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Morphometric characteristics of the Barb horse in Algeria and associated variation factors

Características morfométricas del caballo Barbado en Argelia y factores de variación asociados

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ABSTRACT

The aim of this study was to contribute to the morphometric characterization of Algerian's Barb, to update its dimensional variables, to explore its specific traits and diversity, and to assess certain variation factors. For this purpose, a total of 52 Barb horses registered in the Algerian Studbook aged 3 years and older were subjected to 24 body measurements. Statistical analyses were conducted using a general linear model to assess the variation in these variables according to age, sex, head profile, and coat color. In addition, a principal component analysis was performed. The results were categorized into height, length, girth, weight, and body indices. The mean withers height and croup height were 150.8 ± 3.38 cm and 150.7 ± 3.50 cm, respectively, with an average body length of 150.0 ± 4.73 cm. These nearly equal values resulted in a profile body index of 1.01 ± 0.02, indicating a square shaped conformation. The mean chest girth and Fore cannon girth were 177.8 ± 8.73 cm and 19.63 ± 0.95 cm, respectively, resulting in a dactyl-thoracic index of 1.18 ± 0.05, reflecting a skeletal robustness consistent with the estimated body mass of 441.61 ± 50.85 kg. Analysis of the measurement variation revealed some significant differences ($p < 0.05$), particularly for the sub-sternal gap, shoulder height, shoulder length, arm length, distance between the inner eye angles, and cannon bone girth (Fore cannon girth and Hind cannon girth). In conclusion, all measured parameters were in accordance with the breed standard. However, comparison similar studies reveals noticeable disparities, reflecting a wide range of morphological expressions within the population classified as Barb horses.

Key words: Body indice; coat color; head profil; studbook; phenotypic variation.

RESUMEN

El objetivo de este investigacion era contribuir a la caracterización morfométrica del caballo Barb de Argelia, estudiar sus variables dimensionales, explorar sus características específicas y su diversidad, y evaluar sus determinados factores de variación. Un total de 52 caballos Barb registrados en el Studbook argelino y con una edad de 3 años o más, estaban objeto de una evaluación basada en 24 parámetros corporales. El estudio estadistico se realizó conforme a un modelo lineal general para evaluar la variación de las variables morfométricas en función de la edad, el sexo, el perfil cefálico y el color de la capa. Además, se realizó un análisis de componentes principales. Los resultados se clasificaron en variables de altura, longitud, perímetro, peso e índices corporales. La altura media a la cruz y la altura de la grupa estaban de 150,8 ± 3,38 cm y 150,7 ± 3,50 cm, respectivamente, con una longitud corporal media de 150,0 ± 4,73 cm. Estos valores casi iguales indicaron un índice corporal de perfil de 1,01 ± 0,02, lo que revela una conformación de proporciones cuadradas. El perímetro torácico medio y la circunferencia del hueso del cañón estaban de 177,8 ± 8,73 cm y 19,63 ± 0,95 cm, respectivamente, lo que condujo a un índice dáctilo-torácico de 1,18 ± 0,05, demostrando una robustez esquelética coherente con un peso corporal estimado de 441,61 ± 50,85 kg. El análisis de la variación de las medidas reveló algunas diferencias significativas ($p < 0,05$), en particular para la distancia subesternal, la altura del hombro, la longitud del hombro, la longitud del brazo, la distancia entre los ángulos internos de los ojos, y las circunferencias del hueso del cañón (circunferencia del hueso del cañón y HCG). En conclusión, todos los parámetros medidos estaban en conformidad con el estándar racial. Sin embargo, la comparación con estudios similares revela disparidades notables, lo que indica una amplia gama de expresiones morfológicas dentro de la población clasificada como caballos Barb.

Palabras clave: Indice corporal; studbook; perfil cefálico; color de capa; variación fenotípica

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INTRODUCTION

The Barb horse (*Equus caballus*) is a prominent representative of the equine heritage of Algeria and North Africa. This animal is renewed for its historical significance, docility, endurance, and its ability to adapt easily to a wide range of climates, from sub-Saharan Africa to Europe including the Maghreb, which is the cradle of the breed [1].

In Algeria, the Barb horse population, estimated at approximately 10,000 individuals [1 , 2], is not fully documented. It includes both horses that are officially identified and registered in the national studbook, as well as others exhibiting Barb-type characteristics but remaining unregistered. According to the FAO classification (DAD-IS database) [3], the breed is therefore considered not at risk of extinction.

Despite the existence of a World Organization known as the OMCB (*Oranisation Mondiale du Cheval Barbe*), established in 1989 in Algiers, which manages the breed standard [4 , 5], significant morphological variation is observed among horses classified as Barb, as shown by morphometric studies conducted in Algeria and North Africa [1 , 6 , 7 , 8]. This variation is shaped by environmental adaptations and human-driven selection pressures [2 , 5 , 9]. This phenotypic diversity presents challenges for standardized breed identification and conservation strategies.

The combination of linear and volumetric measurements, along with body indices, offers a replicable and objective means of assessing equine conformation. These parameters enable precise differentiation of skeletal and thoracic traits, reflect functional aptitudes related to speed, strength, and endurance, and assist in detecting structural anomalies [10 , 11].

The aim of this study is to contribute to the morphometric characterization of the Barb horse in Algeria, to update its dimensional parameters, and to explore its specific traits and morphological diversity through a standardized methodological approach.

MATERIALS AND METHODS

Animal material and study site

The study involved 52 purebred Barb horses aged ≥3 years, officially registered in the Algerian Studbook as purebred breeding stock. Sampling was purposive, based on verified pedigree. The animals were sourced from: 1) The National Stud farm of Chaouchaoua (Tiaret, NW Algeria); 2) ONDEEC (National Office for the Development of Equine and Camel Breeding) breeding depots in Tiaret and Constantine; 3) Private owners in Tébessa, Tiaret, El Bayadh, Mascara, and Aflou, with horses registered by ONDEEC.

Methodology

a) Identification: Each horse was identified by name, sex, age, birthplace, and photographs.

b) Qualitative Traits: Visual assessment included two traits: cephalic profile (straight, sub-convex, convex) and coat color (Chestnut, Bay, Black and other coat colors) [12].

c) Body Measurements: Twenty-four morphometric traits were recorded (FIG 1).

The following calibrated equipment was used: 1) A measuring stick (Old Mill Saddlery, Aluminium Horse Measuring Stick, United Kingdom [Northern Ireland]), for height measurements; 2) A spring tape (Prym, Spring Tape Measure Jumbo 300 cm/120 inch, Germany) for girth measurements; 3) A caliper (Aerospace, Stainless Steel Analog Vernier Caliper A120VC 0–3000 mm, China) for linear dimensions.

Each horse was placed squarely on flat even ground while being measured.

d) Data Processing: Descriptive statistics (mean, SD, min, max) were computed, considering the symbols are showed below FIG1.

Body mass (BM) was estimated using INRA (*Institut National de Recherche Agronomique*) formulas Martin-Rosset (1990) [13]: 1) Growing horses: BM = 4.5 × CG – 370; 2) Adults: BM = 4.3 × CG + 3.0 × WH – 785; 3) Brood mares: BM = 5.2 × CG + 2.6 × WH – 855.

Morphometric indices were calculated using formulas from several authors [8 , 9 , 10 , 11], including: 1) Body Index (BI) = CG / WH; 2) Body Profile Index (BPI) = WH / BL; 3) Compactness Index (CI) = BM / WH; 4) Relative Body Index (RBI) = BL / CG; 5) Dactyl-thoracic Index (DTI) = FCG / CG; 6) Chest Depth Index (CDI) = ChH / WH × 100; 7) Front-Back Height Index (FBH) = WH / CH.

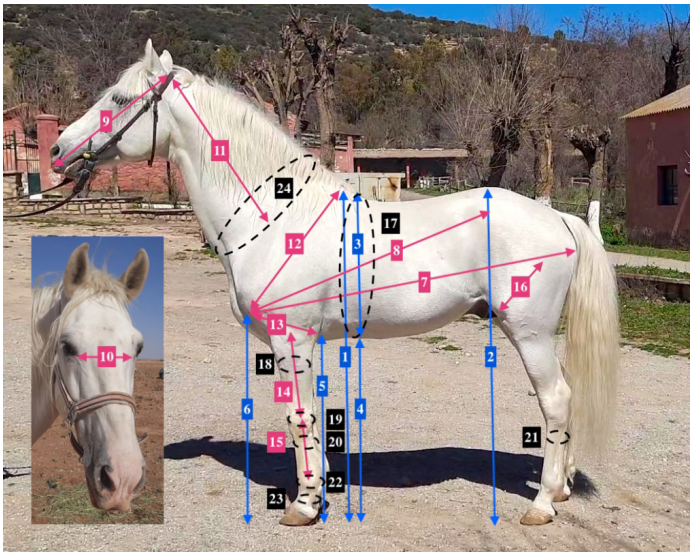

FIGURE 1. Morphometric measurements: 1- Height at the withers (WH); 2- Height at the croup (CH); 3- Chest height (ChH); 4- Sub-sternal gap (SSG); 5- Elbow height (EH); 6- Shoulder height (ShH); 7- Total body length (BL); 8- Scapulo-iliac length (SIL); 9- Head length (HL); 10- Distance between the inner eye angles (IEA); 11- Neck length (NL); 12- Shoulder length (SL); 13- Arm length (AL); 14- Fore-arm length (FAL); 15- Canon length (CL); 16- Thigh length (TL); 17- Chest girth (CG); 18- Fore-arm girth (FAG); 19- Knee girth (KnG);; 20- Front cannon girth (FCG); 21-Hind cannon girth (HCG); 22- Fetlock girth (FG); 23-Pastern girth (PG); 24- Neck girth (NG)

Statistical analysis

Analyses were performed in RStudio® (version 2024.09.1+394). A main effects model was fitted by using the General Linear Model (GLM) for testing the influence of age, sex, head profile, and coat color on the parameters: In that model: refers to the morphometric traits ; is the overall mean ; : refers to the age effect (young < 5 yr; adult ≥ 5 yr); : refers to the sex effect (male, female) ; : stans for head profile effect (straight, sub-convex, convex); : refers to the coat color effect (chestnut, bay, grey); and finally : is the residual effects of the uncontrolled sources of variation. As stated above, all terms of the model were considered fixed except for the error, which was assumed to be random and normal and independent distributed with mean 0 and common variance .

Principal Component Analysis (PCA) was performed on standardized data to explore variable interrelationships, retaining components with eigenvalues ≥1, using the FactoMineR and factoextra packages. Pearson correlation coefficients were also computed.

Significance thresholds were: P<0.05 (significant), *P*<0.01 (highly significant), P<0.001 (very highly significant), and 0.05 ≤ P < 0.10 (trend towards signification).

RESULTS AND DISCUSSION

Height measurements

The descriptive statistics for measurements are presented in TABLE I. The average withers height (WH) was 150.8 ± 3.38 cm, ranging from 144.0 to 159.5 cm. This value falls within the official breed standard (150–160 cm), although it remains slightly below the standard's mean of 155 cm [4 , 7]. It is comparable to the values reported by Rahal *et al.* [1], who described Barb horse WH as ranging between 147 and 157 cm.

The average height at the croup (CH) was 150.7 ± 3.50 cm. Although CH is not explicitly listed as a standalone trait in the official breed standard, the Barb is described as a square-shaped horse meaning WH, CH, and body length (BL) should be approximately equal. This proportional balance is confirmed by the present data (FIG. 2).

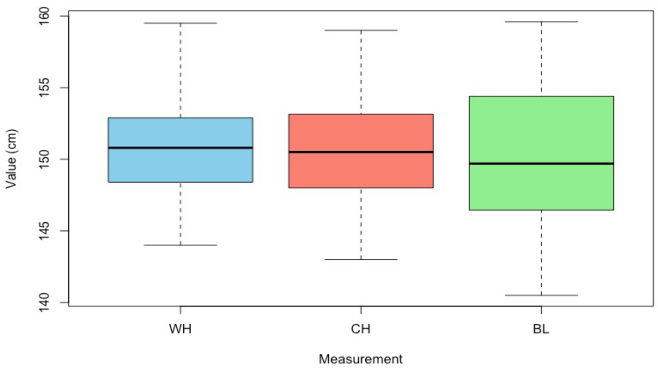

FIGURE 2. Distribution of Withers Height (WH), Croup Height (CH), and Body Length (BL)

Mean WH and CH in this study (150.8 and 150.7 cm, respectively) are slightly lower than previously reported values for Algerian Barb horses: 151.8 / 151.6 cm [1], 151.3 / 150.7 cm [8], and 152.5 / 150.1 cm [7]. They also fall below the averages recorded in Tunisia (155.7 / 154.9 cm) [6] and Morocco (155.1 / 155.9 cm) [1]. These differences likely reflect a combination of genetic and environmental influences, as well as sample composition.

A gradual decline in Barb horse height from east to west across Algeria has been documented [14 , 15]. While this trend may partly explain the difference observed with the Tunisian sample (from eastern side of Algeria), it does not apply to the Moroccan sample, which, despite located further west, did not include shorter horses.

These regional discrepancies raise questions about the comparability and representativeness of the Barb horse samples studied across North Africa. Although the measurement methods used in the three studies were similar, differences in sampling strategy, particularly regarding sex ratio, may account for the variation. Notably, the samples studied in Tunisia and Morocco involved predominantly breeding stallions (sex ratios of 2.73 and 4.11, respectively), whereas the present sample had a sex ratio of 1.73. This is particularly relevant, in light of the sex-related height differences reported in previous research [16].

WH and CH in Barb horses of this study are slightly lower than those recorded in Arabian Thoroughbreds born and raised in Algeria (152.15 cm and 151.61 cm respectively [17]). These findings confirm that Barb horses have a comparatively smaller stature.

When considered alongside breeds historically influenced by the Barb, such as the Pure Spanish Horse, Lusitano, and Mustang [18], as well as those from regions near its cradle (e.g., Iranian types), the Barb's WH places it in an intermediate phenotypic range. It is comparable to the Lusitano (151.20 cm) [19] and Spanish-Arabian (149.01 cm) [20], but lower than the Andalusian (157.8 cm) [21]. Barb horses also stand taller than Kurdish (145.9 cm) and Persian Arabian Thoroughbreds (146.9 cm), slightly below Turkmen Akhal-Teke (154.1 cm), and similar in height to Dareshouri (149.1 cm) and Egyptian Arabian Horses (149.7 cm) [22].

Length Measurements

The average body length (BL) was 150.0 ± 4.73 cm, nearly equal to the withers height (150.8 cm), confirming the square-shaped conformation described in the Barb breed standard, where WH, CH, and BL are expected to be approximately equal [4]. This mediolinear profile, typical of working horses, echoes the proportional balance already noted in the height measurements section and is supported by data from Tunisia [6] and Morocco [1], though it differs slightly from Algerian reports.

Compared to prior studies, the present BL is higher than that reported by Guedaoura *et al.* [8] (148.2 cm), but lower than the values reported by Rahal *et al.* [1] (157 cm), Benhamadi *et al.* [7] (160 cm), Chabchoub *et al.* [6] (155.5 cm) and Jary (151.1 cm) [1]. These discrepancies may stem from differences in sample composition, environmental conditions, genetic variability, or measurement technique. Notably, these earlier studies employed flexible measuring tapes which, by following the animal's contours, potentially inflate linear measurements. In

contrast, the present study used a caliper, which provides more anatomically precise, straight-line values.

Compared to other breeds, Barb horses exhibit longer BL than Hispano-Arabians (147.64 cm) [20] and Egyptian Arabians (147.1 cm) [22], but slightly less than Algerian Thoroughbred Arabians (152.82 cm) [17], and substantially shorter than Turkmen Yamut (162.5 cm), Akhal-Teke (163.9 cm), Iranian Arab (155.6 cm), and Dareshouri (155.0 cm) horses [22]. These findings confirm the Barb's compact morphology.

Limb measurements showed an average shoulder length (SL) of 58.28 ± 3.33 cm, arm length (AL) of 37.25 ± 1.58 cm, and forearm length (FAL) of 42.59 ± 1.96 cm. The SL was lower than that of Algerian Thoroughbred Arabians (63.01 cm) [17], a trait correlated with longer strides in sport horses. Conversely, the Barb shows greater AL than Arabians (30.90 cm) [17] and Lusitanos (30.44 cm) [19], suggesting enhanced stride amplitude and endurance. Similarly, FAL exceeds values in Arabians (31.8 cm) [17] and Lusitanos (37.36 cm) [17], highlighting breed-specific traits.

Cannon bone length (CL) in Barb horses averaged 26.62 cm, notably longer than in Algerian Arabians (18.8 cm) [17] and Lusitanos (22.06 cm) [19]. This reflects a functional adaptation: elongated distal limb bones are linked to stride length and endurance. Indeed, recent studies show a strong association between third metacarpal elongation and enhanced locomotor efficiency in modern equids [23].

Neck length (NL) was 70.27 cm, close to Hispano-Arabians (70.43 cm) [20] and slightly longer than in Algerian Arabians (67.75 cm) [19]. Head length (HL) reached 59.8 cm, exceeding that of Algerian Arabians (52.04 cm) [17], Hispano-Arabians (54.61 cm) [20], and several Iranian breeds [20], indicating a more elongated and robust cranial profile.

Scapulo-iliac length (SIL) averaged 112.6 ± 5.14 cm, indicative of a relatively short and stable back [24], consistent with the Barb breed standard [4]. In contrast, longer backs, while favouring stride amplitude, are associated with increased energy expenditure [25].

Peripheral Measurements

The average chest girth (CG) was 177.8 ± 8.73 cm, which meets the minimum threshold (≥170 cm) specified by the Barb breed standard [4], aligns closely with data reported in Algeria (177.6 cm) and Morocco (178.6 cm) [1], but exceeds those recorded in other Algerian studies (175 cm, 171.4 cm) [7 , 8], while remaining below the 181.6 cm observed in Tunisia [6]. This intra-breed variability may reflect differences in sample composition, conformation, muscular development, age, reproductive status, and environmental or management conditions [26].

Compared with other breeds, the Barb's CG is similar to that of the Hispano-Arabian (179.26 cm) [20], slightly higher than Akhal-Teke (174.6 cm) [22], and markedly greater than Algerian Arabians (166.44 cm) [17], Kurdish (170.2 cm), and Egyptian Arabians (163.3 cm) [22]. However, it remains lower than the Andalusian average (191.3 cm) [21]. A wider thorax anatomically accommodates larger cardiopulmonary structures, which may support increased athletic capacity and endurance [27].

Knee girth (KnG) averaged 30.81 ± 1.59 cm, surpassing Algerian Arabians (27.0 cm) [17], Knee girth (KnG) averaged 30.81 ± 1.59 cm, surpassing Algerian Arabians (27.03 cm) [17], and suggesting greater carpal development. While external girth does not necessarily reflect internal bone strength, enlarged carpal dimensions may be associated with enhanced joint stability, beneficial for locomotion on uneven terrain [28].

Fore cannon girth (FCG) was 19.63 ± 0,95 cm, exceeding both the 18 cm breed minimum [4] and Algerian Arabian's (18.3 cm) [17], a trait positively linked to enhanced load-bearing capacity and reduced post-exercise soreness [29]. Pastern girth (PG) reached 21.1 ± 0.92 cm outstriping Algerian Arabians (19.68 cm) [17], reflecting a robust leg thickness morphotype associated with jumping performance and mechanical resilience [27]. Taken together, these girth measures confirm the Barb horse's solid skeletal conformation, optimized for endurance, weight-bearing, and agility over challenging terrain [30].

Body Mass and Body Indices

The mean estimated body mass (BM) of Barb horses was 441.6 ± 24.6 kg (range: 341.5–570.6 kg), aligning with the values reported in Algeria [1 , 7 , 8], but exceeding those recorded in Tunisia [6] and in Morocco [1]. The presence of pregnant mares, whose thoracic dimensions tend to be broader, likely contributed to this higher mean (TABLE I).

Barb horses proved heavier than Lusitano (415.5 kg) [19], Akhal-Teke (420.5 kg) [22], Algerian Thoroughbred Arabians (395.8 kg) [17], and Egyptian Arabians (328.7 kg) [22], yet remained lighter than Andalusians (511.0 kg) [21]. Their compactness index (CI) of 2.93 kg/cm exceeded the values reported by Chabchoub *et al.* [6] (2.795) and Benhamadi *et al.* (2.688) [7], as well as those of Algerian Arabians (2.60 kg/cm) [17], confirming a notably solid skeletal structure that reflects the breed's historical workhorse aptitude.

The average body index (BI) was 1.18 ± 0.05, indicating compact conformation. This value closely matches the Andalusian average (1.21) [21] and surpasses that of Algerian Arabians (1.09) [17]. The profile body index (PBI) was 1.01 ± 0.02, which is close to those previously reported values [1],[9], and consistent with the square-shaped morphology of the breed [31], while the relative body index (RBI) was 0.84, lower than that of Algerian Arabian horses (0.91 ± 0.03) [17], again emphasizing compactness.

Other indices reinforced this trend: the height ratio index (HRI) balanced at 1.00 ± 0.01, pointing to structural symmetry compatible with endurance [6 , 18]; and the dactyl-thoracic index (DTI) averaged 0.11 ± 0.005, within the range that suggests adequate bone mass relative to thoracic volume [11].

TABLE I
Morphometric measurements and indices of Barb horses in Algeria (n=52)

Parameter	M + SD	Min	Max	Parameter	M + SD	Min	Max
WH	150.8 ± 3.38	144.0	159.5	**CG**	177.8 ±8.73	159	199
CH	150.7 ± 3.50	143.0	159.0	**FAG**	42.18 ±3.16	35.5	48.3
ChH	72.02 ± 2.88	66.2	81.5	**KnG**	30.81 ±1.59	28.5	34.2
SSG	78.81 ± 3.36	68.0	85.5	**FCG**	19.63 ±0.95	18	22
EH	87.69 ± 2.57	81.0	94.0	**HCG**	21.10 ±0.92	19	23.4
ShH	103.3 ± 2.70	98.00	110.0	**FG**	26.79 ±1.21	24	29.2
BL	150.0 ± 4.73	140.5	159.6	**PG**	18.98 ±1.00	17.2	21
SIL	112.6 ± 5.14	98.8	124.6	**NG**	120±8.71	102	137.5
HL	59.80 ± 1.71	56.0	63.0	**BM**	441.6 ± 50.9	341.5	570,6
IEA	16.20 ± 0.61	15.0	18.0	**BI**	1.18 ± 0.05	1.06	1.32
NL	70.27 ± 2.48	64.6	75.7	**PBI**	1.01 ± 0.02	0.95	1.07
SL	58.28 ±3.33	50.2	64.2	**RBI**	0.84 ± 0.03	0.78	0.92
AL	37.25 ±1.58	34.9	41.0	**FBH**	1.00 ± 0.01	0.98	1.02
FAL	42.59 ±1.96	39.5	48.2	**CI**	2.93 ± 0.31	2.3	3.8
CL	26.62 ±1.46	23.5	30.7	**DTI**	0.11 ± 0.005	0.098	0.126
TL	37.57 ±2.20	32.0	42.5	**CDI**	47.75 ± 1.74	44.07	53.1

WH = Height at the withers; CH = Height at the croup; ShH = Shoulder height; ChH = Chest height; SSG = Sub-sternal gap; EH = Elbow height; BL = Total body length; SIL = Scapulo-iliac length; HL = Head length; NL = Neck length; SL = Shoulder length; AL = Arm length; FAL = Fore-arm length; CL = Cannon length; PL = Pastern length; TL = Thigh length; IEA = Distance between the inner eye angles; CG = Chest girth; NG = Neck girth; FAG = Fore-arm girth; KnG = Knee girth; FCG = Front cannon girth; HCG = Hind cannon girth; FG = Fetlock girth; PG = Pastern girth.BM= body mass; BI=Body Index ; BPI=Body Profile Index; RBI= Relative Body Index; FBH= Front-Back Height Index; CI= Compactness Index ; DTI= Dactyl-thoracic Index; CDI= Chest Depth Index

Variation factors

a) Effect of Age

The Morphometric comparison between young (< 5 years) and adult (≥ 5 years) horses revealed overall similarity in most height and length parameters. This is likely due to the predominance of selected riding-type individuals, a low number and the male-biased sample of young horses. However, younger horses showed a significantly wider SSG and greater EH ($p<0.05$), indicating a narrower chest and relatively longer limbs. In contrast, adults had significantly thicker fore cannon bones, along with non-significant increases in CG, HCG, and FG (TABLE III) consistent with advancing skeletal maturity.

These patterns mirror findings in Arabian horses, where PG and FCG continue to increase past age four while other traits such as WH and BL stabilize [27]. Pantaneiro horses likewise show lower CG and FCG girths in 2 to 3 year olds compared to those aged 4 to 9 years, attributed to ongoing postural and musculoskeletal development [32]. Although the present CG differences did not reach significance, the similar tendencies reinforce that conformation assessments are most reliable after four years of age.

While morphometric traits plateau by age five, composite indices reveal continued skeletal maturation in Barb horses. Adults show significantly higher values in BM, BI, PBI, CI, and CDI (TABLE II), reflecting thoracic and mass distribution shifts which were not detected by isolated metrics. Leveraging such indices could refine the timing of performance assessments and breeding selections.

b) Effect of Sex

Males generally exhibited higher values than females across most morphometric traits and greater morphological variability, whereas females were more homogeneous. Only ShH differed significantly (103.9 cm *vs.* 102.3 cm, $P < 0.05$). These results concur with those of Benhamadi *et al.* [7] but differ from those of Chabchoub *et al.* [6], likely due to selection-criteria differences between breeding and utility horses.

In terms of length, SIL was marginally greater in males, yet only SL ($P < 0.05$) and AL ($P < 0.01$) reached significance, contributing to the elevated ShH and EH observed. These differences are consistent with the known effects of sex hormones on skeletal growth and performance traits [6].

Peripheral measurements showed clear sexual dimorphism. Except for CG and FAG both higher in females, males had significantly larger values overall, indicating a more robust skeletal frame. The higher CG and FAG in females may result from the inclusion of pregnant mares, as gestation induces thoracic expansion through hormonal and postural changes [33].

Chest-girth–derived indices (BM, BI, RBI, CI, CDI) were significantly higher in females, whereas DTI was higher in males (TABLE II). These trends reflect gestational mass redistribution and thoracic inflation in late-term mares. No sex differences emerged for Body Profile or Front-Back Height Indices indicating that overall body symmetry and front-back proportions are preserved across sexes reaffirming the Barb's conformational balance.

c) Effect of Cephalic Profile

the horses in this study were classified into three cephalic profile types: straight (32.7%), sub- convex (30.8%), and convex (36.5%). The predominance of convex and sub-convex profiles (67.3%) aligns with previous findings [4 , 8], which reported around 60% convex profiles. The proportion of straight profiles (~33%) was lower than the 40% reported by the Guedaoura *et al.* [8] and the 49% noted by Rahal *et al.* [1]. Concave or sub-concave profiles were absent, consistent with earlier reports in Algeria [1 , 7 , 8] and Tunisia [6].

Morphometric differences among head types were generally subtle. However, two traits varied significantly: the sub-sternal gap (SSG) and interorbital width (AIE). Convex-headed horses exhibited the widest SSG (80.06 ± 3.11 cm) compared to straight (78.99 ± 3.05 cm) and sub-convex types (77.14 ± 3.43 cm), hinting at a link between cranial curvature and thoracic depth. AIE was greater in straight-headed individuals (16.49 ± 0.76 cm; $P < 0.01$), possibly reflecting a broader cranial base. All other linear and peripheral traits remained consistent across profiles.

Peripheral traits did not differ significantly between groups, though convex-headed horses tended to have slightly higher FCG, suggesting possible variations in mass distribution.

In terms of indices, convex-headed horses displayed significantly higher RBI and DTI ($p < 0.05$), while CDI peaked in sub-convex individuals (TABLE III). These patterns support previous suggestions that cephalic profile may correlate with certain thoracic and skeletal proportions [34],[35].

d) Effect of coat color

According to the updated coat color classification [12], grey was the most prevalent color in the studied population, representing 70% of the horses. Bay and chestnut coats followed, representing 17.30% and 11.53%, respectively, while black and white coats were rarely observed. This distribution is consistent with historical data from the Algerian Studbook [4], as well as studies [1 , 8], which reported 71% and 88% grey horses, respectively. Similar findings were also recorded in Moroccan populations [1]. Conversely, a predominantly chestnut coat (73%) was reported among Tunisian Barb horses [6], possibly reflecting regional variation in selection preferences.

Morphometric comparisons revealed no statistically significant differences across coat color groups for most traits, suggesting that pigmentation had minimal impact on overall conformation within this population. Neverthless, emerging research has highlighted the potential for pleiotropic genes to affect both coat color and morphologic characteristics [36 , 37], warranting further exploration.

Among linear measurements, only AIE differed significantly, with chestnut horses displaying broader skulls (16.77 ± 0.87 cm; $p < 0.01$). Height traits remained unaffected. In peripheral measurements, only FAG showed a significant variation, being higher in bay horses ($p = 0.002$), which may reflect underlying links between coat color and muscular development or due to sampling effects.

Estimated body weight and morphometric indices did not vary significantly by coat color, reinforcing the conclusion that pigmentation alone is not a reliable predictor of conformation in Barb horses.

TABLE II
Morphometric Measurements and Indices in Barb Horses: Descriptive Statistics by Variation Factors

Variation Factor	Age		Sex		Cephalic Profile			Coatcolor		
parameter	Adult (43)	Young (9)	Males (n=33)	Females (n=19)	Straight (n=17)	Convex (n=19)	Sub-convex (n= 16)	Grey (36)	Chestnut (6)	Bay (9)
WH	150.7 ± 3.47^{a}	151.6 ± 2.95^{a}	151.3 ± 3.60^{a}	149.9 ± 2.83^{a}	151.7 ± 4.09^{a}	151.1 ± 3.34^{a}	149.6 ± 2.23^{a}	150.8 ± 3.22^{a}	150.8 ± 5.33^{a}	151.3 ± 2.98^{a}
CH	150.5 ± 3.62^{a}	151.4 ± 2.92^{a}	151.2 ± 3.47^{a}	149.8 ± 3.47^{a}	151.5 ± 4.30^{a}	151.2 ± 3.35^{a}	149.1 ± 2.18^{a}	150.8 ± 3.37^{a}	149.9 ± 5.76^{a}	150.8 ± 2.66^{a}
ChH	72.36± 2.83^{a+}	70.39 ± 2.71^{a+}	71.29 ± 2.78^{a}	73.28 ± 2.66^{a}	72.73 ± 2.86^{a}	71.01 ± 2.89^{a}	72.46 ± 2.72^{a}	71.71 ± 3.10^{a}	71.68 ± 1.54^{a}	73.42 ± 2.56^{a}
SSG	78.31 ± 3.27^{a}	81.22 ± 2.80^{b}	80.04 ± 2.72^{a}	76.67 ± 3.34^{a}	78.99 ± 3.05^{ab}	80.06 ± 3.11^{a}	77.14 ± 3.43^{b}	79.08 ± 2.85^{a}	79.07 ± 4.43^{a}	77.84 ± 4.67^{a}
EH	87.42 ± 2.65^{a}	88.94 ± 1.72^{a}	88.15 ± 2.68^{a+}	86.88 ± 2.20^{a+}	88.56 ± 2.36^{a}	87.35 ± 2.91^{a}	87.16 ± 2.24^{a}	87.47 ± 2.48^{a}	89.08 ± 3.80^{a}	87.60 ± 2.10^{a}
ShH	103.0 ± 2.60^{a}	105.1 ± 2.64^{b}	103.9 ± 2.52^{a}	102.3 ± 2.75^{b}	103.5 ± 2.45^{a}	103.9 ± 3.13^{a}	102.6 ± 2.37^{a}	103.3 ± 2.88^{a}	103.8 ± 3.08^{a}	103.2 ± 1.99^{a}
BL	150.4 ± 4.75	148.5 ± 4.60	149.9 ± 4.23	150.2 ± 5.62	149.7 ± 4.61^{a}	151.3 ± 4.54^{a}	148.8 ± 5.00^{a}	150.30 ± 4.57^{a}	148.80 ± 5.91^{a}	150.34 ± 4.94^{a}
SIL	113.1 ± 4.89^{a}	109.8 ± 5.73^{a}	111.8 ± 4.51^{a}	113.9 ± 5.99^{a}	111.4 ± 5.38^{a}	114.6 ± 3.83^{a}	111.5 ± 5.79^{a}	112.84 ± 5.37^{a}	112.08 ± 4.37^{a}	112.96 ± 4.06^{a}
HL	59.93 ± 1.65^{a}	59.19 ± 1.98^{a}	59.59 ± 1.94^{a}	60.17 ± 1.17^{a}	59.54 ± 2.03^{a}	60.35 ± 1.58^{a}	59.43 ± 1.40^{a}	59.88 ± 1.74^{a}	60.13 ± 2.11^{a}	59.47 ± 1.40^{a}
IEA	16.22 ± 0.63^{a}	16.09 ± 0.53^{a}	16.21 ± 0.69^{a}	16.17 ± 0.43^{a}	16.49 ± 0.76^{a*}	16.22 ± 0.54^{a*}	15.86 ± 0.26^{b*}	16.15 ± 0.56^{a}	16.77 ± 0.87^{b}	15.91 ± 0.23^{c}
NL	70.28 ± 2.51^{a}	70.23 ± 2.48^{a}	70.58 ± 2.56^{a+}	69.73 ± 2.29^{a+}	70.61 ± 2.99^{a}	70.49 ± 2.23^{a}	69.65 ± 2.19^{a}	70.10 ± 2.59^{a}	70.70 ± 2.59^{a}	70.73 ± 2.27^{a}
SL	58.47 ± 3.37^{a}	57.39 ± 3.16^{a}	58.22 ± 3.18^{a}	58.39 ± 3.67^{b}	58.88 ± 3.85^{a}	57.94 ± 2.89^{a}	58.07 ± 3.36^{a}	58.19 ± 2.96^{a}	56.65 ± 5.18^{a}	59.79 ± 3.34^{a}
AL	37.38 ± 1.58^{a}	36.60 ± 1.51^{a}	37.65 ± 1.46^{a*}	36.54 ± 1.57^{b*}	37.28 ± 1.81^{a}	37.03 ± 1.47^{a}	37.48 ± 1.52^{a}	37.18 ± 1.60^{a}	37.65 ± 1.85^{a}	37.16 ± 1.55^{a}
FAL	42.43 ± 2.02^{a}	43.39 ± 1.50^{a}	42.92 ± 1.95^{a}	42.02 ± 1.88^{a}	43.25 ± 2.50^{a}	42.22 ± 1.65^{a}	42.33 ± 1.54^{a}	42.79 ± 1.82^{a}	42.15 ± 2.83^{a}	41.87 ± 1.86^{a}

CL	26.60 ± 1.45^{a}	26.69 ± 1.60^{a}	26.82 ± 1.58^{a+}	26.26 ± 1.18^{a+}	27.06 ± 1.81^{a}	26.64 ± 1.10^{a}	26.11 ± 1.35^{a}	26.61 ± 1.44^{a}	27.25 ± 2.17^{a}	26.34 ± 1.03^{a}
TL	37.73 ± 2.33^{a}	36.82 ± 1.27^{a}	37.43 ± 1.85^{a}	37.83 ± 2.74^{a}	37.81 ± 2.50^{a}	37.67 ± 1.85^{a}	37.21 ± 2.33^{a}	37.66 ± 2.16^{a}	36.45 ± 3.55^{a}	37.98 ± 1.19^{a}
CG	178.8 ± 8.15^{a}	173.0 ± 10.26^{a}	176.1 ± 8.40^{a}	180.8 ± 8.67^{b}	180.5 ± 8.12^{a}	175.7 ± 10.06^{a}	177.5 ± 7.31^{a}	177.6 ± 8.66^{a}	175.7 ± 9.22^{a}	181.0 ± 8.91^{a}
FAG	42.29 ± 3.24^{a}	41.67 ± 2.83^{a}	42.02 ± 2.86^{a}	42.47 ± 3.68^{b}	42.25 ± 3.43^{a}	43.00 ± 2.57^{a}	41.14 ± 3.38^{a}	42.35 ± 2.56^{a*}	38.58 ± 3.68^{b*}	44.11 ± 3.45^{c*}
KnG	30.86 ± 1.62^{a}	30.58 ± 1.52^{a}	31.56 ± 1.43^{a***}	29.49 ± 0.80^{b***}	31.17 ± 1.68^{a}	31.05 ± 1.47^{a}	30.14 ± 1.52^{a}	30.75 ± 1.53^{a}	31.03 ± 2.24^{a}	30.94 ± 1.61^{a}
FCG	19.76 ± 0.95^{a}	19.02 ± 0.66^{b}	19.9 ± 0.92^{a***}	19.16 ± 0.80^{b***}	19.67 ± 0.77^{a}	19.96 ± 1.02^{a}	19.19 ± 0.90^{a}	19.58 ± 1.00^{a}	19.73 ± 1.19^{a}	19.83 ± 0.61^{a}
HCG	21.21 ± 0.94^{a+}	20.58 ± 0.64^{a+}	21.36 ± 0.91^{a***}	20.64 ± 0.76^{b***}	21.36 ± 0.92^{a}	21.08 ± 0.89^{a}	20.84 ± 0.93^{a}	21.08 ± 0.85^{a}	21.40 ± 1.72^{a}	21.03 ± 0.57^{a}
FG	26.89 ± 1.21^{a}	26.33 ± 1.15^{a}	27.2 ± 1.11^{a***}	26.09 ± 1.06^{b***}	26.85 ± 1.01^{a}	27.03 ± 1.16^{a}	26.46 ± 1.43^{a}	26.71 ± 1.23^{a}	26.63 ± 1.63^{a}	27.33 ± 0.71^{a}
PG	19.09 ± 1.03^{a+}	18.47 ± 0.73^{a+}	19.15 ± 0.95^{a***}	18.69 ± 1.05^{b***}	18.84 ± 0.92^{a}	19.13 ± 1.13^{a}	18.96 ± 0.97^{a}	18.95 ± 1.04^{a}	18.85 ± 1.31^{a}	19.28 ± 0.67^{a}
NG	120 ± 8.08^{a}	120.0 ± 11.84^{a}	122.8 ± 8.82^{a***}	115.1 ± 6.01^{b***}	122.5 ± 9.32^{a}	117.4 ± 7.59^{a}	120.4 ± 8.92^{a}	118.8 ± 8.10^{a}	119.3 ± 11.72^{a}	124.6 ± 8.73^{a}
BM	448.2 ± 49.0^{a}	410.4 ± 50.4^{b}	425.6 ± 43.34^{a*}	469.4 ± 51.95^{b*}	456.2 ± 47.50^{a}	429.9 ± 60.65^{a}	439.9 ± 39.5^{a}	439.6 ± 51.2^{a}	429.5 ± 46.2^{a}	463.5 ± 51.6^{a}
BI	1.19 ± 0.05^{a}	1.14 ± 0.06^{b}	1.16 ± 0.05^{a*}	1.21 ± 0.05^{b*}	1.190 ± 0.051^{a}	1.162 ± 0.053^{a}	1.187 ± 0.05^{a}	1.178 ± 0.052^{a}	1.165 ± 0.031^{a}	1.197 ± 0.063^{a}
BPI	1.00 ± 0.02^{a}	1.02 ± 0.03^{b}	1.01 ± 0.02^{a}	1.00 ± 0.03^{a}	1.014 ± 0.026^{a}	0.999 ± 0.018^{a}	1.006 ± 0.03^{a}	1.004 ± 0.025^{a}	1.013 ± 0.016^{a}	1.007 ± 0.030^{a}
RBI	0.84 ± 0.03^{a}	0.86 ± 0.03^{a}	0.85 ± 0.03^{a}	0.83 ± 0.03^{b}	0.830 ± 0.027^{a*}	0.863 ± 0.030^{b*}	0.839 ± 0.03^{a*}	0.847 ± 0.033^{a}	0.848 ± 0.020^{a}	0.832 ± 0.034^{a}
FBH	1.00 ± 0.01^{a}	1.00 ± 0.01^{a}	1.00 ± 0.01^{a}	1.00 ± 0.01^{a}	1.001 ± 0.008^{a}	0.999 ± 0.006^{a}	1.003 ± 0.01^{a}	1.000 ± 0.007^{a}	1.006 ± 0.004^{a}	1.003 ± 0.009^{a}
CI	2.97 ± 0.30^{a}	2.70 ± 0.30^{b}	2.81 ± 0.25^{a***}	3.13 ± 0.32^{b***}	3.005 ± 0.294^{a}	2.842 ± 0.363^{a}	2.941 ± 0.26^{a}	2.913 ± 0.315^{a}	2.844 ± 0.214^{a}	3.065 ± 0.349^{a}
DTI	0.111± 0.01^{a}	0.110± 0.01^{a}	0.113± 0.01^{a***}	0.106 ± 0.01^{b***}	0.109 ± 0.006^{a}	0.114 ± 0.007^{b}	0.108 ± 0.01^{a}	0.110 ± 0.007^{a}	0.112 ± 0.006^{a}	0.110 ± 0.008^{a}
CDI	48.03 ± 1.66^{a}	46.43 ± 1.54^{b}	47.11 ± 1.36^{a}	48.88 ± 1.78^{b}	47.94 ± 1.38^{ab}	47.01 ± 1.643^{a}	48.44 ± 1.94^{b}	47.55 ± 1.65^{a}	47.58 ± 1.221^{a}	48.57 ± 2.307^{a}

Different letters in columns (a,b,c) indicate differences in p<0,05 – Signification codes: p<0,0001(***),p<0.001 (**),p<0.01 (*), p< 0.1 (+).
WH = Height at the withers; CH = Height at the croup; ShH = Shoulder height; ChH = Chest height; SSG = Sub-sternal gap; EH = Elbow height; BL = Total body length; SIL = Scapulo-iliac length; HL = Head length; NL = Neck length; SL = Shoulder length; AL = Arm length; FAL = Fore-arm length; CL = Cannon length; PL = Pastern length; TL = Thigh length; IEA = Distance between the inner eye angles; CG = Chest girth; NG = Neck girth; FAG = Fore-arm girth; KnG = Knee girth; FCG = Front cannon girth; HCG = Hind cannon girth; FG = Fetlock girth; PG = Pastern girth.BM= body mass; BI=Body Index ; BPI=Body Profile Index; RBI= Relative Body Index; FBH= Front-Back Height Index; CI= Compactness Index ; DTI= Dactyl-thoracic Index; CDI= Chest Depth Index

PCA and correlation

The Principal Component Analysis (PCA) summarized the 25 initial variables into two main components explaining 52.57% of the total variance (37.91% for axis 1 and 14.66% for axis 2). The correlation circle (FIG. 3) shows that the variables CH and WH are strongly correlated with each other and contribute mainly to axis 1, suggesting a gradient related to the height of the Barb horse. Axis 2 is mainly structured by the variable SSG, associated with trunk height.

Pearson correlation analysis between the different measurements (TABLE III) revealed strong correlations (r > 0.70) as follows: Withers height (WH) is strongly correlated with croup height (CH) (r = 0.95; P< 0.001) and shoulder height (ShH) (r = 0.70; P< 0.001); Body length (BL) is strongly correlated with the scapulo-iliac length (SIL) (r = 0.81; P< 0.001), reflecting a homogeneous pelvis length; Fetlock girth (FG) is strongly correlated with four measurements: Knee girth (KnG) (0.74), Hind cannon girth (HCG) (0.76), Fore cannon girth (FCG) (0.80), and pastern girth (PG) (0.72); Fore Cannon girth (FCG) is correlated with hind cannon girth (HCG) (0.77).

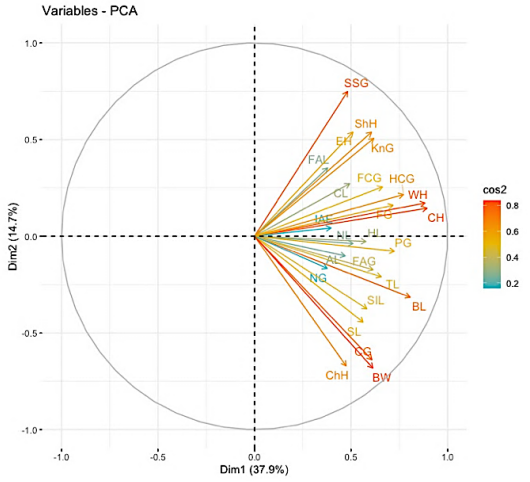

FIGURE 3. PCA correlation circle. WH = Height at the withers; CH = Height at the croup; ShH = Shoulder height; ChH = Chest height; SSG = Sub-sternal gap; EH = Elbow height; BL = Total body length; SIL = Scapulo-iliac length; HL = Head length; NL = Neck length; SL = Shoulder length; AL = Arm length; FAL = Fore-arm length; CL = Cannon length; PL = Pastern length; TL = Thigh length; IEA = Distance between the inner eye angles; CG = Chest girth; NG = Neck girth; FAG = Fore-arm girth; KnG = Knee girth; FCG = Front cannon girth; HCG = Hind cannon girth; FG = Fetlock girth; PG = Pastern girth

TABLE III
Pearson coefficients (r) showing strong correlations (r > 0.70) between the different parameters

r	CH	ChH	SIL	HCG	FG	BM	CG
WH	0.95	0.7	/	/	/	/	/
SSG	/	0.73	/	/	/	/	/
BL	/	/	0.81	/	/	/	/
KnG	/	/	/	0.76	0.74	/	/
HCG	/	/	/	/	0.76	/	/
FCG	/	/	/	0.77	0.8	/	/
PG	/	/	/	0.75	0.72	/	/
ChH	/	/	/	/	/	0.74	/
BM	/	/	/	/	/	/	0.96

WH = Height at the withers; CH = Height at the croupChH = Chest height; SSG = Sub-sternal gap; BL = Total body length; SIL = Scapulo-iliac length; CG = Chest girth; KnG = Knee girth; FCG = Front cannon girth; HCG = Hind cannon girth; FG = Fetlock girth; PG = Pastern girth; BM = Estimated body mass

CONCLUSION

This morphometric assessment of Barb horses confirmed general conformity to breed standards, with slightly lower average values than official references. The population showed moderate stature (mean withers height: 150.8 cm), a robust thoracic region (chest girth: 177.8 cm), and a strong bone structure (mean fore cannon girth: 19.63 cm). The square-shaped conformation and high compactness index (2.93 kg/cm) support the breed's reputation for endurance and agility.

Morphological differences between age groups were limited, likely reflecting selective pressures rather than developmental divergence. Sexual dimorphism appeared mainly in shoulder and limb dimensions, and while head profile and coat color followed traditional distributions, they showed limited influence on overall conformation.

Compared to related breeds, the Barb is more compact than Oriental types (e.g., Arabian, Akhal-Teke), yet lighter than Iberian horses (e.g., Lusitano, Andalusian). Its morphology is closest to the Spanish-Arabian, combining robustness and refinement. This intermediate yet distinctive conformation sets the Barb apart from both Oriental and Iberian types, affirming its versatility and historical adaptability.

Principal component analysis and trait correlations confirmed internal harmony among body proportions, particularly in height and limb traits. Altogether, the Barb horse exhibits a unique blend of resilience, balance, and manoeuvrability, reinforcing its status as a vital component of Algeria's equine genetic heritage.

Conflict interests statement

The authors declare that they have no conflicting interests.

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