lameness scores.

Materials and methods

Horses

Eight adult Quarter Horses (median age 6 years, range 5–10 years) were enrolled in this study. Horses included four mares and four geldings weighing 487–595 kg (mean ± standard deviation, SD, 537 ± 37 kg). Prior to their inclusion, horses were used as sound, control horses for another study, in which they were acclimated to force plate examinations (Boyce et al., 2013). Experimental procedures were approved by the University of Minnesota Institutional Animal Care and Use Committee (IACUC; protocol #1007A86632, date of approval 12 August 2010).

Hoof clamp application

Routine farriery work was performed on all horses prior to the study, including balanced trimming and shoeing on all limbs. Stainless steel pipe clamps (T-Bolt Clamps, HPS Performance Silicone Hoses) were used that had a range in internal diameter of 10.2–12.9 cm and a width of 1.9 cm (Fig. 1A). A variety of clamp diameters were purchased and individually fitted to each hoof. Clamps were fitted to all limbs on all horses so that any effects on the gait due to clamp placement alone, and not due to tightening of the clamps, would be experienced equally in all four limbs. The width of the plantar portion of the clamps (palmar portion for one horse) was reduced by half to prevent impingement on the coronary band (Figs. 1B–D). To decrease the plantar width, a semi-circular area was marked on the distal and plantar portion of the clamp, beginning approximately where the heels contacted the shoe, extending up to the middle of the clamp width (approximately 9 mm). The plantar distal portion of the clamp was removed and edges were smoothed using a grinding tool (Dremel, Robert Bosch Tool Corporation). Clamps were angled slightly dorsoproximal to palmaro/plantarodistal, with the palmar/plantar portion of the clamp touching the bars of the shoe (Figs. 1A–C).

The clamp was secured to the hoof to prevent proximal migration during tightening. Three holes were drilled into the insensitive laminae of the dorsal, lateral and medial hoof walls using a 5/32 inch (~4 mm) diameter titanium drill bit (Robert Bosch Tool Corporation) to a depth of approximately 4.8 mm. Tape was placed around the drill bit to serve as a depth gauge (Fig. 2A). Three cable ties (Cable Ties Plus) were passed around the clamp and 10–24 × 3/8 inch slotted hexagonal head machine screws (Midwest Fastener Corporation) were placed through the eye holes in the cable ties distal to the hoof clamp and secured into the holes in the hoof wall (Fig. 1A).

Screw placement varied slightly by horse and was determined by finding the location on the hoof for best conformity and pressure distribution without impinging on the coronary band. Occasionally, screw holes were stripped and the 10–24 screws were replaced with 10–32 screws (Midwest Fastener Corporation), or a new hole was drilled. The adjusting bolts used to tighten and loosen the clamps were placed laterally on all feet to avoid trauma in case of interference (Fig. 2B). A light protective covering was placed over all clamps to prevent injury during data collection. Between trials, holes in the hoof wall for screw placement were plugged with the ends of cotton-tipped applicators and covered with duct tape. Holes were filled with polymethylmethacrylate (Technovit, Jorgensen Laboratories) following completion of the study.

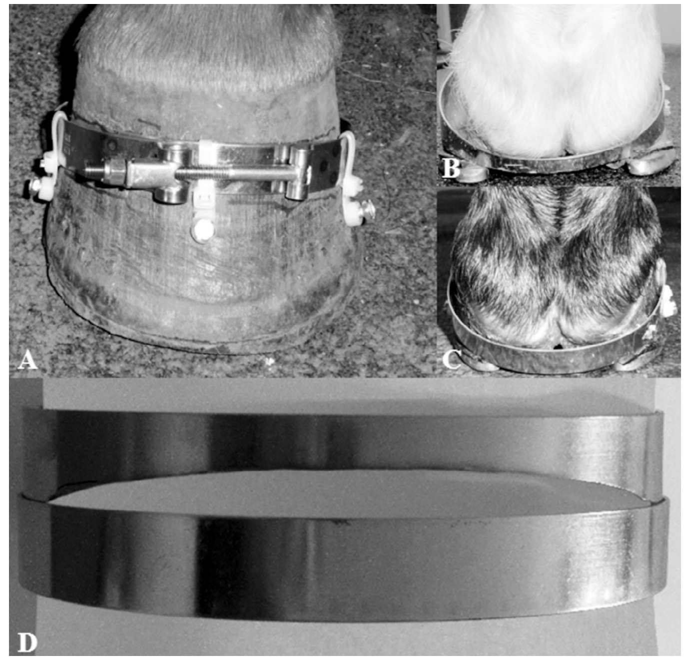

Fig. 1. (A) Dorsal view of clamp in place. Note medial, lateral and dorsal screws through cable ties that pass around the clamp to prevent proximal displacement when the clamp is tightened. (B) Plantar view of a modified clamp on a hind limb. Note the decreased width of the plantar portion of the clamp beginning where the heel contacts the shoe to prevent impingement on the coronary band. (C) Palmar view of an unmodified clamp on a forelimb showing the heel region of the clamps. (D) Note the distal portion of the top clamp has been trimmed, whereas the bottom clamp is unaltered. The altered top clamp is demonstrated on a limb in photograph B and the unaltered bottom clamp in photograph C.

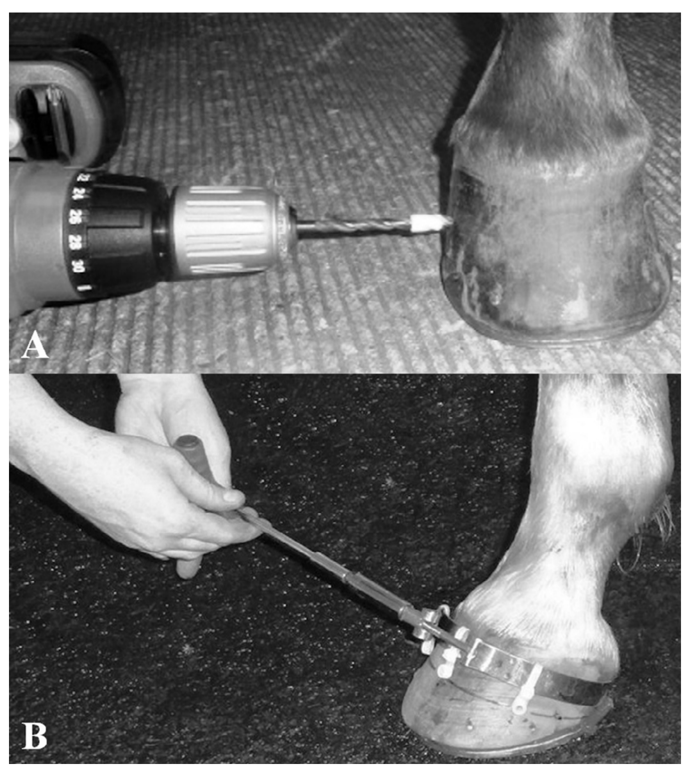

Fig. 2. Preparation hooves for the study. (A) Drilling of a lateral hole for placement of screws to keep the clamp in place. White tape around the drill bit serves as a depth gauge. (B) Hoof clamps in place and being tightened. Tightening bolts were placed laterally for better accessibility and to reduce the likelihood of interference.