Research Article

Osteo-Morphometry in Ouled-Djellal White Arab Sheep: Age-Related Correlations between Mandible, Skull and Body Measurements

Maya Boukerrou [a], Rania Ridouh [a], Alaa Eddine Djeghar [a], Faiza Tekkouk-Zemmouchi[a], Baaissa Babelhadj[b,c], Allowen Evin[d], Claude Guintard[e]
[a] Gestion Santé et Productions Animales Research Laboratory, Institut des Sciences Vétérinaires El-Khroub, Université Constantine 1 Frères Mentouri, Constantine 25000, Algeria
[b] Department of Biological Sciences, Laboratory of Ecosystems Protection in Arid and Semi-Arid Zones, Faculty of Natural and Life Sciences, University of Kasdi Merbah, Ghardaïa road 30000 Ouargla, Algeria
[c] Ecole normale supérieure de Ouargla, Algeria
[d] Institute of Evolutionary Science-Montpellier (ISEM), University of Montpellier, CNRS, EPHE, IRD, Montpellier, France
[e] Comparative Anatomy Unit, National Veterinary School of Nantes, Vet Agro Bio Nantes-Oniris, route de Gâchet, CS 40706, 44307 Nantes cedex 03, France

Keywords
Archaeozoology, correlations, craniometry, sheep

Abstract

The Algerian Ouled Djellal White Arab is the predominant sheep breed in the Algerian steppes and high plains, known for its resilience and meat production capacity. This study examines correlations between mandibular, body, and craniometric measurements in two age groups to create a reference dataset for archaeozoology. Thirty female Ouled Djellal sheep, evenly divided into young adults and adults, were analyzed. Eight body measurements were recorded pre-slaughter, followed by eight mandibular and sixteen craniometric measurements after bone preparation, with four indices subsequently calculated. Results showed significant correlations between mandibular and body measurements, and between mandibular and craniometric parameters. Significant correlations were more numerous and stronger for adults (ranging from 0.47 to 0.70) than for young adults (from 0.41 to 0.67). While differences in covariation strength were observed between age groups, some correlations remained consistent through growth, such as those obtained between thoracic perimeter (TP) and mental foramen length (ML6), and between head length (hL) and the aboral height of the ascending branch (MH1). Dentition-

related measurements were more commonly correlated in adults, indicating their fully mature form compared to the continued growth in young adults. These findings highlight the importance of considering the age of specimens when analyzing morphometric data and provide reference data for estimating body size and cranial dimensions from mandible measurements, useful for archaeozoological studies of North African ancient specimens.

Abbreviations

ANCOVA : Analysis of Covariance

Introduction

The Algerian White Arab sheep, or Ouled Djellal, represents the predominant sheep breed in the Algerian steppes and high plains, accounting for about 63% of the national sheep population, estimated at around 12 million head. Native to the Ouled Djellal region, this breed is characterized by its slim build, refined head, and high-quality white wool. The breed is well-suited to a nomadic lifestyle and highly adapted to arid conditions [1, 2].

Despite being in its early stages, archaeological work in Algeria has led to the discovery of several sites, revealing animal bone remains from periods spanning the Paleolithic to the Neolithic. Sites such as Oued Boucherit in Sétif (dated 2.4–1.7 million years ago) [3], Tighennif in Mascara (around 700,000 years ago) [4], and Gueldaman Cave GLD1 near Akbou, Béjaïa (dated to 5052-4885 B.C.) [5]. These sites have provided a variety of bone remains, including sheep mandibles and skull fragments. Such archaeozoological findings enable researchers to explore the attributes of ancient fauna, yet one major challenge persists: the lack of reference data from live animals, particularly for body measurements. The estimation of body measurements from archaeological bones depends on datasets containing both body measurements and bone measurements of known specimens. Such reference datasets are scarce and currently lack representation from North African populations.

This research is part of a series of osteobiometric studies on native Algerian ruminants, including sheep [6, 7], goats [8, 9], and camels [10, 11]. Building upon this work, the current study aims to examine correlations between the body measurements of living animals and osteometric, cranial and mandibular, measurements in Ouled Djellal sheep. These correlations were compared between young adults and adults. The overarching goal is to establish a reliable reference framework of one of the main breeds of Algeria, enabling archaeozoologists to estimate body size and cranial dimensions based on mandibular remains from archaeological sites.

Results

Univariate analysis

The mandibular parameters MH1, MH7, MH8, and RM1 showed significant differences ($p < 0.05$) between the age groups (Table 1 and Figure 1). Average values for MH1 and MH8 were higher in adults, contrary to MH7 and RM1 that were higher in young adults. Additionally, the mean value of the RM1 index is lower in adults than in young adults.

Table 1.
Descriptive statistics of mandibular parameters.

Groups	Statistical parameters	ML6	ML8	ML9	MB1	MH1	MH7	MH8	MH9	MW	RM1	RM2
Young adults	m	165,05	58,50	24,22	61,71	82,97	41,33	24,26	19,71	83,20	25,10	74,45
N=15	Min	155,36	52,68	19,43	52,44	76,88	37,36	21,41	16,57	70,00	22,19	59,66
	Max	180,15	62,66	28,24	68,18	88,35	47,37	26,06	22,15	94,00	30,18	82,58
	σ	6,99	3,05	1,95	5,00	3,47	2,92	1,45	1,81	6,56	2,26	6,10
	CV%	4,23	5,21	8,04	8,10	4,18	7,07	5,99	9,20	7,88	9,00	8,19
Adults	m	166,74	57,09	24,12	62,16	88,54	38,88	25,55	20,65	85,80	23,35	70,33
N=15	Min	152,66	51,27	21,66	52,82	83,34	35,79	23,70	18,04	67,00	21,31	62,69
	Max	178,39	63,10	26,52	70,35	96,88	42,50	27,63	24,19	122,00	26,61	83,59
	σ	6,62	3,28	1,40	5,02	4,26	1,93	1,19	2,01	14,17	1,48	6,46
	CV%	3,97	5,74	5,81	8,07	4,81	4,95	4,64	9,72	16,51	6,35	9,18
total	m	165,89	57,79	24,17	61,94	85,76	40,10	24,90	20,18	84,50	24,22	72,39
Population	Min	152,66	51,27	19,43	52,44	76,88	47,37	21,41	16,57	67,00	21,31	59,66

N=30	Max	180,15	63,10	28,24	70,35	96,88	2,73	27,63	24,19	122,00	30,18	83,59
	σ	6,74	3,19	1,67	4,93	4,75	35,79	1,46	1,94	10,93	2,08	6,52
	CV%	4,06	5,52	6,90	7,95	5,54	6,81	5,86	9,61	12,93	8,58	9,00
***p* YA-A**		0,389	0,25	0,885	0,87	**0,001**	**0,033**	**0,033**	0,325	0 ,95	**0,019**	0,067

m: mean, Min: minimum, Max: maximum, σ: standard deviation, CV%: coefficient of variation in %.
p YA-A corresponds to the p-value for the Wilcoxon-Mann-Whitney test comparing young adults and adults.

Bivariate analysis

Correlations by Age

Significant correlations between mandibular and body measurements, as well as between mandibular and craniometric parameters, were more numerous and stronger in adults than in young adults (Tables 2 and 3). When significant, the correlation coefficient for adults ranged from 0.47 to 0.70, whereas that for young adults never exceeded 0.67 (from 0.41 to 0.67).

We determined whether young adults and adults exhibited different covariation patterns using a series of two-way ANCOVAs (Table 2). Some of these relationships remain stable across both age groups, such as those between thoracic perimeter (TP) and ML6, as well as between head length (hL) and MH1. However, 5 of the 20 pairs of variables show non homogeneous relationship in young adults and adults for the correlations between mandibular and body parameters. The same is true for 10 of the 44 comparisons between mandibular and craniometric parameters (Table 2). In such case, the correlation must be analyzed separately. For example, in adults, correlations were noted between head length (hL) and ML9, head width (hW) and MH9, as well as between MH8 and CL20, and MH9 and CL31. In young adults, correlations were observed between scapulo-ischial length (SIL) and mandible weight (MW), as well as between CB8 and MB1. Consequently, measurements related to dentition (ML9, MH9, MH8) are more commonly observed in adults.

The four strongest and most significant correlations are illustrated in Figure 2, showing pairs of mandibular and body parameters (Figures 2-A,B), as well as mandibular and craniometric parameters (Figures 2-C,D) for both adults and young adults.

Table 2.
Correlations between mandibular and body parameters by age.

VAR 1	VAR 2	Total population	Adults	Young adults	*p*-value
LW	MH1	0.28	0.66	0.20	0.208
LW	MH8	0.29	0.17	0.65	0.335
SIL	**MW**	**-0.07**	**0.20**	**-0.55**	**0.026**
WH	MH8	0.13	0.73	0.16	0.137
TP	ML6	0.51	0.46	0.60	0.973
TP	MH1	0.38	0.66	0.30	0.298
TP	MH8	0.33	0.18	0.62	0.44
CP	MH1	0.48	0.64	0.35	0.292
CP	MH9	0.42	0.52	0.25	0.335
CP	**MW**	**0.41**	**0.63**	**-0.26**	**0.042**
hL	ML6	0.48	0.45	0.58	0.575
hL	**ML9**	**0.34**	**0.61**	**0.09**	**0.02**
hL	MH1	0.54	0.65	0.46	0.226
hW	**MH9**	**0.20**	**0.57**	**-0.33**	**0.016**
hW	MH1	0.48	0.50	0.52	0.912
hW	MW	0.50	0.63	0.52	0.679
eL	MH1	0.22	0.52	0.19	0.43
eW	MH1	0.29	0.62	0.29	0.516
eW	MH8	0.31	0.51	0.33	0.48
eW	**MW**	**0.16**	**0.47**	**-0.40**	**0.033**

p-value represent the difference between the young adults and the adults using two-way ANCOVA test.

Correlations in the total population

Most of the correlations between mandible and body measurements were consistent between the two age groups (Table 2 and Table 3). Among the 99 correlations calculated between mandibular parameters and body measurements, only 14 differed significantly between the age groups (Table 4). These correlations were considered low, with coefficients ranging from 0.10 to 0.39 or moderate from 0.40 to 0.59.

The analysis of mandible and skull measurements reveals several significant correlations between mandibular and craniometric parameters (Table 5). The strongest correlation is observed between mandible weight (MW) and skull weight (SW), with a correlation coefficient of 0.85.

Table 3.
Correlations between mandibular and craniometric parameters by age.

VAR 1	VAR 2	Total population	Adults	Young adults	*p*-value
CL1	ML6	0.76	0.80	0.72	0.352
CL1	MH1	0.63	0.77	0.56	0.538
CL2	ML6	0.81	0.82	0.80	0.481
CL2	MH1	0.63	0.76	0.57	0.621
CL7	ML6	0.75	0.76	0.76	0.24
CL7	MH1	0.58	0.50	0.60	0.952
CL10	ML6	0.55	0.51	0.56	0.917
CL10	ML9	0.32	0.50	0.21	0.231
CL10	MH1	0.42	0.28	0.56	0.378
CL20	MB1	0.45	0.50	0.39	0.616
CL20	**MH8**	**-0.001**	**-0.38**	**0.48**	**0.032**
CL31	ML6	0.46	0.60	0.52	0.779
CL31	ML8	0.65	0.57	0.68	0.577
CL31	MH7	0.47	0.53	0.27	0.273

CL31	**MH9**	**0.04**	**0.54**	**0.28**	**0.033**
CL31	MW	0.34	0.65	0.04	0.364
CL34	ML6	0.44	0.61	0.31	0.305
CL34	MB1	0.25	0.53	0.04	0.115
CB2	MH1	0.29	0.19	0.69	0.15
CB2	MH7	0.26	0.54	0.10	0.096
CB2	MH9	0.29	0.51	0.04	0.192
CB3	MH1	0.56	0.34	0.62	0.128
CB8	MH1	0.34	0.51	0.22	0.769
CB8	**MB1**	**-0.23**	**0.21**	**0.57**	**0.024**
CB8	**MW**	**-0.04**	**0.19**	**0.46**	**0.044**
CB8	**RM2**	**-0.41**	**0.07**	**0.67**	**0.037**
CB10	MH1	0.65	0.67	0.82	0.203
CB10	**MH7**	**0.06**	**0.56**	**0.14**	**0.045**
CB10	MH9	0.38	0.65	0.07	0.148
CB10	MW	0.33	0.61	0.20	0.087
CB14	MH1	0.68	0.56	0.69	0.453
CB14	**MW**	**0.39**	**0.70**	**0.28**	**0.026**
CB18	MH1	0.55	0.35	0.52	0.307
CB18	**MW**	**0.09**	**0.32**	**0.41**	**0.049**
CB19	MH1	0.60	0.62	0.60	0.947
CB19	MW	0.37	0.50	0.04	0.455
CH5	MH1	0.04	0.02	0.67	0.127
CH6	ML6	0.76	0.71	0.83	0.944
CH6	MB1	0.59	0.67	0.49	0.426
CH6	MH1	0.39	0.36	0.60	0.43
SW	**ML8**	**0.14**	**0.45**	**0.53**	**0.02**
SW	MH1	0.49	0.64	0.28	0.074
SW	**MH7**	**0.19**	**0.63**	**0.16**	**0.003**

SW	MW	0.85	0.92	0.50	0.062

p-value represent the difference between the young adults and the adults using two-way ANCOVA test.

The mental foramen length (ML6) and the aboral height of the ascending branch (MH1) are most frequently correlated with craniometric parameters. ML6 shows the strongest correlations with both skull lengths and height CH6. In contrast, MH1 is primarily correlated with cranial widths, but it also with certain lengths and height CH6.

The four strongest and most significant correlations are illustrated in Figure 3, showing pairs of mandibular and body parameters (Figure 3-A,B), as well as mandibular and craniometric parameters (Figure 3-C,D) for all specimens.

Table 4.
Correlations between mandibular and body measurement for all specimens. Only the significant correlations ($p < 0.05$) are shown.

Body measurements	**Mandibular measurements**	**Coefficient (r)**	***p*-value**
Head length	MH1	0.54	0.0022
Thoracic Perimeter	ML6	0.51	0.0042
Head width	MW	0.50	0.0044
Cannon perimeter	MH1	0.48	0.0068
Head length	ML6	0.48	0.0073
Head width	MH1	0.48	0.0066
Cannon perimeter	MH9	0.42	0.021
Scapulo-ischial length	RM1	0.41	0.022
Cannon perimeter	MW	0.41	0.024
Cannon perimeter	ML6	0.39	0.032
Live weight	ML9	0.38	0.038
Thoracic Perimeter	MH1	0.38	0.040

Scapulo-ischial length	MH7	0.38	0.038
Live weight	MH7	0.37	0.043

Table 5.
Correlations between mandibular and craniometric measurement for all specimens. Only the significant correlations ($p < 0.05$) are shown.

Mandibular measurements	**Craniometric measurements**	**Coefficient (r)**	***p*-value**
MW	SW	0.85	2.17^{e}-09
ML6	CL2	0.81	5.90^{e}-08
ML6	CH6	0.76	9.46^{e}-07
ML6	CL1	0.76	1.14^{e}-06
ML6	CL7	0.75	2.20^{e}-06
MH1	CB14	0.68	3.30^{e}-05
ML8	CL31	0.65	0.00011
MH1	CB10	0.65	9.74^{e}-05
MH1	CL1	0.63	0.00016
MH1	CL2	0.63	0.00021
MH1	CB19	0.60	0.00041
MB1	CH6	0.59	0.00065
MH1	CL7	0.58	0.00086
MH1	CB3	0.56	0.0013
MH1	CB18	0.55	0.0015
ML6	CL10	0.55	0.00181
MH1	SW	0.49	0.00578
MH7	CL31	0.48	0.00805
ML6	CL20	0.47	0.00802
MB1	CL7	0.46	0.00985
ML6	CL31	0.46	0.0100
MB1	CL20	0.45	0.0137
ML6	CB10	0.44	0.0139
MH9	CB10	0.38	0.0384
MW	CB19	0.37	0.0451
MB1	CL2	0.37	0.0445

Table 6.
Denomination of mandibular measurements (variable names starting with M) and craniometric measurements (variable name starting with C), and indices (variable name starting with R).

Mandibular Measurements	Denominations	Craniometric Measurements	Denominations
ML6	Mental foramen length	CL1	Total length
ML8	Molar tooth row length	CL2	Condylobasal length
ML9	Premolar tooth row length	CL7	Oblique length of the muzzle
MB1	Width at the mandibular angle	CL10	Median frontal length
MH1	Aboral height of the ascending branch	CL20	Orbit base to jugular process length
MH7	Mandibular height behind M3	CL31	Naso-dental oblique length
MH8	Mandibular height in front of M1	CL34	Temporal fossaLength
MH9	Mandibular height in front of P1	CB2	Greatest breadth of the occipital condyles
RM1	MH7 / ML6 × 100	CB3	Greatest breadth at the bases of the paraoccipital processes
RM2	MB1 / MH1× 100	CB8	Least frontal breadth
		CB10	Least breadth between the orbits
		CB14	Greatest palatal breadth
		CB18	Greatest breadth across the premaxillae
		CB19	Zygomatic breadth
		CH5	Least height of the occipital
		CH6	Splanchnocranial height
		RC5	CB8 / CL1 × 100
		RC7	CH5 / CL1 × 100

M3: Third molar, M1: First molar, P1: First premolar.

Discussion

The study revealed that the average value of the mandibular height behind M3 (MH7) was higher in young adults, which can be explained by the association of this variable with the eruption of third molar (M3): In adults, the mandibular body tends to lower after the complete eruption of M3 (Figure 4). Similar findings were noted by Ridouh [12] on the native Algerian goat and by Dib, Babelhadj [11] on the Tergui dromedary. Furthermore, the higher value of MH8 in adults may result from the eruption of premolars before adulthood.

When comparing the Ouled Djellal sheep with other breeds, the mental foramen length (ML6) in our breed (165.89 mm) is greater than that in other sheep breeds, including Yankassa (165 mm) [13], Konya Merino (163.44 mm) [14], Barbados Black Belly (160.9 mm), Awassi Females (155.22 mm) [15], French breeds (152 mm) [16], Mehraban (137.4 mm) [17], Morkaraman (122.29 mm), Tuj (118.85 mm) [18], and Iranian Native sheep (112.9 mm) [19]. Thus, the Ouled Djellal females demonstrate relatively longer mandibles compared to other breeds.

Regarding the mandibular angle width (MB1), the Ouled Djellal (61.94 mm) exhibits a mean value close to that of Sharri females (61.64 mm) [20] and Awassi females (60.22 mm) [15]. yet it surpasses that observed in Norduz females (45.14 mm) [21], Konya Merino (56.88 mm) [14], Tuj (43.61 mm), Morkaraman (43.2 mm) [18], and French breeds (58 mm) [16]. This indicates that Ouled Djellal females have broader mandibles compared to other breeds.

Furthermore, the height of the ascending branch (MH1) is particularly higher in Ouled Djellal females, with an average of 85.76 mm. This measurement considerably exceeds those found in French breeds (80 mm) [16], Mehraban (77.5 mm) [22], Konya Merino (76.11 mm) [14], Barbados Black Belly (70.8 mm) [23], Zell sheep females (69.81 mm) [24], Iranian native sheep (62.6 mm) [19], Morkaraman (62.08 mm) [18], Norduz females (61.98 mm) [21], and

Tuj (60.86 mm) [18]. Thus, the Ouled Djellal females are distinguished by the greater height of their mandibular branches.

Compared to Ami [6] results on the same Ouled Djellal breed in the same region, the mean values of ML6 (153.20 mm), MB1 (59.6 mm) and MH1 (79.86 mm) were lower in that study. This difference may be attributed to the presence of juvenile individuals in Ami's sample.

These three measurements (ML6, MB1, MH1) represent the dimensions of the mandible along its three main axes, indicating that the mandibles in our study population are overall relatively larger than those of other sheep breeds.

Furthermore, the average value of RM1 was lower in adults, suggesting that their mandibular bodies are thinner. Additionally, the mean value of RM1 (24.22%) and RM2 (72.39%) indices observed in our study are lower than those reported by Ami [6] for Ouled Djellal breed (26.06% and 74.63%, respectively), as well as by Guintard and Fouché [16] for French breeds (25% and 73%). These findings indicate that the mandibles in our study possess more slender bodies.

Moreover, the correlations observed were stronger and more consistent in adults than in young adults. In young adults, varying growth rates between zootechnical and bone parameters suggest that osteological development is still ongoing. In contrast, adults exhibit a stable and fully mature form across both zootechnical and osteological measures, which likely explains the stronger consistency in correlations at this stage.

Furthermore, the relatively weak correlations observed in the total population can be attributed to several factors, such as age, dentition, nutrition, and environmental conditions. These factors influence the growth and development of sheep in uneven ways, thereby leading to differences in mandible morphology. Despite this variability, certain mandibular measurements (especially MH1 and ML6) show significant correlations with body measurements. For example, the strongest correlations were observed between the head length and the height of the ascending branch (MH1), and between the thoracic perimeter and the mental foramen length (ML6) (Figure 3).

Regarding the correlations between the mandibular and craniometric parameters, the results indicate that mandibular length (ML6) reflects the linear dimensions of the skull, while mandibular height (MH1) is more closely associated with cranial widths. These results suggest that the three axes of the mandible (ML6, MH1, MB1) are significantly correlated with the three main dimensions of the skull (length, width, and height). This reflects harmonious growth between mandibular and cranial structures, confirming that the mandible and skull develop in an interdependent manner.

In conclusion, this study examined the correlations between mandibular and craniometric osteometric measurement, and body measurements on the living animals in Ouled Djellal sheep, focusing on age-related effects. The results indicate that the mandibles of Ouled Djellal females are both larger and more slender than those of other breeds, with adults exhibiting even greater size and slenderness compared to young adults within the same breed. In the entire population, significant and strong correlations were observed between body and mandibular measurements. Additionally, the three axes of the mandible are significantly correlated with skull measurements, reflecting the harmonious growth between the mandible and skull. Most correlations between mandibular, craniometric, and body parameters remain consistent across age groups, while others vary. Significant correlations are more frequent in adults, suggesting that they have reached a stable, mature form in both zootechnical and osteological aspects, whereas young adults exhibit differential growth patterns. The identified correlations highlight the importance of taking into account the age of the specimens when mandibular measurements are used for estimating body and craniometric dimensions. This study paves the way for age-specific predictive models in archaeozoology. Finally, further research including a male sample will provide new insights into sexual dimorphism in the White Arab Ouled Djellal breed.

Materials and Methods

This study included 30 female Ouled Djellal sheep obtained from the slaughterhouses in Aïn Fakroun and Télaghma, located in northeastern Algeria, between March 2022 and May 2023. The animals, which appeared healthy, were over two years old and were divided into two age groups: young adults (YA) aged 2 to 4 years, and adults (A) over 4 years. Before slaughter, eight body measurements (Figure 5) were recorded using a tape measure (in centimeters): withers 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). The live weight was estimated using body weight estimation formulas: LW= 0.635 TP - 23.026 and LW = 0.7536 SIL - 19.2234 [13].

After slaughter, the heads were collected, labeled with identification numbers, and linked to the initial body measurements. Soft tissues were removed, and the bones were prepared by boiling for several hours, rinsing in running water, and air-drying. Each skull and mandible (right side) were labeled and numbered to match its corresponding data sheet. Mandible (MW) and skull (SW) weights were recorded in grams using a precision scale.

A total of eight mandibular and sixteen cranial measurements were taken in millimeters using a caliper with an accuracy of 0.02 mm, a ruler for lengths (e.g., CL1, CL2), and a thickness compass for specific parameters (e.g., CH6), following Ridouh's [14] methodology (Figures 6 and 7, Table 6). Additionally, four indices (RM1, RM2, RC5, and RC7), selected based on their representativeness as proposed by Guintard [15] were calculated to provide further morphometric insights.

All statistical analyses were conducted using R (version 4.3.1) with the RStudio interface. Descriptive statistics, including mean (m), minimum (min), and maximum (max) values, were calculated for each age group and the total population (TP). Variability was assessed using the standard deviation (σ) and coefficient of variation (CV% = (σ/m) × 100).

With a sample of 30 individuals, the Wilcoxon-Mann-Whitney test was applied to compare univariate measurements between the two age groups, using a significance threshold of $p < 0.05$. Pearson correlation coefficients (r) were calculated for each variable pair, with thresholds set as follows: 0–0.10 for no correlation, 0.10–0.39 for low, 0.40–0.59 for moderate, 0.60–0.79 for strong, and 0.80–1 for very strong correlations. Additionally, p-values were also used to assess the significance of the correlations. Finally, two-way ANCOVAs were used to evaluate the homogeneity of correlations between young adults and adults.

References

1. Adaouri M. Evaluation des paramétres zootechniques de la nouvelle race ovine en cours de constitution issue d'un croisement génétique alternatif d'amélioration antre Ouled Djellal et D'man [Thèse de Doctorat en Sciences Agronomiques]: Ecole Nationale Supérieure Agronomique, Algérie; 2019.

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

3. Duval M, Sahnouni M, Parés JM, van Der Made J, Abdessadok S, Harichane Z, et al. The Plio-Pleistocene sequence of Oued Boucherit (Algeria): A unique chronologically-constrained archaeological and palaeontological record in North Africa. Quaternary Science Reviews. 2021;271:107-16. https://doi.org/10.1016/j.quascirev.2021.107116.

4. Geraads D. Pleistocene Carnivora (Mammalia) from Tighennif (Ternifine), Algeria. Geobios. 2016;49(6):445-58. https://doi.org/10.1016/j.geobios.2016.09.001.

5. Merzoug S, Kherbouche F, Sehil N, Chelli R, Hachi S. Faunal analysis of the Neolithic units from the Gueldaman Cave GLD1 (Akbou, Algeria) and the shift in sheep/goat husbandry. Quaternary International. 2016;410:43-9. https://doi.org/10.1016/j.quaint.2015.08.076.

6. Ami K. Approche ostéo-morphométrique des têtes de la population ovine autochtone [Thèse de Magister en Médecine Vétérinaire]. Algérie Université des Frères Mentouri Constantine 1; 2014.

7. Guintard C, Tekkouk-Zemmouchi F. Osteo-biometric approach of the Ouled Djellal breed (Ovis aries, L.-Algeria). Revue de Médecine Vétérinaire. 2010;161(11):521-31.

8. Guintard C, Ridouh R, Thorin C, Tekkouk-Zemmouchi F. Etude ostéométrique des métapodes de chèvres (Capra hircus, L., 1758) d'Algérie: cas de la race autochtone Arabia. Revue de Médecine Vétérinaire. 2018;169:221-32.

9. Ridouh R, Tekkouk-Zemmouchi F, Thorin C, Guintard C. 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 2019;38(1):255-65.

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

11. Dib M, Babelhadj B, Benaissa A, Oudini E, Brahimi Z, Tekkouk Zemmouchi F, et al. Osteo-morphometric Approach to the Heads of Dromedaries (Camelus dromedarius, L, 1758): Case of the Algerian Targui Population. Agricultural Science Digest - A Research Journal. 2024;44(2):372-81. https://doi.org/10.18805/ag.DF-590.

12. Ridouh R. Crâniométrie et ostéométrie des métapodes de la chèvre autochtone [Thèse de Doctorat en Sciences Vétérinaire]: Université des Frères Mentouri Constantine 1, Algérie; 2021.

13. Shehu SA, Bello A, Sonfada ML, Suleiman HM, Umar AA, Danmaigoro A, et al. Morphometrical study of the mandiblar bone of female Yankasa sheep (Ovis aries Linne). Journal of Anatomy and Physiological Studies. 2018;2(1):001-6.

14. Özüdoğru Z, Ilgün R, Teke BE. A Morphometric Study on Mandibula of Konya Merino. Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi. 2019;5:392-5. https://doi.org/10.24180/ijaws.599005.

15. Yılmaz B. İvesi Koyunlarında (Ovis aries) Mandibula'nın Morfometrik İncelemesi. Harran Üniversitesi Veteriner Fakültesi Dergisi. 2020;9(2):189-93. https://doi.org/10.31196/huvfd.813490.

16. Guintard C, Fouché S. Osteometric study of osseous heads of sheep (Ovis aries, L.). Revue de Médecine Vétérinaire. 2008;159(12):603-17.

17. Karimi I, Hadipour M, Nikbakht P, Motamedi S. The lower jawbone of Mehreban sheep: a descriptive morphometric approach. World's Veterinary Journal. 2011;2:57-60.

18. Demiraslan Y, Gülbaz F, Özcan S, Dayan MO, Akbulut Y. Morphometric analysis of the mandible of Tuj and Morkaraman sheep. Journal of Veterinary Anatomy. 2014;7(2):75-86. https://doi.org/10.21608/jva.2014.44813.

19. Monfared AL. Clinical Anatomy of the Skull of Iranian Native Sheep. Global Veterinaria. 2013;10(3):271-5. https://doi.org/10.5829/idosi.gv.2013.10.3.7253.

20. Jashari T, Duro S, Gündemir O, Szara T, Ilieski V, Mamuti D, et al. Morphology, morphometry and some aspects of clinical anatomy in the skull and mandible of Sharri sheep. Biologia. 2021;77:423 - 33. https://doi.org/10.1007/s11756-021-00955-y.

21. Dalga S, Aydın U, Bayram R. Radiological, Morphological and Morphometric Investigation of Mandible in Norduz Sheep. Dicle Üniversitesi Veteriner Fakültesi Dergisi. 2023;16(2):85-90. https://doi.org/10.47027/duvetfd.1334159.

22. Karimi I, Onar V, Pazvant G, Hadipour MM, Mazaheri Y. The Cranial Morphometric and Morphologic Characteristics of Mehraban Sheep in Western Iran. Global Veterinaria 2011;6(2):111-7.

23. Mohamed R, Driscoll M, Mootoo N. Clinical anatomy of the skull of the Barbados Black Belly sheep in Trinidad. Int J Curr Res Med Sci. 2016;2(8):8-19. https://doi.org/10.4322/jms.112017.

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

Figure legends

Figure 1. Boxplots illustrating the variation in the mandibular variables MH1 (left), MH7 (middle), and MH8 (right) between Young Adults (YA) and Adults (A). Descriptions of these variables can be found in Table 6.

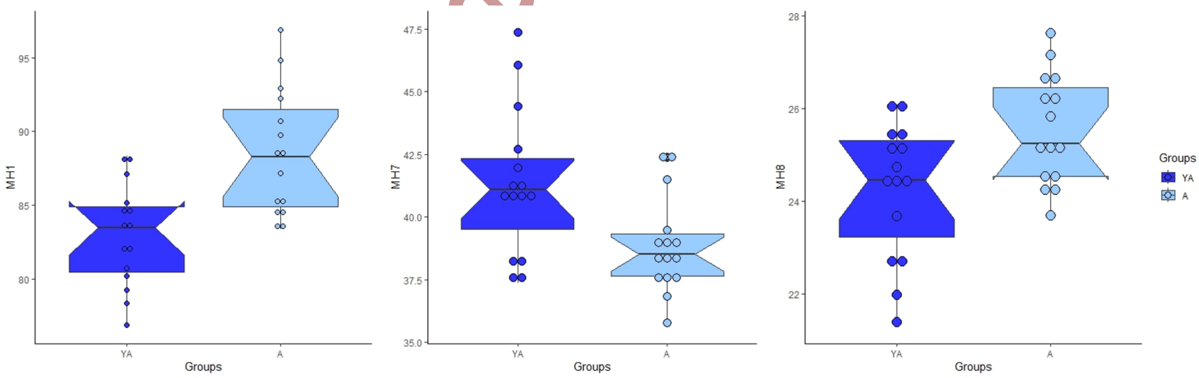

Figure 2. Example of a scatter plots with linear regression between mandibular and body parameters: A. hL=f(ML9), B. hW=f(MH9) and between mandibular and craniometric parameters: C. SW = f(MH7), D. CB8 = f(RM2) for adults and young adults. Only the strongest correlations are shown.

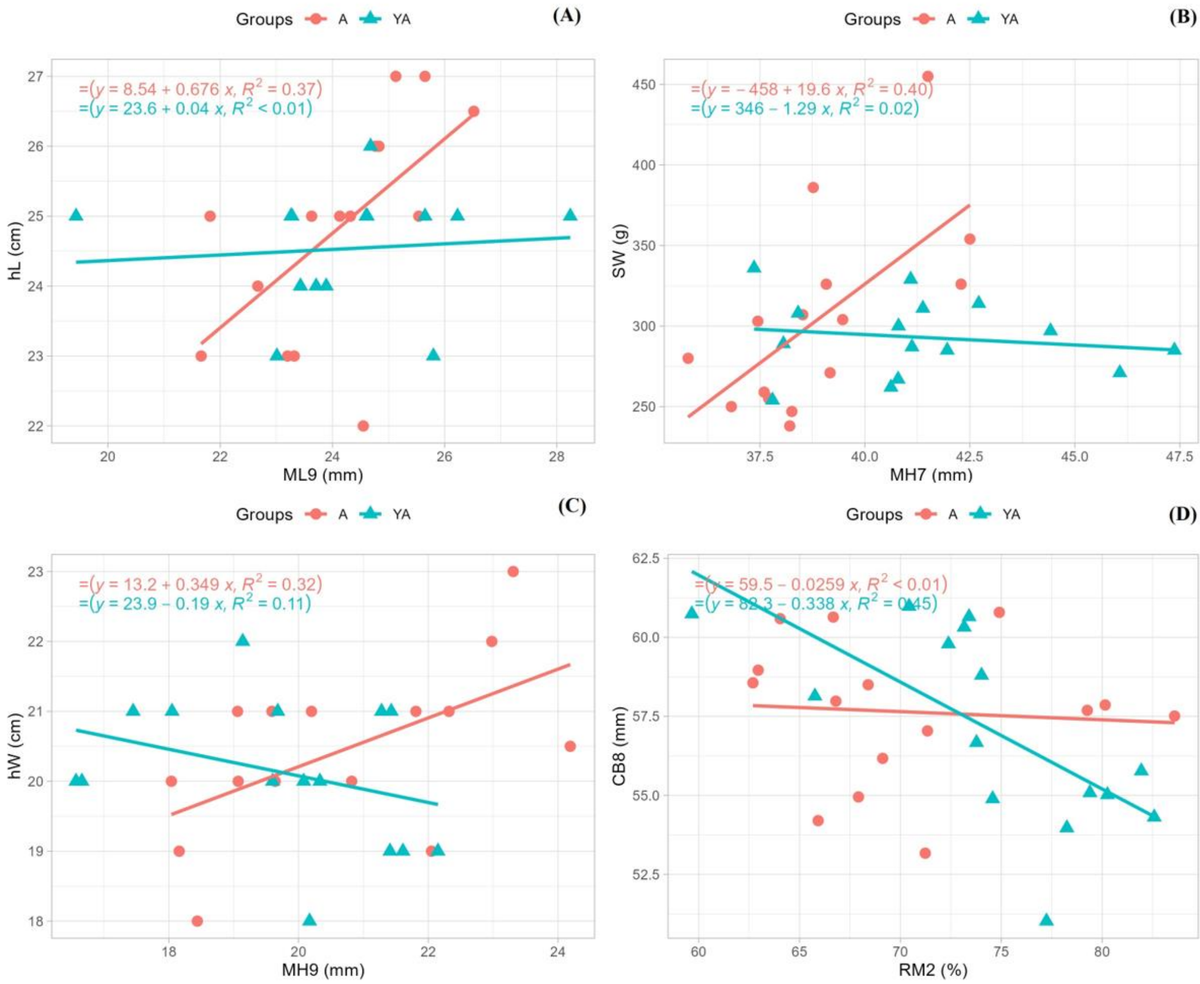

Figure 3. Example of scatter plots with linear regression between mandibular and body parameters: A. hL=f(MH1), B. TP=f(ML6) and between mandibular and craniometric parameters: C. CL2 = f(ML6), D. CH6 = f(ML6) for all specimens. Only the strongest correlations are shown.

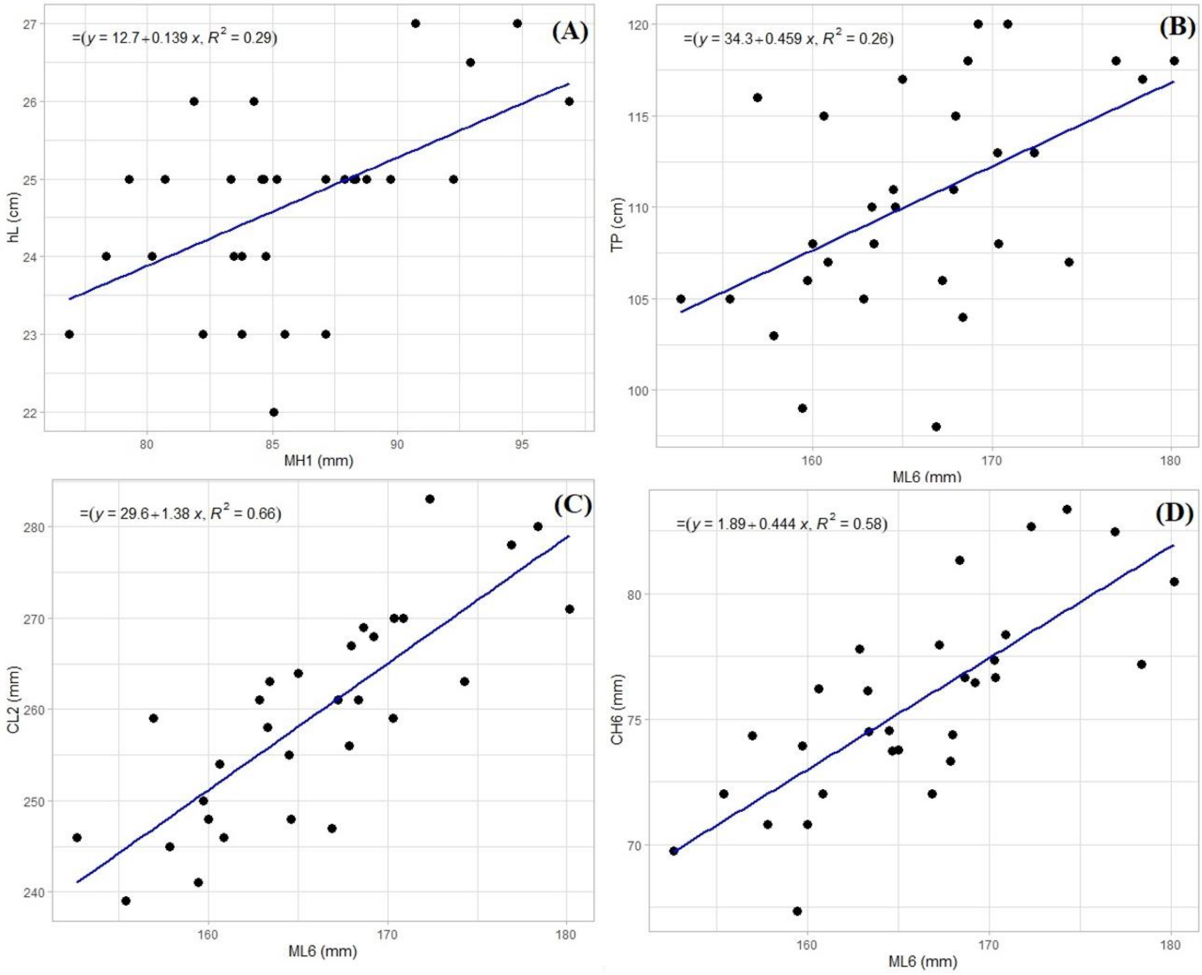

Figure 4. Mandibular corpus height behind the third molar (MH7) in young adults (top) and adults (bottom).

Figure 5. Body measurements on Ouled Djellal sheep.

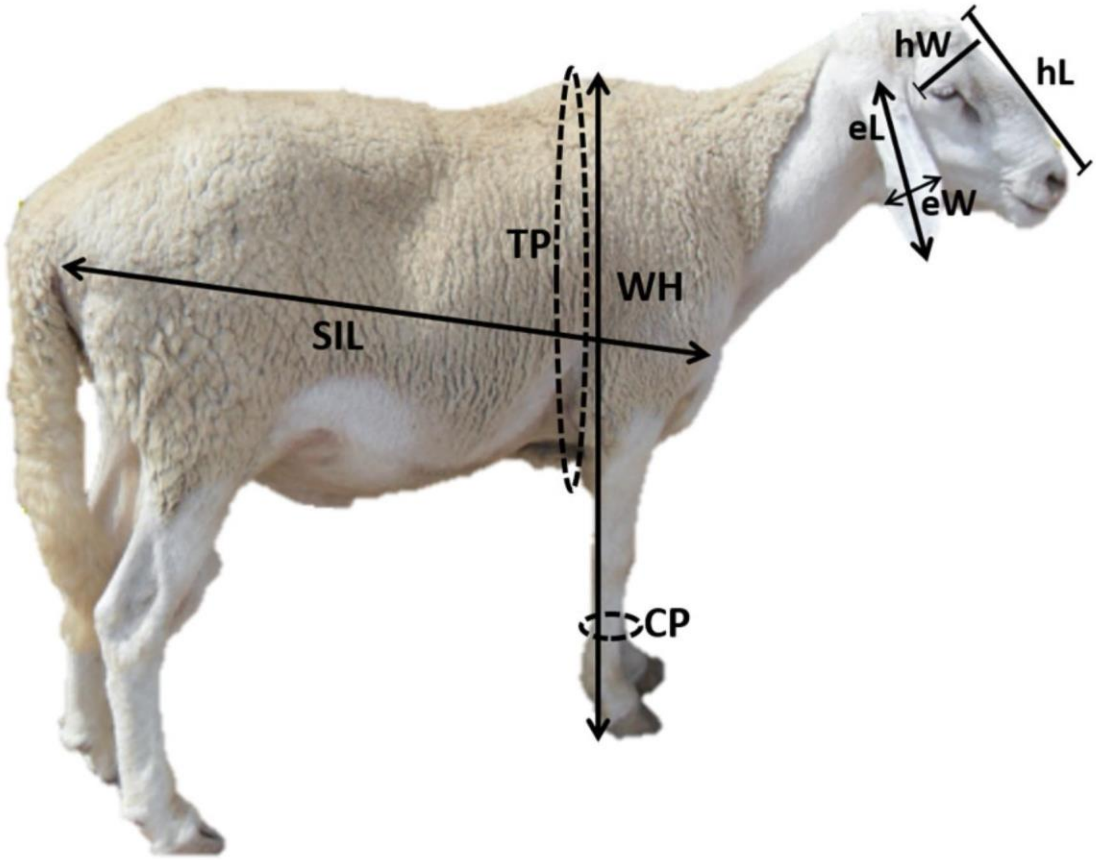

Figure 6. Measurements of the right mandible in lateral view.

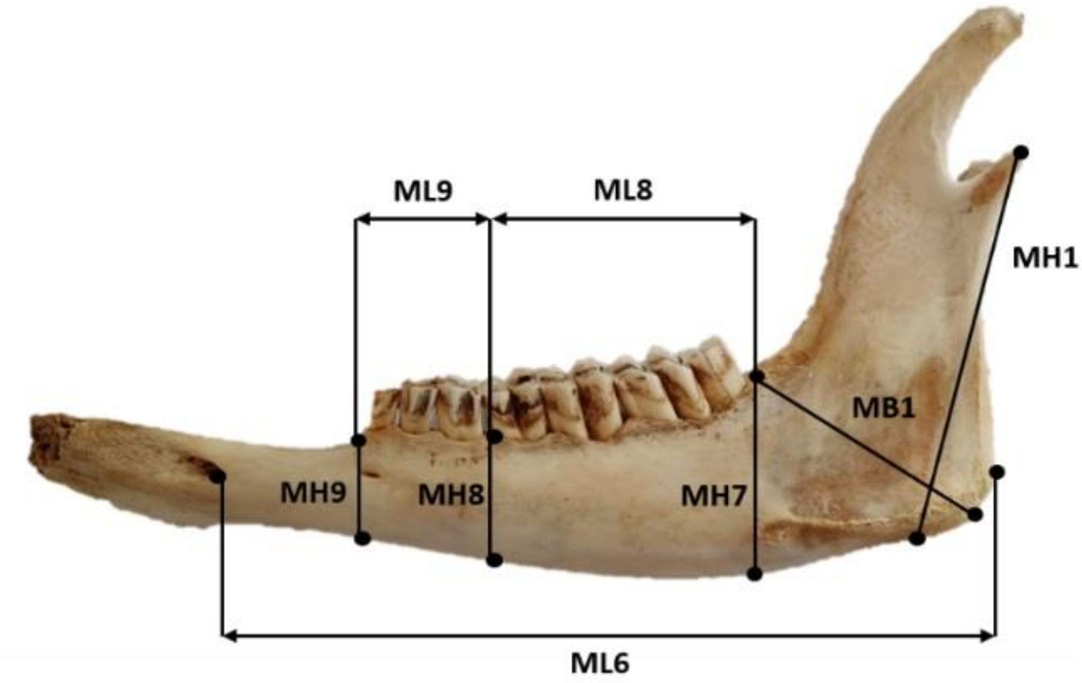

Figure 7. Skull measurements: (A) lateral view, (B), ventral view (C) dorsal view, (D) caudal view.