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Association of phenotypical characteristics with performance of Mangalarga Marchador horses during official competitions of endurance, working equitation and gait assessment

Associação de características fenotípicas com desempenho de cavalos Mangalargas Marchadores durante competições oficiais de resistência, de equitação de trabalho e de marcha

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ABSTRACT: Horses of the *Mangalarga Marchador* breed have traditionally been selected for their morphology and gait pattern, being for comfortable to ride over long periods of time and during ranch work. Meanwhile, the athletic side of the breed has been much overlooked, especially regarding the endurance and working equitation competitions. In this study, 31 *Mangalarga Marchador* horses were evaluated during the national competition *Caminhos do Marchador*. The referred competition was carried out in three stages, with the first being an endurance stage, the second stage a working equitation stage, and the third and last stage was a gait evaluation, where the gait of the horses were assessed subjectively by an official jury. Twenty-five morphometric measurements and indexes of these animals were taken after the competition and were then statistically analyzed. A correlation between gender and athletic performance was found, with geldings having the best results, and females having the worst results. The type of gait also influenced the final ratings, with horses presenting *batida* gait having better placements. Smaller horses had better results than tall horses, while there was no age interference in the final ratings.

KEYWORDS: Morphometry; horse; equestrian events; athletic evaluation.

RESUMO: Os cavalos da raça Mangalarga Marchador são, tradicionalmente, selecionados por sua morfologia e padrão de marcha, sendo confortáveis para cavalgar por longos períodos de tempo e durante o trabalho na fazenda. Enquanto isso, o lado atlético da raça tem sido muito esquecido, principalmente, no que diz respeito às competições de resistência e equitação de trabalho. Neste estudo, foram avaliados 31 cavalos da raça Mangalarga Marchador durante a competição nacional "Caminhos do Marchador". A competição foi realizada em três etapas, sendo a primeira de resistência, a segunda de equitação de trabalho, e a terceira e última etapa de avaliação da marcha, avaliada, subjetivamente, por um juiz oficial. Vinte e cinco medidas e índices morfométricos desses animais foram realizados após a competição e, posteriormente, analisados estatisticamente. Foi encontrada uma correlação entre gênero e desempenho atlético, sendo os cavalos castrados apresentando os melhores resultados e as fêmeas os piores. O tipo de marcha também influenciou nas notas finais, sendo que os cavalos que apresentam marcha batida obtiveram melhores colocações. Cavalos menores tiveram melhores resultados que cavalos altos, e não houve interferência da idade nas classificações finais.

PALAVRAS-CHAVE: Morfometria; cavalo; eventos equestres; avaliação atlética.

INTRODUCTION

Gaited horses are considered special due to their more comfortable walking or trotting styles, compared to non-gaited horses, in many different countries around the world. Some examples of gaited horses include the Tennessee Walking Horses, in the United States of America , the Icelandic Horse in Iceland, Passo Fino, in Colombia, and the *Mangalarga Marchador* breed in Brazil (Staiger *et al.*, 2016; Herbrecht *et al.*, 2020; Novoa-Bravo *et al.*, 2018; Baena *et al.*, 2020; Meira *et al.*, 2013).

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The *Mangalarga Marchador* breed stands out from the other gaited breeds due to its comfortable gait associated with a very good land coverage. This happens due to the dissociation pattern of the its triple support, in which the horses remains with 3 feet on the ground while only 1 remains suspended, intertwined with diagonal and lateral support patterns. This type of gait is divided into the *batida* gait and the *picada* gait, the only two variations accepted by the *Associação Brasileira de Criadores do Cavalo Mangalarga Marchador (ABCCMM)*, the national studbook that regulates the breed development (Gonçalves Fonseca *et al.*, 2017; Lage *et al.*, 2017).

The main difference between the types of gaits is regarding the diagonal and lateral patterns after the triple support stage. In the *batida* gait, there are more diagonal patterns after the triple support, while in the *picada* gait there are more lateral patterns. These lateral moments make the *picada* gait more comfortable while riding, since there is less movement in the horses back, making it easier for the rider to sit still. Meanwhile, the horses that present the *batida* gait tend to have a greater ground coverage and smaller energy expenditure, needing less strides to cover the same distance, when compared to the *picada* gait individuals (Wanderlei *et al.*, 2010; Gonçalves Fonseca *et al.*, 2017; Lage *et al.*, 2017).

In addition to the gait pattern, the ABCCMM also has a rigid breed standardization system for the *Mangalarga Marchador* breed. There are 12 linear measurement parameters evaluated to ensure that the horses fits the breed standards, all taken before the animal can be registered as part of the breed (Meira *et al.*, 2013; Santiago *et al.*, 2016). Considering these measurements, several studies were carried out with the purpose of a better understanding of the *Mangalarga Marchador* morphology. However, most of these studies did not correlate the measurements found the results in competitions, such as work equitation, endurance and gait evaluations (Cabral *et al.*, 2004; Lage *et al.*, 2009; Pinto *et al.*, 2008; Santiago *et al.*, 2014). In other breeds, several factors, in addition to morphology, have been found to also interfere with the athletic performance of horses, such as age, gender, physical conditioning, behavior and rider skill, and thus should also be evaluated in the *Mangalarga Marchador* breed (Duberstein; Gilkeson, 2010; Gunst *et al.*, 2019; Hanousek; Salavati; Fouladi-Nashta, 2018).

Breeders of the *Mangalarga Marchador* breed horse have always sought to select animals that are calm, docile, of distinct beauty, with excellent gait and resistance to travel long journeys (Cabral *et al.*, 2004; Lage *et al.*, 2009). This selection, which used to be done through the empiricism of its breeders, was perfected through the use of linear measurements and the calculation of morphometric indexes, allowing for the selection of animals with adequate proportions for the functions they perform (Santiago *et al.*, 2016; Padilha *et al.*, 2017).

Due to this lack of information regarding the *Margalarga Marchador* horses in athletic competitions, the objective of this study was to analyze and associate age, gender, gait type, morphometric measurements, and indexes with the best athletic performance of horses of the *Mangalarga Marchador* breed during official competitions of endurance, working equitation and gait assessment, held in the *Caminhos do Marchador* national competition.

MATERIAL AND METHODS

This study received approval from the Ethics Committee on Animal Use (CEUA) of the *Universidade Federal Fluminense* (UFF), with the number 914/18.

Horses & Handling Procedures

Thirty-one *Mangalarga Marchador* horses, competing in the *Caminhos do Marchador* competition were selected for this study. Of those horses, 10 were stallions, 13 geldings and 8 were females, between three and 12 years, all clinically healthy and registered with the ABCCMM breed association. Regarding gait type, *batida* gait was seen in 24 horses, being five stallions, 13 geldings and six females, while the *picada* gait was seen in only five geldings and two females. All horses were stabled in mobile stainless-steel stalls measuring 2.5m x 2.5mm and 2 meters high.

Competition Caminhos do Marchador

The competition *Caminhos do Marchador* was carried out in the city of Passa Quatro, in the southern region of the Minas Gerais state, at an altitude of 938 meters. It took place over 2 days. On the first day, the average temperature was 20°C and relative humidity of 75%, while on the second day the average temperature was 22°C with 70% humidity.

The competition was divided into three phases, with the first being the endurance phase. This part of the competition took place on the first day and is similar to the endurance competition partaken by Arabian horses. In this phase, the horse and rider duo had to overcome an 18,122 meters course, using pre-established directions and different speeds during different portions of the course. It was carried out on trails, passaging through forests, valleys, and mountains, with some natural obstacles along the way. The speed check was done through a GPS placed on the riders' vest. At the 9,096 meters mark, there was a mandatory half-hour stop, where the heart rate of the horses was measured at the end of the 30-minute period. If it still exceeded 64 beats per minute (bpm), the pair would be disqualified. In this phase, the winner is the horse & rider pair that finished closest to the stipulated ideal time, having kept the specified speed and route the best way possible. All horses that do not finish this first phase of the competition, either due to time running out, high heart rate or lameness, will be disqualified from the remainder of the competition.

The second phase was the working equitation test. It took place three hours after the end of the endurance phase. The horse & rider pair had to complete, in the shortest possible time, the following obstacles: opening and closing a gate without the rider getting off the horse, contouring posts, contouring a drum, overcoming 60cm jumps, performing a rollback, and going up and down a ramp. All these obstacles were arranged on a rectangular grass arena measuring 50mx200m.

The third and last phase of the competition was the gait assessment, taking place on the second day of competitions. In this part of the *Caminhos do Mangalarga* competition, a panel of ABCCMM certified jury evaluated the quality of the gait in the horses. The scores were subjectively assigned by the jury, in scores ranging from 0 to 10. The parameters analyzed for grading are quality of gesture, movement style, comfort while riding, training level and ground coverage. .

Linear Morphometric Measurements

After the end of all three phases of the *Caminhos do Marchador* competition, the linear morphometric measures mostly used in the *Mangalarga Marchdor* evaluation were obtained, as described by Cabral *et al*. (2004). All measurements were taken in meters (m), using a measuring tape and a hypometer. All the horses were kept in standing position, with all limbs perpendicular to the ground. The measurements selected were as follows:

1. Height at the withers (HW): vertical distance between the highest point of the withers and the ground;
2. Croup height (CH): vertical distance between the highest point at the croup to the ground;
3. Head Length (HL): length between the nuchal crest and the tip of the muzzle;
4. Shoulder Length (SL): length between the top portion of the scapula and its most distal point;
5. Neck Length (NL): length between the nuchal crest and the neck's intersection with the withers;
6. Rump Length (RL): length between the coxal tuberosity and the ischium tuberosity;
7. Body Length (BL): distance between the distal portion of the scapula and the distal portion of the rump;
8. Back length (BAL); length between the dorsal portion of the scapula and the coxal tuberosity:
9. Head Width (HEW): distance between the right and left supraorbital borders;
10. Hip Width (HIW): distance between left and right coxal tuberosities;
11. Thoracic girth (TG): measurement given by the external circumference of the thoracic cavity, in the girthing area;
12. Shin Girth (SG): measurement given by the external circumference of the middle of the metacarpal bone region;
13. Weight (W): measured in kilograms (kg), obtained through the use of a scale, guaranteeing precise measurements of this parameter.

Morphometric Indexes

After the linear morphometric measurements were taken, they were utilized to help calculate several different morphometric indexes of importance for the *Mangalarga Marchador* breed. The first one of those indexes, also used in the calculations of several other indexes, is the estimated weight. It can be calculated, in kilograms, through the following formula:

$$Estimated\ weight = thoracic\ perimeter^3\ x\ 80$$

When the estimated weight is over 550kg, the horse is considered large or hypermetric; between 350 and 550kg is considered average sized or eumetric; and less then 350kg is considered small or hypometric (Torres; Jardim, 1981).

The remaining morphometric indexes calculated are as follows:

1. Body Index = body length / 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; Jardim, 1981)
2. Ratio of the Height of Withers and at Croup = height at withers / height at croup (MacManus *et al*, 2005)
3. Dactyl-thoracic index = cannon girth / thoracic girth
   For small horses, this index cannot be less than 0,105, for medium ou riding horses no less than 0,108, and no less than 0,115 for large horses. Horses that do not fit into those parameters are considered non-standard (Ribeiro, 1988);
4. Form index = thoracic girth^2 / height at withers
   Values equal to 2,1125 indicate that the animal is considered a riding or saddle horse, while values above it indicates the animal is considered a working horse, such as draft breeds. Horses that have values under 2,1125 are considered non-standard (Torres; Jardim, 1981);
5. Load Index 1 = (thoracic girth^2 x 56) / height at withers
   This index indicates the weight, in kg, the horse can withstand without excessive stress in its back while working at a trot or gallop pace (Torres; Jardim, 1981);
6. Load Index 2 = (thoracic girth^2 x 95) / height at withers
   This index indicates the weight, in kg, the horse can withstand without excessive stress in its back while working at walk (Torres; Jardim, 1981);
7. Relative Body Index = (body length x 100) / height at wither (Santos *et al*., 1995);

8. Compactness Index 1 = (estimated weight / height at withers) / 100
   Heavy draft horses will present values greater than 3,15, light draft horses will have values close to 2,75, while saddle or riding horses will have vales near 2,60. Horses that do not fit into those parameters are considered non-standard (MacManus *et al.*, 2005);
9. Compactness Index 2 = [(estimated weight / height at withers) – 1] / 100
   This index demonstrates the suitability of the animal to certain work patterns. Values above 9.5 indicate animals suited for heavy work, while values between 8.0 and 9.5 indicates animals suitable for light work and values between 6.0 and 7.75 indicates animals suitable for riding. Horses that do not fit into those parameters are considered non-standard (MacManus *et al*, 2005);
10. Shin Compactness Index = (shin girth / estimated weight) x 100
    Indicates the ability of the limbs to carry the bod weight (Cabral *et al.*, 2004).

Statistical Analysis

The statistical analysis used in this study was primarily descriptive. Regarding the morphometric measurements and indexes, mean value and standard deviation were also calculated. In the quantitative aspect, several tests were used to find the correlation and association between the different data collected. The Pearson correlation was used in order to calculate correlations between the different variables. The Kruskal-Wallis test was used to verify the occurrence of association between the final placement in the competition and the age of the horses. The Mann-Whitney test was used to assess if there was any gender interference regarding the final placement in the competition. The Chi-Square test was used to evaluate if there was any statistical difference between horses of the *batida* and the *picada* gait regarding their final result in the *Caminhos do Marchador* competition. All of the statistical analysis and procedures were calculated using the SPSS, version 18 computational package.

RESULTS

The mean values and the standard deviations of the values of the morphometric measurements of the *Mangalarga Marchador* horses in the present study are presented in Table 1. In the first column, the values presented reflect the mean value ± standard deviation of all horses analyzed. In the following columns, the measurements are divided by gender and type of gait. All measurements are presented in meters (m), except for the weight, shown in kilograms (kg).

The data collected was analyzed using Pearson correlation. The height at the wither was found to be strongly correlated with rump height (r=0,874; p = 0.001), as well as with body length (p = 0.01) and neck length (p = 0.04). In a similar manner, rump height was also associated to body length (p = 0.01), shoulder length (p = 0.01) and rump length (p = 0.03). Surprisingly, thoracic girth and neck length were also found to be correlated, with a p-value of p = 0.01. The results found for the morphometric indexes, can be found on Table 2.

Table 3 shows, in percentages, the morphometric classifications based on the morphometric indexes found. They are shown in regard to the general group, gender and type of gait of the horses studied. All horses were classified as eumetric, but

Table 1. Mean values and standard deviations, in meters, of the morphometric measurements in the general data and specified by gender and gait type *of Mangalarga Marchador* breed horses participating in the test *Caminhos do Marchador*.

Measurements	General	Geldings	Stallions	Mares	Batida Gait	Picada Gait
HW $_{(m)}$	1.47±0.03	1.48±0.03	1.48±0.02	1.45±0.026	1.48±0.03	1.47±0.02
CH $_{(m)}$	1.46±0.03	1.46±0.034	1.47±0.018	1.44±0.03	1.46±0.034	1.45±0.027
HL $_{(m)}$	0.57±0.01	0.57±0.01	0.57±0.16	0.56±0.018	0.57±0.01	0.56±0.16
BAL $_{(m)}$	0.47±0.02	0.48±0.03	0.47±0.02	0.47±0.03	0.47±0.03	0.49±0.02
SL $_{(m)}$	0.52±0.02	0.52±0.02	0.52±0.02	0.51±0.02	0.52±0.02	0.52±0.03
NL $_{(m)}$	0.60±0.02	0.61±0.03	0.61±0.016	0.59±0.03	0.61±0.03	0.59 ±0.016
RL $_{(m)}$	0.51±0.02	0.51±0.03	0.51±0.02	0.50±0.02	0.51±0.02	0.52±0.02
BL $_{(m)}$	1.50±0.02	1.50±0.029	1.50±0.02	1.49±0.012	1.50±0.027	1.49±0.02
HEW $_{(m)}$	0.20±0.008	0.20±0.01	0.20±0.008	0.20±0.008	0.20±0.007	0.20±0.011
HIW $_{(m)}$	0.49±0.01	0.49±0.02	0.49±0.019	0.48±0.012	0.49±0.02	0.49±0.019
TG $_{(m)}$	1.70±0.04	1.69±0.03	1.70±0.045	1.71±0.049	1.71±0.04	1.70±0.044
SG $_{(m)}$	0.18±0.009	0.17±0.007	0.18±0.009	0.17±0.007	0.18±0.008	0.17±0.009
WEIGHT $_{(kg)}$	399.94±32.23	391.01±24.49	399.91±32.12	400.37±34.80	401.74±32.94	393.91±31.26

HW - height at the withers; CH - Croup height; HL - head length; BAL – Back length; SL - shoulder length; NL – neck length; RL - rump length; BL - body length; HEW - head width; HIW – Hip Width; TG - thoracic girth; SG - shin girth.

Table 2. Mean values and standard deviations, in meters, of the morphometric indexes in the general data and specified by gender and gait type of *Mangalarga Marchador* breed horses participating in the test *Caminhos do Marchador*.

Measurements	General	Geldings	Stallions	Mares	Marcha Batida	Marcha Picada
WEIGHT (kg)	399.94±32.23	391.01±24.49	399.91±32.12	400.37±34.80	401.74±32.94	393.91±31.26
RHWC	1.009±0.01	1.012±0.009	1.01±0.009	1.005±0.012	1.01±0.011	1.008±0.007
DTI	0.105±0.004	0.105±0.004	0.108±0.003	0.103±0.002	0.106±0.004	0.104±0.005
BI	0.87±0.02	0.88±0.017	0.87±0.037	0.87±0.026	0.87±0.02	0.88±0.02
FI	1.97±0.1	1.94±0.07	1.99±0.11	2.01±0.1	1.97±0.11	1.96±0.09
LI1	169.96±9.39	166.84±6.04	171.22±9.85	173.14±12.10	170.25±9.89	168.99±7.98
LI2	187.75±10.37	184.30±6.68	189.43±11.34	191.96±13.37	188.06±10.93	186.68±8.82
RBI	101.63±1.66	101.51±1.39	100.94±1.55	102.69±1.87	101.62±1.80	101.66 ±1.18
CI1	2.70±0.21	2.63±0.14	2.75±0.24	2.75±0.27	2.71±0.22	2.67±0.19
CI2	2.69±0.21	2.62±0.14	2.74±0.25	2.74±0.27	2.70±0.22	2.66±0.19
CCI	0.045±0.003	0.045±0.003	0.045±0.002	0.044±0.002	0.045±0.003	0.045±0.002

RHWC - Ratio of the Height of Withers and at Croup; DTI- Dactyl-thoracic index; BI - Body Index; FI- Form Index; LI1 - Load Index 1; LI2 - Load Index 2; RBI - Relative Body Index; CI1- Compactness Index 1; CI2 - Compactness Index 2; SCI - Shin Compactness Index.

Table 3. Morphometric classifications, in percentages, shown divided into general data and specified by gender and gait type of *Mangalarga Marchador* breed horses participating in the test *Caminhos do Marchador*.

Measurements	General	Geldings	Stallions	Mares	Batida Gait	Picada Gait
Weight	**Eumetric: 100%**	**Eumetric: 100%**	**Eumetric: 100%**	**Eumetric: 100%**	**Eumetric 100%**	**Eumetric: 100%**
DTI	Small Horses: 19.35%	Small Horses: 15.38%	Small Horses: 20%	Small Horses: 25%	Small Horses: 20.83%	Small Horses: 14.28%
	Medium Horses: 29.03%	Medium Horses: 23.01%	Medium Horses: 60%	Non-standard: 75%	Medium Horses: 29.16%	Medium Horses: 28.57%
	Large Horses: 3.22%	Largen Horses: 7.69%	Non-standard: 20%		Largen Horses:4.16%	Non-standard: 57.18%
	Non-standard: 48.38%	Non-standard: 53.84%			Non-standard: 45.83%	
	Long: 19.35%	Long: 23.07%	Long: 20%	Long: 12.5%	Long: 16.6%	Long: 28.57%
BI	Medium: 64.51%	Medium: 69.23%	Medium: 60%	Medium: 62.5%	Medium: 66.6%	Medium: 57.14%
	Short: 16.12%	Short: 7.69%	Short: 20%	Short: 25%	Short: 16.6%	Short: 14.28%
FI	Non-standard: 90.32%	Non-standard: 100%	Non-standard: 90%	Non-standard: 75%	Non-standard: 87.5%	Non-standard: 100%
	Working Horses: 9.67%		Working horses: 10%	Working horses : 25%	Working horses : 12.5%	
CI1	Saddle Horses: 25.80%	Saddle Horses: 23.07%	Saddle Horses: 20%	Saddle Horses: 37.5%	Saddle Horses: 25%	Saddle Horses: 28.57%
	Light Draft Horses: 16.12%	Light Draft Horses : 30.76%	Light Draft Horses : 10%	Heavy Draft Horses: 12.5%	Light Draft Horses: 20.83%	Non-standard: 71.42%
	Heavy Draft Horses: 6.45%	Non-standard: 46.15%	Heavy Draft Horses: 10%	Non-standard: 50%	Heavy Draft Horses: 8.33%	
	Non-standard: 51.61%		Non-standard: 60%		Non-standard: 45.83%	
CI2	Non-standard: 100%	Non-standard: 100%	Non-standard: 100%	Non-standard: 100%	Non-standard: 100%	Non-standard: 100%

DTI- Dactyl-thoracic index; BI - Body Index; FI- Form Index; CI1- Compactness Index 1; CI2 - Compactness Index 2.

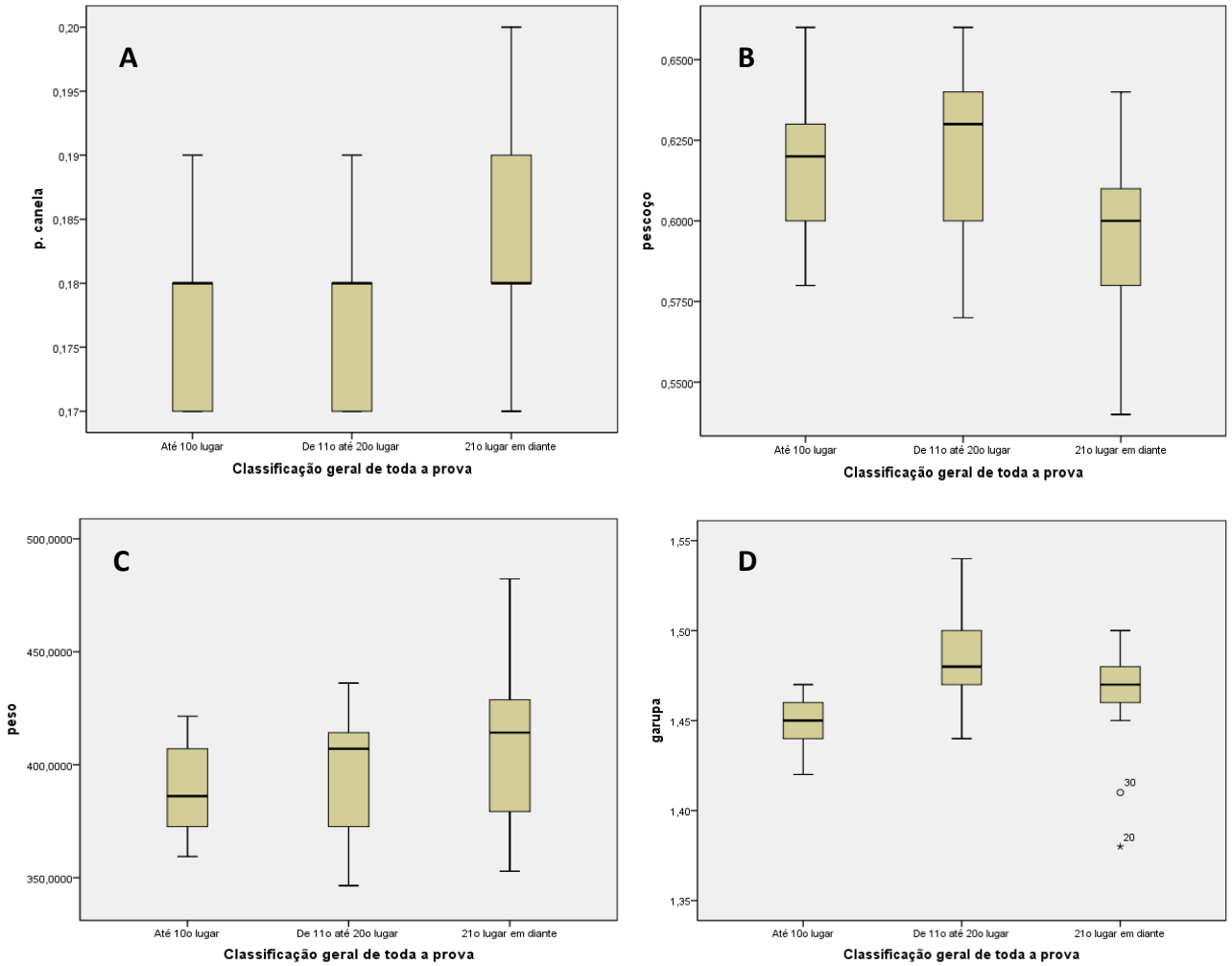
most of the animals did not fit into the *Mangalarga Marchador* breed standard measurements.

When comparing the morphometric measurements and indexes to the final results in the competition, some interesting patterns could be found. Horse with a greater shin girth had worse results than animals with slimmer shins (Figure A), just as horses with shorter necks also presented worse results than those with longer necks (Figure B). Lighter animals had better results than heavier animals (Figure C), and horses with smaller rump height also had better results than those with taller rumps (Figure D).

Gender also had influence in the final results of the *Caminhos do Marchador* competition, with geldings having the best results, while females and stallions had the worst results (Figure E). When comparing females to stallions, there was no statistical difference in the overall placings, while between gelding and females (p=0,004) and geldings and stallions (p=0,007) a statistically significant different could be seen. In the endurance stage geldings had better results (Figure F), while in the gait assessment there was no difference between genders (Figure G). In the working equitation phase, stallions had the worse placings, with females and geldings having similar scores (Figure H).

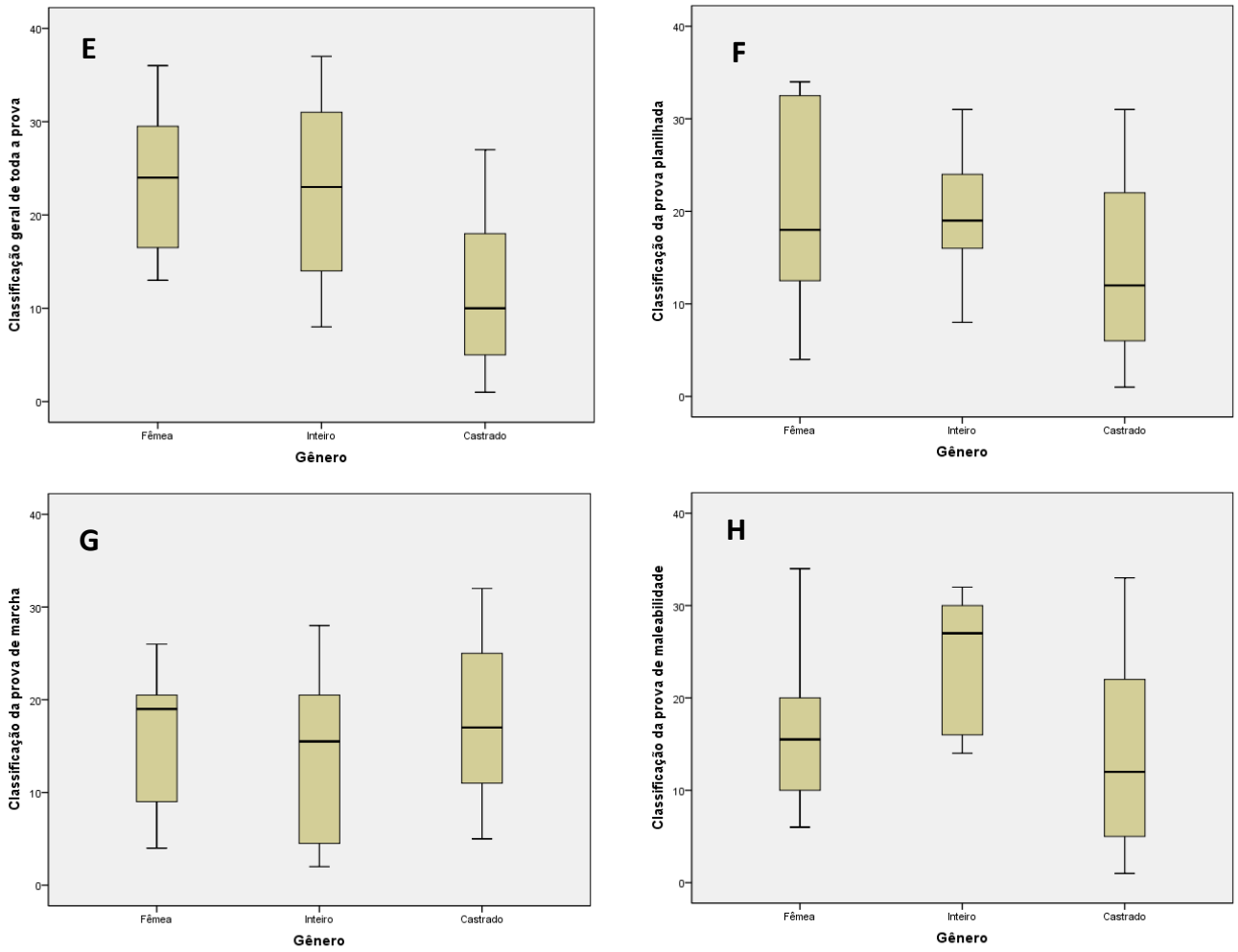
The type of gait also had a significant influence in results of the different phases of the competition. Horses of the *batida* gait had better results in both the endurance (p=0,024, Figure I) and working equitation (p=0,044, Figure J) phases, when compared to horses of the *picada* gait. In regard to the final results of the competition, horses with the *batida* gait once more had better placings than horses of the *picada* gait (Figure L).

Concerning the overall results of the competition, some unexcepted correlations were found. The head length was found to have a medium negative correlation with the final results of the competition (r=0,373, p=0,039), and neck length also had a medium negative correlation with the results of the working equitation phase specifically (r=0,487; p=0,009). In regard to the individual phase of the competition to the overall result,



A- shin perimeter in relation to overall results; B – neck length in relation to overall results; C – weight in relation to overall results; D – rump height in relation to overall results.

Figures A-D. Box-Plot graphs demonstrating the morphometric measures in regard to the overall results of the *Caminhos do Marchador* competition.



E - overall results; F – endurance phase; G – gait assessment phase; H – working equitation phase.
Figures E-H. Box-Plot graphs demonstrating the gender influence in regard to the results in the different phases of the *Caminhos do Marchador* competition.

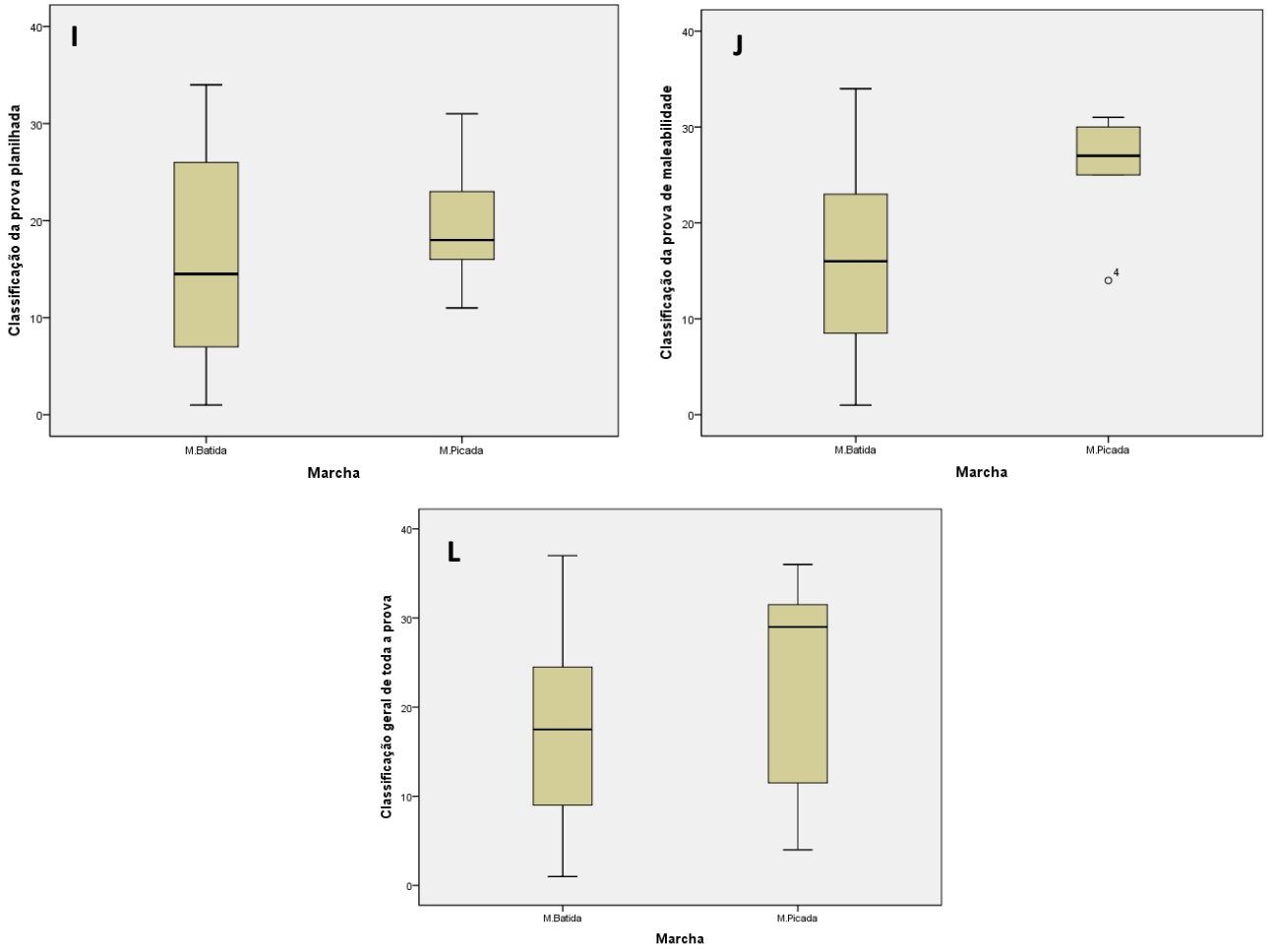
only the working equitation results showed any significant impact on the overall results, having a strong positive correlation (p=0,001; r=0,642).

DISCUSSION

The present study found punctual characteristics associated to the performance in breed-specific competitions which can help predict athletic performance.

The height at the withers of the *Mangalargas Marchadores* in the present study, in both males and females, was similar to the values presented in horses of the same breed, by Pinto *et al.* (2008); Gonçalves *et al.* (2012); Santiago *et al.*, (2016). Those horses were found to be taller than some other Brazilian breeds, such as the *Criola*, *Pantaneira* and *Nordestina*, and smaller than those of the *Campolina* breed (Kurtz Filho *et al.*, 2007; Meserani *et al.*, 2002; Melo *et al.*, 2002; Sousa *et al.*, 2018). The height at the rump was slightly lower than the height at the withers, which is a common finding of the breed (Cabral *et al.*, 2004; Santiago *et al.*, 2014). All the horses in this study, regarding their weight, were classified as eumetric, a result that is expected for a breed that tends to select lighter and more balanced animals (Gonçalves *et al.*, 2012). This inding corroborates with the results found in this study, in which lighter horses had better results. Those findings can indicate that overweight animals tend to have disadvantage in equestrian competitions, since the excess weight can cause a series of physical problems, including locomotor and cardiovascular system alterations. Most of the time, the horse's body is not prepared to make high effort activities, such as the endurance phase of the *Caminhos do Marchador* competition, while carrying the extra weight, giving the lighter animal as advance especially of this stage. Clayton; Buchholz; Nauwelaerts (2013) also demonstrated that lighter horses, in several different breeds, are also quicker, giving the *Mangalarga Marchadores* studied a greater chance of better results in the working equitation phase.

Another important finding was the optimal proportion between withers and rump height, measured by the RHWC index, should be close to one, this ratio being ideal for saddle horses since it allows the rider to remain balanced on top of



I - endurance phase; J – working equitation phase; L - overall results.

Figures I-L. Box-Plot graphs demonstrating the gait influence in regard to the results in the different phases of the *Caminhos do Marchador* competition.

the horse's back (Gonçalves *et al.*, 2012; Lucena *et al.*, 2015). Other Brazilian breeds, such as the *Nordestina* and the *Pantaneiro* also presented a RHWC index close to 1, being considered well-balanced saddle horses (Melo *et al.*, 2011; Luiz *et al.*, 2019). On the other hand, McManus *et al.* (2005) showed that horses of the *Campeiro* breed had RHWC values very far from the ideal value of 1, not being considered to be such a balanced saddle horse breed. Kashimura *et al.* (2001), while studying racehorses, found that balanced horses, considering their RHWC index close to 1, had better results in competition when compared to animals with RHWC index different than 1. Those findings can indicate that the *Mangalarga Marchador* horses were more proportionate and balanced than some other Brazilian breeds, thus being more likely to have better results during competitions.

Unlike some other studied with the *Marngalarga Marchador* breed, no statistically significant correlation was found between the morphometric linear measurements and the different genders., Meira *et al.* (2013) and Lage *et al.* (2009) found a correlation between gender and height at withers, rump length and shin perimeter measures.

The body index (BI) showed a predominance of medium sized horses in this study. This finding disagrees with the trend observed by Santiago *et al.* (2014), who verified a transition from medium to longer animals. a desired characteristic for horse sports that involve agility, but not desired for gait and endurance purposes (Rezende *et al.*, 2016). McManus *et al.* (2008) points out that medium sized equines are ideal for long rides, being the characteristic that proves to be essential for both resistance and gait competitions.

The greater predominance of medium animals found in the present study is aligned with the proposition of Cabral *et al.* (2004), who pointed out this characteristic as essential for the good balance of gaited animals. This happens because longer animals cover more ground per stride, while shorter animals have a more compact muscle mass and center of gravity, being ideal for strength work, such as what is expected from draft horses. Medium length horses combine characteristics from both ends, covering a reasonable amount of ground while still being able to carrying weight. Those characteristics mirror what is expected of the *Mangalarga Marchador* horse, being a comfortable horse breed for both sports and work,

needing to cover ground well while still being able to carry the rider and some extra load during extended amounts of time.

The load indexes 1 and 2 values found at the present study, showed animals capable of withstanding the intended exercise during the *Caminhos do Marchador* competition. As shown on Table 2, the average load index 1 was 169.96±9.39kg, while the average load index 2 was 187.75±10.37kg. Those values represent a load carrying capacity twice as high as the weight of the average rider. The horses studied presented values similar to those found in larger Brazilian breeds, such as the *Campolina* (Lucena *et al*., 2015). Schade *et al*. (2015) worked with mounted police horses, and found slightly lower values for the load index 1 and higher values for the load index 2.

The values found in this study, when compared to the other similar studies presented, help to show that the *Mangalarga Marchador* breed has the capacity to carrying loads equivalent to those carried by larger breeds, such as the *Campolina.* This ability is particularly important for the horses used in ranch work and such, who must carry not only the rider but several different equipment for an extended period of time. For horse athletes, those indexes are more important during the endurance and gait assessment stages, in which the rider must stay mounted for longer periods of time. It is important to mention that even though both indexes indicate the amount of weight the horse can withstand without excessive stress on the back (Torres and Jardim, 1981), the load imposed on the animals should never exceed those limits or be close to it for extended periods of time in order to prevent lesions from happening due to excessive work.

Also, regarding the load indexes, females were found to have a greater capacity to bear load due to their higher load indexes 1 and 2, as shown in table 2. This characteristic was shown not to be so relevant for the execution of the different phases of the *Caminhos do Marchador* competition, where speed and balance were more significant than strength and capacity to bear load, resulting in worse result for females on the competitions analyzed (Bartholazzi *et al*., 2017; Ramos *et al*., 2014).

Females were found to be slightly smaller than males, and also heavier, as shown in Table 1. Santiago *et al*. (2014) reported the same findings concerning size, but not weight, indicating that heavier females are not a common finding in the *Mangalarga Marchador* breed. The fact that females are heavier while being shorter than the other genders should be slightly concerning for the breeders. Overweight females are usually associated with hormonal problems, who in association with fatty tissue deposits, can lead to reproductive problems, such as difficulties getting pregnant and giving birth.

Gender interfered in the overall classification of the competition, as shown in figures E to H. When comparing females to stallions, there was no statistical difference in the overall placings, while between gelding and females (p=0,004) and geldings and stallions (p=0,007) a statistically significant different could be seen. One of the main reasons this might have happened is due to the fact that geldings tend to be calmer and more submissive to the commands given by the rider. Hanousek; Salavati; Fouladi-Nashta (2018), in a study carried out in England with eventing horses, also found a significant influence of gender in the results of competitions, with females presenting worse placements than males. However, that study pointed out that stallions had a better result than geldings. One of the main reasons for this difference could be that eventing competitions, in particular cross country and jumping, requires more strength and speed than the resistance and calmness expected from the *Mangalarga Marchador* horses in the *Caminhos do Marchador* competition.

Another characteristic that can help explain why geldings had a better result is the form index. As shown in table 3 the group of geldings had more horses considered to be of medium or elongated built, a characteristic that would help to explain the better performance of this group in the overall classification of the competition, since longer animals tend to be faster and more agile and medium animals tend to be more stable (Rezende *et al*., 2016; Santiago *et al*., 2016).

Another one of the causes that explain the better results of males in competitions was demonstrated in a study by Murphy *et al*., (2004). They concluded that males have better spatial vision than females, thus better visualizing obstacles and overcoming them with greater precision. In addition, behavioral studies have shown that females tend to be more anxious than males, especially when compared to geldings, justifying their worse performance in competitions (Duberstein *et al*., 2010).

The type of gait showed a strong trend when compared to the general classification of the competition, with horses with *batida* gait having better results than those with *picada* gait, as shown in figures I, J and L. It is believed that this occurred because horses with *picada* gait need more strides to overcome the same distance as horses with the batida gait, leading to a greater energy expenditure when performing similar exercises. This results in a decrease in locomotor efficiency and thus poorer performance in competitions, when compared to the animals with the *batida* gait (Fonseca *et al*., 2017; Lage *et al*., 2017; Wanderley *et al*., 2010).

The difference could be seen mainly in the endurance and working equitation phases of the *Caminhos do Marchador* competition. In the endurance phase, a long distance needed to be covered, and animals presenting the *picada* gait needed to spend more energy than those with *batida* gait to overcome the same distance. Similarly, in the working equitation stage, a lot of the energy was spent to overcome the obstacles in the course, causing any extra energy needed to cover the same distance to be a hindrance to the *picada* gait horses. In the gait assessment test, the energy expenditure is not a significant factor, since horses with the same gait are group together and judged based on the same parameters, such as gesture, temperament, and the quality of the movement.

Regarding age, although there was a predominance of young horses, this characteristic was not correlated with the overall classification in the competition. This diverges from the report made with animals of the Arabian breed that participate in endurance events, where the worst athletic performance was found in a group of young horses (Adamu *et al.*, 2013).

CONCLUSION

In this study, several different factors were taken into consideration to analyze the best athletic performance of horses of the *Mangalarga Marchador* breed during official competitions of endurance, working equitation and gait assessment, held in the *Caminhos do Marchador* national competition. Age was shown to have no major interference with results, while gender, gait type and some morphometric indexes had a big influence on the final results.

Those findings are extremely important for the competitors and the breeders, who tend to be after the magic "success formula" to have the best horse possible for their need. Several different parameters should be used and evaluated when choosing the horse that is best suited for the event in mind, both from the athletic point of view as well as from the reproduction point of view. The main goal to be achieved should always be kept in mind, so that the horse with the most desired characteristics can be selected, increasing the likelihood of better results in competitions and daily tasks.

More studies need to be conducted to corroborate this studies' findings, specially by increasing the number of horses evaluated in each of the different phases of the competition. An interesting addition to the data collected would be the analysis of morphometric angular measurements, bringing into the discussions more information regarding the breed's conformation.

In conclusion, gender and gait type were the factors that most influenced the athletic performance of horses of the *Mangalarga Marchador* breed during official the *Caminhos do Marchador* national competition, with the best results being seen in gelding with the *batida* gait.

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