Journal of Equine Veterinary Science 32 (2012) 231-234

Journal of Equine Veterinary Science

journal homepage: www.j-evs.com

Original Research

Hoof Size and Symmetry in Young Catalan Pyrenean Horses Reared Under Semi-Extensive Conditions

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ARTICLE INFO

Article history:
Received 23 February 2011
Received in revised form
1 August 2011
Accepted 27 August 2011
Available online 20 October 2011

Keywords:
Conformation
Horse
Morphometry
Sole
Symmetry

ABSTRACT

Hoof balance and conformation have been researched extensively in performance horses. The aim of this study was to describe the solar length, width, area, and symmetry of fore and hind hooves of young Catalan Pyrenean horses (*Cavall Pirinenc Català*) reared under semi-extensive conditions and lacking any hoof care, trimming, or shoeing. Measurements were performed on the isolated limbs. Solar length, width, and surface area of 128 distal limbs obtained from 32 yearlings demonstrated no significant differences between left and right forelimbs or hind limbs for any variable ($P = .413$, .975, and .486, respectively). There were no significant differences between fore and hind limbs for length ($P = .831$), whereas the forehoof width and area were significantly larger than those of the hind limb ($P < .001$). Interindividual variability was low for hoof width and length (coefficient of variation, <10%) and slightly larger for solar area (coefficient of variation, <15%). All variables had very high left-right symmetry (≥98%). No relevant laterality could be identified (directional asymmetry indices <2%). Notwithstanding the absence of regular hoof care, young Catalan Pyrenean horses reared under semi-extensive conditions present homogenous hoof sizes and a high level of symmetry for hoof length, width, and solar area.

1. Introduction

Hoof balance and conformation are considered major determinants of equine soundness and performance [1]. In a study on National Hunt racehorses, 27 conformational traits were shown to be significantly different between the left and the right side; six of these traits were hoof and heel measurements [2]. Asymmetry between sides is supposed to result in asymmetrical loading of anatomical structures [2]. Hoof unevenness in horses dramatically shortens competitive life at the elite level of jumping [3]. Recently, pressure plate analysis has proven that even in clinically sound ponies, a hoof with a smaller contact area (eg, more upright hoof with contracted heels and concave sole) is less loaded than a hoof with a larger contact area (eg, hoof with low, spread heels and flat sole) [4]. This is in agreement with previous studies, demonstrating that an increased hoof spread is associated with a lower hoof angle [5], which in turn is associated with a higher limb load [6]. Interestingly, as a result of functional adaptation, hoof unevenness can develop not only from an episode of pain/lameness in the limb with the more contracted foot [7], but also from laterality or handedness very early in life, even in foals [8]. Undoubtedly, the cause-and-effect relationship between hoof conformation and limb loading remains to be elucidated [5].

Most studies on conformation have been performed in horses bred for sports performance [2,9,10]. However, hoof morphometry in wild horses has gained scientific attraction as the natural reference [11].

The *Cavall Pirinenc Català*/Catalan Pyrenean horse (CPC; Fig. 1) is an inexpensive horse bred for meat production in the harsh environment of the northeastern part of the Pyrenees along the Spanish-French border [12]. It is

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doi:10.1016/j.jevs.2011.08.020

Fig. 1. The Catalan Pyrenean horse (*Cavall Pirinenc Català*).

a compact, broad-built, predominantly chestnut horse with rather short limbs [13]. Genetic analysis suggests that this small population of CPC horses (<4,600) [14] is closely related to the Breton and Comtois breeds [15]. The CPC horses are reared outdoors throughout the year and do not receive any additional food besides some low-quality straw in winter. When young horses are selected for slaughter, they are gathered in large paddocks and receive additional feeding with hay and concentrates during the last months before slaughter. Animals of this breed range over rocky mountain pastures and do not receive any hoof care, trimming, or shoeing. Therefore, their hooves must be considered *naturally* shaped [16]. Remarkably, hoof wall problems are rather rarely encountered in this breed [16].

In the wild horse, natural hoof care may provide optimal form for proper function and soundness [11]. Similarly, the harsh Pyrenean environment can be assumed not to tolerate a wide range of hoof asymmetries; hence, there may be a natural selection in the CPC horse population toward homogeneously shaped, symmetrical hooves.

The aim of this study was to describe the solar length, width, area, and symmetry of fore and hind hooves of CPC horses. The hypothesis was tested that the prevalence of hoof sole symmetry in this breed reared under semi-extensive conditions was high.

2. Materials and Methods

At a commercial abattoir, 128 distal limbs were obtained from 32 CPC horses immediately after normal slaughter between October 2009 and June 2010. The healthy and sound horses were all approximately 1 year old (body mass 358.9 ± 30.3 kg). All horses were unshod; no hooves had received any trimming or other interventions. The limbs were disarticulated at the level of the carpus/tarsus. Subsequently, the hooves were rinsed with water before measurements were performed. Hooves with gross lesions like hoof wall avulsions were excluded from the study.

Solar measurements were performed by outlining the perimeter of the distal hoof wall with a pen on paper. Subsequently, these drawings were photocopied, including a calibration ruler, and scanned into dedicated image analysis software (Image Tool 3.0, University of Texas, Health Science Center, San Antonio, Texas). The perimeter of the solar surface was delimited by 50-60 points; subsequently, solar length (cm), width (cm), and area (cm^2) were determined by one operator (Fig. 2), as described previously [16].

Data were collated and prepared for statistical analysis using spreadsheet software (Microsoft Office Excel 2007, Microsoft Corporation, Redmond, Washington), and statistical analysis was performed using SPSS 17.0 (SPSS Inc., Chicago, Illinois) with statistical significance set at $P < .05$. Data are presented as means ± SD, unless otherwise stated.

To assess interindividual variability, coefficients of variation (CV) were calculated as SD/mean × 100% for all variables. The CVs of the four limbs were averaged and are presented as mean ± SD.

A linear mixed-effects model with horse as random component was used to evaluate the effect of fore or hind and left or right and their interaction (fixed factors) on hoof length, width, and area.

Nondirectional and directional symmetry indices (SIs) were calculated. Nondirectional SIs were calculated as: SI_i = lowest/highest value × 100%. Directional asymmetry indices (DAI) were calculated using the equation: $DAI_i = (X_l - X_r)/0.5\ (X_l + X_r) \times 100\%$, where X_l = left limb value and X_r = right limb value [17]. Using this method, a DAI of 0 indicates perfect symmetry for the measured variable, whereas positive or negative values (range, 0%-200%) are seen in case of left- or right-limb dominance, respectively.

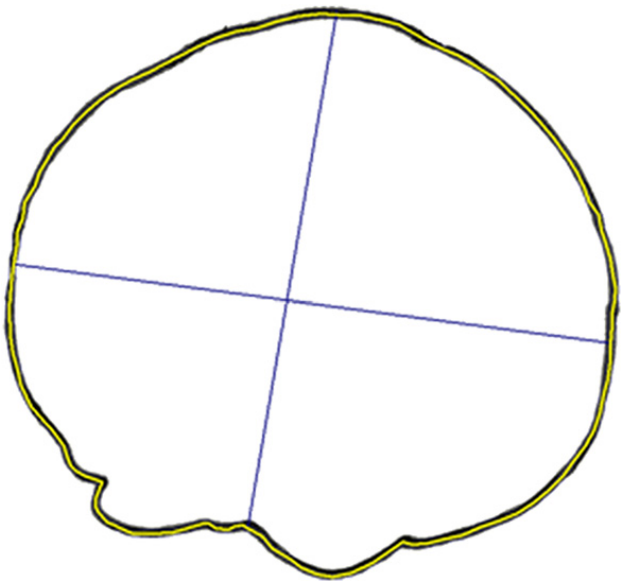

Fig. 2. Example of one left forehoof image, delineating the hoof surface area and illustrating the measurement of hoof sole length and width.

Table 1
Mean ± SD left and right fore- and hind-hoof solar length, width, and area

Variable	Fore		Hind	
	Left	Right	Left	Right
Length (cm)	12.19 ± 0.94	12.27 ± 0.99	12.33 ± 1.07	12.07 ± 1.37
Width (cm)	13.15 ± 1.22[a]	13.17 ± 1.13[a]	12.02 ± 0.95[b]	11.99 ± 0.92[b]
Area (cm^2)	133.42 ± 20.64[a]	133.06 ± 19.69[a]	122.78 ± 17.46[b]	121.39 ± 19.41[b]

[a,b]Within the same row, values with different superscript letters differ significantly ($P < .05$).

Ethical approval was not required, as all measurements were recorded postmortem at a commercial abattoir.

3. Results

Left and right fore- and hind-hoof solar length, width, and area are presented in Table 1. There were no significant differences between the left and right forelimbs or hind limbs for any variable ($P = .413$, .975, and .486, respectively). Interaction terms between left or right and fore or hind were not significant for any of the variables ($P = .119$, .730, and .679, respectively). There were no significant differences between the fore and hind limbs for length ($P = .831$), whereas the forehoof width and area were significantly larger than in the hind limb ($P < .001$).

CVs of solar length, width, and area measurements are presented in Figure 3. Nondirectional symmetry is illustrated in Figure 4. Directional asymmetry indices are shown in Figure 5.

4. Discussion

This study is the first to describe solar length, width, area, and symmetry of fore- and hind-hooves of CPC horses. This breed is reared under semi-extensive conditions, lacking human interventions. Our results indicate that despite the absence of regular hoof care, these horses present excellent left-right hoof symmetry, at least for solar length, width, and area. Moreover, these variables were highly repeatable in this sample of 32 horses.

Studies on Thoroughbred racehorses have reported values for solar length (11.6 cm [9] and 14.5 cm [10]) and width (12.5 cm [9] and 12.2 cm [10]) similar to the ones in the CPC horses described here (length and width approximately 12-13 cm). In contrast, slightly larger hoof dimensions (length 16.0 cm and width 14.1 cm [18]; width 14.4 cm [5]) have been reported in mixed samples of equine breeds. Surface area values in Thoroughbreds [9] were smaller (120 cm^2) than those in the present study (133 cm^2). All these differences may be attributable to breed differences or may be biased by methodology, ranging from a video camera [9] or photographs [10], both in combination with dedicated image analysis software, to flexible tape measurements [18]. Undoubtedly, for a direct comparison between breeds, they should be investigated in a single study.

In agreement with literature [19], our results demonstrated that the solar surface is approximately as wide as it is long, even in the *naturally* shaped hooves of CPC horses. Moreover, fore- versus hind-hoof solar area data were in agreement with literature stating that generally the latter is slightly smaller [1]. Pressure plate analysis has investigated the interface between the hoof and the track during locomotion [4], and has revealed smaller hoof contact area measurements than solar area measurements reported here. Obviously, the direct interface between hoof and track is smaller than the complete area delimited by the perimeter of the hoof.

Notwithstanding the fact that no hoof care was given to the CPC horses, a high degree of left-right symmetry was seen. No obvious limb dominance (ie, laterality) could be demonstrated using directional symmetry indices. It would be interesting to evaluate the degree of asymmetry in other hoof conformational traits such as toe and heel angle in this breed. It is believed that the high level of symmetry may at least partially be attributed to the continuous, free movement on a variety of substrates, a varied diet, and natural selection in a harsh environment where asymmetric conformation and lameness are associated with less chance of survival. All these factors are in contrast with the management of today's sports horses spending most of their time in their stable, receiving mainly concentrates and little roughage, and being trimmed and shod regularly.

A first limitation of this study is that only one particular breed was studied. A second limitation is that only young horses aged approximately 1 year were included. Hoof morphology may change with increasing age. However, it

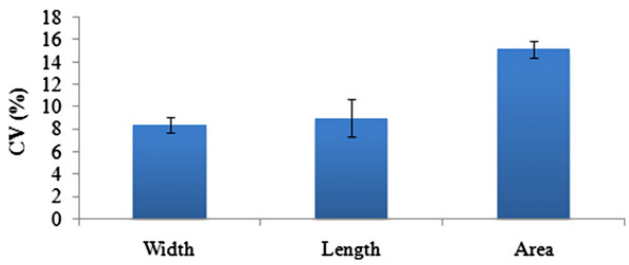

Fig. 3. Mean ± SD bar graphs presenting the coefficient of variation (CV) of solar width, length, and area. Interindividual variability is low for hoof width and length (CV, <10%), and slightly larger for solar area (CV, <15%).

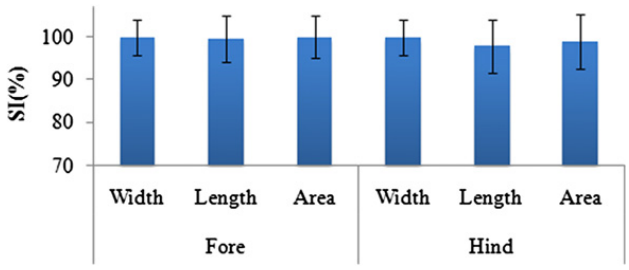

Fig. 4. Mean ± SD bar graphs presenting the nondirectional symmetry indices (%) for fore- and hind-hoof width, length, and area. All variables have very high symmetry (≥98%).

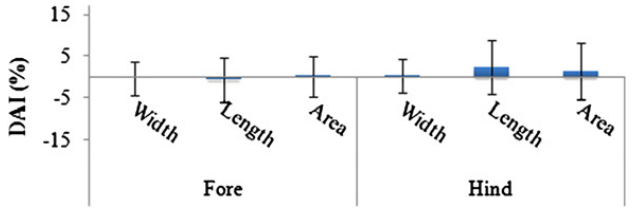

Fig. 5. Mean ± SD bar graphs presenting the directional asymmetry indices (%) for fore- and hind-hoof width, length, and area. All variables have very low asymmetry (≤2%). No relevant left or right limb dominance can be identified.

has been shown that asymmetry in hoof conformation can already be detected in foals [8]. Given the homogeneous results in the rather large sample of 32 yearlings, we believe the reported results have adequate power. However, extrapolation of these results to older horses should be performed judiciously. Nevertheless, our results open perspectives to perform further research on horses over a wide range of breeds and ages.

In conclusion, this study is the first to describe hoof sole morphology and its symmetry in unshod, young CPC horses, reared under semi-extensive conditions. This breed presents homogenous hoof sizes and a high level of symmetry for hoof length, width, and solar area.

Acknowledgments

The authors thank MAFRISEU SA in La Seu d'Urgell (Catalunya, Spain) for providing the study material.

The study conception and data acquisition were performed by P.M.P.C.; statistical analysis was performed by M.O. Both authors contributed equally to data interpretation, writing, and revising of the manuscript and to the final approval of the submitted version.

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