Journal of Animal & Plant Sciences, 34(6): 2024, Page: 1388-1395
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2024.6.0818

THE EFFECT OF BREED AND SEX ON THE BODY CONFORMATION OF BARB, ARABIAN-BARB, AND ARABIAN HORSES IN ALGERIA

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ABSTRACT

The preservation of genetic diversity in Algerian horse breeds is essential for their effective conservation and utilization. However, a current lack of knowledge about their diversity and genetics presents a significant challenge. This study aims to characterize the morphological features of three principal horse breeds in Algeria: Barb, Arabian-Barb, and Purebred Arab. We measured 26 morphological traits, calculated live weight and eight body indices, and evaluated three qualitative parameters: coat color, muzzle shape, and cephalic profile. Average values for these measurements were computed for each breed. We assessed the significance of these averages using multi-factor ANOVA and compared them using the Newman-Keuls homogeneity test with SAS software. The results reveal distinct morphological characteristics for each breed. The Barb breed has a distance between the internal angles of the eyes of 17.27 cm, a neck length of 63.46 cm, a leg length of 38 cm, an average withers height of 154.2 cm, a live weight of 429 kg, a thoracic perimeter of 175.85 cm, and a compactness index of 2.80. The Purebred Arab displays a distance between the internal angles of the eyes of 18.5 cm, a neck length of 59.5 cm, a leg length of 40.01 cm, an average withers height of 150.3 cm, a live weight of 377.64 kg, a thoracic perimeter of 162.8 cm, and a compactness index of 2.44. The Arabian-Barb breed, a result of crossbreeding, is highly heterogeneous and combines desirable traits from both parent breeds. A significant influence of sex was noted on the height at the withers ($p<0.05$), with males generally taller than females, who present wider chests and larger lower leg circumferences.

Keywords: horses; index; live weight; morphometric traits.

Published first online October 13, 2024 Published final December 22, 2024

INTRODUCTION

The history of horses in Africa is a topic of ongoing research and discussion, with the earliest evidence of their presence dating back to the arrival of humans. A particular specimen, known as "Equus Algericus," discovered near Tiaret in Algeria, has sparked debates among scholars (Radovic *et al.*, 2022). However, the consensus is that the domestic horse was likely introduced to North Africa during the second millennium BCE through human migrations and conquests, via routes such as the Strait of Gibraltar or Egypt (Radovic *et al.*, 2022).

One of the most notable horse breeds in north Africa is the Barb, a breed with deep roots in the Maghreb region, which includes present-day Algeria, Tunisia, and Morocco, along the Barbary Coast. The Barb breed is believed to have descended from the Numidian horses and their crosses. The 7th century marked a significant period of complex human and equine migrations in North Africa, coinciding with the Muslim conquests (Radovic *et al.*, 2022).

The origin and identification of the Barb breed have been subjects of interest for archaeology. Historically, the breed's identification was based on its qualities of speed and endurance, rather than its morphological characteristics. For instance, the Emir; the founder of the Algerian states in 1832; considered a horse of "breed" to be noble (H'orr) and judged it based on these qualities (Ben Yasla, 1991). Similarly, General Daumas who served as both a general in the French Army and as the Governor-General of French Algeria; is also notable for his authorship of several books on military strategy and history did not focus on the fundamental morphological characteristics of horse breeds. He believed that the African possessions' horse belonged to the Barb breed, but he also noted the close relationship between the Barb and Arabian horses, considering them part of the same large Eastern breed family. This family, he argued, had a common origin but varied according to climatic influences (Meynier, 2010).

The distinction of the Barb as a distinct breed from the Oriental breed was reinforced in 1844 with the establishment of remount depots in Algeria. The Barb

was universally praised for its robustness and speed, passing on to its offspring exceptional swiftness. Despite its qualities of balance and maneuverability, crucial on the battlefield, it lacked the elevated gaits necessary to excel in arenas (Jamali, 2020; Husser, 2018). The establishment of the Tiaret Mare Depot in 1877 aimed to preserve Oriental stallions to produce a new type of horse called "Arab-Barb" through crossbreeding with the Barb breed. This new breed exhibited both the main morphological characteristics of the two breeds, more imposing than the Barb and Arabian breeds (Ben Yasla, 1991). In recent times, the morphometric characterization of Algerian horses has become crucial for precise identification of the country's indigenous breeds, which is vital for breeding and reproduction.

Morphometric measurements can be used to evaluate a horse's physical capabilities such as speed, endurance, and agility. This information can help determine the activities for which a horse is most suited and to maximize its performance. To preserve the equine breeds of Algeria, comparative morphometric analysis of Barb, Arabian-Barb, and Purebred Arabian horses is being conducted. This study aims to provide valuable insights into the unique characteristics of these breeds and contribute to their preservation and enhancement.

This study will focus on morphometric characterization, discussing the different parameters related to measurements of lengths and circumferences, the estimation of the live weight and indexes and the effect of breed and sex. A comparison between the three horses studied will be done to draw final conclusion.

MATERIELS AND METHODS

The study was meticulously conducted across several prominent equestrian locations in Algeria, including the largest stud farm in the country, Kaïd Ahmed de Tiaret. This stud farm, established in 1877, has a rich history and a well-earned reputation for specializing in the breeding of Arabian horses, pure Barb, Arabinan-Barb, and more recently, Anglo-Arab horses. The choice of this location provided a diverse and representative sample of the country's equine population, thereby enhancing the validity of the study. Additional research was carried out at the equestrian centers of Mostaganem and Ahfed El Amir of Mascara. These locations were selected for their unique contributions to the equine industry in Algeria, further enriching the breadth of the study.

The study encompassed 130 adult horses aged four years and older, comprising 56 Arabian horses, 42 Barb horses, and 32 Arabian-Barb crosses. All horses were officially registered in the Algerian horse stud book as purebred breeding stock, confirming their lineage and quality. This registration underscores the study's reliance on high-pedigree specimens.

Over an extended period, horses with no familial relations were sourced from multiple locations: 57 from the Tiaret stud farm, 53 from equestrian centers in Mostaganem, and 20 from the Mascara equestrian center. Rigorous selection protocols were implemented, which included thorough examination of genealogy and verification of pedigrees using identification cards and entries in the herd book. Utilizing multiple equestrian centers was essential to ensure the sample was both representative and of superior quality, while precluding the inclusion of related individuals.

The research encompassed 26 distinct measurements, conducted post-feeding to provide a comprehensive dataset reflecting the horses' physical characteristics. These measurements were performed on level ground to ensure both accuracy and consistency, thereby enhancing data reliability. The 26 measurements utilized specific instruments: heights were measured using a hippometric rod (R), while lengths and circumferences were assessed with a measuring tape (T). All horses were positioned on a level and vertical plane to standardize measurement conditions.

The study also incorporated the determination of live weight, which was calculated using the chest circumference and withers height of the horses. This method was based on formulas developed by the French Agricultural Research Institute (INRA), This approach allowed for a non-invasive and accurate estimation of the horses' live weight, contributing to the comprehensive understanding of their physical characteristics (Martin-Rosset, 1990).

In addition to the live weight, the study calculated eight indices. These indices were derived from the formulas listed in Table 1. Each index provided specific insights into the horses' physical attributes, such as their proportionality, robustness, and potential performance capabilities. The calculation of these indices further enriched the morphometric analysis, providing a multi-faceted view of the physical characteristics of Barb, Arabian-Barb, and Purebred Arabian horses. This comprehensive approach to measurement and calculation underscores the thoroughness of the study and its commitment to providing a detailed understanding of these indigenous Algerian horse breeds.

Three qualitative traits were evaluated visually, including the coat color, muzzle shape, and cephalic profile.

The study included both males and females for each breed studied in order to analyze the sex effect on morphometric parameters.

Table 1. Weight and indexes estimation using formulas.

Indices	Abbreviations	Formules
Live weight	PV	LW (kg) = 4.3 x CC + 3 x WH – 785
Body profile index	ICP	TG/LT
Body index	IC	LT/PT
Relative cannon bone thickness index	IERC	TCA/TG
Dactylo thoracic Index	IDT	TCA/PT
Compactness index	ICOM	PV/TG
Baron and crevet index	IBC	PT2 *TG*100
Height front to back	HDD	TG/HC
Body proportion	RC	PT/TG

Statistical analysis: The study analyzed data from 130 horse breeds using average values for various measurements. The significance of these averages was evaluated using the ANOVA test, Further comparison between averages was performed using the Newman-Keuls homogeneity test. This test identifies specific differences between group means. All these statistical analyses were conducted using SAS software version 9.1 (SAS, 2008). The qualitative parameters were evaluated and collected as percentages.

RESULTS AND DISCUSSION

Table 2 presents the averages and standard deviations of the measurements of length, circumference, live weight, and indices for the three horse breeds studied, which are the Barb, Arabian-Barb, and Purebred Arabian.

Characteristics of the Barb horse: The Barbe horse has an average height of 154.2 cm, aligning with breed standards that typically range between 150 and 160 cm (Rahal *et al*., 2009). However, these findings contrast with those reported by Guedaoura *et al*. (2011) and Benhamadi *et al*. (2017), who recorded average heights of 151.3 cm and 152.5 cm, respectively.

The chest circumference of the Barbe horse in our study averages at 175.85 cm, exceeding the minimum limit of 170 cm required by the OMCB for registration in the stud-book of the Barb horse (Tamzali, 1989; Chabchoub *et al*., 2004; Guedaoura *et al*., 2011). This result is consistent with Benhamadi *et al's*. (2017) findings of 175.5 cm but differs from the 171.4 cm reported by Guedaoura *et al*. (2011) (Table 2).

The Barbe horse also exhibits a wide chest (distance between the front legs) of 16.65 cm, indicative of a significant respiratory capacity an essential trait for racing horses. The neck dimensions represent a well-grafted neck, crucial for the horse's locomotion, serving as a balance and steering mechanism. The limbs, relatively thick, are particularly important in horses as they serve as supports and propulsion for the animal. The circumference of the front cannon is 19.43 cm, the circumference of the front fetlock is 26.07 cm. This results in a superior circumference of the leg of 50.45 cm and an inferior circumference of the leg of 34.56 cm, indicating a harmonious horse with a strong and homogeneous skeleton.

The average weight of the Barbe horse is 428.95 kg according to the results of (Rahal *et al.,* 2009), differing from the weights of 409.9 kg and 412.7 kg reported by Benhamadi *et al.* (2017) and Guedaoura *et al*. (2011), respectively. The compactness index, estimated by the weight/height at the withers ratio, is 2.809 kg/cm, suggesting that our horse is slightly compact for its weight. This result is higher than the compactness index of 2.589 kg/cm reported by Guedaoura *et al*. (2011) and the 2.688 kg/cm reported by Benhamadi *et al*. (2017).

The dactylo-thoracic index, which expresses the relationship between a horse's mass and the limbs that support it, should not be less than 0.108 for a thoroughbred horse (Carroll and Huntington, 1988). Our horse, with a dactylo-thoracic index of 0.109, has a skeleton thickness compatible with its weight. The dominant color of the Barb horse's coat is gray at 60 %, indicating variations such as dappled gray, shaded gray and chestnut gray. This aligns with the description of the Association Française du Cheval Barbe (2019), which states that the Barb horse's coat is mostly chestnut in Tunisia and gray in Algeria. We also notice the presence of chestnut in 30 % of the horses, and bay colors in 10 %.

According to a study by Rahal and his colleagues in 2009, gray is the most prevalent color among Barb horses at 79 %, with variations such as speckled gray, dappled gray, and chestnut gray. Chestnut is the second most common color at 11%, followed by bay at 10%, and finally, roan at 5%. A retrospective study of data from the Algerian Stud-book also supports these findings, with gray being the predominant color among the 613 initially registered Barb horses, at 62% in the west and 58% in the east, while bay and chestnut colors were found at 28% and 27% respectively for bay and 9% and 15% respectively for chestnut in the West and East. Regarding the shape of the noseband, the beard primarily has a curved shape at 75%, with 15% slightly curved and a convex head profile. This result is in line with similar

studies showing a dominance of the convex profile (Guedaoura *et al*., 2011).

Table 2. Table of means and standard deviations of measurements performed.

Traits	Abreviations	Barb	Arabe-Barb	Arabian	
Height at the withers (cm)	TG	154,2±3,61	152,6±4,78	150,3±3,67	Ns
Croup Height (cm)	HC	152,9±6,16	150±0	148,5±3,58	Ns
Distance between the internel angles of the eyes (cm)	DAIY	17,27±0,58^{b}	17,65±0,62^{b}	18,5±0,69^{a}	***
Neck length (cm)	LE	63,46±3,55^{a}	62,9±2,51^{a}	59,5±3,011^{b}	*
Arm length (cm)	LB	39,97±0,95	38,45±2,46	42,15±6,74	Ns
Anterior Canon Length (Metacarpal Region) (cm)	LCA	19,19±1,07^{b}	24,85±3,02^{a}	16,9±0,84^{c}	***
Leg Length (cm)	LJB	38±1,11^{b}	45,7±6,61^{a}	40,016±2,77^{b}	**
Back Length (cm)	LD	52,344±0,54^{a}	52,6±5,73^{a}	50,02 ± 6,90^{b}	**
Total Length (cm)	LT	155,2±6,01	152,1±1,82	150±0	Ns
Lower Ear Space (cm)	EIO	14,49±0,43^{b}	16,05±1,53^{a}	15±0 ^{b}	***
Posterior Canon Length (cm)	LCP	22,68±1,55^{b}	31,65±5,01^{a}	25,26±0,41^{b}	***
Front Limb Distance (cm)	DMA	16,65±0,18	15,35±2,26	16±0	Ns
Hip point Distance (cm)	DPH	48,16±0,25^{a}	50,5±5,53^{a}	44,49±0,49^{b}	*
Patella buttock distance (DFR)	DFR	63,96±2,55^{a}	62,4±3,06^{a}	55,2±0,59^{b}	*
Anterior Canon Girth (cm)	TCA	19,432±0,05	19,85±1,05	19,4±2,85	Ns
Thoracic Perimeter (PT) (cm)	PT	175,85±8,74^{a}	174,45±4,72^{a}	162,8±7,31b	**
Neckline upper edge (cm)	TSE	80,85±0,183^{a}	84±5,94^{a}	73,6±1,19^{b}	***
Lower Neckline (cm)	TIE	122,94±2,59^{a}	126,4±8,55^{a}	108,58±5,91^{b}	***
Front Ankle Turn (cm)	TBA	26,074±0,13^{b}	26,95 ±1,37^{a}	24,95±0,14^{c}	**
Front Stirrup Turn (cm)	TPA	17,8±0,19^{b}	19,4±1,15^{a}	16,85±0,33^{c}	Ns
Front Hoof Turn (cm)	TSA	39,068 ±0,404^{b}	41,1 ±1,748^{a}	38,35 ±1,04^{b}	***
Upper leg turn (cm)	TSJ	50,45±1,64 ^{a}	42,49±4,10^{b}	43,65±0,44 ^{b}	Ns
Lower leg turn (cm)	TIJ	34,56±0,80^{a}	34,7±1^{a}	31,18±0,06^{b}	Ns
Rear ankle turn (cm)	TBP	26,782±0,41^{b}	28,1±1,20^{a}	26,88±0,95^{b}	**
Rear stirrup turn (cm)	TPP	17,91±0,75 ^{b}	19,9±0,91a	18,1±0,29^{b}	***
Rear hoof turn (cm)	TSP	39,598±0,36^{b}	40,8±1,26^{a}	37,352±0,21^{c}	Ns
Live weight (Kg)	PV	428,955±46,64^{a}	416,035±29,38^{a}	377,64±33,72^{b}	*
Body proportion	RC	1,153±0,05^{a}	1,161±0,02^{a}	1,056±0,053^{b}	***
Compactness index	ICOM	2,809±0,24^{a}	2,764±0,134a	2,448±0,206^{b}	**
Baron and Crevet index	IBC	2,031±0,17^{a}	2,024±0,081a	1,723±0,159^{b}	***
Body profile index	ICP	0,981±0,03^{c}	1,165±0^{a}	1,02±0,019^{b}	Ns
Body index	IC	0,881±0,01^{c}	1,02±0 ^{a}	0,949±0,05^{b}	Ns
Relative cannon bone thickness index	IERC	0,125±0,00^{b}	0,132±0,00^{a}	0,119±0,00^{c}	***
Dactylo thoracic index	IDT	0,109±0,00	0,114±0,00	0,113±0,00	Ns
Height front to back	HDD	1,006±0,01^{c}	1,074±0 ^{a}	1,045±0,03^{b}	Ns

***: p<0.001; very highly significant difference
**: p<0.01; highly significant difference
*: p<0.05; significant difference
Ns : p>0.05 ; non-significant difference
a, b, c: the presence of different letters indicates that the values are significantly different at (p<0.05).

Characteristics of the Arabian-Barb horse: The Arabian-Barb horse, a medium-sized breed, typically weighs between 350 kg and 550 kg (Mariante *et al*., 2002 ; Boujnane *et al.*, 2008). Our study found the average body weight to be 416.03 kg, aligning closely with the weights reported by Mebarki *et al*. (2018) and Boujnane *et al*. (2008), but slightly exceeding the 401.0 kg reported by Guedaoura *et al*. (2011). These variations could be attributed to the number of animals studied, environmental factors, the physiological state of the mares at the time of measurement, and gender differences.

The height at the withers of the Arabian-Barb horse in our study is 152.6 cm, which is lower than the 154.15 cm reported by Mebarki *et al*. (2018), but higher

than the measurements reported by Boujnane *et al*. (2008) and Guedaoura *et al*. (2011).

The thoracic perimeter, a measure of the horse's chest size, was found to be 174.45 cm. This is similar to Mebarki *et al's*. (2018) findings and exceeds the measurements reported by Boujnane *et al*. (2008) and Guedaoura *et al*. (2011). This suggests that the Arab-Barb horse has a voluminous thorax (Mariante *et al*., 2002 ; Boujnane, 2008), a desirable trait for saddle horses with fast gaits (Marcenac *et al*., 1980 ; Boujnane, 2008). The circumference of the front cannon, a measure of the horse's lower leg, is 19.85 cm, which is larger than the measurements reported by Guedaoura *et al.* (2011), Mebarki *et al*. (2018), and Boujnane *et al*. (2008). The body ratio (PT/HG) of the Arabian-Barb horse is 1.161, indicating good thoracic development relative to its size (Mariante *et al*., 2002 ; Boujnane *et al*., 2008). The compactness index, a measure of the horse's density, is 2.764 kg/cm, classifying the Arabian-Barb horse as medium-sized (Khatouf, 2005; Mariante *et al*., 2002; Boujnane *et al*., 2008).

In terms of coat color, our study found a 10% prevalence of bay color, with chestnut, gray, and roan colors each present at a rate of 30%. The head profile of the Arab-Barb horses is predominantly straight (80%), with a smaller percentage showing concave (10%) and slightly concave (10%) profiles. The marked differences within the same population of Arab-Barb horses can be explained by factors such as physical exercise, environmental and breeding conditions, and the degree of Arab blood. We can distinguish three groups of Arab-Barb horses based on the degree of Arab blood: those with less than 25% Arab blood, those with between 25% and 75% Arab blood, and those with over 75% Arab blood. The Arab-Barb horse expresses all these qualities when the percentage of Arab blood does not exceed 50% (Benabdelmoumene, 2003). Therefore, a breeding program needs to be established where the resulting offspring have a degree of Arab blood between 25 and 75% in order to have a more homogeneous and performant population, which represents characteristics that are valued by their owners.

Characteristics of the Arabian Horse: This part of the study focuses on shedding some light on the characteristics of the Arabian horse as far as the weight, the height, and other qualities are concerned. The Purebred Arabian horse typically weighs between 350 and 400 kg (Gendry, 1973). Our model weighs 377.64 kg (Table 2), which is considered medium, and is lighter than the Egyptian Arabian horse, which weighs 467.0 kg (Machmoum *et al*., 2019).

The Arabian horse stands between 14.1 to 15.1 hands (57 to 61 inches, 145 to 155 cm) tall. Our model has a height at the withers of 147.25 cm (Table 2). The compactness index, estimated by the weight/height ratio at the withers, is 2.57 kg/cm, indicating a compact horse (Table 2). In comparison, the Iraqi Arabian horse measures 148.902 cm in height (Allawi *et al*., 2021).

The Arabian horse has changed very little over thousands of years. It is a compact animal, measuring from 1,42 to 1, 52 cm with some individual variations (Gendry, 1973). The distance between the internal angles of the eyes is 18.5 cm (Table 2), indicative of a horse with wide-set eyes and a broad forehead, topped by two well-spaced and nicely shaped ears.

The Arabian horse has a shorter and lighter neck compared to the Barb and the Arabian-Barb. Its neck is admired for its lightness and delicacy of throat (Gendry, 1973). The chest circumference is 162.8 cm, differing from the Egyptian Arabian's chest circumference of 178.6 cm (Machmoum *et al*., 2019). The distance between its front legs is 16 cm, indicating an open chest in front, a sign of great respiratory capacity.

The front cannon circumference is 19.4 cm, the hind fetlock circumference is 26.88 cm, and the hind pastern circumference is 18.1 cm. The body ratio is 1.056. The balance between the withers height and the croup height of the Arabian horse is indicated by a front-rear height of 1.045. The Arabian horse has an average metacarpus-thoracic index of 0.113, which falls between 0.105 and 0.115. This classifies it as a horse with a well-developed thorax in relation to its size. The compactness index of 2.448 indicates an adequate bone thickness in relation to weight, as described by Carroll and Huntington (1988) in riding horses.

Arabian horses are recognized for their distinctive coat colors, with bay, gray, chestnut, and black being the most prevalent. Markings or spotting patterns, typically white, are rare in Arabian horses and have traditionally been considered undesirable (Mayouf *et al*., 2011; Almarzook, 2018). Our model presents the dominance of the chestnut color at 45.28% and the bay color at 41.50%, with light bay, burnt bay, and chestnut bay. Gray comes in last position with a percentage of 11.32% out of a total of 53 Arabian horses. The shape of the horse's muzzle is mostly camus at 72% out of 53 Arabian horses, straight at 12%, and slightly concave at 16%, giving it a short and square head with a concave profile, a very beautiful and noble profile. The cephalic profile is mainly concave at 72% on 53 Arabian horses, straight at 12%, and slightly concave at 16%.

The head of the Arabian purebred is dry, with a clearly marked bone structure. The veins can be seen under the skin. The wide forehead is topped with two well-spaced and nicely drawn ears. Its short and often concave muzzle ends in a fine nose with very open nostrils. The eyes are large and wide-set, very expressive. The wide and flat forehead is another distinctive feature of the Arabian horse (Gendry, 1973).

Comparison between the Three Studied Breeds: When comparing the three studied breeds, namely the Barb, Arabian-Barb, and Arabian Purebred horses, several differences and similarities emerge.

In terms of size traits, the Barb and Arabian-Barb horses have an average withers height of 154.2 cm and 152.6 cm respectively, which is higher than that of the Arabian Purebred horses at 150.3 cm (Table 2). The average total length of the Barb is 155.2cm, differing from the results reported by Guedaoura *et al*., (2011). The Arab-Barb's total length is recorded as 151 cm, consistent with Guedaoura *et al*., (2011) but differing from Mebarki *et al.* (2018). The height at the croup is 150 cm in the Arabian-Barb, the same result reported by Guedaoura *et al*., (2011) but differs from 151.91 cm reported by Mebarki *et al*. (2018). The Barb horse, with a height at the croup of 152.9 cm, appears taller than the Arabian-Barb horse, both of which are taller than the Purebred Arab horse with a height at the croup of 148.5 cm.

When it comes to parameters related to measurements of lengths, significant differences ($p<0.001$) are observed between the three horse populations based on the measured lengths (Distance between internal angles of eyes, lower ear space, length of hind cannon) (Table 2). The neck length of the Barb and the Arabian-Barb horse is significantly ($p<0.05$) longer than that of the Purebred Arab horse, indicating a well-separated neck from the shoulders despite its muscular build. In terms of parameters related to circumferences, very highly significant differences at ($p<0.001$) can be marked concerning the measured circumferences (Table 2). The Barb-Arabian is thicker at the level of the hind pastern and also at the level of the front and hind hoof. These results differ from the results reported by Guedaoura *et al.* (2011), who claim that Barb-Arabian horses differ significantly from Barb horses only by the lengths of the upper bone rays (the neck, shoulder, and arm) which turn out to be more extended for the Barb.

The Arabian horse is less tight in its thoracic perimeter ($p<0.01$) compared to Arabian-Barb and Barb horses, but the latter two represent an important chest circumference. This study shows a very highly significant difference ($p<0.001$) between the three breeds studied regarding the lower neck circumference and the upper neck circumference, which are narrower in the Arabian Purebred horse compared to the Barb and the Barb-Arabian. It is observed that the neck of the Arabian horse is less thick than that of the Barb and the Arabian-Barb, indicating that the Arabian horse is finer and more elegant than the other two horses. The front cannon circumference, the front pastern circumference, the hind hoof circumference, the upper and lower leg circumference do not represent any significant difference among the three breeds studied.

A significant difference ($p<0.05$) is recorded for the lower space between the ears which appears wider in the Arabian-Barb probably due to the shape of its muzzle. The length of the back of the purebred Arabian of 50 cm is significantly lower than the length of the Barb which is 52.8 cm and the Arabian-Barb which is 52.66 ($p<0.05$) (Table 2). This difference can be expressed by the particularity of the Arabian horse which has 17 ribs instead of 18, 5 lumbar vertebrae instead of 6 and 16 coccygeal vertebrae instead of 18 in other horses (Gendry, 1973).

Live weight: The Barb and Arabian-Barb horses have significantly heavier live weights ($p<0.05$) calculated from the thoracic perimeter and the height at the withers compared to the Arabian Purebred horse. The Arabian horse is lighter, with a less thick neck, a straight or concave head profile, a short and high-set tail, and a more horizontal croup (Gaudois, 1989; Haras Nationaux Français, 2019).

Indices: The Arabian Purebred horse has lower body ratio, Baron and Crevet IBC index, and relative cannon thickness index IERC values ($p<0.001$) compared to the Barb and Barb-Arabian horses. The Arabian Purebred horse's compactness index ICm is significantly lower ($p<0.05$) than that of the Barb and Barb-Arabian horses. However, there are no significant differences in the dactylo-thoracic index, front and hind height index (HDD), and body index (IC).

Sex Differences: Sex significantly influences the height at the withers ($p<0.05$), with males generally taller than females. Females typically have a wider chest, indicative of a larger respiratory capacity, reflected in the greater distance between their front legs. Females also have a larger lower leg circumference than males, possibly due to males being more frequently used in sports and competitions.

Significant differences ($p<0.05$) were observed in males, characterized by longer neck lengths, arm lengths, and front limb distances, as well as higher Dactylo thoracic indices. Conversely, females exhibited larger anterior cannon girths. The analysis of breed and sex interactions revealed significant differences; males generally had greater heights at the withers compared to females, who typically presented with wider chests and larger lower leg circumferences. These differences were statistically significant ($p<0.05$), underscoring the impact of both breed and sex on the morphometric parameters measured.

Table 3. Variables influenced by gender.

Traits	Male			Female			
	Barb n=15	Arabian-Barb n=12	Arabian n=22	Barb n=27	Arabian-Barb n=20	Arabian n= 34	
Height at the withers (cm)	156,2±3,56[a]	154,4±3,29[a]	152,5±4,93[a]	152,2±4,09[b]	150,8±6,38[b]	148,1±2,46[b]	*
Neck length (cm)	65,33±2,05[a]	65±3,08[a]	61,8±4,15[a]	61,6±4,93[b]	60,8±2,17[b]	57,2±1,79[b]	Ns
Arm length(cm)	40,8±1,09[a]	39,2±1,64[a]	46±8,09[a]	39,14±0,92[b]	37,7 ± 3,31[b]	38,3±6,08[b]	*
Front limb distance (cm)	17,3±0,25[a]	16,4±1,81[a]	16±0[a]	16±0 [b]	14,3±2,86 [b]	16±0 [b]	*
Thoracic Perimeter (cm)	172,5±1,10 [b]	170,2 ±2,49 [b]	161,4±4,87 [b]	175,2±1,09 [a]	178,7 ±6,62 [a]	164,2 9,83 [a]	*
Anterior canon girth(cm)	19,36±0,08[b]	19,9±0,42[b]	17,2±0,27[b]	19,5±0[a]	19,8±1,52[a]	21,6±4,28[a]	*
Lower neckline (cm)	128,6±8,29	110,56±8,87	118,28±2,08	124,2±9,78	106,6±0	127,6±3,29	Ns
Lower leg turn (cm)	36,2±1,09 [a]	34,1±1,14 [a]	31,2±0 [a]	32,92±0,52[b]	35,3±0,97	31,16±0,08[b]	*
Rear hoof turn (cm)	40,1±0,54[a]	41,4±1,82[a]	37,28±0[a]	39,09±0,05[b]	40,2±0,57[b]	37,42±0,32[b]	*
Dactylo thoracic index	0,11±0,0[a]	0,11±0,0[a]	0,12±0,01[a]	0,10±0,00[b]	0,11±0,00[b]	0,10±0,00[b]	*

*** : p<0.001; very highly significant difference
** : p<0.01 ; highly significant difference
* : p<0.05 ; significant difference
Ns : P>0.05 ; non-significant difference
a, b, c : the presence of different letters indicates that the values are significantly different at (p<0.05).

Conclusions: The comparative analysis reveals that the Arabian-Barb crossbreed exhibits a harmonious blend of the desirable characteristics from both parent breeds, combining the finesse of the Arabian with the ruggedness of the Barb. This crossbreeding strategy is successful in producing a horse with an optimal mix of traits. The effects of sex and breed are significant, particularly in withers height, where males are generally taller, and females exhibit wider chests and larger lower limbs.

Acknowledgments: I would like to offer this work as a tribute to the late Prof. Halbouche, whose significant impact on my life deserves profound gratitude from me.

Conflict of Interest: The authors have declared no conflict of interest.

Author's contribution: All the authors have contributed to the study.

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