anthropozoologica

2022 • 57 • 9

Relations between metatarsal proximal extremity parameters and weight and height at the withers of the dromedary (*Camelus dromedarius* Linnaeus, 1758) in the Sahraoui and Targui “breeds”

Baaissa BABELHADJ, Chantal THORIN, Atika BENAISSA, Mélanie COLLÉAUX, Ana GUINTARD, Revathi NAIR, Faïza TÉKKOUK-ZEMMOUCHI, Rania RIDOUH, Catherine PICARD, Aurélia BORVON, Abdelkader ADAMOU, Éric BETTI & Claude GUINTARD

art. 57 (9) — Published on 5 August 2022
www.anthropozoologica.com

PUBLICATIONS SCIENTIFIQUES
MUSÉUM NAL HIST NATURELLE

Couverture / *Cover*:
Dr. Baaïssa Babelhadj et le dromadaire Sahraoui. Crédit: Mohammed Hammoudi / *Dr. Baaïssa Babelhadj and the Sahraoui dromedary. Credit: Mohammed Hammoudi.*

Anthropozoologica est indexé dans / Anthropozoologica *is indexed in:*

– Social Sciences Citation Index
– Arts & Humanities Citation Index
– Current Contents - Social & Behavioral Sciences
– Current Contents - Arts & Humanities
– Zoological Record
– BIOSIS Previews
– Initial list de l'European Science Foundation (ESF)
– Norwegian Social Science Data Services (NSD)
– Research Bible

Anthropozoologica est distribué en version électronique par / Anthropozoologica *is distributed electronically by:*
– BioOne® (https://www.bioone.org)

Anthropozoologica est une revue en flux continu publiée par les Publications scientifiques du Muséum, Paris, avec le soutien du CNRS.
Anthropozoologica *is a fast track journal published by the Museum Science Press, Paris, with the support of the CNRS.*
Les Publications scientifiques du Muséum publient aussi / *The Museum Science Press also publish:* ***Adansonia***, ***Zoosystema***, **Geodiversitas**, ***European Journal of Taxonomy***, ***Naturae***, ***Cryptogamie*** **sous-sections** ***Algologie***, ***Bryologie***, ***Mycologie***, ***Comptes Rendus Palevol***.

Diffusion – Publications scientifiques Muséum national d'Histoire naturelle
CP 41 – 57 rue Cuvier F-75231 Paris cedex 05 (France)
Tél.: 33 (0)1 40 79 48 05 / Fax: 33 (0)1 40 79 38 40
diff.pub@mnhn.fr / https://sciencepress.mnhn.fr

ISSN (imprimé / *print*): 0761-3032 / ISSN (électronique / *electronic*): 2107-08817

Relations between metatarsal proximal extremity parameters and weight and height at the withers of the dromedary (*Camelus dromedarius* Linnaeus, 1758) in the Sahraoui and Targui “breeds”.

Baaissa BABELHADJ
École normale supérieure de Ouargla,
Cité Ennasr, Ouargla (Algeria)
babelhadjbaaissa@gmail.com

Chantal THORIN
Statistique, Unité de Pharmacologie, École nationale vétérinaire, agroalimentaire
et de l’Alimentation de Nantes-Atlantique (ONIRIS),
Atlanpole – La Chantrerie,101 route de Gachet, CS 40706, F-44307 Nantes Cedex 03 (France)
chantal.thorin@oniris-nantes.fr

Atika BENAISSA
Unité de Recherche sur le Camelin,
Laboratoire de recherche «Protection des Écosystèmes en Zones arides et semi-arides»,
Université Kasdi Merbah, Ouargla (Algérie)
benaissaatika@gmail.com

Mélanie COLLÉAUX
Ana GUINTARD
Institut Agro Rennes-Angers,
65 rue de Saint-Brieuc, CS 84215, F-35042 Rennes Cedex (France)
melanie.colleaux@agrocampus-ouest.fr
ana.guintard@orange.fr

Revathi NAIR
University of Saskatchewan, Department of Pharmacology,
105 Administration Place, Saskatoon SK S7N 5A2 (Canada)
and 223 A Bolstad Manor, Saskatoon, SK S7W0Y1 (Canada)
revumol7@gmail.com

Faïza TÉKKOUK-ZEMMOUCHI
Rania RIDOUH
Institut des Sciences vétérinaires, Laboratoire de Gestion de la Santé et Productions animales,
Université Constantine 1, Route de Guelma, 25100 El Khroub – Constantine (Algérie)
ftekkouk@yahoo.fr
ridouhrania@outlook.fr

Catherine PICARD
Département d'Anatomie, École nationale vétérinaire, agroalimentaire
et de l’Alimentation de Nantes-Atlantique (ONIRIS),
Atlanpole – La Chantrerie,101 route de Gachet, F-44300 Nantes Cedex 03 (France)
et Laboratoire commun NextBone, Groupe d'Étude Remodelage osseux et BioMatériaux (GEROM),
Faculté de Santé de l’Université d’Angers, 28 rue Roger-Amsler, F-49045 Angers Cedex 01 (France)
catherine.picard@oniris-nantes.fr

Aurélia BORVON
Équipe Archéologies environnementales, Archéologie et Sciences de l'Antiquité (ArScAn), CNRS, Université Paris 1, Université Paris Nanterre, Ministère de la Culture, Université Paris 8, Inrap, 21, Allée de l'Université, F-92023 Nanterre Cedex (France)
et Laboratoire d'Anatomie comparée, École nationale vétérinaire, agroalimentaire et de l'Alimentation de Nantes-Atlantique (ONIRIS), Atlanpole – La Chantrerie,101 route de Gachet, CS 40706, F-44307 Nantes Cedex 03 (France)
et Laboratoire commun NextBone, Groupe d'Étude Remodelage osseux et BioMatériaux (GEROM), Faculté de Santé de l'Université d'Angers, 28 rue Roger-Amsler, F-49045 Angers Cedex 01 (France)
aureliageronimo@aol.com

Abdelkader ADAMOU
Unité de Recherche sur le Camelin, Laboratoire de recherche « Protection des Écosystèmes en Zones arides et semi-arides », Université Kasdi Merbah, Ouargla (Algérie)
adamoudz@yahoo.fr

Éric BETTI
Claude GUINTARD
Département d'Anatomie, École nationale vétérinaire, agroalimentaire et de l'Alimentation de Nantes-Atlantique (ONIRIS), Atlanpole – La Chantrerie,101 route de Gachet, F-44300 Nantes Cedex 03 (France)
et Laboratoire commun NextBone, Groupe d'Étude Remodelage osseux et BioMatériaux (GEROM), Faculté de Santé de l'Université d'Angers, 28 rue Roger-Amsler, F-49045 Angers Cedex 01 (France)
eric.betti@oniris-nantes.fr
claude.guintard@oniris-nantes.fr

Submitted on 25 August 2021 | Accepted on 25 January 2022 | Published on 5 August 2022

Babelhadj B., Thorin C., Benaissa A., Colléaux M., Guintard A., Nair R., Tékkouk-Zemmouchi F., Ridouh R., Picard C., Borvon A., Adamou A., Betti E. & Guintard C. 2022. — Relations between metatarsal proximal extremity parameters and weight and height at the withers of the dromedary (*Camelus dromedarius* Linnaeus, 1758) in the Sahraoui and Targui "breeds". *Anthropozoologica* 57 (9): 211-221. https://doi.org/10.5252/anthropozoologica2022v57a9. http://anthropozoologica.co/57/9

ABSTRACT
The metatarsal bone is one of the strongest bone in Ungulates and can provide various information about live animal. A sample of 86 metatarsal bones of 43 adult dromedaries (*Camelus dromedarius* Linnaeus, 1758) was studied. Two breeds were compared, with a total of 22 males and 21 females, organised in four groups: 13 Sahraoui females, 14 Sahraoui males, nine Targui females and seven Targui males. Prior to the osteometric study, biometric parameters (body weight [BW] and height at the withers [HW]) were measured. For each bone, the area of the proximal articular surface was calculated, and the proximal width and thickness were measured. No differences were observed between the left and right sides of each individual and therefore analysis was done only for the right side. The multivariate analysis (PCA) carried out on the articular surfaces and proximal linear measurements highlights sexual dimorphism, however, no statistical difference was noted between the two breeds. The best predictive model for obtaining body weight using osteometric measurements involves the "step-by-step" procedure which only contains one predictive measurement, namely the BpT (the metatarsal proximal width): BW = 128.88*BpT –302.55. Inclusion of the articular surfaces does not improve the prediction of weight in a bivariate model. However, taking into account the total surface area (SA) allows the body weight to be predicted using the following formula: BW = 21.728*SA + 136.840. Finally, no measurements allow the animal's height at the withers to be estimated with a simple bivariate model.

KEY WORDS
Camel,
Sahraoui breed,
Targui breed,
metapodial bone,
metatarsal bone,
osteometry,
zooarchaeology.

RÉSUMÉ
*Relations entre les paramètres de l'extrémité proximale du métatarse, le poids vif et la hauteur au garrot chez le dromadaire (*Camelus dromedarius *Linnaeus, 1758) dans les « races » Sahraoui et Targui.*
Le métatarse est l'un des os les plus solides du squelette des ongulés et permet de fournir des renseignements sur l'animal vivant. Un échantillon de 86 os métatarsiens provenant de 46 dromadaires (*Camelus dromedarius* Linnaeus, 1758) adultes a été étudié. Deux races ont été comparées, comprenant un total de 22 mâles et 21 femelles, correspondant à quatre groupes : 13 femelles Sahraoui, 14 mâles Sahraoui, neuf femelles Targui et sept mâles Targui.

Préalablement à l'étude ostéométrique, des paramètres biométriques des animaux vivants (poids vif et hauteur au garrot) ont été mesurés. Pour chaque os, la surface articulaire proximale a été calculée et la largeur et l'épaisseur proximales ont été mesurées. Aucune différence significative n'a été observée entre le côté droit et le côté gauche, de sorte que l'analyse a été faite sur le côté droit. L'analyse multivariée (ACP) réalisée sur les surfaces articulaires et sur les mesures linéaires permet de mettre en évidence le dimorphisme sexuel, alors qu'aucune différence statistique n'est notée entre les deux races. Le meilleur modèle afin de prédire le poids de l'animal à partir des mesures ostéométriques, selon la procédure pas à pas est celui à partir de la largeur proximale du métatarse (BpT) : BW (poids vif) = 128,88*BpT – 302,55. Si l'on rajoute les surfaces articulaires, le résultat n'est pas meilleur dans un modèle bivarié. Il est toutefois possible de proposer un modèle de prédiction du poids vif à partir de la surface articulaire totale (SA) : BW (poids vif) = 21,728*SA + 136,840. Finalement, aucun modèle bivarié ne permet d'estimer correctement la hauteur au garrot de l'animal à partir des mesures ostéométriques réalisées.

MOTS CLÉS
Camelin,
race Sahraoui,
race Targui,
métapodes,
os métatarsien,
ostéométrie,
archéozoologie.

INTRODUCTION

The bone studied here is the hind metapodial bone, also known as the metatarsal or cannon bone or *Os metatarsale III-IV*, which is one of the strongest bones in the ungulate skeleton (Berteaux & Guintard 1995). It is located in the animal's foot and carries the weight of the body, except the weight of the phalanges which are situated more distally. Bovines have often been studied since the end of the 1950's (Boessneck 1956; Zalkin 1960; Higham 1969; Van Wijngaarden-Baker & Bergström 1988; Albarella 1997; Guintard 1998; Tekkouk & Guintard 2007), but the dromedary (*Camelus dromedarius* Linnaeus, 1758) is a species that still needs to be explored. Several initial works have already been done on the subject since 2013, including recent research on the osteometry of metapodial bones (a population of both Sahraoui and Targui breeds) using a linear measurement of the bones (Adamou *et al.* 2013; Babelhadj *et al.* 2016, 2017, 2020; Guintard & Babelhadj 2018). The uniqueness of this study and its unprecedented nature come from its novel approach that uses the proximal articular surfaces of the metapodial bone in the dromedary as an estimate for its size. The theory behind this method is as follows: the metatarsal bone is positioned vertically, so its proximal articular surfaces receive the entire weight of the body and can hence act as a record for it. O'Connor (2000) describes the tarsometatarsal junction in ungulates and demonstrates that this articulation with bones of the distal row of the tarsus is made in a horizontal plane that is almost perpendicular to the vertical. This would mean that the weight of the animal going through this articulation is not diverted from the vertical component of the gravity that acts upon it. The proximal articular surface of the metatarsal bone can thus theoretically record the body weight of the animal to near perfection. The general question is to understand if it is possible to estimate the body weight (and perhaps the height) of the dromedary from the proximal extremity of a metatarsal bone found at the archeological dig site. This bone is frequently found whole in these sites so it would be very useful and interesting if the animal's size could be estimated from these artifacts. On a young adult dromedary which has not yet undergone epiphysation, the distal extremity can be missing and hence the proximal extremity can reveal more information. Various linear regressions between a live animal and its bones have already been shown in bovines (Matolcsi 1970; Forest 1998). The underlying question therefore is to know if the size of the articular surfaces is a better estimator of the animal's body weight than conventional methods used in osteometry and proposed by Angela von den Driesch (1976), namely the proximal width of the metatarsal bone (Bp) or its proximal depth (Dp). A future study should look at metacarpal bones to see if the metatarsal results are identical. The current sample did not contain these bones and did not permit this work.

Are proximal articulating surfaces of the metatarsal better indicators of the animal's body weight than proximal width (Bp) and depth (Dp)? These last two measurements are already known to be linked with body weight (Guintard 1998). How does sexual dimorphism and belonging to either the Targui or Sahraoui populations affect bone morphology?

MATERIALS AND METHODS

Data used for this study originated from 43 adult dromedaries: 27 Sahraoui animals (13 females and 14 males) and 16 Targui animals (nine females and seven males) corresponding to a total number of 22 females and 21 males. These individuals were over five years old and were slaughtered at Ouargla slaughterhouse in Algeria, between November 2010 and September 2014. For each individual, two biometric measurements were made prior to slaughter: the height at the withers (HW) and body weight (BW). Following slaughter, the rear left and right cannon bones were collected. A total of 86 metatarsals thus constituted the material for the study. The morpho-biometric differences between the two breeds (Sahraoui and Targui) are not explored in this study as there are already many other papers on the subject (Babelhadj *et al.* 2016, 2017; Guintard & Babelhadj 2018).

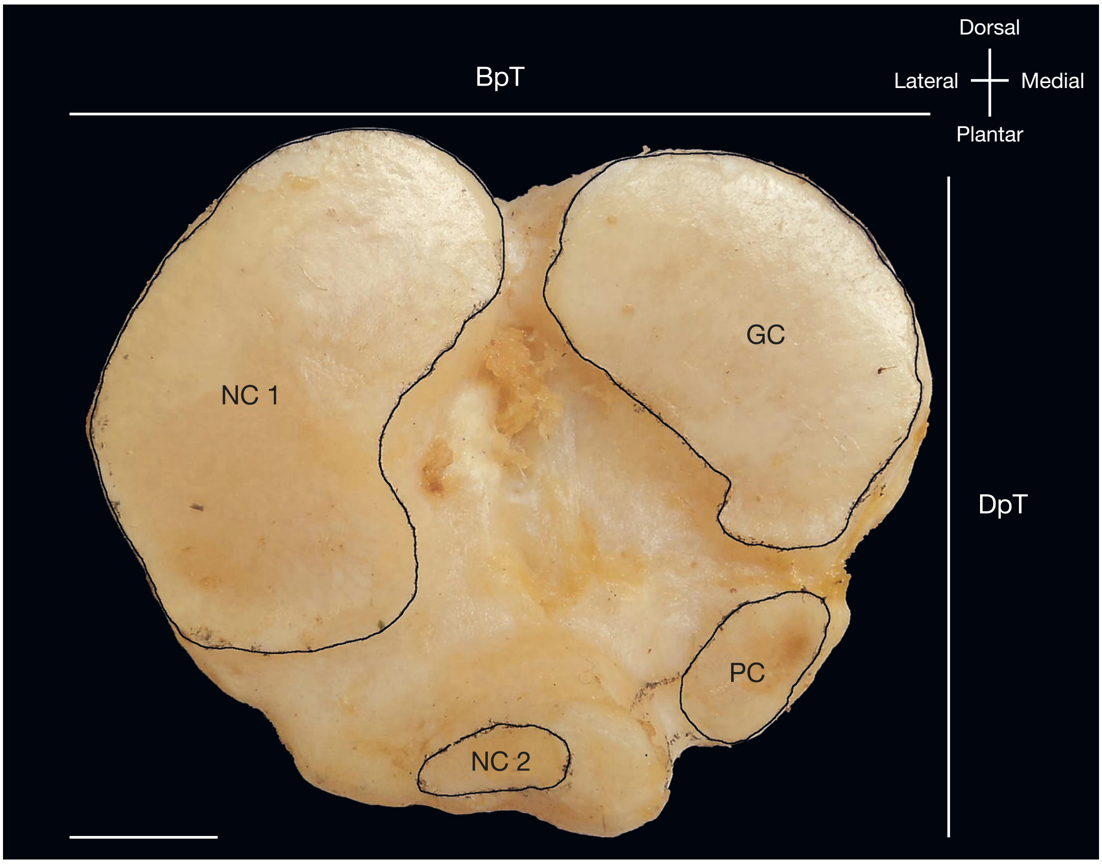

Fig. 1. — Proximal view of a left metatarsal bone of a dromedary. Surface measurements (cm^2): surface for the great cuneiform bone (**GC**); great cranial articular surface for the cuboid bone (**NC 1**); little caudal articular surface for the cuboid bone (**NC 2**); surface for the small cuneiform bone (**PC**). Linear measurements (cm): proximal width with T at the extremity (**BpT**); proximal depth with T at the extremity (**DpT**). Scale bar: 1 cm.

These two camelid populations from Algeria are characterised by their versatility (milk and meat production as well as being used as a beast of burden). The Sahraoui are excellent draught animals that also produce meat, fleece and milk. Their population extends from the Great Western Erg to the center of the Sahara (Ben Aissa 1989). According to Messaoudi (1999), the Targui are excellent racing animals. They have very long, lean limbs and have a grey coat with short, fine hairs. This is the dromedary of the northern Tuareg and it is found in central Sahara, in Hoggar and in the extreme south of Algeria (Tamanrasset). It is also found a little further north as it is often used for breeding and racing. It is also used as a saddle animal and a beast of burden. Algerian studies to distinguish the country's camelin phenotypes and studies on North African genotypes tend to show that Sahraoui and Targui are less actual breeds than ecotypes with little or no genotypic differences. However, the Targui is morphologically slightly larger (Oulad Belkhir *et al.* 2013).

Measurements

For live animals, the biometric parameters were measured using a centimeter-accurate height scale for HW and a precise scale per kilogram for BW.

The weight of the animal (BW) was obtained by the barymetry method, according to the equations of Boué (1949), described by Babelhadj *et al.* (2016).

The right and left hind feet were extracted from below the tarsus and were labelled in order to identify the animal they originated from. After dissection of the surrounding soft tissues, the bones were cooked by immersion in boiling water for several hours. After cooking, they were cleaned with running water and dried for several days in the open air.

Several measurements were performed for each bone (Fig. 1):

– Two linear measurements were made with calliper (Electronic Digital Calliper, with a precision of 1/100 mm reduced for statistics to 1/10 mm), according to the nomenclature of Von den Driesch (1976), which included:
  – BpT = Bp width of the proximal extremity with T at the end for metatarsal;
  – DpT = Dp depth of the proximal extremity with T at the end for metatarsal.

– Four measurements were made of the proximal articular surface: after taking a photograph with a scale of the proximal extremity, the surfaces were measured using ImageJ software (multi-platform and open-source software for processing and image analysis developed by the NIH [National Institutes of Health-USA]):

Table 1. — Osteometric and biometric measurements, depending on the breed and the sex. Abbreviations: **BpT**, proximal width with T at the extremity for the metatarsal; **BW**, body weight; **DpT**, proximal depth with T at the extremity for the metatarsal; **GC**, surface for the great cuneiform bone; **HW**, height at the withers; **NC1**, great cranial articular surface for the cuboid bone; **NC2**, little caudal articular surface for the cuboid bone; **PC**, surface for the small cuneiform bone; **SA**, total proximal articular surface; **Sd**, standard deviation; **SF**, Sahraoui Female; **SM**, Sahraoui Male; **TF**, Targui Female; **TM**, Targui Male.

		Right Side				Left Side			
Measurement		**min**	**max**	**mean**	**sd**	**min**	**max**	**mean**	**sd**
GC (cm²)	SF	4.127	7.057	5.445	0.968	4.186	7.462	5.595	1.037
	SM	5.221	7.047	6.140	0.521	5.953	7.592	6.552	0.539
	TF	3.867	5.799	4.850	0.654	4.480	5.776	5.192	0.498
	TM	5.571	7.995	6.643	0.816	4.631	7.910	6.429	1.080
PC (cm²)	SF	0.430	1.541	0.868	0.276	0.628	1.057	0.890	0.138
	SM	0.843	1.220	0.986	0.114	0.614	1.473	1.040	0.268
	TF	0.559	1.033	0.858	0.163	0.531	1.137	0.801	0.174
	TM	0.431	1.665	1.057	0.471	0.642	1.748	1.082	0.371
NC1 (cm²)	SF	6.331	9.429	7.882	1.040	6.483	11.456	8.038	1.474
	SM	5.168	10.019	7.996	1.327	6.208	10.443	8.257	1.213
	TF	5.487	7.699	6.594	0.757	5.425	8.792	7.111	0.932
	TM	7.661	10.360	8.960	1.080	6.441	11.068	8.649	1.638
NC2 (cm²)	SF	0.275	0.926	0.627	0.222	0.334	1.027	0.576	0.214
	SM	0.316	2.254	0.872	0.483	0.268	2.474	0.912	0.567
	TF	0.248	1.427	0.730	0.425	0.306	1.424	0.682	0.332
	TM	0.198	1.520	0.849	0.516	0.567	1.660	0.844	0.389
SA (cm²)	SF	11.569	18.196	14.821	2.056	11.958	19.006	15.100	2.370
	SM	11.548	19.968	15.993	2.006	13.578	20.357	16.761	1.988
	TF	10.305	14.468	13.032	1.308	12.169	15.897	13.787	1.125
	TM	15.588	19.281	17.508	1.310	13.322	19.116	17.005	2.027
BpT (mm)	SF	5.365	6.504	5.894	0.364	5.496	6.750	5.979	0.397
	SM	5.345	6.597	6.151	0.323	5.662	6.692	6.248	0.314
	TF	5.015	5.925	5.532	0.282	5.250	5.905	5.654	0.191
	TM	5.483	6.925	6.392	0.460	5.443	6.715	6.298	0.475
DpT (mm)	SF	4.594	5.610	5.117	0.348	4.759	5.846	5.174	0.340
	SM	4.698	5.774	5.322	0.293	4.959	6.132	5.415	0.316
	TF	4.328	5.166	4.865	0.262	4.845	5.138	4.967	0.107
	TM	4.697	5.732	5.443	0.383	4.773	5.839	5.406	0.414
BW (kg)	SF	325.000	555.000	433.462	64.210	325.000	555.000	433.462	64.210
	SM	391.000	689.000	538.214	94.638	391.000	689.000	538.214	94.638
	TF	210.000	527.000	377.556	106.026	210.000	527.000	377.556	106.026
	TM	416.000	690.000	511.286	99.368	416.000	690.000	511.286	99.368
HW (cm)	SF	162.000	190.000	179.923	8.995	162.000	190.000	179.923	8.995
	SM	172.000	208.000	186.214	9.862	172.000	208.000	186.214	9.862
	TF	178.000	189.000	181.111	3.551	178.000	189.000	181.111	3.551
	TM	184.000	200.000	192.286	5.736	184.000	200.000	192.286	5.736

– GC: surface for the great cuneiform bone (*Os tarsale II et III* [*Os cuneiforme intermediolaterale*] = fused second and third tarsal bones);
– PC: surface for the small cuneiform bone (*Os tarsale I* [*Os cuneiforme mediale*] = first tarsal [medial cuneiform] bone);
– NC1 and NC2: both surfaces for cuboid bone (*Os tarsale IV* [*Os cuboideum*] = fourth tarsal bone or cuboid bone), (respectively labelled NC1 for the great cranial articular surface, and NC2 for the little caudal articular surface);

The total proximal articular surface (SA) was calculated by summing the four previous ones (noted as SA = NC1 + NC2 + GC + PC).

Statistical analyses

In the following statistical analyses, descriptive parameters used for each group were the minimum and maximum values, the mean and the standard deviation. The four groups included in statistical analyses are as follows: SF for female Sahraoui (n = 13), SM for male Sahraoui (n = 14), TF for female Targui (n = 9) and TM for male Targui (n = 7).

The asymmetry between the right and left side samples was further investigated by comparing the data of each side using a linear mixed model, individuals treated as random effect for each measurement. The independence and the normal distribution of the residuals and random effects have been verified using a graph proposed by linear mixed effects authors (Pinheiro & Bates 2000). The confidence interval for each side was set at 95%.

Firstly, the relationship between body weight (BW), height at the withers (HW) and other different measurements was analysed by a PCA (PCA2) using only the data from the "right" side. The surface variables (NC1, NC2, GC, PC) and the linear variables (BpT, DpT) were considered as the active variables, whereas the height at the withers, the body weight, SA, the breed and sex were treated as supplementary variables. A 95% confidence interval was set for each breed and sex group.

Table 2. — Osteometric statistic parameters depending on the side. Abbreviations: **BpT**, proximal width with T at the extremity for the metatarsal; **DpT**, proximal depth with T at the extremity for the metatarsal; **GC**, surface for the great cuneiform bone; **L**, left; **NC1**, great cranial articular surface for the cuboid bone; **NC2**, little caudal articular surface for the cuboid bone; **PC**, surface for the small cuneiform bone; **R**, right; **SA**, total proximal articular surface; **σ**, standard deviation.

	Mean value		σ		
Measurement	**L**	**R**	**L**	**R**	**p-value**
GC	5.95	5.74	0.96	0.95	0.028
PC	0.95	0.93	0.25	0.26	0.632
NC1	8.01	7.82	1.37	1.30	0.175
NC2	0.75	0.76	0.42	0.41	0.759
BpT	6.05	5.98	0.42	0.45	0.044
DpT	5.25	5.18	0.35	0.37	0.066
SA	15.70	15.30	2.28	2.27	0.071

Secondly, a multilinear regression of BW and HW based on surface and linear measurements was done using a "step by step" procedure to select the best bivariate model (RegBest of the FactomineR package), resulting in a predictive equation for each of the two biological variables to be estimated.

The statistical analyses were carried out using the free R software, Rstudio. The FactomineR package was used for multivariate analyses. The level of significance was set at 0.05.

RESULTS

Sample description

Table 1 shows the measured values including four surface measurements, two linear measurements, the total surface calculated for each bone and biometric data (body weight, the height at the withers) for each breed and sex for the right and left side. The raw values of each individual are shown in Appendix 1.

Influence of asymmetry L *versus* R

The study was conducted on the whole population (n = 86; 43 left and 43 right metatarsal bones).

Results of linear mixed effects models show significantly different averages for both sides only on GC and BpT measurements (p-value = 0.0276, and p = 0.0439 respectively) (Table 2). However, the power of these two models was less than 0.80, respectively 0.6 and 0.528, which means that the false rate risk was too high to conclude a clear, significant difference. Considering these results, the study was then conducted on the right side dataset.

Multivariate analysis and modelling

All multivariate analyses were carried out for the 43 right metatarsals (27 Sahraoui animals [13 females and 14 males] and 16 Targui animals [nine females and seven males]).

The PCA was performed on four surface measurements and two linear measurements as active variables; HW, BW and SA were added as supplementary variables.

The inertia of the first factor plane was 79.43% (59.16% for factor 1 and 20.27% for factor 2). Given the number of variables and individuals, the inertia percentage of these two dimensions is satisfactory for the analysis. On the first axis, the PCA showed a size effect and the parameters that contributed the most were DpT, BpT, GC, NC1 in decreasing order while PC and NC2 contributed to the second axis. Concerning the correlation of supplementary variables with axis 1, SA was highly correlated (r = 0.89), while BW and HW presented a low correlation (r = 0.24 and 0.13 respectively) (Fig. 2A). Concerning the qualitative supplementary variables, the coordinates for male and female points (two breeds together) were significantly different from zero on axis 1 (male abscissa = 1.087, female abscissa = –1.087) (Fig. 2B, D).

The coordinates of each breed's points were not significantly different from zero and confidence ellipsis of the two breeds are practically superimposed (Fig. 2C), this means that there is no statistical difference between the breeds for the osteometry measurements of metatarsals. Moreover, despite the lack of a significant difference between the two breeds, the sexual dimorphism is well marked because the intervals between males and females are disjointed (Fig. 2C, D). However, the sexual dimorphism was not expressed in the same way in the two breeds. Hence, the coordinates for Targui male and Targui female were opposite and significantly different from zero. For Sahraoui breed, the coordinates of male and female were opposite but not different from 0. The biological interpretation of this difference in dimorphism between the two breeds is not clear, probably due to sample selection and to the geographic origin of the animals.

Therefore, it seems logical to examine how the articular surfaces and the height at the withers or the body weight are related to each other in order to determine how a zooarchaeologist who finds the proximal end of metatarsal of a camel could estimate the size of the animal.

Body weight modelling

The best predictive model of body weight from the osteometric measurements according to the step-by-step method contains only one predictive measurement, the proximal width of the metatarsus (BpT) with a correlation coefficient of r = 0.534 (p-value = 0.0002). The predictive equation is written as follows:

$$BW = 128.88*BpT - 302.55$$

The standard error of the slope is 31.88, and the standard error of the original y-axis is 191.25.

Although the previous model is deemed the best, the prediction of the body weight from the proximal thickness of the metatarsus (DpT) is also interesting (r = 0.415, p-value = 0.003). In this case, the predictive equation is:

$$BW = 127.9*DpT - 194.52$$

The standard error of the slope is 40.97, and the standard error of the original y-axis is 212.94.

The predictive equations for the articular surfaces are not better than the linear measurements, but we can propose the following equation for the sum of the articular surfaces which is the best model when using the articular surfaces:

$$BW = 21.728*SA + 136.840 \quad (r = 0.438; \text{p-value} = 0.00196)$$

The standard error of the slope is 6.566, and the standard error of the original y-axis is 101.3.

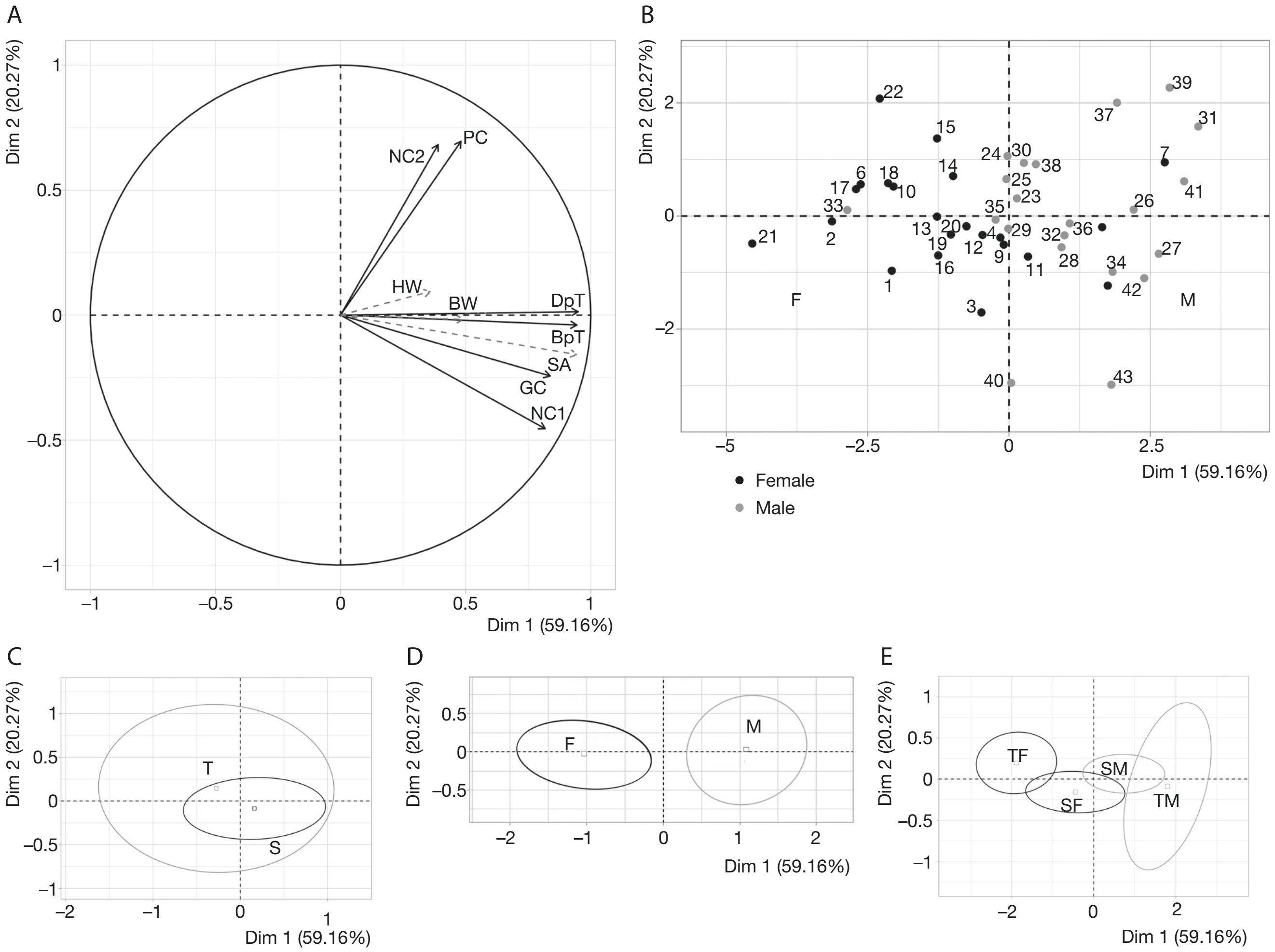

FIG. 2. — Principal component analysis (PCA), graphs for seven parameters per bone, 43 right metatarsal bones. **A**, graph of variables; **B**, scatterplot of individuals; **C**, 95% confidence ellipsis for breed; **D**, 95% confidence ellipsis for sex; **E**, 95% confidence ellipsis for breed and sex. Abbreviations: **BpT**, proximal width with T at the extremity for the metatarsal; **BW**, body weight; **Dim**, Factor of the PCA (Dim 1 = Factor 1, Dim 2 = Factor 2); **DpT**, proximal depth with T at the extremity for the metatarsal; **F**, female; **GC**, surface for the great cuneiform bone; **HW**, height at the withers; **M**, male; **NC1**, great cranial articular surface for the cuboid bone; **NC2**, little caudal articular surface for the cuboid bone; **S**, Sahraoui breed; **SA**, total proximal articular surface; **SF**, female Sahraoui; **SM**, male Sahraoui; **T**, Targui breed; **TF**, female Targui; **TM**, male Targui.

Height at the withers modelling

The best predictive model for the height at the withers is a single variable model, the linear measurement corresponding to the proximal width of the metatarsus, BpT. The p-value is 0.02 and the r^2 is 11.9%. This model proves to be of poor performance because it explains only 12% of the variability. The prediction of the height at the withers by osteometry measurements of width and depth of metapodials cannot be reliably done.

DISCUSSION

Faye *et al.* (1997) mention the appearance of the dromedary in Africa around 2650 BP and Bartosiewicz (2017) suggests that dromedary bones appear frequently at archeological dig sites from the Roman period in the Mediterranean basin, the Arabian Peninsula, and the Carpathian Basin. Hesse & Wapnish (1997) mentioned dromedary remains at Tell Jemmeh from earlier periods (Bronze-Early Iron [1400-800 BC], Assyrian [800-600 BC], Persian-Babylonian [600-400 BC] and Hellenistic [400-200 BC]).

The establishment of a baseline osteometric reference for dromedary metapodials is of particular importance as they are very strong bones often found at dig sites (Morales Muñiz *et al.* 1995; Pigière & Henrotay 2011; Grigson 2012; Galik *et al.* 2015). Bartosiewicz *et al.* (1993) highlighted that the plasticity of the distal articular surfaces of metapodials is linked to the power of an animal. It seems logical to particularly focus on the articular surfaces of a bone as they show planiform surfaces and are easy to quantify in terms of area. To our knowledge, the identification of a relationship between proximal articulation surfaces of dromedary metatarsal and body weight and height at the withers of live animals has never been studied. The establishment of the largest possible sample of metapodial bones required the inclusion of two populations of dromedaries that have otherwise been studied separately (Babelhadj *et al.* 2016, 2017; Guintard & Babelhadj 2018). Those two camelid breeds are close enough in terms of average height and average body weight and are considered to be eumetric. The lack of significant differences for measured parameters between the two breeds justifies, *a posteriori*, grouping them in one single population. Similarly, in order to ease the data presentation, the lateralisation was not studied until the end of the work, as both the right and left sides show no significant difference.

It is interesting to observe that in our study, the most discriminative articular surfaces between males and females are the two biggest surfaces, GC and NC1, located on the dorsal surface of the bone and are gathered on the factor 1 of the PCA (size factor). The other two smaller surfaces (the small surface articulating with the naviculocuboid bone [NC2] and the surface articulating with the small cuneiform bone [PC]) are more variable in shape and are gathered on factor 2 of the PCA (shape factor). The sum of the four areas of articular surfaces (SA) is correlated to factor 1 of the PCA, the other two linear measurements – BpT and DpT, as well as the animal's body weight. As has already been demonstrated in bovines (Guintard 1996), measurements of width and depth are well correlated to the animal's body weight.

The best predictive model of body weight from osteometric measurements, coming from step-by-step procedures, emphasises BpT and to a lesser extent DpT. It also shows that measurements related to areas of articular surfaces are not better than linear measurements when estimating the animal's body weight. This result is interesting because it allows zooarchaeologists to continue making simple measurements with a calliper without having to measure articular surfaces. The proximal width and thickness of the metatarsal bone include not only the articular width, but also the rest of the proximal extremity of the bone and hence is a better estimator of the animal's body weight. This width and thickness integrate not only the force which passes through the articular surfaces, but also the internal configuration of the bone which has to be organised so as to cope with the centrifugal forces that tend to deform the bone structure. The peripheral bone layers, which surround the proximal articular surfaces of the metatarsal bone, thus play a major role, much like the buttresses of a Romanesque church that support and strengthen the structure against which they are built.

Finally, parameters of width, depth and articular surfaces of the proximal end of the metatarsal bone do not allow the height at the withers to be estimated precisely. This is not surprising, as in all osteometric studies performed on ungulates (bovines, ovines, caprines and dromedaries), the height at the withers is above all correlated to elongation parameters of the bone, such as the great length of the metapodials (Guintard 1998; Guintard & Lallemand 2003; Tekkouk & Guintard 2007; Guintard & Tekkouk-Zemmouchi 2010; Adamou *et al.* 2013; Babelhadj *et al.* 2016, 2017; Guintard *et al.* 2018).

It might also be interesting to see whether young individuals (five to seven years) have significantly different values from older animals, since bone growth in this species is relatively late and ends at about seven years of age. The actual data regarding the age was not avaible in this study. Age was estimated by examination of the dentition by experienced breeders and butchers. Despite being the most common method for camels, it is not of exact accuracy.

Similarly, the weight variations observed between individuals do not reflect differences in overweight status, feeding or watering of animals, parameters known to vary significantly with the total mass of an animal; but weight values were obtained by the barymetry method. A study based on the individual weighing of animals would probably be more informative, but this kind of data was not available to us because it is difficult to set up in the field.

CONCLUSION

This study, performed on a relatively large sample of proximal ends of metatarsal bones from Sarahoui and Targui breeds of dromedaries, allowed us to study areas of articular surfaces and to compare them with linear measurements of width and depth. Even if articular surfaces are well correlated to the body weight of the live animal, they do not give a better estimation of the body weight than simple linear measurements, and we highlighted that the best bivariate model to estimate the body weight is based on the proximal width of the bone. A further study on the distal condyle of the metatarsal bone would be interesting to perform, in order to investigate whether this part of the bone follows the same trend as the proximal one.

However, a spatial 3D study is more complicated to carry out, due to the shape of the distal articular surfaces that are curvilinear. Zooarchaeologists do not always find entire bones, and hence setting up a baseline for very strong bone ends (proximal or distal end) such as metapodials is of the greatest interest.

Acknowledgements
The authors are very thankful to the author Baaissa Babelhadj's mother, Messaouda Boublal, who helped in preparing the bones. Many thanks to Tom Hinton for the proofreading of the manuscript. Finally, thanks to Vianney Forest and the second anonymous reviewer whose insightful comments helped us improve this article.

REFERENCES

Adamou A., Tekkouk-Zemmouchi F., Thorin C., Brerhi E. H., Borvon A., Babelhadj B. & Guintard C. 2013. — Étude ostéo-biométrique de la « race » cameline algérienne Sahraoui (*Camelus dromedarius* L., 1758). *Revue de Médecine vétérinaire* 164 (5): 230-244.

Albarella U. 1997. — Shape variation of cattle metapodials: age, sex or breed? Some examples from mediaeval and postmediaeval sites, *in* Kokabi M. & Wahl J. (eds), Actes du 7ème colloque de l'International Council for Archaeozoology, Constance, septembre 1994. *Anthropozoologica* 25-26: 37-47.

Babelhadj B., Adamou A., Thorin C., Tekkouk-Zemmouchi F., Benaissa A. & Guintard C. 2016. — Etude ostéo-biométrique comparée des « races » camelines algériennes Sahraoui et Targui (*Camelus dromedarius* L., 1758). *Revue de Médecine vétérinaire* 167 (3-4): 77-92.

Babelhadj B., Benaissa A., Adamou A., Tekkouk-Zemmouchi F., Raache S., Babelhadj T. & Guintard C. 2017. — Morpho-zoometric approach of female camels (*Camelus dromedarius* L.) of the Sahraoui and Targui Algerian populations. *Revue d'Élevage et de Médecine vétérinaire des Pays tropicaux* 70 (2): 65-69. https://doi.org/10.19182/remvt.31483

Babelhadj B., Benaissa A., Adamou A., Tekkouk-Zemmouchi F., Ridouh R., Djelfaoui Z. & Guintard C. 2020. — Osteometry of dromedary metapods: case of the Algerian population Targui (*Camelus dromedarius* Linné, 1758). *Journal of Animal and Veterinary Advances* 19 (5): 47-56. https://doi.org/10.36478/javaa.2020.47.56

Bartosiewicz L. 2017. — Zooarchaeology in the Carpathian basin and adjacent areas, *in* Albarella U., Rizzetto M., Russ H., Vickers K & Viner-Daniels S. (eds), *The Oxford Handbook of Zooarchaeology*. Oxford University Press, Oxford: 99-112. https://doi.org/10.1093/oxfordhb/9780199686476.013.7

Bartosiewicz L., Van Neer W. & Lentacker A. 1993. — Metapodial asymmetry in draft cattle. *International Journal of Osteoarchaeology* 3 (2): 69-75. https://doi.org/10.1002/oa.1390030203

Ben Aissa R. 1989. — Le dromadaire en Algérie, *in* Tisserand J.-L. (ed.), *Séminaire sur la digestion, la nutrition et l'alimentation du dromadaire*. Ciheam (coll. Options méditerranéennes Série A, Séminaires méditerranéens; 2), Zaragoza: 19-28. http://om.ciheam.org/om/pdf/a02/CI000422.pdf, last consultation on 8 June 2022.

Berteaux D. & Guintard C. 1995. — Osteometric study of the metapodials of Amsterdam Island feral cattle. *Acta Theriologica* 40 (1): 97-110. https://doi.org/10.4098/AT.arch.95-10

Boessneck J. 1956. — Ein Beitrag zur Errechnung der Widerristhöhe nach Metapodienmassen bei Rindern. *Zeitschrift für Tierzuchtung und Zuchtungsbiologie* 68: 75-90.

Boué A. 1949. — Essai de barymétrie chez le dromadaire nord-africain. *Revue d'Élevage et de Médecine vétérinaire des Pays tropicaux* 3: 13-16.

Driesch A. von den 1976. — *A guide to the Measurement of Animal Bones from Archaeological Sites*. Peabody Museum of Archaeology and Ethnology (coll. Peabody Museum Bulletins; 1), Harvard, 137 p.

Faye B., Saint-Martin G., Bonnet P., Bengoumi M. & Dia M. L. 1997. — *Guide de l'élevage du dromadaire*. Sanofi Santé Nutrition animale, Libourne, 126 p.

Forest V. 1998. — De la hauteur au garrot chez les espèces domestiques. *Revue de Médecine vétérinaire* 149 (1): 55-60.

Galik A., Mohandesan E., Forstenpointner G., Scholz U. M., Ruiz E., Krenn M. & Burger P. 2015. — A sunken ship of the desert at the river Danube in Tulln, Austria. *PLOS One* 10 (4): e0121235. https://doi.org/10.1371/journal.pone.0121235

Grigson C. 2012. — Camels, copper and donkeys in the early Iron Age of the Southern Levant: Timna revisited. *Levant* 44 (1): 82-100. https://doi.org/10.1179/175638012X13285409187919

Guintard C. 1996. — Estimation du poids chez les bovins à partir du métapode, *in IIème Congrès des étudiants du MNHN, Biodiversité et Biologie des Organismes et des Populations, Zoologie, 6 et 7 juin 1996*. Muséum national d'Histoire naturelle, Paris: 37-38.

Guintard C. 1998. — Ostéométrie des métapodes de bovins. *Revue de Médecine vétérinaire* 149 (7): 751-770.

Guintard C. & Babelhadj B. 2018. — Morphotypes et force animale développée. Comparaison de deux populations de dromadaires algériens : la Sahraoui et la Targui (*Camelus dromedarius*, L.), *in* Guizard F. & Beck C. (eds), *Animal source d'énergie : enquêtes dans l'Europe pré-industrielle*. Presses universitaires de Valenciennes, Valenciennes: 133-147.

Guintard C. & Lallemand M. 2003. — Osteometric study of metapodial bones in sheep (*Ovis aries* L., 1758). *Annals of Anatomy* 185 (6): 573-583. https://doi.org/10.1016/S0940-9602(03)80131-0

Guintard C. & Tekkouk-Zemmouchi F. 2010. — Aperçu ostéobiométrique de la race ovine (*Ovis aries* L.) Ouled Djellal (Algérie). *Revue de Médecine vétérinaire* 161 (11): 521-530.

Guintard C., Ridouh R., Thorin C. & Tekkouk-Zemmouchi F. 2018. — Étude ostéométrique des métapodes de chèvres (*Capra hircus* L., 1758) d'Algérie : la race autochtone Arabia. *Revue de Médecine vétérinaire* 169 (10-12): 221-232.

Hesse B. & Wapnish P. 1997. — *Animal Bone Archaeology. From Objectives to Analysis*. Taraxacum, Washington, 132 p.

Higham C. F. W. 1969. — The metrical attributes of two sample of bovine limb bones. *Journal of Zoology* 157 (1): 63-74. https://doi.org/10.1111/j.1469-7998.1969.tb01689.x

Matolcsi J. 1970. — Historische Erforschung der Körpergröße des Rindes auf Grund von ungarischen Knochenmaterial. *Zeitschrift für Tierzuchtung und Zuchtungsbiologie* 87 (1-4): 89-137. https://doi.org/10.1111/j.1439-0388.1970.tb01330.x

Messaoudi B. 1999. — Point de situation sur l'élevage camelin en Algérie, *in Les premières journées sur la recherche cameline de Ouargla, 25-26 mai 1999*. Université de Ouargla, Algérie: 13-14.

Morales Muñiz A., Riquelme J. A. & Liesau von Lettow-Vorbeck C. 1995. — Dromedaries in Antiquity: Iberia and beyond. *Antiquity* 69 (263): 368-375. https://doi.org/10.1017/S0003598X00064772

O'Connor T. P. 2000. — *The Archaeology of Animal Bones*. Sutton, Gloucestershire, 206 p.

Oulad Belkhir A., Chehma A. & Faye B. 2013. — Phenotypic variability of two principal Algerian camel's populations (Targui and Sahraoui). *Emirates Journal of Food and Agriculture* 25 (3): 231-237. https://doi.org/10.9755/ejfa.v25i3.15457

Pigière F. & Henrotay D. 2011. — Camels in the northern provinces of the Roman Empire. *Journal of Archaeological Science* 39 (5): 1531-1539. https://doi.org/10.1016/j.jas.2011.11.014

Pinheiro J. C. & Bates M. D. 2000. — *Mixed-Effects Models in S and S-PLUS*. Springer, New York, 548 p.

Tekkouk F. & Guintard C. 2007. — Approche ostéométrique de la variabilité des métacarpes de bovins et recherche de modèles applicables pour l'archéozoologie : cas de races rustiques françaises, algériennes et espagnole. *Revue de Médecine vétérinaire* 158 (7): 388-396.

Van Wijngaarden-Baker L. H. & Bergström P. L. 1988. — Estimation of the shoulder height of cattle. *Archaeozoologia* 2 (1-2): 67-82.

Zalkin V. J. 1960. — Metapodial variation and its significance for the study of ancient horned cattle. *Bulletin de la Société des Naturalistes de Moscou. Section biologique* 65 (1): 109-126.

Submitted on 25 August 2021;
accepted on 25 January 2022;
published on 5 August 2022.

Appendix 1. — List of measurements carried out. Abbreviations: **BpT**, proximal width with T at the extremity for the metatarsal; **BW**, body weight; **DpT**, proximal depth with T at the extremity for the metatarsal; **GC**, surface for the great cuneiform bone; **HW**, height at the withers; **L**, left; **NC1**, great cranial articular surface for the cuboid bone; **NC2**, little caudal articular surface for the cuboid bone; **PC**, surface for the small cuneiform bone; **R**, right; **SA**, total proximal articular surface.

	Sex	Side	GC (cm^2)	PC (cm^2)	NC1 (cm^2)	NC2 (cm^2)	BpT (mm)	DpT (mm)	Age (year)	BW (kg)	HW (cm)	SA (cm^2)
Sahraoui nº1	female	R	4.852	0.5	7.431	0.597	5.682	4.705	13	481	172	13.38
Sahraoui nº1	female	L	6.588	0.628	11.456	0.334	6.018	5.101	13	481	172	19.006
Sahraoui nº2	female	R	4.127	0.836	6.331	0.275	5.365	4.594	12	385	184	11.569
Sahraoui nº2	female	L	4.43	0.873	6.852	0.442	5.52	5.017	12	385	184	12.597
Sahraoui nº4	female	R	5.955	0.43	8.267	0.562	5.727	5.298	8	360	168	15.214
Sahraoui nº4	female	L	5.831	0.678	7.669	0.466	5.926	4.963	8	360	168	14.644
Sahraoui nº5	female	R	5.301	0.722	8.191	0.864	5.991	5.243	14	401	162	15.078
Sahraoui nº5	female	L	4.186	0.752	6.483	0.537	5.628	4.759	14	401	162	11.958
Sahraoui nº6	female	R	6.442	1.076	9.429	0.867	6.283	5.357	7	467	184	17.814
Sahraoui nº6	female	L	5.778	1.019	8.593	1.027	6.235	5.343	7	467	184	16.417
Sahraoui nº7	female	R	4.182	0.867	6.392	0.688	5.534	4.616	11	394	171	12.129
Sahraoui nº7	female	L	4.967	1.009	6.576	0.435	5.925	4.86	11	394	171	12.987
Sahraoui nº8	female	R	7.057	1.541	8.761	0.837	6.504	5.61	7	388	186	18.196
Sahraoui nº8	female	L	7.192	1.057	9.49	0.646	6.75	5.766	7	388	186	18.385
Sahraoui nº9	female	R	6.919	0.899	8.864	0.426	6.389	5.608	5	325	178	17.108
Sahraoui nº9	female	L	7.462	1.04	9.026	0.475	6.672	5.846	5	325	178	18.003
Sahraoui nº10	female	R	6.058	0.963	7.7	0.404	5.936	5.193	7	458	181	15.125
Sahraoui nº10	female	L	6.006	0.867	7.677	0.501	5.849	5.307	7	458	181	15.051
Sahraoui nº11	female	R	4.644	0.785	6.743	0.926	5.425	4.851	11	450	190	13.098
Sahraoui nº11	female	L	4.784	0.894	7.155	1.025	5.496	4.923	11	450	190	13.858
Sahraoui nº13	female	R	5.066	0.894	9.175	0.547	6.149	5.299	14	465	186	15.682
Sahraoui nº13	female	L	5.684	0.971	9.437	0.606	6.181	5.412	14	465	186	16.698
Sahraoui nº14	female	R	4.867	0.722	8.136	0.813	5.935	5.241	16	555	190	14.538
Sahraoui nº14	female	L	4.527	0.837	7.204	0.514	5.876	5.022	16	555	190	13.082
Sahraoui nº15	female	R	5.315	1.043	7.045	0.343	5.701	4.911	9	506	187	13.746
Sahraoui nº15	female	L	5.306	0.947	6.877	0.478	5.649	4.944	9	506	187	13.608
Targui nº1	female	R	5.78	0.858	6.299	1.02	5.621	5.088	11	396	178	13.957
Targui nº1	female	L	5.776	0.93	6.531	0.604	5.75	5.045	11	396	178	13.841
Targui nº2	female	R	4.553	1.033	7.121	1.159	5.513	5.015	13	409	181	13.866
Targui nº2	female	L	5.029	1.137	8.792	0.939	5.56	5.024	13	409	181	15.897
Targui nº4	female	R	5.166	0.897	7.699	0.248	5.805	4.869	12	459	189	14.01
Targui nº4	female	L	5.684	0.789	7.965	0.523	5.905	4.909	12	459	189	14.961
Targui nº5	female	R	4.222	0.955	6.471	0.508	5.418	4.622	10	211	179	12.156
Targui nº5	female	L	4.48	0.743	7.248	0.472	5.537	4.852	10	211	179	12.943
Targui nº6	female	R	4.651	1.002	6.286	0.528	5.521	4.805	7	371	182	12.467
Targui nº6	female	L	4.941	0.789	6.755	0.657	5.66	4.889	7	371	182	13.142
Targui nº7	female	R	4.981	0.86	7.293	0.44	5.925	5.052	15	527	178	13.574
Targui nº7	female	L	5.195	0.871	7.297	0.742	5.731	5.078	15	527	178	14.105
Targui nº8	female	R	5.799	0.623	7.067	0.979	5.722	5.166	9	439	182	14.468
Targui nº8	female	L	5.776	0.626	7.02	0.475	5.819	5.138	9	439	182	13.897
Targui nº9	female	R	3.867	0.559	5.62	0.259	5.015	4.328	8	376	183	10.305
Targui nº9	female	L	5.325	0.531	6.964	0.306	5.671	4.919	8	376	183	13.126
Targui nº10	female	R	4.629	0.939	5.487	1.427	5.247	4.842	10	210	178	12.482
Targui nº10	female	L	4.525	0.795	5.425	1.424	5.25	4.845	10	210	178	12.169
Sahraoui nº2	male	R	5.755	0.878	7.42	0.976	6.036	5.3	15	669	206	15.029
Sahraoui nº2	male	L	6.089	1.449	7.688	1.071	6.233	5.471	15	669	206	16.297
Sahraoui nº3	male	R	5.574	1.122	7.234	0.745	5.998	5.215	13	495	183	14.675
Sahraoui nº3	male	L	6.362	0.961	7.995	0.894	6.472	5.615	13	495	183	16.212
Sahraoui nº4	male	R	5.853	1.22	6.869	0.748	6.144	5.241	13	459	178	14.69
Sahraoui nº4	male	L	6.062	0.852	7.211	0.818	5.892	4.971	13	459	178	14.943
Sahraoui nº5	male	R	6.007	0.963	9.608	1.22	6.335	5.774	14	569	188	17.798
Sahraoui nº5	male	L	7.592	1.473	10.443	0.409	6.692	6.132	14	569	188	19.917
Sahraoui nº6	male	R	6.552	1.165	10.019	0.567	6.597	5.689	6	451	172	18.303
Sahraoui nº6	male	L	6.583	1.144	9.914	0.702	6.558	5.425	6	451	172	18.343
Sahraoui nº7	male	R	6.522	1.013	8.293	0.502	6.195	5.344	11	594	183	16.33
Sahraoui nº7	male	L	6.413	1.178	8.207	0.662	6.087	5.367	11	594	183	16.46
Sahraoui nº8	male	R	6.518	0.943	7.796	0.71	5.818	5.066	16	563	186	15.967
Sahraoui nº8	male	L	6.259	0.614	7.799	0.268	5.82	5.11	16	563	186	14.94
Sahraoui nº9	male	R	5.946	0.883	6.649	1.335	6.076	5.133	18	628	189	14.813
Sahraoui nº9	male	L	5.953	0.719	6.767	1.634	6.346	5.308	18	628	189	15.073
Sahraoui nº10	male	R	7.047	1.033	9.634	2.254	6.52	5.66	15	689	208	19.968
Sahraoui nº10	male	L	7.278	1.36	9.245	2.474	6.579	5.657	15	689	208	20.357
Sahraoui nº11	male	R	5.873	0.982	8.63	0.674	6.372	5.333	13	532	185	16.159
Sahraoui nº11	male	L	7.253	1.116	9.463	0.924	6.443	5.614	13	532	185	18.756
Sahraoui nº12	male	R	5.221	0.843	5.168	0.316	5.345	4.698	6	391	182	11.548
Sahraoui nº12	male	L	6.164	0.76	6.208	0.446	5.662	4.959	6	391	182	13.578
Sahraoui nº13	male	R	6.978	0.926	8.684	0.513	6.408	5.626	9	430	178	17.101

Appendix 1. — Continuation.

	sex	side	GC (cm²)	PC (cm²)	NC1 (cm²)	NC2 (cm²)	BpT (mm)	DpT (mm)	age (year)	BW (kg)	HW (cm)	SA (cm²)
Sahraoui nº13	male	L	7.181	0.93	8.869	0.497	6.463	5.683	9	430	178	17.477
Sahraoui nº14	male	R	5.977	0.897	7.467	0.746	5.958	5.074	7	447	186	15.087
Sahraoui nº14	male	L	6.362	0.904	7.432	0.926	6.015	5.234	7	447	186	15.624
Sahraoui nº15	male	R	6.132	0.93	8.474	0.899	6.313	5.353	12	618	183	16.435
Sahraoui nº15	male	L	6.174	1.098	8.361	1.039	6.207	5.259	12	618	183	16.672
Targui nº1	male	R	5.909	1.665	8.123	1.017	6.403	5.478	10	554	195	16.714
Targui nº1	male	L	5.455	1.748	7.804	0.624	6.378	5.405	10	554	195	15.631
Targui nº2	male	R	5.571	1.173	7.866	0.978	6.174	5.171	17	449	188	15.588
Targui nº2	male	L	4.631	1.223	6.441	1.027	5.837	4.898	17	449	188	13.322
Targui nº4	male	R	6.939	1.502	7.661	1.52	6.563	5.71	9	416	184	17.622
Targui nº4	male	L	6.838	1.242	7.542	1.66	6.497	5.689	9	416	184	17.282
Targui nº5	male	R	7.995	0.431	10.36	0.495	5.483	4.697	8	465	189	19.281
Targui nº5	male	L	7.08	0.945	10.428	0.663	5.443	4.773	8	465	189	19.116
Targui nº8	male	R	7.074	1.149	9.423	1.393	6.609	5.681	8	574	192	19.039
Targui nº8	male	L	7.91	1.041	8.264	0.714	6.636	5.548	8	574	192	17.929
Targui nº9	male	R	6.212	1.006	9.254	0.341	6.925	5.732	9	690	200	16.813
Targui nº9	male	L	6.507	0.642	8.999	0.655	6.577	5.689	9	690	200	16.803
Targui nº10	male	R	6.801	0.47	10.033	0.198	6.586	5.635	8	431	198	17.502
Targui nº10	male	L	6.58	0.734	11.068	0.567	6.715	5.839	8	431	198	18.949