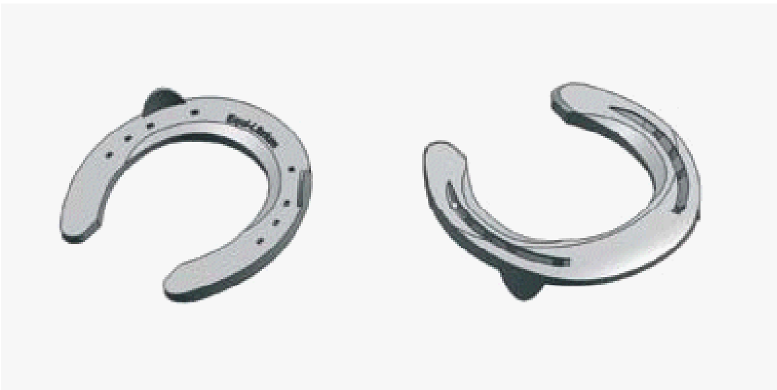
A comparison between the effects of the aluminium keg shoe and the EquiLibrium® shoe on the loading pattern of the front hooves in Thoroughbreds



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Summary

The aim of this pilot- study was to compare the effects of the standard racing shoe, i.e. the keg shoe, and the Equilibrium® shoe on the loading pattern of the front hooves of six Thoroughbreds using a pressure measuring system (Rsscan®).

Due to technical problems the objective of using six horses has not been met. Therefore only three adult Thoroughbreds were trotted by hand in a straight line across a pressure measuring system. The horses were randomly shod with either the Equilibrium® or the keg shoe, after which they were given three days to get used to them. After data collection the horses were shod with the other type of shoe. Three valid measurements of each front hoof for both types of shoes were obtained.

Certain tendencies could be identified using the data collected in the current study. When comparing the Equilibrium® shoe to the keg shoe it appears that the maximal ground reaction force is higher, the duration of landing is shorter, and the centre of pressure remains in closer proximity to the sagittal hoof axis during break- over.

Due to technical problems encountered during data collection and the development of forelimb lameness in two of the horses, only the data of one horse could be used in the current study. Therefore no conclusions can be drawn from the current results, and further research is needed on this subject.

Introduction

Hoof conformation

Different parameters are used to describe the conformation of the equine hoof. One of the most commonly used parameters is the hoof angle: the angle between the dorsal hoof wall and the ground surface or solar surface of the hoof wall. The hoof angle influences the way a horse distributes its weight between the dorsal and palmar parts of the hoof during ground contact.

A lot of discrepancy exists between authors as to the normal angle of the equine front hoof. Originally a standard hoof angle was defined by Stashak as an angle between dorsal hoof wall and ground surface of 45^o to 50^o. A low hoof angle is thus defined as an angle of 45^o or less, a large angle as an angle over 50^o.

Another parameter describing hoof conformation is the angle between the caudal part of the hoof, i.e. the heels, and the ground surface or solar surface of the hoof wall. From the two aforementioned parameters a third one can be defined: the toe- heel angle difference. A term used to describe hoof conformation using the third parameter is the term underrun heels, which is defined as a toe- heel angle difference of 5^o. (Marks, 2000; Kane *et al.*, 1998)

Roland *et al*. (2003) also examined the medio- lateral variations in several parameters describing the conformation of front feet in Thoroughbreds. They found a medio- lateral asymmetry in width of the solar surface of the hoof and of the hoof- wall angle, in which the solar surface was larger on the lateral side and the hoof wall of the medial side was steeper. Horses that had sustained musculoskeletal injuries during racing appeared to have a lesser degree of asymmetry, which might have contributed to the development of the injuries. This theory is supported by Kane *et al*.

Horses with a low hoof angle will bear more weight on the caudal parts of the hoof, i.e. the heels, in comparison to horses with a normal or standard hoof angle. Structures in the weight- bearing part of the hoof will be compressed, which will cause the horn tubules in the caudal part of the hoof to grow more slowly, thus leading to a vicious circle of underrun heels and a long toe.(Dyson and Marks, 2003; Kane *et al.*, 1998)

Hoof angles of less than 45^o and underrun heels are associated with lesions of the palmar structures of the lower limb, again caused by the greater load placed on the caudal or palmar part of the limb. The strain on the deep and superficial digital flexor tendons is larger, as is the pressure on the distal phalanx and the navicular bone and bursa. (Marks, 2000; Eliashar *et al.*, 2004; Ovnicek *et al.*, 2003) The long toe- underrun heel conformation also causes the pastern to move forward, thus creating a broken- back hoof-pastern axis. This may subsequently contribute to, for example, joint effusion. (O'Grady and Poupard, 2003)

Previous studies on the association between hoof conformation of Thoroughbred racehorses and the prevalence of musculoskeletal injuries have shown that lower toe and heel angles increase the risk of racehorses sustaining musculoskeletal injury. Additionally, Balch *et al.* concluded that the severity of underrun heels is a significant risk factor in the development of lesions of the soft tissues of the lower limb in racehorses. (Kane *et al.*, 1998; Balch *et al.*, 2001)

Prevalence of underrun heels in Thoroughbred racehorses is reported to exceed 97%, which suggests that this hoof conformation might be hereditary to this breed. (Balch *et al.*, 2001) Another study however has shown a potentially large effect of gallop training on hoof angle as well. Horses at the gallop tent to land heel first, which causes the heels to expand and lower towards the ground, thus compressing the horn- producing structures of the caudal part of the hoof. This will lead to a slower growth of the hoof wall in the heel region, thus lowering the toe- heel angle difference. The same study showed a possible association between pasture and bedding conditions and hoof angle, in which wet conditions also tent to lead to a decreased hoof angle. (Peel *et al.*, 2006) It is also common practice in the racehorse industry for farriers to trim the feet of Thoroughbreds towards a lower heel and long toe, as this is supposed to elongate the stride of the horse.(Eliashar, 2007)

The stance phase

Studies on the weight bearing pattern of the untrimmed, unshod front feet of feral horses maintained on pasture have shown that the solar surface of the hoof wall bears a large proportion of the weight of the horse. In these studies it was concluded that the loading pattern of the hoof wall comprises four main loading- points: the heels in the caudal part of the hoof and two points medial and lateral to the toe dorsally. After trimming, the area of contact between the hoof and ground surface is enlarged, and thus the four- point loading pattern is lost. (Hood *et al.*, 2001; Ovnicek, 1995)

The stance phase of a stride can be divided into four phases: initial contact (IC), mid-stance (MS), heel- lift (HL) and toe-off (TO). The moment of initial contact is defined as the moment of first contact of the hoof with the ground surface. In horses with underrun heels, landing is usually toe- first, instead of heel- first. During mid- stance the GRF is maximal, and during heel lift the GRF shifts swiftly from a palmar to a dorsal position. Toe- off is the moment the foot leaves the ground. The process of break over can be defined as the phase between heel- lift and toe- off. (Heel *et al.*, 2006; Clayton, 1990; Parks, 2006) In horses with a long toe and underrun heels, the break over process is thought to be significantly delayed. (O'Grady and Poupard, 2003; Page and Hagen, 2002)

A line to describe the point of break over is formed between the 2 most cranial loading-points, approximately 2,5 to 4 centimeters cranial to the point of the frog. (Eliashar *et al.*, 2002; Hood *et al.*, 2001; Ovnicek *et al.*, 2003) Page *et al.* however related the position of the break over point of the hoof capsule to the third phalanx. They defined the point of break over as the most dorsal location of the solar aspect of the hoof capsule to contact the ground. (Page and Hagen, 2002)

The process of break over is initiated by tension in the deep digital flexor tendon (DDFT) and forces on the distal interphalangeal (DIP) joint, thus rotating the heels. As the DDFT inserts on the navicular bone, forces on this bone are highest during start of break over.

The DIP joint is extended by the ground reaction force (GRF), the force applied to the hoof by the ground. The dimension of the GRF is determined by the weight of the horse and the speed of movement, and described by the point of zero moment (PZM) of the centre of pressure (CoP). During the stance phase of a stride the PZM, and thus the GRF, moves from the palmar part of the solar surface towards the toe. During initial contact and toe- off the GRF is low, and during mid- stance it peaks. (Eliashar *et al.*, 2002; Page and Hagen, 2002; Hood *et al.*, 2001)

Trimming and shoeing

By shoeing the feet of horses the four- point loading pattern is lost, and instead the area of contact between the ground and the hoof is enlarged, especially along the hoof- wall. (Hood *et al.*, 2001)

The process of hoof unrollment, and break over, is believed to be influenced not only by speed of movement, hoof angle and pathological changes, but also by trimming and shoeing. (Heel *et al.*, 2006; Clayton, 1990) Certain types of shoes, for example the rocker-toe shoe and the rolled-toe shoe, and ways of trimming are believed to ease the process of break over. Page *et al.* have shown that a decrease in break over distance after trimming leads to an improvement in the alignment of the second and third phalanx, a proximal movement of the navicular bone and a decreased strain of the deep digital flexor tendon on the navicular bone. (Page and Hagen, 2002) Eliashar *et al.* concluded that the use of Natural Balance shoes, in which the toe is pulled back, reduces the moment arm of the ground reaction force during break over. (Eliashar *et al.*, 2002)

Recently, the Equilibrium® shoe has been developed by Mustad® Hoof care. One of the most distinct features of this shoe is the rounded toe, designed to ease the process of hoof-unrollment. Previous studies have shown that the Equilibrium® shoe has a positive effect on the peak limb loading and the process of break over in sound Warmblood horses. The peak limb loading is lowered compared to a standard shoe and the movement during break over is better coordinated and more fluent. Consequently, the loading of the joints and tendons in the equine digit will be less abrupt and less high. (Heel *et al.*, 2006)

Aim of the study and hypotheses

The aim of this study is to compare the effects of the standard racing shoe, i.e. the keg shoe, and the Equilibrium® shoe on the loading pattern of the front hooves of 2 adult Thoroughbreds. Loading patterns were acquired by trotting the horses across a pressure plate, the RsFootscan®.

The hypotheses tested in the current study are: when comparing the Equilibrium® shoe to the keg shoe, the duration of break over will be shorter, the peak load during break over will be lower, and the centre of pressure will remain closer to the central hoof axis during break over.

Materials and Methods

Horses

Originally the aim of the current study was to collect data of six clinically sound adult Thoroughbreds. Due to technical problems however this objective has not been met.

Three clinically sound adult Thoroughbred horses were used in this study. The horses have been trained for racing, but are now retired. Weight of the horses was estimated at between 500 and 550 kilos. Height at the withers was estimated at about 1.65 meters for all three horses.

Shoeing procedure

An experienced farrier was involved in our research project. He was instructed to trim the hooves towards a straight hoof axis (seen from the front).
Horses were shoed at random order. For example, horse number 1 was shod with the Equilibrium® shoe first, horse number 2 with the keg shoe. After shoeing, the horses were given three days to get used to both types of shoes. After data collection both horses were shod with the other type of shoe, i.e. horse number 1 with the keg shoe and horse number 2 with Equilibrium® shoe.
The time between two shoeing-sessions was short so that the same nail holes could be used. Also, as the hoof grows several parameters will change. In order to minimize the variables involved the shoeing interval was reduced as much as possible. (Eliashar, 2007)

Data collection

The horses were trotted by hand across a pressure-measuring system, after cleaning the solar surface of the feet using a hoof pick and a wire brush.
Galisteo *et al.* concluded that horses trotted by hand tend to spontaneously repeat their trotting speed. Since several stride parameters are known to be influenced by trotting-velocity, it was important that the horses were able to trot at a speed which was comfortable to them. (Galisteo, 1998)

The Rsfootscan® is a pressure- plate that contains small pressure sensitive polymer sensors (5mm* 7mm). This allows accurate analysis of pressure deviations under all regions of the hooves. We have used a two-meter plate. The consequence of using a two-meter plate is that the recording frequency used is less (256Hz) than the maximum frequency (500Hz). The threshold level of the plate was 3 N/cm^2. Pressures above threshold level were recorded and were given a colour, blue for minimum pressure and red for maximum pressure.
The Rsfootscan® plate is embedded in an aluminium plate and covered by two rubber mats of approximately 2 to 5 mm thick to form a continuing flat surface. In front, on both sides and at the end of the plate wooden boards were placed to stabilise the pressure plate and to enlarge the track, so as to prevent horses and handlers to anticipate on the position

of the plate. At the start of the tract two wooden beams were placed in a triangle shape to guide the horses towards the track in which the plate was embedded.

A measurement was defined as valid when the horses trotted across the plate in a straight line and hit the measurement system with at least one forelimb. For each shoe type three valid measurements were obtained for the right as well as the left front hoof.

The horses were filmed using a digital video- camera (Panasonic NV-GS15). The camera was placed halfway alongside the Rsfootscan® plate, thus capturing the entire plate in one view. The recorded images were used to determine which front hoof came into contact with the pressure plate first. These findings were then compared to the findings concerning way of landing listed during data- collection.

For each of the horses the Rsscan® program requested the creation of a new account, in which no weight over 400 kilos could be entered. Therefore the weight of the horses has been listed in the Rsscan® software as being 400 kilos, instead of the estimated weight.

Data analysis

The software we used to analyse our data is the Rsscan® version 7.0 and Microsoft Excel®. The centre of force line was transferred from the Rsscan® software to Microsoft Excel® to enable the researchers to process the data.

The stance phase can be divided into four moments: initial contact (IC), mid- stance (MS), heel lift (HL) and toe-off (TO). The moment of IC is defined as the moment of first contact of the hoof with the Rsfootscan plate. MS is the moment at which the vertical component of the ground reaction force (GRF) is maximal. HL is defined as the moment when the shift of the centre of pressure (CoP) in two consecutive frames in dorso-palmar direction is the largest. TO is the moment of last contact with the Rsfootscan plate (end_x and end_y). (Heel *et al.*, 2006)

The hoof- unrollment pattern is described using the shift in CoP from MS to TO. The x- and y- values of MS are placed in the origin of an x- and y- axis and thus the pattern of hoof-unrollment can be calculated. To be able to compare the left and right foot, the x-axis-values of the right foot have to be mirrored. (Heel *et al.*, 2004)

Results

Hypotheses tested in the current study are: when comparing the Equilibrium® shoe to the keg shoe, the duration of break over will be shorter, the peak load during break over will be lower, and the centre of pressure will remain closer to the central hoof axis during break over.
Initially the aim was to collect data of three clinically sound adult Thoroughbreds. However, two of the horses have been excluded from this study due to the development of forelimb lameness during data collection.
Data obtained for horse number one are listed in *table 1* and *figure 1* and *2*.

	Keg RV	**EquiLibrium RV**	**Keg LV**	**EquiLibrium LV**
GRF-max during stance phase	806 676 541	829	711 820	934
Max GRF hoof-unrollment	154 119 113	169	146 161	214
Time from HL to TO (duration of breakover)	46,18 ms 46,19 ms 34,64 ms	22,84 ms	34,64 ms 34,45 ms	22,85 ms
End_x	-38,67 -5,52 14,36	6,04	-27,15 -57,52	-20,39
End_y	184,85 188,28 148,38	179,79	144,38 155,68	133,67

Table 1: Data collected for horse no 1
GRF: Ground Reaction Force in Newton ; BO: break- over, defined as the period between mid- stance and toe- off ; HL: heel lift ; TO: toe off ; end_x and end_y in millimeters

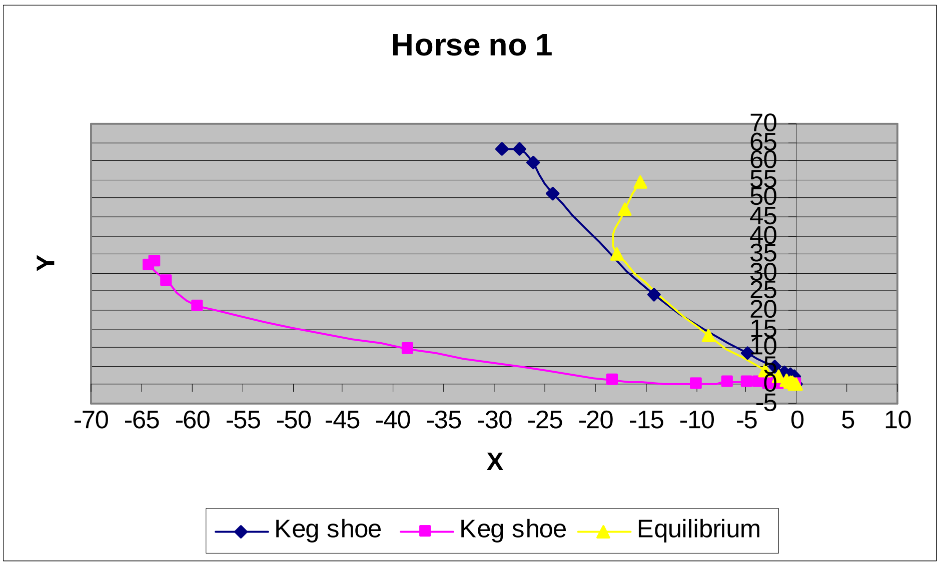

Figure 1: Graph of x- and y- values collected for horse no 1, left front hoof

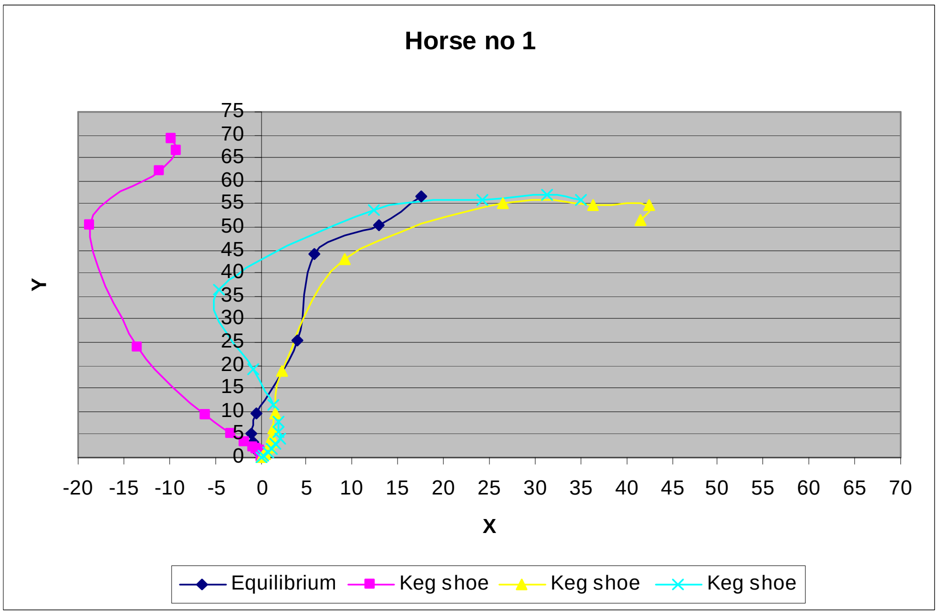

Figure 2: Graph of x- and y- values collected for horse no 1, right front hoof

Values of all parameters acquired during testing in the current study differ between measurements, as is shown in the *table 1* and *graphs 1* and *2*. Therefore no concrete conclusions can be drawn from the numbers and figures listed above. However, it may be possible to identify certain tendencies using the collected data.

The maximal ground reaction force appears to be higher for the Equilibrium® shoe than for the standard keg shoe during the stance phase in both front hooves. However, when comparing the GRF- values of the current study to values recorded in the co- study, the values listed above are approximately 25% or less of those found in the untrimmed and trimmed front feet of Thoroughbreds. Hence the values listed in *table 1* do not seem to be highly representative of the forces placed upon the solar surface of the hoof during the stance phase of a stride.

The duration of break over, defined as the time- laps from heel lift to toe- off in milliseconds, appears to be shorter for the Equilibrium® shoe than for the keg shoe in the left front hoof as well as the right front hoof (*table 1*).

The x_end and y_ end values generally appear to be lower for the Equilibrium® shoe than for the keg shoe for the left front hoof as well as the right front hoof. This could indicate that movement of the centre of pressure during break over is in closer proximity to the sagittal hoof axis in the Equilibrium® shoe than in the keg shoe, were it can be expected to be in an ideal situation.

Discussion

The aim of the current study was to evaluate the effects of the keg shoe and Equilibrium® shoe on the loading pattern of front feet in Thoroughbreds, using a pressure plate to collect data.

The pressure plate has previously been used to asses the way of landing in sound ponies at the walk. Data collected during this study appeared to be highly repeatable, thus making the pressure plate a promising tool to asses loading patterns in horses. (Oosterlinck *et al.*, 2009)
In the current study the pressure plate has been used to asses loading patterns of the front feet in trotting Thoroughbreds. However, it has not been calibrated using a known weight or a force plate. By calibrating the pressure plate a known weight is linked to a certain pressure or force in Newton, thus creating a starting point for data- collection.
Because the pressure plate has not been calibrated, the ground reaction forces measured in this study might not be highly reliable.

The resolution at which data are collected is related to the length of the pressure plate. In the current study a two meter plate has been used, which has a maximal resolution of 256 Hertz or 256 frames per second. By using a one meter plate, which measures at a frequency of 500 Hertz, more accurate data can be obtained due to the reduced period between frames and thus more frames can be collected for each footprint.

Due to the restriction in the amount of frames collected of each front hoof, the moment of heel lift and toe off used to calculate the duration of break over can not be defined very accurately. Differences found between the Equilibrium® and keg shoe in duration of break over might therefore not be as large as can be concluded from *table 1*.
A previous study on the effects of shoes with a rolled toe (Heel *et al.*, 2006) has found no effect of the rolled toe on the duration of break over, in contrast to the results found in the current study. However, inclusion criteria for horses used in that study did not include a long toe- low heel conformation, in contrast to the horse used in the current one. It could be postulated that the effects of the rolled toe may be larger in horses with underrun heels than in horses with a normal hoof conformation. If this proves to be true by further research, shoeing horses with an abnormal hoof conformation, i.e. a long toe and low heel, might be a valuable tool in reducing the incidence of orthopaedic injuries or in the treatment of certain conditions.

In the current study x_end and y_end values for horse number one differ considerably between different measurements or runs. This is shown in *table 1* as well as *graphs 1* and *2*. This implies that the hoof unrollment pattern varies considerably between different runs, even for one horse. This might be due to the horse not trotting across the plate in a straight line or stumbling of the horse as it trots across the plate.
Due to technical problems encountered during data- collection, the x- and y- graphs as they are normally depicted by the Rsscan® software were lost. Hence it was not possible to compare graphs of the x- and y- values acquired in the current study to those collected

in previous studies. X- and y- values depicted in the table and graphs above are therefore most likely not very accurate and no definite conclusions can be drawn from them, although there appears to be a tendency of the centre of pressure staying closer to the sagittal hoof axis during break over in the Equilibrium® shoe.

The six horses used in the setup of the current study were all adult Thoroughbreds, with an age ranging from approximately six to twelve. The horses had been trained for and/ or used in racing at a younger age, but had all been retired from this and were kept on pasture during the entire year. The horses were kept bare- foot and the feet of the horses were trimmed only twice a year.
As mentioned before, the long toe – low heel conformation is not just a hereditary trait of Thoroughbreds, but is also influenced by gallop- training and trimming. (Peel *et al.*, 2006; Balch *et al.*, 2001) Therefore, the hoof conformation investigated in the current study might be more obvious in younger horses, which are actively in training.
Data collected in this study might also have been influenced by hidden orthopaedic ailments, of which the prevalence might be higher in older horses than in young ones.
The horses used in the setup were not used to being shod and were not trimmed regularly. Therefore, it might have taken these horses longer to get used to the keg and Equilibrium® shoes than the three days the researchers had aimed for.
Taking the reasons mentioned above into consideration, using younger horses which are being trained and/ or raced at the moment of data collection would be more representative of the Thoroughbred population and the Thoroughbred hoof conformation.

To determine the hoof angle of the horses being used in the current study a hoof- angle measurement device can be used. Because the aim of the study was to determine the loading pattern in Thoroughbreds, which are predisposed to a long toe- low heel conformation (Kane *et al.*, 1998; Balch *et al.*, 2001), hoof angle- measurements are only aimed at confirming the aforementioned hoof conformation. Thus, taking latero- medial radiographs of the front feet, which is deemed the golden standard, does not appear to be necessary in the current setup. By using a Dallmer hoof gauge, the long toe- low heel conformation can be identified. The horses should stand squarely on a flat ground surface during collection of these data, and all measurements should be taken by one experienced person. (Molemen *et al.*, 2005)

In the current study the assumption has been made that horses trotted by hand tend to spontaneously repeat their trotting speed. Thus, the trotting velocity during data collection has not been registered. (Galisteo *et al.*, 1998) However, as the magnitude of the ground reaction force depends on the weight of the horse and the trotting velocity, and the weight does not vary between measurements, the differences in peak- GRF between measurements in one horse seem to be caused by the horse trotting at different velocities.
In previous studies the velocity has been calculated using an infrared system. (Heel *et al.*, 2004) This system consists of two infrared gates placed at the beginning and end of the track, which is six meters in length if the two meter pressure plate is being used. Thus, time measurement is initiated by the horse trotting past the infrared gate at the beginning of the track and ended by the horse crossing the one at the end of the track. By dividing

the length of the track, six meters, by the time registered during each measurement the trotting velocity can be calculated.
The benefit of using the infrared system is that, during data collection, one can asses if the trotting velocity of a horse is constant between different measurements.

In order to acquire more accurate results than the ones that have been collected in the current study, further research is needed. Recapitulating the above, it would be advisable to use a calibrated one meter pressure plate to acquire more accurate data; young Thoroughbreds which are still in race- training to obtain a more representative study group; a Dallmer hoof gauge to measure the hoof angle of the front feet to identify the conformation investigated; and the infrared system to calculate the trotting velocities of the horses.

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