The Relationship Between Superficial Digital Flexor Tendon Lesions and Asymmetric Feet in Equine Forelimbs

S J H Hill AWCF

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A. Northrop.
Faculty of Science and Technology,
Anglia Ruskin University,
East Road, Cambridge, CB1 1PT.

R. Burton M.A. (Hons) Cantab, M.Sc (Hons)
10 Westferry Road.
London.
E14 8LS

R. Shave FWCF.
Greenacre, Cow Green, Bacton,
Stowmarket, Suffolk, IP14 4HJ.

S. Curtis FWCF Hon RCVS.
The Forge, Moulton Road,
Newmarket, Suffolk, CB8 8DU.

M. Tyler. BSc (Hons).
34 Main Street.
Belton-in-Rutland

Summary

Reasons for performing this study: For many years vets and horse owners alike have tried to influence the trimming and shoeing techniques undertaken by farriers in the belief that a short toe will help reduce the risk of tendon injuries. The author however, found that tendon injuries were more common in the limb where the foot was smaller and more upright.

Objectives: The objectives were to measure the foot size of the forefeet of horses that have sustained superficial digital flexor tendon (SDFT) injuries, and to measure the forefeet of horses within a control group.

Methods: The measurements of 25 horses with diagnosed SDFT injuries and a control group of 25 horses were used in this study, all of the measurements were recorded. Measurements of the width at the widest part of the foot, the distance between the heels and the distance from the centre of toe to the last bearing surface of the lateral heel were recorded. Disparities between the size of feet of each horse and the relationship between this and SDFT injury were compared. Differences between the injured group and a control group were statistically analysed using a Kruskall-Wallis test of difference. Associations between the smaller foot and the foot that was injured were investigated using a Chi-squared test.

Results: Within the 20 horses that only had injury to the SDFT in one limb, 16 horses had SDFT core lesion injuries to the smaller foot, 1 had a pair of feet and 3 horses had SDFT core lesion injury to the bigger foot. There was a significant difference between the control and injured groups for percentage difference in foot length ($P<0.01$) and percentage difference in the sum of all the dimensions ($P<0.05$).

Conclusion: Tendon injuries in the horse's forelimb have been associated with long toes. This study disproves that theory and highlights the need for further research in to this area. The greater the difference in foot size, the more likely a horse is to rupture the SDFT and ruptures of the SDFT are more likely to occur in the limb with the smaller foot.

Declaration

I hereby declare that the work within this Fellowship thesis is my own. Any sources have been duly referenced and any illustrations or diagrams that are not my own are used with the permission of the owner.

Contents **Page**

Word count, 4953.

Introduction

Anecdotally for many years, horse owners and veterinary surgeons have tried to influence the trimming and shoeing techniques, undertaken by farriers to reduce the length of toe in the belief that this reduces the pressure on the flexor tendons of the forelimb and reduces the chance of sustaining tendon injury. However, the term "long toe" is inconsistently defined. Horses that have large flat feet are often considered to have long toes. A horse with a lesser angle of dorsal hoof wall (DHW) is often described as having a long toe, however, exactly the same length toe may be described as short or normal simply due to a greater angle of DHW. Toe to heel ratio is the major factor and a horse with a low weak heel can give the appearance of the toe looking long.

Stashak (2008) has stated that excessive pastern slope, improper shoeing (short shoeing, shoeing with long toe/low heel, a low hoof angle, toe grabs or club feet) are predisposing causes of tendon injury. Historically, it has been reported that toes that are described as being too long must always increase the strain on the back tendons during locomotion (Mattinson 1922). For every centimetre of toe length in an average Thoroughbred results in 50 kilograms of force acting on the tendons (Weller 2016). However, in cases where the horse has asymmetric feet, foot size and DHW angle appear to be more significant factors affecting tendon injury. Asymmetric feet are common in lots of horses and do not always mean a horse has a club foot. Asymmetric feet are defined as pairs of opposing feet that are not similar in appearance; one foot appears larger than the other with the smaller foot often being more boxy in shape, with the appearance of being more upright. Personal experience shows that horses with SDFT lesions most commonly have the injury to the limb with the smaller more upright foot. Research has shown that the smaller foot is more vulnerable, indicating that horses are less likely to suffer catastrophic musculoskeletal injury (CMI) in the foot with a greater solar surface area (Kane 1998). More recently, it has been reported that Warmblood horses with asymmetric forefeet are likely to retire from competition earlier than horses with symmetrical feet, especially in the case of jumping horses (Ducro 2009). Kummer (2005) found that 70% of Warmblood horses (n=40) had a significantly larger left foot and distal phalanx than the right. It was noted that all the horses in this study were clinically sound and the feet showed no abnormality or distortion, suggesting that asymmetry is a significant occurrence. In a study of flexural deformity in a population of 373 Thoroughbred foals, 75% of club feet were found to be on the right front (Curtis 2012). Any asymmetry in hoof spread measurements may suggest unequal loading of the limbs, which in turn may contribute to injuries and reduced performance (Wilson 2009). Load can be derived as the horse's body weight moving over the weight-bearing limb, causing the phalangeal joints to extend.

With reference to the relation of shoeing practice to the various tendons, reducing the length of toe is proven to reduce the peak strain in the deep digital flexor tendon (DDFT) at the point of break over (Balch 1995). This has very little effect on the strain placed on the superficial digital flexor tendon (SDFT); in fact raising a horse's heels and creating a broken forward hoof pastern axis increases fetlock drop which in turn increases the pressure on the SDFT but reduces pressure in the DDFT (Lawson 2007). A broken back hoof pastern axis (HPA) has the opposite effect and reduces pressure on the SDFT, but increases pressure on the DDFT (Riemersma 1996). Long toes/flat feet are often associated with having a broken back HPA.

The forelimb SDFT is far more likely to be injured than any other tendinous structures in the equine limb, with approximately 90% of tendon injuries in racehorses occurring to this tendon (Ely 2004; Ely 2009). The ground surface of the hoof should be at right angles to the load bearing line, failure to achieve this can have a significant affect on the way both foot and limb are placed, which in turn will affect the foot flight of the limb (Colles 2010). Williams & Deacon (1999) stated that 95% of all horses have some form of foot imbalance which predisposes them to injury.

Tendon injury has been found to be the most common reason for retirement in racing thoroughbreds. Signs of SDFT injury have been found in 24% (n=263) of national hunt horses that were assessed by ultrasound scan (Avella 2009) Additionally, the risk of tendon injury increases with age (Avella 2009; Thorpe 2010). While tendon injuries occurring to horses in other disciplines are less well reported, a small number of studies have shown a significant risk of injury to the SDFT, suspensory ligament (SL) when compared to injuries occurring in the DDFT depending on the discipline undertaken (Murray et al., 2006; Singer et al., 2008).

Tendons

Tendons are longitudinally arranged collagen fibres that act as a tensile communication between muscle and bone to facilitate locomotion as seen in (Figure 1). They are composed of dense connective tissue arranged in parallel densely packed bundles. Peritendon surrounds these bundles and epitendon surrounds the entire tendon unit. Both of these connective tissues carry the blood supply to the internal structures of the tendon.

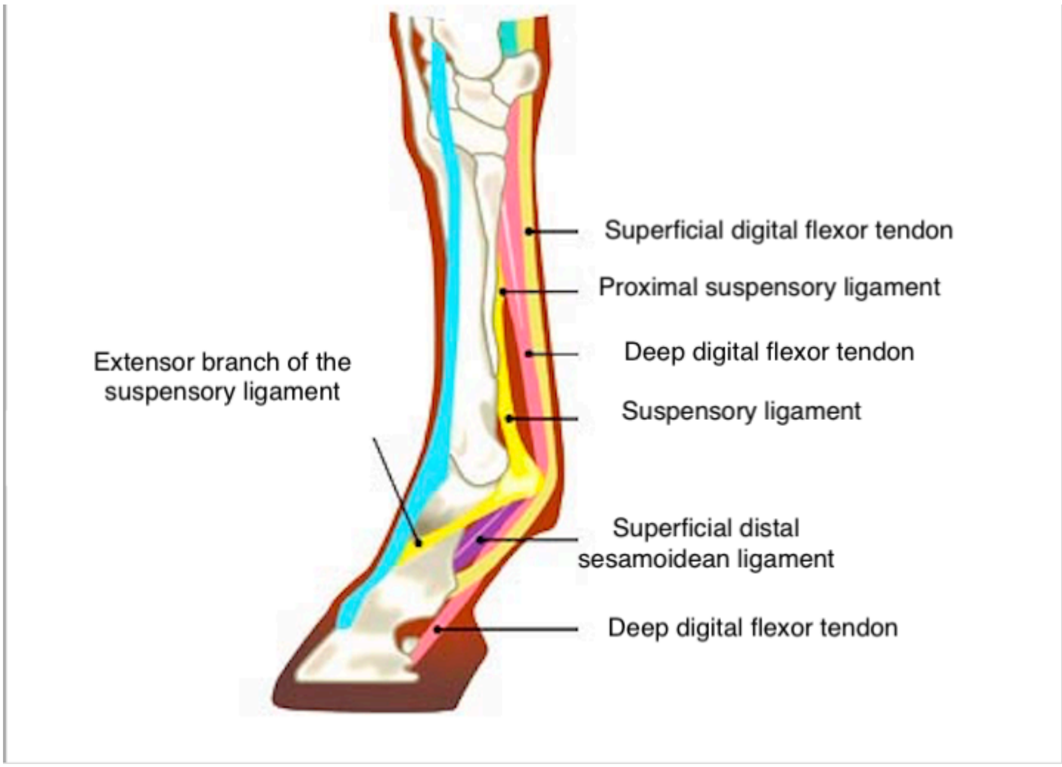

Figure 1. Lateral view showing tendons and ligaments of the lower limb (www.novobrace.com)

The Superficial Digital Flexor Tendon (SDFT)

The SDFT originates from the superficial digital flexor muscle, which originates from the medial epicondyle of the humerus, with the superior check ligament attaching it to the radius proximal to the carpus. Proximal to the fetlock, the SDFT forms a ring through which the DDFT passes through called the manica flexoria. The SDFT continues dorsally where it bifurcates to pass abaxially around the DDFT to insert on the distal-dorsal surface of the proximal phalanx and the proximal-dorsal surface of the middle phalanx. The SDFT, along with the suspensory ligament (SL), plays a major role in the energy recycling system of the forelimb. As the fetlock descends, the kinetic energy created is stored temporarily as strain energy in the SDFT. Elastic recoil converts most of the stored energy back to kinetic energy as the foot leaves the ground (Alexander 1988). This allows efficient locomotion. 5-10% of stored strain energy is released as heat (Ker 1981, Riermersma 1985). The SDFT has a similar function to the Achilles tendon in humans and is unique in its ability to store energy. It can stretch and recoil up to 16% with each stride at gallop, functioning close to its mechanical limit (Stephens 1989). In comparison, the maximum strain of the common digital extensor tendon has been estimated at 2.5% (Birch 2008).

Tendon Injury

Tendon injuries are a breakdown in the matrix that holds the collagen fibres together. Such breakdown in the matrix causes the tendon fibres to rupture. There are several potential causes of tendon injuries. The majority of tendon injuries are thought to occur due to an accumulation of micro-damage over a number of loading cycles, rather than being caused by an acute injury (Riley 2008). As a horse gets older, the elasticity within tendons is reduced, which also increases the risk of tendon injury (Thorpe 2015).

A single overstrain can cause a tendon to rupture and such overstrain can occur as a result of uneven ground creating hyper-extension of the fetlock or slipping due to the fact that a horse is performing close to its mechanical limit (Stashak 2008). A direct trauma whilst the tendon is loaded can also cause damage. Muscle fatigue can result in reduced neuromuscular control and this can cause instability of tendons (Kai. 1999) and therefore increase the risk of overstrain. The DDFT helps stabilise the fetlock joint but is more susceptible to muscle fatigue than the SDFT. This instability can cause further strain to the SDFT. Higher incidences of injury are reported on firmer surfaces (Williams 2001). Studies have shown that when horses are racing, the inside leg in relation to the bend is slightly more prone to injury (Rooney 1981).

Core Lesions

Core lesions are most accurately diagnosed using ultrasound examination (Figure 2). Initial assessment normally demonstrates excessive heat and thickening of the tendon on palpation. The most common site of injury is in the middle third of the metacarpus region (Figure 3). This area is narrower than the proximal and distal parts of the SDFT with more restricted blood supply, it is also proven to degenerate more with age and use than other areas within the tendon (Patterson-Kane 1998). Peripheral tendon injuries can occur and are often accompanied by skin contusions, such injuries can often be tested by pulling the skin away in the affected area and by pinching the skin to see if there is a reaction. This can aid in confirming whether there is direct trauma or not.

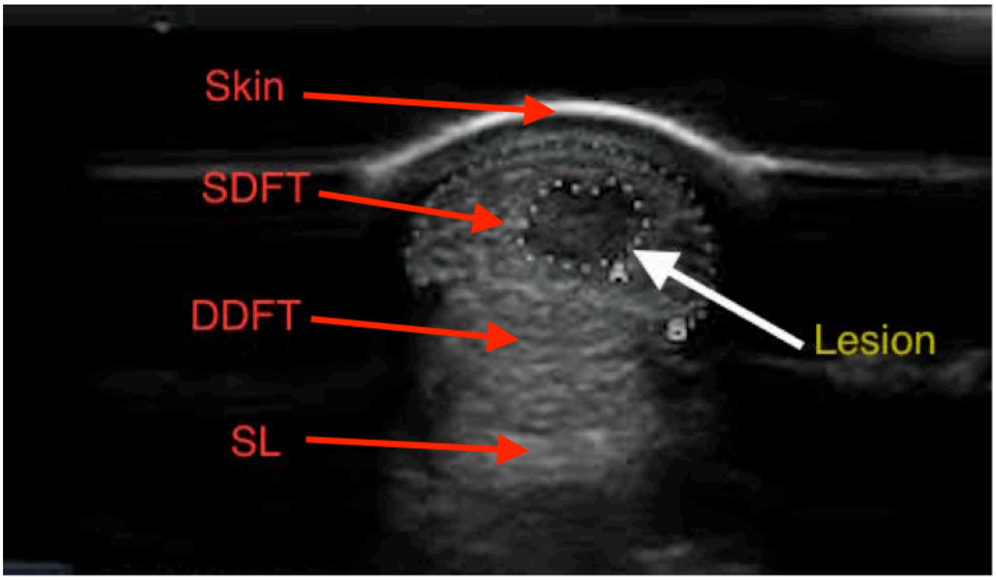

Figure 2. Ultrasound scan showing a core lesion injury to the SDFT. (© Town and Country Vets)

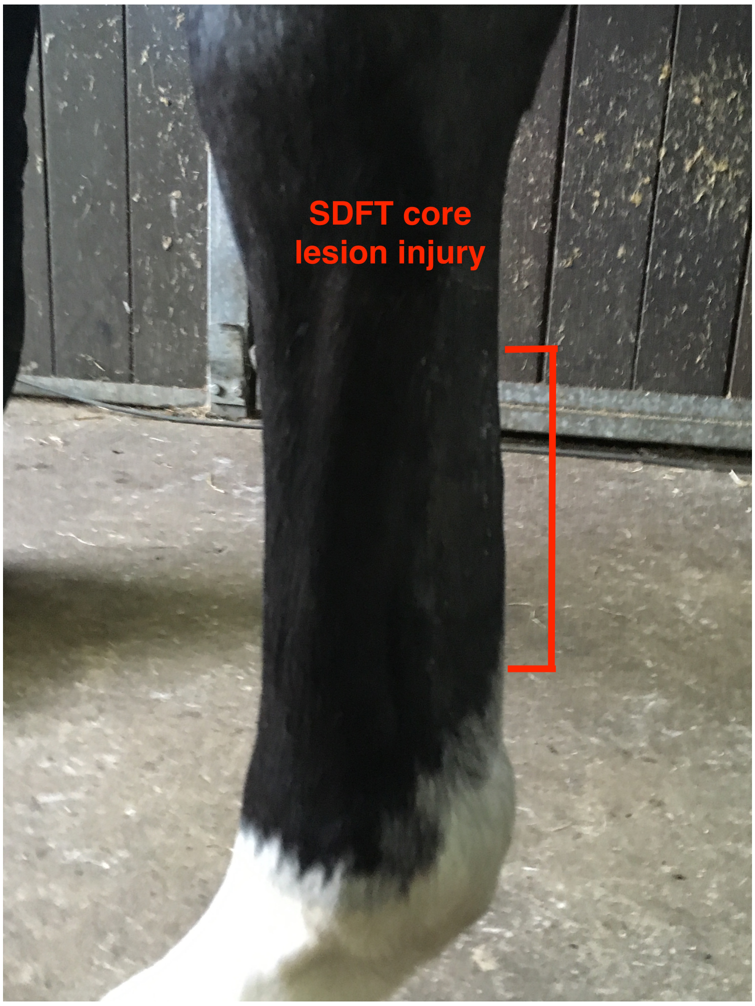

Figure 3. SDFT lesion in the mid third of metacarpal region. (©S.Hill)

The core of the SDFT can reach temperatures of 45°C after seven minutes at a gallop, which is 10°C higher than the temperature of the peripheral surface (Stashak 2008). Prolonged exposure to heat can cause excessive damage to the cells that create the extracellular matrix between the collagen fibres, causing the core of the tendon to rupture (Thorpe 2010). At temperatures above 45°C, cell survival drops dramatically and at 51°C, less than 5% of cells survive (Birch 1997). Poor blood supply in a tendon contributes to an increase in temperature; in addition, the heat is dissipated relatively slowly (Thorpe 2010). Poor blood supply also greatly reduces the speed of the healing process. There is a need to understand more about susceptibility to core lesions in the SDFT, due to its high prevalence in the ridden horse.

Aims and objectives

The aim of this study was to test the hypotheses that 1) lesions to the SDFT are related to asymmetric feet; and 2) where there are disparities in foot size the smaller foot is on the affected limb.

The objectives were to measure the foot size of the forefeet of horses that have sustained SDFT injuries; to measure the forefeet of horses within a control group, and to compare the size difference between the feet of each horse. These measurements were to be statistically analysed in order to identify differences between the control and injured groups, in order to explore the relationship between the smaller foot and the affected limb and to test whether the limb with the smaller foot was more susceptible to SDFT injury.

Methods & Materials

Selection of SDFT lesion horses

All horses that were selected with SDFT lesions, were owned by customers of the author. All horses with a superficial SDFT injury were diagnosed and confirmed with ultrasound scans by a veterinary surgeon. All injuries were core lesion injuries in the forelimbs and not direct trauma injuries.

Selection of control group horses

The control group was a selection of convenience, comprising of (n=25) horses that were measured using the same methods as described below. The control group consisted of the first (n=25) horses that the author was granted permission to include within the study. Horses were of mixed breed and type and used for various types of work. Written permission was granted from the owners of all the horses used in the study. There was no ethical concern with this study as no change was made to the way horses were shod or treated.

Trimming and measuring protocol

All horses were trimmed and measured by the author to avoid inconsistency. The frogs were trimmed symmetrically to gauge the heel height of each foot and the hoof proportions. Any exfoliating sole was removed and the hoof wall bars and heels were trimmed to achieve a level plane, correct HPA and symmetrical proportions where possible, ready to receive a shoe, shod in leisure horse style. This often meant reducing the heel height more on the smaller more upright foot. Dorsal wall flares were dressed to try and achieve symmetry where possible and equal wall thickness around the toe. The bearing border of the hoof capsule was trimmed perpendicular to the long axis of the flexor tendons. No rounding of the distal border of the hoof was carried out prior to measuring. The author measured the widest part of each foot (Figure 4), the width between the heels (Figure 5) and the distance from the centre of toe to the lateral heel (Figure 6) in millimeters (mm) using a brass rule[4]. The angle of the dorsal hoof wall (Figure 7) was also recorded using a brass hoof gauge[3] while the foot was non-weight bearing.

Figure 4. Widest part of the foot (© S.Hill) **Figure 5. Width between the heels(© S.Hill)**

Figure 6. Distance from the centre of toe to the lateral heel. (© S.Hill)

Figure 7. Angle of dorsal hoof wall (DHW) (©S.Hill)

Data collection and analysis

The measurements were recorded using separate forms for each horse taking note of the horse's age, breed and type of work the horse was used for, which limb/limbs were affected and when and how the injury happened (if known). The measurements were recorded in Excel[1]. The limb with the tendon injury was recorded, together with the age of the horse at the time of injury and the type of work being undertaken. Photos were recorded to demonstrate the findings for either foot and/or tendon.

The three measurements of each foot (width of foot, width between heels and distance from toe to lateral heel) were all added together to give a single number in order to compare size difference between feet. Calculations were converted into a percentage to allow for direct comparisons between subjects. The bigger foot was said to be % bigger than the smaller foot. The data was analysed using Minitab[2] to test for any statistical associations and differences.

Statistical analysis

The data was checked for normality and it was found to be non-parametric; it was not normal. Data was analysed using a Kruskal-Wallis test to identify if there were any significant differences between the hoof morphology of the injured and control groups. Additionally, data was analysed to investigate significant associations between left or right smaller foot against whether the injury was on the smaller foot. The test that was used for this was a Chi-Squared test.

Qualitative Observations

Horses were visually assessed both statically and dynamically. The horse's lower limb was assessed whilst non-weight bearing to observe any limb deviations. The author noted the conformation of each limb and foot comparatively within bilateral pairs. The movement of each horse was assessed visually at walk and recorded using Coaches Eye[5] software to evaluate the foot flight of each limb.

Results

Hoof morphology; differences between the smaller and larger foot

Within the group with the SDFT injury, (n=18) horses had a smaller right fore (RF), (n=6) had a smaller left fore (LF) and (n=1) were measured to have an evenly sized pair of feet, (n=25 in total). Within the control group, (n=12) horses had a smaller RF, (n=12) horses had a smaller LF, and (n=1) had an evenly sized pair of feet. The findings within the injured group found that 72% of horses had a smaller right fore. (Figure 8)

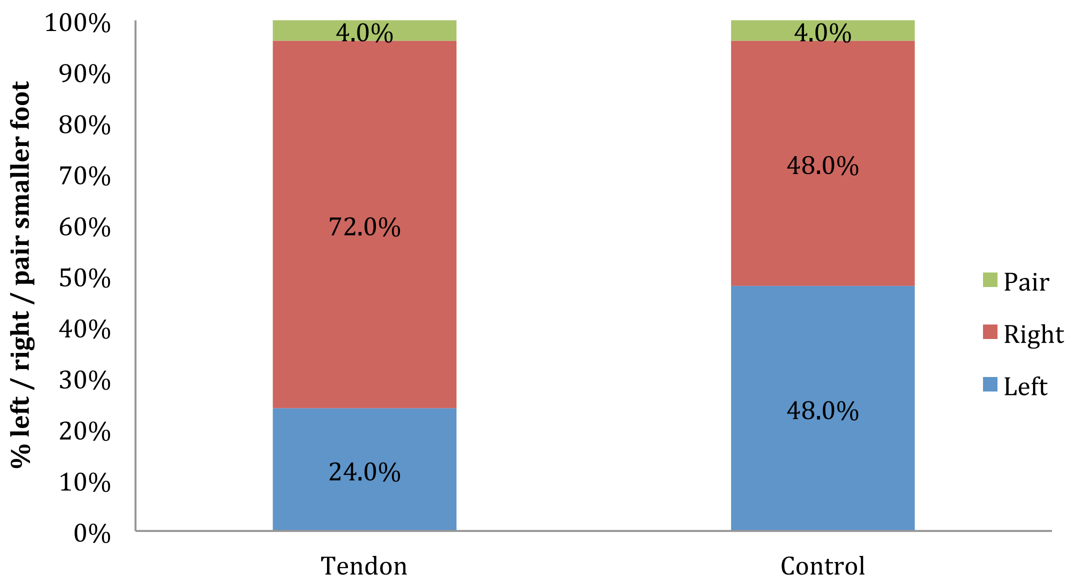

Figure 8. The percentage (%) of left and right smaller foot or pair in the SDFT injured group (Tendon) and the control group (Control).

When compared, (n=12) horses had a core lesion injury in the SDFT in the RF, (n=8) in the LF and (n=5) had SDFT core lesion injury in both forelimbs. Within the (n=20) horses that only had injury to the SDFT in one limb, (n=16) horses had SDFT core tendon injuries to the smaller foot, (n=1) had a pair of feet and (n=3) horses had SDFT core lesion to the bigger foot. (Figure 9)

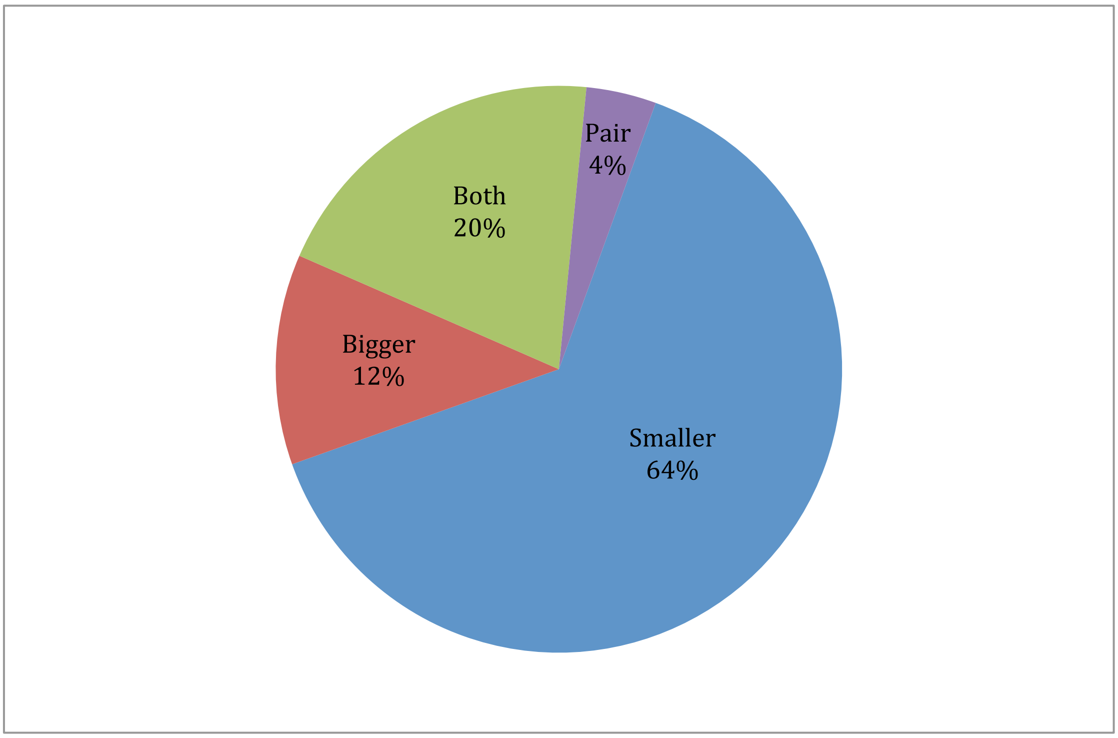

Figure 9. The number of horses, by percentage (%), with a SDFT injury in the smaller or bigger footed limb, SDFT injury to both limbs, or if the horse had a pair of feet.

Using a Kruskal-Wallis test of difference, there were no significant differences between the control and injured groups for percentage difference in foot width (P=0.65) or percentage difference in heel width (P=0.80). There was however, a significant difference between the control and injured groups for percentage difference in foot length (P=0.006) (Figure 10), and percentage difference in the sum of all the dimensions (P=0.049) (Figure 11).

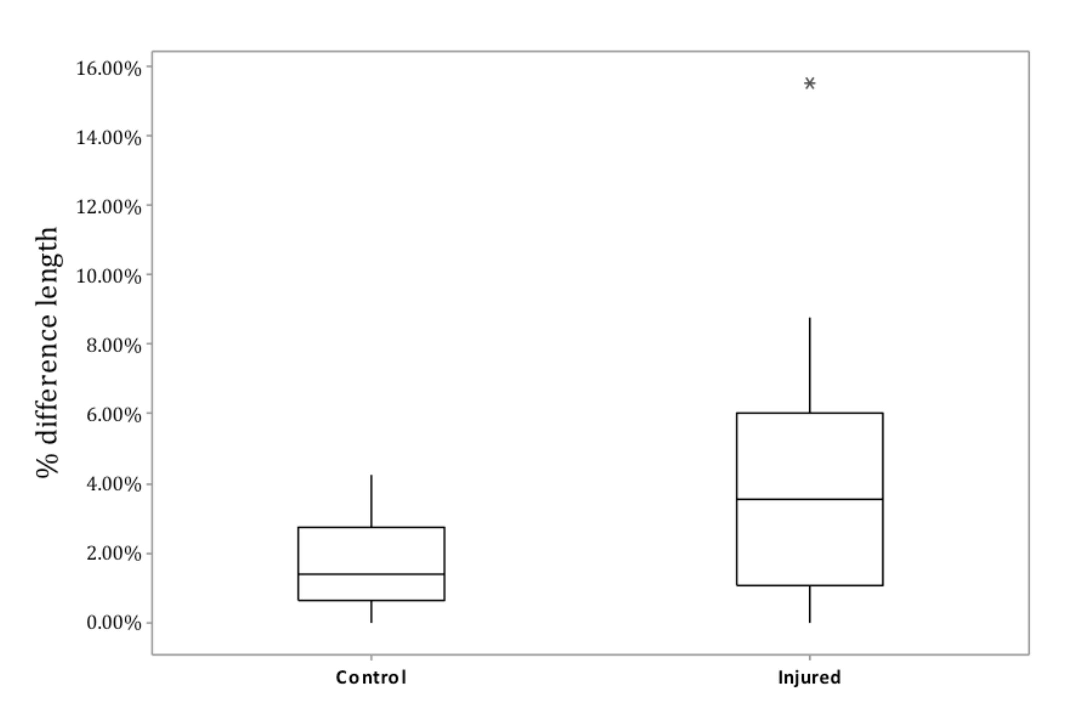

Figure 9. Percentage difference in the foot length between the smaller and larger foot, comparing the control and injured groups; there was a very significant difference between control and injured horses (P<0.01).

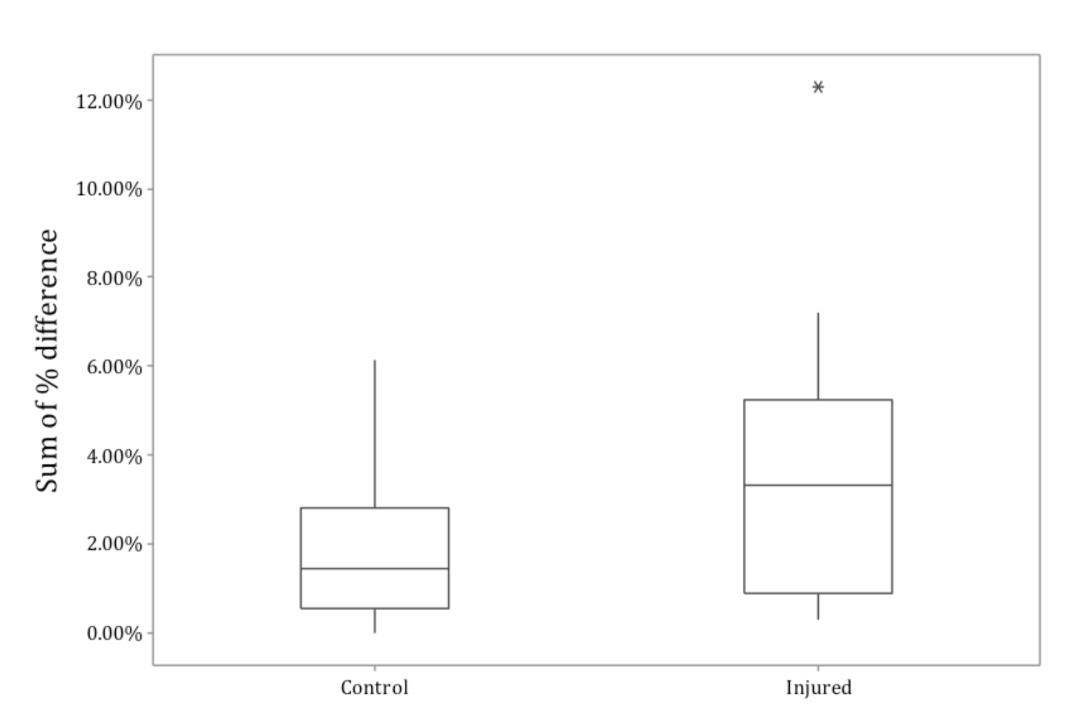

Figure 10. Percentage difference in the sum of all foot dimensions between the smaller and larger foot, comparing the control and the injured groups; there was a significant difference between the control and injured horses (P<0.05).

Association between injury and smaller foot

The smaller foot was identified as being either the left or the right foot. One horse was identified as having feet of the same size and this horse was not included in this analysis. Therefore, 96% (n=24) of the horses with a limb injury presented either the left or the right foot as smaller. From this sample, 25% (n=6) have a smaller left foot and 75% (n=18) were found to have a smaller right foot. There were a relatively high percentage of horses that demonstrated injury in the limb that was the smaller foot (67%, n=16). A Chi-Squared test was carried out to investigate the association between the limb the injury was presented on and the smaller foot. There was a significant association (P=0.008) found between the smaller foot and the corresponding limb that the injury was on (Figure 12).

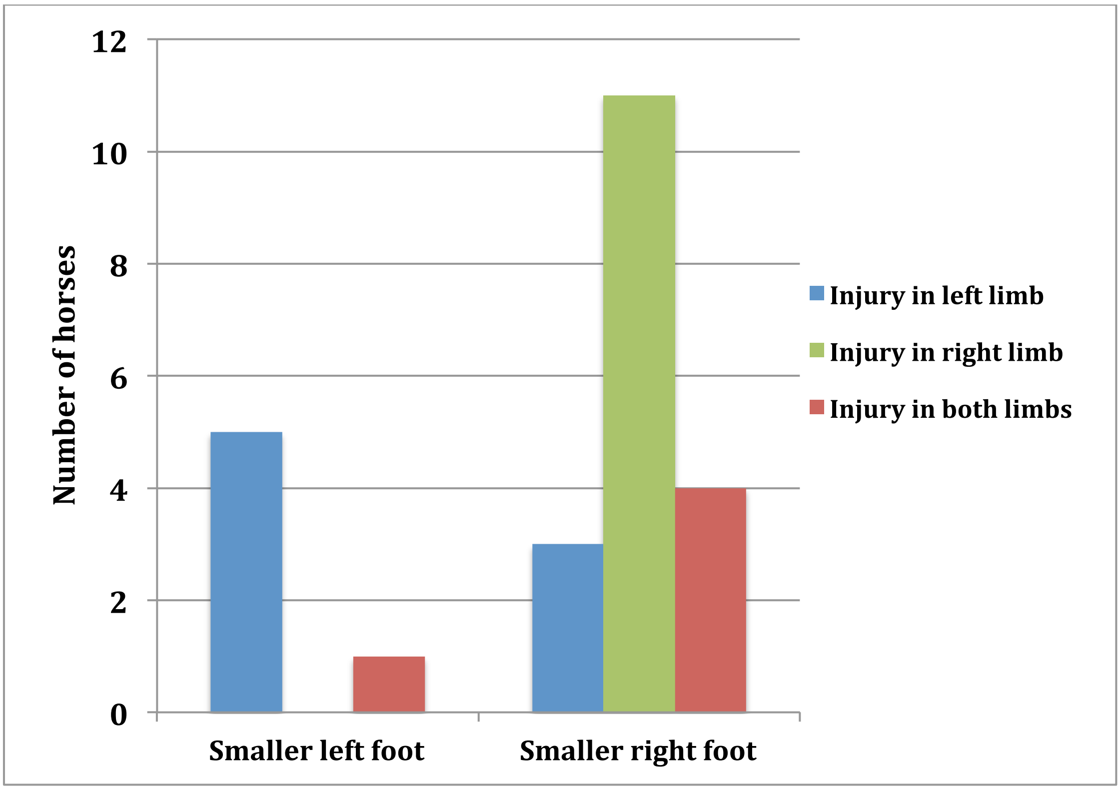

Figure 11. Frequency of the relationship between the smaller foot and the injured limb. There was a significant association between the smaller foot and the limb the injury was on (P<0.01).

Discussion

The aim of this study was to test the following hypotheses.

1) SDFT lesions are related to uneven feet; this was proven. After testing, the percentage difference between pairs of feet was significantly greater within the group with the SDFT injury compared to the percentage difference of the control group ($p<0.05$).

2) Where there are disparities in foot size, the smaller foot is on the affected limb. This was also proven and the results were highly significant. The greatest difference within pairs of feet was found to be in the distance from toe to lateral heel ($P<0.01$). This was also the measurement that the author felt was increased in length of the smaller foot due to the trimming protocol. The author believes that without the prior intervention of standard farriery, these measurements would have displayed even greater significance.

These results suggest that the greater the difference in foot size, the more likely a horse is to have a SDFT core lesion injury. These results also demonstrated that a horse is more likely to have a core lesion in the SDFT in the limb with the smaller foot.

The number of horses with a smaller right fore within the injured group was similar to (Kummer 2005) where it was found that 70% of horses had a smaller right fore and Curtis (2012) also found that 75% of foals studied had a club foot on the right fore. However the control group showed equal numbers of horses with smaller left and right feet.

Kane (1998) showed that catastrophic muscular injuries (CMI) were less likely to occur in limbs where the ground surface area and foot width were greater. CMI was not categorized solely as SDFT injuries but also included SL damage and DDFT injuries. Nevertheless Kane's results support the findings of the present study.

Wilson (2009) suggests that a foot with a lesser DHW angle is often subjected to greater loading. The author observed that flatter feet with a lesser DHW angle have a greater hoof spread than that in smaller more upright feet. The author believes that a foot with more hoof spread has greater shock-absorbing abilities that will reduce the amount of vibration and peak stresses sent through the limb.

Although the angle of the DHW was measured and recorded, statistical testing was not undertaken. The author considered the difficulty in achieving a straight DHW when trimming more upright feet, due to the natural DHW concavity often associated with such foot conformation. Measuring the DHW angle after trimming often reduced the difference between pairs of feet in the attempt to achieve correct HPA. Moleman (2005) found hoof gauges to be an inaccurate method of measuring hoof wall angle (HWA) when compared to the use of radiographs, suggesting that viewing a foot laterally without the use of radiographs may be misleading in assessing hoof conformation. Horses with long toes often have a broken back HPA. Riesmersma (1996) states that lowering the heels of the foot and thus creating a possible broken back HPA increases strain on the DDFT but reduces strain on the SDFT. This mechanical alteration in limb balance would move the fetlock dorsally, thus reducing the tension on the SDFT as it passes over the metacarpal-phalangeal articulation (fetlock joint), but would have an opposite effect on the DDFT as the distal interphalangeal articulation (coffin joint) would move caudally. This supports the author's findings that feet with longer toes are less likely to suffer SDFT injuries, whereas a more upright foot would. Horses with asymmetric feet would appear to have more heel to trim off the more upright foot when being shod/trimmed each time in order to achieve correct limb alignment, this could be caused by an underlying predisposition such as limb length disparity or flexural contraction which can cause a focal point of load. This increase in heel height between shoeing cycles will cause the fetlock joint to drop and in turn increase the strain on the SDFT.

Moving the point of breakover back, towards the centre of rotation of the distal interphalangeal joint reduces the length of the moment arm, reducing the strain on the DDFT (Balch. O 1995). The amount of force applied to the structures of the back of the limb has not changed, so reducing the strain on the DDFT will in turn increase the pressure on the other structures (SDFT & SL).

To date most studies concerning tendon injuries and catastrophic muscular injuries have assessed biomechanics on a sagittal plane rather than a 3D view. Few have taken into consideration the medial lateral and or torque movement.
When viewed from in front at a walk, the author noticed that horses who had asymmetric feet had different limb conformation and foot flight from each other. The limb with the smaller more upright foot displayed a greater degree of vertical axis rotation, offset knee and/or foot, had a tendency to land lateral heel first and then shifted the load on to the medial heel. The smaller foot often displayed medial/lateral asymmetry as a result of uneven loading.

Load is when the horse's bodyweight moves over the weight-bearing limb causing the phalangeal joints to extend. Even loading is when the metacarpophalangeal joint (fetlock) descends equally between the bulbs of the heels. Uneven loading causes the fetlock to descend over one heel more than the other. A horse that lands lateral first usually causes the fetlock to descend over the medial heel more. The effect of this is that the fetlock descends in an arc rather than a vertical plane; this in turn causes a torque or spiral effect as the limb is being loaded. The foot flight of a limb that lands lateral first has a tendency to wing in and then move laterally just before the foot is placed on the floor, this is the horse trying to achieve level footfall. When the limb does not travel in a straight line from breakover to foot placement, a greater distance is travelled and therefore more energy is used. Energy cannot be created or destroyed; it can only be changed from one form to another. Science defines heat as the flow of energy from a warm object to a cooler object. Heat energy is the result of movement; extra movement will manifest as heat [temperature] (Ker 1981). This will also cause more fatigue to the structures involved. Ker (1981) suggests that 7% of energy is lost with each cycle.

Some horses may appear to land level, but in fact do not load equally, with the fetlock descending over one heel more than the other. Horses that do not land or load evenly do not recycle the kinetic energy efficiently. Energy is transferred into heat, which will weaken a structure making it more susceptible to injury. The hotter the tendon becomes, the less chance of cell survival within the matrix holding the collagen fibres together, allowing the tendon to rupture. Further research is needed to test whether there is more heat within the tendon on the more upright limb whilst a horse is at work.

Williams (2001) states that horses are more likely to suffer injuries on harder ground. Harder ground is less sympathetic to any imbalance and uneven loading in a horse's limb, therefore causing more vibration that manifests as heat. Rooney (1981) found that horses in racing were more likely to break down on the inside leg and it is the author's view that Rooney's findings are the result of greater imbalance and greater loading on that leg. The inside leg is more likely to land lateral first whilst on the turn. Any imbalance of a limb is exaggerated on the inside leg due to the fact that the horse is leaning on that side in order to go round the bend.

During this study the author found that in the 5 horses that had SDFT injuries to both limbs, the severity of damage that could be palpated within the tendon of the smaller footed limb was far greater. This supported the findings that the greater damage occurred to the smaller footed limb.

The author observed that out of the (n=25) horses with SDFT injuries, (n=13) had asymmetric feet prior to injury. However, through experience, the author believed that all of the horses would have had asymmetric feet from a young age and that injury was not the cause of asymmetry due to non-weight bearing on the injured limb.

Study Limitations

The author took hoof wall angle (HWA) measurements of all the feet. However, it was felt that trimming protocol reduced the difference between the hoof wall angles due to the fact the heel height was reduced more in the smaller foot. This also increased the length of the horse's foot, which would negatively affect the results by increasing the total sum of measurements and therefore reducing the chance of showing which is the smaller foot. The smaller, more upright foot was often found to have a dorsal dip making it difficult to achieve a level plane on which the hoof gauge can rest.

Although every care was taken by the author when measuring the horses' feet, human error will always be a factor. If the study were conducted again the author felt the use of image analysis software would enable the surface area of the sole to be measured more accurately, providing a better comparison in foot size.

Farrier consideration.

A Farrier should observe a horse's balance both statically and dynamically before trimming a horse's foot. The requirements of each individual limb need to be considered in order to allow the foot and limb to land, load and push off in the most efficient way to minimise muscle and tendon fatigue. Rarely do both feet need trimming in the same manner. More attention is needed to the medial-lateral balance to achieve level footfall and loading, this can only be achieved by watching the horse walk.

If a horse's foot is not symmetrical then it is not bearing weight evenly and the farrier and/or veterinary surgeon needs to consider why and where, the uneven loading is coming from. Reducing the height of heels to restore correct hoof proportions aiming to achieve dorsal/palmer symmetry within the hoof capsule and a correct HPA, this will often result in the heel height in the smaller foot being trimmed more. Reducing the dorsal hoof wall thickness in the toe region does not change the angle of the pedal bone. It only gives the impression that the horse's foot is anatomically correct and can lead to weakening the integrity of the hoof capsule. Positioning the shoe to support the limb as it loads will help to distribute the forces more evenly and therefore reduce the chance of injury. Bringing the point of breakover back will reduce peak force on the DDFT but may increase the force on other structures, which are known to have a higher instance of injury when compared to the DDFT.

Conclusion

The conclusions drawn from this study are:

1) The historical opinion that tendon injuries in the horse's forelimb are associated with long toes is incorrect when relating to the injury to the SDFT. The SDFT is reported to be the tendon involved in over 90% of tendon injuries.

2) Modern shoeing techniques are undertaken in the belief that reducing the toe length or by moving the breakover point back, reduces the chance of injury to the flexor tendons, this may aid in the prevention of DDFT injuries, but can also exacerbate the chance of injury occurring in the SDFT. Where horses have asymmetric feet, the limb with the smaller foot is more likely to sustain a SDFT injury.

3) Horses with larger difference in hoof size within pairs of feet are more susceptible to tendon injury.

4) Conformation for soundness is often overlooked with fashionable exaggerated movement taking priority in the breeders mind. This comes at a cost as asymmetry in horse's feet and limbs are proven to reduce a horse's working life. Conformation is a major factor to the cause of SDFT injuries; more attention is needed when breeding horses. This study highlights the need for further research in this area.

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Manufacturers Addresses

1. Excel 2007 (version 12); Microsoft Corp, One Microsoft Way, Redmond, WA98052-6399, USA.

2. Minitab 17, Minitab Ltd.; Progress Way, Binley Industrial Estate, Coventry, CV3 2TE, UK.

3.Brass hoof gauge. Anvil Brand Shoe Co. 500 S. Spencer St. P.O. Box 198. LEXINGTON, IL 61753,UNITED STATES

4.Brass Rule. Jim Blurton Ltd. Rose Hill. Kingswood. Forden. Welshpool. Wales. UK.

5. Coaches Eye, TechSmith Corporation, 2405 Woodlake Drive, Okemos, Michigan, 48864-5910 UNITED STATES

Appendices

Consent letter

Recipient Address
xxxxxxxxxxxxxxx
xxxxxxxxxxxxxxx
xxxxxxxxxxxxxxx
xxxxxxxxxxxxxxx
xxxxxxxxxxxxxxx

Stephen Hill AWCF
Home Farm
Belton
Rutland
LE15 9JT

10 September 2015

Dear XXXX,

I am currently developing a case study in which I am examining the correlation of asymmetric feet and tendon injuries in the forelimbs of horses.

Therefore I intend to invite owners of horses with tendon injuries to be included in this study.

With regard to my request to include your horse as part of a case study approach to my Fellowship of the Worshipful Company of Farriers dissertation, I have put together the following details.

Details of study:

1. *The names of horses and owners will be withheld to ensure anonymity and confidentiality.*
2. *All information and photographs/recording material will be securely stored.*
3. *The use of photographs and video recordings will be utilised as a means of examining the premise of my thesis. These materials may have to be utilised as part of a thesis presentation to confirm my findings.*
4. *A copy of the dissertation/case study will be made available to the owner.*
5. *It is my intention that parts of the paper will be submitted for inclusion in appropriate publications.*

If you are satisfied with the terms as laid out in this letter and consent to your horse participating in this study, please sign and date below.

Yours sincerely,

Stephen Hill

Owner signature:

Date of signature:

Email from Novobrace giving permission to use their image.

Hello Stephen,

Yes, you may use images on our site for your thesis; please give credit to www.novobrace.com as warranted.

Have a good week and good luck on your exams.

Sincerely,

Dee Fife
Equinext, LLC
+1 859.421.0032

Consent email from Town and Country Veterinary Centre.

I can confirm that I have consented for Stephen Hill to print and present images I have provided of the cases he has worked on.

John Abbott BVM&S CertEM(IntMed) Dipl. ECEIM MRCVS

Town and Country veterinary centre
Le16 9HE

Sent from my iPhone