TÜBİTAK

Research Article

Turk. J. Vet. Anim. Sci.
2009; 33(3): 199-207

doi:10.3906/vet-0709-23

The relationship between morphometric and long bone measurements of the Morkaraman sheep

Hasan ALPAK*, Vedat ONAR, Rıfat MUTUŞ

Department of Anatomy, Faculty of Veterinary Medicine, Istanbul University, 34320 Avcılar, İstanbul - TURKEY

Received: 24.09.2007

Abstract: In this study, a total of 40 adult female Morkaraman sheep, a local Turkish breed, were used. After taking their body measurements and carcass weights, the meat was cut off the bones; the skeletal bones were then removed, macerated and every long bone weighed. Thereafter, morphometric measurements of the long bones were taken. The coefficients obtained from the correlation of osteometric measurements and morphological data were in general low ($r < 0.600$), though certain relationships were found to be significant. Regression of morphological variables on osteometric measurements was statistically significant. By this, regression formulas were obtained which can contribute to predict the visible morphology in zooarchaeological studies. Length measurements would be more suitable for predicting shoulder height than using width measurements of the long bone. On the other hand, body and carcass weights and chest circle would be determined more efficiently by measuring the width of long bones (Bp, Bd, SD). Furthermore, the humero-femoral index formula can be used to identify sheep in an archaeological bone collection of several animals.

Key Words: Correlation and regression analysis, osteometry, long bone, Morkaraman sheep

Morkaraman koyunlarında morfometrik değerler ile uzun kemik ölçümleri arasındaki ilişkinin belirlenmesi

Özet: Bu çalışmada, yerli koyun ırklarından toplam 40 adet erişkin dişi Morkaraman koyunu kullanıldı. Koyunların morfolojik değerleri (yaş, cinsiyet, canlı ağırlık, omuz yüksekliği ve göğüs çevresi) belirlendikten sonra İstanbul Üniversitesi Veteriner Fakültesi Mezbahasında kesimleri yapıldı. Kesim işlemini takiben karkas ağırlıkları alındıktan sonra, kaba etleri temizlenip iskelet kemikleri çıkarılarak maserasyon işlemine tabi tutuldu. Daha sonra, morfometrik inceleme için uzun kemik ölçümlerinin alımı işlemine geçildi. Osteometrik ölçümlerle morfolojik veriler arasında hesaplanan korrelasyon analizlerine bakıldığında elde edilen korrelasyon katsayılarının bazılarının önem taşımasına rağmen $r < 0,600$ düzeyinde olması düşük bir ilişkinin bulunduğunu göstermesi açısından önem taşımaktaydı. Aralarında istatistikî açıdan önemli yüksek korrelasyonlar tespit edilen osteometrik ölçümler ile morfolojik verilerin regresyon analizi yapılarak regresyon denklemleri oluşturuldu. Böylece zooarkeolojik çalışmalarda, görünür morfolojinin tahmin edilmesine katkı sağlayabilecek regresyon formülleri elde edildi. Omuz yüksekliğinin tahmin edilmesinde uzun kemiklerin genişlik ölçümlerinden çok, uzunluk ölçümlerinin daha yararlı olabileceği, buna karşın vücut ve karkas ağırlıkları ile göğüs çevresi hesaplamalarında ise uzun kemiklerin enine (Bp, Bd, SD) ölçümlerinin daha etkin olduğu kanısına varıldı. Humero-femoral indeks formülünün ise birden fazla hayvan kemiğinin olduğu arkeolojik koleksiyonlarda, özellikle koyun kemiklerinin bireysel olarak ayrımı işleminde kullanılabileceği düşünülmektedir.

Anahtar Sözcükler: Korrelasyon ve regresyon analizi, osteometri, uzun kemikler, Morkaraman koyunu

* E-mail: alpak@istanbul.edu.tr

Introduction

Sheep are an important source of food (meat and milk) as well as of other products of high economic value, such as wool and leather (1,2), which is also the case for historic societies, sheep remains constitute important archaeological finds. The evaluation of sheep bones provides morphological information on the animals` shoulder height, body weight, sex, age, and other features, which can be used to define the animal population, and allows comparison with other historic or modern sheep populations (3-8).

The development morphology of animals shows considerable variation with respect to breed, age, sex, nutritional situation and environmental factors among others. Bone marrow quantities (excess or deficiency) are not only related to bone development but also to trabecular bone structures and the width of the cavum medullare (9).

To estimate morphological variables such as body weight and chest circle, measurements on small ruminants were used (goats) because of its ease of application (10); however, few attempts have been made to correlate it with osteometric values.

Examination of sheep metapodial bones has both yielded data that cast light on the domestication of sheep (11,12), and valuable information on their skeletal bones, which constitute a good source of fat in animals (13).

Examination of long bones provides rather significant insights into intra-species as well as inter-species differences. It has, for example, been reported that distal metacarpal and distal and proximal metatarsal bones were used to distinguish between Neolithic sheep and goat bones (14).

Besides their visible morphology, osteological material is also important for a principal distinction between sheep and goats, with metapodial bones of goats reported as being shorter and broader than those of sheep (15).

Other research has looked into the relationship between the body condition scores of sheep (good or average) and their associated osteometric differences. It was found that sheep in good condition were larger (16), thus establishing a correlation between osteometric measurements and the animals` morphology.

Zooarchaeologists focus on the importance of morphological data in the definition of animal populations. The relationship, however, between morphological and osteological data has always been limited. Parameters, such as body weight and shoulder height, and their correlation with bone measurements (5-8,17,18) provide information on the morphological structure of animals and allow comparison of zooarchaeological materials (3,6,12,16).

Sheep breeds exhibit an unusual intra-species polymorphism. Within the sheep species, we find virtually hundreds of races which look different and also have different productivity properties. Using these properties as characteristics, sheep races can be classified into a number of groups (1,19).

Among the sheep breeds in Turkey, Karaman sheep rank first in quantity. They belong to combined productivity races (1,2,19). An osteometric examination of these races with their wide breeding potential was considered relevant with respect to the evaluation of material excavated at numerous sites in Anatolia (20-22).

It can be concluded that osteometric measurements of Morkaraman sheep will not only contribute to our knowledge of the relationship between morphological values and carcass weight, and lend support to future ontogenetic investigations but also improve our understanding of the visible morphology of sheep derived from osteoarchaeological material. The analyses applied in this study yielded data that shed light on both allometric and morphometric studies.

Material and Methods

In this study, a total of 40 adult female Morkaraman sheep, a local Turkish breed, were used. After determination of the age and sex of the sheep and measurement of morphometrical and carcass data (body and carcass weights, shoulder height, and chest circle), they were slaughtered in the slaughter house of the İstanbul University Veterinary Faculty. The meat was cut off the skeletal bones and then macerated (23).

Following maceration, the weight of every long bone was measured on a high-precision electronic digital calliper (the precision of the measurement is 0.1 mm) and recorded. Thereafter, morphometric measurements of the long bones were taken (24).

Measurement of the long bones (Figure):

Scapula

1. Height along the spine (HS); 2. Diagonal height (DHA): from the most distal point of the scapula to the thoracic angle; 3. Maximum length of the processus articularis (glenoid process) (GLP)

Humerus

1. Greatest length (GL); 2. Breadth of the proximal end (Bp); 3. Breadth of the distal end (Bd); 4. Minimum breadth of diaphysis (SD)

Radius

1. Greatest length of the radius (GL); 2. Breadth of the proximal end (Bp); 3. Breadth of the distal end (Dp); 4. Minimum breadth of diaphysis (SD)

Ulna

1. Greatest length of the ulna (GL); 2. Minimum depth of the olecranon (SDO); 3. Depth across the processus anconaeus (DPA)

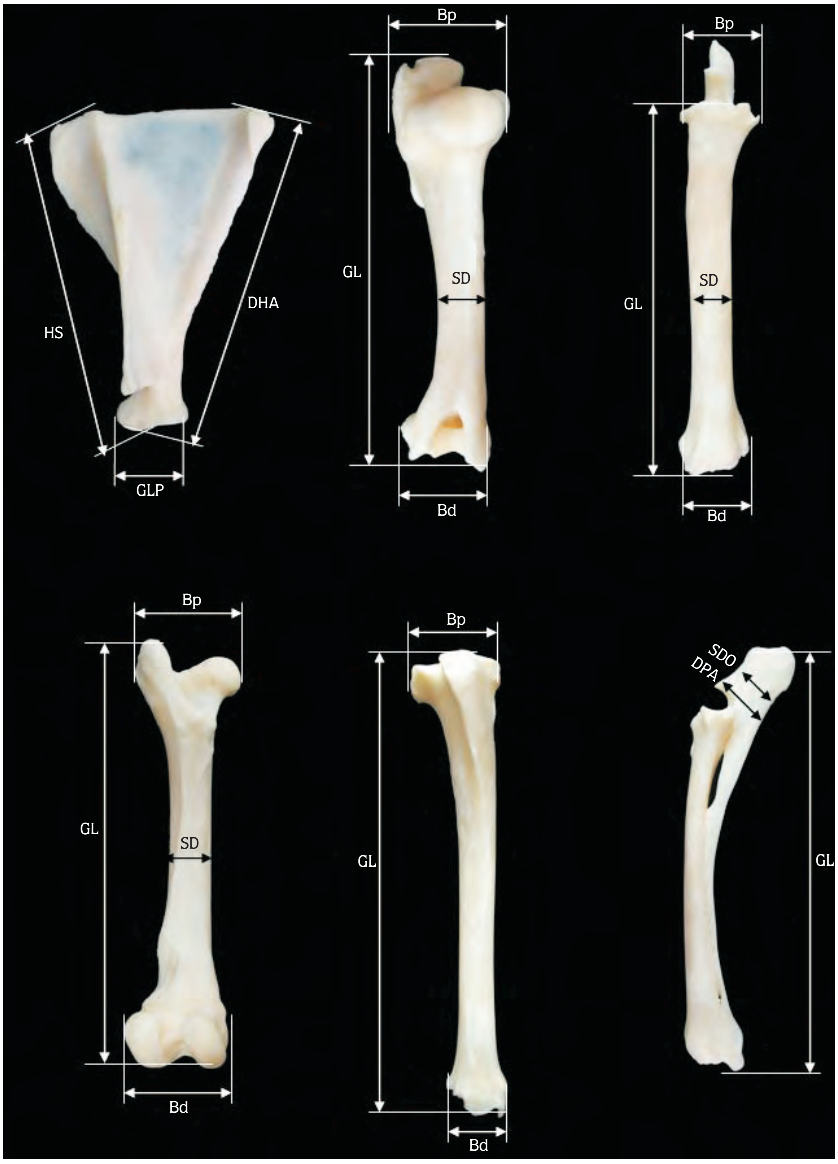

Figure. Osteometric measurements.

Femur

1. Greatest length (GL); 2. Breadth of the proximal end (Bp); 3. Breadth of the distal end (Dp); 4. Minimum breadth of diaphysis (SD)

Tibia

1. Greatest length (GL); 2. Breadth of the proximal end (Bp); 3. Breadth of the distal end (Dp); 4. Minimum breadth of diaphysis (SD)

Fibula

This measurement was not included in the evaluation because in small ruminants the corpus of this bone has undergone reduction, and only its proximal end remains attached to the side of the tibia`s lateral condylus (15).

Statistical analyses

All osteometric data were used for statistical calculations. For this purpose, mean values and standard deviations were calculated along with their correlation with morphological data and the carcass weight, in order to elucidate the relationship between osteometric measurements, sheep's morphology, and carcass weight. For statistical calculations: mean value, standard deviation, correlation and regression analyses were obtained using SPSS 8.0.

The simple regression model used is as follows:

Y = a + bX... Simple linear equation

Y = Dependent variable

a = intercept

b = regression coefficient

X = independent variable

Results

The morphological and osteometric data of the 40 Morkaraman sheep examined in this study together with mean values and standard deviations are presented in Table 1.

For all long bone measurements of the animals, which suffered from no bone pathologies, the fibula was excluded for reasons explained above.

Correlation between the body weight measurements and shoulder height and chest circle were significant ($P < 0.001$) for the morphological data, while no significant correlations were found between shoulder height and other morphological measurements. For carcass weight, only a correlation with the chest circle ($P < 0.001$) could be established (Table 2).

Table 1. Mean values and standard deviations of morphological and osteometric measurements.

Body characteristics	n	Mean	SD±
Body weight (kg)	40	56.48	4.481
Carcass weight (kg)	40	20.60	2.069
Shoulder height (cm)	40	68.7	2.7
Chest circle (cm)	40	102.6	3.7
Scapula (mm)			
HS	40	171.49	5.984
DHA	40	179.38	6.091
GLP	40	38.08	1.483
Humerus (mm)			
GL	40	161.18	4.017
Bp	40	44.14	1.743
Bd	40	34.97	2.076
SD	40	17.69	0.913
Ulna (mm)			
GL	40	207.17	5.800
SPO	40	25.25	1.059
DPA	40	29.13	1.065
Radius (mm)			
GL	40	168.71	5.114
Bp	40	35.93	1.103
Bd	40	33.48	0.985
SD	40	17.68	0.748
Femur (mm)			
GL	40	188.15	4.720
Bp	40	50.09	2.039
Bd	40	43.16	1.305
SD	40	18.88	0.933
Tibia (mm)			
GL	40	220.33	6.329
Bp	40	47.03	1.096
Bd	40	30.41	2.457
SD	40	16.92	0.684

Table 2. Correlation analysis of the morphological data.

	Carcass weight	Shoulder height	Chest circle
Body weight	0.777***	0.112^{NS}	0.663***
Carcass weight		0.288^{NS}	0.661***
Shoulder height			0.299 ^{NS}

***: P < 0.001; ^{NS}: Not significant

Results of the correlation analysis of scapula and humerus measurements with morphological data are given in Table 3. For the scapula height (HS) and the other parameters with the exception of the chest circle, a positive and significant (P < 0.05, 0.01) correlation was found. While no significant relationship was established for scapula diagonal height (DHA) and live weight as well as chest circle, a positive and significant (P < 0.05 and 0.01, respectively) correlation was found for carcass weight and shoulder height. Maximum length of the glenoid process (GLP) was positively correlated with only body weight.

For the humerus measurements only greatest length (GL) was correlated with shoulder height (P < 0.01), while no significant correlation could be established with any other parameter (Table 3).

Radius and ulna measurements of the antebrachia were evaluated separately.

For ulna greatest length (GL) and shoulder height, correlation was high, significant, and positive (P < 0.01), while the correlation factor for the oleacranon-related measurements (SDO and DPA) and the morphological data was found to be generally low (r < 0.500) (Table 4).

In the case of the radius measurements, only greatest length (GL) was highly correlated with shoulder height, while the other correlation factors calculated were < 0.500 (Table 4).

The results of the correlation analysis of the femur and the tibia measurements with the morphological data are compiled in Table 5. As shown in the table, the correlation factor is generally < 0.500 though some correlations were significant.

Among the tibia measurements, only greatest lengths were highly and positively correlated with shoulder height (P < 0.01) with no significant relationship with the other morphological traits (Table 5).

The results of the correlation analysis of long bone weight and morphological data are given in Table 6.

Table 3. Correlation analysis between morphological data and scapula and humerus measurements.

	Scapula measurements			
	HS	DHA	GLP	
Body weight	0.381 *	0.302^{NS}	0.320 *	
Carcass weight	0.460**	0.402 *	0.251^{NS}	
Shoulder height	0.433**	0.521**	0.070^{NS}	
Chest circle	0.220^{NS}	0.223^{NS}	0.276^{NS}	
	Humerus measurements			
	GL	Bp	Bd	SD
Body weight	0.203^{NS}	0.184^{NS}	-0.018^{NS}	0.149^{NS}
Carcass weight	0.269^{NS}	0.317 *	-0.162^{NS}	0.193^{NS}
Shoulder height	0.474**	-0.048^{NS}	-0.054^{NS}	0.088^{NS}
Chest circle	0.267^{NS}	-0.044^{NS}	-0.142^{NS}	0.213^{NS}

*: P < 0.05; **: P < 0.01: ***: P < 0.001; ^{NS}: Not significant

Table 4. Correlation analysis between morphological data and ulna and radius measurements.

	Ulna measurements			
	GL	SPO	DPA	
Body weight	0.214 NS	0.173 NS	0.438**	
Carcass weight	0.134 NS	0.159 NS	0.346 *	
Shoulder height	0.515**	-0.001 NS	-0.022 NS	
Chest circle	0.177 NS	0.047 NS	0.051 NS	
	Radius measurements			
	GL	Bp	Bd	SD
Body weight	0.156NS	0.377 *	0.366 *	0.475**
Carcass weight	0.089NS	0.346 *	0.294NS	0.362 *
Shoulder height	0.563**	0.212NS	0.122NS	-0.015NS
Chest circle	0.074NS	0.243NS	0.210NS	0.350 *

*: $P < 0.05$; **: $P < 0.01$; NS: Not significant

Table 5. Correlation analysis between morphological data and femur measurements.

	Femur measurements			
	GL	Bp	Bd	SD
Body weight	0.143NS	0.229NS	0.239NS	0.398 *
Carcass weight	0.249NS	0.227NS	0.341 *	0.447**
Shoulder height	0.459**	-0.088NS	0.071NS	0.067NS
Chest circle	0.164NS	0.071NS	0.060NS	0.438**
	Tibia measurements			
	GL	Bp	Bd	SD
Body weight	0.239NS	0.134NS	0.112NS	0.220NS
Carcass weight	0.212NS	0.109NS	0.120NS	0.780NS
Shoulder height	0.515**	0.041NS	-0.074NS	0.136NS
Chest circle	0.119NS	0.159NS	-0.049NS	0.142NS

*: $P < 0.05$; **: $P < 0.01$; NS:Not significant

Table 6. Correlation analysis between morphological data and long bone weight.

Body measurements	Long bone weights				
	Scapula weight	Humerus weight	Radius and Ulna weight	Femur weight	Tibia weight
Body weight	0.512***	0.536***	0.461**	0.376 *	0.424**
Carcass weight	0.692***	0.553***	0.557***	0.465**	0.458**
Shoulder height	0.381*	0.181 NS	0.425**	0.03NS	0.213NS
Chest circle	0.420**	0.398 *	0.338 *	0.211NS	0.246NS

*: $P < 0.05$; **: $P < 0.01$;***: $P < 0.001$; NS: Not significant

For the scapula, a significant correlation was found for carcass and body weight ($P < 0.001$), while the correlation factors for shoulder height and chest circle were found to be lower ($r < 0.500$). The same applies to the humerus weight correlations.

As radius and ulna, the constituent components of the antebrachium, are characterised in these animals by synostosis, they feature together as antebrachium weight. Their weight was found only to be highly positively correlated to the carcass weight while the other correlation factors were lower ($r < 0.500$).

For the relationship of femur and tibia weights with morphological data, correlation factors of $r < 0.500$ were found.

Regression equations were obtained for regression of morphological data on osteometric measurements having highly significant correlations. The regression equations of data with high correlation coefficients are presented in Table 7.

Discussion

In this study, a homogenous group of Morkaraman sheep from the same origin (3) was used in order to reduce the variation due to sampling from different races and sources to a minimum (8,17,25).

The Morkaraman sheep, which have been bred as a combined race for improved productivity of meat, milk and wool, are one of the main sheep races in Turkey (1,2).

The morphological data of the sheep examined in this study fall within the limits in the literature (1,2). Consequently, the data obtained from this material can be considered as valid.

The coefficients obtained from correlation analysis for osteometric measurements and morphological data are in general rather low ($r < 0.600$), though certain relationships were found to be significant ($P < 0.05$ and 0.01). The observed low correlation between bone measurements and the animals' morphology needs to be taken into consideration when deducing the visible morphology of sheep from excavated bone remains. The regression formulas for osteometric and morphologic data with high correlation coefficients will be useful in zooarchaeologic studies. Considering the inability to have a whole bone always in

Table 7. The regression formulas between morphological data and osteometric measurements.

Body weight (BW) = dependent variable	P < 0.05
BW=7.5 + 0.29 Scapula HS	0.05
BW=19.7+ 0.97 Scapula GLP	0.05
BW=2.8 + 1.84 Ulna DPA	0.01
BW=1.5 + 1.53 Radius Bp	0.05
BW=0.8 + 1.66 Radius Bd	0.05
BW=6.2 + 2.84 Radius SD	0.01
BW=20.4 + 1.91 Femur SD	0.05
BW=39.1 + 0.32 Scapula weight	0.01
BW=34.3 + 0.30 Humerus weight	0.01
BW=33.4 + 0.39 Radius and Ulna weight	0.01
BW=42.2 + 0.16 Femur weight	0.05
BW=36.4 + 0.27 Tibia weight	0.01
Carcass weight(CW)=dependent variable	
CW=-6.7 + 0.16 Scapula HS	0.01
CW=-3.9 + 0.14 Scapula DHA	0.05
CW= 4.0 + 0.38 Humerus Bp	0.05
CW=1.0 + 0.67 Ulna DPA	0.05
CW=-2.7 + 0.65 Radius Bp	0.05
CW=2.9 + 1.00 Radius SD	0.05
CW=-2.7 + 0.54 Femur Bd	0.05
CW=1.9 + 0.99 Femur SD	0.01
CW=9.8 + 0.20 Scapula weight	0.01
CW=10.1 + 0.14 Humerus weight	0.01
CW=7.7 + 0.22 Radius and Ulna weight	0.01
CW=12.5 + 0.09 Femur weight	0.01
CW=10.6 + 0.13 Tibia weight	0.01
Shoulder Height(SH)=dependent variable	
SH=35.3 + 0.20 Scapula HS	0.01
SH=27.3 + 0.23 Scapula DHA	0.01
SH=17.4 + 0.32 Humerus GL	0.01
SH=19.1 + 0.24 Ulna GL	0.01
SH=18.6 + 0.30 Radius GL	0.01
SH=19.4 + 0.26 Femur GL	0.01
SH=20.4 + 0.22 Tibia GL	0.01
SH=60.9 + 0.14 Scapula weight	0.05
Chest circle(CC)=dependent variable	
CC=71.9 + 1.73 Radius SD	0.05
CC=69.8 + 1.74 Femur SD	0.01
CC=90.8 + 0.22 Scapula weight	0.01
CC=89.0 + 0.18 Humerus weight	0.05
CC=88.6 + 0.24 Radius and Ulna weight	0.05

zooarchaeologic studies, our study will have a big contribution in predicting the visible morphology by using long bone measurements. When the regression equations were calculated – taking account of the correlation factors – it was found that all were highly significant ($P < 0.01$). Despite those findings, findings from this study suggests that the humero-femoral index formula can be used to identify sheep in an archaeological bone collection of several animals (26). For humerus and femur greatest lengths the following formula was obtained:

Humerus GL (mm) = 21.7 + 0.741 × Femur GL (mm)   R – Sq = 75.8 ($P < 0.05$)

We believe that this model will contribute considerably to archaeological studies where the objective is to determine which humerus and femur belong to the same individual.

In this study, a high correlation ($r > 0.600$) between bone weight and morphological data could only be established for the scapula. For all other bone weight to morphological data correlations r were < 0.600. This difference may be due to the different structural make-up of the scapula as compared to other long bones. The reason may be that the scapula, which belongs to the ossa plana, does not feature a cavum medullare, which is rather wide in the other bones.

The low correlations reported in this study as well as the osteometric measurements of the long bones will find consideration as reference values for Morkaraman sheep, and will thus contribute both to morphometric and zooarchaeological investigations.

As most zooarchaeologists use various measuring systems, the standard measurements have a great importance in the use of Log-ratio technique which enables simplification, comparative equality measurements, and evaluations (27). This method has been developed by Simpson et al. (28) for the first time and used widely by various researchers with modifications (29,30). In this study, the system used by Von den Driesch (24) was used as standard measuring system and we think it would be accepted as a standard value in measurements obtained. Correlations between the osteometric measurements and morphologic data gave high positive coefficients observed particularly among the GL measurements of the long bones of the shoulder length. This showed that the shoulder length increased proportionately with the maximal length of bones. For this, prediction of maximum length of bones from the shoulder length, instead of the bone width measurements and length measurements would be more useful. However, in body and carcass weight and chest circle calculations instead of maximal bone lengths, other width measurements (Bp, Bd, SD) would be more efficient and these values would specially be more useful for calculations of more efficient regression equations.

Acknowledgement

This work was supported by the Research Fund of İstanbul University (grant number 278/22092004).

References

1. Kaymakçı, M., Oğuz, I., Ün, C., Bilgen, G., Taşkın, T.: Basic characteristics of some Turkish indigenous sheep breeds. Pakistan J. Biol. Sci., 2001; 4 : 916-919.
2. Soysal, M.İ., Özkan, E., Gürcan, E.K.: The status of native farm animal genetic diversity in Turkey and in the world. Trakia J. Sci., 2003; 1: 1-12.
3. Guintard, C., Lallemand, M.: Osteometric study of metapodial bones in sheep (*Ovis aries*, L.1758). Ann. Anat., 2003; 185: 573-583.
4. Onar, V.: Estimating the body weight of dogs unearthed from the Van-Yoncatepe necropolis in Eastern Anatolia. Turk. J. Vet. Anim. Sci., 2005; 29: 495-498.
5. van Wijngaarden-Bakker, L.H., Bergström, P.L.: Estimation of the shoulder height of cattle. Archaeozoologia, 1988; 2: 67-82.
6. Forest, V.: De la hauteur au garrot des espèces domestiques en archéozoologie. Rev. Méd. Vét., 1998; 149: 55-60.
7. Schramm, Z.: Long bones and height in withers of goat. Roczniki Wyzszei Szkoly Rolniczej w Poznaniu, 1967; 36: 89-105.
8. Haak, D.: Metrische Untersuchungen an Röhrenknochen bei Deutschen Merinoslandschafen und Heidschnuken. Th. Med. Vet., 90, München. 1965.
9. Outram, A., Rowley-Conwy, P.: Meat and marrow utility indices for horse *(Equus)*. J. Archaeol. Sci., 1998; 25: 839-849.

10. Slippers, S.C., Letty, B.A., de Villiers, J.F.: Prediction of the body weight of Nguni goats. S. Afr. J. Anim. Sci., 2000; 30(Suppl. 1): 127-128.

11. Guintard, C., Betti, E.: Ostéométrie des métapodes des ruminants domestiques *(Bos taurus* et *Ovis aries)* : typologie et sexage, Mondial Vet Lyon 99, 23-26 September 1999, Lyon (F), Proceedings, WVA Conferences, 26ème Congrès Mondial WVA ; Recherche/search, CDRom Mac/PC, Conception ACM. 1999.

12. Lallemand, M.: Etude osteometrique de metapodes de mouton (*Ovis aries* L). Ecole Nationale Veterinaire de Nantes, PhD Thesis, Nantes. 2002.

13. Outram, A.K.: Bone fracture and within bone nutrients: an experimentally based method for investigating levels of marrow extraction. In: Miracle, P., Milner, N. Eds., Consuming Passions and Patterns of Consumption. Chapter 6, MacDonald Institute Monographs Series., 2002; 51-63.

14. Rowley-Conwy, P.: Improved separation of neolithic metapodials of sheep (*Ovis*) and goats (*Capra*) from Arene Candide Cave, Liguria, Italy. J. Archaeol. Sci., 1998; 25: 251-258.

15. Boessneck, J.: Osteological differences between sheep *(Ovis aries* Linné*)* and goat *(Capra hircus* Linné*)*. In: Brothwell, D., Higgs, E., Clark, G., Eds., Science in Archaeology. 2nd edn. London, Thames and Hudson, 1969; 331-358.

16. Davis, S.J.M.: Measurements a group of adult female Shetland sheep skeletons from a single flock: a baseline for zoo archaeologists. J. Archaeol. Sci., 1996; 23: 593-612.

17. Harcourt, R.A.: The dog in prehistoric and early historic Britain. J. Archaeol. Sci. 1974; 1: 151-175.

18. Peters, J.: Osteomorphology and osteometry of the appendicular skeleton of the Grant's Gazelle, *Gazella granti* Brooke, 1872, Bohor reedbuck, *Redunca redunca* (Pallas, 1767) and Bushbuck, *Tragelaphus scriptus* (Pallas, 1766). Occasional Papers, Laboratorium Voor Paleontologie. Rijksuniversiteit Gent, No. 2, Ghent. 1986.

19. Yalcin, B.C.: Sheep and Goats in Turkey. FAO Animal Production and Health Paper No: 60, Rome. 1986.

20. Hongo, H.: Patterns of animal husbandry, environment, and ethnicity in central Anatolia in the Ottoman Empire period: faunal remains from Islamic layers at Kaman-Kalehöyük. Japan Rev., 1997; 8: 275-307.

21. Hongo, H.: Patters of animal husbandry at Kaman-Kalehöyük, Turkey : continuity and changes during the second and first Millenia B.C., In: Mikasa, T., Ed. Essays on Ancient Anatolia in the Second Millennium B.C., Harrassowitz Verlag, Wiesbaden, 1998; 239-278.

22. Hongo, H., Meadow, R.H.: Faunal remains from Prepottery Neolithic levels at Çayönü, Southeastern Turkey: a preliminary report focusing on pigs (Sus sp.). ICAZ Archaeozoology of the Near East IV A. Proceedings of the fifth international symposium on the archaeozoology of southwestern Asia and adjacent areas. Mashkour, M., Choyke, A.M., Buitenhuis, H., Poplin, F., Eds., ARC-Publicatie 32: Groningen, The Netherlands, 2000; 121-140.

23. Onar, V.: A morphometric study on the skull of the German shepherd dog (Alsatian). Anat. Histol. Embryol., 1999; 28: 253-256.

24. Von den Driesch, A..: A guide to the Measurement of Animal Bones from Archaeological Sites. Peabody Museum Bulletin 1. Harvard University, Massachusetts. 1976.

25. Clutton-Brock, J., Dennis-Bryan, K., Armitage, P.L., Jewell, P.A.: Osteology of the Soay sheep. Bull. Br. Mus. Nat. Hist (Zool)., 1990; 56: 1-56.

26. Richmond, B.G., Aiello, L.C., Wood, B.A.: Early hominin limb proportions. J. Hum. Evol., 2002; 43: 529–548.

27. Haber, A., Dayan, T.: Analyzing the process of domestication: hagoshrim as a case study. J. Archaeol. Sci., 2004; 31: 1587-1601.

28. Simpson, G.G., Roe, A., Lewontin, R.C.: Quantitative Zoology. Harcourt, Brace and Company, New York, 1960.

29. Grigson, C.: Size and sex: evidence for the domestication of cattle in the Near East. In: Milles, A., Williams, D., Gardner, N., Eds., The Beginnings of Agriculture, BAR International Series, vol. 496, BAR, Oxford, 1989; 77-109.

30. Meadow, R.H.: Animal domestication in the Middle East: a view from the eastern margin. In: Clutton-Brock, J., Grigson, C., Eds., Early Herders and Their Flocks, BAR International Series, BAR Oxford, 1984; 309-330.