

Original Research

The Forelimb and Hoof Conformation in a Population of Mongolian Horses

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ABSTRACT

This article describes the lower limb and hoof conformation of a population of semi-feral Mongolian horses living on an open tundra/steppe environment. Data were collected from a convenience sample of 120 Mongolian horses used in the 2011 Mongolian Derby. Digital images of the hooves were obtained, and the lower limb conformation was assessed by four veterinarians involved in the screening of the horses offered for the derby. The horses were predominantly geldings (96%, 100/104), approximately 8.6 ± 2.5 years old, and 137 ± 8 cm at the withers. None of the horses were subjected to routine hoof trimming. Based on a 7-point linear score, lower limb conformation was normal, with a trend (>1 linear score deviation) slightly toward carpal valgus, mildly offset cannon (third metacarpal), and valgus at the metacarpophalangeal joint. Hoof measurements were within the norm for horses of this size. Fetlock valgus was associated with a smaller hoof width:length ratio ($P = .016$). None of the other hoof measurements were significantly associated with abnormal conformation scores. Overall, few conformation abnormalities were observed, and hoof shape and size was within the normal expected range for horses of this size. The hoof conformation in this population of Mongolian horses represented the natural interaction of the hoof with the environment.

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1. Introduction

Ideal hoof and lower limb conformation has been the subject of much attention within the technical manuals and the lay equine literature [1,2]. Much of this information has been the result of the observations and associations identified by equine practitioners over many years. However, there is little scientific or empirical evidence to support the ideal hoof and limb conformation proposed. Only recently, in relation to our domestication and use of the horse, we

have had the ability to measure the forces and loads within the hoof and lower limb or the data collection and statistical techniques to quantify risk factors for injury [3,4] or longevity [5]. These data provide an understanding of the effect of different trimming and shoeing techniques [6] and also a scientific framework around which we can examine and quantify current practice [7].

Often the feral or wild horse population is promoted as the “gold standard” for hoof conformation [8]. A pattern of trimming and hoof conformation has been developed from observations of feral horses in semi-arid environments. Recent data have indicated that hoof shape and conformation is a by-product of genetics and the environment [4,9,10]. In semi-arid environments, hoof shape and conformation is relatively homogeneous [8,9]; however,

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a wide range in hoof conformation has been reported in the presence of a softer substrate and an environment with easy access to pasture and water [9]. This heterogeneity in conformation was greater than that expected owing to the seasonal patterns of natural hoof trimming [11], reported gross asymmetry within feet, altered mediolateral balance, long toes, and large wall flares [9].

Exercise has also been implicated in altering hoof conformation, with racehorses in work having a decrease in hoof circumference during training [12,13]. Modern management systems reduce access to free exercise, which has implications for development of the equine musculo-skeletal system [14]. Within modern management systems, such as confinement within a yard or a loose box, it is reported that horses will travel only 1.1 (range: 0.2–1.9) km/d compared with an average of 15.9 ± 1.9 km/d for feral horses [15]. In a feral environment, this free access to exercise would encourage a different type of hoof conformation compared with that observed with domesticated horses within intensive management systems.

Within intensive management systems, the farrier attempts to provide optimal hoof balance in relation to the lower limb conformation. It is important that hoof shape and conformation is interpreted in relation to the lower limb conformation [16]. To date, it seems there are limited reports within the literature regarding the effect of deviations from the ideal lower limb conformation and the association of these with hoof shape and conformation. The Mongolian horse provides a unique model of a horse managed under semi-feral environment with little to no hoof care or intensive husbandry. Therefore, the aim of this study was to investigate the typical lower limb and hoof conformation in a population of Mongolian native horses maintained on an open tundra environment and to investigate the association of lower limb conformation with hoof conformation and shape.

2. Materials and Methods

Data were collected as part of a convenience sample of horses offered for the 2011 Mongolian Derby: a 1,000-km race where riders travel the entire distance but each horse is ridden only on one occasion for a distance of approximately 40 km. Digital images of hooves and linear assessment of lower limb conformation were collected by four veterinarians involved in the screening of the horses offered for the riders during the derby.

The Mongolian native horses were from the Töv, Övörkhangai, Arkhangai, and Bulgan regions of Mongolia, which are characterized by 250-mm of annual rainfall, a temperature range of -22°C to 33°C , and open tundra grasslands or steppe. The horses were managed extensively (no confinement in paddocks) as semi-feral herds grazing the rangeland/steppe.

At each transition point during the race, the veterinarian's role was to screen the suitability of the horses offered for the competing riders. During this process, a random sample of horses was selected, and data were recorded on the limb and hoof conformation. A brief one-page survey was completed by the horse owner, via an interpreter, to provide data on the age and gender of the horse, the general hoof care procedures, and typical weekly riding activity.

2.1. Linear Assessment of Lower Forelimb Conformation

Lower forelimb conformation was assessed via a 7-point linear scale based on the system developed by Mawdsley et al. [17], where a score of 4 represented ideal or normal conformation, and a score of 0 or 7 represented the maximal deviation in either direction from the ideal. Briefly; the linear scale was used to measure seven parameters: knee 1 (bucked to calf/back at the knee), knee 2 (tied in to chopped), hoof pastern axis (broken forward to broken back), cannon (3rd metacarpal bone) angle (carpal varus to carpal valgus), knees relative to cannon (bench knee [lateral deviation] to inset cannon), metacarpophalangeal angle (varus to valgus), and upstandingness (base wide to base narrow). The asymmetry of the hoofs was also scored as a univariable trait (symmetric or asymmetric).

Digital images were obtained using compact digital cameras, and images were subsequently saved as png files for later analysis. For each horse, lateral and solar views of each hoof were obtained with the camera at a focal distance of approximately 1 m. Within the field of view, the images were identified by a 100-mm pro forma identification card, held in the same transverse plane as the hoof, which provided the object for calibration for subsequent image analysis.

Digital images were uploaded into ImageJ V1.44 (National Institute of Mental Health, Bethesda, Maryland, USA) (NIH) for linear and angle measurements. Data were collected on the dorsal hoof wall angle, the angle of the pastern (line bisecting pastern) relative to the hoof solar surface, hoof width (width of the hoof at its widest point), hoof length (length of the solar ground bearing surface), frog length (the distance buttress of heels/palmar hoof line to the point of frog) [18], and distance from the widest point of the hoof to the most caudal solar surface (buttress of heel/palmer hoof line). Within-operator trials based on five repeated measurements per parameter demonstrated high repeatability of measurement with coefficients of variation $<2\%$.

A variable to describe limb asymmetry was created to quantify the difference in lower limb score for a given conformation trait between the left and the right leg. This was obtained by calculating the absolute difference between the score of the left and the right leg for each conformation trait.

2.2. Statistical Analysis

Data were entered into excel for manipulation, and preliminary descriptive statistics were performed to check for errors. All analyses were conducted using PASW statistics 18 (IBM Corporation, Somers, NY). The differences in hoof measurements between horses with normal (linear score of 4) and abnormal lower limb conformation (a deviation of greater than 1 point from the ideal score of 4) were tested using a univariate general linear model, with a significance level of $P < .05$.

3. Results

Demographic data and initial images of 120 horses were collected from a pool of approximately 630 horses offered for the derby. Complete digital images of hooves suitable

for analysis were available for 104 horses. These horses had a mean age of $8.6 \pm$ (SD) 2.5 years and were approximately $137 \pm$ (SD) 8 cm. Most of the horses were geldings (96%; 100/104), 2% were stallions, and 2% were mares. No owner reported providing routine hoof care or trimming. The majority of the horses were ridden once a week (60/104, 58%), followed by every few days (24/104, 23%), with few horses ridden daily (9/104), monthly (3/104), or rarely (8/104).

Descriptive data on the limb conformation scores for the assessed conformation parameters are shown in Table 1. The general trend was for horses that were slightly carpal valgus, mildly offset cannon (bench knees), and were slightly valgus at the metacarpophalangeal joint. Overall, the limb scoring identified a population displaying what appeared to be a normal distribution around the mean. Most values were normal (score of 4) (43%; 714/1668), and 93% (1546/1668) of the values were within 1 linear score of the mean.

The distribution of the asymmetry index for knees relative to cannon and metacarpophalangeal joint angle is presented in Figures 1 and 2. The common trend was for horses that were mildly offset and valgus and bilaterally affected. Asymmetry of hoofs scored as a univariable trait revealed that 78 of 104 (75%) of the horses had even-sized hoofs, and 26 of 104 were scored as uneven. A nondirectional symmetry index for hoof parameters was generally high, with $91\% \pm 8\%$ for hoof angle, $94\% \pm 6\%$ for hoof width, and $95\% \pm 5\%$ for hoof length.

Comparison of horses with normal and abnormal limb conformation for metacarpophalangeal joint valgus/varus, hoof pastern axis, and carpal valgus/varus did not identify a significant difference between groups for hoof measures. Significant differences were found with hoof width length (with metacarpophalangeal joint valgus/varus) and pastern angle with hoof pastern axis ($P < .05$) (Table 2).

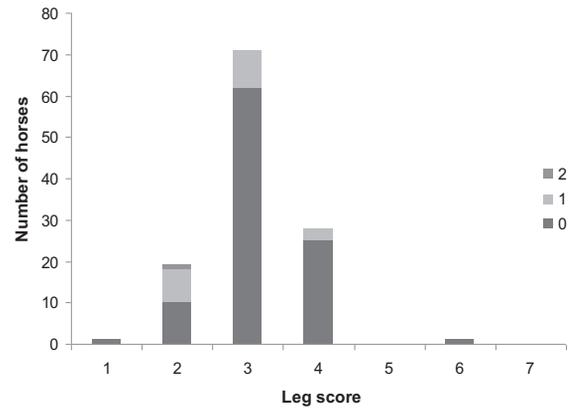


Fig. 1. Frequency of the trait knees relative to cannon. Values on the x axis represent the score for the left leg, and shaded sections represent the frequency of absolute deviation of the comparative score for the same trait in the right leg.

4. Discussion

This article describes the lower limb and hoof conformation in a population of semi-extensively managed Mongolian horses ridden in the Mongol Derby. The aim of the study was to describe the typical lower limb and hoof conformation and to investigate the association of lower limb conformation with hoof conformation and shape. Overall, there was limited variation within the population, with most horses being scored with normal conformation. Additionally, there was a lack of significant changes observed in hoof shape in relation to limb conformation. The horses in the sample population had no routine hoof care, and as such, the data obtained reflect the influence of the environment on hoof shape. The limited variation of the

Table 1

Descriptive data of number (percentage) of horses with lower limb conformation scores for eight assessed conformation traits in a cohort of 104 Mongolian horses

Conformation Parameter	Conformation Score						
	1	2	3	4	5	6	7
Knee 1							
Left	2 (2)	0	25 (21)	82 (69)	8 (7)	1 (1)	0
Right	1 (1)	0	23 (19)	85 (71)	11 (9)	0	0
Knee 2							
Left	0	0	35 (30)	74 (63)	7 (6)	2 (2)	0
Right	0	2 (2)	30 (25)	77 (64)	10 (8)	1 (1)	0
Hoof pastern axis							
Left	0	2 (2)	41 (35)	42 (36)	27 (23)	6 (5)	0
Right	0	4 (3)	32 (27)	61 (51)	16 (13)	6 (5)	0
Carpal valgus/varus							
Left	1 (1)	0	3 (3)	38 (32)	66 (55)	10 (8)	1 (1)
Right	1 (1)	0	3 (3)	37 (31)	65 (55)	13 (11)	0
Knees relative to cannon							
Left	1 (1)	19 (16)	71 (59)	28 (23)	0	1 (1)	0
Right	2 (2)	14 (12)	72 (60)	31 (26)	0	1 (1)	0
Metacarpophalangeal joint valgus/varus							
Left	0	5 (4)	69 (58)	34 (29)	10 (8)	0	1 (1)
Right	0	8 (7)	67 (56)	37 (31)	5 (4)	1 (1)	1 (1)
Upstandingness							
Left	0	5 (4)	46 (38)	42 (35)	23 (19)	4 (3)	0
Right	0	1 (1)	49 (41)	46 (39)	18 (15)	5 (4)	0

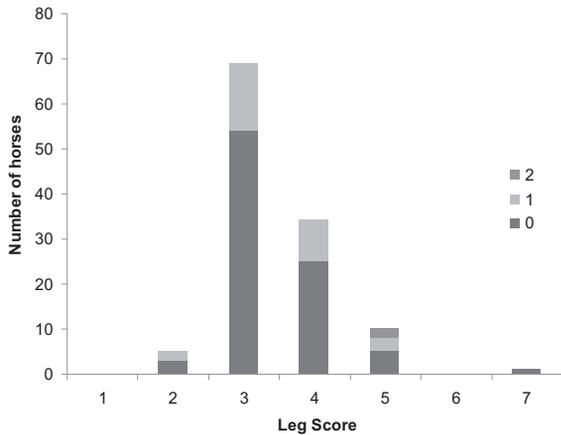


Fig. 2. Frequency of the trait metacarpophalangeal joint valgus/varus. Values on the x axis represent the score for the left leg, and shaded sections represent the frequency of absolute deviation of the comparative score for the same trait in the right leg.

parameters measured within this population and deviation from the normal hoof implies that the semi-arid steppe environment maintained a normal hoof shape.

The data presented in this article represent a convenience sample of a subpopulation of Mongolian native horses and as such may not represent the wider population of Mongolian native horses. The horses presented for the derby were considered to be more rideable and better quality horses. At each transition stage of the race, the selection of horses for data capture was randomized. However, at times, the sampling was rapid, which resulted in some missing data because of variable image quality. Data were collected by four veterinarians, and to reduce intra observer variation, data were recorded on *pro forma* recording sheets, which contained reference guides for the conformation assessment.

Field surveys of conformation within domestic horse populations have identified that in some cases, the normal conformation is not what was previously considered the ideal, such as the high prevalence of bench knees in

Warmbloods [19] and cow hocks in Standardbred horses [20]. Within the sample population in this study, there was limited extreme deviation from the ideal conformation. It is likely that under semi-feral husbandry and the extensive distances covered by feral horses, there would be limited variation in lower limb or hoof conformation.

For some parameters such as metacarpophalangeal joint valgus/varus, carpal valgus/varus, and offset/bench knees, most horses had mild deviation from the ideal. It is possible that the biomechanical impact of such conformations was not significant with the workload/exercise stress that the horses were exposed to. At the gallop, the time taken to absorb shock is 50% of that at the walk, and the magnitude of the load is approximately 6 N kg⁻¹ vs. 13 N kg⁻¹ body mass at the gallop [21,22]. Data from racehorses indicate that there is differentiation in the response of tissue and the magnitude of the loads applied to the limb at the threshold of gallop (~12–14 m/s) compared with horses that had only cantered [23]. The application of the stress placed on the limb, or its components, are reported to increase linearly with increases in velocity [24]. Therefore, if the horses in this sample population were used at velocities below that used for gallop training in Thoroughbred racehorses, it is probable that the variations in conformation seen in this study would not provide significant risk factors for injury or lameness compared with those found with the galloping racehorse [25].

Within the Mongolian population, there are also two confounding factors. First, a large pool of horses was available, so any lameness would result in the horse being substituted with another. Second, the soft substrate of the open tundra may attenuate much of the limb forces and reduce the negative association of the limb deviation, as surface compliance has a direct and proportional effect on the amplitude and frequency of impact accelerations [26]. The variation in hoof conformation of the Kaimanawa feral horses, which live in a relatively less abrasive environment, compared with the homogeneous hoof conformation of Australian feral horses lends support for this hypothesis [9].

The hoof parameters of the Mongolian horses in the present study are in agreement with other published data

Table 2

Comparison of hoof measurements for horses categorized as having normal or abnormal (a deviation of greater than 1 point from the ideal score of 4) limb conformation, for a cohort of 104 Mongolian ponies

Conformation Parameter	Limb Conformation		P Value
	Normal (Mean ± S.E.)	Abnormal (Mean ± S.E.)	
Metacarpophalangeal joint valgus/varus			
Dorsal hoof angle	53.204 ± 1.014	51.628 ± 0.638	.19
Pastern angle	62.431 ± 0.994	61.589 ± 0.653	.48
Hoof length	109.069 ± 1.307	107.766 ± 0.940	.42
Distance from palmar hoof line to widest	48.065 ± 1.514	47.743 ± 1.206	.86
Frog length/hoof length	0.654 ± 0.009	0.670 ± 0.007	.16
Distance from palmar hoof line to widest/hoof length	0.442 ± 0.013	0.451 ± 0.011	.57
Hoof width/hoof length	1.109 ± 0.013	1.069 ± 0.009	.02
Carpal valgus/varus			
Dorsal hoof angle	53.091 ± 0.980	51.549 ± 0.647	.19
Pastern angle	61.627 ± 0.960	61.901 ± 0.663	.82
Hoof length	108.525 ± 1.257	108.349 ± 0.989	.93
Distance from palmar hoof line to widest	46.258 ± 1.423	49.825 ± 1.268	.06
Frog length/hoof length	0.661 ± 0.008	0.666 ± 0.007	.70
Distance from palmar hoof line to widest/hoof length	0.432 ± 0.012	0.464 ± 0.011	.06
Hoof width/hoof length	1.090 ± 0.012	1.078 ± 0.010	.42

for horses of similar size [9]. In general, the hooves fitted a pattern of the normal equine hoof with respect to size and balance (hoof:widest part, hoof:width ratio). The exception to the data is perhaps the consistency of the HPA being broken back with a pastern angle of approximately 60°. Generally, parallelism of the pastern and the hoof angle occurs when the fore hoof has an angle of between 50° and 54° [27]. The mild broken back hoof pastern axis observed in this study may be a characteristic of the breed/type of horse, as the conformation of the lower limb, and the pastern in particular, is reported to vary between breeds [27]. None of the horses measured had routine hoof care, so the hoof parameters observed in the sample population of horses is a result of natural wear. The horses were usually kept on the open tundra of the steppe, but not exclusively, and had access to a varying terrain, including stony arid rangeland that may have been sufficient to maintain hoof shape. Hoof shape may not only be due to the resistance or abrasive qualities of the substrate but also due to the interaction of ambient moisture, which would alter the abrasiveness of the substrate and, possibly to a lesser extent, the stiffness of the equine hoof [28,29]. In the region of the Mongolia where the horses were measured, the average annual rainfall was 250 mm/yr, approximately 20% of that which is recorded in the habitat of the Kaimanawa horses (~1,200 mm/yr).

In conclusion, few limb conformation abnormalities were observed. The population was characterized by a broken back hoof pastern axis, although hoof size and shape was within the normal expected range for horses of this size. The hoof conformation in this population of Mongolian horses represented the natural interaction of the hoof with the environment.

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