The influence of body mass and height on equine hoof conformation and symmetry.

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Abstract

Despite the likelihood that a horse's mass influences hoof morphology, empirical evidence is lacking. A clearer understanding of factors influencing hoof shape could enable prevention, or better treatment of, foot-based disorders; common causes of equine lameness. The study's aim was to investigate the relationship between horse body size, in terms of mass and height, and fore hoof dimensions. A further aim was to determine changes in the occurrence of hoof asymmetry as body size increases. Height, mass and fore hoof dimensions; coronet band width (CBW), hoof base width (HBW), dorsal hoof wall angle (DHWA) and hoof spread (HS) of 63 riding school horses were measured within two weeks of routine shoeing. Regression analysis demonstrated positive relationships between body mass and both CBW and HBW in left and right hooves, indicating basic hoof dimensions increased as body mass increased. No relationship between horse height and hoof variables was found suggesting mass is more influential on hoof morphology. Left and right DHWL were moderately correlated, however, paired t-test results identified a greater right than left DHWA. As left DHWA increased, left HS decreased, indicating development of a more upright hoof geometry. Both left and right HS increased as corresponding HBW increased. Both hooves tended towards a more upright conformation as horse height and body mass increased. However, asymmetries observed suggest a splayed left hoof compared to a 'boxy' right hoof. Such morphological adjustments may indicate variation in horn tubule orientation in response to greater structural loading; an important consideration for hoof practitioners.

Keywords: Equine; Hoof conformation; Body mass; Asymmetry; Fore

1.0 Introduction

The advanced evolutionary structure of the equine hoof provides leverage, support and shock absorption to facilitate locomotion [1]. Its conformation dictates how the foot interacts with the ground and directly influences the magnitude and direction of forces entering the limb [2]. Factors influencing hoof capsule dimensions, and therefore forces interacting with the foot, include trimming and shoeing practices, heritability and early life environmental stressors [1]. The high body mass to weight-bearing surface ratio of the equine hoof results in significant, repetitive impact stresses during locomotion [3,4]. Consequentially, foot problems are common and poor foot pathologies have implicated in up to 70-80% of lameness cases **[5, 6]**. One of the aims of trimming and farriery interventions is to influence the biomechanics and loading patterns of the hoof, and by association the foot, through achieving optimal hoof geometry for the individual's hoof conformation [7,8]. Early farriery texts document the ideal dorsal hoof wall angle (DHWA), and therefore the hoof-pastern axis (HPA), as 45-50°. Angles achieved in practice have long challenged this with evidence of HPA ranging from 42° to 58°, with mean values between 51.8° and 53.7° [9,10]. Acute hoof angles, associated with longer relative growth of the toes than heels, results in a broken-backwards HPA and increased toe-first impact, resulting in a prolonged breakover time [9]. Upright or broken forwards hoof conformation, where the toe is relatively shorter than the heel, creates a boxy foot shape, reducing breakover duration [11]. The geometry of the hoof therefore has the potential for subtle, yet significant influences on stride bimechanics. Gait parameters, such as stride length and duration, remain consistent throughout shoeing and trimming intervals [7]; however, transient morphological changes in distal limb joints angles occur to retain these [12]. Regular farriery is therefore fundamental to keep the horse sound [1,9].

Musculoskeletal disorders [13], such as osteoarthritis of the knee [14] and hip [15] have been linked to excessive body mass in humans; as have foot and distal limb pathologies through the resulting increased loading [13,15]. The only foot pathologies that have been linked to body mass in the horse is laminitis. Minimal investigation into the effects of body mass on hoof geometry has occurred to date.

This study aimed to investigate the relationship between horses' body mass and hoof shape. The study hypothesised that horses of a larger body mass would present hooves with an increased proportional weight-bearing surface in order to facilitate distribution of the higher loading forces generated. Angular and linear hoof measurements were postulated to increase proportionally with changes to the weight-bearing surface. An increased asymmetry of hoof-spread has previously been reported with a corresponding increase in limb length [16] ; as such a further aim of the study was to evaluate whether left-right hoof symmetry changes with an increase in body size: either height or mass. It was postulated that as height increased, any left-right asymmetries would also increase.

2.0 Material and methods

2.1 Study population

Sixty-three riding school horses of mixed breed, age (6 – 25yrs), height (146.3cm to 177.0cm) and sex were selected using convenience sampling. All subjects were subjected to comparable workloads, farriery and management regime: two 45 minute flat, jump or lunge lessons per day on an artificial surface (ProWax, Andrews Bowen, Lancashire, UK), with one day off per week; stabled (rubber matting and shavings) with restricted grass turnout[1]. One main farriery team (WCF (Worshipful Company of Farriers) qualified) provided regular farrier treatment (hot shod; full set or front shoes) to all horses within the study population at shoeing intervals between four and six weeks. Under the direction and supervision of a lead farrier, farriery was performed by one of four farriers to promote a consistent approach. All horses had been previously exposed to farriery interventions and were not undergoing any corrective farriery. Inclusion criteria required the horses to be in a regular shoeing routine of ≥ four to six weeks [8] and to have been shod within the two weeks prior to data collection. Horses that had any signs of lameness reported by the riding school veterinarian within the previous six months, or during the study, were excluded. Ethical approval for the study was granted by the University of the West of England (Hartpury) Ethics Committee (Project Identification Code: ETHICS2011/13).

2.2 Experimental method

Horses were stood square, with equal weight bearing on all four limbs, on a level concrete surface for hoof measurements and lateral digital images of the hoof to be taken [8,17,18]. Height (m) was measured with a horse height measuring stick (±0.01m accuracy) (Shires, UK). A weighbridge (Burghley, Horse Weigh, Gloucestershire, UK) was used to attain body mass (kg). Direct measurements of the coronet band width (CBW) (mm) and hoof base width (HBW) (mm) (Figure 1) were obtained using callipers (±1mm accuracy) (Invicta metric callipers, Invicta, Oxfordshire, UK). A digital camera (DSC-W180; 36.34 MP/cm^2, Sony UK, Surrey, UK) placed on the ground perpendicular to the hoof, captured lateral digital images of both front feet.

[1] Horses were restricted to between 2-5 hours turnout per day.

Dartfish™ software (Dartfish Version 6, Dartfish Solutions, Fribourg, Switzerland) was employed to determine dorsal hoof wall angle (DHWA). DHWA was defined as the angle of intersect between a) the line drawn from the proximal limit to the distal limits of the dorsal hoof wall at the weight-bearing border with b) the line drawn from the palmar margin of the heel and the shoe, and the most dorsal margin of the toe and the shoe (Figure 2) [18]. Use of photography to measure hoof dimensions supported intra- and inter-horse standardisation [19] and ensured greater repeatability than manual methods [20]. Mean values from three measurements were used for the analysis.

Horses were grouped according to a) mass and b) height, independently to determine individual influences on hoof conformation. Horse body mass was categorised into 500kg, 5-600kg and >600kg groups, in accordance with 500kg being a commonly used benchmark category within literature [21] and anecdotally within industry to define the weight of the average horse. Height was divided into shorter horses: <16hh (≤1.625m) and taller horses; ≥16hh (≥1.626m) [8]. In addition, to determine a combined influence, individuals within each height category were grouped according to mass for comparison e.g. horses ≥16hh were split in to 500kg, 5-600kg and >600kg subgroups. Group and sub-group sizes are reported in Table 1.

2.3 Data analysis

Hoof spread (HS) was defined as the difference between HBW and CBW **[16, 23]**.

Hoof spread ratio, defined as HBW (mm) / CBW (mm), was calculated for the left and right front hooves for horses within each mass and height category.

Data were tested for normality using the Kolmogorov–Smirnov test. Hoof variables and mass data were normally distributed and demonstrated a linear relationship, had no multicollinearity, no auto-correlation and were homoscedastic. Paired t-tests were used to determine differences in the DHWA of the left and right hooves independently within each mass (<500kg, 5-600kg and >600kg) and height groupings (<16hh, >16hh). Associations between all hoof variables were examined through a series of Pearson's Product Moment Correlation Coefficient analyses. A series of regression analyses investigated the impact of mass and height (as the independent variables) upon the measured hoof variables. Correlation Coefficients were interpreted according to Taylor [22]. Correlation Coefficients were defined as weak if ≤0.35, moderate if 0.36 to 0.67 and high if 0.68 to 1.0.

All analyses were performed using the statistical analysis software SPSS (IBM SPSS version 24) with the significance level set at $P<0.05$ throughout.

3.0 Results and discussion

The study aim was to assess changes in hoof conformation with increasing body size, in terms of height and mass, within a population of general riding horses. Whilst mass was identified to have a greater influence on the conformation of the hooves investigated, horses above 16hh did present with more upright feet in comparison to those under 16hh. Furthermore, whilst left and right DHWA increased as height and mass increased, a concurrent increase in the asymmetry of the paired hooves also presented; the left hoof presenting with a more acute DHWA compared to the more upright (boxy) right foot.

The mixed age range, breed type, height ($\bar{x}$=1.611±0.073m) and mass ($\bar{x}$=565.08±69.81kg) (Table 1) demographics within the cohort reflect a general population. The lack of accurate age and breed type[2] data was a limitation of this data set as such information would have facilitated a more in-depth interpretation of the results. Results are presented as means (±SD) unless otherwise stated.

3.1 Influences of mass and height on hoof variables

No correlation was found between HS and either horse mass or height, or between height and any assessed hoof variable (p>0.05). This may be partially due to individual farriery practices [23] but as breed associations with hoof conformation traits are well documented [23], this is more likely a result of the breed diversity within the study population. Mass data for the shorter horses (i.e. those ≤1.625m) were normally distributed. Mass data for the taller horses (i.e. those ≥1.626m) were not normally distributed and presented with a positive skew indicating a number of the horses weighed lower than the mean 606.83 (±60.63). Observation of the distribution suggest mean mass (606.8kg) was impacted by the inclusion of a small number of horses with greater mass as it was greater than both the median (595kg) and mode (595.9kg) values for mass.

As mass increased, so too did HBW in both the left (r^2=0.25 p=0.001) and right (r^2=0.24 p=0.001) fore feet. The HS results indicate that taller horses appear to have larger hooves which would translate to a corresponding increase in greater solar surface area. However, further research integrating the measurement of solar surface area is required to confirm this. Increased ground contact area can be postulated through the increased dorsopalmar length, the longer DHW length observed here in heavier horses would support this theory [24]. The increases

[2] Due to inaccuracies notes in a few of the establishment's documentation, recorded breed type and age were not considered accurate enough to include within data analysis.

observed could be attributable to two possible mechanisms: 1) a relatively even distribution of increased spread in the dorsal half of the hoof capsule (Figure 3a). Such expansion would increase the ground contact area without significantly increasing toe length, promoting greater breadth across the whole toe region. Alternatively, 2) extension is isolated to the toe (Figure 3b) [25]. Whilst the area for ground contact potentially increases, the lengthened duration of break-over increases strain on the underlying laminar junction [25]; strain magnitude of the DHW would be transferred to the deep digital flexor tendon. The results suggest that horses with a higher body mass (>500kg) have a foot shape more closely associated with mechanism 1 (Figure 3a), which could be considered a preferable adaptation to reduce dorsal hoof wall strain. Additional mass placed on the hoof, for example through obesity, could have wider equine welfare implications. Body condition scores, and therefore obesity levels, were not determined within the current study population. However, excessive body weight may have the potential to detrimentally effect such hoof compensatory mechanisms. Despite evidence that obesity negatively affects human foot morphology and associated biomechanics [13], particularly in children [26], this area is yet to be researched in the horse. Further research is required to confirm these propositions; however, such effects would predispose individuals to more significant injury than previously considered.

Despite the clear benefits of a larger ground contact area, large hooves could also be detrimental. Larger hooves better distribute locomotory forces but, in relation to body size, the extra mass significantly influences the limbs' pendulum action increasing the force of the swing [27]. Amplified swing increases net joint moments, or turning forces. This is particularly applicable within joints such as the equine radiohumeral joint [27] which has restricted movement, consequentially increasing power generation and the propensity for soft-tissue injury. Large feet also require more energy to move; therefore, a proportionally smaller foot size, as suggested within the current results could benefit gait economy over shock absorption. Such compromise has the potential to result in increased concussive forces within the limb and digit [28], and predisposition to lameness.

3.2 Hoof asymmetries

The weak positive correlation between left and right DHWA (r=0.59, p<0.001) indicated comparable increases in DHWA. However, the significantly (p<0.05) larger right DHWA determined by the paired t-test reinforces the notion that hooves demonstrate distinct individual conformation and asymmetries [16]. Varied left-right differences in DHWA and hoof spread existed in this sample (Table 1). Bilateral hoof symmetry is important in facilitating even mass distribution. The angular variation present has the potential to predispose one of the contralateral hooves to injury through the resultant uneven loading [29,30].

The lack of a correlation between either height or mass with DHWA (p>0.05), the relationships between mass and right DHWA in horses over 16hh, and the lack of a relationship between mass and CBW, all imply larger horses possess more significant limb asymmetries than smaller horses. This supports Wilson et al.'s [16] findings that as limb length increased, specifically third metacarpal length and elbow height, left HS decreased and that as the difference in left-right limb length increased, left HS became more pronounced.

The solar aspect of the distal phalanx is normally aligned between 2-10˚ to the horizontal [31]. The more acute DHWA of the left hoof (p≤0.01) would result in a decrease of this angle. A 1° reduction in the angle of the distal phalanx can increase compressive forces on the deep digital flexor tendon (DDFT) and navicular bone by as much as 20% at the beginning of stance [2]. A trend for the left hoof to be more acutely angled has been previously reported [32] which positions the centre of pressure more palmarly; potentially predisposing horses to strain of the DDFT and navicular structures [30]. No research has directly considered this, however Ducro et al. [33] suggested presence of asymmetric fore feet reduced career longevity of dressage horses and almost doubled risk of early retirement in elite level showjumpers. The reported asymmetries within the current study are likely to have undesirable implications for sustained soundness and manifest as pathologies [34]; however, the positive complexities of such relationships require further investigation. Asymmetries as a result of farrier left-right handedness cannot be ruled out. Ronchetti et al. [35] identified distinct asymmetries between medial and lateral wall length in relation to the handedness of the apprentice farrier undertaking the trim. Results in the current study however, do not reflective this; likely due the difference in experienced between farriers used within the two studies.

The extent of asymmetry and variation in hoof shape observed between individuals, implies hoof geometry is an individual trait. The significant forefeet asymmetries observed suggests that, for the majority, hoof conformation is not symmetrical. Left hoof conformation is more splayed compared to the upright, boxy right hoof conformation; observed to increase with increase in height and mass. The significant difference found in DHWA supports this, implying asymmetries occur in the distal phalangeal alignment. Thomason et al. [36] suggest the interplay between shape measurements is too complex to analyse with a small sample; their study used nine horses in comparison to the 63 horses used within the current investigation. They further propose that although hoof measurements often show little, or no, correlation with each other, they have a collective effect on hoof strain magnitudes and distribution, which at present is too subtle to determine.

3.3 Influence of mass on hoof geometry

For the group as a whole and for horses under 16hh, body mass significantly influenced increases in both CBW and HBW (Table 3; $p \leq 0.05$-0.001); the greatest impact on the already more upright left foot. Body mass increases resulted in increased HBW, but not CBW, in horses over 16hh. As body mass increased, right DHWA significantly increased ($r^2=0.29$ $p=0.05$) and left HS ratio increased by 5% between the two mass categories (5-600kg and 600+kg).

Within the whole group, left CBW increased as right CBW increased ($r=0.96$, $p \leq 0.001$), a pattern also reflected in HBW ($r=0.94$, $p \leq 0.001$ respectively). Furthermore, as CBW increased the corresponding HBW increased (left: $r=0.80$, $p \leq 0.001$; right: $r=0.80$, $p \leq 0.001$) by approximately the same ratio (1:1.22) (Table 1); reflecting the strong positive correlation between left and right HS ($r=0.84$, $p \leq 0.001$). Increasing HBW was also related to larger HS across the cohort (Table 2). However, this relationship was reduced in horses >16hh which demonstrated smaller hoof spread ratios than those <16hh (Table 3). Right DHWA increased as right CBW increased, resulting in development of a more upright (boxy) hoof (Figure 2). As left DHWA increased, left HS decreased although this was not found to be correlated in analysis ($r=-0.29$, $p<0.05$). These results support previous reports that the left hoof geometry is larger than the right in the majority of horses studied [16,37], suggesting an element of laterality or sidedness exists in working horses [16].

The lack of relationships found between DHWA and either height or mass may be associated with variation in body type due to breed and muscle/ adipose tissue distribution, whereby the tallest horse in the sample was not necessarily the heaviest. However, although only weak correlations presented, mass ($\bar{x}$=56±73.4kg) was positively associated with both CBW and HBW of both left (*r*=0.49, *p*=≤0.001 and *r*=0.50, *p*≤0.001 respectively) and right hooves (*r*=0.53, *p*≤0.001 and *r*=0.48, *p*≤0.001 respectively) regardless of height. The linear measurements within the current study are somewhat supported by recent associations between body mass and the volume of both the whole hoof, and the distal phalanx [38]. Future work in this area evaluating breed type and body condition score alongside the current hoof variables with increased numbers of horses would be beneficial. It should also be noted that allocation of horses to height and mass groups reduced the sample size for correlation analyses, which could negatively affect the power of the output.

The more upright hoof orientation of larger horses observed in this study could be associated with structural support.

Approximately half of the hoof-wall [39] is composed of keratinised tubular horn pillars orientated at 50˚ and cemented together by intertubular horn. The hatching orientation of the two promote strength in multiple planes [39] and regional differences in density reflect loading forces variations [40]. Whilst tubules resist axial compression loads [41], intertubular horn resists fracture occurrence between horn tubules by redirecting vertical fracture orientation to a horizontal plane thus protecting the delicate coronary region [39].

The more upright hoof wall orientation in larger horses indicates more vertically orientated stratum medium horn tubules, offering greater structural capability to support the higher loading associated with a larger body mass. Where DHWA is too acute in relation to body mass, bending moments are increased. For example, a lengthened toe extends break-over increasing tension on the laminar junction creating a greater bend within the dorsal horn tubules [25]. Tubular horn angle in relation to horse's size can therefore be explained by Newton's Second Law to determining the correct angle of inclination for a ladder [42]. As mass at the top of the ladder increases (or as here, the horse's body mass increases), friction force at ladder base needs to increase to maintain the integrity of the ladder's angle. Where mass forces exceed frictional forces, the ladder's base will slip away from the wall. In the hoof, such acute angulations would result in excessive bending of the stratum medium (Figure 4c), potentially leading to fracture strains along regions weakened through bending. Prevention of *ladder slip* is achieved by increasing the ladder's vertical alignment [43]; or as here, by increasing the vertical alignment of the hoof wall (Figure 4a). Body mass and height of the horse are therefore important variables for the farrier to consider during routing interventions.

4.0 Conclusion

Differences observed in hoof conformation between the smaller (<16hh) and larger horses (>16hh) in this study suggest horse height influences hoof conformation. However, for the horses in this study, the impact of body mass on horse hoof geometry was significantly greater than their height. We found, larger horses presented with more upright 'boxy' fore feet compared to smaller horses and an increase in left-right asymmetry of the fore feet. The boxy conformation appears to result from the development of a more upright hoof wall angulation, which could be related to corresponding increase in loading forces amplified by larger body mass. The differences in hoof geometry and symmetry reported here should be considered by farriers, trimmers and veterinarians when undertaking both maintenance and remedial care of equine feet.

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Table 1 *Mean (±SD) measurement data for the study population as a whole and between mass (kg): 1) 500kg, 2) 5-600kg and 3) 600kg and height (m); a) <16hh and b) >16hh sub-groupings. Significant differences in DHWA within each sub-group indicated by * (p≤0.05) and ** (p≤0.01). DHWA: dorsal hoof wall angle; CBW: coronet band width; HBW: hoof base width*

	n	Height (m)	Mass (kg)	Hoof	CBW (cm)	HBW (cm)	HS (cm)	DHWA (˚)	HS Ratio
ALL	63	1.61±0.073	565.08±69.81	Left	11.17±0.92	13.61±1.00	2.44±0.61	52.43±2.83	1.22
				Right	11.20±0.95	13.61±1.06	2.40±0.64	**53.34±2.64	1.22
<500kg	12	1.58±0.056	473.44±27.94	Left	10.55±0.74	13.13±0.92	2.58±0.80	52.02±2.04	1.25
				Right	10.49±0.72	13.12±0.87	2.63±0.73	52.63±1.87	1.25
5-600kg	35	1.61±0.072	555.03±27.42	Left	11.03±0.66	13.42±0.66	2.39±0.49	52.14±3.01	1.22
				Right	11.05±0.69	13.36±0.80	2.31±0.57	*53.15±2.67	1.21
>600kg	16	1.65±0.073	655.79±46.22	Left	11.93±1.07	14.40±1.27	2.47±0.73	53.50±2.86	1.21
				Right	12.07±1.02	14.51±1.16	2.44±0.71	54.33±2.97	1.20
<16hh	35	1.56±0.04	532.20±58.01	Left	10.97±1.00	13.42±1.03	2.46±0.55	53.07±3.06	1.23
				Right	10.96±1.03	13.39±1.10	2.48±0.62	53.98±2.57	1.23
<16hh <500kg	11	1.57±0.049	471.94±28.79	Left	10.47±0.72	13.07±0.72	2.60±0.83	51.82±2.01	1.25
				Right	10.44±0.73	13.06±0.88	2.62±0.77	52.53±1.93	1.25
<16hh 5-600kg	18	1.55±0.043	536.39±19.68	Left	10.89±0.71	13.31±0.70	2.41±0.34	52.90±3.36	1.22
				Right	10.89±0.76	13.23±0.89	2.34±0.58	54.54±2.52	1.22
<16hh >600kg	6	1.58±0.042	630.08±18.89	Left	12.09±1.43	14.42±1.49	2.33±0.50	*55.87±2.07	1.20
				Right	12.09±1.43	14.50±1.47	2.41±0.42	54.95±3.00	1.20
>16hh	28	1.68±0.040	606.83±60.63	Left	11.45±0.75	13.87±0.92	2.41±0.69	51.66±2.34	1.21
				Right	11.54±0.77	13.88±0.93	2.30±0.67	*52.57±2.55	1.21
>16hh <600kg	18	1.67±0.025	570±27.54	Left	11.19±0.59	13.550.60	2.36±0.60	51.049±2.45	1.21
				Right	11.20±0.57	13.51±0.68	2.31±0.58	51.78±1.99	1.21
>16hh >600kg	10	1.70±0.054	671.21±51.55	Left	11.84±0.86	14.39±1.20	2.56±0.86	52.07±2.30	1.22
				Right	12..06±0.76	14.52±1.02	2.35±0.84	*53.96±3.06	1.21

Table 2: *Regression relationships between horses' mass (kg) and the measured hoof variables. r: correlation coefficient; r^2: regression coefficient; SEE: standard error of estimation; DW: Durbin Watson statistic.* DHWA: dorsal hoof wall angle; CBW: coronet band width; HBW: hoof base width; HS: hoof spread; -L: variable of the left foot; -R: variable of the right foot

Variable	Probability	r	r^2	Variance	Beta	SEE	DW
Whole cohort (n=63)							
CBW-L	≤0.001	0.50	0.25	25% of 0.50	0.56	0.81	1.70
HBW-L	≤0.001	0.50	0.25	25% of 0.50	0.55	0.88	1.57
HS-L	>0.05						
DHWA-L	>0.05						
CBW-R	≤0.001	0.54	0.29	29% of 0.54	0.60	0.82	1.59
HBW-R	≤0.001	0.49	0.24	24% of 0.49	0.54	0.92	1.64
HS-R	>0.05						
DHWA-R	0.012	0.37	0.14	14% of 0.37	0.37	2.51	1.67
Horses under 16hh (n=35)							
CBW-L	0.005	0.53	0.28	28% of 0.53	0.51	0.88	2.10
HBW-L	0.029	0.45	0.20	20% of 0.45	0.45	0.95	2.11
HS-L	>0.05						
DHWA-L	>0.05						
CBW-R	0.004	0.54	0.29	29% of 0.54	0.53	0.90	2.01
HBW-R	0.043	0.42	0.18	18% of 0.42	0.42	1.02	2.21
HS-R	>0.05						
DHWA-R	>0.05						
Horses over 16hh (n=28)							
CBW-L	>0.05						
HBW-L	0.027	0.50	0.25	25% of 0.50	0.52	0.84	1.95
HS-L	>0.05						
DHWA-L	>0.05						
CBW-R	>0.05						
HBW-R	0.025	0.51	0.26	26% of 0.51	0.54	0.84	2.15
HS-R	>0.05						
DHWA-R	0.013	0.54	0.29	29% of 0.54	0.50	2.26	2.18

Table 3: *Correlations (p≤0.05-p≤0.001) identified between horses mass, height and the measured hoof variables.* DHWA: dorsal hoof wall angle; CBW: coronet band width; HBW: hoof base width; HS: hoof spread; -L: variable of the left foot; -R: variable of the right foot

Variables		R coefficient	P-value
Mass	Height	0.532	<0.001
Mass	CBW-L	0.485	<0.001
Mass	HBW-L	0.498	<0.001
Mass	CBW-R	0.531	<0.001
Mass	HBW-R	0.483	<0.001
DHWA-L	DHWA-R	0.590	<0.001
DHWA-L	HS-L	-0.285	0.024
DHWA-R	CBW-R	0.245	0.053
HS-L	HS-R	0.842	<0.001
HS-L	HBW-R	0.337	0.007
HS-L	HBW-L	0.435	<0.001
HS-R	HBW-L	0.470	<0.001
HS-R	HBW-R	0.476	<0.001
HBW-R	HBW-L	0.937	<0.001
CBW-R	HBW-L	0.756	<0.001
CBW-L	HBW-L	0.800	<0.001
CBW-R	HBW-R	0.798	<0.001
CBW-L	CBW-R	0.962	<0.001
CBW-L	HBW-R	0.797	<0.001
CBW-L	DHWA-R	0.271	0.032

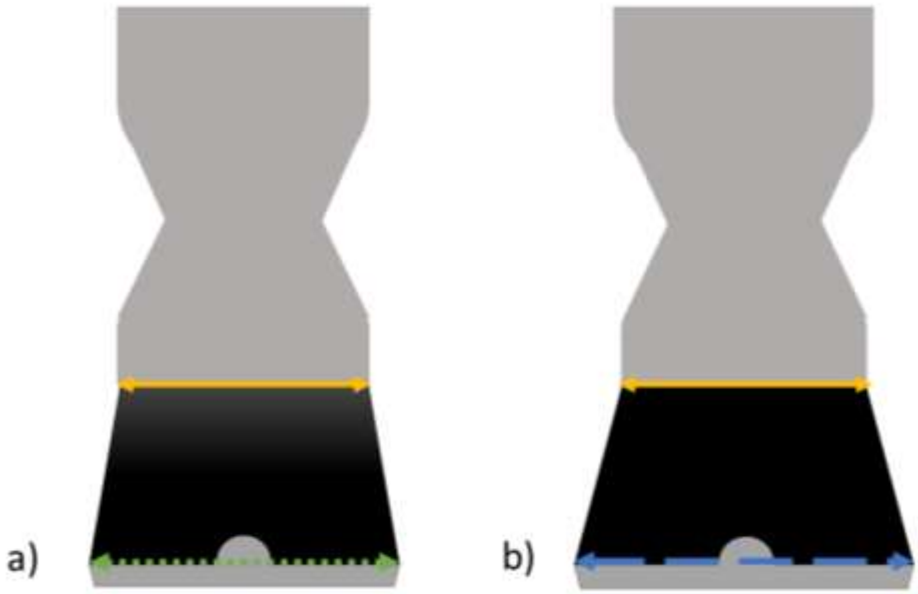


Figure 1: *Dorsopalmar view of the front hooves of the horse. In this study, the average horse's right hoof a) was squarer in shape compared to the left hoof b) which was broader and flatter in appearance. Coronet band width (yellow; solid line) of both feet were statistically comparable (P≥0.05) whilst the hoof base width of the left foot (blue; dashed line) was larger than that of the right (green; dotted line) due to its greater CBW: HBW ratio. As a result, the medial and lateral walls were angled on a greater slope in the left foot.*

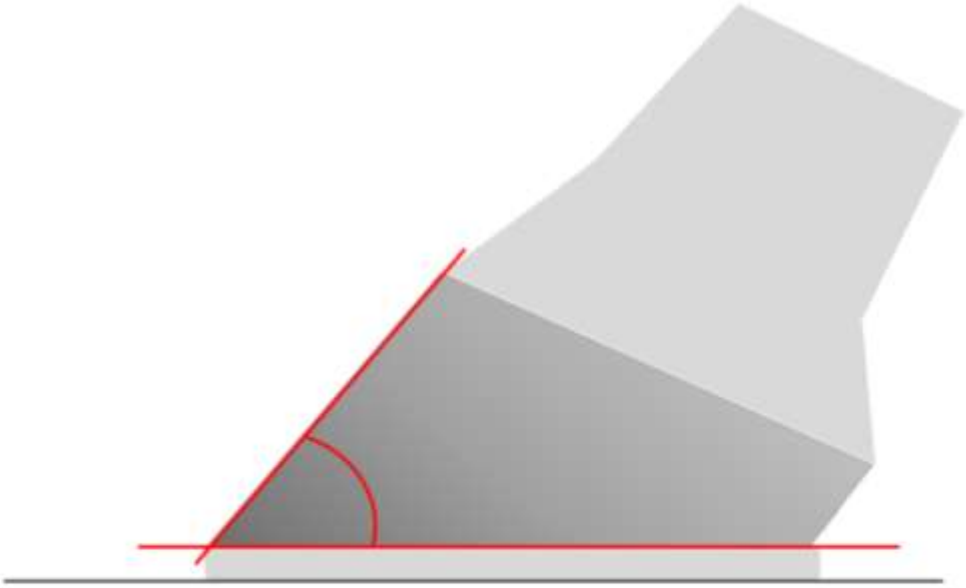
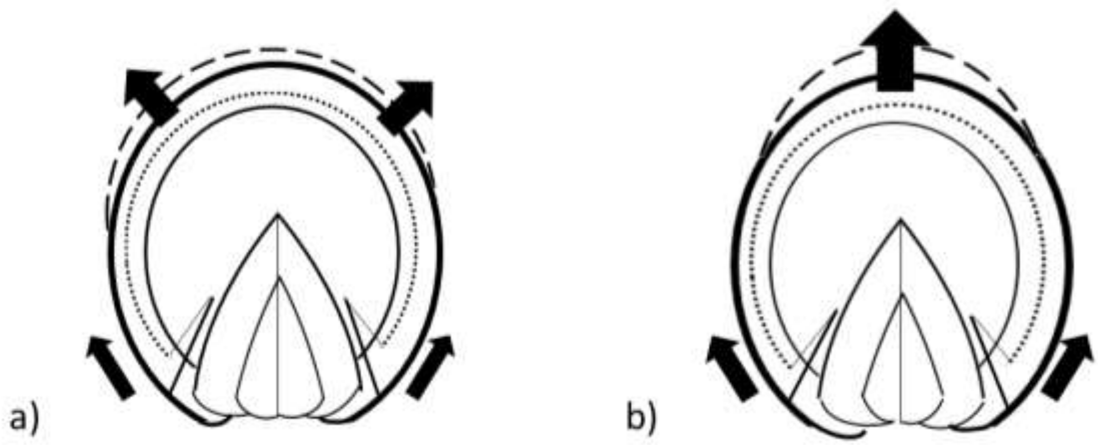


Figure 2: Lateral view of the horses front hoof illustrating the DHWA, defined as the angle of intersect between a) the line drawn from the proximal limit to the distal limits of the dorsal hoof wall at the weight-bearing border with b) the line drawn from the palmar margin of the heel and the shoe, and the most dorsal margin of the toe and the shoe



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568 **Figure 3:** *Mechanisms by which the hoof surface area can increase in larger horses*

569 *without increasing mediolateral width; a) Increased spread in the dorsal half of the*

570 *hoof capsule b) Isolated toe extension* [25]*.*

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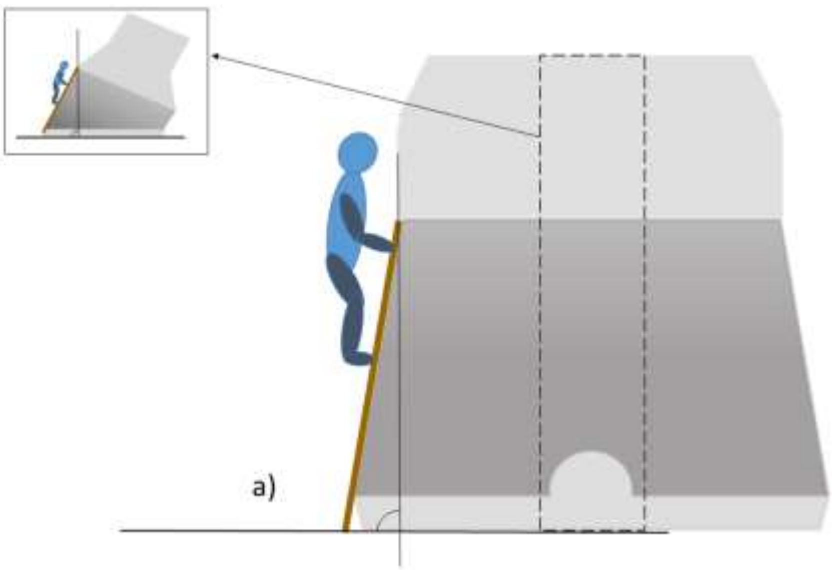

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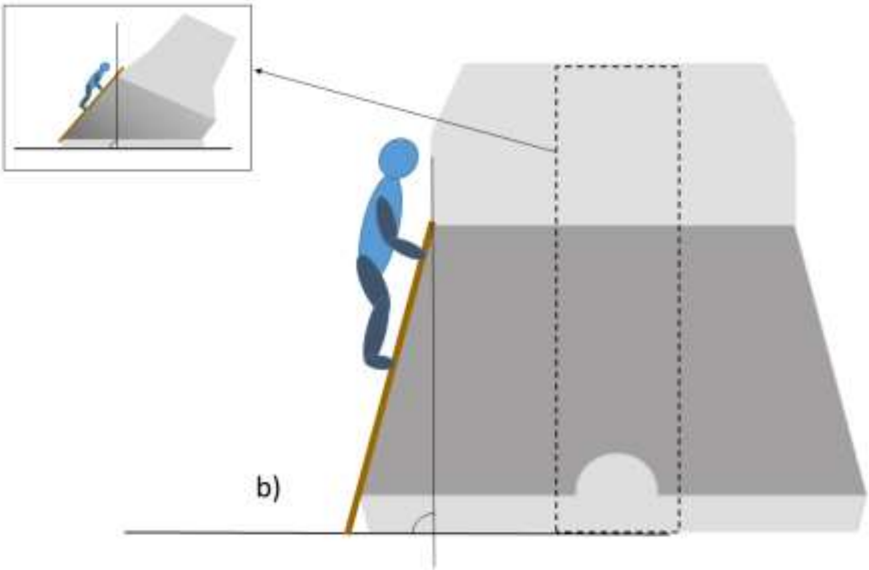

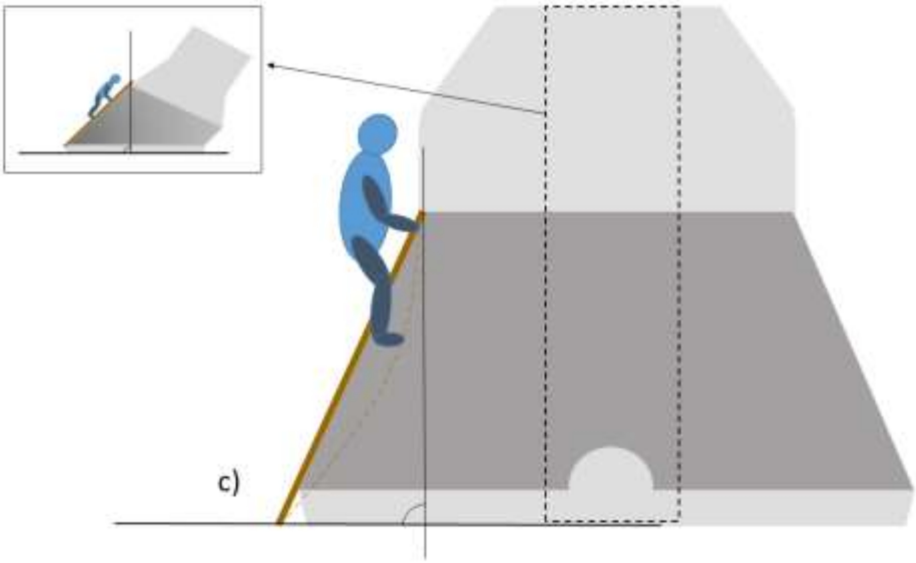

Figure 4: *Equine hoof wall angulation using the ladder slip analogy; a) Horses over 16hh present with more upright hoof walls compared to b) horses under 16hh in order to prevent c) the increased load weakening the stratum medium and bending the hoof wall.*