





Temporal analysis of demographic and biometric parameters of the Mangalarga breed

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ABSTRACT: *This study analyzed the demographic and biometric changes in registered animals of the Mangalarga breed over the decades. Information from 206,428 Mangalarga horses born between 1930 and 2018 extracted from the genealogic registry system of the Associação Brasileira de Criadores de Cavalos da Raça Mangalarga was employed. The data referred to sex, birth date, fur coat, breeding site location, score achieved at genealogic registration, and three body measurements. Height at withers and the thoracic and cannon bone circumferences were used to calculate five morphometric indices. Results were submitted to analysis of variance using a completely randomized split-plot design where the plots comprised the sexes and the split-plots comprised the decades of selection. Between 1930 and 1990, genealogic registrations progressively increased, particularly in the 1970s and 80s, when the herd experienced the highest growth rate. In 2018, Mangalarga breeding sites were reported in 23 Brazilian states and the states of São Paulo, Minas Gerais, and Bahia held the largest herds. Between 1970 and 2018, the height at withers of mares, stallions, and geldings increased by 5.1, 3.1, and 2.1 cm, respectively. The thoracic circumference of stallions increased by 3.3 cm and the cannon bone circumference of mares decreased by 0.34 cm. It is concluded that the Mangalarga breed is found across Brazil, especially in the Southeast region. Irrespective of sex, the selection of the breed has led to taller Mangalarga horses. In addition, the stallions became heavier and gained thoracic circumference, while mares became hypometric.*

Key words: horses, morphometric indices, linear measurements.

Análise temporal de parâmetros demográficos e biométricos da raça Mangalarga

RESUMO: *Objetivou-se analisar as alterações demográficas e biométricas dos animais registrados da raça Mangalarga, ao longo das décadas. Foram utilizadas informações de 206.428 equinos Mangalarga, extraídas do sistema de registro genealógico da Associação Brasileira de Criadores de Cavalos da Raça Mangalarga. Dos animais nascidos entre 1930 e 2018, foram consideradas informações referentes ao sexo, data de nascimento, pelagem, localização do criatório, pontuação obtida no ato do registro genealógico e três medidas corporais dos equinos. Utilizando a medida de altura à cernelha e os perímetros torácico e de canela foram calculados cinco índices morfométricos. Os resultados foram submetidos à análise de variância, utilizando delineamento inteiramente ao acaso em esquema de parcelas subdivididas, sendo as parcelas compostas pelos sexos e as subparcelas constituídas pelas décadas de seleção. Entre 1930 e 1990 houve aumento progressivo na emissão de registros genealógicos, com destaque para as décadas de 70 e 80, quando se registrou maior taxa de crescimento do rebanho. Em 2018 identificou-se criatórios da raça Mangalarga em 23 estados brasileiros, sendo o Estado de São Paulo detentor do maior rebanho, seguido de Minas Gerais e Bahia. Entre 1970 e 2018 registrou-se aumento na altura à cernelha das fêmeas, garanhões e machos castrados, que se tornaram 5,1 cm, 3,1 cm e 2,1 cm mais altos, respectivamente. Enquanto o perímetro torácico dos garanhões aumentou 3,3 cm, o perímetro de canela das fêmeas reduziu 0,34 cm. Concluiu-se que a raça Mangalarga está distribuída por todo o Brasil, com destaque para a região sudeste. Independente do sexo, a seleção aplicada à raça tornou os equinos Mangalarga mais altos. Além disso, os garanhões ficaram mais pesados e com maior perímetro torácico e as fêmeas tornaram-se hipométricas.*

Palavras-chave: cavalos, índices morfométricos, medidas lineares.

INTRODUCTION

The quest for horses with a comfortable gait, able to be used in hunting and herding, is part of the cultural history of the southern

portion of the Brazilian state of Minas Gerais. With the arrival of the Portuguese royal family to the country in 1808, the genetic of horses of the Álder Stud Farm was introduced to the herd at Campo Alegre Farm, owned by Baron of Alfenas,

setting off the formation of the Mangalarga breed (SIMÕES, 2014).

Given the sports ability and diagonal, comfortable gait of the horses descending from that herd, the breed soon spread across the state of São Paulo and then neighboring states. The expansion of the herd and appearance of new breeding sites intensified selection. Nonetheless, for over 100 years, breeders employed their own selection criteria as the Mangalarga breed itself had not been well defined at the time (JUNQUEIRA, 2004). Those breeders valued the role required more than proper conformation and beauty, which made the herd functionally superior, but highly heterogeneous morphologically (SIMÕES, 2014).

In 1934, the *Associação Brasileira de Criadores de Cavalos da Raça Mangalarga* (Brazilian Association of Breeders of Mangalarga Breed Horses - ABCCRM) was founded and, with the breed standard defined, herd standardization efforts began (ABCCRM, 2019). Over time, differences in biotype were minimized. However, between the 1960s and 1970s, an increase in importation of foreign horse breeds led many breeders to attempt to change the profile of the Mangalarga breed to fit the standard of the international saddle horse (PRADO, 2008). Horse husbandry, which previously aimed to select animals for labor and leisure, now focused more on morphology and aesthetic beauty, resulting in zootechnical losses.

Over time, groups of breeders dissatisfied with the bearings of the selective process started questioning the direction the breed was taking as they defended the preservation of the functional characteristics of horses (PRADO, 2008; SIMÕES, 2014). Nowadays, the ABCCRM is guiding the selection of the breed to fit the current modern labor and sports horse while maintaining the peculiar traits of the breed, in particular the comfortable gait, with no loss of aesthetic beauty (ABCCRM, 2019).

The present study analyzed the geographic distribution of the Mangalarga herd over decades of selection and compared the measurements and morphometric indices of mares, stallions, and geldings of the breed between 1960 and 2018.

MATERIALS AND METHODS

Information from 206,428 Mangalarga horses born between 1930 and 2018 extracted from the genealogic registry system of the *Associação Brasileira de Criadores de Cavalos da Raça Mangalarga* was employed. Data were extracted from

animals born between 1930 and 2018 regarding sex, date of birth, final coat, Brazilian state of the breeding site, score achieved by the horse at the zootechnical evaluation for the definitive genealogic registration. Of this horse population, measurements of height at withers, thoracic circumference, and cannon bone circumference, from 51,795 equine were used.

Based on birth date, the information on the location of the breeding site and final coat of the animals was sorted by decades and submitted to descriptive statistical analysis. The linear measurements of height at withers, thoracic circumference, and cannon bone circumference were also grouped by decade and used to calculate five morphometric indices described and endorsed by OOM & FERREIRA (1987), RIBEIRO (1989), and TORRES & JARDIM (1992).

- Calculated weight index = (thoracic circumference)³ x 80 (kg);
- Dactyl-thoracic index = cannon bone circumference/thoracic circumference (non-dimensional);
- Conformation index = (thoracic circumference)²/height at withers (non-dimensional);
- Load index 1 = ((thoracic circumference)² x 56)/height at withers (kg);
- Load index 2 = ((thoracic circumference)² x 95)/height at withers (kg).

During the inspection for the definitive registration, ABCCRM technicians analyzed the morphology, gait, and temperament of the animal while awarding scores for each item, always based on a pre-defined chart. Thus, the horse is compared to the current breed standard and, after the sum of the scores of each of the evaluation items, the individual falls into the classifications “Regular” (60 to 69 points), “Good” (70 to 79 points), “Very good” (80 to 89 points), or “Excellent” (90 to 100 points).

In order to compare the data regarding the scores achieved in the zootechnical evaluation, linear measurements, and morphometric indices of mares, stallions, and geldings over decades of selection, a completely randomized split-plot experimental design was employed, with the plots comprising the sexes (mares, stallions, and geldings) and the split-plots comprising the decades (1970s, 1980s, 1990s, 2000s, and 2010s).

Given the small volume of data and/or lack of information, the scores of morphometric measurements of individuals born between the 1930s and 1960s were not taken into account.

Next, the results were submitted to analysis of variation using a completely randomized split-plot design with means compared by Tukey's test at

5% significance level using the statistical software SISVAR (version 5.6).

RESULTS AND DISCUSSION

Distribution and evolution of breeds

Of the 206,428 horses with definitive registration at the ABCCRM between 1930 and 2018, 119,334 were mares, 83,564 were stallions, and 3,530 were geldings. Between the 1930s and 1990s, the number of registrations issued for Mangalarga horses progressively increased, particularly between the 1970s and 1980s, when the highest number of definitive registrations were issued (Figure 1). Over the same period, the breed expanded to different regions of Brazil (Figure 2).

In the 1990s, definitive registrations slowed down and increased by only 7.69% across the country compared to the prior decade. In the first decade of the 21st century, the number of definitive registrations issued by the ABCCRM experienced a sharp drop, of 70.89% on average, in all Brazilian states. Between 2010 and 2018, the number of definitive registrations issued continued to decrease, with a nationwide reduction by 7.83%, except in the states of Minas Gerais and Bahia, which saw increases by 37% and 13.47%, respectively.

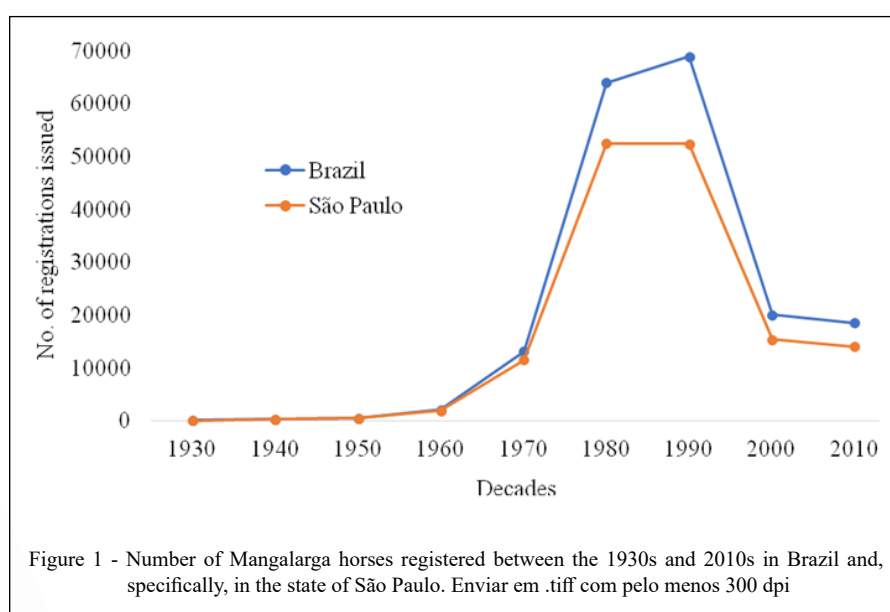
In 2018, Mangalarga breeding sites were identified in only 23 Brazilian states (of 26 total) and in the Federal District. The state of São Paulo held the largest Mangalarga herd, with 14,001 registered horses

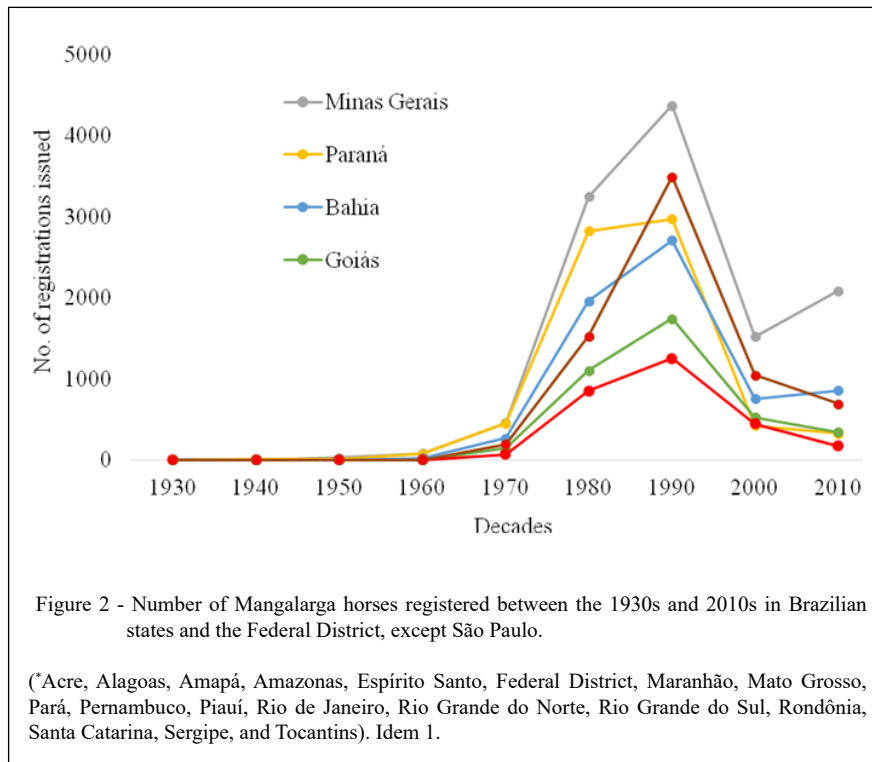
(75.71% of individuals), followed by Minas Gerais with 2,088 registrations (11.29%) and Bahia with 859 definitive registrations (4.64%). Hence, just two states of the southeast region of Brazil (São Paulo and Minas Gerais) accounted for 87% of the registered herd.

The foundation of the ABCCRM and the initial possibility of open-book animal registration contributed to the increase in the number of animals mainly aiming rapid expansion of the breed. In the first decades of the genealogic registry, the increase in the Mangalarga herd showed the acceptability of the breed among breeders, in addition to the market aspects of the time. Such increase contributed to greater genetic variability, which was extremely important for future genetic gains, as well as to the market expansion of the breed.

The increase in the number of states that began registering animals of the breed from the 1960s onwards may be linked to the expansion of Brazilian horse husbandry over the period. In agreement with that fact, COSTA et al. (2004) also observed an increase in the number of births of Mangalarga Marchador horses, a Brazilian breed with common origin as Mangalarga animals and marcha gait characterized by clear triple support, in the 1960s. Thus, the increase in the registered herd, verified in the present study based on official ABCCRM data, contrasts with the statement by PRADO (2008) that the Mangalarga herd decreased in the 1960s.

The reduction in the registered Mangalarga herd in the 2000s in all Brazilian states may be





associated with unpopular decisions by the executive administration of the ABCCRM in the late 1990s, which made some associates fail to register their animals in that institution. At the same time, due to intense selection work by Mangalarga breeders, those animals started being desired by breeders of other breeds. However, the registry books of the Brazilian associations of marching breeds were closed in the 1990s. That led to the illegal insertion of Mangalarga animals in other associations aiming genetically contribution to improve other herds.

Years later, in order to fix the illicit incorporation of Mangalarga horses, such as in the Mangalarga Marchador herd, the Ministry of Agriculture, Livestock, and Food Supply and the *Associação Brasileira dos Criadores de Cavalos Mangalarga Marchador* (Brazilian Association of Mangalarga Marchador Horse Breeders – ABCCMM) signed a deferred prosecution agreement. That allowed legalizing the incorporation of Mangalarga horses and their descendants into ABCCMM. That measure prevented those individuals from returning to the ABCCRM, which explains the retraction in the Mangalarga herd seen since the early 2000s.

The fact the Southeast region holds the largest Mangalarga region may be rooted in the breed

originating in Minas Gerais and later developing in São Paulo. Moreover, the Brazilian Southeast region has the largest horse herd in Brazil (IBGE, 2017).

According to VIEIRA et al. (2015), Minas Gerais features a very strong equestrian culture and is the home of major horse breeding sites in the country. Added to that is the wealth and diversity of activities that make up the equine agribusiness in the state, which houses the largest horse herd in the country (IBGE, 2017). All those facts combined may have contributed to the growth of the Mangalarga population in Minas Gerais even during a nationwide retraction of the registered herd of the breed.

Fur Color

Between 1930 and 1960, horses with buckskin and bay coats prevailed, followed by chestnut and grey animals (Table 1). Ever since, the chestnut coat has prevailed among registered animals at 88.9% in the 2000s.

Between 2010 and 2018, the prevalence of that coat decreased by approximately 16% and was followed by a significant increase in tobiano coat, which became the second most common coat in the registered herd (12.8%). Irrespective of the period assessed, the grullo, roan, red roan, and blue roan had low prevalence.

Table 1 - Coat frequency of horses registered in the Mangalarga breed, in percentage (%), between 1930 and 2018.

Coats	Decades									
	1930	1940	1950	1960	1970	1980	1990	2000	2010	
Chestnut	13.0	26.5	33.5	44.4	53.4	66.6	80.4	88.9	72.7	
Palomino	0.0	1.5	1.4	0.6	1.4	1.3	1.1	1.1	3.3	
Buckskin/Bay	53.7	45.5	38.7	28.2	19.8	14.3	9.0	4.1	3.2	
Tobiano	1.9	0.6	3.2	6.5	6.8	3.2	1.4	1.1	12.8	
Black bay	11.1	8.9	6.1	3.4	4.1	4.0	2.1	1.4	2.2	
Grey	18.5	16.0	13.9	13.1	12.0	8.2	5.0	3.0	5.7	
Others*	1.9	0.9	3.2	3.6	2.5	2.4	0.9	0.3	0.2	

*Grullo, roan, red roan, blue roan.

The prevalence of buckskin and bay coats until the 1960s is possibly related to the high frequency of those coats in the individuals that formed the breed. According to REZENDE & COSTA (2012), in order for those coats to manifest, dominant alleles of the genes Black, Agouti, and Dilution are needed. Thus, after the 1960s, the higher use of recessive stallions and mares for those genes may justify the increase in the frequency of chestnut coats, which is 100% recessive for those genes (REZENDE & COSTA, 2012).

Starting in 2010, the increase in the frequency of the tobiano coat may be associated with several factors. Initially, the dominance condition of the tobiano gene increased the frequency of the coat in the herd (REZENDE & COSTA, 2012). Another factor is the decision by the ABCCRM director's board of, starting in 2004, separately judging and awarding animals with tobiano, palomino, bay, buckskin, grey, and black or black bay coats. In addition, the very market appeal generated from the differentiation of animals of spotted coats may have also contributed to the spread of this coat in the herd. LUCENA et al. (2015) stated that the ease in commercializing horses of certain coats is often key for the selection of breeding animals.

Prior to the decision by the ABCCRM to foster rarer coats in the breed, the *Associação Brasileira dos Criadores do Cavalo Pampa* (Brazilian Association of Tobiano Horse Breeders - ABCPampa) was founded in 1993, which allowed horses with tobiano coats to be registered in duplicity in both entities. Therefore, the possibility of awards and commercialization of horses in both associations also contributed to the increase in tobiano coats in the Mangalarga herd.

Registration Score

Between 1970 and 2010, the score achieved during the zootechnical evaluation for the definitive genealogic Mangalarga registration increased by 9.22% for mares and by 3.57% for stallions. Conversely, the score achieved by geldings over that period did not change (Table 2).

Between 1980 and 2000, Mangalarga stallions scored 85.02 on average, higher than mares (83.56 points), which, in turn, scored higher than geldings (79.51 points). Since 2010, mares and stallions have achieved similar scores, both higher than geldings.

The fact mares and stallions have achieved similar scores, higher than geldings, over the last decade suggested the selection of breeding animals and the selection criterion adopted for the definitive registration through the scoring chart met the expected goal by eliminating from reproduction exactly those with lower scores. That underscores the importance of the genealogic registry for the selection of phenotypically superior individuals in eliminating undesirable characteristics from the herd.

Linear Measurements

Between the 1970s and 1990s, the height at withers of stallions and geldings increased by 3.1 and 2.1 cm, respectively. Over the following decades, this measurement stabilized. In mares, the height at withers continued increasing until the year 2000, resulting in a final gain of 5.1 cm.

In addition, between 1970 and 2000, both stallions and geldings had greater height at withers than mares, with stallions being always taller than geldings. Since 2010, mares and geldings exhibited

Table 2 - Registration score, linear measurements, and indices of Mangalarga mares (MAR), stallions (STA), and geldings (GEL) born between 1970 and 2018, with their respective coefficient of variation (CV).

Variables	Categories	1970	1980	1990	2000	2010	CV %
Score	MAR	78.16 ^d	81.76 ^{Bc}	83.91 ^{Bb}	85.00 ^{Ba}	85.37 ^{Aa}	7,7
	STA	82.71 ^b	83.52 ^{Ab}	85.74 ^{Aa}	85.80 ^{Aa}	85.66 ^{Aa}	
	GEL	79.63	76.64 ^C	79.88 ^C	82.02 ^C	80.80 ^B	
HW (cm)	MAR	150.3 ^{Bd}	151.7 ^{Cc}	154.4 ^{Cb}	155.4 ^{Ca}	155.6 ^{Ba}	2,2
	STA	154.7 ^{Ac}	155.8 ^{Ab}	157.8 ^{Aa}	157.7 ^{Aa}	157.7 ^{Aa}	
	GEL	153.1 ^{Ac}	154.1 ^{Bbc}	155.2 ^{Bba}	156.1 ^{Ba}	156.2 ^{Ba}	
TC (cm)	MAR	-	176.2	180.5 ^A	180.3 ^A	180.5 ^A	4,9
	STA	176.0 ^c	175.6 ^c	177.8 ^{Bb}	179.3 ^{Ba}	180.0 ^{Aa}	
	GEL	175.9 ^{abc}	173.9 ^c	174.5 ^{Cbc}	176.7 ^{Ca}	176.0 ^{Bab}	
CC (cm)	MAR	-	19.11 ^a	18.88 ^{Cab}	18.80 ^{Cb}	18.77 ^{Cb}	3,8
	STA	19.56 ^{Aa}	19.40 ^b	19.61 ^{Aa}	19.53 ^{Aab}	19.55 ^{Aa}	
	GEL	18.95 ^B	19.28	19.31 ^B	19.21 ^B	19.21 ^B	

Different small letters in the rows differ among decades according to Tukey's test ($p < 0.05$).

Different capital letters in the columns differ among sexes according to Tukey's test ($p < 0.05$).

Height at withers (HW); thoracic circumference (TC); cannon bone circumference (CC).

similar values for this measurement at 155.6 cm and 156.2 cm, respectively. Aligned with the present study, LUCENA et al. (2015) reported greater height at withers values among Campolina stallions compared to geldings. According to those authors, the lower height of Campolina geldings may be one of the reasons why they have been excluded from reproduction. Although, Mangalarga stallions have always been taller than mares, that difference has decreased over time.

Such reduction may be related to the high heritability of the height at withers characteristic. MEIRA et al. (2013) reported heritability for height at withers of 0.70 among Mangalarga Marchador horses. Thus, after the Mangalarga registry book was closed in 1943, the definitive registration of only stallions with greater mean height at withers than mares has contributed for taller mares in the following generations.

Whereas mares have shown no variation in thoracic circumference, this measurement linearly increased among stallions between 1980 (176.0 cm) and 2000 (179.3 cm), after which it stabilized.

Among geldings; although, the thoracic circumference has oscillated over time, the mean value reported in 1970 (175.9 cm) was similar to the average of 176.0 cm reported between 2010 and 2018. Furthermore, mares had greater thoracic circumference than stallions and geldings until 2000. In 2010, stallions matched the measurement of mares at 180.0 cm and 180.5 cm, respectively.

The cannon bone circumference of mares decreased between 1980 and 2018, from 19.11 cm to 18.77 cm. Although, this measurement has oscillated among stallions over decades, the value in 1970 (19.56 cm) was similar to that in 2010 (19.55 cm). A similar variation was observed for geldings. Starting in 1990, the mean cannon bone circumference of 19.56 cm of stallions was greater than the 19.24 cm average of geldings, in turn greater than the 18.81 cm average reported for mares.

Morphometric Indices

Only among stallions did the calculated weight index value increase between 1970 and 2018, from 438.8 kg to 468.8 kg (Table 3). This index did not vary among mares and; although, values for geldings have varied over time, the mean calculated weight of 437.1 kg in 1970 was similar to the 437.8 kg in the 2010s. In the 1990s and 2000s, the calculated weight of mares was greater than that of stallions, which were heavier than geldings. Since 2010, mares and stallions have exhibited similar values at 476.8 kg and 468.8 kg; respectively, higher than the average of geldings (437.8 kg).

Over the period assessed, the dactyl-thoracic index decreased from 0.1078 to 0.1035 for mares and from 0.1101 to 0.1083 for stallions. Among geldings, despite oscillations over time, the dactyl-thoracic index in 1970 (0.1072) was similar to that in the 2010s (0.1094). Since 1980, both stallions and

Table 3 - Morphometric indices of Mangalarga mares (MAR), stallions (STA), and geldings (GEL) born between 1970 and 2018, with their respective coefficient of variation (CV).

Variables	Categories	1970	1980	1990	2000	2010	CV %
CWI (kg)	MAR	-	442.4	477.1 ^A	476.1 ^A	476.8 ^A	11.5
	STA	438.8 ^c	435.2 ^c	452.0 ^{Bb}	463.1 ^{Ba}	468.8 ^{Aa}	
	GEL	437.1 ^b	422.8 ^{ab}	427.3 ^{Cab}	444.0 ^{Ca}	437.8 ^{Bab}	
DTI	MAR	-	0.1078 ^{Ba}	0.1045 ^{Bb}	0.1039 ^{Bb}	0.1035 ^{Bb}	5.3
	STA	0.1101 ^a	0.1099 ^{Aba}	0.1100 ^{Aa}	0.1088 ^{Ab}	0.1083 ^{Ab}	
	GEL	0.1072 ^b	0.1103 ^{Aa}	0.1105 ^{Aa}	0.1085 ^{Aab}	0.1094 ^{Aab}	
CI	MAR	-	2.0278 ^A	2.1111 ^A	2.1019 ^A	2.1036 ^A	6.8
	STA	2.0079 ^b	1.9829 ^{Abc}	2.0064 ^{Bb}	2.0411 ^{Ba}	2.0572 ^{Ba}	
	GEL	2.0050 ^{ab}	1.9600 ^{Bb}	1.9700 ^{Cb}	2.0100 ^{Ca}	1.9900 ^{Cab}	
LI1 (kg)	MAR	-	113.54 ^A	118.23	117.71 ^A	117.80 ^A	6.8
	STA	112.45 ^b	111.04 ^{Abc}	112.34 ^b	114.29 ^{Ba}	115.20 ^{Ba}	
	GEL	112.32 ^{ab}	109.54 ^{Bb}	110.15 ^b	112.38 ^{Ca}	111.57 ^{Cab}	
LI2 (kg)	MAR	-	192.62 ^A	200.57 ^A	199.68 ^A	199.84 ^A	6.8
	STA	190.77 ^b	188.38 ^{Abc}	190.59 ^{Bb}	193.89 ^{Ba}	195.42 ^{Ba}	
	GEL	190.55 ^{ab}	185.83 ^{Bb}	186.87 ^{Cb}	190.65 ^{Ca}	189.27 ^{Cab}	

Different small letters in the rows differ among decades according to Tukey's test ($p < 0.05$).

Different capital letters in the columns differ among sexes according to Tukey's test ($p < 0.05$).

Calculated weight index (CWI); dactyl-thoracic index (DTI); conformation index (CI); load index 1 (LI1); load index 2 (LI2).

geldings have exhibited higher dactyl-thoracic index values than mares, at averages of 0.1098, 0.1096, and 0.1049, respectively.

Between 1970 and 2018, the conformation index of stallions increased from 2.0079 to 2.0572. Although, this index has varied over decades for geldings, the conformation index of 2.0050 observed in 1970 was similar to the 1.9900 in 2010, as in mares. Since 1990, the conformation index values of mares have been higher than those of stallions, in turn higher than those of geldings, at mean values of 2.1055, 2.0349, and 1.9900, respectively.

The increase in thoracic circumference of Mangalarga stallions can be attributed to selection based on the breed standard, which establishes well-arched ribs are ideal, leading to broad and deep thorax, besides improved nutritional conditions. According to LAGE et al. (2009), the greater thoracic circumference is directly related to the genetic and fitness of horses. Moreover, the thoracic circumference may also be associated with gestational conditions (LUCENA et al., 2016), which justifies the greater values of Mangalarga mares when compared with stallions and geldings.

The increase in thoracic circumference of Mangalarga stallions justifies the greater calculated weight index observed only among stallions between 1970 and 2018 since the formula to reach that

estimation is based on the external circumference of the thoracic cavity, in cm, measured at the level of the brisket, cubed and multiplied by a constant of value 80 (RIBEIRO, 1989).

A greater cannon bone circumference denotes bone quality, essential for horses to efficiently hold their body weight and work load (CABRAL et al., 2004). According to LOUGHRIDGE et al. (2017) and WULSTER (2018), lower bone density combined with intensive and repetitive exercise increases the risk of bone fatigue and fractures. Thus, the lower cannon bone circumference observed in Mangalarga mares in recent decades may worsen in the following generations since this trait has heritability of 0.68 (MEIRA et al., 2013).

The reduction in cannon bone circumference among Mangalarga mares reported in the present study contributed to them being classified as hypometric, which leaves them more prone to orthopedic lesions due to more fragile bones and/or tendons. Limb fragility may be related to a disproportion between body weight and cannon bone circumference, determined by the dactyl-thoracic index, which takes into account the ratio between the thoracic and cannon bone circumferences and results in the following classifications: hypermetric (> 0.108); eumetric ($0.105 < 0.108$); hypometric (< 0.105) (RIBEIRO, 1989; TORRES & JARDIM, 1992),

Conversely, the selection process of stallions showed, simultaneously, stabilization of cannon bone circumference values and increase in thoracic circumference, which impacted dactyl-thoracic index values to bring breeding animals closer to the recommended breed standard.

According to MCMANUS et al. (2005), saddle horses must have conformation index of 2.1125, while higher values indicated draft horses. In the present study, Mangalarga horses exhibited values below those recommended for saddle horses in all decades assessed. However, that is not worrisome as mares and stallions tended to return to the breed standard in recent decades.

The load indices (LI) 1 and 2 of stallions increased between 1970 and 2018. Although, those indices have oscillated over time for geldings, the average calculated for 1970 was the same as in 2010, similarly among mares. Since 2000, mares have been able to hold more weight on the back (LI1 of 117.80 and LI2 of 199.84) while walking or trotting than stallions (LI1 of 115.20 and LI2 of 195.42) and geldings (LI1 of 111.57 and LI2 of 189.27).

The higher LI1 and LI2 values reported in Mangalarga stallions may be attributed to the selection process that resulted in greater thoracic circumference over the same period. However; although, stallions have exhibited equivalent thoracic circumference values as mares, the fact the latter have shorter height at withers increases their capacity of holding weight on the back whether trotting or walking.

CONCLUSION

The Mangalarga breed is reported across Brazil, especially in the Southeast region. Irrespective of sex, the selection of the breed has led to taller Mangalarga horses. In addition, the stallions became heavier and gained thoracic circumference, while mares have become hypometric.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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