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A morphometrics study of equine Brazilian Fjord

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SUMMARY

In Brazil only one herd of locally bred Fjord horses exists, located in the state of Espírito Santo, established in 2003. These horses are used mainly in equestrian events and family outings. Since these animals have not yet been scientifically studied, the objective of this work is to characterize the morphology of these horses by linear measures and conformation indices. The morphology was evaluated by 22 measures of adult animals, used to calculate body, meloscopic, dactilo-thoracic and body indices. The measurement of the total head length was used in the eclectic system of linear proportions. The analysis of variance included the fixed effect of sex and the covariable age. There were no significant differences between the body measures of males and females. The animals had average withers height of 1.42±2.60 m and body weight of 472.1±40.4 Kg. The Fjord mares presented hip width proportion of 0.83, smaller than in males. The classification of the body index of the males and females indicated these animals are medioline, but according to the meloscopic index, they are classified as breviline. According to the dactilo-thoracic index, the males are considered to by hypermetric and the females eumeric. In conclusion, the animals can be classified as medium-sized with morphological traits of a robust body structure and good capacity for shifting their body mass.

Medidas morfométricas e índices corporais de cavalos Fjord Brasileiros

Palavras chave adicionais
Biometria.
Equino.
Fjord.
Índices corporais.

RESUMEN

No Brasil existe apenas um rebanho de cavalos Fjord, localizado no estado do Espírito Santo, estabelecido em 2003. Esses cavalos são utilizados em eventos equestres e passeios familiares. Como ainda não foram estudados cientificamente, o objetivo deste trabalho é caracterizar a morfologia desses cavalos por meio de medidas lineares e índices de conformação. A morfologia foi avaliada por 22 medidas de animais adultos, utilizadas para cálculo dos índices corporais, meloscópicos, dactilo-torácicos e corporais. A medida do comprimento total da cabeça foi utilizada no sistema eclético de proporções lineares. A análise de variância incluiu o efeito fixo do sexo e da co-variável idade. Não houve diferenças significativas entre as medidas corporais de machos e fêmeas. Os animais tinham altura média de cernelha de 1,42 ± 2,60m e peso corporal de 472,1 ± 40,4 Kg. As éguas apresentaram proporção da largura do quadril de 0,83, menor que os machos. A classificação do índice corporal de machos e fêmeas indicou que esses animais são mediolíneos, entretanto, pelo índice meloscópio classificaram-se como brevilíneos. De acordo com o índice dactilo-torácico, os machos são considerados hipermétricos e as fêmeas eumétricas. Em conclusão, os animais podem ser classificados como de médio porte com traços morfológicos de estrutura corporal robusta e boa capacidade de deslocamento de sua massa corporal.

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INTRODUCTION

Horses have numerous purposes, and for each of them different types are needed, that is, with specific characteristics related to conformation, aptitude, temperament, training and performance (Leach, 1983). Morphometric evaluation supports the choice of horses, especially for sports activities, since the body proportion defines the limits and the capacity of the animals to perform movements (De Godoi *et al.*, 2013). As observed in Mangalarga Marchador horses, used for walking sport activities (Cabral et al. 2004). A horse is considered well proportioned if the parts of the body, taken together, are adapted to the function for which the animal is intended (Costa et al., 1998). Body proportions can be assessed using indices that show relationships between length, girth and weight measurements (Oom; Ferreira, 1987).

Many of the equine breeds in Brazil have been morphologically characterized, such as the Creole (Mcmanus et al., 2005), Pantaneira, Campolina (Pinto Almeida; Quirino, 2005), Mangalarga Marchador (Cabral et al., 2004), Quarter Horse, Arabian (Rezende et al. 2018), and Brazilian Pony (Bartolazzi et al., 2017). However, the body proportions of Fjord horses bred in Brazil are still unknown. Fjord horses are considered a Norwegian national symbol and are now distributed throughout Europe and North America, with Brazil and Chile

being the only countries in Latin America that have specimens (FJHI, 2019). The first animals in Brazil were imported from Norway and Chile in 2003, for use in family outings and tourist rides (FJORDLAND, 2020). The only Brazilian breeder of this breed is located in the city of Pedra Azul, a mountain region in the state of Espírito Santo. Fjord horses have great resistance to low temperatures (GOODWIN; LEVINE; MCGREEVY, 2008) and a robust body structure, but they are relatively small, with withers height, as defined by the Norwegian Fjord Horse Registry (NFHR), between 1.37 and 1.47 meters and body weight ranging from 400 to 500 kilograms (NFHR, 2010). In Brazil, the registration of these animals is performed by the Brazilian Association of Pony Breeders (ABCCP), after the morphological inspection of the animal. In view of the lack of morphometric data for Fjord horses bred in Brazil, the objective of this study was to use the eclectic system of linear proportions and body conformation indices for morphometric evaluation of adult Fjord horses.

MATERIAL AND METHODS

The study was conducted in January 2020, at the farm of a Fjord horse breeder in the mountainous region of the state of Espírito Santo, Brazil. The investigation was approved by the Ethics and Animal Use Committee of Darcy Ribeiro North Fluminense State University (CEUA/UENF), under protocol number 482555. Conformation measurements were performed on 15 adult Fjord horses, nine of which were castrated males, with an average age of 13 years and an average body weight of 445.55 ± 23.9 kg, and six females, with an average age 17 years and average body weight of 472.1 ± 40.4 kg, all used for tourist rides. The animals were kept in a semi-intensive grazing system with mineral salt, forage (Cynodon dactylon, Tifton 85 and cowgrass), water "ad libitum" and concentrated horse feed (EquiTech 40kg - PRESENCE®). They were vaccinated annually against rabies, encephalomyelitis, rhinopneumonitis, influenza and tetanus, and the foals were weaned at six months.

The morphometric evaluations carried out by a single evaluator using a metal hypsometer (Walmur® - 2 meters) and a millimeter measuring tape (Arktus®). Body weight was estimated using a weight tape for horses (Walmur®). The animals were always evaluated on the left side of the body, positioned in a forced stance on a rigid, smooth and flat floor (**Figure 1**). The determination of the 22 linear measurements (**Table I**) followed the definitions of Cabral et al. (2004). Based on linear measurements, six conformation indices (CFIs) were calculated (OOM; FERREIRA; 1987; Cabral et al., 2004; MCMANUS et al. 2005; REZENDE et al. 2018), in order to ascertain the relationships between length, girth and weight measurements.

They were:

- Body index (BI) – The ratio between body length and thorax girth, classifying the animal is long (BI ≥ 90), medium (86 ≤ BI ≤ 88) or short (BI ≤ 85);

$$BI = \frac{\text{body length}}{\text{thorax girth}} \times 100$$

- Meloscopic index (MI) – The ratio between the distance from the elbow to the ground and the sum of three circumferences, or girths (foreleg + knee + cannon). This index indicates whether the legs are well proportioned in relation to the trunk; when they are not, this indicates faulty gait. The animal is classified as long (> 1), medium (= 1) or short (< 1).

$$MI = \frac{\text{distance from the elbow to the ground}}{\text{Foreleg girth + knee girth + cannon girth}}$$

- Dactyl-thoracic index (DTI) – The ratio between the fore cannon girth and thorax girth, classifying the animal is a large horse (> 11.5), riding horse (10.5 ≤ DTI ≤ 10.8) or small horse (< 10.5).

$$DTI = \frac{\text{fore cannon girth}}{\text{thorax girth}} \times 100$$

- Weight in cannon index (WCI)- The ratio of the cannon girth to body weight, indicates the ability of the animal to move its body mass. Low values indicate animals with weak limbs in relation to weight, which can compromise their performance for any use.

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

- Body ratio (BR) – The ratio between the withers height and croup height, The closer this index. Is to 1, the better will be the balance of the locomotor members.

$$BR = \frac{\text{withers height}}{\text{Croup height}} \times 100$$

- Compactness index (CI) – The ratio between the estimated body weight and withers height. Animals used as saddle horses have CI < 2.20; animals suited for light traction have 2.60 ≤ CI ≤ 3.15, and horses used for heavy pulling have CI > 3.15.

$$CI = \frac{\text{weight}}{\text{withers height}} \times 100$$

For the evaluation of linear proportions, we used the eclectic system described by Lesbre (1920) and used by Cabral *et al*. (2004).

Descriptive statistics were calculated to determine frequencies, means, standard deviations, maximum and minimum values and coefficients of variation, followed by analysis of variance to test the effect of sex (PROC GLM, SAS). The evaluation of sexual dimorphism was performed using the Tukey test at 5% significance (SAS University Edition,2020).

RESULTS

In the analysis of variance of the morphometric measurements, there was no difference between males and females (**Table II**). However, females had greater withers height (152.2 cm) and rump height (152.9 cm) than males (145.7 cm and 146.4 cm, respectively). The classification of the body index of males (89.89 ± 6.22) and females (89.33 ± 9.17) indicated these animals are medium-sized, but according to the meloscopic index,

Table I. Characterization of linear measurements performed on Fjord horses, Pedra Azul – ES, 2019 (Caracterização de medições lineares realizadas em cavalos de fiordes, Pedra Azul – ES, 2019).

Linear Measurements	Topographic description of linear measurements0
Hypometer measurement	
Withers height (WH)	Measurement from the highest point of the interscapular region, located in the space defined by the spinous process of T5 and T6, until the ground;
Croup height (CH)	Measurement from the highest point of the croup, specifically on the sacral tuberosity, to the ground;
Distance from the elbow to the ground (DEG)	Distance between the apex of the olecranon and the ground;
Head width (HW)	Distance between the free portion of the right supraorbital border and the left border;
Croup width (CrW)	Distance between the lateral portions of the coxal tuberosities
Chest width (CW)	Distance between the lateral edges of the right and left scapulohumeral joints;
Measurement with metric tape measure	
Shuttle perimeter (SP)	Measured circumference measured in the median region of the shin of the left thoracic limb, formed by the metacarpal bones II, III and IV;
Forearm perimeter (FP)	Measured circumference measured in the median region of the forearm, formed by the radius and ulna bones;
Knee perimeter (KP)	Measured circumference measured in the median region of the knee, comprised by the Carpian bones;
Billet Perimeter (BP)	Measurement of the circumference in the median region of the billet, formed by the metacarpal-phalangeal joint);
Thoracic perimeter (TP)	Circumference measurement using a tape measure placed just after the end of the withers, between the spinous processes T8 and T9, passing through the intercostal space of the 8th and 9th ribs, until the articulation of the last rib with the xiphoid process.
Body length (BL)	Distance between the cranial portions of the greater tubercle of the humerus and caudal of the ischial tuberosity;
Croup length (CL)	Distance between the cranial portions of the iliac tuberosity and caudal ischial tuberosity;
Shoulder length (SL)	Distance between the dorsal edge of the scapular cartilage and the distal angle of the scapula or central portion of the scapulohumeral joint;
Head length (HL)	Distance between the proximal end of the head, which coincides with the nuchal crest, and the medial or central portion of the lower incisor arch;
Back-length (BaL)	Distance between the ends of the spinous processes of T8 and T9 and the cranial portion of the sacral tuberosity;
Neck length (NL)	Distance between the cranial portion of the dorsal arch of the atlas and the middle third of the cranial edge of the scapula;
Side height (SH)	Measurement measured from the highest point of the interscapular region, located in the space defined by the spinous process of T8 and T9, up to the midline in the cranial portion of the manubrious bone;
Scapula- billet distance (SBD)	Distance between the dorsal edge of the scapular cartilage and the billet (metacarpal-phalangeal joint);
Codillo-knee distance (CKD)	Distance between the apex of the olecranon and the median region of the knee, comprised by the Carpian bones;
Knee-billet distance (KBD)	Distance between the median region of the knee, comprised by the Carpian bones and the billet (metacarpal-phalangeal joint);
Hock-billet distance (HBD)	Distance between the median hock region, comprised by the Tarcian bones and the billet (metatarsal-phalangeal joint);

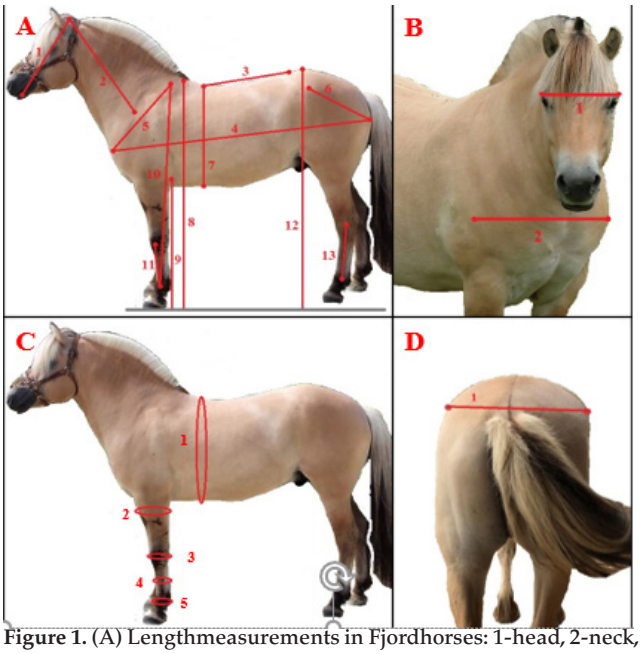

Figure 1. (A) Lengthmeasurements in Fjordhorses: 1-head, 2-neck, 3-back-loin, 4-body, 5-shoulder, 6-croup; Heightmeasurements: 7-side, 8-withers; 12-croup; Distancemeasurements: 9-codilho-solo, 10-scapula-boleto, 11-knee-boleto, 13-hock-boleto. (B) Widthmeasures: 1-head, 2-chest; (C) Perimeters: 1- thoracic, 2 forearm, 3-knee, 4-shin, 5-boletus and (D) 1-width ofthecroup. Source: Adaptedfrom NFH, 2020 ((A) Longasmedições em cavalos de fiorde: 1 cabeça, 2 pescoço, 3-back-loin, 4-body, 5-shoulder, 6-croup; Measurements de altura: 7 lados, 8-withers; 12-croup; Measurements de distância: 9-codilho-solo, 10-scapula-boleto, 11-knee-boleto, 13-hock-boleto. (B) Meassões de largura: 1 cabeça, 2 peito; (C) Perímetros: 1- torácica, 2 antebraço, 3-knee, 4-shin, 5-boletus e (D) 1 largura do acroup.Fonte: Adaptado da NFH, 2020).

males (0.96 ± 0.05) and females (0.97 ± 0.04) were classified with breviline. According to the dactyl-thoracic index, males were hypermetric (11.55 ± 0.57) and females were eumetric (10.77 ± 0.93). Males showed a higher load in cannon index (4.78 ± 0.31) than females (4.46 ± 0.42). As for the withers-croup ratio, males and females had the same value (0.99 ± 0.01).

The compactness index indicated that males (3.14 ± 0.16) were classified as light traction horses and females (3.28 ± 0.22) as heavy traction horses (**Table III**).

The linear proportions of males and females in relation to the total length of the head were equal for head width (0.32) and shuttle perimeter (0.34), but males presented values of knee perimeter (0.52) and the billet perimeter (0.46) greater than the proportions verified in males. The other proportions of linear measures evaluated were greater in females (**Table IV**). The Fjord horses presented equal proportion of the width of the croup in relation to the width of the head according to the eclectic system.

The Eclectic System of Linear proportions have been used several decades ago in the study of the proportions of saddle horses, is based on the length of the head and presents the following relationships, among others: height at the withers and croup and the length of the body equals two and a half times the length of the head, as well as the length of the neck and

of the shoulders have the same value as the length of the head (Ribeiro, 1988). The measures of withers height, croup height, neck length, shoulder length, head width and chest width were lower in the eclectic system, while the other variables analyzed were higher (**Table IV**).

DISCUSSION

Table II. Means, standard deviations (cm), maximum and minimum values of morphometric measurements of adult Fjord males and females raised in Brazil (Meios, desvios padrão (cm), valores máximos e mínimos de medidas morfométricas de machos e fêmeas de fiorde adultos levantados no Brasil**).**

Morphometric Measurements (cm)	$\overline{X}$ ± SD	Males		Females	
		Min	Max	Min	Max
WH	141.92±2.60	138.3	145.7	138.2	152.2
CH	142.35±2.73	136.8	146.4	137.4	152.9
SH	85.44±6.87	69.3	92.2	85.5	86.5
BL	165.34±10.55	143.6	175.8	166.4	184.6
BaL	60.20±4.60	52.8	68	58.6	65
CL	56.26±3.82	47.3	60.2	53.9	59.9
SL	52.37±5.57	43.2	59	51.6	56.6
NL	59.10±2.89	54.2	63.2	57.3	66.8
HL	62.12±0.92	61	63.6	61.7	63.4
CKD	53.22±2.98	50.1	58.9	52.4	58
DEG	91.53±3.49	85.4	96.3	88	101
SBD	122.45±11.63	123	133.7	124.2	133.5
HBD	40.50±1.25	38.6	42.7	37	41.1
KBD	25.82±1.46	23.1	27.8	25.2	29
CrW	51.22±1.41	49.4	53.9	50.2	55
HW	20.03±0.77	18.6	21.2	19.1	20.9
CW	40.51±1.90	36.7	42.4	38.7	48.7
FP	41.37±2.54	37.5	46.6	39.9	52
BP	28.46±0.66	27.5	29.5	26.5	29
SP	21.24±0.77	20	22.3	20	22.2
KP	32.26±1.28	30	33.6	29.5	32
TP	184.23±10.32	175.5	210.2	178.5	220.1

Withers height (WH); Croup height (CH); Side height (SH); Body length (BL); Back-length (BaL); Croup length (CL); Shoulder length (SL); Neck length (NL); Head length (HL); Codillo-knee distance (CKD); Distance from the elbow to the ground (DEG); Scapula-billet distance (SBD); Hock-billet distance (HBD); Knee-billet distance (KBD); Croup width (CrW); Head width (HW); Chest width (CW); Forearm perimeter (FP); Billet perimeter (BP); Shuttle perimeter (SP); Knee perimeter (KP); Thoracic perimeter (TP).

Table III. Means, standard deviations of the conformation indexes of adult Fjord males and females raised in Brazil (Meios, desvios padrão dos índices de conformação de machos e fêmeas de fiorde adultos levantados no Brasil).

Conformation Indices	$\overline{X}$ ± DP	
	Males	Females
Body Index	89.89±6.22[a]	89.33±9.17[a]
Meloscopic index	0.96±0.05[a]	0.97±0.04[a]
Dactyl-thoracic index	11.55±0.57[a]	10.77±0.93[a]
Load index in shuttle	4.78±0.31[a]	4.46±0.42[a]
Relationship index whithers- croup	0.99±0.01[a]	0.99±0.01[a]
Compactness index	3.14±0.16[a]	3.28±0.22[a]

Means followed by the same letter on the same line do not differ by the Tukey test at 5% significance.

Table IV. Values of the proportions of the linear measurements in relation to the head length of adult Fjord males and females raised in Brazil, in relation to the eclectic system (Valores das proporções das medidas lineares em relação ao comprimento da cabeça de machos e fêmeas de fiorde adultos levantados no Brasil, em relação ao sistema eclético).

Variables	Eclectic system	Fjord	
		Males	Females
Head length	1	1	1
Withers height	2.5	2.28	2.31
Croup height	2.5	2.29	2.32
Body length	2.5	2.66	2.79
Neck length	1	0.95	0.97
Shoulder length	1	0.84	0.87
Back-length	0.83	0.97	0.99
Croup length	0.83	0.91	0.93
Head width	0.33	0.32	0.32
Croup width	0.83	0.82	0.83
Chest width	0.83	0.65	0.69
Side height	-	1.38	1.44
Scapula-billet distance	-	1.97	2.08
Codilho-solo distance	-	1.47	1.49
Codillo-knee distance	-	0.86	0.87
Knee-billet distance	-	0.42	0.44
Hock-billet distance	-	0.65	0.64
Thoracic perimeter	-	2.97	3.15
Forearm perimeter	-	0.67	0.7
Knee perimeter	-	0.52	0.5
Billet Perimeter	-	0.46	0.44
Shuttle perimeter	-	0.34	0.34

The animals evaluated showed average withers height (1.41 ± 2.6 m) and average body weight (445.55 ± 23.9 kg) within the racial standards described by the Fjord record book in Brazil (https://site.ponei.org.br/padratildeo-fjord.html). **Table II** shows that the females had maximum values of withers height, croup height, body length and thorax girth slightly higher than the males. Despite these small variations, in general there was similarity between the sexes, as also seen in Mangalarga Marchador horses (Cabral et al., 2004).

The similar values between the morphometric measurements and the conformation indices between males and females could be explained by the interruption in the release of sex hormone, the testosterone, caused by the castration of the males. After castration, there is a decrease in hormonal release, and consequently, deposition of a large amount of muscle tissue (Mooradian; Morley; Korenman, 1987). Thus, we believe that the early castration of males (at two years of age) directly influenced the body differentiation of these animals, providing less robustness in the analyzed castrated males. Studies carried out in castrated and non-castrated males of the Campolina breed also have found association between the hormonal action and development of animals (Cabrera; Costa; Fonseca, 2004; Lucena et al., 2015), in line with our findings.

In horses, conformation indices (CFIs) make it possible to estimate aptitudes (Cabral et al., 2004). The CFIs calculated in this study indicate there are no differences between males and females of the Fjord breed raised in Brazil. According to body indices, adult males and females of the Fjord breed are medium-sized animals (**Table III**) with intermediate ability between strength and speed, corroborating the description of the Fjord Horse Registration Book in Brazil (https://site.ponei.org. br / padratildeo-fjord.html), which describes the use of these animals in leisure activities. These characteristics are similar to animals of the Mangalarga Marchador breed, which in adulthood are classified as medium-sized horses (Cabral et al., 2004). However, castrated males of the Campolina breed were classified as medium-sized, whereas females of the same breed were classified as small horses (Lucena et al., 2016). The body index allows assessing the aptitudes of the animals, and consequently directing them to the most appropriate activities (Cabral et al., 2004). Long-haired animals are more suitable for speed sports (> 0.90), while short-haired animals are more suitable for activities that require strength (< 0.85) and medium-sized animals, such as Fjords, have intermediate skills between strength and speed (0.86 to 0.88) (Rezende et al. 2018).

The meloscopic index relates the height of the forelimb to three circumferences of the same limb (foreleg, knee and cannon). Male and female Fjord horses are short-lived. Animals of the Mangalarga Marchador breed are classified as mediolinous (Cabral et al., 2004) and of the Alter breed as the longilíneus (Oom; Ferreira, 1987). By the dactyl-thoracic index (**Table III**), males are classified as hypermetric and females as eumeric. This index refers to the ability of these animals to support their body mass on their limbs. Despite the differences between male and female Fjords, we belie-

ve there is no imbalance between the body mass and bone structure of this breed. The same was observed in horses of the Campolina breed (Lucena et al., 2016). Castrated males of the Campolina breed are classified as hypermetric and females as hypometric, whereas both males and females of the Mangalarga Marchador breed are classified as eumeric in adulthood (Cabral et al., 2004). The results presented for this index suggest that Fjord horses have intermediate aptitude between saddle and light traction animals, results similar to those obtained for Pantaneiro (Miserani; Mcmanus; Santos, 2002) and Campeiros (Mcmanus et al., 2005) horses.

Adult Fjord males had an average weight in cannon index (4.77) higher than the average value presented by females (4.44), but regardless of gender, Fjord animals have strong limbs. Values close to 1 suggest animals with weak limbs (Oom; Ferreira, 1987). The ability to support weight by the cannon is also explained by the short stature of Fjord horses, as also described by Rezende et al. (2015). The data presented for the Fjord breed are similar to those reported in male (3.63) and female (3.89) Alter horses (Oom; Ferreira, 1987). However, significant differences were observed between the mean weight in cannon index values of males (4.16) and females (4.96) of the Mangalarga breed (Cabral et al., 2004).

The general average of the withers-croup height index (WCHI) was 0.99 (**Table III**), demonstrating the good body balance of these animals. The closer to 1 the value of this index is, the greater the balance between the locomotor members (Cabral et al., 2004). When there is a great imbalance between the withers and croup heights, the articular angles of the anterior and posterior locomotor members are abnormal, impairing both the walking and the resistance of the horse (Mcmanus et al., 2005). Thus, Quarter and Arabian animals that have the IRCGs (withers and croup ratio) of 1.01 to 1.03 and 1.0 to 1.01 respectively, tend to have withers height greater than the croup height (Rezende et al. 2018).

According to the compactness index, males and females raised in Brazil have aptitude for traction activities, with females capable of performing heavy traction and males light traction activities, although there were no statistical differences between the sexes. Different results were observed for Arabian, Creole, Pantaneiro, Mestizo and Quarter Horse males, which showed fitness between light activities for saddle and light traction, and females for Quarter Horse fitness for heavy traction (Rezende et al. 2018).

The evaluation by the eclectic system (**Table IV**) showed that the values of the proportion of the body length in relation to the head length were 2.5 (Lesbre, 1920). This allows us to suggest that these proportions vary between different breeds, as in Mangalarga Marchador 2,5, similar to that found in the Fjods (Cabral et al., 2004), in Campolina with 2,590 (Lucena et al., 2015) and in the animals of the present study, being the values of height at the withers of inferior Fjord males and females. In the morphological evaluation, the age of the animals must be taken into account, because at birth the proportions are smaller than in adults (Lesbre, 1920; Cabral et al., 2004), so a morphological judgment without considering the animals' age range cause misclassification of aptitude and incorrect transmission of genetic characteristics of the breed.

CONCLUSIONS

Fjord horses bred in Brazil have morphological characteristics within the racial patterns of the equines, which allows for the proper breeding and registration of these animals. The body conformation indices did not differ between adult males and females, and it is possible to classify them as light to heavy, medium-sized, strong horses, with a good balance between the locomotor limbs and good capacity to move their body mass. The eclectic system of proportions indicated that adult Fjord horses bred in Brazil do not fit the proportions of this system.

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