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Biometric parameters of adult and growing Pêga donkeys

Camilla Garcia Moreira[1], Madalena Lima Menezes[1], Tamires Romão Nunes[1], Thais Pagotti Mota[1], Júlio Cesar de Carvalho Balieiro[2], Chiara Albano de Araujo Oliveira[3], Roberta Ariboni Brandi[1]*

[1] Universidade de São Paulo, Faculdade de Zootecnia e Engenharia de Alimentos, Departamento de Zootecnia, Pirassununga, SP, Brasil.
[2] Universidade de São Paulo, Faculdade de Medicina Veterinária e Zootecnia, Departamento de Nutrição e Produção Animal, Pirassununga, SP, Brasil.
[3] Universidade Federal da Bahia, Escola de Medicina Veterinária e Zootecnia, Salvador, BA, Brasil.

***Corresponding author:**
robertabrandi@usp.br

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ABSTRACT - This study aimed at establishing the morphological characteristics and morphometric indexes of Pêga donkeys, utilizing 47 animals, of which 22 were adults and 25 were growing donkeys. Prior to taking their measurements, the animals were restrained and made to stand squarely. The morphological data were measured, and the following morphometric indexes were determined: body index (BI), meloscopic index (MI), dactylothoracic index (DTI), weight in cannon index (WCI), conformation index (CFI), and real live weight (RLW). The experimental design was subdivided into plots and repeated in time, in which the animals represented the plot and the data collection times were the subplots. No sex effect was noted for the morphological measurements and morphometric indexes of growing donkeys. The effect of growth period was observed for all the variables. At birth, donkeys weighed around 14.86% of the weight of dams, and at six months they reached up to 40.37%. For the height taken at the withers, the animals at birth were 67.77% of the height of dams, and at six months they achieved up to 84.45%. Based on the morphometric indexes, it is suggested that adult and growing Pêga donkeys can be classified as being suited for both saddle and draft activities and possess a higher load capacity when compared with horses. A few indexes including BI, MI, and RLW need to be adjusted to be suitably used in rating the donkeys.

Keywords: equidae, growth, morphometry, morphology

Introduction

The Pêga donkeys are raised in Brazil to produce mules and animals for breeding, both having substantial economic worth in the country and with the well-recognized genetic potential for ambling gait (Oliveira, 2004).

To accurately evaluate the equid production, the development of animals must be observed (Santos et al., 2007), accompanied by morphometric evaluations (Hoffmann et al., 2013). Pimentel et al. (2011) stated that the morphometric evaluation of the animals is based on relationships between the development of various regions of the body, and that the animal is accepted as well-proportioned if the body parts are adapted to their designed functions. In the present evaluation, some of the indexes are investigated such as body index (BI), meloscopic index (MI), dactylothoracic index (DTI), weight in

cannon index (WCI), conformation index (CFI), and real live weight (RLW) (Cabral et al., 2004; Brum, 2010; Pimentel et al., 2014).

There is a paucity of studies in the literature related to this field of knowledge, and more specifically for the Pêga donkeys. Brum (2010) investigated adult Pêga donkeys and suggested that these animals fall under the category of eumerics, having saddle characteristics.

Pimentel et al. (2014), in their study on adult Nordestino breed of donkeys, classified these animals as longilineal, which included animals of the racing type that possess a higher load capacity than horses. These authors also state that the indexes used were developed for horses, and this could be the reason for the differences between the results when applying them to donkeys.

This study was carried out to explore the morphological measurements and morphometric indexes of both adult and growing Pêga donkeys to define the morphometric parameters and aptitudes of this breed.

Material and Methods

This study received approval from the local Ethics Committee on Animal Use, case number: 2743200315. The experiment was conducted in Jaú, São Paulo, Brazil (latitude 22°17'44" S and longitude 48°33'28" W) from January of 2015 to March 2016, using 22 female donkeys (jennies) in the age range of 12.73±4.78 years and weighing 289.63±35.72 kg, and their offspring, which were evaluated at six months of age (25 animals). Three of the adult female donkeys in the study had two pregnancies during the evaluation period, bringing the total to 47 animals.

The jennies were maintained in 1 ha per head of pasture land having Coast Cross grass (*Cynodon dactylon* (L) Pers) during the pregnancy period; ten days prior to giving birth, they were placed in masonry stalls and fed every day with 2 kg of natural matter of wet whole oats (*Avena* sp.) and 3 kg of natural matter of alfalfa hay (*Medicago sativa*) (Table 1).

The pasture samples of oats and alfalfa hay were stored in plastic bags, identified, and dried in a forced-circulation oven at 65 °C for 72 h. Dry matter, crude protein, mineral matter, neutral detergent fiber, acid detergent fiber, cellulose, hemicellulose, and lignin were determined by adopting the methodology of Silva and Queiroz (2002). Gross energy was determined using a calorimetric pump.

Thirty days post foaling, the animals with their offspring were relocated back to the pasture.

The jennies were weighed on a 1000-kg capacity digital electronic scale (Leader B-650®) every month until they reached six months of age; their body condition score (BCS) was measured using the methodology described by Pearson and Oussat (1996). The growing donkeys were weighed every month from birth to six months, employing the identical scale used for the adult animals.

For reliability, the morphological measurements were always recorded by the same person and always from the left side of the animal (Melo et al., 2011). To accomplish this, animals were restrained and

Table 1 - Nutritional composition of the ingredients used in the feed of Pêga jennies during the first month of lactation

Component (g kg^{-1})	Coast Cross grass	Whole oat	Alfalfa hay
Dry matter	339.7	877.3	822.1
Mineral matter	75.1	36.2	85.7
Crude protein	69.4	158.6	221.4
Neutral detergent fiber	793.2	375.9	476.3
Acid detergent fiber	351.5	172.1	330.8
Cellulose	301.8	137.6	249.3
Hemicellulose	441.7	203.8	145.5
Lignin	49.7	34.5	81.5
Gross energy (kcal kg^{-1})	3800	3900	4700

made to stand squarely on a masonry surface without a slope (Cabral et al., 2004). The adult animals were restrained using halters, while the growing ones were restrained by the person positioning his or her hands on the chest and croup and/or using the halter. The morphological parameters thus recorded are listed in Table 2 (Brum, 2010; Pimentel et al., 2011; Godoi et al., 2012; Pimentel et al., 2014).

After evaluating the morphological measurements, the morphometric indexes were calculated as cited below and described earlier (Cabral et al., 2004; Brum, 2010; Pimentel et al., 2014; Melo et al., 2011; Godoi et al., 2012).

Body index (BI): This relates to the body length with the thoracic perimeter and enables the classification of the animals as longilineal (BI ≥ 90), mediolineal (86 ≤ BC ≤ 88) and brevilineal (BI ≤ 85).

$$BI = \frac{body\ length}{thoracic\ perimeter} \times 100$$

Meloscopic index (MI): This refers to the height of the forelimb with the three circumferences thereof (forearm, knee, and cannon), categorized as longilineal (MI > 1), mediolineal (MI = 1), and brevilineal (MI < 1), respectively.

$$MI = \frac{elbow - ground\ distance}{forearm + knee + cannon\ perimeter}$$

Dactylothoracic index (DTI): This is indicative of the relationship between the mass of the animal and the members that support it and facilitates the classification of the animals as hypermetric (heavy - DTI > 11.5), eumetric (medium - 10.5 ≤ DTI ≤ 10.8), or hypometric (light - DTI < 10.5).

$$DTI = \frac{cannon\ perimeter}{thoracic\ perimeter} \times 100$$

Table 2 - Description of morphological measurements of jennies and growing Pêga donkeys

Morphological measurement	Description
Scale weight	Using electronic scale with 1000 kg capacity
Tape weight	Using commercial tape for horses, placed just behind the withers, behind shoulders, and passing by the girth
Withers and croup height	Through hipometer applied to the highest point of these regions
Elbow-ground distance	Measured with tape placed between the apex of the olecranon and the ground
Body length	Measured with tape placed between the cranial portions of the greater tubercle of the humerus and caudal of the ischial tuberosity
Thoracic perimeter	Measured with tape placed just behind the withers, behind shoulders, and passing by the girth
Forearm, cannon, and knee perimeter	Measured with the tape placed around in the center of these regions
Head length	Distance of the proximal end of the head and the medial or central portion of the lower incisor arcade
Neck length	Measured between the cranial portion of the dorsal arch of the atlas and the middle third of the cranial border of the scapula
Shoulder length	Distance of the dorsal edge of scapular cartilage and distal angle of the scapula or the central portion of the scapular-humeral joint
Back-loin length	Distance of the ends of the spinous process of T8 and T9 and cranial portion of sacral tuberosity
Croup lenght	Distance of the cranial portion of the iliac tuberosity and caudal portion of the ischial tuberosity
Head width	Measured between the free portion of the right supra-orbital edge and the left edge
Chest width	Distance of the side edges of the left and right scapular-humeral joints
Hip width	Distance of the side portions of the iliac tuberosity
Forearm length	Distance of the central area of the humeral-radial joint to the lateral middle third of the carpal joint
Cannon length	Distance of the lateral middle third of the carpal joint to the middle third of the lateral face of the metacarpophalangeal joint

Weight in cannon index (WCI): This indicates the capacity of the members to shift the body weight.

$$WCI = \frac{cannon\ perimeter}{body\ weight} \times 100$$

Real live weight (RLW): This is an estimation of the live weight of the animal, calculated by using the thoracic perimeter (TP) cubed multiplied by 80.

$$RLW = TP^3 \times 80$$

Conformation index (CFI): This index enables the evaluation of the aptitude of the animal, identifying it as saddle (CFI = 2.11), racing (CFI < 2.11), or draft type (CFI > 2.11).

$$CFI = \frac{thoracic\ perimeter^2}{withers\ height}$$

A mixed model for repeated measurements was adopted for the analyses, according to the work of Littell et al. (1998). The statistical model was as follows:

$$y_{ijk} = \mu + \alpha_i + a_{ij} + t_k + (\alpha t)_{ik} + \varepsilon_{ijk},$$

in which y_{ijk} is the response to the evaluation k of the individual j in the sex i; μ is the overall mean; α_i is the fixed effect of sex i; a_{ij} is the random effect of animal j on sex i; t_k is the fixed effect of time k; $(\alpha t)_{ik}$ is the effect of a double interaction of sex with time; and ε_{ijk} is the random error. The fixed effect α_i was considered a factor of variation between the animals, and the repeated measurements within the animal were accepted as the evaluation conditions reflecting the correlation structure within animals. As the main effects for sex (α_i) and sex × time $(\alpha t)_{ik}$ were not significant (P>0.05), they were deleted from the model, retaining the remaining effects, both fixed and random. In this model, the a_{ij} effect was considered independent and showing a variance of σ2a. Different covariance structures were evaluated and selected using model cooperation, based on the AIC proposed by Akaike (1974). All analyses were performed using the PROC MIXED procedure of the SAS program (Statistical Analysis System, version 9.4).

Results

In the first month of lactation, the jennies weighed 289.63±35.72 kg, values close to those cited by the Associação Brasileira dos Criadores de Jumento Pêga (ABCJPÊGA) as the ideal for females. The BCS was 4.68, ranking the animals with a less than moderate score.

The morphometric measurements of jennies during lactation and/or gestation were taken to determine the reference values to monitor their offspring, because these data are not available in the literature (Table 3). The values recorded were similar to that observed for the male Pêga donkeys (Brum, 2010).

The growth of young donkeys was monitored through a comparative study with the measurements of the dam. No studies were found in the literature comparing the evaluations for growing donkeys in terms of the dams; however, it is accepted that the morphological measurements of the jennies may have affected the results observed.

The birth weight of young donkeys, taken on an electronic scale, was 43.05±8.39 kg, representing roughly 14.86% of the weight of the dams and, at six months, they reached 116.91±4.47 kg, equivalent to around 40.37% of the weight of dams (Table 4).

The effect of growth period (P<0.001) was noted for all variables under investigation (Table 5). The sex of the animal exerted no effect (P>0.001) for any of the variables.

From the morphometric indexes of jennies, the BI was 95.7±4.61 (Table 6), enabling them to be categorized as longilineal, this classification being suitable for animals adapted to the racing activity, which is different from the goals of producing the Pêga donkeys.

The DTI was 10.9±0.44 (Table 6), falling between the eumetric (10.5 ≤ DTI ≤ 10.8) and hypermetric (DTI > 11.5) ratings, suggesting that the donkeys in this study are adapted for saddle activity, as well as for draft work.

The CFI was 1.66±0.13 (Table 6), facilitating the categorization of adult donkeys as longilineal and adapted to saddle activities, as indicated by the DTI.

The WCI of adult female donkeys was 5.7±0.65 (Table 6), implying that the Pêga donkeys have traction capacity superior to that of some horse breeds.

For the MI of adult donkeys, an average value of 1.1±0.08 (Table 6) indicated that the Pêga donkeys could be adapted to racing activities, showing a result similar to that presented by the BI determination.

The RLW of adult female donkeys was 257.9±28.06 kg (Table 6), which was lower than the actual weight obtained on the electronic scale (289.62 kg).

For growing animals, the time of evaluation (P<0.001) affected the values of the morphometric indexes (Table 7).

Table 3 - Morphological measurements (cm), mean±SD, of Pêga jennies

Morphological measurement	N	Mean	Minimum	Maximum	CV (%)
Withers height	22	131.1±5.5	121.0	149.0	4.2
Croup height	22	136.1±7.6	129.0	167.0	5.6
Thoracic perimeter	22	147.5±5.3	137.0	160.0	3.6
Forearm perimeter	22	29.2±2.3	24.0	32.0	7.5
Knee perimeter	22	26.8±1.1	25.0	29.0	4.1
Cannon perimeter	22	16.1±0.8	15.0	18.0	4.7
Croup lenght	22	43.1±2.4	39.0	48.0	5.5
Forearm length	22	35.5±3.8	31.0	46.0	10.7
Cannon lenght	22	17.2±2.1	15.0	22.0	12.1
Body length	22	141.0±5.4	131.0	151.0	3.8
Back-loin length	22	62.6±6.7	54.0	79.0	10.7
Neck length	22	52.5±2.8	48.0	58.0	5.3
Head length	22	55.7±3.0	48.0	61.0	5.4
Shoulder length	22	42.7±2.6	37.0	50.0	5.9
Head width	22	26.5±2.4	23.0	31.0	9.2
Hip width	22	46.1±3.7	42.0	56.0	7.9
Chest width	22	31.6±3.1	26.0	40.0	9.7
Elbow-ground distance	22	76.5±4.2	70.0	84.0	5.5

N - number of animals; CV- coefficient of variation.

Table 4 - Weight (electronic scale), mean±SD, of growing Pêga donkeys and proportion to the weight of dams (289.63±35.72 kg)

Age (months)	Weight (kg)	% related to the weight of the dam
0 (close to birth)	43.05±8.39	14.86
1	56.07±4.82	19.35
2	72.41±4.25	25.00
3	87.71±4.21	30.28
4	102.76±4.43	35.48
5	112.10±4.35	38.71
6	116.91±4.47	40.37

Table 5 - Morphological measurements (cm), mean ±SD, of growing Pêga donkeys

Morphological measurement	Age (months)							P
	0	1	2	3	4	5	6	
Withers height	88.8±1.4	92.2±0.8	97.9±0.8	101.5±0.8	105.8±0.9	109.4±0.9	110.7±0.9	<0.0001
Croup height	91.4±1.5	95.5±0.9	101.7±0.9	105.6±0.9	109.8±0.9	113.7±0.9	114.7±0.9	<0.0001
Thoracic perimeter	75.5±2.1	81.8±1.2	90.4±1.2	98.1±1.2	102.6±1.3	106.3±1.3	108.4±1.4	<0.0001
Forearm perimeter	17.7±0.6	19.2±0.3	20.8±0.3	21.6±0.3	22.3±0.4	22.7±0.4	23.3±0.4	<0.0001
Knee perimeter	20.7±0.4	21.3±0.3	22.9±0.3	23.4±0.3	24.1±0.3	24.5±0.3	24.7±0.3	<0.0001
Cannon perimeter	10.8±0.3	11.6±0.2	12.6±0.2	13.4±0.2	13.8±0.2	14.1±0.2	14.1±0.2	<0.0001
Croup lenght	23.3±0.8	26.4±0.5	29.6±0.4	31.8±0.5	33.2±0.5	33.9±0.5	35.1±0.5	<0.0001
Forearm length	26.0±0.9	26.6±0.5	27.9±0.5	28.9±0.5	29.7±0.6	30.8±0.6	31.1±0.6	<0.0001
Cannon lenght	10.8±0.5	15.3±0.3	15.8±0.3	16.2±0.3	16.8±0.3	16.8±0.3	17.4±0.3	<0.0001
Body length	67.8±2.1	77.3±1.2	86.8±1.1	94.5±1.2	99.2±1.3	103.4±1.3	104.4±1.3	<0.0001
Back-loin length	27.4±1.4	32.7±0.7	37.5±0.7	40.7±0.7	43.2±0.8	45.6±0.8	48.3±0.8	<0.0001
Neck length	28.1±1.3	31.2±0.7	35.9±0.6	38.3±0.7	39.8±0.7	41.8±0.7	42.9±0.8	<0.0001
Head length	32.9±1.1	35.1±0.6	38.6±0.6	41.1±0.6	43.5±0.7	45.5±0.7	46.3±0.7	<0.0001
Shoulder length	24.4±0.7	26.1±0.4	29.0±0.4	30.1±0.4	31.7±0.4	32.6±0.4	33.1±0.4	<0.0001
Head width	17.8±0.6	18.7±0.3	20.4±0.3	20.9±0.3	21.0±0.3	21.4±0.3	21.9±0.3	<0.0001
Hip width	22.0±1.1	24.7±0.6	27.5±0.6	29.3±0.6	30.3±0.6	32.6±0.6	32.7±0.7	<0.0001
Chest width	18.6±0.8	20.7±0.5	22.7±0.4	24.3±0.5	24.9±0.5	25.5±0.5	25.9±0.5	<0.0001
Elbow-ground distance	60.1±1.0	62.1±0.6	65.2±0.6	67.7±0.6	69.4±0.6	71.1±0.6	72.2±0.7	<0.0001

Table 6 - Morphometric indexes, mean±SD, of adult Pêga donkeys

Morphometric index	N	Mean	Minimum	Maximum	CV (%)
Body index	22	95.7±4.61	86.75	102.19	4.82
Meloscopic index	22	1.1±0.08	0.95	1.26	7.50
Dactyl-thoracic index	22	10.9±0.44	10.00	11.74	4.05
Weight in cannon index	22	5.7±0.65	4.63	6.84	11.40
Conformation index	22	1.66±0.13	1.26	1.94	0.79
Real live weight	22	257.9±28.06	206.00	328.00	10.88

N - number of animals; CV- coefficient of variation.

Table 7 - Morphometric indexes, mean±SD, of growing Pêga donkeys (from birth to six months of age)

Age (months)	Morphometric indexes					
	BI	MI	DTI	WCI	CFI	RLW (kg)
0 (close to birth)	90.84±1.8	1.22±0.023	14.30±0.3	28.9±1.41	0.64±0.036	32.03±4.4
1	95.15±1.0	1.19±0.013	14.22±0.1	25.3±0.79	0.73±0.019	43.76±2.8
2	96.19±0.9	1.16±0.012	13.88±0.1	19.7±0.67	0.84±0.019	60.42±2.7
3	96.36±1.1	1.16±0.013	13.62±0.2	17.1±0.66	0.95±0.019	75.34±2.8
4	96.87±1.1	1.15±0.014	13.52±0.2	15.2±0.71	0.99±0.021	87.54±2.9
5	97.23±1.1	1.16±0.014	13.32±0.2	14.1±0.69	1.04±0.021	97.60±2.9
6	96.82±1.1	1.17±0.015	13.12±0.2	13.0±0.71	1.06±0.022	105.47±2.9
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mean	95.97±4.34	1.2±0.061	13.68±0.8	17.4±5.04	0.92±0.157	74.18±25.24

BI - body index; MI - meloscopic index; DTI - dactyl-thoracic index; WCI - weight in cannon index; CFI - conformation index; RLW - real live weight.

The BI of the growing donkeys (Table 7) was above 90, enabling the animals to be classified as longilineal from birth to six months of age, categorizing these animals as the racing type, similar to the observation made for adult Pêga donkeys (Table 6).

From the values of the DTI, the growing animals were classified as hypermetric (DTI > 11.5) from birth to six months (Table 7), and the WCI ranged from 28.9±1.41 to 13.0±0.71.

The CFI of growing Pêga donkeys ranged from 0.64±0.036 to 1.06±0.022 from birth to six months (Table 7), classifying them as having a saddle aptitude, similar to the observation made for adult female donkeys (Table 6).

The MI of growing donkeys showed an average of 1.2±0.061 (Table 7), similar to that reported for adult donkeys (Table 6). This classification indicated that growing and adult Pêga donkeys could be adapted for racing activities.

The RLW revealed a variation from 32.03±4.4 to 105.47±2.9 kg from birth to weaning (Table 7), with lower values noted from the scale (Table 4).

Discussion

The scores recorded from the body condition of Pêga jennies in the first month of lactation concurred with those reported by Pearson and Ouassat (1996) and Yoseph et al. (2005). Although the BCS presented was less than moderate, the average weight observed for the jennies was close to values cited by the ABCJPÊGA (2016) as being ideal for females.

The BCS affects the reproductive efficiency in mares (Gastal et al., 2004) and, according to the NRC (2007), mares with BCS values of 5 (moderate), on a scale of 1 to 9, can possess maximum reproductive efficiency. No data were found in the literature on BCS of female donkeys, either during pregnancy or lactation; however, the findings from this study bear close similarity to those cited by the NRC (2007) as being ideal for the higher reproductive efficiency in mares.

The morphological measurements of female Pêga donkeys investigated in this study (Table 3) were higher than those reported for the Nordestino breed (Pimentel et al., 2014; Mariz et al., 2014) and bore similarity to those observed for the male Pêga donkeys (Brum, 2010) and were close to those described for the Catalan, one of the forming breeds of the Pêga (Folch and Jordana, 1997).

For adult donkeys, withers height (WH) was 131.1±5.5 cm (Table 3), falling well within the range established by the ABCJPÊGA (2016), which require a minimum WH of 120 cm for females. The findings of this study corroborate those of Brum (2010), who reported a mean value of 131 cm for male Pêga donkeys, but differ from those reported by Mariz et al. (2014) and Pimentel et al. (2014), who investigated the Nordestino breed of donkeys and reported WH values of 117 cm and 106 cm, respectively, indicating that Pêga donkeys are taller. These data also corroborate the findings of Oliveira (2004), who reported that the Pêga animals are larger when compared with other national breeds.

The average croup height (CH) in this study was 136.1±7.6 cm (Table 3), higher than the 133 cm reported by Brum (2010), in his evaluation of the Pêga breed, and close to the value of 135.79 cm reported by Folch and Jordana (1997) in their study of the Catalan breed.

The 5 cm variation observed between the heights of both withers and croup (Table 3) was because the CH was higher than the WH. This variation is the maximum accepted value for the registration of animals by the ABCJPÊGA (2016). According to Nascimento (1999), it is ideal when the CH is equal to or greater than that of WH, because when the CH is less than the WH, the center of gravity of the animal moves cranially, thus affecting the quality of the movement (Brum, 2010; Nascimento, 1999).

The WH is also related to body length (BL). Based on the work of Oom and Ferreira (1987), well-proportioned animals should be as tall as they are long, implying that the ratio of WH to BL should be equal to 1. In the jennies studied, this ratio was 0.93 indicating that the donkeys are longer than they are tall, which is considered a desirable trait for draft animals (Torres and Jardim, 1981), one of

the main uses of the donkeys and their crosses. Folch and Jordana (1997) stated that donkeys, besides being capable of saddle activity, have higher draft capacity when compared with horses.

On assessing the thoracic perimeter (TP) of adult female donkeys, the observed value of 147.5±5.3 cm (Table 3) exceeded the recommended limit of 144 cm for adult females and 148 cm for adult males by the ABCJPÊGA (2016). This higher value can be explained by the fact that most of the animals in this study were in the stages of lactation and pregnancy, concurring with the statement cited by Kosťuková et al. (2015), meaning that TP is a morphological measurement that shows great variation and can be affected by physiological and health conditions. The TP value obtained in this study fell below the one observed by Brum (2010) for the Pêga male donkeys and above the value cited by Pimentel et al. (2014) for the Nordestino donkeys. Pêga animals are better adapted to handle physical efforts when compared with the Nordestino animals, because, according to Nascimento (1999) and Pimentel et al. (2011), animals possessing superior chest amplitude (larger thoracic volume) can withstand a greater degree of physical effort.

For cannon perimeter (CP) of adult female donkeys, the mean value obtained was 17.2±2.1 cm (Table 3), similar to results reported by Brum (2010), but higher than that reported by Pimentel et al. (2014). In their work on draft equids, Mariz et al. (2014) reported CP for horses, mules, and donkeys (Nordestino breed) as 17.5, 15.8, and 13.5 cm, respectively, and stated that the horses had a higher traction capacity than did the mules and donkeys evaluated. The CP value for donkeys employed in this study (17.2 cm) was similar to that observed by Mariz et al. (2014) for draft horses, which may suggest that the Pêga donkeys investigated have a weight carrying capacity similar to that of horses adapted to traction, but higher than that of mules and Nordestino donkeys.

To follow the growth of young donkeys, a comparative study was performed utilizing the measurements of the dam, as reported earlier for horses by Julliand and Martin-Rosset (2005). The growth rate of the animals in this study bears close similarity to growth rate of horses, as they achieved 25% of the adult body weight at two months of age and 40% of the adult body weight at six months (Table 4), as stated by Julliand and Martin-Rosset (2005).

No effect was exerted by sex ($P>0.001$) on morphological measurements of growing donkeys until they reached six months of age, corroborating the results of Folch and Jordana (1997) in their study on the Spanish breed of Catalan donkeys and those of Pimentel et al. (2014) in their work on the Nordestino breed.

The WH in the growing donkeys ranged from 88.8±1.4 to 110.7±0.9 cm from birth to six months (Table 5), which at birth, represents approximately 67.77% of the height of the dam, and around 84.45% at weaning (six months), almost the same as the report cited by Julliand and Martin-Rosset (2005), who stated that equine foals are born having approximately 60% of the adult height and achieving around 80% at six months. According to Rezende et al. (2000), the horses considered best adapted to saddle activity will reach about 90% of the adult height at six months, data which is almost the same as the findings observed in this study.

In growing animals, WH is also related to CH, and the same is true for adult animals. The donkeys were born possessing around 67.14% of the CH of dams (91.40±1.5 cm) (Table 5) and, at six months, they reached nearly 83.52% of this height (113.7±0.99 cm). As for the adult donkeys, in growing animals, variations below 5 cm were observed during the six months of evaluation (Table 5); this assessment during the development of the donkeys is significant for the prior selection of animals to register them in the breeders' association.

In the assessment of the TP, values of 75.5±2.1 at birth and 108.4±1.4 cm at six months were recorded (Table 5). The TP plus the BL of growing animals were the morphological measurements that showed higher variations during the assessment months (Table 5), thus demonstrating higher growth dynamics than any other body measurement (Mota et al., 2010), which may suggest a similar growth behavior in these two variables. The BL ranged from 67.8±2.1 cm at birth to 104.4±1.3 cm at six months (Table 5).

A proportional relationship is evident between BL and WH, in which the BL of donkeys at birth is 76.35% of the WH, whereas for the adult female donkeys, it is 107.55% of the WH. This corroborates the results recorded by Willoughby (1975), who observed that BL of the American Quarter horse breed is 76 to 76.2% of the WH at birth, while for the adults, it is 106.7 to 107.6%, which may indicate that both the Pêga donkeys investigated in this study and some equine breeds are born higher than longer; when they reach adulthood, this ratio becomes equal or gets reversed, and the animals become slightly longer than high (Cabral et al., 2004; Brum, 2010; Oom and Ferreira, 1987), as observed with the adult female donkeys assessed in this study.

On estimating the CP of growing donkeys, a variation of 10.8±0.3 to 14.1±0.2 cm was noted from birth to six months (Table 5), and these values represent, at birth, about 67.06% of the CP of dams and, at six months, approximately 88.88%. The CP evaluation is crucial, because it is related to the ability to shift weight, and a higher CP may indicate superior traction capacity (Cabral et al., 2004; Mariz et al., 2014), as observed in the adult female donkeys studied here (Table 3). It is also essential for evaluating a few of the morphometric indexes such as MI, DTI, and WCI, as discussed below (Cabral et al., 2004; Brum, 2010).

In the analysis of morphometric indexes of adult female donkeys (Table 6), at the first evaluation of BI, it was confirmed that the animals could be classified as longilineal, similar to the observations recorded in other studies conducted on donkeys (Brum, 2010; Pimentel et al., 2014; Mariz et al., 2014; Folch and Jordana, 1997). Longilineal animals are morpho-functionally adapted to the racing activity, indicating the longer BL in relation to the thoracic depth, which thus provides greater speed (Cabral et al., 2004; McManus et al., 2010). This classification of donkeys differs from the saddle-type animals, which is one of the objectives of Pêga donkeys for the production of ambling-gaited mules (ABCJPÊGA, 2016). The morphometric indexes used were developed for horses (Pimentel et al., 2014), and a few differences may arise when applying these indexes for donkeys.

On assessing DTI, the adult female donkeys showed a distinction between the eumetric and hypermetric types (Table 6); this could indicate that the donkeys investigated are adapted for saddle activity as well as for use as draft animals, fulfilling both the objectives of raising donkeys in Brazil (Brum, 2010; ABCJPÊGA, 2016). The results observed in this study agree with other research conducted by testing donkeys, such as the work of Mariz et al. (2014), who studied the Nordestino donkeys used for draft and reported a rating between the eumetric and hypermetric types. Folch and Jordana (1997), while studying the Catalan donkey breed, and Pimentel et al. (2014), using the Nordestino breed, classified the animals as hypermetric, whereas Brum (2010), using the Pêga breed, classified the animals as eumetric. Only a minimum variation was noted between the studies using donkeys, probably because this index can be a reliable indicator for the use of these animals and, for donkeys, which can do both saddle and draft activities, as cited above.

Weight in cannon index (Table 6) fell below that observed in the Nordestino donkeys by Pimentel et al. (2014), but was higher than that reported for the Mangalarga Marchador horses by Cabral et al. (2004), indicating that Pêga donkeys have a lower traction capacity than do the Nordestino breed and are superior for this feature, compared with the Mangalarga horses. When relating the WCI to the DTI, the Pêga donkeys were observed to be adapted both to the saddle and draft activities, but showed greater efficiency in saddle activity (Brum, 2010). Based on the DTI, they did not exhibit as high a traction capacity as do the Nordestino donkeys, and their characteristic feature was their ambling gait, a highly sought-after trait by breeders and which gets transmitted genetically to their offspring (Oliveira, 2004; ABCJPÊGA, 2016).

The capacity for saddle activity is once again confirmed when evaluating the CFI (Table 6), in which the donkeys were classified as longilineal, implying that they possessed an aptitude to be saddled (Pimentel et al., 2014). This result corroborates the findings of Mariz et al. (2014), who stated that in the adult Nordestino donkeys, the value of the CFI was below 2, which also enabled classifying these animals as longilineal, and demonstrating that, although they are used as draft animals, they possess the conformation for saddle activities (Oliveira, 2004).

On assessing the MI for adult donkeys, it was noted that they were classified as longilineal, indicating that these animals possessed long members and were adapted to activities involving speed. Regarding the corporal index, the MI may not have been appropriate to classify the donkeys in this study, because it had been developed only for horses, and therefore more studies which have applied this index to the species are necessary.

Considering the RLW of the Pêga jennies, it was evident that the mean value observed was below the actual weight obtained on the electronic scale (289.62 kg), indicating the necessity to adapt this index to weight prediction for the adult donkeys.

On analyzing the morphometric indexes of the growing donkeys (Table 7), the BI results facilitated classifying them as longilineal from birth to six months of age. Cabral et al. (2004) reported different findings in their study on growing horses and classified the animals at three months of age as brevilineal and, after four months, when the animals exhibited a BI value higher than 85, they were reclassified as mediolineal. This classification observed for the growing animals (Table 7) confirms the results observed for the adult donkeys (Table 6), distinguishing them as the racing type, a classification very remote from fulfilling the objective of producing Pêga donkeys (Brum, 2010; ABCJPÊGA, 2016).

The results of the DTI of the growing donkeys were similar to those observed by Cabral et al. (2004) in their work using the growing Mangalarga Marchador breed of horses, indicating that donkeys are born heavier and possess the characteristics of draft animals, and this classification may get altered in adulthood, as cited above for the adult donkeys (Table 6).

On analyzing the WCI in the growing donkeys, similar results to those observed by Cabral et al. (2004) were confirmed. This index indicates the ability of the members to move the body mass, and the decrease in this index as age advances can be explained by the weight gained by the animal (Table 4), with only a slight variation in the cannon perimeter (Table 5). The WCI in the growing donkeys was higher than that observed in the growing Mangalarga Marchador breed of horses (Cabral et al., 2004), likely because the donkeys have a superior ability to move the body mass, which is indicative of a greater capacity for traction, compared with horses as cited earlier by Folch and Jordana (1997) in their study on the Catalan donkeys. This superior traction capacity of donkeys is confirmed when the relationship between the BL and WH is observed, as mentioned above.

As observed in the adult donkeys, the morphometric indexes classify the growing donkeys as being adapted to both traction and saddle activities, very similar to the CFI of the growing animals, ranging from 0.64±0.036 to 1.06±0.022 from birth to six months (Table 7), which were classified as longilineal, or animals possessing saddle aptitude (Pimentel et al., 2014).

On assessing the MI, as well as the BI, it can be confirmed that these animals are adapted to the racing activity, as they have been classified as longilineal from birth to six months of age (Table 7), and the animals possess long limbs, the characteristic feature of racing animals, according to Cabral et al. (2004), who ranked the Mangalarga Marchador horses as being longilineal from birth to adulthood.

On assessing the RLW of the growing donkeys, a variation of 32.03±4.4 to 105.47±2.9 kg was observed from birth to weaning (Table 7), while the weight on the scale ranged from 43.05±8.39 to 116.91±4.47 kg (Table 4). Therefore, for the growing animals, RLW also requires adjustments for greater efficiency in predicting the actual weight.

Conclusions

Donkeys are born weighing approximately 14.86% of the weight and 67.77% of the height of dams, and, at six months, they reach up to around 40.37% of that weight and 84.45% of that height. They are morphologically adapted both to saddle as well as to draft activities and possess a higher load capacity when compared with horses.

A few morphometric indexes, such as body index, conformation index, meloscopic index, and real live weight index need adjustments to be accurately used in rating donkeys.

The morphometric study of donkeys from birth is significant in monitoring the adequate growth rates for the species and evaluating growth disorders caused by diseases or poor nutrition. Thus, utilizing the dam as a reference for the growth parameters facilitates monitoring the donkey development.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: R.A. Brandi. Funding acquisition: R.A. Brandi. Investigation: C.G. Moreira and R.A. Brandi. Methodology: C.G. Moreira, M.L. Menezes, J.C.C. Balieiro and R.A. Brandi. Project administration: C.G. Moreira, M.L. Menezes, T.R. Nunes, T.P. Mota and R.A. Brandi. Resources: C.G. Moreira and R.A. Brandi. Software: J.C.C. Balieiro. Supervision: C.G. Moreira and R.A. Brandi. Validation: R.A. Brandi. Visualization: C.G. Moreira, J.C.C. Balieiro and R.A. Brandi. Writing-original draft: C.G. Moreira and R.A. Brandi. Writing-review & editing: C.G. Moreira, C.A.A. Oliveira and R.A. Brandi.

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