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RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Craniometric and Morphometric Characterization of Ouled Djellal Algerian White Arab Sheep

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10.18805/ag.DF-639

ABSTRACT

Background: In zooarchaeology, reference collections are essential for identifying skeletal remains and for predicting measurements of living animals. To date, the archaeozoological studies in Algeria are still limited and morphometric reference datasets of local breeds are yet to be established. This study aimed to reveal the correlations between measurements of living animals and their skulls.

Methods: A total of 30 females of the Ouled Djellal Algerian White Arab breed were analyzed: 15 adults and 15 young adults. Eight external body measurements were taken before slaughter and the live weight was estimated. After slaughter, the heads were collected, meticulously cleaned, weighed and measured. Sixteen craniometric measurements were taken and two indices were calculated.

Result: The differences between the mean values of young adults and adults were not statistically significant ($p>0.05$), except for wither height, naso-dental oblique length (CL31), greatest palatal breadth (CB14), greatest breadth across the premaxillae (CB18) and least height of the occipital (CH5). Young adults have a higher neurocranium and are more massive, whereas adults have a wider viscerocranium. Correlations between cranial and external measurements were partially significant, predominantly in adults. The strongest correlation was observed between the thoracic perimeter and condylobasal length ($p<0.0001$). These results provide a new reference dataset for archaeozoology.

Key words: Osteometry, Ouled djellal, Skull, Zooarchaeology.

INTRODUCTION

Even though infrequent in Algeria, zooarchaeological excavations have uncovered sheep skull remains, providing valuable information on animals exploited by ancient civilizations for meat, milk and wool (Kherbouche *et al*., 2016; Merzoug *et al*., 2016). However, the lack of modern references on local breeds complicates comparisons with current populations. The skull, an essential part of the skeleton, plays a vital role in taxonomy and understanding changes due to selection (Marzban Abbasabadi *et al*., 2020; Sathapathy *et al*., 2022; Sathapathy *et al*., 2021). Its unique structure in each animal enables species and breed distinction and allows for examining individual differences on a finer scale.

The Algerian White Arab sheep, known as “Ouled Djellal”, is the typical sheep of the Algerian steppe and high plains. This breed is the most numerous among Algerian sheep, with about 12 million heads, accounting for 63% of the sheep population (Feliachi *et al*., 2003). Originating from the town of Ouled Djellal, approximately 100 km Southwest of Biskra, from which it derives its name. Phenotypically, it is characterized by its size, slender appearance, thin head, sub-convex or convex profile, long and hanging ears and white skin. It has long limbs suited for walking and white, refined and less coarse wool. The breed is primarily used for meat production, is well-adapted to the nomadic lifestyle and arid regions and is known for its remarkable long-distance walking ability (Ami, 2014; IANOR, 2007).

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How to cite this article: BOUKERROU, M., RIDOUH, R., DJEGHAR, A.E., CHAABI, A.Z., TEKKOUK-ZEMMOUCHI, F., BABELHADJ, B., EVIN, A. and GUINTARD, C. (2024). Craniometric and Morphometric Characterization of Ouled Djellal Algerian White Arab Sheep. Agricultural Science Digest. doi: 10.18805/ag.DF-639

Submitted: 01-07-2024 **Accepted:** 02-09-2024 **Online:** 10-10-2024

This study is part of a series of osteo-biometric research on Algeria’s native ruminants, including sheep (Ami, 2014; Guintard and Tekkouk-Zemmouchi, 2010), goats (Guintard *et al*., 2018; Ridouh *et al*., 2019) and camels (Babelhadj *et al*., 2016; Dib *et al*., 2024). Though the White Arab breed is the most widespread in Algeria, its osteometry is little studied. Ami (2014) focused on its craniometry, while Guintard and Tekkouk-Zemmouchi (2010) studied its metapods. However, no studies have yet explored the potential relationship between cranial measurements and those taken on live animals.

This study aims to establish correlations between external body measurements of live animals and craniometric measurements to create a reference for zooarchaeology, where measurements of live animals are unknown. Additionally, it aims to position the White Arab breed among other sheep breeds of French origins (Guintard and Fouché, 2008), categorizing them into groups such as rustic, meat, or dwarf, thereby enhancing understanding of the breed characteristics.

MATERIALS AND METHODS

This study analyzed 30 White Arab female sheep, including only apparently healthy individuals. All subjects were collected from Ain Fakroun and Teleghma slaughterhouses (North-east of Algeria) between March 2022 and May 2023. Two age groups were defined: young adults (YA) aged 2 to 4 years and adults (A) over 4 years old. The research was conducted at the Gestion Santé et Productions Animales Research Laboratory in the Institute of Veterinary Sciences of El-Khroub. Before slaughter, eight external measurements on the living animals were taken using a tape measure (in centimeters), including: wither height (WH), scapulo-ischial length (SIL), thoracic perimeter (TP), cannon perimeter (CP); head length (hL), head width (hW), ear length (eL) and ear width (eW) (Fig 1). In addition, live weight (LW, in kilograms) was estimated by barymetry method, according to the equations of Rasamisoa (1988): LW= 0.635 CT - 23.026 et LW = 0.7536 SIL - 19.2234. After slaughter, the heads were collected, numbered for identification, linked to the external data of the animals and then prepared by dissecting the soft tissues. Further, the bones were boiled for several hours, cleaned with running water and air-dried. Each skull was labelled and numbered to match its data sheet to secure the consistency of the data. Skull weight (SW) was recorded using a balance in grams. Sixteen craniometric measurements were taken, listed in Table 1 and illustrated in Fig 2A-D, using a ruler (lengths CL1, CL2), a 0.02 mm precision digital caliper and a thickness compass (CH6) in millimeters, according to the methods of Ridouh *et al.* (2019) and Von den Driesch (1976).

Two indices (RC5 and RC7) were calculated from cranial measurements. RC5 was calculated by dividing the least frontal breadth by the total length (CB8/CL1) $\times$ 100. RC7 was calculated by dividing the least height of the occipital by the total length (CH5/CL1) $\times$ 100. The results obtained were recorded in Excel 2019®.

All statistical analyses were performed using R (Team, 2023) *via* the R Studio 4.3.1® interface. Descriptive statistics mean (m), minimum (min) and maximum (max) were calculated for each age class and the total population (TP). Variability was estimated using the standard deviation (σ) and coefficient of variation (CV% = (σ/m) $\times$ 100), freeing the measure from unit dependence.

With a sample of 30 individuals, the Wilcoxon-Mann-Whitney test was first applied, with a significance threshold of $p<0.05$. Pearson's correlation coefficient (r) was then evaluated for each pair of variables, using thresholds: 0-0.10 for low correlation, 0.10-0.39 for a weak correlation, 0.40-0.59 for a moderate correlation, 0.60-0.79 for a strong correlation and 0.80-1 for a very strong correlation, along with p-values to assess the significance of the correlations across the population. Then, the 2-way ANCOVA evaluated the homogeneity of the correlation between young adults and adults.

Finally, the White Arab breed was compared to French breeds analyzed by Guintard and Fouché (2008), using bivariate analysis CB19 = f(CL2) and categorizing it as either meat, rustic, or dwarf breed.

RESULTS AND DISCUSSION

Univariate analysis

Table 2 shows the morphometric description for the two age groups and for the total population. The differences in mean values between young adults and adults were non-significant, except for the wither height (p = 0.04).

The means values recorded for the White Arab breed in this study, including live weight (47.72 kg), wither height (87.13 cm) and thoracic perimeter (110.40 cm), are comparable to those reported by Guintard and Tekkouk-Zemmouchi (2010), who recorded 45.1 kg, 80.7 cm and 112.6 cm, respectively. Whereas, Djaout *et al.* (2018) and Dekhili and Aggoun (2013) reported lower wither height

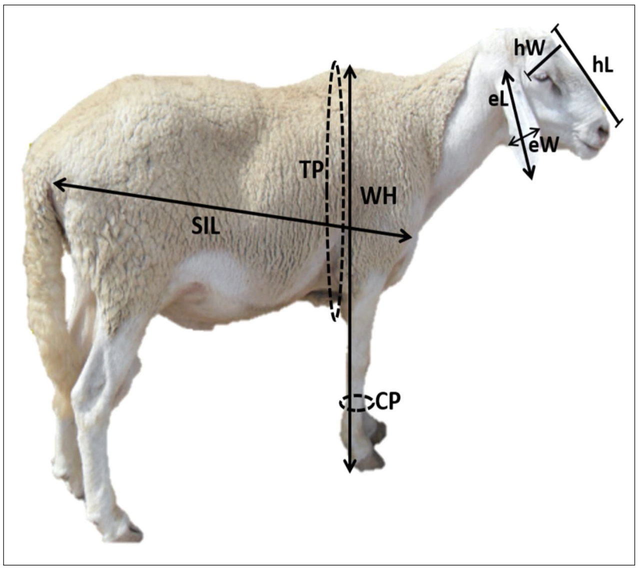


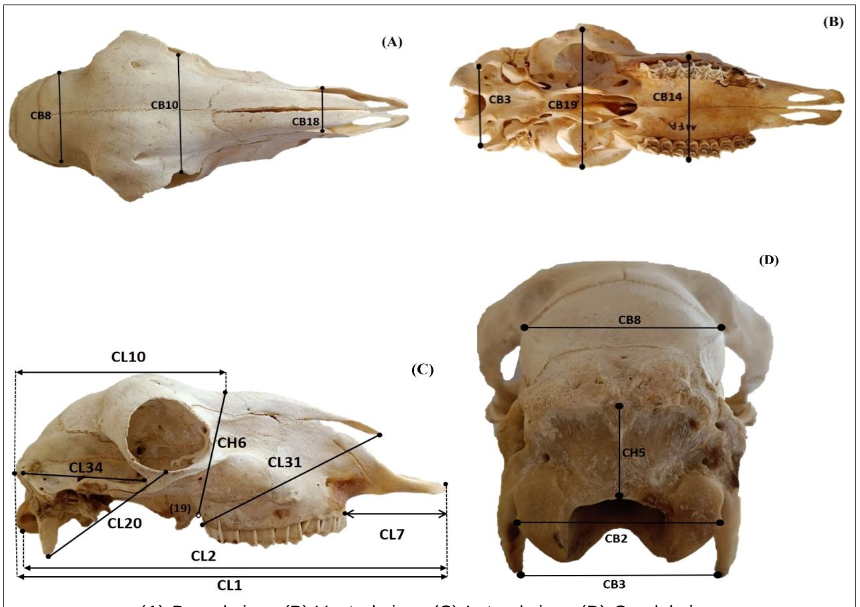
Fig 1: External body measurements taken on live animals.

values of 79.64 cm and 60.9 cm, respectively. The live weight observed in our study falls within the expected standard range of 42 to 81 kg, although the wither height appears slightly above with values varying from 61 to 82 cm (IANOR, 2007).

Table 3 summarizes the craniometric measurements and the two calculated indices. The differences in mean values between young adults and adults were non-significant except for CL31, CB14, CB18 and CH5. Young adults had higher CL31, related to the eruption of the third upper molar and CH5, indicating a higher neurocranium. Adults had higher CB14 and CB18, indicating a wider viscerocranium.

Overall variability for craniometric measurements was low, with CV% ranging from 3.66% to 15.05%. It has to be mentioned that adults showed higher CV%, in skull weight, CB18 and CL7, indicating a higher heterogeneity and a late bone development.

For the craniometric parameters such as total length (CL1), condylobasal length (CL2) and oblique length of the



(A) Dorsal view, (B) Ventral view, (C) Lateral view, (D) Caudal view.

Fig 2: Measurements of the skull.

Table 1: Craniometric measurements and descriptions.

Measurements	Denominations	Descriptions
CL1	Total length	Acrocranion - Prosthion
CL2	Condylobasal length	Aboral border of the occipital condyles - Prosthion
CL7	Oblique length of the muzzle	Premolare - Prosthion
CL10	Median frontal length	Acrocranion - Nasion
CL20	Orbit base to jugular process length	Orbit base - Jugular process
CL31	Naso-dental oblique length	Between the midpoint of the line joining the most oral points of the nasal bones and the most aboral points of the alveoli of the last molar teeth
CL34	Temporal fossa Length	Between the most oral points of the temporal fossa and the most aboral points of the temporal fossa, on the occipital bone
CB2	Greatest breadth of the occipital condyles	Between the most lateral points of the occipital condyles
CB3	Greatest breadth at the bases of the paraoccipital processes	Between the most ventral points of jugular processes
CB8	Least frontal breadth	Euryon - Euryon
CB10	Least breadth between the orbits	Entorbitale - Entorbitale
CB14	Greatest palatal breadth	Between the most lateral points of the dental alveoli
CB18	Greatest breadth across the premaxillae	Nasointermaxillare- Nasointermaxillare
CB19	Zygomatic breadth	Zygion - Zygion
CH5	Least height of the occipital	Opisthion - Acrocranion
CH6	Splanchnocranial height	Staphylion - Nasion

muzzle (CL7), the White Arab breed showed values comparable to or higher than Hasmer and Hasak of Turkey (Can *et al*., 2022), Xisqueta of Spain (Parés *et al*., 2010), Female Zell of Iran (Marzban Abbasabadi *et al*., 2020), Sharri of Macedonia (Jashari *et al*., 2021), French breeds (Guintard and Fouché, 2008), Iranian Native (Monfared, 2013), Bardhoka Autochthonous of Kosovo (Gündemir *et al*., 2020), Morkaraman and Tuj of Turkey (Özcan *et al*., 2010) and South Karaman of Turkey (Özüdoğru *et al*., 2022). The exception was the Konya Merino of Turkey, which had a greater total skull length (Özüdoğru *et al*., 2023).

However, for the median frontal length (CL10), the White Arab breed presented the lowest value compared to the Bardhoka Autochthonous of Kosovo (Gündemir *et al*., 2020), French breeds (Guintard and Fouché, 2008), Konya Merino of Turkey (Özüdoğru *et al*., 2023), Xisqueta of Spain (Parés *et al*., 2010) and Hasmer and Hasak of Turkey (Can *et al*., 2022).

Regarding widths, such as the least breadth between the orbits (CB10) and the greatest palatal breadth (CB14), the White Arab breed exhibited values comparable to or lower than those observed in the other breeds mentioned. Consequently, the skulls of the White Arab breed are characterized by being longer and narrower with a shorter neurocranium.

The values of the two indices were slightly higher in young adults due to increased CL1 in adults. Even though

Table 2: Descriptive statistics of external body measurements for the total population and each age group.

Groups		Young adults n= 15	Adults n=15	Total population n=30	p YA - A
LW	m	48.18	47.26	47.72	
	Min-Max	43.63-52.97	41.66-52.42	41.66-52.97	0.547
	σ	2.68	3.0	2.84	
	CV%	5.57	16.37	5.95	
SIL	m	90.47	88.73	89.60	
	Min-Max	83.00-98.00	83.00-97.00	83.00-98.00	
	σ	4.72	4.43	4.58	0.279
	CV%	5.22	4.99	5.12	
WH	m	88.60	85.67	87.13	
	Min-Max	82.00-95.00	80.00-91.00	80.00-95.00	
	σ	3.91	3.04	3.75	0.04
	CV%	4.41	3.55	4.30	
TP	m	110.73	110.00	110.40	
	Min-Max	103.00-118.00	98.00-120.00	98.00-120.00	
	σ	5.55	6.78	6.10	0.0884
	CV%	5.01	6.17	5.53	
CP	m	8.67	8.80	8.73	
	Min-Max	8.00-9.50	8.00-11.00	8.00-11.00	
	σ	0.59	0.82	0.70	0.843
	CV%	6.78	9.31	8.06	
hL	m	24.53	24.83	24.68	
	Min-Max	23.00-26.00	22.00-27.00	22.00-27.00	
	σ	0.83	1.55	1.24	0.434
	CV%	3.40	6.26	5.00	
hW	m	20.13	20.43	20.28	
	Min-Max	18.00-22.00	18.00-23.00	18.00-23.00	
	σ	1.06	1.24	1.14	0.533
	CV%	5.27	6.06	5.63	
eL	m	19.57	19.13	19.35	
	Min-Max	17.00-23.00	15.00-23.00	15.00-23.00	
	σ	1.57	1.70	1.62	0.584
	CV%	8.02	8.86	8.37	
eW	m	8.97	8.80	8.88	
	Min-Max	8.00-10.00	7.50-10.00	7.50-10.00	
	σ	0.67	0.65	0.65	0.574
	CV%	7.44	7.38	7.34	

young adults' heads appeared to be more massive, there was a non-significant difference (p = 0.061).

Bivariate analysis

Correlations in the total population

By the whole of the correlations in external body measurements, in craniometric measurements and between external and cranial measurements, 174 out of 378 correlations were significant.

Craniometric measurements

Most lengths were moderately to strongly correlated with each other, particularly between CL1, CL2 and CL7 (r>0.79) with significant p-values, except for CL31 with CL10 and CL20. Similarly, most widths were correlated with each other, except for CB8 with CB2, CB3 and CB10 and CB14 with CB2. Additionally, most lengths showed moderate to strong and significant correlations with most widths, e.g., CL34 and CB18 (r = 0.67), as shown in Fig 3A.

Furthermore, concerning the height measurements, CH6 had significant moderate to strong coefficients with lengths, *e.g.*, CH6 and CL7 (r = 0.78) (Fig 3B).

The correlation between CL1 and CL10 was found to be higher in the White Arab breed (r = 0.69) than in the Mehraban sheep of Iran (r = 0.36) (Karimi *et al.*, 2011). Yet, it was lower than in the South Karaman sheep of Turkey (r = 0.84) (Özüdoğru *et al.*, 2022). Additionally, the White Arab breed exhibited correlations between CL2 and CL7 and between CL1 and CB10, with coefficients of r = 0.83 and r = 0.60, respectively. These values were similar to those observed in the Konya Merino sheep of Turkey (r = 0.88) (Özüdoğru *et al.*, 2023) and the Mehraban sheep of Iran (r = 0.60) (Karimi *et al.*, 2011), respectively.

Between external and cranial measurements

A strong correlation (*i.e.*, r≥0.60) was observed between some external measurements and certain cranial lengths and widths. The strongest correlation and the most significant was found between thoracic perimeter (TP) and condylobasal length (CL2) (r = 0.69) with p<0.0001 (Fig 5C). Significant correlations were identified between live weight and the cranial measurements of CL1, CL2 and CB8, with correlation coefficients equal to 0.43, 0.48 and 0.39, respectively. Thoracic perimeter showed correlations with all cranial lengths (r values ranging from 0.38 to 0.69), the width CB10 (r = 0.36) and the height CH6 (r = 0.45). Cannon perimeter was correlated with most cranial lengths and widths, excluding CL10, CL20, CB8, CH6 and SW. Head measurements were correlated with the cranial measurements CL1, CL2, CB3 and CB10. Additionally, head length was also correlated with CL7, CL10, CB14 and RC5, while head width showed a correlation with CB18 and SW. Ear length (eL) was correlated with CL1, CL2, CL31 and CH6, but eW had more correlations, including with various lengths (CL1, CL2, CL31, CL34), some widths (CB2, CB8, CB18) and height CH6. However,

Table 3: Descriptive statistics of craniometric measurements.

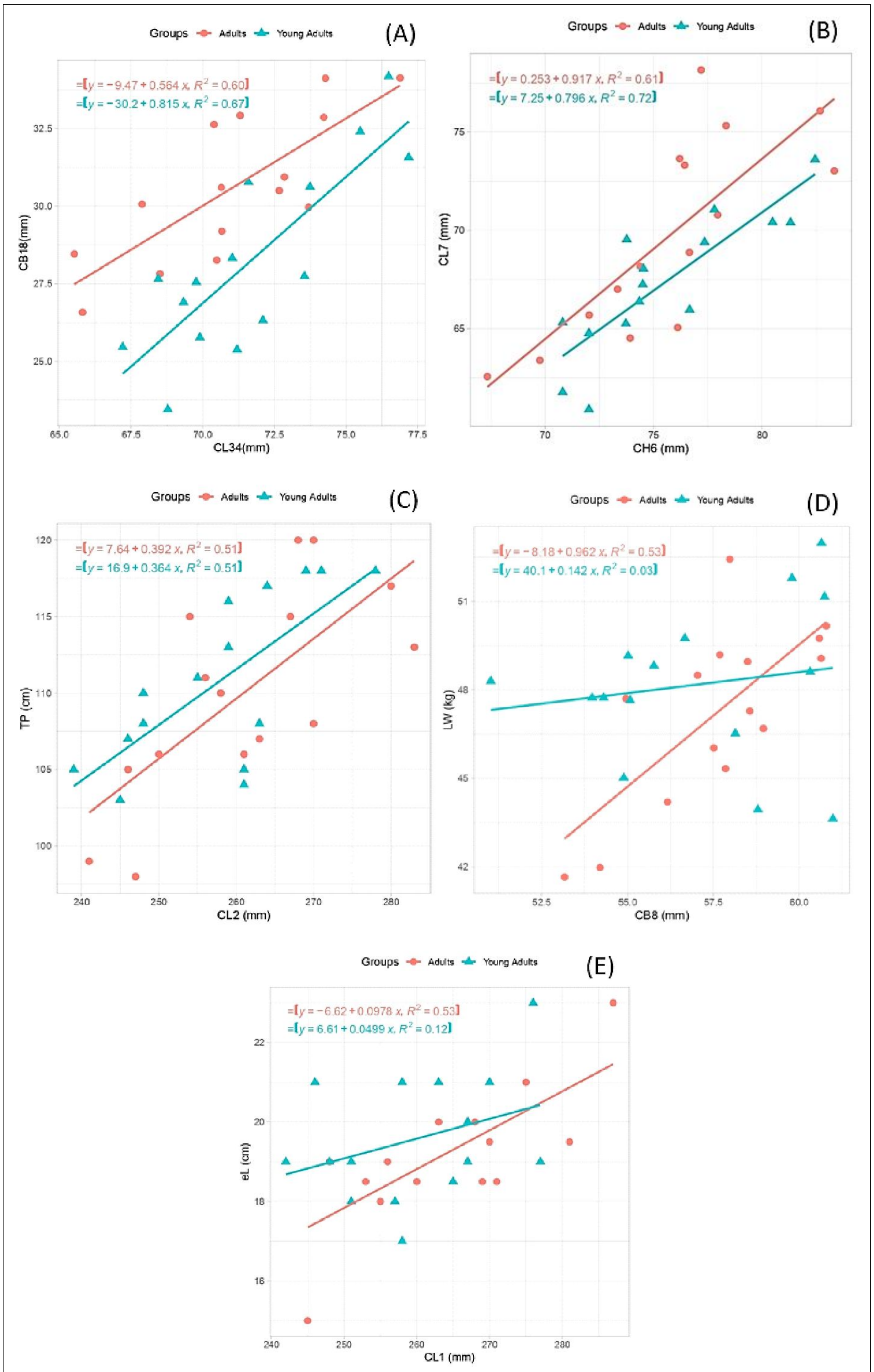
Groups		CL1	CL2	CL7	CL10	CL20	CL31	CL34	CB2	CB3	CB8	CB10	CB14	CB18	CB19	CH5	CH6	SW	RC5	RC7
YAN=15	m	259.73	257.73	67.34	121.18	93.46	119.88	71.72	50.37	51.84	57.08	79.77	68.16	28.27	106.41	28.03	75.50	293.00	21.99	10.81
	Min	242.00	239.00	60.89	111.31	88.55	111.33	3.02	45.91	44.16	51.02	73.30	64.63	23.45	102.25	26.14	70.81	254.00	19.88	9.89
	Max	277.00	278.00	73.61	133.63	99.80	128.67	67.21	53.83	57.51	60.98	84.64	73.68	34.18	117.26	30.16	82.44	336.00	24.29	11.76
	σ	10.75	10.87	3.51	5.67	2.91	4.91	77.18	2.63	3.26	3.07	3.82	2.68	3.02	3.61	1.23	3.73	23.94	1.21	0.65
	CV%	4.14	4.22	5.21	4.68	3.12	4.10	4.21	5.23	6.29	5.39	4.79	3.93	10.67	3.40	4.37	4.94	8.17	5.48	6.02
AN=15	m	263.27	260.93	69.71	123.35	93.59	116.06	71.05	50.17	53.80	57.64	80.60	70.34	30.60	108.00	26.82	75.71	304.07	21.92	10.20
	Min	245.00	241.00	62.56	111.45	87.09	105.28	65.52	44.41	50.30	53.17	73.32	65.54	26.58	100.67	24.15	67.34	238.00	19.56	8.99
	Max	287.00	283.00	78.16	139.13	103.79	123.50	76.88	54.45	57.97	60.79	86.49	76.32	34.13	118.20	29.98	83.33	455.00	23.61	11.60
	σ	12.57	12.31	5.00	6.29	4.76	4.78	3.20	3.11	2.43	2.28	3.65	2.81	2.33	4.18	1.76	4.24	59.53	0.94	0.71
	CV%	4.78	4.72	7.18	5.10	5.09	4.12	4.50	6.20	4.51	3.95	4.53	3.99	7.62	3.87	6.56	5.60	19.58	4.29	6.96
TPN=30	m	261.50	259.33	68.52	122.26	93.53	117.97	71.39	50.27	52.82	57.36	80.19	69.25	29.44	107.20	27.42	75.61	298.53	21.96	10.50
	Min	242.00	239.00	60.89	111.31	87.09	105.28	65.52	44.41	44.16	51.02	73.30	64.63	23.45	100.67	24.15	67.34	238.93	19.56	8.99
	Max	287.00	383.00	78.16	139.13	103.79	128.67	77.18	54.45	57.97	60.98	86.49	76.32	34.18	118.20	30.16	83.33	455.00	24.29	11.76
	σ	11.63	11.52	4.41	5.99	3.88	5.14	3.07	2.83	3.00	2.67	3.70	2.91	2.90	3.92	1.61	3.93	44.93	1.06	0.74
	CV%	4.45	4.44	6.44	4.90	4.15	4.36	4.30	5.63	5.67	4.66	4.61	4.21	9.86	3.66	5.88	5.19	15.05	4.84	7.02
pYA-A		0.48	0.533	0.267	0.25	0.838	0.044	0.744	0.935	0.161	0.775	0.709	0.019	0.029	0.152	0.033	0.74	0.95	0.935	0.061

scapulo-ischial length (SIL) and wither height (WH) showed non-significant correlations.

Correlations by age

Among all the correlations tested, strong relationships (*i.e.*, r≥0.60) were more prevalent in adults (N=168) than in young individuals (N=106) (Fig 4). Out of 168 pairs, 60 were between cranial and external body measurements, indicating that the adult's skulls align more closely with their body measurements.

The 2-way ANCOVA results, presented in Table 4, reveal notable differences in correlation strength between



(A) CB18 =f(CL34), (B) CL7=f(CH6), (C) TP=f(CL2), (D) LW=f(CB8), (E) eL=f(CL1).

Fig 3: Example of scatterplots with linear regression for adults and young adults.

adults and young adults for certain pairs of external and cranial variables. These findings highlight the importance of considering age when interpreting the relationships between external and cranial variables. Pairs of variables with stable and moderate correlation coefficients were found within the total population and young adults, while elevated correlations were observed within adults, *e.g.*, between live weight and CB8 (Fig 3D) and ear length and CL1 (Fig 3E). Conversely, other pairs exhibited stable and moderate coefficients for the total population and adults but were elevated in young adults, *e.g.*, between the cannon perimeter and CB18. These results indicate that the strength of correlation between cranial and external measurements varied significantly within the two age groups and across all specimens, suggesting that age, along with other zootechnical factors, significantly impacted some of these relationships.

However, some pairs showed moderate to strong correlations and remained stable across the three categories (young adults, adults and all specimens),

Table 4: Correlation analysis and age-related variability.

Var1	Var2	Total population	Adults	Young adults	p-values
WH	eL	0.34	-0.10	0.67	0.016
CL1	LW	0.43	0.60	0.30	0.417
CL1	eL	0.52	0.73	0.34	0.298
CL2	LW	0.48	0.61	0.40	0.531
CL2	eL	0.51	0.68	0.36	0.368
CL7	hL	0.46	0.40	0.57	0.915
CL7	eL	0.33	0.63	0.03	0.167
CL10	TP	0.52	0.53	0.56	0.937
CL20	TP	0.49	0.40	0.69	0.21
CL20	CL34	0.38	0.64	-0.04	0.025
CL20	CB18	0.28	0.62	-0.06	0.012
CL31	CP	0.38	0.62	0.23	0.119
CL31	hL	0.31	0.27	0.65	0.808
CL31	hW	0.38	0.64	0.28	0.202
CL31	eL	0.52	0.62	0.44	0.422
CL34	TP	0.50	0.68	0.28	0.167
CB2	CP	0.49	0.39	0.69	0.556
CB2	hL	0.21	-0.02	0.78	0.109
CB3	TP	0.34	0.60	0.20	0.101
CB3	CP	0.48	0.60	0.41	0.143
CB3	hL	0.42	0.29	0.66	0.956
CB3	eL	0.35	0.61	0.28	0.158
CB3	eW	0.33	0.62	0.25	0.181
CB8	LW	0.39	0.73	0.16	0.031
CB8	SIL	0.35	0.58	0.24	0.235
CB8	TP	0.27	0.57	0.03	0.063
CB8	eW	0.54	0.47	0.63	0.986
CB10	CP	0.53	0.65	0.38	0.164
CB10	hW	0.48	0.60	0.33	0.292
CB10	eW	0.40	0.59	0.27	0.353
CB14	CP	0.49	0.73	0.17	0.04
CB14	hL	0.46	0.56	0.28	0.155
CB18	CP	0.63	0.62	0.73	0.359
CB18	eW	0.45	0.35	0.72	0.449
CB19	CP	0.48	0.70	0.12	0.057
CH6	SIL	-0.16	0.18	-0.53	0.048
CH6	CP	0.49	0.56	0.39	0.463
CH6	hL	0.36	0.24	0.63	0.66
CH6	eL	0.48	0.73	0.18	0.118
CH6	eW	0.41	0.55	0.27	0.54
PCr	CP	0.48	0.65	-0.06	0.153

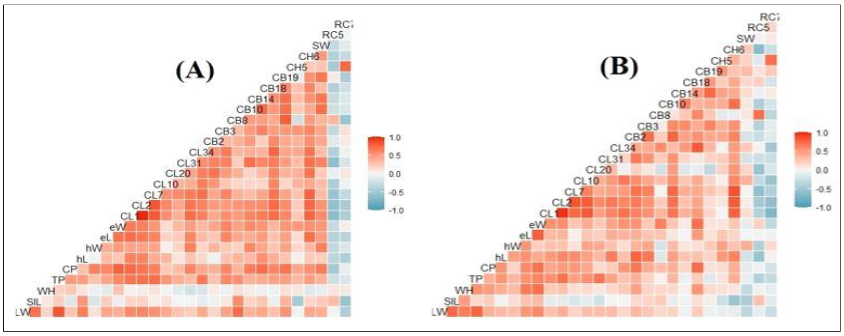


Fig 4: Correlation matrices by age: (A) adults, (B) young adults.

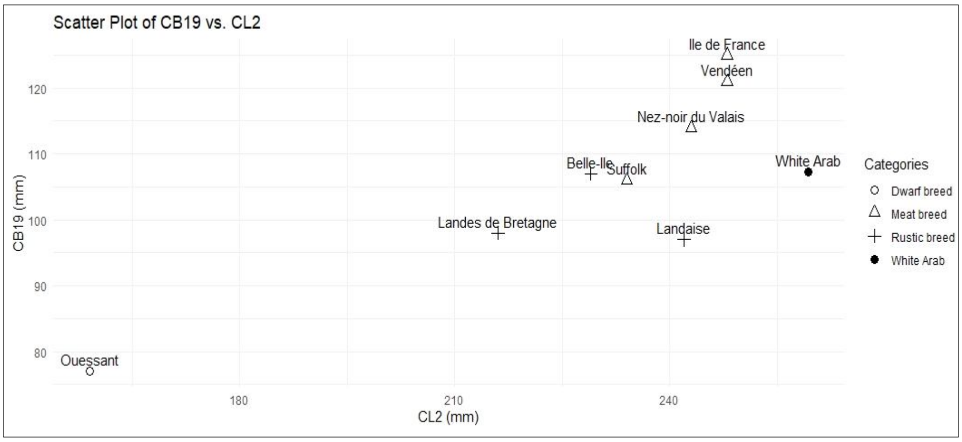


Fig 5: Position of the white arab breed within French breeds.

highlighting relationships that were not influenced by age. *e.g*., between the condylobasal length (CL2) and certain external measurements such as thoracic perimeter, head length and ear width. This finding was particularly interesting given that the Algerian White Arab breed is distinguished by its characteristic head and ear shapes and sizes (IANOR, 2007).

The scatter plot, shown in Fig 5, positions the White Arab breed in the upper right quadrant between the rustic and meat categories, highlights its dual quality as both a rustic and meat-producing breed, in accordance with the literature references and confirms its characteristics previously reported by Feliachi *et al.* (2003) and Chekkal *et al.* (2015).

CONCLUSION

Our results have shown that it is possible to estimate one craniometric measurement from another measurement taken on skull fragments found in zooarcheological excavations. More interestingly, it is also possible to infer a measurements of the standing animals of ancient civilisations based on craniometric measurements. For example, the thoracic perimeter can be estimated from the Condylobasal length (CL2). Also, significant correlations were more pronounced in adults than in young adults, indicating that adult skulls exhibit more coherence with both external and cranial measurements, particularly with external body measurements. Young adults have a higher neurocranium and are more massive, whereas adults have a wider viscerocranium. The variability observed in adults shows that the White Arab breed is heterogeneous and has a late bone development, at least for the females. This breed's rustic and meat-producing characteristics have been confirmed from an osteometric point of view and their skulls were found to be the longest compared to other breeds, except for the Konya Merino sheep. A more extensive study, including a sample of their mandibles and at later stage, of males, will provide further details and new perspectives on sexual dimorphism in the White Arab breed.

ACKNOWLEDGEMENT

The authors would like to thank Dr. BOUKERROU Abderrahmane for his assistance in collecting the samples, Dr. KOUTCHOUKALI Hafida for her help in preparing the skulls, Prof. BERERHI El Hacene for his valuable guidance, Prof. LAKHDARA Nedjoua for refining the English translation of the manuscript and all the staff of the Ain Fakroun and Teleghma slaughterhouses for their cooperation.

Funding statement

This research received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

Ami, K. (2014). Approche ostéo-morphométrique des têtes de la population ovine autochtone. Thèse de Magister en Médecine Vétérinaire. Université des Frères Mentouri Constantine 1, Algérie 171 p.

Babelhadj, B., Adamou, A., Thorin, C., Tekkouk-Zemmouchi, F., Benaissa, A. and Guintard, C. (2016). Étude ostéo-biométrique comparée des «races» camelines Algériennes Sahraoui et Targui (*Camelus dromedarius* L., 1758). Revue de Médecine Vétérinaire. 167: 77-92.

Can, M., Özüdoðru, Z. and Ilgün, R. (2022). A morphometric study on skulls of hasmer and hasak sheep breeds. International Journal of Morphology. 40(6): 1536-1545. https://doi.org/10.4067/S0717-95022022000601536.

Chekkal, F., Benguega, Z., Meradi, S., Berredjouh, D., Boudibi, S. and Lakhdari, F. (2015). Guide de caractérisation phénotypique des races ovines de l'Algérie. (CRSTRA, Université Mohamed Khider, Biskra.

Dekhili, M. and Aggoun, A. (2013). Path coefficient analysis of body weight and biometric traits in Ouled-Djellal breed (Algeria). Agriculture. 4: 41-46.

Dib, M., Babelhadj, B., Benaissa, A., Oudini, E., Brahimi, Z., Tekkouk Zemmouchi, F., Ridouh, R. and Guintard, C. (2024). Osteo-morphometric approach to the heads of dromedaries (*Camelus dromedarius* L. 1758): Case of the Algerian Targui Population. Agricultural Science Digest-A Research Journal. 44(2): 372-381. https://doi.org/10.18805/ag.DF-590.

Djaout, A., Afri-Bouzebda, F., Bouzebda, Z., Benidir, M. and Belkhiri, Y. (2018). Application of linear body measurements for predicting live weight in ouled djellal breed. The Indian Journal of Animal Sciences. 88(8): 966-971. https://doi.org/10.56093/ijans.v88i8.82962.

Feliachi, K., Kerboua, M., Abdelfettah, M., Ouakli, K., Selheb, F. and Boudjakji, A. (2003). Rapport national sur les ressources génétiques animales: Algérie. MADR.

Guintard, C. and Fouché, S. (2008). Osteometric study of osseous heads of sheep (*Ovis aries* L.). Revue de Médecine Vétérinaire. 159(12): 603-617.

Guintard, C., Ridouh, R., Thorin, C. and Tekkouk-Zemmouchi, F. (2018). Etude ostéométrique des métapodes de chèvres (*Capra hircus* L., 1758) d'Algérie: Cas de la race autochtone Arabia. Revue de Médecine Vétérinaire. 169: 10-12.

Guintard, C. and Tekkouk-Zemmouchi, F. (2010). Osteo-biometric approach of the Ouled Djellal breed (*Ovis aries* L.-Algeria). Revue de Médecine Vétérinaire. 161(11): 521-531.

Gündemir, O., Duro, S., Jashari, T., Kahvecioğlu, O., Demircioğlu, İ. and Mehmeti, H. (2020). A study on morphology and morphometric parameters on skull of the Bardhoka autochthonous sheep breed in Kosovo. Anatomia, Histologia, Embryologia. 49(3): 365-371. https://doi.org/10.1111/ahe.12538.

IANOR. (2007). PN.NA 15457: Standard de la race ovine Arabe Blanche dite Ouled-Djellal. Institut Algérien de Normalisation.

Jashari, T., Duro, S., Gündemir, O., Szara, T., Ilieski, V., Mamuti, D. and Choudhary, O.P. (2021). Morphology, morphometry and some aspects of clinical anatomy in the skull and mandible of Sharri sheep. Biologia. 77: 423-433. https://doi.org/10.1007/s11756-021-00955-y.

Karimi, I., Onar, V., Pazvant, G., Hadipour, M.M. and Mazaheri, Y. (2011). The cranial morphometric and morphologic characteristics of mehraban sheep in western Iran. Global Veterinaria. 6(2): 111-117.

Kherbouche, F., Dunne, J., Merzoug, S., Hachi, S. and Evershed, R.P. (2016). Middle Holocene hunting and herding at Gueldaman Cave, Algeria: An integrated study of the vertebrate fauna and pottery lipid residues. Quaternary International. 410: 50-60. https://doi.org/10.1016/j.quaint.2016.01.005.

Marzban, A.B., Hajian, O. and Rahmati, S. (2020). Investigating the morphometric characteristics of male and female zell sheep skulls for sexual dimorphism. Anatomical Sciences Journal. 17(1): 13-20.

Merzoug, S., Kherbouche, F., Sehil, N., Chelli, R. and Hachi, S. (2016). Faunal analysis of the Neolithic units from the Gueldaman Cave GLD1 (Akbou, Algeria) and the shift in sheep/goat husbandry. Quaternary International. 410: 43-49. https://doi.org/10.1016/j.quaint. 2015.08.076.

Monfared, A.L. (2013). Clinical Anatomy of the Skull of Iranian Native Sheep. Global Veterinaria. 10(3): 271-275.

Özcan, S., Aksoy, G., Kürtül, İ., Aslan, K. and Özüdoğru, Z. (2010). A comparative morphometric study on the skull of the Tuj and Morkaraman sheep. Kafkas Universitesi Veteriner Fakultesi Dergisi. 16: 111-114.

Özüdoðru, Z., Özdemir, D., Emre Teke, B. and Kirbas, M. (2022). Morphological and craniometrical studies on the skull of the south karaman sheep. Acta Morphologica et Anthropologica. https://doi.org/10.7546/AMA.29.1-2.2022.17.

Özüdoğru, Z., Özdemir, D., Teke, B.E. and Kirbas, M. (2023). A study on morphological and morphometrical parameters on the skull of the Konya merino sheep. Turkish Journal of Veterinary Research. 7(2): 59-66. https://doi.org/10.47748/tjvr.1189675.

Parés, P.M., Sarma, K. and Vidal, J.J. (2010). On biometrical aspects of the cephalic anatomy of Xisqueta sheep (Catalunya, Spain). International Journal of Morphology. 28(2): 347-351. https://doi.org/10.4067/S0717-95022010000200001.

Rasamisoa, S.V. (1988). Contribution de la determination de formules barymetriques chez le mouton Malgache. Thèse de fin d'études. Université de Madagascar, Madagascar. 57 p.

Ridouh, R., Tekkouk-Zemmouchi, F., Thorin, C. and Guintard, C. (2019). Prédiction du sexe à partir d'un échantillon de métacarpes de chèvres (*Capra hircus* L., 1758) de race Arabia (Algérie): Réalisation d'un référentiel pour l'archéozoologie. Revue de Paléobiologie, Genève. 38(1): 255-265.

Sathapathy, S., Dhote, B., Bharti, S. and Singh, I. (2022). Morphometrical studies on skull bones of adult blue bull (*Boselaphus tragocamelus*). Indian Journal of Animal Research. 56(11): 1351-1355. doi: 10.18805/IJAR.B-4181.

Sathapathy, S., Dhote, B., Singh, I., Mrigesh, M., Joshi, S., Biswal, S., Sahu, S. and Ali, I. (2021). Sex wise morphometrical studies on orbital cavity and foramina of skull of adult blue bull (*Boselaphus tragocamelus*). Indian Journal of Animal Research. 55(9): 1027-1033. doi: 10.18805/IJAR.B-4169.

Team, R.C. (2023). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.

Von den Driesch, A. (1976). A guide to the measurement of animal bones from archaeological sites. (Harvard University, Peabody Museum Bulletin, Peabody Museum of Archaeology and Ethnology.