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Novel Information About The Kinetic Effects Of Equine Shoe Modifications And Kinematic Effects Of Human Digital Devices For Improved Performance In Both Species

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NOVEL INFORMATION ABOUT THE KINETIC EFFECTS OF EQUINE SHOE MODIFICATIONS AND KINEMATIC EFFECTS OF HUMAN DIGITAL DEVICES FOR IMPROVED PERFORMANCE IN BOTH SPECIES

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ABSTRACT

Equine shoes are frequently modified to enhance traction for horses that travel on paved surfaces for work, pleasure, or entertainment. Little is known about other common shoe modifications used to enhance traction like calks, tungsten carbide granules, or plastic composition. This information is vital to shoe design to protect the safety and welfare of all service, working, and leisure horses. The objective of the first part of this thesis was to quantify the effect of shoes with and without traction adaptions on kinetic measures in non-lame, light breed horses at a trot. Kinetic data was collected with a force platform from horses while unshod (U) and subsequently shod in random order with five distinct shoes: standard (S), high profile-low surface area calk (HC), low profile-high surface area calk (LC), thin layer tungsten carbide (TLC), and plastic-steel composite (C). Results indicate that in the forelimbs, peak vertical force increased with C versus S (P=0.0001), HC (P=0.0049), LC (P= 0.0110), and TLC (P=0.0246) shoes. In the hind limbs, peak braking force increased with C versus S ($P<0.0001$), HC ($P<0.0001$), LC ($P<0.0001$), and TLC (P=0.0041). It increased with TLC versus HC ($P<0.0001$) and S ($P<0.0001$) and increased with LC versus HC (P=0.0079) and S shoe (P=0.0474). The human wrist (radiocarpal joints) has complex anatomy and motion that likely contributes to overuse injuries. Digital device use requires distinct wrist motions that may contribute to tissue damage with frequent, prolonged use and static loading. The second part of the thesis aimed to quantify wrist motion in radial-ulnar deviation and flexion-extension planes for use of digital devices and their manual counterparts in dominant and non-dominant hands of male and female professionals. Twelve subjects completed 4 paired daily living activities using digital and manual devices. Left and right wrist 3D motion was recorded with eight markers of a wireless, active motion detection system. This study established baseline values for

medial and lateral radiocarpal extension and radial-ulnar deviation angles and ROM using digital devices. Both sex, handedness, and device size influence wrist motion.

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

1.1. Shoes affect hoof-ground interaction

"No hoof, no horse" is a widely used adage in the equine veterinary field (Johnston and Back 2006). Horse hooves are flexible structures that provide an interface between the distal limbs and ground surface (Burn and Brockington 2001; Wilson and Weller 2011). Impact force, ground surface, and shoe conditions affect hoof function and structure (Brunsting et al. 2019; Bras and Redden 2018). Hooves receive an impact force generated by the ground during the stance phase when in contact with ground surface (Bras and Redden 2018). The initial impact phase usually happens the first few milliseconds after collision, when then hooves rapidly decelerate (Back et al. 2006; Gustas et al. 2001). The vibration produced in the hooves and the impact force applied during each stance phase is attenuated as they are transmitted up the limbs due to damping (Back, van Schie, and Pol 2007). Hoof expansion mechanisms play an important role in damping (Burn and Brockington 2001), and include the hoof wall moving to a palmar direction, the sole and frog moving towards the ground surface, and the heel expanding to dampen the vibration and absorb the impact force (Brunsting et al. 2019). In addition, hoof expansion helps to dissipate the energy generated during the stance phase (O'Grady 2008). Damping also plays an important role in reducing high-frequency oscillations;therefore, reducing the risk of subchondral bone and joint damage (Back et al. 2006). Hooves have a tendency of slipping after their initial impact phase, which causes a secondary impact phase. The braking force, as one component of the ground reaction force (GRF), plays an important role during the secondary impact phase. The ground surface, shoe conditions, and shoe modifications, including calks, studs, and toe-grabs, affect the braking force (Parkes and Witte 2015a; Harvey, Williams, and Singer 2012). If braking force is too little, it can cause the horse to fall, especially on ice or snowy road surfaces. On the other hand,

if there is too much braking force, the risk of injury is increased (Harvey, Williams, and Singer 2012). Following the secondary impact phase, the hooves receive support from the ground and the vertical GRF increases, reaching the maximum at the mid-stance (McGuigan and Wilson 2003). The vertical GRF determines the loading on the hooves (Witte, Knill, and Wilson 2004a) The loading applied on the tendons, ligaments, and bones on the horse limbs affect tissue modeling and adaption (Parkes and Witte 2015a).

Shoes and their modifications have important functions in horses. First, shoes can protect hooves against excessive wear and keep horses working in a comfortable environment (Willemen, Savelberg, and Barneveld 1997; Roepstorff, Johnston, and Drevemo 1999; Karle et al. 2010). Second, shoes and modifications provide therapeutic aid for limb injury to reduce the mechanical limitations and create a better healing environment (Van Heel et al. 2005; Bras and Redden 2018). For instance, heart-bar shoes provide frog pressure to support the digital phalanx (Ritmeester et al. 1998), which was originally designed for laminitis. Laminitis is a common health issue in horses (Egenvall et al. 2006; Penell et al. 2005; Putnam et al. 2014; Eustace and Caldwell 1989). Pressure on hoove heels can be relieved by increasing the load on the frog, which is a reason to apply heart bar shoes to horses with palmar hoof pain (Hüppler et al. 2016). Heel wedges at 6 degrees are commonly used to lift the heel (Chateau, Degueurce, and Denoix 2004a; Peham et al. 2006; Chateau, Degueurce, and Denoix 2004b), and studies have demonstrated that heel wedges can decrease strain on deep digital flexor tendon (DDFT) (Riemersma et al. 1996; Willemen, Savelberg, and Barneveld 1999). This is done when the heel wedge reduces the compressive force produced by DDFT on the navicular bone and reduces the moment of torque during break over (Wilson et al. 2001; Willemen, Savelberg, and Barneveld 1999; Chateau, Degueurce, and Denoix 2006). Heel wedges have been used to increase the maximal flexion of both the proximal and distal

interphalangeal joints at a walk and trot; however, in contrast, maximal flexion of those two joints has also been found to decrease with toe wedges by Lawson *et al* (Lawson et al. 2007). Egg-bar shoes increase the stability of hooves, especially at sand tracks (Ostblom, Lund, and Melsen 1984; Rogers and Back 2003), but shift the point of the GRF towards the heel and decrease the moment of force at the digital interphalangeal joint (Chateau, Degueurce, and Denoix 2006) and deep DDFT (Rogers and Back 2007) by extending out behind the foot with a larger contact area for weight bearing in horses (Ritmeester et al. 1998). It is believed that egg bar shoes reduce the pressure on the navicular bone, and therefore, they are used in the treatment of navicular lame horses. Diverse types of shoes and their adaptations are commonly used to enhance horse performance by affecting kinematics and kinetics of horse locomotion (Johnston and Back 2006; Clayton, Sigafoos, and Curle 1991; Willemen, Savelberg, and Barneveld 1997; White et al. 2018; Gross et al. 2004). Evidence-based studies are needed to further characterize the value of these shoes.

1.2. Ground reaction force

Ground reaction force is an important aspect of kinetics research and represents the effects of force that cause body movements (Kaufman and An 2017). To assess kinetic effects of shoes and their adaptions on horse gait, GRF is measured by using various equipment. GRF is the external impact force generated when hooves contact ground surfaces during the stance phase (Eliashar 2007). In the limb biomechanics study, GRF is regarded as a single point of impact where the hoof and force plate meet (Eliashar et al. 2002). A number of factors can affect GRF, including bodyweight, movement velocity (Weishaupt et al. 2010), ground surface, and shoes and their modifications (Crevier-Denoix et al. 2010). GRF increases with body weight and velocity in horses (Clayton et al. 1999). Horses with shoes usually have a greater peak vertical force than unshod

horses (Parkes and Witte 2015a; Roepstorff, Johnston, and Drevemo 1999). Different objective methods have been developed to measure GRF, including force plates, pressure plates, and instrumented horseshoes (Bobbert, Álvarez, et al. 2007; Roland, Hull, and Stover 2005; Eliashar et al. 2002; Amitrano, Gutierrez-Nibeyro, and Schaeffer 2016). Traditionally, force plates have been used to quantify the effects of various shoeing conditions on horse gait (Rogers and Back 2007), and have become the standard reference for detection and evaluation of equine lameness (Keegan et al. 2012). Peak vertical GRF is measured from the force plate to indicate the severity of the lameness (Schoonover et al. 2018). A force plate was first employed for studying equine biomechanics by Pratt and O'Connor (Pratt and O'Connor 1976). In 1873, Marey *et al* published their methods for measuring force data using a wooden frame on rubber supports. Gradually, force plates have been developed as a fundamental tool in gait analysis. A force plateform offers peak ground reaction force in three direstions (X, Y and Z), which corresponds to 3 orthogonal components (vertical, longitudinal, transverse) by the resolving GRF vector (Gnagey, Clayton, and Lanovaz 2006; Rogers and Back 2003). Furthermore, it can measure stance, braking, and propulsive times; vertical, braking, and propulsive impulses (defined as the area under force-time curve); and time at which peak GRF occurs (Bell et al. 2016; Amitrano, Gutierrez-Nibeyro, and Schaeffer 2016; Clayton and Schamhardt 2013). The peak vertical force is regarded as an indicator of weight bearing in each hoof. The peak braking force and coefficient of friction (COF) can be used to assess the traction among shoes. COF is the ratio between vertical and braking forces (Pardoe et al. 2001b). Force plates provide accurate and repeatable results for the gait analysis (Keegan et al. 2012). However, it cannot identify the local pressure from interested areas (Rogers and Back 2007) and can only measure force from one hoof at a time (Bobbert, Gomez Alvarez, et al. 2007). In addition, force plates are usually embedded into the ground, so that the force platform

is not fit to compare different ground surfaces. It is hard for horses to step into the center of the force plate at a gallop, especially when the stride length is more than 6 m longer than the plate (Roland, Hull, and Stover 2005).

The stress plate system has been used to study the static or dynamic stress distribution under equine hoof (Rogers and Back 2003; Rogers and Back 2007), trimming (Moleman et al. 2006), and shoeing conditions (van Heel, van Weeren, and Back 2006; Oomen et al. 2012). Compared with the force plate, which only has four receptor cells at each corner, stress data can be calculated using hundreds of receptor cells, allowing high resolution across the shoe-bearing area (Rogers and Back 2003). In van Heel *et al* study, high spatial accuracy was achieved by placing the 2.6 sensors per cm^2 (van Heel et al. 2004). Furthermore, stress plates provide the forces in real-time and can be used to gain a deep undersatnding of characteristics of the hoof during loading and unloading (van Heel et al. 2004; Rogers and Back 2007). Compared with force plates or stress plates, force shoes measure the GRF in dynamic motion. Piezoelectric load cells are often used to construct force shoes. Henry Chateau *et al* designed shoes to measure GRFs of horses on different types of tracks (Chateau et al. 2009). Robin *et al* showed that force shoes can measure GRF during the impact deceleration of the hooves due to high responsiveness of the piezoelectric transducers (Robin et al. 2009). A stress plate or instrumented horseshoes have the advantages of providing complete force information on different portions of the hoof during a stance phase (van Heel et al. 2004; Rogers and Back 2003; Oosterlinck et al. 2010) and measure the GRF directly (Roland, Hull, and Stover 2005). Unfortunately, the weight of force shoes can vary (up to 860 g) and are typically heavier than standard shoes (300 g); this can affect biomechanics of a horse's gait at the swing phase (Roland, Hull, and Stover 2005; Lanovaz et al. 1999). A major difference between force

plates and force shoes is that the force plate can only measure one single foot strike at a time, whereas the force shoes can measure continuous force data (Morris and Lawson).

1.3. Shoe materials

Various materials have been used to design horseshoes, including steel, wood, aluminum, rubber, and plastic. The type of material can influence the weight and traction property of the shoes (Steward 2010; Pardoe et al. 2001a; White et al. 2018). Steel is the most commonly used material to build shoes since it is inexpensive, easy to access (Huguet and Duberstein 2012). Aluminum shoes are popular in racehorses because they are lightweight, compared with steel shoes (Caure et al. 2018), and reduce the chance of injury in the forelimbs where loading is higher. Studies have found that aluminum shoes can reduce the risk of forelimb lameness compared with steel shoes (Huguet and Duberstein 2012; Moyer and Anderson 1975). Shoes designed from different materials can alter traction by influencing the friction between the hooves and ground surface (Harvey, Williams, and Singer 2012; Pardoe et al. 2001a; Heidt et al. 1996). For instance, rubber shoes have greater friction than plastic or steel shoes and can reduce slippage on concrete pavement due to their softness (Pardoe et al. 2001a). Polyurethane shoes have more damping and slower shock absorption (Back, van Schie, and Pol 2007); therefore, these shoes are recommended to reduce joint pain in horses with osteoarthritis (Back, van Schie, and Pol 2007). Shoe materials can also affect shoe weight. Several studies have found that shoe weight primarily affects the kinematic variables in forelimbs and hind limbs during the swing phase (Rumpler et al. 2010; Willemen, Jacobs, and Schamhardt 1999). The results from one study suggested that increased shoe weight can improve the height of carpus, fetlock, and hoof of horses at swing phase (Huguet and Duberstein 2012; Balch, Clayton, and Lanovaz 1996). Rumpler *et al* used rubber boots and found that increased weight on the hoof can attenuate the impact force and increase flight arc height

(Rumpler et al. 2010; Murphy 2009). The kinetic energy is increased due to shoe weight increment and fast footfall, which causes a higher load in the forelimb during the stance phase. The horse body has to overcome a larger gravity at the initial heel-off due to the increased weight, which may increase the risk of tissue and tendon injury (Huguet and Duberstein 2012).

1.4. Shoe traction modifications

Toe grabs, studs, and calks are commonly used to improve traction in horses. These modifications increase friction between shoes and pavement surfaces. Toe grab is a raised steel rim placed at the toe area on the horseshoes. It is designed to improve traction and reduce sliding during horseracing. However, the risk of musculoskeletal injury in horses with toe grabs has been found to increase compared to unshod horses (Kane et al. 1998; K. Balch, Gayman Helman, and A. Collier 2001; Kane, Stover, Gardner, Case, Johnson, Read, et al. 1996; Hill et al. 2001). Toe grabs delay break over and causes excessive heel compression. As a result, toe grabs increase strain on the suspensory apparatus and increase the risk of suspensory apparatus failure (Harvey, Williams, and Singer 2012; Schaer et al. 2006). Kane AJ *et al* examined the deaths of 201 thoroughbred racehorses in California and found that horses with toe grabs had a greater chance of developing suspensory apparatus failure compared to horses without toe-grabs (Kane, Stover, Gardner, Case, Johnson, Read, et al. 1996).

Studs are often used to enhance traction in sound athletic horses or to increase grip in draft horses (Hagen et al. 2017). In Harvey *et al*, studs were placed on the lateral sides of the shoes on all four hooves of nine horses. They found that shoes with studs decreased slip distance in horses cantering on grass compared with shoes without studs (Harvey, Williams, and Singer 2012). Impact force and induced vibrations increased due to more sudden braking with studs, which increased the risk of subchondral bone and joints damage(Parsons et al. 2011; Harvey, Williams,

and Singer 2012; Parkes and Witte 2015b). Studs may also change normal energy generation and dissipation mechanisms (Parkes and Witte 2015a; Kane, Stover, Gardner, Case, Johnson, Read, et al. 1996; Parsons et al. 2011).

Adding calks to horseshoes is a common practice to enhance the traction and prevent slipping in horses. Calks are usually made of borium, which is a tungsten carbide product and has higher hardness than concrete or asphalt. It increases friction between the shoes and the pavement surface. On the other hand, calks have been reported to be the main cause of pavement damage on Amish travel routes.(Nazzal and Holcombe 2017) It reduces the contact area between the shoes and the pavement, which induces high stress and causes rutting. One scientific report from the Department of Transportation found that the average repair cost per mile is around $26,805 for Amish buggy routes, which was much higher than non-Amish buggy routes($19,979 per mile) (Nazzal and Holcombe 2017). In addition, Amish buggy routes have a very high repair frequency. These roads typically need to be repaired every three years, compared to non-Amish routes that need to be repaired every six years (Nazzal and Holcombe 2017). There is a lack of evidence on the effects of shoes with calks on horse gait, but such information is vital to improve the well-being of horses.

1.5. The kinematic influences of digital devices on human wrist motion

Kinematic studies measure locomotion without considering the applied force and are used to reduce the limitations associated with subjective visual assessment (Kaufman and An 2017; Pitti et al. 2018). Human wrist motion provides valuable information about the patient's progress for the surgeon and hand therapists (Carter et al. 2009). Several factors affect human wrist joint motion, including the contact surface and the surrounding tissues and devices (Kitsoulis et al. 2010). The

past few decades have seen a rapid increase in digital devices, such as cell phones and tablets (Jonsson et al. 2011). Cell phones play an important role in today's modern lifestyle due to their numerous convenient features, including games, internet access social networks, emails, instant messaging, and navigation (Demirci, Akgonul, and Akpinar 2015; Montag et al. 2015). There were more than seven billion mobile cellular subscriptions worldwide in 2016 (Parasuraman et al. 2017), and a study in 2016 found that Americans spend approximately 2 hours and 37 minutes per day on their mobile devices (Eun et al. 2018). In addition, with the advancement of mobile technology, people are more likely to use their cell phones than traditional counterparts, such as computers and manual calculators (Woo et al. 2016a).

Although cell phones have brought enormous convenience to users in the modern world, they are known to cause obvious adverse effects on physical and mental health, such as sleep disturbances, depression, and musculoskeletal disorders (Haug et al. 2015; Eun et al. 2018; Jonsson et al. 2011). Overuse of cell phones has been associated with weakness of the thumb and wrist (Parasuraman et al. 2017) and repetitive strain injury of the wrist (Woo et al. 2016a). Repetitive strain injury refers to disorders that are caused by repetitive movements, sustained force, and other factors (van Tulder, Malmivaara, and Koes 2007). For example, repetitive wrist-hand movements that require digit movements in wrist extension and ulnar deviation are factors that contribute to carpal tunnel syndrome (Woo et al. 2016a). In addition, given the nature of cell phones, users often use one hand to hold devices, with the thumb being used to manipulate keys (Trudeau et al. 2012). As a result, wrist motion can be restricted due to prolonged cell phone use without posture change, compared with counterparts such as books or keyboards. Tablets and cellphones also have small spacing on the keyboard, which can restrict wrist range of motion compared with keyboards and

books. Overuse of digital devices and restricted wrist motion may be associated with repetitive strain injury and requires further study.

1.6. Kinematics analysis of wrist motion in daily activities

Several methods are commonly used to measure human wrist joint movements, including goniometers, electro-goniometers, video-based optoelectronic systems, and infra-red based kinematic analysis equipment. Goniometers are a traditional and simple tool used to measure wrist joint movement in a single plane and static position. It is the primary device used to measure wrist joint movement in clinics (Gutierrez-Martinez et al. 2014). A novel goniometer was used to measure the wrist radial ulnar deviation in 300 subjects whose forearms were fixed in a pronated position by Kitsoulis *et al* (Kitsoulis et al. 2010). In that study, the authors found that there were no differences between sexes and handedness. However, differences in total deviation of athlete left hands and non-athlete left hands were significant (Kitsoulis et al. 2010). Additionally, there were significant differences in the radial deviation of manual worker left hands and non-manual worker left hands (Kitsoulis et al. 2010). These results suggest that participants' occupations affect wrist motion. In Carter *et al*, a manual goniometer was used to measure accuracy and reliability of three techniques used to measure wrist motion (Carter et al. 2009). The authors applied three techniques, ulnar, radial and dorsal-volar, to 10 cadaveric wrists and found no significant differences among the three techniques. While the goniometer is considered as a standard reference and has advantages in cost and ease of use, it still has some drawbacks. For instance, the experiences of the examiner can affect the results and the goniometer itself can restrict wrist motion (Kim et al. 2017; Cuesta-Vargas, Galán-Mercant, and Williams 2010). Further study is needed to elucidate these limitations.

Electrogoniometers are another tool used to measure and record wrist joint motion and are widely used in ergonomic scientific research (Ugbolue, Nicol, and Maclean 2008; Serina, Tal, and Rempel 1999a). Compared with a manual goniometer, it can measure more than one plane and provides dynamic data. In Dauncey *et al*, a flexible, biaxial electrogoniometer was used to measure wrist extension-flexion and radial-ulnar deviation in 83 volunteers that performed several different daily activities, including writing, picking up a phone, and pouring from a cup or jar (Dauncey, Singh, and Dias 2017). In another similar study, Ryu *et al* evaluated wrist motion during selected activities using a biaxial electrogoniometer (Ryu et al. 1991). It was determined that all 24 activities could be completed within 60 º extension, 54 º flexion, 40 º ulnar deviation, and 17 º radial deviation (Ryu et al. 1991). This study also suggests that wrists should be positioned at ulnar deviation and extension during splinting or arthrodesis(Palmer et al. 1985). Wrist movement during typing with a computer keyboard was recorded and a novel electrogoniometer was also developed (Serina, Tal, and Rempel 1999a). Besides goniometers, video-based motion analysis is widely used in human gait and movement studies (Kuo et al. 2002). In these types of systems, multiple video cameras are used to visualize the retro-reflective markers and track wrist motion in three dimensions (Cuesta-Vargas, Galán-Mercant, and Williams 2010). Fingertip motion has been recorded during a keystroke with the help of video-based motion systems (Rempel et al. 1994; Somia et al. 1998). The infra-red based analysis system usually consists of markers that can emit infrared-red and cameras that are capable of receiving the infra-red signals (Shefer Eini et al. 2017). In Brigstocke *et al*, the authors placed reflective markers on the volunteers' right forearm and hand and used eight digital infrared cameras to record movements (Brigstocke et al. 2012). Wrist flexion-extensions and radioulnar deviations were recorded from ten right-handed male volunteers while performing several daily activities, including drinking from a glass and combing their hair

(Brigstocke et al. 2012). Compared with goniometry, the 3D infrared-based system was more accurate, repeatable, and reliable (Reissner et al. 2019). The Cartesian Optoelectronic Dynamic Anthropometer motion analysis system is one of the most cutting edge technologies used to measure gait analysis (O'Brien and Broderick 1990; Exell et al. 2012; Diss 2001; Monaghan, Delahunt, and Caulfield 2007; Delahunt et al. 2013; O'Byrne et al. 1997), cervical range of motion (Song et al. 2018), lumbopelvic posture (O’Sullivan et al. 2012), other sports-specific skills (Williams et al. 2012), joint kinematics (Birch and Deschamps 2014; Charalambous et al. 2012), and wrist motion (Shin and Park 2017). The marker-based motion analysis measurement is more precise and was used in my study.

With the assistance of kinematics analysis equipment, we can improve our understanding of wrist motion and measure disability impairment, optimal position of the wrist for a designated task, and surgical planning for fusion position (Liu, Inoue, and Shibata 2009; Liu et al. 2012). It will also improve our ability to better predict functional impairment following surgeries, fractures, and other injuries/diseases (O'Brien and Broderick 1990). Although cell phones and other digital devices are widely used, there is little known about their effects on the human radiocarpal joint. This information is important to instruct guidelines for preventing overuse injury and help guide recommendations for using digital devices.

CHAPTER 2. KINETIC GAIT EVALUATION OF EQUINE GAIT ALTERATIONS FROM DISTINCT SHOE CALKS

2.1. Introduction

Equine shoes are frequently modified to enhance traction for horses that travel on paved surfaces for work, pleasure, or entertainment (Stutz et al. 2018; Back, van Schie, and Pol 2007; Moore, Zsoldos, and Licka 2019; Kane, Stover, Gardner, Case, Johnson, O'Brien, et al. 1996). Breeds range from draft horses to ponies, and use varies from basic means of transportation in Amish communities (Nazzal and Holcombe 2017) to police service horses (Upjohn et al. 2012) and tourist wagon and buggy rides (Newsome, Smith, and Moore 2008; Moore, Zsoldos, and Licka 2019). Information is available about the impact of toe grabs and studs on traction and other gait kinetics, primarily for racing and pulling horses, but comparably little is known about other common shoe modifications used to enhance traction like calks, tungsten carbide granules, or plastic composition (K. Balch, Gayman Helman, and A. Collier 2001; Hagen et al. 2017; Harvey, Williams, and Singer 2012). This information is vital to shoe design to protect the safety and welfare of all service, working, and leisure horses.

Calks are elevations of metal forge-welded to the shoe road surface (Mahaffey et al. 2016). They are frequently composed of tungsten carbide, an exceptionally hard and durable metal (Sun et al. 2019). Typically added to the toe and heels, calks can be high or low profile (Mahaffey et al. 2016). Hard metal calks, especially high profile, damage paved roads due to stress concentration (Nazzal and Holcombe 2017). In order to reduce road damage and enhance traction, a relatively thin layer of tungsten carbide granules over the entire road-surface of the shoe or a custom shoe composed of a steel frame embedded in a compressible plastic component can be employed (Nazzal and Holcombe 2017; Stoffels et al. 1995). To date, objective data on equine hoof traction

affected by these shoe adaptations is limited. A direct comparison among distinct shoes is necessary to identify those that best enhance traction and minimize gait alterations.

Force platform quantification of ground reaction force (GRF) is an established mechanism to quantify hoof traction and weight-bearing in horses (Amitrano, Gutierrez-Nibeyro, and Schaeffer 2016; Thomason and Peterson 2008). It is measured in three planes that intersect at a single point in the center of a force platform, vertical (Z), mediolateral (X), and craniocaudal (Y) (Rogers and Back 2003). The peak force is the maximum force on a given limb during stance in each of the planes. Peak vertical forces are used to assess weight-bearing in limbs, frequently before and after systemic or local treatments, and they typically increase with protection from hard ground surfaces by shoes (Merkens and Schamhardt 1988; Witte, Knill, and Wilson 2004b). Forces measured over time are impulses, or the area under vertical, braking, and propulsion force-time curves (Bell et al. 2016). Craniocaudal forces are divided into braking and propulsion phases. Braking begins to increase with initial impact and accounts for around 60 and 40 percent of total stance time in the forelimbs and hindlimbs, respectively (Clayton et al. 1999). Slipping typically occurs during braking (Pardoe et al. 2001b). The coefficient of friction (COF) is the dimensionless ratio of braking and vertical GRF that corresponds to the friction between hoof and ground surface (Bird and Chivers 1993; Zhang 2016); a greater value indicates better traction (Pardoe et al. 2001b; Parkes and Witte 2015a). Together, GRF measures provide valuable metrics by which to assess the impact of distinct shoes on limb weight-bearing and traction in horses.

Shoe material, shoe surface roughness, and contact area between shoe and ground surfaces affect the COF (Blanchette and Powers 2015; Li and Chen 2004; Moghaddam et al. 2018; Manning et al. 1998). Lateral heel studs and toe grabs significantly increase the COF and reduce hoof slip in horses (Parkes and Witte 2015a; Harvey, Williams, and Singer 2012), but toe grabs reportedly

increase the risk of suspensory apparatus strain and failure from toe elevation on hard surfaces (K. Balch, Gayman Helman, and A. Collier 2001; Kane, Stover, Gardner, Case, Johnson, Read, et al. 1996). Calks used to provide traction for horses that travel on hard surfaces create a level platform that may limit abnormal hoof placement, but COF data for metal calks on such surfaces is lacking (Nazzal and Holcombe 2017). Since COF decreases with increasing contact stress (Ura, Carré, and Dominguez-Caballero 2015), shoes with calks may have a lower COF than standard shoes, and the difference may increase with smaller calk contact surface area. Since the COF increases with surface roughness, addition of a thin layer of tungsten carbide to the shoe surface could improve traction (Manning et al. 1998). Compressible plastic shoes might have a greater COF than metal shoes, owing to both material properties and increased contact surface area (Derler, Kausch, and Huber 2008; Persson et al. 2005).

The purpose of the present study was to compare the kinetic gait effects of standard and customized shoes in non-lame horses trotting on a concrete runway. The fore- and hindlimb percent change from unshod (U) in peak vertical and braking forces were determined standard (S), high profile-low surface area calk (HC), low profile-high surface area calk (LC), thin layer tungsten carbide (TLC), and plastic-steel composite (C) shoes. The two hypotheses tested were that all shoes increase peak vertical force (PVF_Z) over U similarly and that TLC and C shoes increase peak braking force (PBF) over U more than S, all three increase PBF over shoes with calks and LC shoes increase PBF more than HC shoes in fore- and hind limbs.

2.2. Material and Methods

2.2.1. Ethics statement

This study is supported by the Federal Highway Administration and the Ohio Department of Transportation. All animal procedures were approved by the Institutional Animal Care and Use Committee at Louisiana State University (protocol No. 18-129) prior to investigation initiation.

2.2.2. Inclusion criteria

Horses were selected from a research herd based on the following inclusion criteria: (1) light breed that is mainly used for riding or light work, (2) no evidence of illness or lameness, (3) body condition score of 4 -7, (4) 10 to 25 years of age, (5) mare or gelding, and (6) body weight of 400 - 600 kg. Data were obtained from four American quarter horse geldings and one Tennessee walking horse mare (499.0 ± 36.7 kg; 16.4 ± 2.2 years [mean ± SEM]). Horses were housed individually in 3.6 × 3.6 m stalls with concrete floors covered by rubber mats throughout the study beginning 5 days prior to first data collection. Each horse had free access to water in a 16 L bucket that was refreshed a minimum of two times per day, and each was fed 2.7 kg of a commercial horse feed (Purina Strategy, Purina Animal Nutrition LLC, Shoreview, MN) and 4 kg of Bermuda grass hay twice daily.

2.2.3. Study design

This prospective study was designed as a six-way treatment crossover. Approximately 5 days after horse hooves were trimmed by a professional farrier, kinetic gait data was collected from the horses while U. Subsequently, S, HC, LC, TLC, and C shoes were applied by the same farrier in random order according to a randomized block design. Force platform gait trials were performed approximately 22 hours after shoe application the preceding day, and shoes were changed immediately after gait data collection. Following completion of kinetic gait data collection for all shoes, standard hoof radiographs were performed.

2.2.4. Shoe design and application

A commercially available iron shoe (Front unclipped standard shoe, Stockhoff's Horseshoes and Supplies, La Grange, KY) (S) was used without modification or served as the base for application of thin layer of tungsten carbide or calks (Fig. 1A, Table 1). The HC shoe (Fig. 1B) had a total of five calks measuring approximately 10 mm in height and 10 mm in diameter. Three calks were equidistantly spaced along the toe with the central calk at the point of the toe. The distance between the center of central calk and the center of the calks on either side was around 20 mm. There was one calk on each heel with the center of each about 10 mm from the palmar/plantar edge. The LC shoe (Fig. 1C) had three calks, one at the point of the toe (height: 5 mm; length: 40 mm; width: 20 mm) and one on each heel (height: 5 mm length: 20 mm; width: 20 mm). The centers of the heel calks were about 20 mm away from the palmar/plantar edge. The TLC shoe (Fig. 1D) had a thin layer of tungsten carbide granules (1-3 mm in diameter) over the entire shoe road-surface. Commercially available C shoes (Duplo composite horseshoes, MT EquiSports LLC, Big Timber, MT) (Fig. 1E and F) were composed of a steel frame embedded in compressible plastic. The shoe covered the entire hoof surface except for a window over the frog and each sulcus. The hoof surface had 15 rounded (diameter: 2 mm, height: 3 mm) plastic elevations and a metal clip (20 × 20 × 5 mm) at each quarter. The road surface had two treads (30 × 40 × 20 mm) at each quarter. Shoes were affixed to hooves with two number 5 nails (E-slim nail, Delta Mustad Hoofcare Center Inc, Forest Lake, MN) on each side. The nail holes conditions were checked each time before shoes were applied by the same farrier and these holes that can hold nails properly were reused. Nail hole causes hoof tissue damage and reuse these holes can minimize damages (Hampson and Wilson 2018).

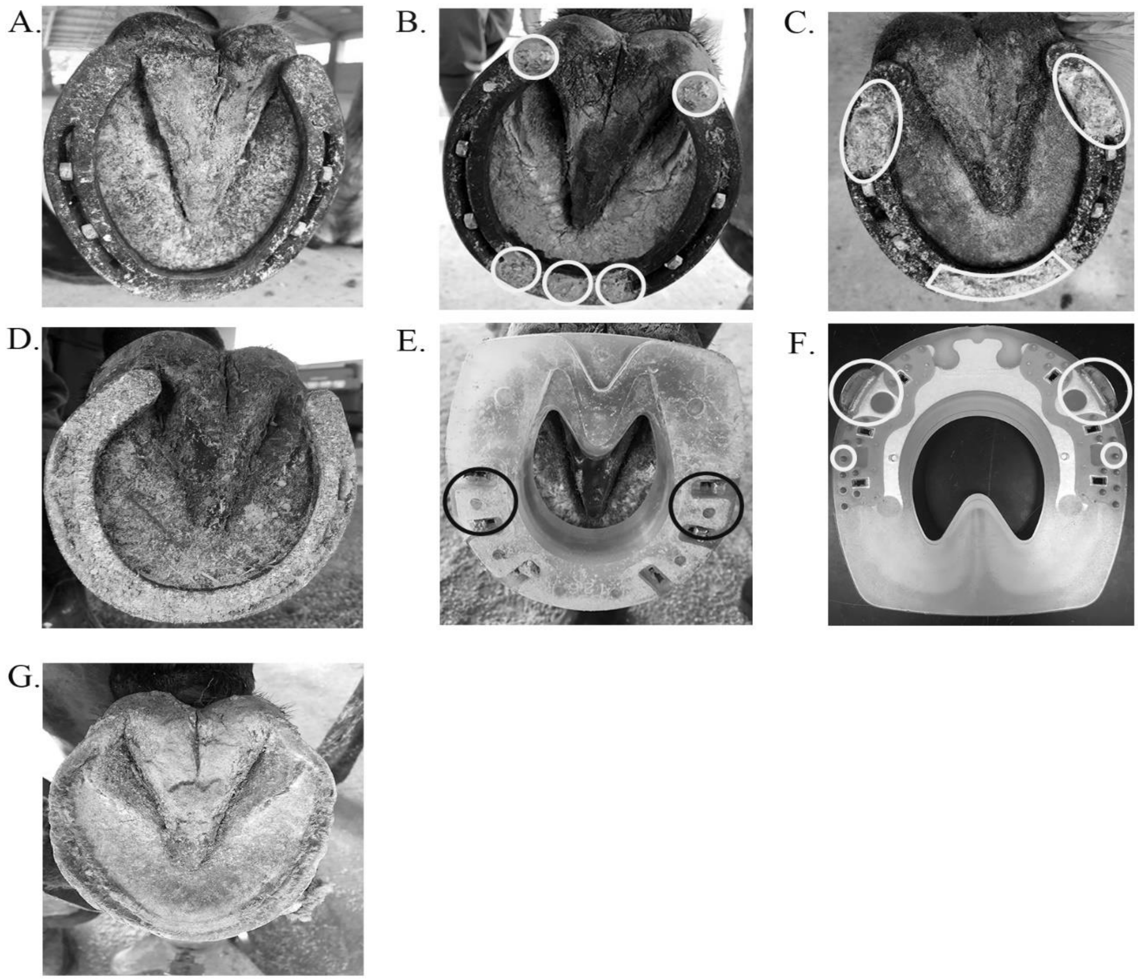

Figure 1. Photographs of shoes tested in the study, S (A), HC (B), LC (C), TLC (D), C shoes (E, F), and an unshod hoof (G). Calks are indicated by white circles on HC (B) and LC shoes (C), and treads indicated by black circles on the road-surface of the C shoe (E). Quarter clips and a rounded plastic elevation are indicated by large and small white circles, respectively, on the hoof surface of the C shoe (F).

Table 1. Shoes included in the study.

Shoe	Calk Dimensions (mm)	Contact Surface Area (mm^2)	Weight (g)
S	None	5200-6000	244-326
HC	Three toe, one each heel Height: 10 mm Diameter: 10 mm	250-393	301-387
LC	One toe Height: 5 Length: 40 Width: 20 One each heel Height: 5 Length: 20 Width: 20	1600-1800	365-451
TLC	None	5200-6000	244-330
C	None	8000-10750	290-370

Note: Ranges are provided for contact surface area and weight since they varied with shoe size.

2.2.5. Kinetic gait collection

Kinetic gait data collection was performed according to a previously described protocol (Mirza et al. 2016; Taguchi et al. 2018; Lopez, Quinn, and Markel 2006). Ground reaction forces were measured with a 900 × 900 mm force platform (advanced Mechanical Technology Inc., Watertown, MA) embedded in the center of a 40 m concrete runway. The surface of the force platform was the same color and texture as the runway. Experienced handlers trotted horses for trials after the horses were conditioned to the force platform. A trial was considered successful if a forelimb and then the ipsilateral hind limb contacted the force platform at a velocity of 2.00-4.0 m/s and acceleration of -1.0 to 1.0 m/s^2. Trials were rejected if the hoof was not entirely on the force platform, was not straight on the platform, or was within 5 cm of the platform edge. Trial velocity and acceleration was determined with a series of five retroreflective photocell sensors. A minimum of five successful trials were recorded for the left and right sides. Data logging was trigged by a force ≥ 50 N, and all trials were recorded at a rate of 1,000 Hz and subsequently processed with commercially available software (Acquire V7.3, Sharon SoftwareInc, Watertown, MA).

2.2.6. Radiographic evaluation

Horses were sedated with 0.5 mg/kg xylazine (MWI Veterinary Supply Co, Boise, ID) together with 0.1 mg/kg butorphanol (Zoetis. Inc, Parsippany-Troy Hills, NJ) administered via the jugular vein about 15 minutes before radiographs were performed. Lateromedial radiographic views were obtained of each unshod hoof with the horse standing on wooden blocks and the radiographic beam centered on the hoof from a distance of about 0.3 m (Siemens Polydoros LX model, Siemens, Munich, Germany). All the radiographic were evaluated for bone, joint, and hoof capsule changes by a board certified large animal surgeon.

2.2.7. Data reduction

Gait variables included peak vertical force (PVF_Z), vertical impulse (IMP_Z), peak braking force (PBF), peak propulsion force (PPF), braking impulse (IMP_B), propulsion impulse (IMP_P), stance time, braking time, propulsion time, weight distribution, and coefficient of friction (COF). All forces were normalized to horse body weight (Fairbanks FB1100, Fairbanks Scales Inc, Kansas City, MO). The percent change in PVF_Z, IMP_Z, PBF, PPF, IMP_B, IMP_P, and stance time for each shoe type from U was determined as

[(mean fore- or hind limb shod value – mean fore- or hind limb unshod value) / (mean fore- or hind limb unshod value)] × 100

Where mean shod value = mean of a given parameter from 10 trials with each shoe type; mean unshod value = mean of a given parameter from 10 trials unshod.

Forelimb and hind limb percent weight distribution was calculated for each shoe type and U as

[(sum of PVF_Z from both fore- or hind limbs) / (sum of PVF_Z from all limbs)] × 100

Percent change in percent weight distribution for each shoe relative to unshod was determined as

[(fore- or hind limb percent weight distribution for each shoe – fore- or hind limb percent weight distribution for U) / (fore- or hind limb percent weight distribution for U)] × 100

The COF for each shoe and U was calculated as PBF/PVFz.

2.2.8. Statistical analysis

An a priori power analysis using 80% power (β = 0.20), a significance level of (α = 0.05), and GRF mean and standard deviation data from previous studies indicated that 5 was the minimum subject number for a mixed model ANOVA with repeated measures (G*Power, v3, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). A repeated measures one-way ANOVA with Greenhouse-Geisser correction was used to compare trial velocity among shoeing conditions (GraphPad Prism, v7, GraphPad Software, San Diego, CA). A mixed model was used to compare fixed effect of shoe with random effect of horse on gait variables (JMP, v14, SAS Institute Inc, Cary, NC). Tukey-HSD post hoc tests were performed when there were statistically significant differences in group means. Significance was considered at $P \leq 0.05$.

2.3. Results

2.3.1. Kinetic gait analysis

PVF_Z change increased with C versus S (P = 0.0001), HC (P = 0.0049), LC (P = 0.0110), and TLC (P = 0.0246) (Fig. 2A, Table 2) in the forelimbs. The PPF change was greater for the C versus S (P = 0.0043) and LC (P = 0.0139) shoes (Fig. 2A). Percent change in IMP_Z was highest for the S shoes than HC (P < 0.0001), LC (P = 0.0004), TLC (P = 0.0004) and C (P < 0.0181), and the IMP_P increased more for the C than HC (P = 0.0037) and LC shoes (P = 0.0118)(Fig. 2B). PBF increased with C shoes versus S (P< 0.0001), HC (P < 0.0001), LC (P < 0.0001), and TLC

shoes (P = 0.0041). It increased with TLC versus HC (P < 0.0001) and S shoes (P < 0.0001). It increased with LC versus HC (P = 0.0079) and S shoe (P = 0.0474) (Fig. 2C). Additionally, IMP_Z increased more for S than HC (P = 0.0011), LC(P = 0.0035), or C shoes (P = 0.0240) (Fig. 2D). Trial velocity (3.0±0.03 m/s) and acceleration (0.12±0.08 m/s^2) were similar among distinct shoes (Table 2). In the forelimbs, stance time increased with S shoes versus HC (P < 0.0001), LC (P = 0.0007), TLC (P = 0.0010), and C shoes (P = 0.0002) (Fig. 3A). In the hind limbs, stance time increased with S versus HC (P < 0.0001), LC (P = 0.0283), and C shoes (P = 0.0009) and it increased with TLC versus HC shoes (P = 0.0030) (Fig. 3A). Changes in weight distribution to fore- and hind limbs relative to unshod were not significantly different among shoes (Fig. 3B). In the forelimbs, COF was increased with S (P < 0.0297), HC (P < 0.0111), LC (P < 0.0336) and C shoes (P < 0.0123) versus U. In the hind limbs, COF was increased with C versus S (P < 0.0001), HC (P < 0.0001), LC (P < 0.0001), TLC shoes (P < 0.0014) and U (P < 0.0001). It was increased with TLC versus S (P < 0.0004), HC shoes (P < 0.0204), and U (P < 0.0002). It was increased with LC versus S shoes (P < 0.0328) and U (P < 0.0183) (Fig. 4). The braking time was greater with S shoes versus U in the forelimbs (P < 0.0011) and hind limbs (P < 0.0429) (Fig. 5). The propulsion time was lower for the HC shoes versus U (P < 0.0237) in the forelimbs (Fig. 5).

2.3.2. Radiography

Radiographic findings for the hoof capsule and distal phalanges were within normal limits for all hooves.

Table 2. Percent Change in Gait Variables S, HC, LC, TLC, and C Shoes Relative to Unshod.

		PVF_Z (%)	IMP_Z (%)	PBF (%)	IMP_B (%)	PPF (%)	IMP_P (%)	Stance time (%)	Weight distribution (%)
HC	F	4.0±2.8	2.1±2.0	21.3±10.0	26.0±14.3	-8.8±6.1	-16.2±7.0	-2.5±2.2	8.9±2.5
LC	F	4.3±2.8	3.5±2.0	21.0±10.0	29.5±14.3	-11.1±6.1	-13.9±7.0	1.1±2.2	1.5±2.5
TLC	F	4.6±2.8	3.4±2.0	17.4±10.0	24.0±14.3	-9.1±6.1	-8.9±7.0	1.3±2.2	2.2±2.5
C	F	7.8±2.8	4.7±2.0	26.0±10.0	31.6±14.1	0.9±6.1	1.1±7.0	0.4±2.2	2.1±2.5
S	F	2.9±2.8	8.3±2.0	19.0±10.1	36.6±14.4	-12.8±6.1	-0.3±7.0	8.9±2.2	1.7±2.5
HC	H	1.5±1.7	2.1±2.1	5.5±13.4	25.0±24.6	-9.1±4.3	-11.9±6.2	-1.8±1.7	-10.8±3.0
LC	H	1.1±1.7	2.6±2.1	21.5±13.3	30.5±24.5	-8.6±4.0	-8.0±6.0	2.0±1.7	-1.5±3.0
TLC	H	2,0±1.7	3.8±2.1	31.2±13.3	40.2±24.5	-8.0±4.0	-8.1±5.9	3.8±1.7	-2.3±3.0
C	H	2.9±1.7	3.3±2.1	47.2±13.3	45.2±24.6	-2.5±4.0	2.2±6.1	0.4±1.7	-2.4±3.0
S	H	-0.6±1.7	6.6±2.1	9.0±13.3	40.0±24.6	-12.4±4.1	-10.9±6.6	6.5±1.7	-1.9±3.0

F: forelimbs; H: hindlimbs.

Table 3. The COF, Braking Time, Propulsion Time, Velocity, and Acceleration for S, HC, LC, TLC, and C Shoes and U.

		COF	Braking time (ms)	Propulsion time(ms)	Velocity (m/s)	Acceleration (m/s^2)
HC	F	-0.108±0.004	224.1±11.4	87.7±13.4	3.10±0.05	0.53±0.26
LC	F	-0.106±0.004	227.2±11.3	93.8±13.3	2.98±0.08	0.04±0.07
TLC	F	-0.103±0.004	224.3±11.3	96.9±13.3	2.94±0.10	-0.06±0.09
C	F	-0.108±0.004	220.6±11.2	100.2±13.3	3.07±0.08	0.33±0.31
S	F	-0.107±0.004	237.6±11.5	105.8±13.3	2.80±0.05	-0.21±0.19
U	F	-0.096±0.004	208.4±11.2	109.8±13.3	2.98±0.03	0.11±0.07
HC	H	-0.101±0.012	139.1±13.4	169.5±8.7	3.10±0.05	0.53±0.26
LC	H	-0.109±0.012	146.9±13.0	170.4±8.3	2.98±0.08	0.04±0.07
TLC	H	-0.113±0.012	146.1±13.3	171.1±8.6	2.94±0.10	-0.06±0.09
C	H	-0.127±0.012	145.6±13.1	166±8.3	3.07±0.08	0.33±0.31
S	H	-0.098±0.012	152.2±14.1	171.8±9.4	2.80±0.05	-0.21±0.19
U	H	-0.097±0.012	122.3±12.7	186.9±7.9	2.98±0.03	0.11±0.07

F: forelimbs; H: hind limbs. COF is the ratio of braking and vertical GRF, not percent change. The braking force was negative value from force platform.

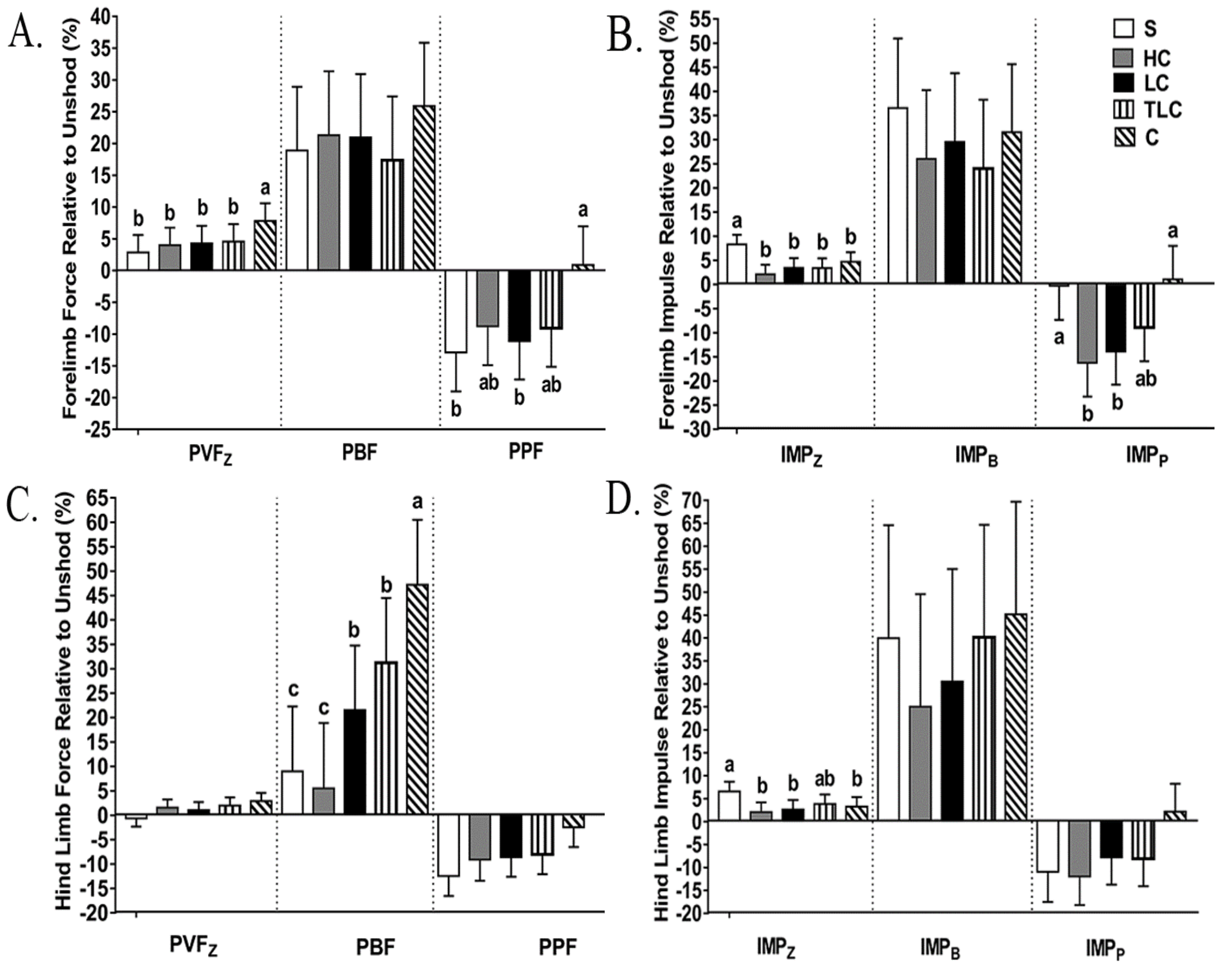

Figure 2. Least square mean ± SEM forelimb (A, B) and hind limb (C, D) PVF_Z, PBF, and PPF and IMP_Z, IMP_B, and IMP_P for S, HC, LC, TLC, and C shoes relative to U. Columns with different letters are significantly different among shoeing conditions.

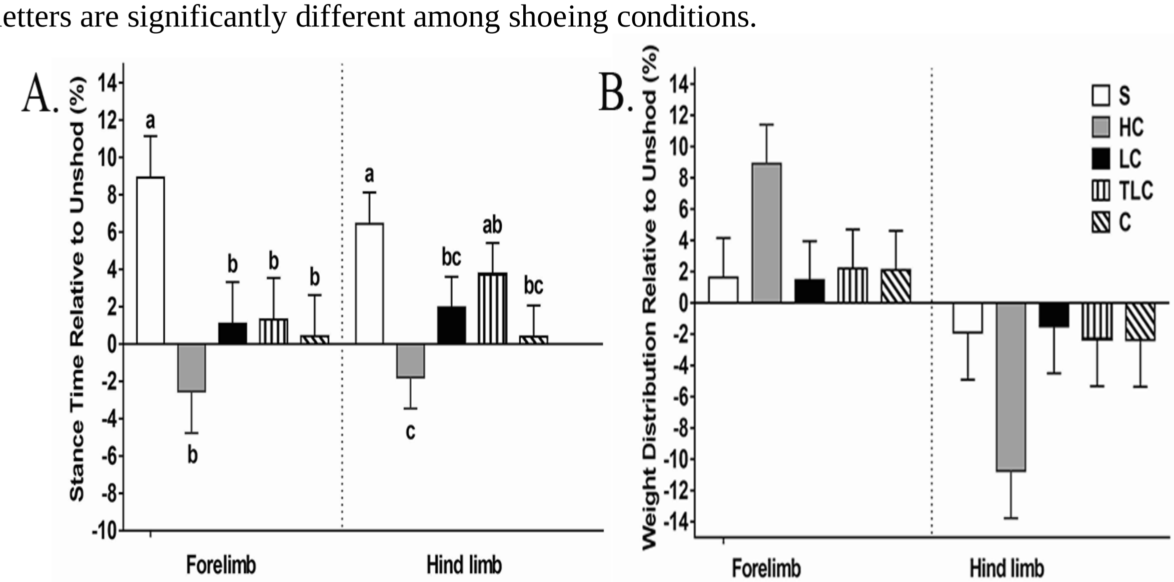

Figure 3. Percent chance (LS mean +/ SEM) in forelimb and hind limb stance time (A) and weight distribution (B) for tested shoes relative to unshod. Columns with different letters are significantly different among shoeing conditions.

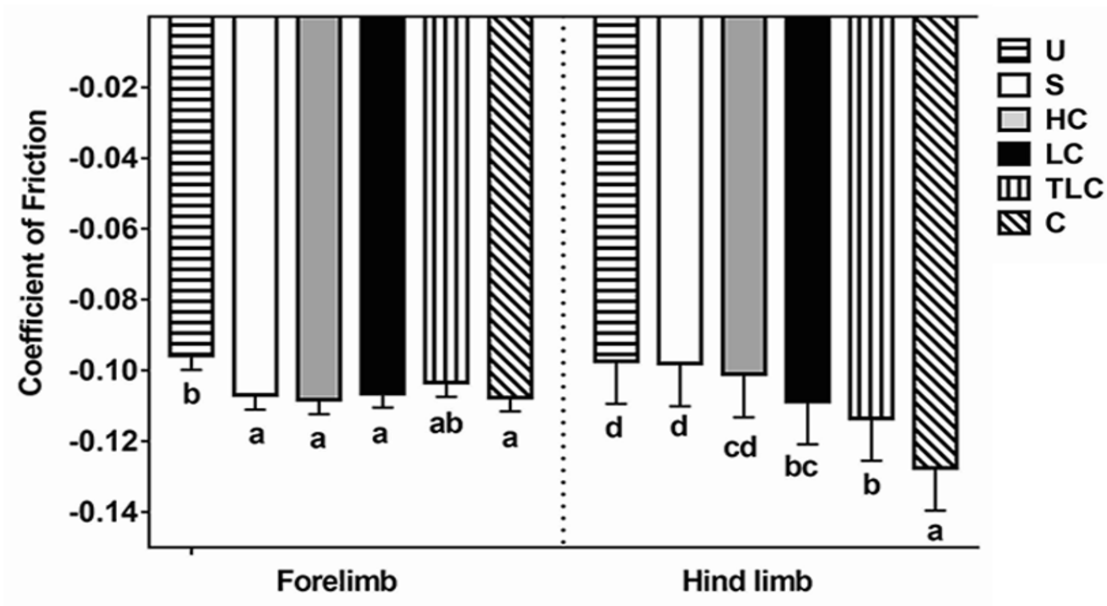

Figure 4. The COF for tested shoes and unshod (LS mean +/ SEM). Columns with different letters are significantly different among shoeing conditions.

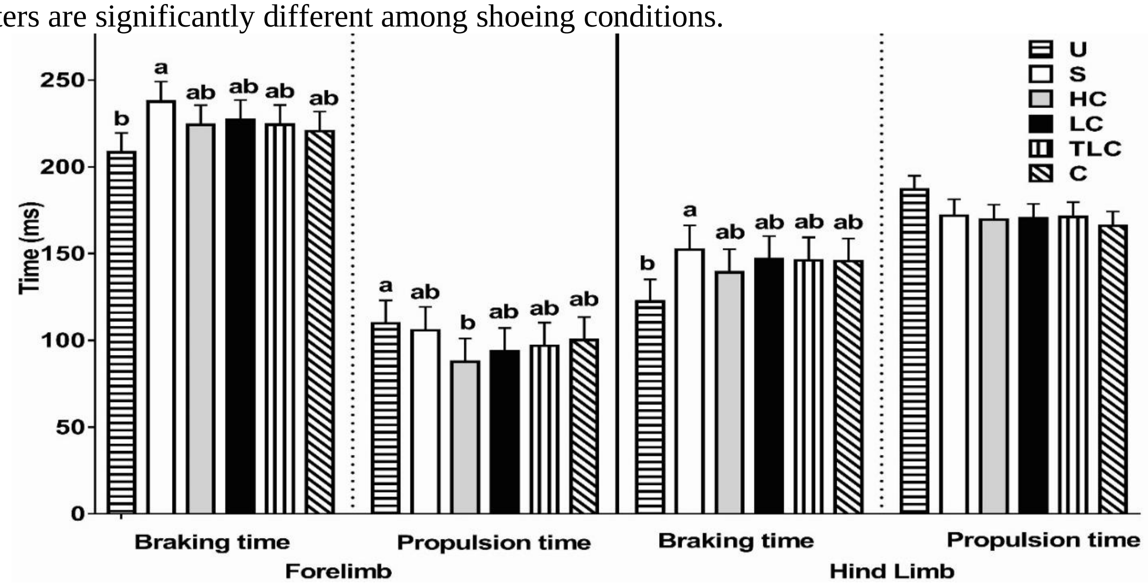

Figure 5. Forelimb (left) and hind limb (right) braking and propulsion times while U and for S, HC, LC, TLC, and C shoes (Least square mean ± SEM). Columns with different letters are significantly different among shoeing conditions.

2.4. Discussion

Hoof protection and traction are vital to horse and rider/driver safety when working on paved surfaces. Despite the fact that PVF_Z increased with all shoes over U as anticipated, the first hypothesis of the study, that all shoes increase PVF_Z over U similarly, was rejected since the C shoes increased PVF_Z significantly more than the other shoes in the forelimbs, and the parameter increased only marginally in hind limbs. In the hind limbs, the predicted increase in braking force was fairly well aligned with the second hypothesis, that TLC and C shoes increase PBF over U more than S, all three increase PBF over shoes with calks, and LC shoes increase PBF more than HC shoes fore- and hind limbs. Specifically, the C and TLC shoes increased PBF the most followed by LC, S, and HC shoes in the hind limbs, but the significantly higher increase in PBF with LC versus S shoes precludes acceptance of the hypothesis. The second hypothesis was also not true in the forelimbs. Consideration of the COF suggests that the C and TLC shoes confer the most and the S shoes the least traction in the hind limbs among the shoes tested. The C and TLC shoes may also have less potential to damage roads than shoes with calks. Taken together, these results suggest that the C and TLC shoes may enhance equine hoof protection and traction on solid stone-like ground without altering weight distribution.

The fact that all shoes increase PVF_Z over U is consistent with long established knowledge that shoes protect hoof tissues (Parkes and Witte 2015a; Wilson and Weller 2011). Ground reaction forces generated on impact through the hoof are absorbed by tissue deformation as they propagate up the limb (Spaak, van Heel, and Back 2013; Kawcak 2016). A previous study in non-lame warmblood horses trotting on asphalt confirmed that vertical deceleration forces were lower with polyurethane versus steel shoes or unshod (Back, van Schie, and Pol 2007). Based on the information, polyurethane shoes were recommended to reduce joint pain in horses with osteoarthritis since they provide lower-impact accelerations. Though the C shoes tested in this

study were not identical to the previous report, the greater deformation of the plastic versus steel shoes may have reduced impact forces from the ground to the hoof. Hence, less vertical impact may have been propagated through the hoof and up the limb, resulting in greater comfort with higher PVFz. The C shoes might help mitigate the high incidence of injuries associated with hard surfaces that occur, in part, due to high mechanical stresses on the distal limbs (Oosterlinck et al. 2014). The greater change in forelimb forces with all shoes tested in this study is likely due to the fact that forelimbs bear 60% and hind limbs 40% of the body weight in non-lame horses and the vertical impact is higher in the forelimbs, so changes in GRFs are expected to be more discernable in the forelimb (Stachurska et al. 2008; Back et al. 1995).

The highest change in IMPz for S shoes in both fore- and hind limbs may be attributed to higher stance time since the velocity, which is negatively correlated with stance time, was consistent among trials (Schilling, Falvo, and Chiu 2008; McLaughlin et al. 1996). The ratio of braking to propulsion time was predominantly braking in the forelimb and more evenly distributed between breaking and propulsion in the hind limb with slightly higher propulsion time overall. This is consistent with the braking function of the forelimbs and propulsion function of the hind limbs (Clayton and Hobbs 2019). However, the relatively higher braking time for the S shoes explains the higher stance time. This could be a product of slipping, which typically occurs at the beginning of impact, during braking (Pardoe et al. 2001b). Steel shoes reportedly have higher slip distance than steel shoes with studs in all four limbs of horses cantering on grass surfaces; the highest slip is in the hind limbs (Harvey, Williams, and Singer 2012). Though differences between the two studies make comparisons difficult, results of this study suggest more “hoof slip” with S shoes compared to the others. Further investigation with kinematic equipment is required to investigate this potential (Harvey, Williams, and Singer 2012; Pardoe et al. 2001b)

Shoe material, surface roughness and contact area can all affect friction (Pardoe et al. 2001b),(Manning et al. 1998). As previously mentioned, both PBF and COF correspond to traction (Pardoe et al. 2001b). Friction is increased by malleable, porous materials and even more so with the presence of treads (Mohamed, Samy, and Ali 2012; Ziaei et al. 2013). The C shoe supported the greatest traction among shoes tested in this investigation while U had the lowest traction of all. This contrasts with in vitro work with cadaver limbs that showed that the kinetic friction coefficient was higher in unshod hooves compared to those shod with iron shoes on a concrete slab surface (Vos and Riemersma 2006). Inherent distinctions between in vitro and in vivo studies may explain the differences. Findings of this study also contrast with another study that included braking force and COF of non-lame horses trotting on a concrete surface with forelimbs shod with steel, rubber, or plastic shoes and hind limbs shod with steel shoes (Pardoe et al. 2001b). These findings included lower forelimb braking force and COF with plastic versus rubber or steel shoes. Notably, the plastic shoes were not identical to those of this study, and those tested here may have more closely resembled the rubber shoes of the previous study based on the descriptions provided.

The high contact surface area and increased friction from carbide granules likely resulted in the highest increase in hind limb PBF and COF in TLC shoes among the steel shoes tested. The higher contact surface area of LC versus HC calks may have also resulted in the expected results, especially since the HC shoe calks more closely resembled studs than those on the LC shoe, and they may be more appropriate for penetrable versus nonpenetrable surfaces (Kirk et al. 2007; Harvey, Williams, and Singer 2012; Parkes and Witte 2015a). The lower PBF and COF in S versus LC shoes suggests that the LC shoes improved traction over S shoes despite the lower contact surface area. As described above, this could have been a result of hoof slip with the S shoes. The

somewhat granular surface of the LC shoe calks may have increased friction over the S shoes similar to the TLC surface, despite the lower contact surface area.

Significant differences in braking forces were only evident among shoes on the hind versus forelimbs, despite higher weight distribution and associated forces in the forelimb, and the greater participation of the forelimb in braking relative to the hind (Clayton and Hobbs 2019). The hind limbs also usually have a greater horizontal velocity and associated higher deceleration than forelimbs (Gustas et al. 2004), so changes in traction may be more evident. The findings of this study confirm the importance of traction in both fore- and hind limbs. Future work is necessary to compare different shoe combinations on fore- and hind limbs since all hooves received the same shoes for trials in this study.

A limitation of this study is a small sample size of light breed horses. The cross over study design helped reduce inherent variability since each horse served as its own control, especially given that a gaited horse was included. Additional studies with a more diverse population of horses as well as with warmblood and draft breeds will augment these study findings. The color and texture of the force platform were similar to the concrete runway, but differences in stiffness between them can affect GRFs, an inherent limitation to kinetic studies (Burn and Usmar 2005; Parkes and Witte 2015a). The results of this study are additionally limited to the concrete surface tested. Variable properties among paved surfaces may have different results (Pardoe et al. 2001b). Additionally, the potential damage to pavement among shoe types can only be surmised as it was not directly tested in this study.

CHAPTER 3. WRIST MOTION VARIES BETWEEN ACTIVITIES USING DIGITAL VERSUS MANUAL DEVICES

3.1. Introduction

The complex anatomy and motion of the wrist joints, in addition to nearly continuous motion during daily activities, likely contribute to a relatively high propensity of overuse injuries (Tsyrulnik 2015; Chammas 2014). Among wrist overuse injuries, carpal tunnel syndrome is one of the most common (Peetrons and Derbali 2013; LeBlanc and Cestia 2011). Overuse injuries result from repetitive motions within or beyond the normal joint range of motion as well as maintaining the same joint position (static loading) for long periods (Gelberman et al. 1981; Park and Yang 2012). Inflammation contributes to tissue thickening (Tat, Wilson, and Keir 2015) and subsequent compression and ischemia (O'Neil, Forsythe, and Stanish 2001; Toosi et al. 2015). A typical range of motion for daily activities in 1991 were approximately 60° of extension, 54° of flexion, 40° of ulnar deviation, and 17°of radial deviation (Ryu et al. 1991), with the majority of motions requiring ulnar deviation and extension. With advancing technology, use of digital and mobile devices now constitutes a large part of work and leisure activities (Eun et al. 2018).

Overuse injuries from manual devices, especially static wrist positioning for typing, are well established (Kiesler and Finholt 1994; Keller, Corbett, and Nichols 1998; Green and Briggs 1989; Atroshi et al. 2007). Digital devices have decreased or obviated the use of manual devices like telephones, typewriters, standard calculators, and even books (Jonsson et al. 2011). Cell phones and tablets are replacing many activities previously performed using a keyboard or mouse on desk- or laptop computers (Parasuraman et al. 2017; Woo et al. 2016b). Digital devices have a set of wrist motions associated with their use that also appear to contribute to tissue damage with frequent, prolonged use (Xie et al. 2016; Gilman et al. 2015). Examples include weakness and

repetitive strain injury of the wrist with cell phone use (Parasuraman et al. 2017; Woo et al. 2016b) and carpometacarpal joint osteoarthritis with texting (Ming, Pietikainen, and Hänninen 2006).

Recognition of relationships between occupational and leisure digital device use and overuse injuries drive ergonomic device design, recommendations for posture and positioning, and other strategies to optimize productivity without injury. As indicated above, wrist motion data for use of non-digital devices is available, but, to date, there is limited information about the predominant wrist angles and range of motion associated with digital device use (Brigstocke et al. 2012). Given that the range of motion for a given activity can vary between males and females, baseline range of motion values is assumed to be distinct for each (Chaparro et al. 2000). This information is vital to instruct guidelines intended to prevent consequences of overuse injury (Lee et al. 2015). The objective of this study was to quantify wrist motion in two planes, radioulnar deviation and flexion-extension, while using digital devices and their manual counterparts in dominant and non-dominant hands of male and female professionals to test the hypothesis that digital device use reduces wrist motion.

3.2. Material and Methods

3.2.1. Participants

The study was approved by the institutional review board (IRB) at Louisiana State University (IRB approval # 9078). Participants were recruited from medical school personnel and selected based on gender, age, and dominant hand. Inclusion criteria included: (1) aged between 20 and 36 years, (2) single dominant hand (no ambidexterity), and (3) no history of upper extremity musculoskeletal disorder. Data were obtained from twelve individuals, 6 males and 6 females.

Three male (29.8±1.83 years (mean ± SEM)) and 3 female (28.8±2.10) participants had dominant left or right hands (Table 4).

Table 4. Participants Information in This Study.

	Age (mean ± SEM)	Dominant hand	
		Left hand	Right
Male (n = 6)	29.8±1.83	3	3
Female (n = 6)	28.8±2.10	3	3

n: number of participants.

3.2.2. Devices and Activities

Devices used in this study included a cell phone with a touch activated display screen (138×67×7 mm, diagonal length 119 mm, weight 148 g, Apple Inc., Cupertino, CA) (Fig. 6A); traditional phone receiver (200×30×20 mm, weight 246 g, Cortelco Inc., Corinth, MS) (Fig. 6B); book (234×155×25 mm, HarperCollins Publishers LLC, New York, NY) (Fig. 6C); manual calculator (145×81×18 mm, weight 65 g, Texas Instruments Inc., Dallas, TX) (Fig. 6D); tablet with a touch activated display screen (241×186×9 mm, diagonal length 246 mm, Apple Inc., Cupertino, CA) (Fig. 6E); and keyboard (460×160×20 mm, incline angle about 6º, Dell

Inc.,RoundRock,TX)(Fig.6F).

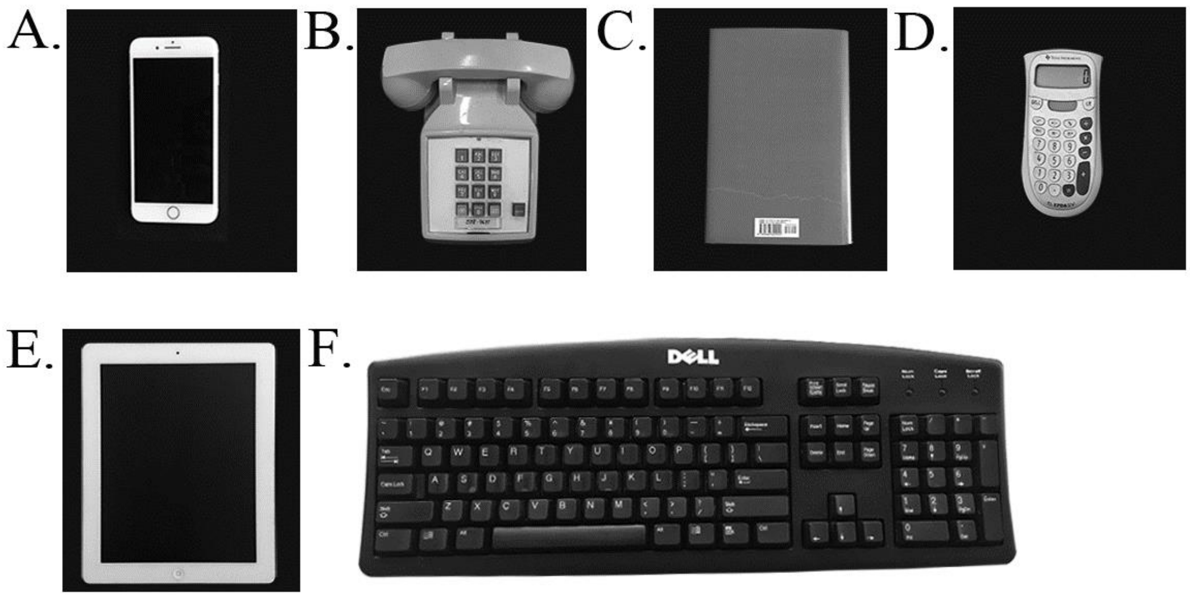

Figure 6. Photographs of devices tested in the study, including a cell phone (A), traditional phone receiver (B), book (C), manual calculator (D), tablet (E), and keyboard (F).

Evaluators placed markers on all study subjects. Participants were seated at a desk with the chair adjusted to a comfortable height (4-6 cm lower than the flexed elbow). Each participant performed four activities in the same order with the dominant hand first. Immediately prior to a given activity, subjects practiced with the designated hand three times. A tone triggered the participants to start three repetitions of a single activity within 18 seconds and the activity was finished when another tone sounded. Activities included: raise a cell phone from the desk surface to the ear on the ipsilateral side as the hand in use and return it to the desk; raise a traditional phone receiver from the cradle to the ear on the ipsilateral side as the hand in use and return it to the cradle; swipe three times forward and then three times backward on a tablet on the desk surface, turn three pages forward and three pages backward in a book on the desk surface; text the sentence “The red fox jumped over the sleeping brown hound” on a cell phone at a comfortable distance from the face; type the sentence above on a computer keyboard using both hands; enter the

numbers “10, 8, 6, 4, 2, 0” on a cell phone calculator; and enter the numbers above on a manual calculator.

3.2.3. Marker Placement

Wireless infrared markers (2×1.5×1 cm) of an active motion detection system (Codamotion, Charnwood Dynamics Ltd, Leicestershire, UK) were attached to the right and left hands and forearms with pieces of VELCRO® (2×1.5 cm) adhered to anatomical landmarks. Landmarks included the 5th metacarpal bone base, hamate, ulna styloid, ulna midpoint, 2nd metacarpal bone base, trapezium, radial styloid, and radius midpoint. The medial carpal angle vertex was formed by the intersection of vectors between markers on the 2nd metacarpal bone base and trapezium and markers on the radial styloid and radius midpoint. The lateral carpal angle vertex was formed by the intersection of vectors formed by markers on the 5th metacarpal bone base and hamate and markers on the ulna styloid and ulna midpoint (Fig. 7).

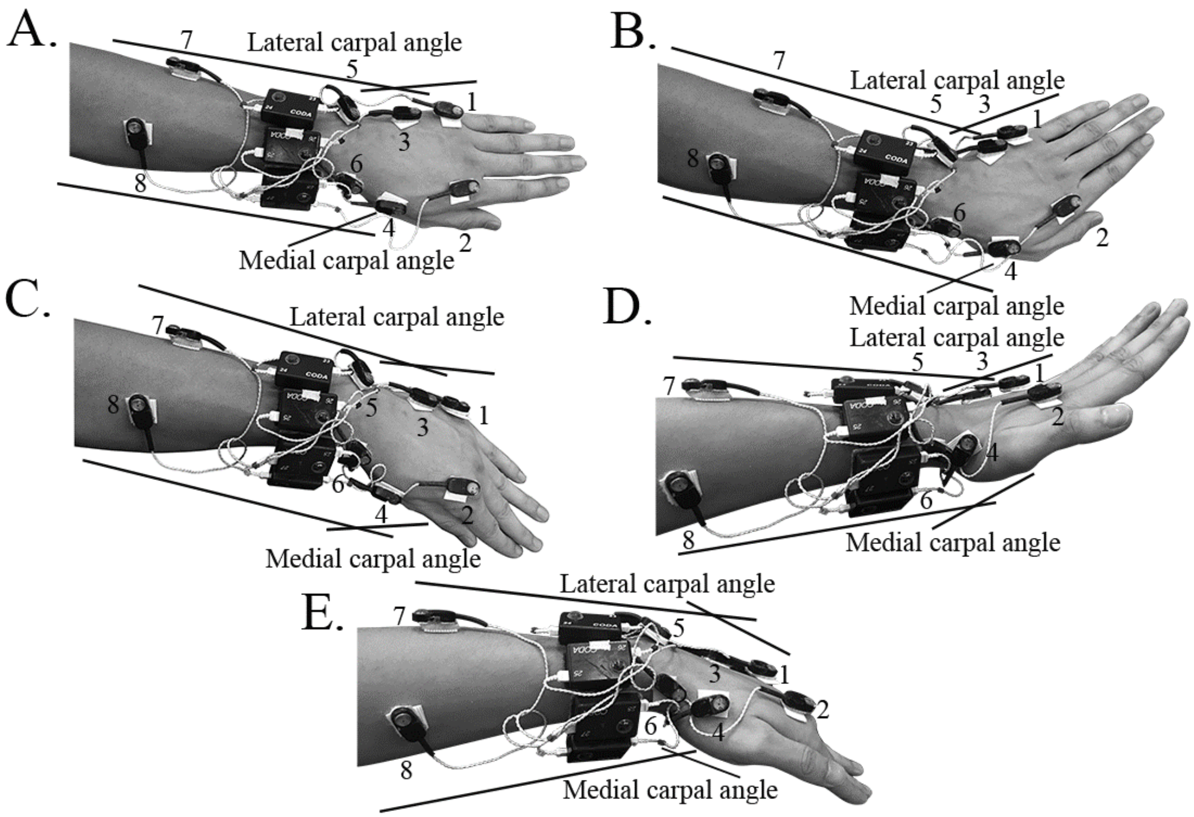

Figure 7**.** Marker placement on a left hand (A) demonstrating radiocarpal ulnar deviation (B), radial deviation (C), extension (D), and flexion (E). The lateral carpal angle vertex was formed by the intersection of vectors formed by markers 1 and 3, and markers 5 and 7. The medial carpal angle vertex was formed by the intersection of vectors between markers 2 and 4, and markers 6 and 8.

3.2.4. Data Reduction

Radioulnar deviation was measured for the first two activities and flexion-extension for the last two activities. The baseline angle was determined in the "resting" position prior to activity initiation, and the minimum and maximum angles (lateral and medial), as well as the difference between them (range of motion, ROM), were determined using software functions (Codamotion system, Codamotion Charnwood Dynamics Ltd, Leicestershire, UK) for all repetitions of each activity (Fig. 8).

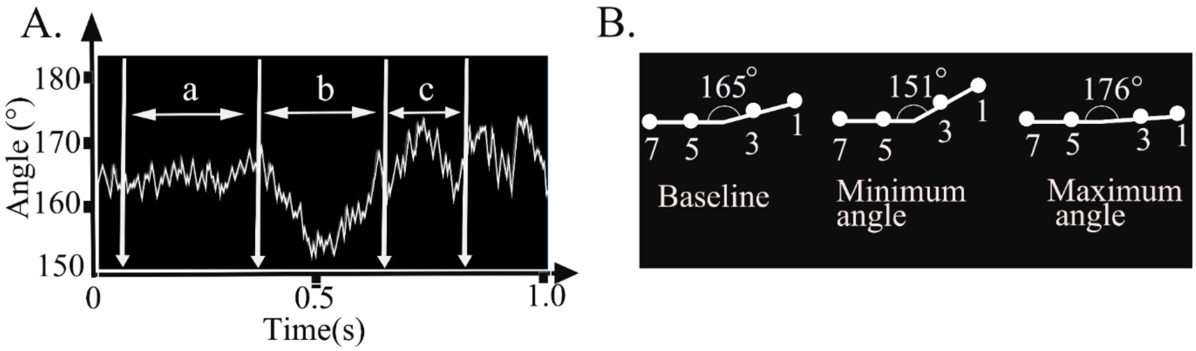

Figure 8. Representative images of the raw lateral carpal radial deviation angle data collected during swiping on a tablet backward (A) and corresponding stick figure diagram (B) illustrating the baseline (a), minimum (b) and maximum (c) angles from the lateral to medial perspective. Markers are indicated in numbers and represented as white dots.

3.2.5. Statistical Analysis

A mixed ANOVA model with fixed effects of sex, handedness, activity, and their interactions, and random effects of each participant, was used to evaluate differences between sexes, digital and manual devices, and dominant versus non-dominant hands. When a fixed effect was detected, Fisher's least significant difference post-hoc comparisons were performed for the effect. Significance was considered at $P \leq 0.05$. The results were presented as least square mean (LSM) ± SEM. All statistical analyses were performed with JMP Pro 14 software (SAS Institute, Cary, NC, USA).

3.3. Results

One right-handed male participant only completed texting on a cell phone versus typing on a keyboard activities. One right-handed female participant only completed texting on a cell phone versus typing on a keyboard and using a cell phone calculator versus manual calculator activities. The rest of participants completed all the activities.

Maximum medial carpal radial deviation angle (P = 0.0401) and medial carpal radial deviation ROM (P = 0.0108) were greater using a cell phone versus a traditional phone with sexes and handedness combined (Fig. 9A.). While turning book pages forward, medial minimum ulnar deviation angle was higher in non-dominant versus dominant hands in males (P = 0.0028). It was higher in females versus males in dominant hands (P = 0.0203) and was greater in males versus females in non-dominant hands (P = 0.0078) (Fig. 9B.). Minimum lateral carpal ulnar deviation angle was greater while swiping on a tablet versus turning book pages forward in females with handedness combined (P = 0.0035) (Fig. 10). Minimum lateral carpal ulnar deviation angle was less when turning book pages forward using dominant hands (P = 0.0025) or swiping on a tablet forward using non-dominant hands (P = 0.0013) than swiping on a tablet forward using dominant hands for both sexes combined (Fig. 10). Maximum medial carpal radial deviation angle was greater while turning book pages backward versus swiping on a tablet backward for sexes and handedness combined (P = 0.0367) (Fig. 10).

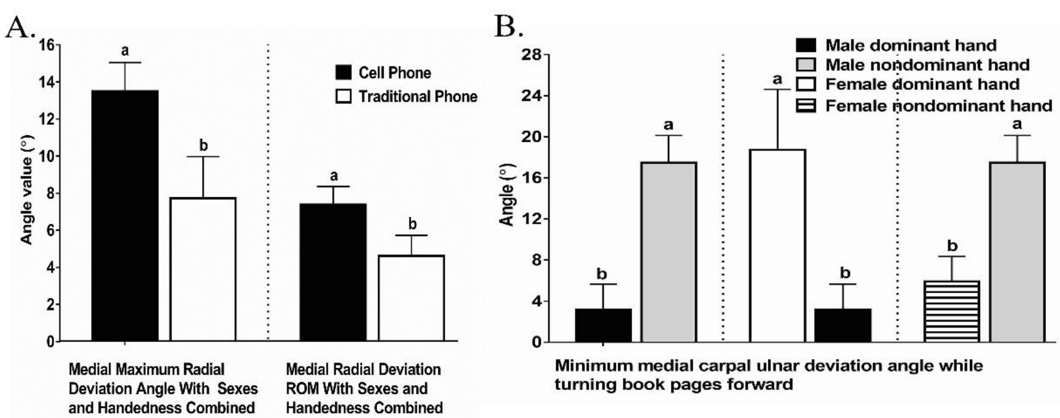

Figure 9. Least square mean ± SEM maximum medial carpal radial deviation angle and medial carpal radial deviation ROM while using a traditional or cell phone (A); Least square mean ± SEM minimum medial carpal ulnar deviation angle while turning book pages forward (B). Columns with different letters are significantly different within each parameter.

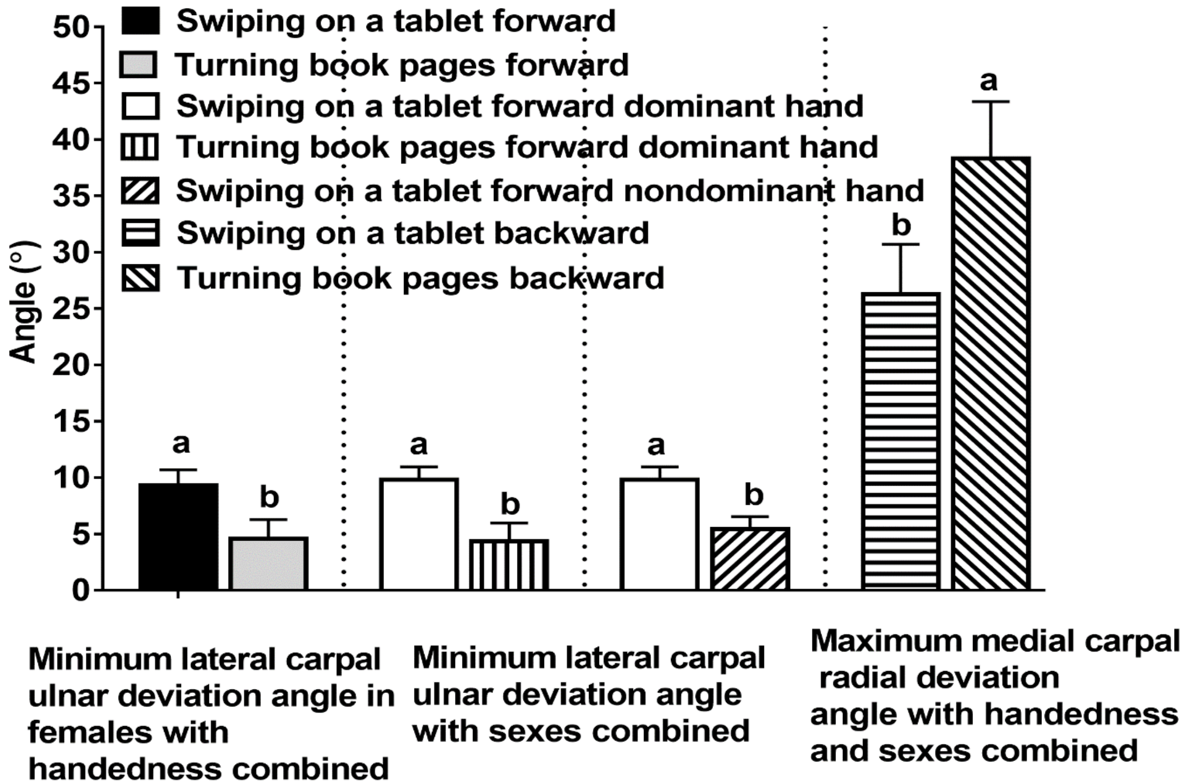

Figure 10. Least square mean ± SEM minimum lateral carpal ulnar deviation angle and maximum medial carpal radial deviation angle while swiping on a tablet or turning book pages forward and backward. Columns with different letters are significantly different within each parameter.

Maximum lateral carpal extension angle was greater in dominant versus non-dominant hands while texting on a cell phone in females (P = 0.0059) and was greater while typing versus texting in female non-dominant hands (P = 0.0005). It was greater in females versus males while typing on a computer keyboard in non-dominant hands (P= 0.0224) (Fig. 11A). Lateral carpal extension ROM was greater while typing versus texting in female non-dominant hands (P < 0.0001) and it was greater in females versus males in nondominant hands while typing (P = 0.0022) (Fig. 11B). The maximum and minimum medial carpal extension angles and medial extension ROM were greater while typing versus texting with sexes and handedness combined (P < 0.0001, P = 0.0016 and P < 0.0001, respectively) (Fig. 11C.). Maximum medial carpal

extension angle ($P = 0.0052$) and lateral carpal extension ROM ($P = 0.0323$) were greater while using a manual calculator versus cell phone calculator in females with handedness combined (Fig. 11D.). Maximum lateral carpal extension angle ($P = 0.0365$) and lateral carpal extension ROM ($P = 0.0112$) were greater in females versus males while using a manual calculator with handedness combined (Fig. 11D.).

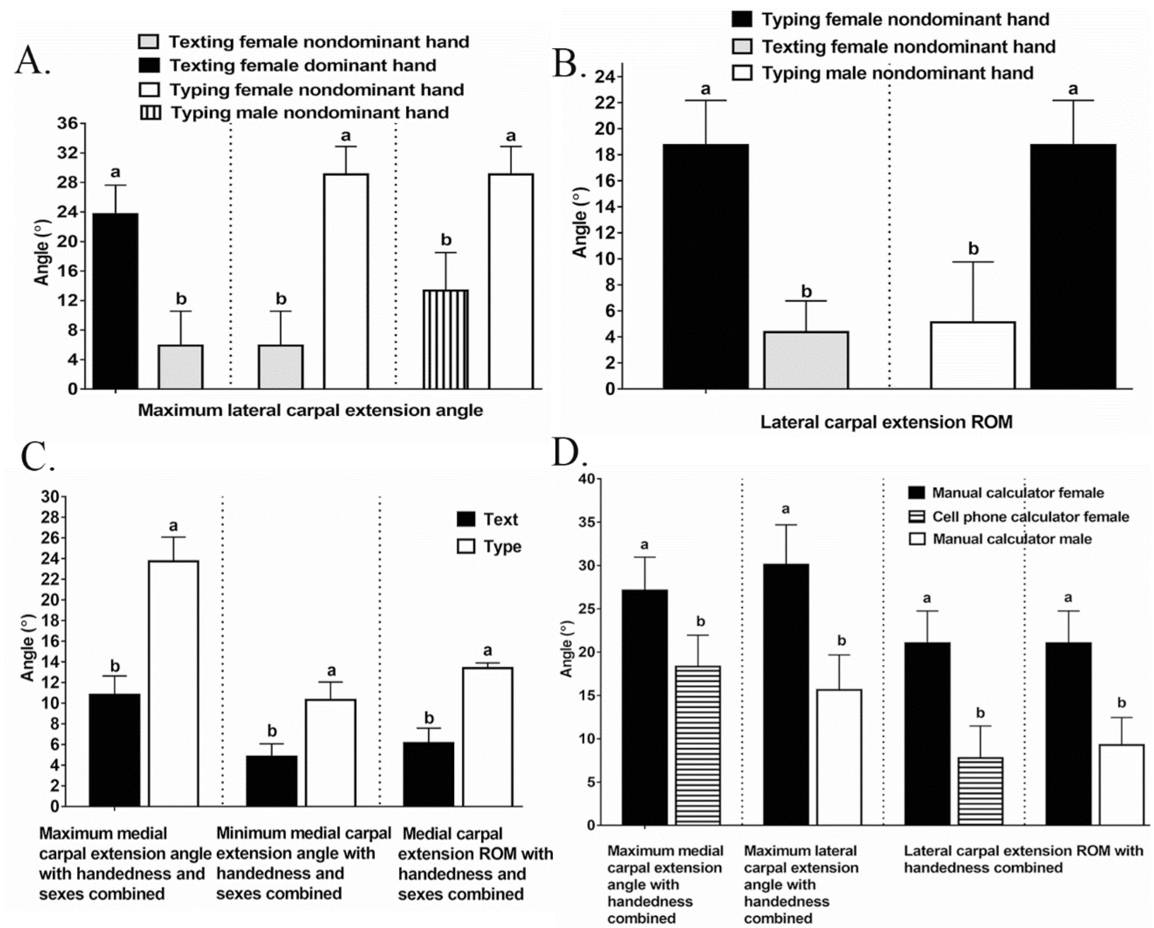

Figure 11. Least square mean ± SEM maximum lateral carpal extension angle (A), lateral carpal extension ROM (B), maximum and minimum medial carpal extension angles and medial carpal extension ROM (C) while texting on a cell phone or typing on a keyboard. Least square mean ± SEM maximum medial and lateral carpal extension angle and lateral carpal extension ROM while entering numbers on a manual or cell phone calculator (D). Columns with different letters are significantly different within each parameter.

3.4. Discussion

The repetitive and overuse of digital devices with increased static loading and acute joint angles may contribute to wrist tissue damage (Gustafsson et al. 2018; Kietrys et al. 2015). The hypothesis that digital device use reduces wrist motion was rejected because wrist radioulnar deviation was higher using a cell phone versus traditional phone receiver. An additional, important finding is that results differed between sexes and dominant versus nondominant hands while using a digital or manual device. Taken together, these results suggest that some digital devices reduced wrist radiocarpal joint flexion-extension, and sex, handedness, and device size affect wrist motion during use of digital devices and their manual counterparts. These are important considerations for device design and recommendations for use.

Device attributes like key activation and size may explain some of the observations in this study. In general, device key activation is achieved by touch on a screen or physical key depression on a keypad or keyboard (Gustafsson et al. 2018; Kietrys et al. 2015). Key activation to text on a cell phone requires greater thumb flexion-extension and median ROM in adults using a phone with a keypad versus a touchscreen (Gustafsson et al. 2018). This may be the basis for the greater wrist motion evident in the maximum and minimum medial carpal extension angle and ROM to text on a cell phone versus type on a computer keyboard and lower maximum medial carpal extension angle required to enter numbers on a cell phone versus a manual calculator. The higher radial deviation angle while using a cell phone versus a traditional receiver might be attributable to the larger grasp required to hold the cell phone in this study that was about 2 times greater than the receiver. Wrist motion was recorded during supermarket bagging process using a motion monitor and it was found that greater wrist radioulnar deviation was required to grasp 10 cm objects than 5 cm objects (Estill and Kroemer 1998). The findings in this study support published observations

that prolonged and repetitive texting on a cell phone increases static muscle loading (İNal et al. 2015; Xie et al. 2016) and the odds of wrist pain or discomfort increases incrementally with usage time (Toh et al. 2019; Toh et al. 2017), which increases the risk of carpometacarpal joint osteoarthritis and thumb tendinopathy (Gold et al. 2012; Ming, Pietikainen, and Hänninen 2006). Additionally the higher radial deviation wrist angle is associated with tendon and tendon sheath microdamage (Veeger et al. 1998) and stress (Serina, Tal, and Rempel 1999b).

Wrist anatomical distinctions between males and females, primarily in size, affect wrist motion and explain differences between males and females while typing and entering numbers with manual devices (Won et al. 2003; Chesky and Yoshimura 2007) (Szeto and Ng 2000). Reportedly, normative data on wrist motion from 363 females and 387 males collected by using a goniometer showed that females had higher flexion-extension than males (Klum et al. 2012). Additionally, females are thought to have greater wrist flexibility than males (Klum et al. 2012; Mallon, Brown, and Nunley 1991; Stathokostas et al. 2013). The smaller size and greater flexibility of the female wrist in addition to the greater motion required for manual key activation might explain the greater maximum lateral carpal extension angle and extension ROM while typing on a computer keyboard and entering numbers on a manual calculator. Unfortunately, the greater motion related to these activities may contribute to greater documented overuse injuries in females for the reasons described in the preceding paragraph (Karlqvist et al. 2002; Treaster and Burr 2004).

Wrist motion differed between dominant versus nondominant hand while texting on a cell phone. Handedness is determined by congenital inheritance, environment, and learning (Park and Yang 2012; Clerke and Clerke 2001). In general, dominant hand has greater dexterity than nondominant hand (Mathew et al. 2019; Wang et al. 2011; Noguchi et al. 2006). In this study, we

found that dominant hand had a greater maximum extension angle than nondominant hand while texting, which was consistent with previous studies that dominant hand had greater wrist motion than nondominant hand while using digital devices (Ryu et al. 2013; Young et al. 2013). Our finding also suggests dominant hand may have greater flexibility than nondominant hand when texting on a cell phone (Young et al. 2013). Similar to other previous studies (Gustafsson et al. 2018; Kietrys et al. 2015), all participants used one single hand, either dominant or nondominant hand to hold a cell phone while texting in this study. Different from texting, participants used dominant and nondominant hand at the same time while typing on a computer keyboard, which may result in the effects of handedness was indiscernible.

There are several limitations in this study. First, although the Cartesian Optoelectronic Dynamic Anthropometer (CODA) motion analysis system is easy to use (Monaghan, Delahunt, and Caulfield 2006; Rose, Birch, and Kuisma 2011), and has high sensitivity in a laboratory environment (Shefer Eini et al. 2017), the issue of skin movement may have affected the results (Dugan and Bhat 2005). In this study, markers were placed on bone landmarks where subcutaneous tissue was minimal. As a result, the influences of skin movements could be minimized (Rose, Birch, and Kuisma 2011). Second, the order of tasks was not randomized but participants had 10-15 minutes to rest between tasks, with the hope that that carryover effect would be reduced (McMillian et al. 2006). Third, participants' background and age can affect wrist motion (Kitsoulis et al. 2010; Chung and Wang 2009; Hwang and Jung 2015). In this study, participants were medical personnel at a similar age range, which may limit the generalizability of these findings to a larger population (Kietrys et al. 2015).

CHAPTER 4. CONCLUSION AND FUTURE STUDY

The first part of this thesis provides novel baseline information for shoe adaptions that are intended to enhance traction in horses trotting on concrete pavement. Slippage can contribute to injury in horses (Parkes and Witte 2015a), and it is imperative to use equine shoe modifications to enhance traction and avoid slip in horses. Results from this study indicate that C and TLC shoes enhance traction over the others tested without altering normal weight-distribution in non-lame light-breed horses. The shoe modifications may be the best options for hoof protection and traction in horses working on concrete. Overall, outcomes provide useful information on the effects of shoe traction adaptions on equine gait kinetics. This information can be used to guide shoe designs and enhance safety of horses and riders participating in work and pleasure activities.

The degree of road damage from shoes with calks, or a thin layer of tungsten carbide or plastic, was not included in this study but should be evaluated in future research. The optimal calk size and placements should be investigated to minimize road damage and ensure adequate traction in horses. More study is required to confirm the auspicious finding from this pilot study in a larger horse population from different breeds and in horses trotting on concrete or asphalt pavements. Considering the similarity between toe-grabs and calks being placed on the toe area, the calks may delay the break over and increase the lever arm of the GRF, resulting in increased strain on the suspensory apparatus. Furthermore, different ground surfaces have different deformation and friction properties. These differences affect the GRF, including the braking and vertical forces. Asphalt is commonly used on public pavements and additional study about the kinetic effects of shoes with calks in horses trotting on asphalt pavement is needed.

The results of the second study proves that digital devices reduce wrist radiocarpal joint motion in flexion-extension plane in males and females in medical professionals. It provides insights into effects of sex and handedness on digital versus manual devices use on wrist motion. One previous study suggested that cross sectional area of the median nerve was higher in dominant than nondominant hand among cell phone users and enlargement of median nerve was a predisposing factor of developing carpal tunnel syndrome (İNal et al. 2015). It is suggested that cell phone users should use dominant and nondominant hand alternatively to minimize the risk of carpal tunnel syndrome development and texting on a cell phone for a long period of time should be avoided (Tegtmeier 2018; Berolo, Wells, and Amick 2011). Cell phone users should not keep their fingers floating on cell phone screens when not texting to reduce static loads on wrist. Digital devices with external keyboards or larger screen may increase wrist motion and mitigate physical strain on wrist joint and provides better protection (Tegtmeier 2018).

APPENDIX. IRB APPROVAL FORM

ID#:________________

Page 1 of 3
LSUHSC-NO
IRB#: 9078
Consent Rev. date: 8/7/15
Protocol Revision #:

LOUISIANA STATE UNIVERSITY HEALTH SCIENCES CENTER in NEW ORLEANS
Informed Consent Form

Please refer to the Website Instructions for assistance in writing your Informed Consent Form

1. Study Title: Contemporary Update of Functional Wrist Range of Motion

2. Performance Sites: LSUHSC

3. Investigators:

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Phone: 985-969-1933

4. Purpose of Study:

To determine updated wrist range of motion parameters needed for modern functions.

5. Description of the Study:

An electrogoniometer will be placed on subjects wrists. They will then asked to complete various

activities of daily living. Range of motion of the wrist will be collected during these activities. This data will be analyzed to determine average parameters of wrist range of motion.

6. Benefits to Subjects: Participation in this study will help guide treatment and expectations of various orthopedic injuries around the wrist.

7. Risks to Subject:
Irritation or damage to the skin around the wrist. Pain associated with moving the wrist.

8. Alternatives to Participation in the Study:
The alternative is not to participate.

9. Subject Removal:

The researcher may stop you from taking part in this study if at any time it is believed to be in your best interest; if you do not follow the study procedures; if the study is stopped. You could be taken off the study if your health worsens; if another treatment option appears to be appropriate; or for any other cause which prevents your continuing in the study.

10. Subject's Right to Refuse to Participate or Withdraw:

Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. You may refuse to participate or withdraw from the study at any time without jeopardizing, in any way, your medical treatment at this institution in the present or future. Information already collected about you and sent to the sponsor will still be used. Tell the researcher if you are thinking about withdrawing from the study so that you may do so safely. If you decide not to continue participation in the study you should seek medical advice for alternatives. Should significant new findings take place during the course of the research that may relate to your willingness to continue participation, that information will be provided to you.

11. Subject's Right to Privacy:

If the results of the study are published the privacy of subjects will be protected and they will not be identified in any way. Your personal information may be disclosed if required by law.

12. Release of Information:

Organizations that may inspect and/or copy your study-related medical records for quality assurance and data analysis include: LSUHSC-NO Institutional Review Board, and the doctors listed on page 1 of this consent form and their staff. While every effort will be made to maintain your privacy, absolute confidentiality cannot be guaranteed. Records will be kept private to the extent allowed by law.

13. Financial Information:

There will be no cost associated with participation in this study.
The principal investigator will arrange for medical care for any emergency medical problem that you may experience as a direct result of your participation in this research. This will be provided on a fee-for-service basis. There are not funds available to pay for any disability that results or for damages such as lost wages, etc.

You will not be paid for your participation as reimbursement for your time and travel.

14. Acknowledgment:

The study has been discussed with me and all my questions have been answered. Additional questions regarding the study should be directed to the investigators listed on page 1 of this consent form. If I have questions about subject's rights, or want to discuss problems, concerns or questions, or obtain information or offer input, I can contact the Chancellor of the LSU Health Sciences Center New Orleans at (504) 568-4801.

REFERENCES

Amitrano, F. N., S. D. Gutierrez-Nibeyro, and D. J. Schaeffer. 2016. 'Effect of hoof boots and toe-extension shoes on the forelimb kinetics of horses during walking', *Am J Vet Res*, 77: 527-33.

Atroshi, I., C. Gummesson, E. Ornstein, R. Johnsson, and J. Ranstam. 2007. 'Carpal tunnel syndrome and keyboard use at work: a population-based study', *Arthritis Rheum*, 56: 3620-5.

Back, W., H. C. Schamhardt, W. Hartman, and A. Barneveld. 1995. 'Kinematic differences between the distal portions of the forelimbs and hind limbs of horses at the trot', *Am J Vet Res*, 56: 1522-28.

Back, Willem, Maaike Hm, Van Schie, and Jessica N Pol. 2006. *Synthetic shoes attenuate hoof impact in the trotting warmblood horse*.

Back, Willem, Maaike H. M. van Schie, and Jessica N. Pol. 2007. 'Synthetic shoes attenuate hoof impact in the trotting warmblood horse', *Equine and Comparative Exercise Physiology*, 3: 143-51.

Balch, OK, HM Clayton, and JL Lanovaz. 1996. "Weight-and length-induced changes in limb kinematics in trotting horses." In *Proceedings of the Annual Convention American Association of Equine Practitioners*, 218-9.

Bell, R. P., S. K. Reed, M. J. Schoonover, C. T. Whitfield, Y. Yonezawa, H. Maki, P. F. Pai, and K. G. Keegan. 2016. 'Associations of force plate and body-mounted inertial sensor measurements for identification of hind limb lameness in horses', *Am J Vet Res*, 77: 337-45.

Berolo, Sophia, Richard P. Wells, and Benjamin C. Amick. 2011. 'Musculoskeletal symptoms among mobile hand-held device users and their relationship to device use: A preliminary study in a Canadian university population', *Applied Ergonomics*, 42: 371-78.

Birch, I., and K. Deschamps. 2014. 'Dynamic in-vivo subtalar joint kinematics measured using a skin marker based protocol: a face validity study', *J Am Podiatr Med Assoc*.

Bird, J. O., and P. J. Chivers. 1993. '28 - Friction.' in J. O. Bird and P. J. Chivers (eds.), *Newnes Engineering and Physical Science Pocket Book* (Newnes).

Blanchette, M. G., and C. M. Powers. 2015. 'The influence of footwear tread groove parameters on available friction', *Appl Ergon*, 50: 237-41.

Bobbert, M. F., C. B. Gomez Alvarez, P. R. van Weeren, L. Roepstorff, and M. A. Weishaupt. 2007. 'Validation of vertical ground reaction forces on individual limbs calculated from kinematics of horse locomotion', *J Exp Biol*, 210: 1885-96.

Bobbert, Maarten F., Constanza B. Gómez Álvarez, P. René van Weeren, Lars Roepstorff, and Michael A. Weishaupt. 2007. 'Validation of vertical ground reaction forces on individual limbs calculated from kinematics of horse locomotion', 210: 1885-96.

Bras, R. J., and R. Redden. 2018. 'Understanding the Basic Principles of Podiatry', *Vet Clin North Am Equine Pract*, 34: 391-407.

Brigstocke, G., A. Hearnden, C. A. Holt, and G. Whatling. 2012. 'The functional range of movement of the human wrist', *Journal of Hand Surgery (European Volume)*, 38: 554-56.

Brunsting, J., M. Dumoulin, M. Oosterlinck, M. Haspeslagh, L. Lefere, and F. Pille. 2019. 'Can the hoof be shod without limiting the heel movement? A comparative study between barefoot, shoeing with conventional shoes and a split-toe shoe', *Vet J*, 246: 7-11.

Burn, J. F., and C. Brockington. 2001. 'Quantification of hoof deformation using optical motion capture', *Equine Vet J Suppl*: 50-3.
Burn, Jeremy F., and Steven J. Usmar. 2005. 'Hoof landing velocity is related to track surface properties in trotting horses', *Equine and Comparative Exercise Physiology*, 2: 37-41.
Carter, T. I., B. Pansy, A. L. Wolff, H. J. Hillstrom, S. I. Backus, M. Lenhoff, and S. W. Wolfe. 2009. 'Accuracy and reliability of three different techniques for manual goniometry for wrist motion: a cadaveric study', *J Hand Surg Am*, 34: 1422-8.
Caure, Sébastien, Perrine Mortagne, Denis Leveillard, Faustine Blanville, Marielle Carro, Matthieu Cousty, Diana Salazar, and Renate Weller. 2018. 'The Influence of Different Hind Shoes and Bare Feet on Horse Kinematics at a Walk and Trot on a Soft Surface', *Journal of Equine Veterinary Science*, 70: 76-83.
Chammas, M. 2014. 'Carpal tunnel syndrome', *Chir Main*, 33: 75-94.
Chaparro, Alex, Michael Rogers, Jeffrey Fernandez, Mike Bohan, Choi Sang Dae, and Laszlo Stumpfhauser. 2000. 'Range of motion of the wrist: implications for designing computer input devices for the elderly', *Disability and Rehabilitation*, 22: 633-37.
Charalambous, L., G. Irwin, I. N. Bezodis, and D. Kerwin. 2012. 'Lower limb joint kinetics and ankle joint stiffness in the sprint start push-off', *J Sports Sci*, 30: 1-9.
Chateau, H., C. Degueurce, and J. M. Denoix. 2004a. 'Effects of 6° elevation of the heels on 3D kinematics of the distal portion of the forelimb in the walking horse', *Equine Veterinary Journal*, 36: 649-54.
———. 2006. 'Effects of egg-bar shoes on the 3-dimensional kinematics of the distal forelimb in horses walking on a sand track', *Equine Vet J Suppl*: 377-82.
Chateau, H., D. Robin, T. Simonelli, L. Pacquet, P. Pourcelot, S. Falala, J. M. Denoix, and N. Crevier-Denoix. 2009. 'Design and validation of a dynamometric horseshoe for the measurement of three-dimensional ground reaction force on a moving horse', *J Biomech*, 42: 336-40.
Chateau, Henry, Christophe Degueurce, and Jean-Marie Denoix. 2004b. 'Evaluation of 3D kinematics of the distal portion of the forelimb in horses walking in a straight line', *Am J Vet Res*, 65: 447-55.
Chesky, Kris, and Eri Yoshimura. 2007. 'Hand size and PRMDs in Japanese female pianists', *Medical problems of performing artists*, 22: 39.
Chung, Meng-Jung, and Mao-Jiun J. Wang. 2009. 'The effect of age and gender on joint range of motion of worker population in Taiwan', *International Journal of Industrial Ergonomics*, 39: 596-600.
Clayton, H. M., and S. J. Hobbs. 2019. 'A Review of Biomechanical Gait Classification with Reference to Collected Trot, Passage and Piaffe in Dressage Horses', *Animals (Basel)*, 9.
Clayton, H. M., J. L. Lanovaz, H. C. Schamhardt, and R. van Wessum. 1999. 'The effects of a rider's mass on ground reaction forces and fetlock kinematics at the trot', *Equine Vet J Suppl*: 218-21.
Clayton, H. M., R. Sigafoos, and R. D. Curle. 1991. 'Effect of three shoe types on the duration of breakover in sound trotting horses', *Journal of Equine Veterinary Science*, 11: 129-32.
Clayton, Hilary M, and Henk C %J Equine locomotion Schamhardt. 2013. 'Measurement techniques for gait analysis', 2: 31-60.
Clerke, Anita, and Jonathan Clerke. 2001. 'A Literature Review of the Effect of Handedness on Isometric Grip Strength Differences of the Left and Right Hands', *American Journal of Occupational Therapy*, 55: 206-11.

Crevier-Denoix, N., D. Robin, P. Pourcelot, S. Falala, L. Holden, P. Estoup, L. Desquilbet, J. M. Denoix, and H. Chateau. 2010. 'Ground reaction force and kinematic analysis of limb loading on two different beach sand tracks in harness trotters', *Equine Vet J Suppl*: 544-51.

Cuesta-Vargas, Antonio I., Alejandro Galán-Mercant, and Jonathan M. Williams. 2010. 'The use of inertial sensors system for human motion analysis', *Physical therapy reviews : PTR*, 15: 462-73.

Dauncey, Thomas, Harvinder P. Singh, and Joseph J. Dias. 2017. 'Electrogoniometer measurement and directional analysis of wrist angles and movements during the Sollerman hand function test', *Journal of Hand Therapy*, 30: 328-36.

Delahunt, E., K. Cusack, L. Wilson, and C. Doherty. 2013. 'Joint mobilization acutely improves landing kinematics in chronic ankle instability', *Med Sci Sports Exerc*, 45: 514-9.

Demirci, K., M. Akgonul, and A. Akpinar. 2015. 'Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students', *J Behav Addict*, 4: 85-92.

Derler, S., F. Kausch, and R. Huber. 2008. 'Analysis of factors influencing the friction coefficients of shoe sole materials', *Safety Science*, 46: 822-32.

Diss, C. E. 2001. 'The reliability of kinetic and kinematic variables used to analyse normal running gait', *Gait Posture*, 14: 98-103.

Dugan, S. A., and K. P. Bhat. 2005. 'Biomechanics and analysis of running gait', *Phys Med Rehabil Clin N Am*, 16: 603-21.

Egenvall, A., B. N. Bonnett, P. Olson, J. Penell, and U. Emanuelson. 2006. 'Association between costly veterinary-care events and 5-year survival of Swedish insured warmblooded riding horses', *Prev Vet Med*, 77: 122-36.

Eliashar, E. 2007. 'An evidence-based assessment of the biomechanical effects of the common shoeing and farriery techniques', *Vet Clin North Am Equine Pract*, 23: 425-42.

Eliashar, E., M. P. McGuigan, K. A. Rogers, and A. M. Wilson. 2002. 'A comparison of three horseshoeing styles on the kinetics of breakover in sound horses', *Equine Vet J*, 34: 184-90.

Estill, Cheryl Fairfield, and K. H. E. Kroemer. 1998. 'Evaluation of Supermarket Bagging Using a Wrist Motion Monitor', *Human Factors*, 40: 624-32.

Eun, Chung Jee, Choi Soo An, Kim Ki Tai, Yee Jeong, Kim Joo Hee, Seong Jin Won, Seong Jong Mi, Kim Ju Young, Lee Kyung Eun, and Gwak Hye Sun. 2018. 'Smartphone addiction risk and daytime sleepiness in Korean adolescents', *Journal of Paediatrics and Child Health*, 54: 800-06.

Eustace, R. A., and M. N. Caldwell. 1989. 'The construction of the heart bar shoe and the technique of dorsal wall resection', *Equine Vet J*, 21: 367-69.

Exell, T. A., M. J. Gittoes, G. Irwin, and D. G. Kerwin. 2012. 'Gait asymmetry: composite scores for mechanical analyses of sprint running', *J Biomech*, 45: 1108-11.

Gelberman, R. H., P. T. Hergenroeder, A. R. Hargens, G. N. Lundborg, and W. H. Akeson. 1981. 'The carpal tunnel syndrome. A study of carpal canal pressures', *J Bone Joint Surg Am*, 63: 380-83.

Gilman, L., D. N. Cage, A. Horn, F. Bishop, W. P. Klam, and A. P. Doan. 2015. 'Tendon rupture associated with excessive smartphone gaming', *JAMA Intern Med*, 175: 1048-9.

Gnagey, L., H. M. Clayton, and J. L. Lanovaz. 2006. 'Effect of standing tarsal angle on joint kinematics and kinetics', *Equine Veterinary Journal*, 38: 628-33.

Gold, J. E., J. B. Driban, N. Thomas, T. Chakravarty, V. Channell, and E. Komaroff. 2012. 'Postures, typing strategies, and gender differences in mobile device usage: An observational study', *Applied Ergonomics*, 43: 408-12.
Green, R. A., and C. A. Briggs. 1989. 'Anthropometric dimensions and overuse injury among Australian keyboard operators', *J Occup Med*, 31: 747-50.
Gross, D. K., S. M. Stover, A. E. Hill, and I. A. Gardner. 2004. 'Evaluation of forelimb horseshoe characteristics of thoroughbreds racing on dirt surfaces', *Am J Vet Res*, 65: 1021-30.
Gustafsson, Ewa, Pieter Coenen, Amity Campbell, and Leon Straker. 2018. 'Texting with touchscreen and keypad phones - A comparison of thumb kinematics, upper limb muscle activity, exertion, discomfort, and performance', *Applied Ergonomics*, 70: 232-39.
Gustas, P., C. Johnston, L. Roepstorff, and S. Drevemo. 2001. 'In vivo transmission of impact shock waves in the distal forelimb of the horse', *Equine Vet J Suppl*: 11-5.
Gustas, P., C. Johnston, L. Roepstorff, S. Drevemo, and H. Lanshammar. 2004. 'Relationships between fore- and hindlimb ground reaction force and hoof deceleration patterns in trotting horses', *Equine Vet J*, 36: 737-42.
Gutierrez-Martinez, J., A. Ortiz-Espinosa, P. R. Hernandez-Rodriguez, and M. A. Nunez-Gaona. 2014. 'System to measure the range of motion of the joints of the human hand', *Rev Invest Clin*, 66 Suppl 1: S122-30.
Hagen, Jenny, Michael Hüppler, Sandra M. Geiger, Daniela Mäder, and Florian S. Häfner. 2017. 'Modifying the Height of Horseshoes: Effects of Wedge Shoes, Studs, and Rocker Shoes on the Phalangeal Alignment, Pressure Distribution, and Hoof-Ground Contact During Motion', *Journal of Equine Veterinary Science*, 53: 8-18.
Hampson, Brian, and John Wilson. 2018. 'A Comparative Study on the Effects of Copper and Steel Nails on the Health of Horseshoe Nail Holes', *Journal of Equine Veterinary Science*, 69: 29-33.
Harvey, A. M., S. B. Williams, and E. R. Singer. 2012. 'The effect of lateral heel studs on the kinematics of the equine digit while cantering on grass', *Vet J*, 192: 217-21.
Haug, S., R. P. Castro, M. Kwon, A. Filler, T. Kowatsch, and M. P. Schaub. 2015. 'Smartphone use and smartphone addiction among young people in Switzerland', *J Behav Addict*, 4: 299-307.
Heidt, Robert S., Stephen G. Dormer, Patrick W. Cawley, Pierce E. Scranton, Gary Losse, and Mark Howard. 1996. 'Differences in Friction and Torsional Resistance in Athletic Shoe-Turf Surface Interfaces', *The American Journal of Sports Medicine*, 24: 834-42.
Hill, A. E., S. M. Stover, I. A. Gardner, A. J. Kane, M. B. Whitcomb, and A. G. Emerson. 2001. 'Risk factors for and outcomes of noncatastrophic suspensory apparatus injury in Thoroughbred racehorses', *J Am Vet Med Assoc*, 218: 1136-44.
Huguet, Elodie E., and Kylee J. Duberstein. 2012. 'Effects of Steel and Aluminum Shoes on Forelimb Kinematics in Stock-Type Horses as Measured at the Trot', *Journal of Equine Veterinary Science*, 32: 262-67.
Hüppler, Michael, Florian Häfner, Sandra Geiger, Daniela Mäder, and Jenny Hagen. 2016. 'Modifying the Surface of Horseshoes: Effects of Eggbar, Heartbar, Open Toe, and Wide Toe Shoes on the Phalangeal Alignment, Pressure Distribution, and the Footing Pattern', *Journal of Equine Veterinary Science*, 37: 86-97.
Hwang, J., and M. C. Jung. 2015. 'Age and sex differences in ranges of motion and motion patterns', *Int J Occup Saf Ergon*, 21: 173-86.

İNal, Esra Erkol, kadİr Demİrcİ, Azİze ÇetÏntürk, Mehmet Akgönül, and Serpİl Savaş. 2015. 'Effects of smartphone overuse on hand function, pinch strength, and the median nerve', 52: 183-88.

Johnston, C., and W. Back. 2006. 'Hoof ground interaction: when biomechanical stimuli challenge the tissues of the distal limb', *Equine Veterinary Journal*, 38: 634-41.

Jonsson, P., P. W. Johnson, M. Hagberg, and M. Forsman. 2011. 'Thumb joint movement and muscular activity during mobile phone texting - A methodological study', *J Electromyogr Kinesiol*, 21: 363-70.

K. Balch, Olin, R. Gayman Helman, and Michael A. Collier. 2001. 'Underrun Heels and Toe-Grab Length as Possible Risk Factors for Catastrophic Musculoskeletal Injuries in Oklahoma Racehorses', *Proc. Am. Ass. equine Practnrs.*, 47: 334-38.

Kane, A. J., S. M. Stover, I. A. Gardner, J. T. Case, B. J. Johnson, M. J. O'Brien, D. H. Read, and A. A. Ardans. 1996. 'Postmortem evaluation of homotypic variation in shoe characteristics of 201 thoroughbred racehorses', *Am J Vet Res*, 57: 1141-6.

Kane, A. J., S. M. Stover, I. A. Gardner, J. T. Case, B. J. Johnson, D. H. Read, and A. A. Ardans. 1996. 'Horseshoe characteristics as possible risk factors for fatal musculoskeletal injury of thoroughbred racehorses', *Am J Vet Res*, 57: 1147-52.

Kane, Albert, Susan Stover, Kirsten Bock, and Ian Gardner. 1998. 'Hoof Balance Characteristics Associated with Catastrophic Injury of Thoroughbred Racehorses', *44th Annu Conv Am Assoc Equine Pract*.

Karle, AS, PH Tank, HS Vedpathak, HK Mahida, RG Shah, and MA %J Veterinary World Dhami. 2010. 'Horseshoeing: an overview', *Veterinary World*, 3: 148.

Karlqvist, Lena, Ewa Wigaeus Tornqvist, Mats Hagberg, Maud Hagman, and Allan Toomingas. 2002. 'Self-reported working conditions of VDU operators and associations with musculoskeletal symptoms: a cross-sectional study focussing on gender differences', *International Journal of Industrial Ergonomics*, 30: 277-94.

Kaufman, Kenton, and KaiNan An. 2017. 'Chapter 6 - Biomechanics.' in Gary S. Firestein, Ralph C. Budd, Sherine E. Gabriel, Iain B. McInnes and James R. O'Dell (eds.), *Kelley and Firestein's Textbook of Rheumatology (Tenth Edition)* (Elsevier).

Kawcak, Christopher E. 2016. 'Biomechanics in Joints.' in C. Wayne McIlwraith, David D. Frisbie, Christopher E. Kawcak and P. René van Weeren (eds.), *Joint Disease in the Horse (Second Edition)* (W.B. Saunders: Edinburgh).

Keegan, K. G., C. G. MacAllister, D. A. Wilson, C. A. Gedon, J. Kramer, Y. Yonezawa, H. Maki, and P. F. Pai. 2012. 'Comparison of an inertial sensor system with a stationary force plate for evaluation of horses with bilateral forelimb lameness', *Am J Vet Res*, 73: 368-74.

Keller, Katy, Julie Corbett, and Diane Nichols. 1998. 'Repetitive strain injury in computer keyboard users: Pathomechanics and treatment principles in individual and group intervention', *Journal of Hand Therapy*, 11: 9-26.

Kiesler, Sara, and Thomas Finholt. 1994. 'The mystery of RSI.' in Huff Chuck and Finholt Thomas (eds.), *Social issues in computing* (McGraw-Hill, Inc.).

Kietrys, D. M., M. J. Gerg, J. Dropkin, and J. E. Gold. 2015. 'Mobile input device type, texting style and screen size influence upper extremity and trapezius muscle activity, and cervical posture while texting', *Appl Ergon*, 50: 98-104.

Kim, J. Y., H. S. Sung, Y. K. Kang, I. Gaponov, and B. K. Jung. 2017. 'Development and evaluation of a method to measure wrist range of motion on paretic hand rehabilitation device', *IEEE Int Conf Rehabil Robot*, 2017: 1337-42.

Kirk, R. F., I. S. G. Noble, T. Mitchell, C. Rolf, S. J. Haake, and M. J. Carré. 2007. 'High-speed observations of football-boot-surface interactions of players in their natural environment', *Sports Engineering*, 10: 129-44.

Kitsoulis, P., G. Paraskevas, K. Iliou, P. Kanavaros, and A. Marini. 2010. 'Clinical study of the factors affecting radioulnar deviation of the wrist joint', *BMC Musculoskelet Disord*, 11: 9.

Klum, M., M. B. Wolf, P. Hahn, F. M. Leclere, T. Bruckner, and F. Unglaub. 2012. 'Normative data on wrist function', *J Hand Surg Am*, 37: 2050-60.

Kuo, Li-Chieh, Fong-Chin Su, Haw-Yen Chiu, and Chin-Yin Yu. 2002. 'Feasibility of using a video-based motion analysis system for measuring thumb kinematics', *Journal of Biomechanics*, 35: 1499-506.

Lanovaz, J. L., H. M. Clayton, G. R. Colborne, and H. C. Schamhardt. 1999. 'Forelimb kinematics and net joint moments during the swing phase of the trot', *Equine Vet J Suppl*: 235-9.

Lawson, S. E., H. Chateau, P. Pourcelot, J. M. Denoix, and N. Crevier-Denoix. 2007. 'Effect of toe and heel elevation on calculated tendon strains in the horse and the influence of the proximal interphalangeal joint', *J Anat*, 210: 583-91.

LeBlanc, K. E., and W. Cestia. 2011. 'Carpal tunnel syndrome', *Am Fam Physician*, 83: 952-8.

Lee, Minkyung, Yunkyung Hong, Seunghoon Lee, Jinyoung Won, Jinjun Yang, Sookyoung Park, Kyu-Tae Chang, and Yonggeun Hong. 2015. 'The effects of smartphone use on upper extremity muscle activity and pain threshold', *Journal of Physical Therapy Science*, 27: 1743-45.

Li, Kai Way, and Chin Jung Chen. 2004. 'The effect of shoe soling tread groove width on the coefficient of friction with different sole materials, floors, and contaminants', *Applied Ergonomics*, 35: 499-507.

Liu, Tao, Yoshio Inoue, and Kyoko Shibata. 2009. 'Development of a wearable sensor system for quantitative gait analysis', *Measurement*, 42: 978-88.

Liu, Tao, Yoshio Inoue, Kyoko Shibata, and Kouzou Shiojima. 2012. "A Wireless Measurement System (M3D) for Three-Dimensional Gait Analysis System." In *Internet of Things*, edited by Yongheng Wang and Xiaoming Zhang, 166-71. Berlin, Heidelberg: Springer Berlin Heidelberg.

Lopez, M. J., M. M. Quinn, and M. D. Markel. 2006. 'Evaluation of gait kinetics in puppies with coxofemoral joint laxity', *Am J Vet Res*, 67: 236-41.

Mahaffey, C. A., M. L. Peterson, J. J. Thomason, and C. W. McIlwraith. 2016. 'Dynamic testing of horseshoe designs at impact on synthetic and dirt Thoroughbred racetrack materials', *Equine Vet J*, 48: 97-102.

Mallon, William J., Howard R. Brown, and James A. Nunley. 1991. 'Digital ranges of motion: Normal values in young adults', *The Journal of Hand Surgery*, 16: 882-87.

Manning, Derek P., Carla Jones, Frederick James Rowland, and Martin Roff. 1998. 'The Surface Roughness of a Rubber Soling Material Determines the Coefficient of Friction on Water-Lubricated Surfaces', *Journal of Safety Research*, 29: 275-83.

Mathew, James, Fabrice R. Sarlegna, Pierre-Michel Bernier, and Frederic R. Danion. 2019. 'Handedness Matters for Motor Control But Not for Prediction', *eNeuro*, 6: ENEURO.0136-19.2019.

McGuigan, M. P., and A. M. Wilson. 2003. 'The effect of gait and digital flexor muscle activation on limb compliance in the forelimb of the horse Equus caballus', *J Exp Biol*, 206: 1325-36.

McLaughlin, R. M., E. M. Gaughan, J. K. Roush, and C. L. Skaggs. 1996. 'Effects of subject velocity on ground reaction force measurements and stance times in clinically normal horses at the walk and trot', *Am J Vet Res*, 57: 7-11.

McMillian, D. J., J. H. Moore, B. S. Hatler, and D. C. Taylor. 2006. 'Dynamic vs. static-stretching warm up: the effect on power and agility performance', *J Strength Cond Res*, 20: 492-99.

Merkens, H. W., and H. C. Schamhardt. 1988. 'Distribution of ground reaction forces of the concurrently loaded limbs of the Dutch Warmblood horse at the normal walk', *Equine Vet J*, 20: 209-13.

Ming, Zhiyong, Seppo Pietikainen, and Osmo Hänninen. 2006. 'Excessive texting in pathophysiology of first carpometacarpal joint arthritis', *Pathophysiology*, 13: 269-70.

Mirza, M. H., P. Bommala, H. A. Richbourg, N. Rademacher, M. T. Kearney, and M. J. Lopez. 2016. 'Gait Changes Vary among Horses with Naturally Occurring Osteoarthritis Following Intra-articular Administration of Autologous Platelet-Rich Plasma', *Front Vet Sci*, 3: 29.

Moghaddam, Seyed Reza M., Arjun Acharya, Mark S. Redfern, and Kurt E. Beschorner. 2018. 'Predictive multiscale computational model of shoe-floor coefficient of friction', *Journal of Biomechanics*, 66: 145-52.

Mohamed, M. K., Abdelhalim Samy, and W. Y. Ali. 2012. 'Friction Coefficient of Rubber Shoes Sliding against Ceramic Flooring', *KGK Kautschuk Gummi Kunststoffe*, 65: 52-57.

Moleman, M., M. C. van Heel, P. R. van Weeren, and W. Back. 2006. 'Hoof growth between two shoeing sessions leads to a substantial increase of the moment about the distal, but not the proximal, interphalangeal joint', *Equine Vet J*, 38: 170-4.

Monaghan, K., E. Delahunt, and B. Caulfield. 2007. 'Increasing the number of gait trial recordings maximises intra-rater reliability of the CODA motion analysis system', *Gait Posture*, 25: 303-15.

Monaghan, Kenneth, Eamonn Delahunt, and Brian Caulfield. 2006. 'Ankle function during gait in patients with chronic ankle instability compared to controls', *Clinical Biomechanics*, 21: 168-74.

Montag, C., K. Blaszkiewicz, R. Sariyska, B. Lachmann, I. Andone, B. Trendafilov, M. Eibes, and A. Markowetz. 2015. 'Smartphone usage in the 21st century: who is active on WhatsApp?', *BMC Res Notes*, 8: 331.

Moore, L. V., R. R. Zsoldos, and T. F. Licka. 2019. 'Trot Accelerations of Equine Front and Hind Hooves Shod with Polyurethane Composite Shoes and Steel Shoes on Asphalt', *Animals (Basel)*, 9: 1119.

Morris, RG, and SEM Lawson. 'A review and evaluation of available gait analysis technologies, and their potential for the measurement of impact transmission'.

Moyer, W., and J. P. Anderson. 1975. 'Lamenesses caused by improper shoeing', *J Am Vet Med Assoc*, 166: 47-52.

Murphy, J. 2009. 'Weighted boots influence performance in show-jumping horses', *Vet J*, 181: 74-6.
Nazzal, Munir D., and Evan Holcombe. 2017. 'Evaluation of partial depth pavement repairs on routes heavily traveled by Amish horse and buggies : phase 1 : final report'.
Newsome, D., A. Smith, and S. A. Moore. 2008. 'Horse Riding in Protected Areas: A Critical Review and Implications for Research and Management', *Current Issues in Tourism*, 11: 144-66.
Noguchi, T., S. Demura, Y. Nagasawa, and M. Uchiyama. 2006. 'An examination of practice and laterality effects on the Purdue Pegboard and Moving Beans with Tweezers', *Percept Mot Skills*, 102: 265-74.
O'Brien, T., and A. Broderick. 1990. 'The technique of gait analysis using a Coda-3 motion analysis system', *Ir Med J*, 83: 79-80.
O'Byrne, J. M., A. Kennedy, A. Jenkinson, and T. M. O'Brien. 1997. 'Split tibialis posterior tendon transfer in the treatment of spastic equinovarus foot', *J Pediatr Orthop*, 17: 481-5.
O'Grady, S. E. 2008. 'Basic farriery for the performance horse', *Vet Clin North Am Equine Pract*, 24: 203-18.
O'Neil, B. A., M. E. Forsythe, and W. D. Stanish. 2001. 'Chronic occupational repetitive strain injury', *Can Fam Physician*, 47: 311-6.
O'Sullivan, Kieran, Leonard O'Sullivan, Amity Campbell, Peter O'Sullivan, and Wim Dankaerts. 2012. 'Towards monitoring lumbo-pelvic posture in real-life situations: Concurrent validity of a novel posture monitor and a traditional laboratory-based motion analysis system', *Manual Therapy*, 17: 77-83.
Oomen, A. M., M. Oosterlinck, F. Pille, D. C. Sonneveld, F. Gasthuys, and W. Back. 2012. 'Use of a pressure plate to analyse the toe–heel load redistribution underneath a normal shoe and a shoe with a wide toe in sound warmblood horses at the walk and trot', *Research in Veterinary Science*, 93: 1026-31.
Oosterlinck, M., F. Pille, W. Back, J. Dewulf, and F. Gasthuys. 2010. 'Use of a stand-alone pressure plate for the objective evaluation of forelimb symmetry in sound ponies at walk and trot', *Vet J*, 183: 305-9.
Oosterlinck, M., E. Royaux, W. Back, and F. Pille. 2014. 'A preliminary study on pressure-plate evaluation of forelimb toe-heel and mediolateral hoof balance on a hard vs. a soft surface in sound ponies at the walk and trot', *Equine Vet J*, 46: 751-55.
Ostblom, L. C., C. Lund, and F. Melsen. 1984. 'Navicular bone disease: results of treatment using egg-bar shoeing technique', *Equine Vet J*, 16: 203-6.
Palmer, A. K., F. W. Werner, D. Murphy, and R. Glisson. 1985. 'Functional wrist motion: a biomechanical study', *J Hand Surg Am*, 10: 39-46.
Parasuraman, S., A. T. Sam, S. W. K. Yee, B. L. C. Chuon, and L. Y. Ren. 2017. 'Smartphone usage and increased risk of mobile phone addiction: A concurrent study', *Int J Pharm Investig*, 7: 125-31.
Pardoe, C. H., M. P. McGuigan, K. M. Rogers, L. L. Rowe, and A. M. Wilson. 2001a. 'The effect of shoe material on the kinetics and kinematics of foot slip at impact on concrete', *Equine Vet J Suppl*: 70-3.
———. 2001b. 'The effect of shoe material on the kinetics and kinematics of foot slip at impact on concrete', *Equine Vet J Suppl*: 70-73.
Park, Soohee, and Yeongae Yang. 2012. '3D Motion Analysis Comparison of the Dominant Hand Wrist Flexion during Writing', *Journal of Physical Therapy Science*, 24: 1013-15.

Parkes, R. S. V., and T. H. Witte. 2015a. 'The foot–surface interaction and its impact on musculoskeletal adaptation and injury risk in the horse', *Equine Veterinary Journal*, 47: 519-25.

Parkes, R. S., and T. H. Witte. 2015b. 'The foot-surface interaction and its impact on musculoskeletal adaptation and injury risk in the horse', *Equine Vet J*, 47: 519-25.

Parsons, K. J., A. J. Spence, R. Morgan, J. A. Thompson, and A. M. Wilson. 2011. 'High speed field kinematics of foot contact in elite galloping horses in training', *Equine Vet J*, 43: 216-22.

Peetrons, P. A., and W. Derbali. 2013. 'Carpal tunnel syndrome', *Semin Musculoskelet Radiol*, 17: 28-33.

Peham, C., D. Girtler, C. Kicker, and T. Licka. 2006. 'Raising heels of hind hooves changes the equine coffin, fetlock and hock joint angle: a kinematic evaluation on the treadmill at walk and trot', *Equine Veterinary Journal*, 38: 427-30.

Penell, J. C., A. Egenvall, B. N. Bonnett, P. Olson, and J. Pringle. 2005. 'Specific causes of morbidity among Swedish horses insured for veterinary care between 1997 and 2000', *Vet Rec*, 157: 470-7.

Persson, Bo, U. Tartaglino, O. Albohr, and Erio Tosatti. 2005. 'Rubber friction on wet and dry road surfaces: The sealing effect', *Physical Review B*, 71.

Pitti, L., M. Oosterlinck, M. L. Diaz-Bertrana, J. M. Carrillo, M. Rubio, J. Sopena, A. Santana, and J. M. Vilar. 2018. 'Assessment of static posturography and pedobarography for the detection of unilateral forelimb lameness in ponies', *BMC Vet Res*, 14: 151.

Pratt, G. W., Jr., and J. T. O'Connor, Jr. 1976. 'Force plate studies of equine biomechanics', *Am J Vet Res*, 37: 1251-5.

Putnam, J. R., L. M. Holmes, M. J. Green, and S. L. Freeman. 2014. 'Incidence, causes and outcomes of lameness cases in a working military horse population: a field study', *Equine Vet J*, 46: 194-7.

Reissner, L., G. Fischer, R. List, W. R. Taylor, P. Giovanoli, and M. Calcagni. 2019. 'Minimal detectable difference of the finger and wrist range of motion: comparison of goniometry and 3D motion analysis', *J Orthop Surg Res*, 14: 173.

Rempel, David, Jack Dennerlein, C. D. Mote, and Thomas Armstrong. 1994. 'A method of measuring fingertip loading during keyboard use', *Journal of Biomechanics*, 27: 1101-04.

Riemersma, D. J., A. J. van den Bogert, M. O. Jansen, and H. C. Schamhardt. 1996. 'Influence of shoeing on ground reaction forces and tendon strains in the forelimbs of ponies', *Equine Vet J*, 28: 126-32.

Ritmeester, A. M., W. E. Blevins, D. W. Ferguson, and S. B. Adams. 1998. 'Digital perfusion, evaluated scintigraphically, and hoof wall growth in horses with chronic laminitis treated with egg bar-heart bar shoeing and coronary grooving', *Equine Vet J Suppl*: 111-8.

Robin, D., H. Chateau, L. Pacquet, S. Falala, J. P. Valette, P. Pourcelot, B. Ravary, J. M. Denoix, and N. Crevier-Denoix. 2009. 'Use of a 3D dynamometric horseshoe to assess the effects of an all-weather waxed track and a crushed sand track at high speed trot: preliminary study', *Equine Vet J*, 41: 253-6.

Roepstorff, L., C. Johnston, and S. Drevemo. 1999. 'The effect of shoeing on kinetics and kinematics during the stance phase', *Equine Vet J Suppl*: 279-85.

Rogers, C. W., and W. Back. 2007. 'The effect of plain, eggbar and 6 degrees-wedge shoes on the distribution of pressure under the hoof of horses at the walk', *N Z Vet J*, 55: 120-4.

Rogers, Chris W., and Willem Back. 2003. 'Wedge and Eggbar Shoes Change the Pressure Distribution Under the Hoof of the Forelimb in the Square Standing Horse', *Journal of Equine Veterinary Science*, 23: 306-09.

Roland, E. S., M. L. Hull, and S. M. Stover. 2005. 'Design and demonstration of a dynamometric horseshoe for measuring ground reaction loads of horses during racing conditions', *J Biomech*, 38: 2102-12.

Rose, Alice, Ivan Birch, and Raija Kuisma. 2011. 'Effect of motion control running shoes compared with neutral shoes on tibial rotation during running', *Physiotherapy*, 97: 250-55.

Rumpler, B., A. Riha, T. Licka, A. Kotschwar, and C. Peham. 2010. 'Influence of shoes with different weights on the motion of the limbs in Icelandic horses during toelt at different speeds', *Equine Vet J Suppl*: 451-4.

Ryu, J. Y., W. P. Cooney, 3rd, L. J. Askew, K. N. An, and E. Y. Chao. 1991. 'Functional ranges of motion of the wrist joint', *J Hand Surg Am*, 16: 409-19.

Ryu, Taebeum, Jihyoun Lim, Joobong Song, Myung Hwan Yun, and Moonsoo Shin. 2013. 'Performance comparison between the preferred right and preferred left hands in text entry using Qwerty touch keyboard smartphones', *International Journal of Industrial Ergonomics*, 43: 400-05.

Schaer, B. L., C. T. Ryan, R. C. Boston, and D. M. Nunamaker. 2006. 'The horse-racetrack interface: a preliminary study on the effect of shoeing on impact trauma using a novel wireless data acquisition system', *Equine Vet J*, 38: 664-70.

Schilling, Brian K., Michael J. Falvo, and Loren Z. F. Chiu. 2008. 'Force-velocity, impulse-momentum relationships: implications for efficacy of purposefully slow resistance training', *Journal of sports science & medicine*, 7: 299-304.

Schoonover, M. J., C. T. Whitfield, J. M. Young, K. M. Sippel, and M. E. Payton. 2018. 'Quantitative assessment of intravenous regional limb perfusion of tiludronate as an adjunctive treatment for lameness caused by navicular syndrome in horses', *Am J Vet Res*, 79: 1313-20.

Serina, E. R., R. Tal, and D. Rempel. 1999a. 'Wrist and forearm postures and motions during typing', *Ergonomics*, 42: 938-51.

Shefer Eini, D., N. Z. Ratzon, A. A. Rizzo, S. C. Yeh, B. Lange, B. Yaffe, A. Daich, P. L. Weiss, and R. Kizony. 2017. 'Camera-tracking gaming control device for evaluation of active wrist flexion and extension', *J Hand Ther*, 30: 89-96.

Shin, Joong-il, and Soo-hee Park. 2017. '3D motion analysis of the wrist splint effect to wrist joint movement', *Journal of Physical Therapy Science*, 29: 1089-91.

Somia, N., G. S. Rash, M. Wachowiak, and A. Gupta. 1998. 'The initiation and sequence of digital joint motion. A three-dimensional motion analysis', *J Hand Surg Br*, 23: 792-5.

Song, H., X. Zhai, Z. Gao, T. Lu, Q. Tian, H. Li, and X. He. 2018. 'Reliability and validity of a Coda Motion 3-D Analysis system for measuring cervical range of motion in healthy subjects', *J Electromyogr Kinesiol*, 38: 56-66.

Spaak, B., M. C. van Heel, and W. Back. 2013. 'Toe modifications in hind feet shoes optimise hoof-unrollment in sound Warmblood horses at trot', *Equine Vet J*, 45: 485-9.

Stachurska, A., R. Kolstrung, M. Pieta, P. Silmanowicz, and A. Klimorowska. 2008. 'Differentiation between fore and hind hoof dimensions in the horse (<i>Equus caballus</i>)', *Arch. Anim. Breed.*, 51: 531-40.

Stathokostas, Liza, Matthew W. McDonald, Robert M. D. Little, and Donald H. Paterson. 2013. 'Flexibility of Older Adults Aged 55–86 Years and the Influence of Physical Activity', *Journal of aging research*, 2013: 743843.

Steward, M. L. 2010. 'The use of the wooden shoe (Steward Clog) in treating laminitis', *Vet Clin North Am Equine Pract*, 26: 207-14.

Stoffels, SM, TA Bitonti, GL Gleason, and H Bahia. 1995. "Mitigation of Horseshoe Damage to Pavements." In, No. FHWA/PA 95-0204.

Stutz, J. C., B. Vidondo, A. Ramseyer, U. E. Maninchedda, and A. M. Cruz. 2018. 'Effect of three types of horseshoes and unshod feet on selected non-podal forelimb kinematic variables measured by an extremity mounted inertial measurement unit sensor system in sound horses at the trot under conditions of treadmill and soft geotextile surface exercise', *Vet Rec Open*, 5: e000237.

Sun, Jialin, Jun Zhao, Zhifu Huang, Ke Yan, Xuehui Shen, Jiandong Xing, Yimin Gao, Yongxin Jian, Hejie Yang, and Bo Li. 2019. 'A Review on Binderless Tungsten Carbide: Development and Application', *Nano-Micro Letters*, 12: 13.

Szeto, Grace P. Y., and Joseph K. F. Ng. 2000. 'A Comparison of Wrist Posture and Forearm Muscle Activities While Using an Alternative Keyboard and a Standard Keyboard', *Journal of Occupational Rehabilitation*, 10: 189-97.

Taguchi, T., R. Koh, C. Takawira, N. Rademacher, G. M. Gilad, R. D. Aronson, and M. J. Lopez. 2018. 'Agmatine for Pain Management in Dogs With Coxofemoral Joint Osteoarthritis: A Pilot Study', *Front Vet Sci*, 5: 311.

Tat, Jimmy, Katherine E. Wilson, and Peter J. Keir. 2015. 'Pathological changes in the subsynovial connective tissue increase with self-reported carpal tunnel syndrome symptoms', *Clinical Biomechanics*, 30: 360-65.

Tegtmeier, P. 2018. 'A scoping review on smart mobile devices and physical strain', *Work*, 59: 273-83.

Thomason, J. J., and M. L. Peterson. 2008. 'Biomechanical and mechanical investigations of the hoof-track interface in racing horses', *Vet Clin North Am Equine Pract*, 24: 53-77.

Toh, S. H., P. Coenen, E. K. Howie, S. Mukherjee, D. A. Mackey, and L. M. Straker. 2019. 'Mobile touch screen device use and associations with musculoskeletal symptoms and visual health in a nationally representative sample of Singaporean adolescents', *Ergonomics*, 62: 778-93.

Toh, S. H., P. Coenen, E. K. Howie, and L. M. Straker. 2017. 'The associations of mobile touch screen device use with musculoskeletal symptoms and exposures: A systematic review', *PLoS One*, 12: e0181220.

Toosi, K. K., N. S. Hogaboom, M. L. Oyster, and M. L. Boninger. 2015. 'Computer keyboarding biomechanics and acute changes in median nerve indicative of carpal tunnel syndrome', *Clin Biomech (Bristol, Avon)*, 30: 546-50.

Treaster, D. E., and D. Burr. 2004. 'Gender differences in prevalence of upper extremity musculoskeletal disorders', *Ergonomics*, 47: 495-526.

Trudeau, M. B., J. G. Young, D. L. Jindrich, and J. T. Dennerlein. 2012. 'Thumb motor performance varies with thumb and wrist posture during single-handed mobile phone use', *J Biomech*, 45: 2349-54.

Tsyrulnik, A. 2015. 'Emergency department evaluation and treatment of wrist injuries', *Emerg Med Clin North Am*, 33: 283-96.

Ugbolue, U. C., A. C. Nicol, and J. Maclean. 2008. 'Development and validation of an electrogoniometric wrist alignment device', *Proc Inst Mech Eng H*, 222: 637-46.
Upjohn, M. M., K. Shipton, D. U. Pfeiffer, T. Lerotholi, G. Attwood, and K. L. P. Verheyen. 2012. 'Cross-sectional survey of owner knowledge and husbandry practices, tack and health issues affecting working horses in Lesotho', 44: 310-18.
Ura, Daniel, Matt Carré, and Javier A. Dominguez-Caballero. 2015. 'Tennis shoe–court interactions: examining relationships between contact area, pressure and available friction', *Footwear Science*, 7: S87-S89.
van Heel, M. C., A. Barneveld, P. R. van Weeren, and W. Back. 2004. 'Dynamic pressure measurements for the detailed study of hoof balance: the effect of trimming', *Equine Vet J*, 36: 778-82.
Van Heel, M. C., M. Moleman, A. Barneveld, P. R. Van Weeren, and W. Back. 2005. 'Changes in location of centre of pressure and hoof-unrollment pattern in relation to an 8-week shoeing interval in the horse', *Equine Vet J*, 37: 536-40.
van Heel, M. C., P. R. van Weeren, and W. Back. 2006. 'Shoeing sound warmblood horses with a rolled toe optimises hoof-unrollment and lowers peak loading during breakover', *Equine Vet J*, 38: 258-62.
van Tulder, Maurits, Antti Malmivaara, and Bart Koes. 2007. 'Repetitive strain injury', *The Lancet*, 369: 1815-22.
Veeger, H. E., L. S. Meershoek, L. H. van der Woude, and J. M. Langenhoff. 1998. 'Wrist motion in handrim wheelchair propulsion', *J Rehabil Res Dev*, 35: 305-13.
Vos, Nicolas J., and Dirk J. Riemersma. 2006. 'Determination of coefficient of friction between the equine foot and different ground surfaces: an in vitro study', *Equine and Comparative Exercise Physiology*, 3: 191-98.
Wang, Y. C., S. R. Magasi, R. W. Bohannon, D. B. Reuben, H. E. McCreath, D. J. Bubela, R. C. Gershon, and W. Z. Rymer. 2011. 'Assessing dexterity function: a comparison of two alternatives for the NIH Toolbox', *J Hand Ther*, 24: 313-20; quiz 21.
Weishaupt, M. A., H. P. Hogg, J. A. Auer, and T. Wiestner. 2010. 'Velocity-dependent changes of time, force and spatial parameters in Warmblood horses walking and trotting on a treadmill', *Equine Vet J Suppl*: 530-7.
White, Laura, Paeden Underwood, Libby Hirtz, Douglas Hogue, and Kelly Walter. 2018. 'Effects of squared-toe or perimeter-fit horseshoes on quality of movement and gait kinematics of the western pleasure horse', *The Professional Animal Scientist*, 34: 488-93.
Willemen, M. A., M. W. Jacobs, and H. C. Schamhardt. 1999. 'In vitro transmission and attenuation of impact vibrations in the distal forelimb', *Equine Vet J Suppl*: 245-8.
Willemen, M. A., H. H. Savelberg, and A. Barneveld. 1999. 'The effect of orthopaedic shoeing on the force exerted by the deep digital flexor tendon on the navicular bone in horses', *Equine Vet J*, 31: 25-30.
Willemen, M. A., H. H. C. M. Savelberg, and A. Barneveld. 1997. 'The improvement of the gait quality of sound trotting warmblood horses by normal shoeing and its effect on the load on the lower forelimb', *Livestock Production Science*, 52: 145-53.
Williams, G., G. Irwin, D. G. Kerwin, and K. M. Newell. 2012. 'Kinematic changes during learning the longswing on high bar', *Sports Biomech*, 11: 20-33.
Wilson, A. M., M. P. McGuigan, L. Fouracre, and L. MacMahon. 2001. 'The force and contact stress on the navicular bone during trot locomotion in sound horses and horses with navicular disease', *Equine Vet J*, 33: 159-65.

Wilson, Alan, and Renate Weller. 2011. 'The Biomechanics of the Equine Limb and Its Effect on Lameness.' in, *Diagnosis and Management of Lameness in the Horse*.

Witte, T. H., K. Knill, and A. M. Wilson. 2004a. 'Determination of peak vertical ground reaction force from duty factor in the horse', 207: 3639-48.

———. 2004b. 'Determination of peak vertical ground reaction force from duty factor in the horse', *Journal of Experimental Biology*, 207: 3639-48.

Won, Erik, Pete Johnson, Laura Punnett, Theodore Becker, and Jack Dennerlein. 2003. 'Gender Differences in Exposure to Physical Risk Factors during Standardized Computer Tasks', *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 47: 1155-58.

Woo, H. C., P. White, H. K. Ng, and C. W. Lai. 2016a. 'Development of Kinematic Graphs of Median Nerve during Active Finger Motion: Implications of Smartphone Use', *PLoS One*, 11: e0158455.

Woo, Hoi-Chi, Peter White, Ho-Kwan Ng, and Christopher W. K. Lai. 2016b. 'Development of Kinematic Graphs of Median Nerve during Active Finger Motion: Implications of Smartphone Use', *PLoS One*, 11: e0158455.

Xie, Y., G. P. Szeto, J. Dai, and P. Madeleine. 2016. 'A comparison of muscle activity in using touchscreen smartphone among young people with and without chronic neck-shoulder pain', *Ergonomics*, 59: 61-72.

Young, Justin G., Matthieu B. Trudeau, Dan Odell, Kim Marinelli, and Jack T. Dennerlein. 2013. 'Wrist and shoulder posture and muscle activity during touch-screen tablet use: Effects of usage configuration, tablet type, and interacting hand', *Work*, 45: 59-71.

Zhang, H. 2016. '2 - Surface characterization techniques for polyurethane biomaterials.' in Stuart L. Cooper and Jianjun Guan (eds.), *Advances in Polyurethane Biomaterials* (Woodhead Publishing).

Ziaei, M., S. H. Nabavi, H. R. Mokhtarinia, and S. F. Tabatabai Ghomshe. 2013. 'The effect of shoe sole tread groove depth on the gait parameters during walking on dry and slippery surface', *Int J Occup Environ Med*, 4: 27-35.

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