



Biometric evaluation of Criollo horses participating in the Freio de Ouro competition, Brazil

Anelise Maria Hammes Pimentel¹, João Ricardo Malheiros de Souza^{2*} , Arione Augusti Boligon¹, Heden Luiz Marques Moreira³, Cláudio Alves Pimentel⁴, Charles Ferreira Martins⁵

¹ Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel, Departamento de Zootecnia, Campus Capão do Leão, Capão do Leão, RS, Brasil.

² Universidade Federal de Santa Maria, Programa de Pós-graduação em Medicina Veterinária, Santa Maria, RS, Brasil.

³ Universidade Federal de Pelotas, Instituto de Biologia, Campus Capão do Leão, Capão do Leão, RS, Brasil.

⁴ Universidade Federal de Pelotas, Faculdade de Veterinária, Departamento de Patologia Animal, Campus Capão do Leão, Capão do Leão, RS, Brasil.

⁵ Universidade Federal de Pelotas, Faculdade de Veterinária, Departamento de Clínicas Veterinária, Campus Capão do Leão, Capão do Leão, RS, Brasil.

ABSTRACT - The objective of this study was to quantify linear and angular morphological measurements of male and female horses participating in the Freio de Ouro competition. This study represents the first scientific evaluation of the biometrics of the Criollo breed, providing essential information for the evaluation of the development of the breed and supporting objective selection. We examined linear and angular measurements of 634 Criollo horses participating in the Freio de Ouro competition in 2011 and 2012, including height, chest circumference, cannon bone circumference, body length, metatarsus length, croup length, chest width, head length, dorsal neck length, throat circumference, and angles of the croup, scapula, and hock. Statistical analysis showed that males had a greater average cannon bone circumference (19.76 cm) than females (18.95 cm) and a greater throat circumference (77.66 cm for males and 73.30 cm for females). None of the other traits evaluated differed between genders. The average height (141.73 cm for males and 141.41 cm for females) was close to the minimum requirement for the breed standard. Subjective observations suggesting that animals of this breed are decreasing in size were not confirmed in this study, as the height and other evaluated measures did not differ between competing horses less or more than seven years of age. Although these measurements in isolation do not indicate the qualities of individual animals, they serve as valuable auxiliary elements for selection work, showing breed tendencies and providing objective data to support technical decisions of judges regarding conformation.

Key Words: animal production, breed, equine, horse, morphometry

Introduction

The Criollo breed of horses is one of the most common horse breeds, with over 400,000 registered animals in Brazil and other South American countries, France, and the United States. This breed has great socioeconomic importance in Brazil and is responsible for transactions totaling R\$ 1.28 billion annually and >200,000 jobs (Lima and Cintra, 2015).

The Criollo breed was developed in the southern part of South America. Its official genealogical registry started in Brazil in 1932 with the foundation of the Associação Brasileira de Criadores de Cavalos Crioulos (ABCCC).

At that time, an inspection commission visited farms to collect horses that were the product of 400 years of natural selection to serve as the breed standard: medium-sized, muscular animals with broad chests, a firm top line, a strong croup, a small head, and full tail and mane (Affonso and Correa, 1992; Dalto, 2006).

The ABCCC breed standard states that height, chest circumference, and cannon bone circumference are required body measurements for registration. For males, the requirements include height of 140.0 to 150.0 cm, chest circumference of at least 168.0 cm, and cannon bone circumference of at least 18.0 cm. For females, the requirements include height of 138.0 to 148.0 cm, chest circumference of at least 170.0 cm, and cannon bone circumference of at least 17.0 cm (ABCCC, 2016). Other equally important qualities or morphological faults are assessed by intuitive observations. The lack of deductive information is a problem for other equine breeds as well (Beeman, 2008; Lage et al., 2009; Mawdsley et al., 1996).

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*Corresponding author: joao.rms@gmail.com

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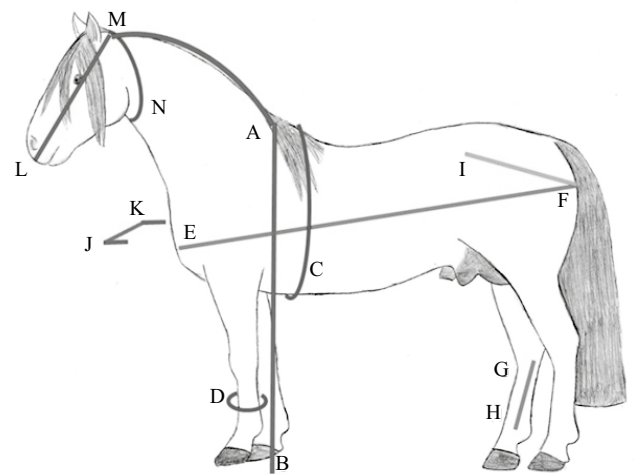
The objective of this study was to quantify linear and angular morphological measurements of horses participating in the Freio de Ouro competition, which is considered the most important competition for the Criollo breed. As these measurements are not registered anywhere, our findings provide an initial record of the morphology of the breed and will reduce subjectivity and variability in judgments regarding this breed.

Material and Methods

Research on animals was conducted according to the Ethics and Welfare Committee (CEEA; case no. 3.943). All techniques used in this study were non-invasive.

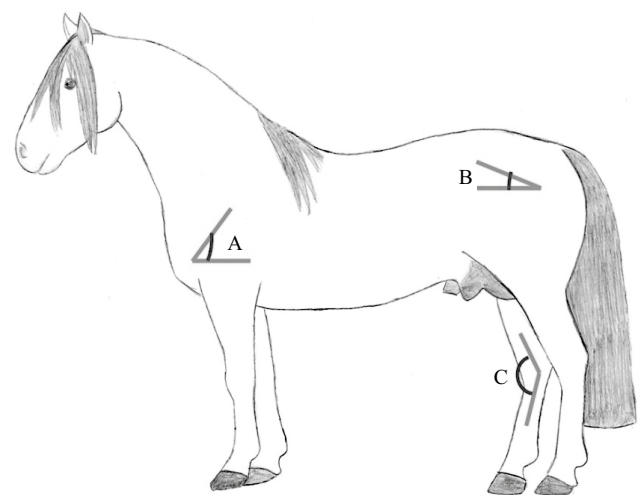
We measured 634 Criollo horses during admission to the 11 qualifying and final events of the 2011 and 2012 Freio de Ouro competitions (501 animals in Rio Grande do Sul, 56 in Santa Catarina, 29 in Paraná, and 48 in the Distrito Federal states). Linear and angular measurements were taken at the time of admission for each event, on the left side, as the animals stood still with their four hooves planted on a horizontal and regular floor. The measurements were obtained using a tape measure, except for height, which was measured using a horse measuring stick at the highest point of the interscapular region, located in the space defined by the T5 spinous process and the ground. The chest circumference was measured just behind the withers, from the T8 and T9 spinous processes, passing through the intercostal space between the 8th and 9th ribs, to the articulation of the last rib and the xiphoid process. The cannon bone circumference was measured in the middle third of the shin on the left forelimb, formed by metacarpal bones II, III, and IV; the suspensory ligament; and the superficial and deep flexor tendons. The body length was determined as the distance between the cranial portion of the greater tubercle of the humerus and the ischial tuberosity. The metatarsal length was determined as the distance between the proximal and distal epiphysis of the third metatarsal bone. The croup length was determined as the distance between the coxal and ischial tuberosity. The chest width was determined as the distance between the right and left lateral borders of the scapulohumeral joints. The head length was determined as the distance between the ends of the head, from the nuchal crest to the midline of the upper lip edge. The dorsal neck length was determined as the distance between the cranial portion of the dorsal arch of the atlas and the middle third of the cranial border of the scapula. The throat circumference was measured at the level of the atlas region and the inferior insertion of the head and neck junction (Figure 1).

Angular measurements were obtained using an arthrogoniometer: the angle of the scapula was formed between the spine of the scapula and a horizontal line; the croup angle was formed between the straight line of the coxal tuberosity to the greater trochanter of the femur and a horizontal line; and the angle of the hock was formed by the angle of the tibio-tarso-metatarsal joint (Figure 2). Anatomical points were identified and marked with adhesive tape. Height, chest circumference, and cannon bone circumference measurements were taken by ABCCC technicians, while the other measurements were taken by two members of our research team.



A-B: height; C: chest circumference; D: cannon bone circumference; E-F: body length; G-H: metatarsal length; I-F: croup length; J-K: chest width; L-M: head length; M-A: dorsal neck length; N: throat circumference.

Figure 1 - Illustrative image of the linear measurements evaluated in this study.



A: angle of the scapula; B: angle of the croup; C: angle of the hock.

Figure 2 - Illustrative image of the angular measurements evaluated.

In addition to sex effects, all traits were evaluated in relation to the age of the horses. Thus, they were classified as younger (less than seven years of age) or older (more than seven years of age) competing horses. For each trait, differences between means based on sex (male or female) and age (younger or older) were compared by performing Student's t-test, using the R program (R Core Team, 2016). Results were considered statistically significant when $P < 0.05$.

Results

Horses that participated in the Freio de Ouro competition showed some variability in the measured morphological traits, although little difference was found between male and female Criollo horses.

The average cannon bone circumference was significantly greater ($P = 0.0241$) in males (19.76 ± 0.68 cm) than in females (18.95 ± 0.63 cm) (Table 1). In addition to cannon bone circumference, throat circumference was the only measure that differed significantly ($P = 0.0403$) between males (77.66 ± 3.26) and females (73.30 ± 3.75 cm). The other evaluated traits did not show significant difference between genders ($P > 0.05$).

The age of horses participating in the Freio de Ouro competition ranged from 4 to 13 years, with a mean age of seven years. Younger animals (< 7 years of age) accounted for 54% of the competition horses, whereas older animals (> 7 years of age) accounted for 46%. Statistical analysis showed that height and the other evaluated measures did not differ between younger and older competing horses ($P > 0.05$) (Table 2).

Table 1 - Morphometric measurements of horses participating in qualifying and final Freio de Ouro 2011 and 2012 competitions

| Linear variable | Male | | | | Female | | | |
|---------------------------|------|------------|------|---------------|--------|------------|------|---------------|
| | N | Means (cm) | SD | Min-max (cm) | N | Means (cm) | SD | Min-max (cm) |
| Height | 322 | 141.73a | 1.7 | 140.0-147.50 | 312 | 141.41a | 2.13 | 138.00-148.00 |
| Chest circumference | 322 | 175.4a | 3.74 | 168.0-186.0 | 312 | 177.17a | 3.45 | 169.00-187.00 |
| Cannon bone circumference | 322 | 19.76a | 0.68 | 18.00-22.00 | 312 | 18.95b | 0.63 | 17.50-21.00 |
| Body length | 304 | 163.38a | 4.36 | 152.00-174.00 | 304 | 165.12a | 5.23 | 154.00-185.50 |
| Metatarsal length | 247 | 20.75a | 1.01 | 17.50-23.50 | 248 | 20.84a | 1.14 | 18.00-29.50 |
| Croup length | 254 | 56.88a | 3.09 | 51.50-77.00 | 243 | 56.64a | 2.66 | 50.00-68.50 |
| Chest width | 284 | 41.38a | 1.66 | 38.00-46.50 | 283 | 40.49a | 2.11 | 35.00-48.00 |
| Head length | 300 | 64.26a | 2.54 | 57.50-74.50 | 292 | 63.56a | 2.13 | 59.50-70.00 |
| Dorsal neck length | 305 | 80.01a | 5.64 | 59.00-96.00 | 305 | 78.63a | 5.66 | 64.00-94.50 |
| Throat circumference | 308 | 77.66a | 3.26 | 66.50-87.50 | 303 | 73.30b | 3.74 | 66.00-84.50 |
| Angular variable | | Mean (°) | | | | Means (°) | | |
| Croup angle | 300 | 22.37a | 4.47 | 13.00-39.00 | 301 | 22.21a | 4.93 | 11.00-38.00 |
| Scapula angle | 305 | 59.73a | 5.41 | 45.00-71.00 | 304 | 61.2a | 6.01 | 30.00-74.00 |
| Hock angle | 286 | 152.61a | 5.58 | 129.00-168.00 | 295 | 152.97a | 4.49 | 139.00-169.00 |

Min-max - minimum-maximum; SD - standard deviation.

The values within the row that are followed by different letters are significantly different by statistics ($P < 0.05$).

Table 2 - Age effect on morphometric measures of horses participating in qualifying and final Freio de Ouro 2011 and 2012 competitions

| Linear variable | < 7 years | | | > 7 years | | |
|---------------------------|-----------|------------|------|-----------|------------|------|
| | N | Means (cm) | SD | N | Means (cm) | SD |
| Height | 340 | 141.79a | 1.90 | 293 | 141.33a | 1.95 |
| Chest circumference | 340 | 176.66a | 3.66 | 293 | 175.82a | 3.72 |
| Cannon bone circumference | 340 | 19.35a | 0.77 | 293 | 19.37a | 0.78 |
| Body length | 329 | 164.72a | 4.73 | 279 | 163.7a | 5.03 |
| Metatarsal length | 276 | 20.93a | 1.19 | 219 | 20.62a | 0.90 |
| Croup length | 282 | 56.79a | 2.73 | 215 | 56.72a | 3.08 |
| Chest width | 322 | 40.89a | 1.94 | 244 | 40.99a | 1.97 |
| Head length | 330 | 63.97a | 2.43 | 261 | 63.84a | 2.31 |
| Dorsal neck length | 331 | 79.44a | 5.33 | 268 | 79.14a | 6.11 |
| Throat circumference | 340 | 75.5a | 3.98 | 270 | 75.4a | 4.30 |
| Angular variable | | Means (°) | | | Means (°) | |
| Croup angle | 327 | 21.93a | 4.43 | 274 | 22.73a | 5.01 |
| Scapula angle | 340 | 60.55a | 5.67 | 267 | 60.36a | 5.88 |
| Hock angle | 327 | 152.85a | 4.61 | 254 | 152.72a | 5.56 |

SD - standard deviation.

The values within the row that are followed by different letters are significantly different by statistics ($P < 0.05$).

Discussion

Animals advancing to the qualifying and final events of this competition are considered excellent horses, considering the morphological patterns required by the ABCCC, their ability to work with cattle, and their agreeability for being ridden.

The heights of the animals were close to the minimum values required for the breed standard (at least 140 cm for males and 138 cm for females). This result was similar to those of Kurtz Filho and Löff (2007), who evaluated the height, chest circumference, and cannon bone circumference of 2,054 Criollo horses participating in the morphological evaluation contest at the Expointer annual exhibition, in Esteio, RS, Brazil, from August 1993 to August 2002. They identified males of an average height of 143 ± 2 cm and females of an average height of 142 ± 2 cm, emphasizing that the height of this breed may be lowering over time.

The decline in the average height is believed to be due to the use of Chilean stallions in Brazil in the early 1970s (Dalto, 2006), with a subset of animals adapted mainly for the Media Luna competition. These animals are shorter than the breed standard, with an average height of 137.4 cm for males and 137.7 cm for females at the age of three years (Porte, 2000). According to the Federation of Criollo Horses Breeders of Chile, the average height of all horses classified in the final of Media Luna competition was 139.8 cm (Dowdall and Flores, 2016). The authors evaluated the biometric trends of great Criollo champions in Argentina between 2004 and 2015 and found that height declined by 0.11 cm per year in these animals, which represents a total reduction of 1.32 cm in height during the 12 years analyzed. According to the authors, one of the causes for this reduction is that the harmony judgment and evaluation of smaller animals is easier, but they emphasize the need to continue monitoring the progress of this measure and to penalize further declines in height.

The average height of the Campeiro breed was 144 cm (McManus et al., 2005), slightly taller than the Criollo breed, and the Pantaneiro breed was 138 cm on average (a little shorter) (Miserani et al., 2002). Although both Brazilian breeds share the same origin, South American horse breeds have unique characteristics, shaped by geography, type of work, and technical orientation. The Quarter Horse breed has different bloodlines due to different selection objectives. Quarter Horse racing lines presented an average height of 155 cm, while working/functional competition lines presented an average height of 146 cm (Meira et al., 2013). A similar value of 145 cm for

working Quarter Horses was found by Ramos et al. (2014). The Mangalarga Marchador breed is the tallest of the Brazilian breeds, with a height of 151.5 cm for adult males and 151.6 cm for females (Cabral et al., 2004), although Zamborlini et al. (1996) reported a lower average height of 146 cm.

Subjective observations indicating that animals of the Criollo breed are decreasing in size were not confirmed in this study. The height did not differ ($P>0.05$) between younger (<7 years old) and older (>7 years old) competing horses, with means and standard deviations of 141.79 ± 1.90 and 141.33 ± 1.95 cm, respectively (Table 2). These results differ from those of Kurtz Filho and Löff (2007), in which younger adult animals were shorter than older animals, as a result of their smaller Chilean ancestors. It is possible that this phenomenon was not identified in this study due to the short evaluation period of only two years; therefore, it is necessary to continue monitoring this measurement to analyze its progress, since both technicians and breeders are concerned about the height of this breed.

Chest circumference is associated with genetic, nutritional, and physical conditioning factors. Males and females presented similar chest circumferences (175.39 ± 3.74 and 177.17 ± 3.45 cm, respectively) (Table 1). These measurements were in accordance with the minimum standards of the breed of 168 cm for males and 170 cm for females. According to the ABCCC (2016), the chest should be broad, wide, and deep, with well-separated and muscular intercostal spaces and arched deep ribs. These measurements are slightly smaller than the values for the Criollo horses that participated in the morphological evaluation contest at the Expointer, as recorded by Kurtz Filho and Löff (2007), who found an average chest circumference of 180 cm for females and 179 cm for males. This result probably reflects the fact that these animals were prepared for morphological competition, which requires a different type of preparation and larger quantities of food than for athletic competitions, such as the Freio de Ouro competition. The average chest circumference of the Campeiro breed was 173 cm, and there was a considerable gender influence. Females showed greater measurements (174.4 cm) than males (167.2 cm) (McManus et al., 2005), despite the claim of the author that the males engaged in more physical activity. The Pantaneiro breeds showed a greater chest circumference in males (Miserani, 2001), as did the Mangalarga Marchador breed, with the chest circumference of adult males being 180.8 cm and that of females being 175.7 cm (Cabral et al., 2004). The average value found by Lage et al. (2009) for the same breed was 177 cm. In this study, this finding probably indicates a

tendency to start competitions using animals with a better body score to achieve a better morphological result.

The cannon bone circumference was greater in males than in females (19.76 ± 0.68 vs. 18.95 ± 0.63 cm, respectively) ($P = 0.0241$). These values were similar to the measurements of 20 cm for males and 19 cm for females found by Kurtz Filho and Löf (2007). According to the breed standard, the shin should be short and upright, with strong and defined tendons. The minimum measurement required for registry confirmation is 18 cm for males and 17 cm for females. Pimentel et al. (2017) evaluated Criollo colts from birth to three years of age and found that males reached the minimum requirement for registration at 18 months of age, while females reached the minimum requirement for registration, on average, at 11 months of age. Males presented greater cannon bone circumferences. In addition, males entering the Freio de Ouro competition also had a greater throat circumference than females (77.66 ± 3.26 vs. 73.30 ± 3.75 cm, respectively) ($P = 0.0403$), 4.36 cm on average (Table 1). These are traits that are probably related to gender and influenced by hormones. According to Cunningham (1993), testosterone not only stimulates muscular development but also favors bone growth.

Body length did not differ between males and females (163.38 ± 4.37 vs. 165.12 ± 5.2 cm, respectively), and no previous studies have reported significant gender-based differences in body length in the Criollo breed. Morphology has been studied in other Brazilian saddle breeds originating from Berber horses, all of which present shorter body lengths than does the Criollo breed. The Campeiro breed averaged 147 cm (McManus et al., 2005), and the Mangalarga Marchador breed averaged 155.55 cm (Ramos et al., 2014). Another study with the Mangalarga Marchador breed showed that males were longer bodied than females, with an average of 157.6 ± 6.1 cm for males and 149.4 ± 12.2 cm for females (Cabral et al., 2004). Racing lines of the Quarter Horse breed were longer and had an average length of 180 cm, while working lines had an average length of 163 cm (Meira et al., 2013). Participants in the Vaquejada competition showed an average of 149.52 cm (Meneses et al., 2014), and working and riding Quarter Horse animals had an average length of 150.33 cm (Ramos et al., 2014). The average length of horses entered into barrel-racing events was 154.50 cm (Donofre et al., 2014).

The ideal saddle horse should have similar measurements for body length and height at the withers (Solonet, 1946; Dowdall, 1982; Torres and Jardim, 1987), which characterizes the mediolateral horse. Animals

participating in the Freio de Ouro competition presented an average height of 141.6 cm, compared with the average body length of 164 cm. Thus, the study population horses were, on average, 23.4 cm longer than they were tall, a typical characteristic of longilinear horses. According to Dowdall (1982), 30 Criollo horses participating in exhibitions at Palermo (Argentina) in the Marcha de Resistência and Raid were 144.3 cm tall and 149.9 cm long on average, respectively, a difference of only 5.6 cm, similar to mediolateral horse measurements. Racing lines of Quarter Horse breed also showed a difference of 24 cm in the relationship between the average body length (180 cm) and height at the withers (156 cm). These racing bloodlines are different ($P < 0.05$) from working lines regarding the average length (163 cm) and height (146 cm). The body length for the working line was, on average, 17 cm greater than the height (Meira et al., 2013), showing a clear relationship between the physical characteristics and the animal function, as in the Criollo breed.

The dorsal neck length was similar between genders, with an average of 80.01 ± 5.6 cm for males and 78.63 ± 5.6 cm for females. A similar value of 78.2 cm was found for the Arabian breed (Sobczuk and Komosa, 2012), in which the neck length was highly associated with morphological beauty and was also important for forelimb movement. Strong neck muscles control the action of the shoulder, arm, and forearm muscles, releasing forelimbs with more agility (Denoix, 2014). Compared with the Mangalarga Marchador breed, these adult horses have shorter necks and presented average values of 66.9 cm for males and 63.3 cm for females (Cabral et al., 2004). The angle of the scapula was also similar, with an average of $59.73 \pm 5.4^\circ$ for males and of $61.2 \pm 6.0^\circ$ for females. The overall average was 60° , differing from the results of Dowdall (1982), who reported that the inclination of the scapula over the horizontal line varied by approximately 50° in Criollo horses. According to Monina (2006), an angle of 45° enables the step length and height at the withers to present with a similar measurement, which results in greater gait amplitude and performance. Greater angles (i.e., more vertical or less inclined scapulae) reduce the amplitude of the step, according to Souza (1998), probably because the oblique scapula absorbs the impact of the hoof on the ground better, resulting in greater cushion and softness during movement (Jones, 1987).

Neither croup length nor angle differed between males and females (Table 1). According to the ABCCC (2016), the croup should be muscular, strong, well developed, medium in width and length, and slightly inclined, but these measurements have not been defined numerically.

In this study, the average croup length was 56.7 cm (50.0 minimum/77.0 cm maximum). According to Sobczuk and Komosa (2012), long croups significantly impact motor performance and speed test results. The average croup angle was 22.2° (11° minimum/39° maximum), similar to the angle of inclination of 23° mentioned by Pons (1993), but smaller than the 30° mentioned by Dowdall (1982) for Criollo horses. Although no significant differences ($P>0.05$) were found between the mean croup angles of younger versus older animals (Table 2), the means of 21.93° (younger animals) and 22.73° (older animals) observed in this study indicated a trend towards more horizontal croup angle, which can be confirmed in future evaluations considering a longer observation period.

The metatarsal length did not differ between Criollo horses of differing gender (Table 1) or age (Table 2) and was, on average, 20.8±1.0 cm, shorter than the length of 27 cm documented by Dowdall (1982). In the Arabian breed, the average value was 41.4 cm. A longer metatarsus is associated with greater motor efficiency, a greater predisposition to galloping (Sobczuk and Komosa, 2012), and the ability to make quick turns and abrupt stops (Meneses et al., 2014). This ability may contribute to a better execution of some movements, as evidenced by the improved performances year after year in the Freio de Ouro competition.

The average angle of the hock was 152.8±0.29° and did not differ between males and females. The breed standard states that the anterior angle of the hock should be “moderately” open, requiring judges to make subjective decisions. Our measurement provides specific information that enables judges and technicians to select animals with greater objectivity.

Although the concept of perfect conformation varies among breeds, the consensus view holds that morphological beauty results when all parts of the body are brought together harmoniously, symmetrically, and in proportion to the size of the body (Torres and Jardim, 1987; Ensminger, 1978; Souza, 1998; McManus et al., 2008), while following the breed standard. In this context, the isolated evaluation of these measurements may not enable quality judgments to be made on specific animals, but the data represent valuable support for selection to refine the breed and for providing an objective basis for the decisions of judges.

Conclusions

Our findings suggest that animals are near to minimum height limits required for the definitive registration in

Criollo breed. The cannon bone circumference is greater in males; however, slim throat is observed in females. The evaluated measures do not differ in Criollo horses less or more than seven years old in Freio de Ouro competitions.

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