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Morphometric changes in the hoof capsule of Criollo foals from birth to weaning

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ABSTRACT: *South America has numerous Criollo horse breeding farms; however, information on foal hoof growth is still limited and identifying the ideal periods to apply corrective trimming is a frequent concern for horse owners. In the present study, a morphometric analysis of hoof growth was performed on 46 Criollo foals from birth to weaning (0-8 months). Results showed that hoof growth rate was higher in the first four months followed by a decrease until the eighth month. Average growth rate of the hoof was 0.21cm per month, whereas that of the heel was 0.14cm per month. However, no significant differences were observed between medial and lateral heel length or between limbs. Coronary band perimeter and solar width showed an average increase of 0.97cm and 0.46cm per month, respectively, and were significantly correlated (r=0.99, P≤0.01). The characteristic most positively correlated to biometric variables was foal age, followed by solar width, toe length, and coronary band perimeter. In conclusion, hoof length increase in Criollo foals was more intensive during the first four months of life.*
Key words: *foals, hoof capsule, morphometric analysis, long-term study.*

Alterações morfológicas na capsula do casco em potros Crioulos do nascimento ao desmame

RESUMO: *A América do Sul possui um grande número de criatórios da raça Crioula, no entanto, há uma carência de informações sobre o desenvolvimento natural dos cascos dos potros, tornando a identificação de períodos ideais para o casqueamento corretivo uma dúvida frequente entre os criadores. Portanto, o objetivo deste estudo foi realizar a biometria natural (do nascimento aos 8 meses) no casco de 46 potros da raça Crioula. Os resultados indicaram uma taxa de crescimento mais rápido nos primeiros 4 meses, com subsequente desaceleração até o desmame. O crescimento médio do casco foi em média 0,21cm mo-1, enquanto o comprimento do talão foi de 0,14cm mo-1. Não foram observadas diferenças significativas no equilíbrio médio/lateral do casco ou entre os membros durante o período experimental. O perímetro da banda coronária e a largura solar do casco apresentaram um crescimento médio de 0,97 e 0,46cm mo-1, respectivamente, e foram altamente correlacionados (r=0,99, P≤0,01). A idade dos potros foi a característica mais correlacionada positivamente, seguida da largura solar, do comprimento do casco e do perímetro da banda coronária. Nós concluímos que o crescimento do casco em potros da raça Crioula foi mais intenso durante os quatro primeiros meses de vida.*
Palavras-chave: *potros, cápsula do casco, morfometria, estudo progressivo.*

INTRODUCTION

The functionality of the structures composing the equine hoof is strongly related to the morphology of the hoof capsule. Moreover, the presence of appropriate proportions of the hoof capsule and its enclosed skeletal structures are crucial for optimal resistance against the biomechanical load exerted from the ground to the limb, with implications on performance, injury, and lameness (VAN WEEREN & CREVIER-DENOIX, 2006).

Tubules comprising the hoof wall are arranged in a way that allows their movement as the hoof expands and contracts, and the vertical extension

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of this flexible structure may reveal disorders caused by clinical injury, growth failure, irregular wear, or trimming. Development of the hoof capsule is affected by environmental conditions and the horn is continuously pushed distally. In adult horses, the hoof wall of thoracic limbs increases by 0.63cm and that of pelvic limbs by 0.72cm (GLADE & SALZMAN, 1985), within the 270-365 d required to complete its growth down to the weight-bearing margin (KAINER, 2006). Recent studies investigated hoof formation during pregnancy (FRANCIOLLI et al., 2011) and evaluated the time necessary for the fetal hoof to grow down from the coronary band to the distal margin (CURTIS et al., 2014). However, no studies conducted so far have investigated the biometrics of natural hoof growth from birth to weaning.

Several patterns related to hoof growth have been investigated and LANDEAU et al. (1983) and KAINER (2006) recognized that hoof pigmentation and its resistance to pressure and tension were not correlated. Conversely HINTZ (1983) described several factors positively affecting hoof growth, including hoof angle, genetics, nutrition, exercise regime, season, and humidity.

South America has numerous Criollo horse breeding farms. Knowing which patterns are correlated with hoof growth is important to improve foal management and identify the proper time to attempt corrective trimming. Based on the hypothesis that there is a period of increased hoof growth in developing Criollo foals, the present study evaluated the morphometric changes in the hoof capsule of Criollo foals from birth to weaning.

MATERIALS AND METHODS

Foals

Forty-six Criollo foals descending from seven Criollo stallions, and born from September to January under normal climatic conditions (spring/summer), were selected from a farm near Jaguarão, Rio Grande do Sul, Brazil (latitude 32º33'58'', longitude 53º22'33''). Foals were maintained with the mares on natural pasture grazing systems, mainly comprising *Paspalum notatum*, *Paspalum dilatatum*, *Andropogon lateralis*, and *Coelorachis selloana* (PILLAR et al., 2009), and had *ad libitum* access to mineral salts and water.

Measurements

Hooves were not trimmed to facilitate the study of their natural growth. Data were first collected 15 days after birth, and then collected monthly until weaning at eight months. Hoof capsule morphometric changes were evaluated in both forelimbs based on: (1) toe length, from the coronet to the distal margin; (2) heel length, from each bulb to the weight-bearing margin of the heel; (3) coronary band perimeter; (4) solar width, i.e., width of the solar surface of the hoof; and (5) toe angle, measured between the dorsal hoof wall and the bottom of the hoof (Figure 1). Hooves were lifted to obtain the linear and angular distances using a measuring tape (cm) and hoof gauge (°), respectively.

Data analyses

Measurements were taken by a trained person from the research team, and a coefficient of variation (CV) was established. Data were organized in Microsoft Office Excel[a], and statistical analyses were performed in JMP software[b]. Parametric data were evaluated using regression analysis, Pearson's correlations, and are expressed as average monthly-growth rates. Differences were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Morphometric changes occurring in the hoof capsule are presented in table 1. Average growth rate of the hoof was higher in the foals' first four months (4.69±0.08, 5.21±0.08, 5.60±0.05, and 6.01±0.10cm in months 1 to 4, respectively), which was in accordance with that reported in Thoroughbred foals by CURTIS et al. (2014). In addition, changes in toe length can be described as: toe length = 4.8060987 + 0.2875192 × month - 0.0524012 (month - 3.74569)2, R^2=0.54, $P \leq 0.01$. Thus, because toe length also increased during the first four months, orthopedic examinations should be intensified during this period, as this might lead to fewer surgical interventions and to a higher success of possible corrections. Toe length average in the weaning (6.14±0.10) were similar on the first four months, and similar to the 8.69cm observed in adult Criollo horses (CANTO et al. (2006).

At birth, heel length was 2.85±0.07cm, increasing gradually and significantly in the following months: 3.52±0.08, 3.67±0.06, 3.71±0.08, 3.77±0.06, 3.80±0.06, 3.86±0.09, and 3.66±0.09cm. Changes in heel length can be described as: heel length = 3.229017 + 0.1511211 × month - 0.0473424 (month - 3.74569)2, R^2=0.34, $P \leq 0.01$. No significant differences were observed in medial/lateral hoof balance or among limbs during the experimental period. TURNER (1992) reported that

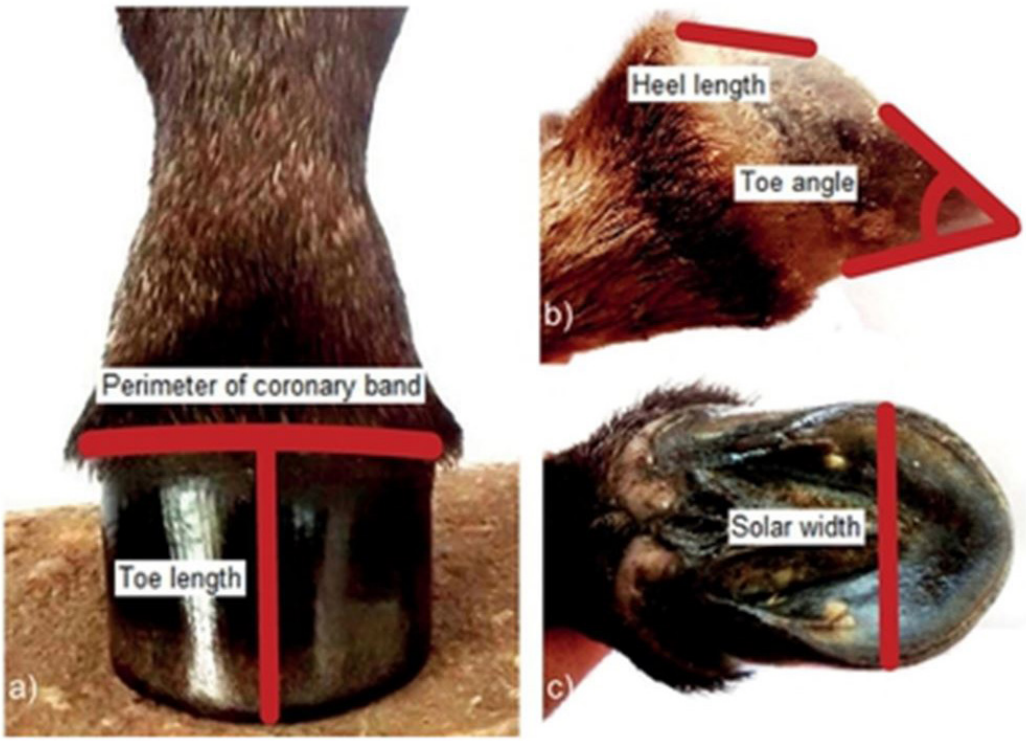

Figure 1 - Morphometric measurements assessed monthly in Criollo foals from 15 days after birth to weaning (eight months). a) Dorsal view, b) Lateral view, and c) Solar view. Toe length: from the coronet to the distal margin; Heel length: from each bulb to the weight-bearing margin of the heels; Coronary band perimeter; solar width, width of the solar surface of the hoof; and Toe angle: measured between the dorsal hoof wall and the bottom of the hoof.

heel length differences higher than 0.5cm indicated disequilibrium in the lateral/medial hoof. In the present study, the average difference in heel length was less than 0.5cm. Heel length increased at a rate of 0.12cm per month, which was lower than that of the toe length. This might be related to the heel abrasion by soil reaction forces occurring during the movement of equine limbs.

Changes in the coronary band perimeter could be described using the equation: coronary band perimeter=19.379971+1.114097×month-0.1229946 (month -3.74569)2, R^2=0.79, P≤0.01. Average values registered during the first three months (19.48±0.23, 21.24±0.21, and 22.80±0.14cm) differed both among the first three months and from that registered in months 4 (24.03±0.14) and 5 (24.52±0.20cm), which were similar; the average value obtained in month 7 (25.82±0.21cm) were similar to that obtained in months 6 (25.23±0.21cm) and 8 (26.30±0.30cm). Solar width could be described using the equation: solar width = 5.3056607 + 0.5051792 × month - 0.0320693 (month - 3.74569)2, R^2=0.81, P≤0.01. It significantly differed during the first six months (5.50±0.06, 6.31±0.07, 6.86±0.06, 7.28±0.09, 7.62±0.11, and 8.25±0.14cm), and then stabilized in months 7 and 8 (8.60±0.10 and 8.72±0.09cm, respectively). The coronary band perimeter and solar width increased progressively during the experimental period at 0.97cm and 0.46cm per month, respectively and were significantly correlated (r=0.99; P≤0.01). Previous studies reported that an average solar width of 12.5cm for adult Thoroughbred racehorses (KANE et al., 1998) and 12.1cm for Catalan Pyrenean horses (PARÉS I CASANOVA & OOSTERLINCK, 2012), which are larger than the values obtained here for Criollo horses.

Toe angle varied during the experimental period from 54.9°±0.81 to 57.7°±0.68 and had no significant interaction with any other traits. Changes in toe angle can be described using the equation: toe angle = 56.587303 + 0.1663238 × month - 0.1388137 (month - 3.74569)2, R^2=0.04, P≤0.01. Similar results have been reported in Dutch Warmblood foals (KROEKENSTOEL et al., 2006), adult Criollo horses (CANTO et al., 2006), and Polo horses (SAMPAIO, 2013). Although,' there was no significant interaction

Table 1 - Morphometric changes in the hoof capsule of Criollo foals from birth to weaning.

Measurements	Months	1	2	3	4	5	6	7	8
Toe length	Means±SE	4.69±0.08	5.21±0.08	5.60±0.05	6.01±0.10	6.03±0.09	6.24±0.14	6.33±0.17	6.14±0.10
	Increase	0.53	0.44	0.36	0.07	0.15	0.09	-0.21	
	min/max	4-6.4	4.0-6.5	5.0-7.5	5.0-7.0	5.0-7.8	5.0-7.3	5.0-7.3	5.5-6.8
Heel length	Means±SE	2.85±0.07	3.52±0.08	3.67±0.06	3.71±0.08	3.77±0.06	3.80±0.06	3.86±0.09	3.66±0.09
	Increase	0.81	0.03	0.06	0.02	0.03	0.05	-0.20	
	min/max	1.9-3.9	2.8-8.8	3.0-5.2	2.7-5.2	3.0-4.3	3.2-4.4	3.0-4.6	3.0-4.3
Perimeter of coronay band	Means±SE	19.48±0.23	21.24±0.21	22.80±0.14	24.03±0.14	24.52±0.20	25.23±0.21	25.82±0.21	26.30±0.30
	Increase	1.69	1.59	1.27	0.49	0.70	0.59	0.48	
	min/max	16.9-22.8	19.8-24.5	21.0-24.75	22.65-26.85	22.3-27.0	24.0-27.15	24.0-28.0	24.0-29.0
Heel width	Means±SE	5.50±0.06	6.31±0.07	6.86±0.06	7.28±0.09	7.62±0.11	8.25±0.14	8.60±0.10	8.72±0.09
	Increase	0.82	0.54	0.43	0.33	0.63	0.35	0.11	
	min/max	5.0-6.6	5.4-7.3	6.0-7.8	6.25-8.5	6.5-9.2	7.0-9.5	8.0-9.6	8.0-9.3
Toe angle	Means±SE	55.61±0.50	56.22±0.53	57.63±0.48	57.79±0.47	56.20±0.49	54.76±0.68	56.52±0.77	55.63±0.58
	Variation	0.61	1.41	0.16	-1.58	-1.26	1.58	-0.90	
	min/max	48.0-62.0	50.0-64.0	53.0-64.0	53.0-62.0	52.0-68.0	44.0-64.0	52.0-64.0	50.0-60.0

Age of foal was evaluated in months, toe angle in degrees, and the remaining in centimeters.

between toe angle and toe length, HINTZ (1983) and GLADE and SALZMAN (1985) reported that a low hoof angle positively influenced hoof growth.

In the present study, a significant positive correlation was reported between toe length, heel length, coronary band perimeter, and solar width of foals (Table 2). Overall, these results provided important information that will facilitate better decisions regarding corrective trimming, if orthopedic alterations need to be performed.

Table 2 - Correlation between age (in months) and measurements of the hoof capsule in Criollo foals. Age was the characteristic presenting more positive correlations, followed by solar width, toe length, and coronary band perimeter.

Variables	Solar Width	Toe Length	Toe Angle	Perimeter of coronary band	Heel Length
Age of foal	0.9862	0.8888	-0.2369	0.9685	0.9767
Solar Width	--	0.9436	-0.1642	0.9890	0.9950
Toe Length	--	--	0.0496	0.9712	0.9646
Toe Angle	--	--	--	-0.0643	-0.0971
Perimeter of coronary band	--	--	--	--	0.9988

Age of foal was evaluated in months, toe angle in degrees, and the remaining in centimeters.

CONCLUSION

The most intense hoof-growth period in Criollo foals was during their first four months of life.

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SOURCE OF SOFTWARE MANUFACTURERS

[a]Microsoft Corporation, Redmond, WA, USA.
[b]SAS institute Inc., Cary, NC, USA.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

This study (code: 5.05.01.036) was approved by the Ethics and Welfare Committee (code: 9279), Universidade Federal de Pelotas (UFPel). All techniques used in this study were non-invasive.

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