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ANIMAL PRODUCTION

Principal component analysis of linear measures of young horses national champions of Mangalarga Marchador breed

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ABSTRACT: *The conformation is directly related to the quality of the movements, and can direct the selection by equine aptitude. This study aimed to identify which are the morphometric measurements that explain the total variance available in the marcha batida and picada gaits of young Mangalarga Marchador horses. Analyses were performed by evaluating 20 linear measurements of 420 champion horses. Measures were separated by gender (male-M and female-F), type of marcha, (batida-MB e picada-MP) and divided into eight age groups. Principal component analysis (PCA) was used to identify which measurements were most important in determining marcha variance by selecting principal component (PC) which sum of eigenvalues was able to explain the minimum percentage of 80% of the total variation. The PC number varied randomly according to age groups, being 2 to 3 in both genders in MP, 3 to 4 for M-MB, and up to 5 for F-MB, suggesting lower overall variability in MP, and higher in F-MB. There was no defined pattern concerning the amount of PC per age group, demonstrating that each category may have independent variations. Although, some repetitions of variables occurred similarly in different ages, sexes, and marcha types, the responsibility for the highest occurrence of variation was the posterior cannon and gaskin length. The significant variance in the length of these segments, regardless of gender, age, and marcha, and the fact they are not measured daily suggested there is not only a lack of standardization of these segments, but there is also size compensation among them since the group evaluated is composed of breed champions.*
Key words: *marcha, conformation, morphometric measurements, variance.*

Análise de componentes principais das medidas lineares de equinos jovens campeões nacionais da raça Mangalarga Marchador

RESUMO: *A conformação pode estar diretamente relacionada a qualidade dos movimentos direcionando a seleção dos equinos por aptidão. Objetivou-se identificar quais medidas lineares explicam a variância total disponível nas marchas batida e picada em cavalos jovens da raça Mangalarga Marchador. As análises foram realizadas pela avaliação de 20 medidas lineares de 420 equinos campeões de exposições, separados por sexo (macho-M e fêmeas-F), tipo de marcha (batida-MB e picada-MP) e oito grupos etários. Utilizou-se análise de componentes principais (ACP) para identificar quais características eram mais importantes na determinação da variância das marchas, selecionando aquelas contidas em CP, cuja soma de autovalores foi capaz de explicar o percentual mínimo de 80% da variação total. O número de CP variou de acordo com as faixas etárias, sendo de 2 a 3 em M e F-MP, de 3 a 4 para M-MB e até 5 para F-MB, o que sugere menor variação em animais de MP, e maior em F-MB. Não houve padrão na quantidade de CP por classe etária demonstrando variações independentes entre categorias. A maior variância geral foi explicada pelo comprimento de canela posterior e perna. A grande variância no comprimento desses segmentos, independentemente de sexo, idade, tipo de marcha e o fato dos mesmos não serem mensurados cotidianamente, sugere que não ocorre somente a ausência de padronização, mas também há compensação de tamanho entre eles, visto que se avaliou apenas animais campeões da raça.*
Palavras chave: *marcha, conformação, morfometria, variância.*

INTRODUCTION

The Mangalarga Marchador (MM) breed has 600,000 registered animals (MAPA, 2016), and is the fastest growing breed of horses in the country, generating great employment and income for Brazilian equine culture. They present marcha as gait, which give them the characteristic of being smooth horses and differentiate them from trot animals, which take their selection for marcha gait and leisure contests.

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Gaited horses perform a wide range of different stride (NICODEMUS & CLAYTON, 2003), which are supposed to require several skeletal adaptations (STAIGER et al., 2016). Therefore, different types of four-beat stepping gaits can be comparatively studied. The "marcha" is the main characteristic attributed to the MM breed mainly because, in general, it does not have suspension times between the change of the members that touch the ground. According to BARCELOS et al. (2016), this is a comfortable gait for the rider and has two subtypes called "marcha batida", in which the horse spends more time on diagonal supports, and "marcha picada", in which the horse spends more time on lateral supports or triple supports. Individuals with different gaits standarts, marcha batida or picada, do not come from different populations, and may be born with one phenotype or another (FONSECA et al., 2017). This gait characteristic of MM results from neuromotor coordination of movements, training and appropriate morphometric measures (PINTO et al., 2005).

Body size and conformation are critically important characteristics in almost all breeds of horses and, presumably, are under strong selection. Many breed registries select horses based on functional criteria and encourage horse breeding with body types more suitable to specific functions. Correct skeletal conformation is the body type as a determinant key (BROOKS et al., 2010).

Gaited horses have morphological differences when compared to trot horses. Comparisons of individual measurements demonstrate that trot horses have smaller widths between the eyes and jaw, as well as proportionally longer segments in the forelimbs, and thinner circumferences in the lower parts of these limbs (STAIGER et al., 2016). The selection of the MM breed gave the animals a smaller head, shorter body length, a larger diameter of the bone rays and an increase in the size of these animals within the standard values of the breed (PINTO et al., 2005). However, similarities and differences in conformation within the race can be noticed in relation to gender and type of marcha, especially regarding measurements related to limb flexion, frequency, and stride length (SANTIAGO et al., 2014). Similarly, it is assumed that differences may also occur that explain the total variance in different age groups due to the maturity of certain body regions in relation to others during different growth phases of the horse.

The purpose of this study was to identify which linear measures explain the highest cumulative proportion of the total variance available in young Mangalarga Marchador horses of different genders, ages, and types of marcha (batida and picada).

MATERIALS AND METHODS

There were analysed using the morphometric data of 20 linear conformation measurements of 420 animals of the MM breed, holders of titles of champion, reserved champion, 1st, 2nd, 3rd, 4th or 5th prize in marcha picada (MP) and marcha batida (MB) in the conventional breed contest held at the 33rd and 34th National Exhibition of MM, corresponding to the years 2014 and 2015, in the Bolívar de Andrade Park in Belo Horizonte, MG. The analyses were carried out with information from stallion and female animals, from 15 to 60 months of age. All classified animals had already secured the title of champion or reserved champions in several regional classification exhibitions for the national exhibition.

The linear measurements collected were: height at withers (HTW), height at croup (HC), height at back (HB), body length (BL), head length (HL), neck length (NL), shoulder length (SL), back-loin length (BLL), croup length (CL), croup width (CPW), barrel height (girth-back distance) (BH), chest width (CTW), head width (HDW), arm length (AL), forearm length (FL), cannon length of forelimb (CLFL), pastern length of forelimb (PLFL), thigh length (TL), gaskin length (GL) and cannon length of hindlimb (CLHL). All measurements were made using a hipometer and measuring tape graduated in centimetres, as described by BARCELOS (2016). The data descriptive analysis is shown in table 1.

Before the data analysis, Bartlett's sphericity tests were conducted, and the adequacy measure of the Kaiser-Meyer-Olkin (KMO) sample was estimated, which presented a p-value of 0.01, and an index of 0.91, respectively. These values demonstrated that the PCA proposed in the present research is adequate for the database in question.

For data analysis, these were grouped according to gender (M-male and F-female), type of marcha (MB and MP), and age range, as shown in table 2. The G5 subgroup of M-MP was excluded of the analyses because it presented only one individual in this category.

The importance of variables for determining variability was evaluated through PCA. The original data were centralized and resized by subtracting the average and dividing by standard deviation (auto scaling) to avoid bias in the analysis of main components due to the different magnitudes of the variables. Only the PC in which the sum of the variance ratio exceeded 80% was selected. Variables that comprise the other PCs were discarded, as they made an insignificant contribution to the discrimination of groups (MORRISON, 1976, and

Table 1 - Mean, maximum, minimum, standard deviation, and coefficient of variation of the morphometric measurements collected in 420 Mangalarga Marchador horses from 15 up to 60 months of age, national champions in the years 2014 and 2015.

Variables	Average	Maximum	Minimum	SD	VC
HTW	146.88	157.00	130.00	5.43	3.69
HB	137.99	146.00	126.00	4.58	3.32
HC	144.66	153.00	135.00	3.99	2.76
BL	146.58	158.00	130.00	5.93	4.04
HL	57.12	62.00	47.00	2.51	4.40
NL	63.13	70.00	57.00	2.86	4.53
SL	48.96	64.00	41.00	3.50	7.14
BLL	43.25	49.00	36.00	3.04	7.04
CL	50.16	56.00	42.00	2.73	5.44
CPW	49.07	54.00	40.00	2.89	5.89
BH	59.31	65.00	39.00	3.70	6.24
CTW	36.24	64.00	29.00	4.57	12.62
HDW	19.42	23.00	17.00	1.17	6.04
AL	27.87	47.50	23.00	3.72	13.33
FL	43.07	51.00	35.50	3.44	8.00
CLFL	27.66	30.50	17.50	1.76	6.36
PLFL	12.13	13.50	10.00	0.84	6.89
TL	33.85	39.00	28.00	3.36	9.92
GL	44.12	55.00	36.00	6.29	14.25
CLHL	42.99	53.00	31.50	8.14	18.94

SD– standard deviation; VC – variation coefficient; HTW - height at withers ;; HB - height at back ; HC - height at croup; BL - body length ; HL - head length ; NL - neck length ; SL - shoulder length; BLL - back-loin length ; CL - croup length ; CPW - croup width ; BH - barrel height (girth-back distance); CTW - chest width ; HDW -head width ; AL arm length ; FL - forearm length ; CLFL- cannon length of forelimb ; PLFL - pastern length of forelimb ; TL- thigh length ; GL- gaskin length; CLHL - cannon length of hindlimb

employed by BARBOSA, 1993). The variables that were not eliminated in this process were those that were considered the most important to discriminate the variation of the group. The software R (R CORE TEAM, 2019) was used to obtain the components by gender, type of marcha gait and age range.

RESULTS AND DISCUSSION

The number of PC justifying 80% of the phenotypic variation reported in the different types of marcha varied according to the age range, being 2 to 3 in both sexes in the MP animals (Tables 3 and 4),

Table 2 - Number of Mangalarga Marchador horses, national champions in the years 2014 and 2015, submitted to the collection of morphometric measurements in each of the analyzed subgroups.

----------Age range (months)----------										
		G1	G2	G3	G4	G5	G6	G7	G8	Total
Type of Marcha	Gender	----------Number of Animals----------								
MB	M	11	30	22	20	14	14	13	21	145
MB	F	11	36	19	25	9	20	11	22	153
MP	M	3	8	3	7	1	8	14	11	55
MP	F	3	10	5	10	4	12	10	13	67
----------Total----------		28	84	49	62	28	54	48	67	420

G1=15.0-18.9 months; G2=19.0-24.9 months; G3=25.0-30.9 months; G4=31.0-36.9 months; G5=37.0-42.9 months; G6=43.0-48.9 months; G7=49.0-54.9 months; G8=55.0-60.9; MB=Marcha Batida; MP=Marcha Picada; M=Stallion; F=Females

Table 3 - Loadings of principal components (PC) that explained at least 80% of the proportion of the accumulated variance, by age group, in marcha picada gait national champions females of the Mangalarga Marchador breed in the years 2014 and 2015.

MARCHA PICADA FEMALE (F-MP)											
G1(15-18.9m)			G2(19-24.9m)			G3(25-30.9m)			G4(31-36.9m)		
HTW	0.782	PC1	CLHL	0.52	PC1	CLHL	0.26	PC1	CLHL	0.74	PC1
CL	0.308	PC1	GL	0.52	PC1	GL	0.509	PC1	GL	0.501	PC1
BLL	0.284	PC1	BL	0.325	PC1	TL	0.26	PC1	TL	0.232	PC1
CTW	0.562	PC2	HTW	0.473	PC2	BL	0.681	PC2	BH	0.786	PC2
HL	0.411	PC2	CLHL	0.46	PC2	HB	0.331	PC2	BLL	0.332	PC2
BH	0.323	PC2	HB	0.41	PC2	CLHL	0.271	PC2	HTW	0.286	PC2
HB	0.323	PC2							HB	0.599	PC3
									HC	0.426	PC3
									HTW	0.317	PC3
G5(39-42.9m)			G6(43-48.9m)			G7(49-54.9m)			G8(55-60.9m)		
CLHL	0.625	PC1	CLHL	0.589	PC1	CLHL	0.629	PC1	CLHL	0.714	PC1
AL	0.453	PC1	CTW	0.516	PC1	GL	0.47	PC1	GL	0.524	PC1
GL	0.356	PC1	GL	0.448	PC1	FL	0.313	PC1	TL	0.256	PC1
AL	0.765	PC2	CTW	0.592	PC2	AL	0.43	PC2	HB	0.574	PC2
FL	0.388	PC2	SL	0.397	PC2	CLFL	0.408	PC2	HTW	0.509	PC2
CLHL	0.358	PC2	GL	0.339	PC2	HC	0.356	PC2	HC	0.425	PC2
						HTW	0.614	PC3	HL	0.726	PC3
						HB	0.408	PC3	BL	0.361	PC3
						BH	0.312	PC3	CLFL	0.235	PC3

HTW-height at withers; HC-height at croup; HB-height at back; BLL-back-loin length; CLHL-cannon length of hindlimb; TL-thigh length; BH-barrel height (girth-back distance); CL-croup length; FL-forearm length; GL-gaskin length; BL-body length; AL-arm length; SL-shoulder length; CTW-chest width; HL-head length; CLFL-cannon length of forelimb.

Table 4 - Loadings of principal components (PC) that explained at least 80% of the proportion of the accumulated variance, by age group, in marcha picada gait national champions males of the Mangalarga Marchador breed, in the years 2014 and 2015.

MARCHA PICADA MALE (M-MP)											
G1(15-18.9m)			G2(19-24.9m)			G3(25-30.9m)			G4(31-36.9m)		
CLHL	0.664	PC1	CLHL	0.75	PC1	CLHL	0.744	PC1	CLHL	0.706	PC1
GL	0.592	PC1	GL	0.501	PC1	GL	0.488	PC1	GL	0.593	PC1
FL	0.266	PC1	TL	0.3	PC1	TL	0.259	PC1	TL	0.214	PC1
BL	0.62	PC2	TL	0.488	PC2	HB	0.476	PC2	BL	0.617	PC2
HB	0.31	PC2	BL	0.414	PC2	FL	0.42	PC2	SL	0.375	PC2
CLHL	0.284	PC2	GL	0.295	PC2	HC	0.339	PC2	NL	0.346	PC2
G5(39-42.9m)			G6(43-48.9m)			G7(49-54.9m)			G8(55-60.9m)		
HTW	1	PC1	CLHL	0.739	PC1	CLHL	0.695	PC1	CLHL	0.744	PC1
			GL	0.515	PC1	GL	0.469	PC1	GL	0.45	PC1
			TL	0.294	PC1	TL	0.346	PC1	TL	0.332	PC1
			BL	0.883	PC2	AL	0.57	PC2	CPW	0.613	PC2
			HTW	0.278	PC2	BL	0.322	PC2	CL	0.4	PC2
			BLL	0.237	PC2	HTW	0.314	PC2	HTW	0.279	PC2
						FL	0.441	PC3	BL	0.578	PC3
						CLHL	0.43	PC3	AL	0.471	PC3
						CPW	0.405	PC3	CLFL	0.4	PC3

HTW-height at withers; HC-height at croup; HB-height at back; BLL-back-loin length; CLHL-cannon length of hindlimb; TL-thigh length; CL-croup length; FL-forearm length; GL-gaskin length; BL-body length; AL-arm length; NL-neck length; CPW-croup width; SL-shoulder length.

from 3 to 4 for M-MB (Table 5), and from 3 to 5 for F-MB (Table 6). This suggested that it was necessary to use a larger number of variables to discriminate the animals of MB regarding to less variables used to discriminate animals of MP, which denotes a higher level of standardization in the group of champion animals of MP in both genders.

The F-MB group showed the greatest variation with up to five PC. PINTO et al. (2005) observed an even greater number of PC finding seven components to explain a minimum percentage of 80% of the total variation of horses less than 12 months old. Therefore, it is suggested that the younger the animal, the greater the variance of the body parts.

Divergences between studies may have occurred because they evaluate different age ranges and different morphofunctional measures. The number of PC used to assess variance by PINTO et al. (2005) was also much higher, which may be due to the fact that they evaluated linear, angular and perimeter measurements, or because they used another age range in which growth is much more relevant in changing proportions. However, it is mostly because in the present study we worked with national champion animals, which makes the group previously evaluated here selected to present a standardization consistent with the best specimens of the MM breed.

There was no defined pattern in relation to the amount of PC by age range demonstrating that different variables can discriminate among animals of different ages, which can be justified by the fact that in the majority of vertebrates the growth of the body parts occurs in an allometric way.

Measures that contributed with the highest proportion of the total variance of the subgroups and, therefore, were identified more frequently in PC1,

Table 5 - Loadings of principal components (PC) that explained at least 80% of the proportion of the accumulated variance. by age group. in marcha batida gait national champions males of the Mangalarga Marchador breed in the years 2014 and 2015.

----------MARCHA BATIDA MALE (M-MB)----------											
----------G1(15-18.9m)----------			---------G2(19-24.9m)---------			---------G3(25-30.9m)----------			----------G4(31-36.9m)----------		
HTW	0.478	PC1	CLHL	0.676	PC1	CLHL	0.076	PC1	CLHL	0.685	PC1
HC	0.402	PC1	GL	0.563	PC1	GL	0.557	PC1	GL	0.542	PC1
HB	0.343	PC1	TL	0.283	PC1	TL	0.234	PC1	TL	0.283	PC1
BLL	0.666	PC2	BL	0.698	PC2	BL	0.602	PC2	BL	0.599	PC2
CLHL	0.489	PC2	HTW	0.324	PC2	HTW	0.422	PC2	CLHL	0.455	PC2
TL	0.315	PC2	HC	0.274	PC2	HB	0.332	PC2	HB	0.297	PC2
BH	0.739	PC3	HTW	0.479	PC3	FL	0.628	PC3	GL	0.608	PC3
CL	0.372	PC3	BL	0.463	PC3	HC	0.345	PC3	CLHL	0.493	PC3
FL	0.323	PC3	HB	0.394	PC3	AL	0.324	PC3	TL	0.296	PC3
BH	0.47	PC4									
BLL	0.379	PC4									
CL	0.367	PC4									
----------G5(39-42.9m)----------			---------G6(43-48.9m)---------			----------G7(49-54.9m)----------			----------G8(55-60.9m)----------		
CLHL	0.719	PC1	BL	0.487	PC1	BL	0.396	PC1	CLHL	0.727	PC1
GL	0.574	PC1	HC	0.426	PC1	HB	0.388	PC1	GL	0.499	PC1
TL	0.243	PC1	HTW	0.356	PC1	HTW	0.385	PC1	TL	0.334	PC1
BL	0.524	PC2	BL	0.679	PC2	CL	0.707	PC2	BL	0.54	PC2
HC	0.45	PC2	BH	0.338	PC2	BH	0.415	PC2	HTW	0.376	PC2
NL	0.351	PC2	HB	0.319	PC2	HTW	0.266	PC2	CL	0.346	PC2
BH	0.507	PC3	HC	0.319	PC2	BL	0.641	PC3	HC	0.591	PC3
BL	0.442	PC3	FL	0.513	PC3	TL	0.304	PC3	GL	0.523	PC3
GL	0.412	PC3	CPW	0.391	PC3	CL	0.3	PC3	TL	0.33	PC3
			TL	0.381	PC3	HB	0.441	PC4			
						CL	0.337	PC4			
						BL	0.333	PC4			

HTW-height at withers; HC-height at croup; HB-height at back; BLL-back-loin length; CLHL-cannon length of hindlimb; TL-thigh length; BH-barrel height (girth-back distance); CL-croup length; FL-forearm length; GL-gaskin length; BL-body length; AL-arm length; NL-neck length; CPW-croup width.

were CLHL and LL that occurred in the subgroups F-MP (G2, 4, 7, 8) (Table 3), M-MP (G2, 4, 6, 7, 8) (Table 4), M-MB (G2, 3, 4, 5, 8) (Table 5), and F-MB (G1, 2 , 3, 4, 5, 6, 8) (Table 6). This suggested that these segments be measured in the technical evaluation routine, as the absence of such measures may contribute to their variance in the studied population. The subgroups G1, G3 of M-MP and G5 of F-MP presented results similar to those described above; however, the number of animals in these categories is small, which may have interfered with the results.

It is possible that the lengths of longer hindlimbs contribute to the variation of the gaited phenotype, but this result is difficult to separate from sexual dimorphism (STAIGER et al., 2016). The fact is that these measurements have not been taken daily in the MM breed, which, possibly, led to the lack of standardization in these segments. However, the values reported can be related to the movement and stride length of the hindlimbs, since stride range is a constant concern in the selection of exhibition animals, since values of cannon and gaskin length can be complementary.

MEIRA et al. (2013), after analyzing the database of the Brazilian Association of Mangalarga Marchador Horse Breeders (ABCCMM) discarded the height measures at the withers, body length, thorax perimeter, shoulder length, neck length, head length and hip width, as it shows little data variability and had a significant correlation with the other measures. Discrepancy and differences in results that were reported in the present study in relation to the research of MEIRA et al. (2013) is not only due to the fact that the referred authors have worked with animals older than 36 months, but also showed that the data collection method and the evaluator can

Table 6 - Loadings of principal components (PC) that explained at least 80% of the proportion of the accumulated variance, by age group, in marcha batida gait national champions females of the Mangalarga Marchador breed in the years 2014 and 2015.

----------MARCHA BATIDA FEMALES (F-MB)----------											
----------G1(15-18.9m)----------			---------G2(19-24.9m)---------			---------G3(25-30.9m)---------			----------G4(31-36.9m)----------		
CLHL	0.56	PC1	CLHL	0.725	PC1	CLHL	0.621	PC1	CLHL	0.736	PC1
GL	0.47	PC1	GL	0.545	PC1	GL	0.595	PC1	GL	0.573	PC1
NL	0.399	PC1	TL	0.305	PC1	HB	0.301	PC1	TL	0.245	PC1
HC	0.499	PC2	BL	0.446	PC2	HB	0.544	PC2	BL	0.552	PC2
BL	0.415	PC2	HTW	0.434	PC2	HTW	0.402	PC2	HB	0.518	PC2
HTW	0.357	PC2	HC	0.425	PC2	CLHL	0.381	PC2	HTW	0.38	PC2
CPW	0.781	PC3	BL	0.608	PC3	FL	0.703	PC3	BL	0.642	PC3
AL	0.286	PC3	HTW	0.441	PC3	NL	0.373	PC3	HB	0.539	PC3
HC	0.25	PC3	FL	0.408	PC3	BLL	0.317	PC3	AL	0.351	PC3
----------G5(39-42.9m)----------			---------G6(43-48.9m)---------			---------G7(49-54.9m)---------			----------G8(55-60.9m)----------		
CLHL	0.768	PC1	CLHL	0.838	PC1	HTW	0.646	PC1	CLHL	0.712	PC1
GL	0.471	PC1	GL	0.36	PC1	HC	0.295	PC1	GL	0.512	PC1
TL	0.343	PC1	TL	0.228	PC1	HB	0.484	PC1	TL	0.32	PC1
GL	0.571	PC2	BL	0.683	PC2	CL	0.694	PC2	HTW	0.438	PC2
BL	0.46	PC2	HTW	0.374	PC2	BL	0.385	PC2	HC	0.399	PC2
CLHL	0.41	PC2	BH	0.266	PC2	BLL	0.35	PC2	HB	0.373	PC2
BL	0.623	PC3	BH	0.654	PC3	NL	0.537	PC3	BH	0.68	PC3
BLL	0.344	PC3	HL	0.348	PC3	BL	0.487	PC3	SL	0.377	PC3
SL	0.342	PC3	BLL	0.293	PC3	SL	0.373	PC3	HC	0.32	PC3
			BL	0.451	PC4	CTW	0.643	PC4	BL	0.768	PC4
			HTW	0.446	PC4	HB	0.445	PC4	BH	0.524	PC4
			HB	0.347	PC4	CLHL	0.33	PC4	HB	0.204	PC4
			GL	0.594	PC5	SL	0.623	PC5			
			HB	0.349	PC5	CTW	0.438	PC5			
			HC	0.322	PC5	BH	0.296	PC5			

HTW-height at withers; HC-height at croup; HB-height at back; BLL-back-loin length; CLHL-cannon length of hindlimb; TL-thigh length; BH-barrel height (girth-back distance); CL-croup length; FL-forearm length; GL-gaskin length; BL-body length; AL-arm length; NL-neck length; CPW-croup width; SL-shoulder length.

significantly influence the results, especially when analyzing the database of an association.

It should be noted that MEIRA et al. (2013), even affirming that the analysis of main components allows identifying characteristics to be eliminated, cites that the choice of characteristics that should be eliminated is a technical decision. Thus, PC analyses should be used with caution in these cases, especially in populations with greater heterogeneity, in other words, different from the ones in this study, national champion animals, which were previously selected in regional exhibitions as the best specimens in their regions.

The variables PLFL and HDW do not explain much of the variance reported in all subgroups. Regarding the length of the pastern, this is possibly due to the fact that ossification of the middle and proximal phalanx occurs up to 30 or 38 weeks; respectively, of the foal's life (SMALLWOOD et al., 1989); therefore, not considering this age range of the studied animals. Likewise, the head width, despite being an endochondral ossification, does not appear to undergo significant changes in animals older than 15 months of age. Therefore, both linear measures can be discarded in later studies in the age group evaluated.

Regarding gender and type of marcha, in F-MP, NL, and CPW have low discriminatory power, as well as HL, BH, and CTW in M-MP; likewise, NL, CTW, CLFL, and AL for M-MB, and also HL and CLFL for F-MB. These variables are possible to be eliminated only in relation to the gender and type of marcha of the groups of champion animals studied.

Although, there are specific conformation patterns for gait in relation to breeds, some marcha breeds still have varying conformation patterns (STAIGER et al., 2016). SANTIAGO et al. (2014) when evaluating linear and angular measurements of adult MM also reported a difference between gender and type of marcha related to limb flexion, length and frequency of strides. These findings corroborate that the differences in conformation may have occurred due to the different type of gait.

The choice of PC that can be reduced, especially for measurements that require monitoring of defects such as animals that have croup height greater than withers (downhill) or heights previously defined in definitive genealogical record standards, should be interpreted very carefully and based on technical references of animal growth, since the purely mathematical exclusion of certain variables can jeopardize the future registration of many animals, compromising their selection.

CONCLUSION

The great variance in the length of the evaluated segments occurred regardless of gender, age and type of marcha. Pastern length and head width have a low discriminatory value in all age ranges above 15 months of age, and can thus be discarded. It is suggested to routinely evaluate cannon length of the hindlimb and gaskin, because even in groups of well-standardized champion animals there were segments of higher variability.

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BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

This project was previously approved by the Animal Use Ethics Committee (CEUA) of Federal University of Minas Gerais (UFMG), under protocol No. 215/2014.

DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflicts of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the article.

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