



Morphometric measurements and animal-performance indices in a study of racial forms of Brazilian Sport Horses undergoing training for eventing

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ABSTRACT - This study aimed to evaluate, in a practical manner, the use of linear and angular measurements and different animal-performance indices in a study on the breed-specific conformation of Brazilian Sport Horses training for eventing. These data can form the basis for the development of future studies based on the parameters evaluated and the calculations made. Seventeen Brazilian Sport Horses training for eventing were selected. Morphometric evaluations were made of all animals using linear and angular measurements. The linear measurements were withers, croup, and barrel heights; body, croup, shoulder, neck, and head lengths; head, chest, and hip widths; distance from the elbow to the ground and from the sternum to the ground (empty substernal); and thorax, forearm, knee, fetlock, and fore cannon girths. The angular measurements were shoulder-ground, shoulder-humerus, humerus-radius, metacarpus-phalanx, coxae-ground, coxae-femur, femur-tibia, and tibia-metatarsus angles. Thirteen animal-performance indices were calculated to have a better understanding of the conformation of the animals and their proportions: the relationship between the withers and croup heights, chest index, dactyl-thoracic index, estimated weight, body index, thoracic index, conformation index, load index 1, load index 2, relative body index, compactness index 1, compactness index 2, and meloscopic index. Brazilian Sport Horses in eventing training were within the expected conformation for an athletic horse, but the animal-performance indices differed among them because they are heterogeneous horses resulting from crossing among various different breeds. The use of linear and angular measurements allows the correct characterization of racial forms of Brazilian Sport Horses undergoing training for eventing. Animal-performance indices can be useful in a study of a breed-specific conformation of athletic horses.

Key Words: angular measurements, conformation, equines, linear measurements

Introduction

The Brazilian Sport Horse breed began to appear in 1977, influenced by the English Thoroughbred, Hanoverian, Westphalian, Holsteiner, and Trakehner breeds, which contributed to its great genetic variability with an inbreeding coefficient close to zero (Dias et al., 2000).

The study on the breed-specific conformation of horses includes the calculation of linear and angular measurements

and their proportions. The proportions are the relations between the different parts of the body of the animal and the associations they form. The proportions should be harmonious and the animal must be able to function as intended. To study these proportions, one must consider the linear and angular measurements, their continuity and general measurements, as well as any variations and compensations (Ribeiro, 1988).

Measuring the linear dimensions between various regions of the body allows a thorough assessment of the animal (Ribeiro, 1988; Torres and Jardim, 1981). The angular measurements are the relationships between the bone orientations. The open anterior angles, known as impellers, are strong and are related to the movements of the animal. Other angles (opening to the back) are called complementary or connection angles. As the angles are a function of the breed and type of horse according to the type of work/exercise for which the horse is intended, these angles vary among different horse breeds. For the animal to be harmonious, there must be a relative agreement between

Received: April 2, 2016

Accepted: October 2, 2016

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<http://dx.doi.org/10.1590/S1806-92902017000100005>

How to cite: Padilha, F. G. F.; Andrade, A. M.; Fonseca, A. B. M.; Godoi, F. N.; Almeida, F. Q. and Ferreira, A. M. R. 2017. Morphometric measurements and animal-performance indices in a study of racial forms of Brazilian Sport Horses undergoing training for eventing. *Revista Brasileira de Zootecnia* 46(1):25-32.

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the openings of such angles. (Ribeiro, 1988; Torres and Jardim, 1981).

In the equestrian industry, selection is based on individual performance, pedigree, and phenotype. The physical conformation plays an important role in the phenotypic evaluation and is generally subjective and based on personal experience or opinion. However, little data are available on conformation and its relationship with performance and musculoskeletal disorders (Anderson and McIlwraith, 2004). Furthermore, Jönsson et al. (2014) stated that the standard conformations that experienced judges preferred were associated with the good health of the animal.

This study aimed to evaluate, in a practical manner, the use of linear and angular measurements and different animal-performance indices in an investigation on the breed-specific conformation of Brazilian Sport Horses training for eventing. These data can form the basis for the development of future studies based on the parameters evaluated and calculations made.

Material and Methods

The procedures of this study were approved by the Animal Use Ethics Committee (CEUA) of the Universidade Federal Fluminense (case no. 276/2013). The study was conducted on 17 Brazilian Sport Horses (*Equus caballus*) in Deodoro, Rio de Janeiro, Brazil. The horses (both male and female) were clinically healthy and were taking part in the eventing course of the Brazilian Army Riding School.

Morphometric evaluations were conducted by measuring the linear and angular dimensions of all animals. To obtain accurate measurements, each animal was placed in a forced stance with the fore and hind limbs perpendicular to a flat floor forming a rectangular parallelogram so that, seen in profile, each leg on one side obscured the leg on the opposite side; seen from the front or back, the legs were vertical and also on the floor (Figure 1).

A horse measuring stick, a tape measure, and an arthro-goniometer were used to measure 18 linear and eight angular dimensions according to Pinto et al. (2008) (Figure 2). The linear measurements were withers, croup, and barrel heights; body, croup, shoulder, neck, and head lengths; head, chest, and hip widths; distance from the elbow to the ground and from the sternum to the ground (substernal height); and thorax, forearm, knee, fetlock, and fore cannon girths. The angular measurements were shoulder-ground, shoulder-humerus, humerus-radius, metacarpus-phalanx, coxae-ground, coxae-femur, femur-

tibia, and tibia-metatarsus. Finally, 13 animal-performance indices were calculated to obtain a better understanding of the conformation of the animals and their proportions based on the different linear measurements:

Relationship between height at withers and croup: height at the withers divided by croup height (McManus et al. 2005);

Chest index: relationship between the barrel and substernal height. The substernal height should be as close as possible to half the height of the horse (Ribeiro, 1988);

Dactyl-thoracic index: relationship between the fore cannon girth and thorax girth. This index cannot be less than 0.105 for small horses, 0.108 for riding horses, or 0.115 for large horses (Ribeiro, 1988);



Figure 1 - Brazilian Sport Horse placed in a forced stance for morphometric evaluation.



A - Height at the withers with the aid of a measuring stick; B - Height at croup with the aid of a measuring stick; C - shoulder-floor angle with the aid of an Arthro Goniometer; D - tibia-metatarsus angle with the aid of an Arthro Goniometer.

Figure 2 - Linear and angular measurements of Brazilian Sport Horses undergoing training for eventing.

Estimated weight: cube of the thorax girth multiplied by the constant 80. Weights ≥ 550 kg, between 350 and 550 kg, and ≤ 350 kg correspond to large horses (or those considered hypermetric), average sized horses (or medium), and small horses (or hypometric), respectively (Torres and Jardim, 1981);

Body index: relationship between body length and thoracic girth. A body index greater than 0.90 indicates that the animal is long; between 0.86 and 0.88 indicates that the animal is medium; less than 0.85 indicates that the animal is short. The long animal is best suited for speed, the short animal for strength, and the medium, with intermediate ratios, has intermediate abilities (Torres and Jardim, 1981);

Thoracic index: ratio between the width of the chest and height of the thorax. The thoracic index is ≤ 0.85 for a long animal; between 0.85 and 0.90 for a medium animal; and ≥ 0.90 for a short animal (Torres and Jardim, 1981);

Form index: thoracic girth squared and divided by the height of the withers. A riding horse must have a form index equal to 2.1125, whereas values above this indicate that the animal is suitable for work (Torres and Jardim, 1981);

Load index 1: thoracic girth squared and multiplied by the constant 56, divided by the withers height. The load index indicates the weight in kilograms the animal can withstand without excessive stress on the back, working at a trot or gallop (Torres and Jardim, 1981);

Load index 2: thoracic girth squared and multiplied by the constant 95, divided by the withers height. This index indicates the weight in kilograms the animal can withstand without excessive stress on the back, working at a walking speed (Torres and Jardim, 1981);

Relative body index: body length multiplied by the constant 100 and divided by the withers height (Santos et al., 1995);

Compactness index 1: estimated weight divided by withers height, which is then divided by 100. Heavy horses should have values greater than 3.15; values close to 2.75 indicate medium animals, and values near 2.60 indicate animals suitable for riding (light horses) (McManus et al., 2005);

Compactness index 2: estimated weight divided by the withers height minus 1, which is then divided by 100. This index also indicates the suitability of the animal. Values above 9.5 indicate animals for heavy work; between 8.0 and 9.5, animals for light work; and between 6.0 and 7.75, animals for riding (McManus et al., 2005);

Meloscopic index: This index is given by the relation among three circumferences measured at the middle of the forearm, at the knee, and at the shin and the height of the

leg, i.e., the distance from the elbow to the ground. This index indicates whether the legs are well proportioned in relation to the trunk; when they are not, they indicate faulty gaits. The sum of the three circumferences should be lower (negative value), equal to (i.e., 0), or higher (positive value) than the height at the elbow in long, medium, and short horses, respectively (Torres and Jardim, 1981).

The SPSS software (Statistical Package for the Social Sciences, version 17) was used for all the descriptive statistics of the data analyzed and the correlations between the morphometric measurements and the animal-performance indices were based on Pearson's linear correlation coefficient and the corresponding significance test. Associations between parameters were analyzed using the Mann-Whitney U test. In all analyses, the 5% significance level was used.

Results and Discussion

The data obtained from the physical morphometric measurements of Brazilian Sport Horses in training for eventing (Tables 1 and 2) present some numerical differences compared with the findings of Souza (2013), who also evaluated horses of the same breed undergoing the same training with the following results (in m): withers height, 1.55; croup height, 1.57; barrel height 0.67; body length, 1.58; croup length, 0.50; head length, 0.60; head width, 0.21; chest width, 0.41; and hip width 0.50. These values are lower than those found in this study for the same

Table 1 - Individual linear measurements, means, standard deviations, and medians of Brazilian Sport Horses undergoing training for eventing

	Mean (m)	Standard deviation (m)	Median (m)
Withers height	1.62	0.034	1.62
Croup height	1.63	0.039	1.62
Barrel height	0.69	0.018	0.68
Body length	1.6	0.062	1.61
Croup length	0.52	0.026	0.51
Shoulder length	0.53	0.022	0.53
Neck length	0.68	0.042	0.68
Head length	0.63	0.021	0.63
Head width	0.22	0.012	0.22
Chest width	0.42	0.018	0.42
Hip width	0.54	0.018	0.55
Distance from the elbow to the ground	0.92	0.03	0.93
Distance from the sternum to the ground (empty substernal)	0.86	0.019	0.86
Thorax girth	1.84	0.041	1.84
Forearm girth	0.4	0.032	0.4
Knee girth	0.34	0.032	0.33
Fetlock girth	0.28	0.01	0.28
Fore cannon girth	0.2	0.01	0.2

measurements, which were: 1.62, 1.63, 0.69, 1.60, 0.52, 0.63, 0.22, 0.42, and 0.54 m, respectively. This difference indicates that the Brazilian Sport Horses selected for eventing training are becoming overall larger and these findings show that the characteristics of these animals are being modified for this sport as a result of selective breeding.

Our observation that sport horses in training for eventing are becoming larger is in contradiction with the data obtained for Crioulo horses in Brazil, which have shown a tendency to decrease their height over the generations (Kurtz Filho and Löff, 2007).

Warmblood horses studied by Catalano et al. (2016) presented higher mean values for withers height (1.67 m), body length (1.79 m), and thorax girth (1.99 m) compared with the Brazilian Sport Horses undergoing eventing training (1.62, 1.60, and 1.84 m, respectively). It is important to emphasize that the origin of the Brazilian Sport Horse breed is mainly European warmbloods.

The horse described as having a downhill conformation (withers height lower than croup height) indicates that, in the exercise of their skills over generations, the best animals have such a conformation, even though, according to the literature, this is considered undesirable (Ribeiro, 1988).

Table 2 - Individual angular measurements, means, standard deviations, and medians of Brazilian Sport Horses undergoing training for eventing

	Mean	Standard Deviation	Median
Shoulder-floor angle	70.82°	3.557°	70°
Shoulder-humerus angle	99.53°	5.58°	100°
Humerus-radius angle	145.41°	5.432°	145°
Metacarpus-phalanx angle	151.24°	6.17°	151°
Coxae-ground angle	27.06°	3.363°	26°
Coxae-femur angle	77.47°	5.535°	80°
Femur-tibia angle	109.18°	4.613°	108°
Tibia-metatarsus angle	147.18°	3.245°	148°

This defect, as stated by Ribeiro (1988), is in fact a desired characteristic in Brazilian Sports Horses, corroborating the findings of this study. Stronger muscles in the hind limbs and taller hind limbs indicate greater power for jumping and ability to give a solo performance. This greater power is a desired trait in these horses. This feature was also found in Campeiro horses (McManus et al., 2005), in Brazilian Sport Horses and Thoroughbreds (Rezende et al., 2014), in horses from a mounted police squadron (Schade et al., 2015), and in Quarter Horses (Mariz et al., 2015).

Lucena et al. (2015) stated that the good performance of Marchador horses is influenced by the relation between withers height and croup height. Therefore, it is desirable that Campolina horses have a withers height higher than croup height, in contrast to the Brazilian Sport Horses of this study. Additionally, the proportions of the topline of Icelandic horses revealed an advantage of high withers and an uphill conformation, an important characteristic for riding ability in this five-gaited breed (Kristjansson et al., 2016).

The greatest chest width of the Brazilian Sport Horses in this study, compared with the findings of Souza (2013), indicates an increase in the ribcage and a tendency of a greater physical condition and respiratory ability of these horses.

Angeli et al. (2011) found highly positive significant correlations in Brazilian Sport Horses between withers height, croup height, body length, and knee-ground and hock-ground distances. A similar result was found in this study in horses of the same breed training for eventing in which correlations (Table 3) were found between withers height and croup height ($IrI = 0.622$; $P = 0.008$), withers height and substernal height ($IrI = 0.625$; $P = 0.007$), croup height and body length ($IrI = 0.718$; $P = 0.001$), and croup height and substernal height ($IrI = 0.620$; $P = 0.008$), as well as a trend between withers height and body length ($IrI = 0.543$; $P = 0.024$). Corroborating the findings of

Table 3 - Correlations and tendencies of correlations among linear measurements of Brazilian Sport Horses undergoing training for eventing

Linear measurement	Correlation	Tendency
Withers height	Croup height; empty substernal	Body length; head width
Croup height	Body length; empty substernal	
Body length	Head length; head width	
Neck length		Forearm girth
Head length		Head width; chest width
Head width	Croup height	Thorax girth; fore cannon girth
Hip width	Elbow to ground distance	Empty substernal
Elbow to ground distance	Forearm girth	Empty substernal
Knee girth		Body length
Fetlock girth		Fore cannon girth; head length
Fore cannon girth	Knee girth; fetlock girth	Head length; head width

this study in Brazilian Sport Horses, Lucena et al. (2015) found in Campolina horses a correlation ($P < 0.01$) between withers height and croup height ($IrI = 0.712$ and $IrI = 0.908$ for geldings and stallions, respectively) and between withers height and body length ($IrI = 0.737$ and $IrI = 0.718$ for geldings and stallions, respectively).

Correlations were also found between croup height and body length ($IrI = 0.718$; $P = 0.001$), croup height and substernal height ($IrI = 0.620$; $P = 0.008$), body length and head length ($IrI = 0.615$; $P = 0.009$) and width ($IrI = 0.693$; $P = 0.003$), and head width and croup height ($IrI = 0.610$; $P = 0.012$). There were also tendencies of correlations between neck length and forearm girth ($IrI = 0.589$; $P = 0.013$), head length and width ($IrI = 0.559$; $P = 0.024$), head length and chest width ($IrI = 0.566$; $P = 0.018$), head width and thorax girth ($IrI = 0.567$; $P = 0.022$), and fore cannon girth ($IrI = 0.588$, $P = 0.017$).

Hip width demonstrated a correlation with the elbow to ground distance ($IrI = 0.616$; $P = 0.008$) and a correlation tendency with substernal height ($IrI = 0.555$; $P = 0.021$). The distance from the elbow to the ground was correlated with forearm girth ($IrI = 0.643$; $P = 0.005$) and there was a correlation tendency with the substernal height ($IrI = 0.570$; $P = 0.017$). A correlation tendency was found between knee girth and body length ($IrI = 0.500$; $P = 0.041$) and between head length and fetlock girth ($IrI = 0.537$; $P = 0.026$) and fore cannon girth ($IrI = 0.516$, $P = 0.034$).

The fore cannon girth was correlated with the knee ($IrI = 0.610$; $P = 0.009$) and fetlock ($IrI = 0.740$; $P = 0.001$) girths and there was a correlation tendency between the fore cannon girth and the head length ($IrI = 0.516$; $P = 0.034$) and width ($IrI = 0.588$; $P = 0.017$).

Torres and Jardim (1981) reported that the horse must have joint angles suitable for its intended use. Thus, they established certain limits for the angles. Some average angles found in horses of this study were below those regarded as reference by these authors: shoulder-humerus angle, $99.53 \pm 5.58^\circ$ (reference: $102-115^\circ$); coxae-femur angle, $77.47 \pm 5.54^\circ$ (reference: $85-125^\circ$); femur-tibia angle, $109.18 \pm 4.61^\circ$ (reference: $122-150^\circ$); and tibia-metatarsus angle, $147.18 \pm 3.25^\circ$ (reference: $152-160^\circ$). The humerus-radius angle ($145.41 \pm 5.43^\circ$) and metacarpus-phalanx

angle ($151.24 \pm 6.17^\circ$) were within the limits set by these authors ($140-150^\circ$ and $150-159^\circ$, respectively). These angles can be explained by the type of animal wanted and the sport for which it is intended. The authors probably based their data on the most common riding horses at the time, which were Mangalarga Marchador. This breed of horse presents a different way of walking, using a tri-pedal support style, unlike the trotting style of Brazilian Sport Horses. Furthermore, the Mangalarga Marchador horses are intended for light riding, unlike the Brazilian Sport Horse, which is intended for sport.

The shoulder-humerus angle was correlated with the distance from the elbow to the ground ($IrI = 0.603$; $P = 0.010$) and a correlation was found between the metacarpus-phalanx angle and barrel height ($IrI = 0.601$; $P = 0.011$) and neck length ($IrI = 0.607$; $P = 0.010$). The coxae-ground angle, in turn, was correlated with neck length ($IrI = 0.607$; $P = 0.010$), coxae-femur angle ($IrI = 0.727$; $P = 0.001$), and tibia-metatarsus angle ($IrI = 0.646$; $P = 0.005$), and there was a correlation tendency with barrel height ($IrI = 0.582$; $P = 0.014$). The coxae-femur angle showed a correlation tendency with the femur-tibia angle ($IrI = 0.545$; $P = 0.024$) and tibia-metatarsus angle ($IrI = 0.527$; $P = 0.030$) and the elbow to ground distance ($IrI = 0.566$; $P = 0.020$) (Table 4).

Regarding the animal-performance indices, the average value of the relationship between withers height and croup height was 0.99 ± 0.019 and the conformation index had an average value of 2.1034, which is near the value for a riding horse.

The average value for the estimated weight of the animals was 501 ± 34.017 kg, which characterizes a medium-sized animal. This result is in agreement with Godoi et al. (2013), who also classified such horses, in general, as medium. On the other hand, these authors classified Brazilian Sport Horse colts as large. Individually, in the present study, 88.2% of the animals ($n = 15$) were classified as medium and 11.8% ($n = 2$) as large or hypermetric animals.

The average value for the thoracic index was 0.62 ± 0.025 , which indicates a long or sleek animal, and all of the individual horses (100% or $n = 17$) were classified as sleek.

Table 4 - Correlations and correlation tendencies among angular and linear measurements of Brazilian Sport Horses undergoing training for eventing

Angular measurement	Correlation	Tendency
Shoulder-humerus angle	Distance from the elbow to the ground	
Metacarpus-phalanx angle	Barrel height; neck length	
Coxae-ground angle	Neck length; coxae-femur angle; tibia metatarsus angle	Barrel height
Coxae-femur angle		Femur-tibia angle; tibia-metatarsus angle

The average value for the compactness index 1 was 3.104 ± 0.187 , which indicates an animal capable of medium-to-light work. On evaluating the individual values, 58.8% of the horses ($n = 10$) were grouped into the medium-to-light work category and 41.2% ($n = 7$) into the heavy-work category. The average value for the compactness index 2 was 8.15 ± 0.509 , again a value characterizing an animal capable of medium-to-light work. In the individual assessment, 82.4% ($n = 14$) were categorized as capable of medium-to-light work and 17.3% ($n = 3$) as riding horses. The mean values of the compactness indices in Brazilian Sport Horses were consistent with the type of exercise to which the horses are subjected. In contrast, Lucena et al. (2016) found inconclusive results in Campolina horses, suggesting that more studies are needed to better classify this breed.

The average weight of the load index 2 was 199.83 ± 7.85 kg, i.e., the maximum weight carried by these animals without undue effort while walking. For load index 1, the maximum load without undue effort while working at a trot and gallop, the average weight was 117.79 ± 4.63 kg. Both indices had lower mean values compared with those found by Schade et al. (2015) in horses from a mounted police squadron (210.51 ± 13.97 and 124.09 ± 8.23 kg, respectively).

The dactyl-thoracic index gave an average value of 0.111 ± 0.01 , which classified the animals as riding horses. On evaluating the values individually, 47.1% of the animals ($n = 8$) were classified as riding horses, 29.4% ($n = 5$) as heavy working horses, and 11.8% ($n = 2$) as small horses, and 11.8% ($n = 2$) were outside the range of this classification with values below 0.105.

The chest index gave a mean value of 0.8 ± 0.028 and the relative body index was 98.87 ± 3.25 . The average value for the body index (0.87 ± 0.035) classified the animals, in general, as medium-sized horses. Individually, 52.9% ($n = 9$) were classified as medium, 23.5% ($n = 4$) as small, and 23.5% ($n = 4$) as sleek or long animals.

The meloscopic index showed that 58.8% ($n = 10$) of the animals were small, whereas 35.3% ($n = 6$) were sleek and 5.9% were medium-sized ($n = 1$).

Associations were found among compactness index 1 and thorax girth ($P = 0.001$), estimated weight ($P = 0.001$), conformation index ($P = 0.001$), compactness index 2 ($P = 0.002$), and load indices 1 ($P = 0.001$) and 2 ($P = 0.001$). There was also an association between the dactyl-thoracic index and fore cannon girth ($P = 0.009$) and an association tendency between the dactyl-thoracic index and head width ($P = 0.085$) and knee ($P = 0.055$) and fetlock ($P = 0.044$) girths. The meloscopic index was associated with the knee ($P = 0.009$) and fore cannon ($P = 0.020$) girths, body index ($P = 0.028$), and dactyl-thoracic ratio ($P = 0.005$) and tended to be associated with body ($P = 0.044$) and neck ($P = 0.044$) lengths as well as the age of the animals ($P = 0.049$) (Table 5).

In a literature review by the present authors, little was found concerning the ratio of angular measurements with respect to better performance in sports and the correlation of animal-performance indices with different characteristics of equine athletes, especially those within the scope of the present study. This observation was also made by Sole et al. (2014), who found a lack of correlation of morphological and functional variables in the equestrian sport of dressage.

Another factor worth highlighting is the heterogeneity of the animals of the Brazilian Sport Horse breed. As pointed out by Dias et al. (2000), this breed has been produced from various different breeds and, consequently, there is a large genetic variability. Thus, this genetic variability can explain the divergent phenotypic characteristics found by applying different formulas for the animal-performance indices in this study. The effect of breeding leading to differences in the phenotypic characteristics of horses was reported by Rezende et al. (2015).

The low rate of inbreeding in Brazilian Sport Horse was also observed in Lusitano horses, as mentioned by Vicente et al. (2014). However, these authors stated that this is detrimental to the evaluation of all morphological traits.

In the choice of animals for sports such as jumping, dressage, and eventing, height is taken into account; however, the most important factor is the actual performance

Table 5 - Associations and association tendencies among animal-performance indices and linear measurements of Brazilian Sport Horses undergoing training for eventing

Animal-performance index	Association	Tendency
Compactness index 1	Thorax girth; estimated weight; conformation index; compactness index 2; load index 1; load index 1	
Dactyl-thoracic index	Fore cannon girth	Head width; knee girth; fetlock girth
Meloscopic index	Knee girth; fore cannon girth; body index; dactyl-thoracic index	Body length; neck length; age of the animals

of animals in competition, which was shown by Koenen et al. (1995). The authors claimed that, owing to correlations of genetics and reduced performance, indirect selection based on morphometrics has limited value.

Campos et al. (2007) evaluated the useful characteristics in the horse herd of the Brazilian Army, including Brazilian Sport Horses and mixed-breed horses, and claimed that selection by weight could obtain gains in height. However, that study was on animals during their growth stage, which is approximately from six to 48 months. In the present study, age was not taken into account, as they were all Brazilian Sport Horses aged between four and 10 years and were already at the end of their growth period.

Mangalarga Marchador horses are significantly influenced by age and environment, factors that, according to the authors, should be taken into consideration when choosing an animal based on angular and linear measurements (Lage et al., 2009). Miserani et al. (2002) cited the sub-regions (subtropical regions) and the year of registration as significant factors of variation. Because the Brazilian Sport Horses training for eventing, the heart of this study, were in the final stage of growth, age did not warrant much attention. In addition, they received the same kind of food and were exposed to similar environmental conditions. Therefore, such factors had little importance here.

A linear scoring system is able to generate quality information on different morphological traits (Sánchez et al., 2013). Duensing et al. (2016) affirmed that, based on comprehensive linear schemes for conformation and performance, it is possible to identify indicator traits that allow an efficient selection of a durable and competitive riding horse. Therefore, the study on morphometrics through linear and angular measurements and calculation of the various animal-performance indices enabled a deeper understanding of Brazilian Sports Horses in training for eventing. The determination of a more consolidated breed-specific conformation is still a step in the future, since the mixing of different breeds has resulted in great phenotypic heterogeneity as evidenced in this work.

Conclusions

The use of linear and angular measurements allows the correct characterization of racial forms of Brazilian Sport Horses undergoing training for eventing. Animal-performance indices can be useful in a study of a breed-specific conformation of athletic horses.

Acknowledgments

The authors thank Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

References

- Anderson, T. M. and McIlwraith, C. W. 2004. Longitudinal development of equine conformation from weanling to age 3 years in the Thoroughbred. *Equine Veterinary Journal* 36:563-570.
- Angeli, A. L.; Reis, A. D. G.; Brusorio, D. R.; Simioni, L. C. and Hartmann, W. 2011. Biometria de cavalos da raça Brasileiro de Hipismo: resultados parciais. *Revista eletrônica: Biociências, Biotecnologia e Saúde*. Available at: <https://ayrtonsennabecalle.files.wordpress.com/2014/03/art_biometria_de.pdf>. Accessed on: Mar. 28, 2016.
- Campos, V. A. L.; McManus, C.; Fuck, B. H.; Cassiano, L.; Pinto, B. F.; Braga, A.; Louvandini, H.; Dias, L. T. and Teixeira, R. A. 2007. Influência de fatores genéticos e ambientais sobre as características produtivas no rebanho equino do Exército Brasileiro. *Revista Brasileira de Zootecnia* 36:23-31.
- Catalano, D. N.; Coleman, R. J.; Hathaway, M. R.; McCue, M. E.; Rendahl, A. K. and Martinson, K. L. 2016. Estimation of actual and ideal bodyweight using morphometric measurements and owner guessed bodyweight of adult draft and warmblood horses. *Journal of Equine Veterinary Science* 39:38-43.
- Dias, I. M. G.; Bergmann, J. A. G.; Rezende, A. C. C. and Castro, G. H. F. 2000. Formação e estrutura populacional do equino Brasileiro de Hipismo. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 52:647-654.
- Duensing, J.; Stock, K. F. and Krieter, J. 2016. Implementation and prospects of linear profiling in the Warmblood horse. *Journal of Equine Veterinary Science* 34:360-368.
- Godoi, F. N.; Bergmann, J. A. G.; Almeida, F. Q.; Santos, D. C. C.; Miranda, A. L. S.; Vasconcelos, F. O.; Oliveira, J. E. G.; Kaipper, R. R. and Andrade, A. M. 2013. Morfologia de potros da raça Brasileiro de Hipismo. *Ciência Rural* 43:736-742.
- Koenen, E. P. C.; Van Veldhuizen, A. E. and Brascamp, E. W. 1995. Genetic parameters of linear scored conformation traits and their relation to dressage and show-jumping performance in the Dutch Warmblood Riding Horse population. *Livestock Production Science* 43:85-94.
- Kristjánsson, T.; Björnsdóttir, S.; Albertsdóttir, E.; Sigurdsson, A.; Pourcelot, P.; Crevier-Denoix, N. and Arnason, T. 2016. Association of conformation and riding ability in Icelandic horses. *Livestock Science* 189:91-101.
- Kurtz Filho, M. and Löf, H. K. 2007. Biometria de equinos da raça Crioula no Brasil. *Archives of Veterinary Science* 12:47-51.
- Jönsson, L.; Näsholm, A.; Roepstorff, L.; Egenvall, A.; Dalin, G. and Philipsson, J. 2014. Conformation traits and their genetic and phenotypic associations with health status in you Swedish warmblood riding horses. *Livestock Science* 163:12-25.
- Lage, M. C. G. R.; Bergmann, J. A. G.; Procópio, A. M.; Pereira, J. C. C. and Biondini, J. 2009. Associação entre medidas lineares e angulares de equinos da raça Mangalarga Marchador. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 61:968-979.
- Lucena, J. E. C.; Vianna, S. A. B.; Berbari Neto, F.; Sales Filho, R. L. M. and Diniz, W. J. S. 2015. Estudo comparativo das proporções morfométricas entre garanhões e castrados da raça Campolina. *Semina: Ciências Agrárias* 36:353-366.

- Lucena, J. E. C.; Vianna, S. A. B.; Barbari Neto, F.; Sales Filho, R. L. M. and Diniz, W. J. S. 2016. Caracterização morfométrica de fêmeas, garanhões e castrados da raça Campolina baseada em índices. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 68:431-438.
- Mariz, T. M. A.; Santos, W. K.; Mota, L. F. M.; Martins, R. B.; Lima, C. B.; Escodro, P. B.; Lima Júnior, D. M.; Oliveira, L. P.; Sousa, M. F. and Ribeiro, J. S. 2015. Avaliação de medidas morfoestruturais em equinos da raça Quarto de Milha utilizando análises de imagens. *Acta Veterinaria Brasilica* 9:362-368.
- McManus, C.; Falcão, R. A.; Spritze, A.; Costa, D.; Louvandini, H.; Dias, L. T.; Teixeira, R. A.; Rezende, M. J. M. and Garcia, J. A. S. 2005. Caracterização morfológica de equinos da raça Campeiro. *Revista Brasileira de Zootecnia* 34:1553-1562.
- Miserani, M. G.; McManus, C.; Santos, S. A.; Silva, J. A.; Mariante, A. S. and Abreu, U. G. P. 2002. Avaliação dos fatores que influem nas medidas lineares do cavalo Pantaneiro. *Revista Brasileira de Zootecnia* 31:335-341.
- Pinto, L. F. B.; Almeida, F. Q.; Quirino, C. R.; Azevedo, P. C. N.; Cabral, G. C.; Santos, E. M. and Corassa, A. 2008. Evaluation of the sexual dimorphism in Mangalarga Marchador horses using discriminant analysis. *Livestock Science* 119:161-166.
- Rezende, M. P. G.; Abreu, U. G. P.; Souza, J. C.; Santos, S. A.; Ramires, G. G. and Sitorski, L. G. 2015. Morfologia corporal de equinos Quarto de Milha puros e mestiços utilizados no Laço Comprido no Mato Grosso do Sul. *Archivos de Zootecnia* 246:183-186.
- Rezende, M. P. G.; Souza, J. C.; Mota, M. F.; Jardim, R. J. D.; Ramires, G. G.; Silva, R. M. and Souza, C. F. 2014. Morfometria corporal de equinos utilizados em trabalho, esporte e lazer em três municípios do Mato Grosso do Sul. *Veterinária e Zootecnia* 21:569-583.
- Ribeiro, D. B. 1988. O cavalo de raças, qualidade e defeitos. Editora Globo Rural, Rio de Janeiro.
- Sánchez, M. J.; Gómez, M. D.; Molina, A. and Valera, M. 2013. Genetic analyses for linear conformation traits in Pura Raza Español horses. *Livestock Science* 157:57-64.
- Santos, S. A.; Mazza, M. C. M.; Sereno, J. R. B.; Abreu, J. R. B. and Silva, J. A. 1995. Avaliação e conservação do cavalo Pantaneiro. EMBRAPA-CPAC, Corumbá.
- Schade, M. F. S.; Menegatti, J.; Schade, J.; Souza Júnior, V. A. and Fontequ, J. H. 2015. Avaliação morfométrica de equinos do Esquadrão de Polícia Montada dos municípios de Lages, Joinville e Florianópolis-SC. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 67:1335-1342.
- Sole, M.; Cervantes, I.; Gutierrez, J. P.; Gomez, M. D. and Valera, M. 2014. Estimation of genetic parameters for morphological and functional traits in a Menorca horse population. *Spanish Journal of Agricultural Research* 12:125-132.
- Souza, B. G. 2013. Efeitos do exercício físico em esteira ergométrica de alta velocidade e do período de treinamento de equinos de Concurso Completo de Equitação: parâmetros morfológicos, metabólicos, bioquímicos e caracterização histoquímica e enzimo-histoquímica do músculo glúteo médio. Tese (D.Sc.). Universidade Federal Fluminense, Niterói.
- Torres, A. P. and Jardim, W. R. 1981. Criação do cavalo e de outros equinos. 3.ed. Nobel, São Paulo.
- Vicente, A. A.; Carolino, N.; Ralão-Duarte, J. and Gama, L. T. 2014. Selection for morphology, gaits and functional traits in Lusitano horses: II. Fixed effects, genetic trends and selection in retrospect. *Livestock Science* 2014:13-25.