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RELIABILITY TESTING OF METRIC METHODS FOR SEX DETERMINATION IN ANCIENT SKELETAL REMAINS IN GREECE

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ABSTRACT

The skeletal study of archaeological material is the only detailed source of demographic information on ancient populations and investigating sex differences is crucial for the reconstruction of the social structure of past societies. Determination of skeletal sex can be achieved using visual (non-metric) or metric methods. Metric methods are considered more appropriate for assessing sex in archaeological skeletal remains since the accuracy of non-metric methods decreases in cases of fragmented bones. Additionally, it is well established that the expression of sexual dimorphism is population specific. Therefore, sex prediction equations should be used only when the sample is known to come from the same population from which the functions were derived. The aim of this study is to test the application of sex prediction equations, which were produced using measurements from the arm bones of a modern Greek population, in ancient Greek skeletal remains. For the purpose of this research five ancient populations were examined; Ancient Corinth, Corfu, Agia Triada Thebes, Edessa and Thebes. According to our results, ulnar sex prediction equations cannot be considered adequate for sex determination of ancient skeletal remains. On the contrary, humeral as well as radial sex prediction equations can be considered adequately reliable for sex determination of ancient skeletal remains. More specifically, sex prediction equations containing the humeral vertical head diameter, its combination with the humeral epicondylar width as well as the maximum radial distal width, achieve a classification accuracy over 72%.

KEYWORDS: reliability testing; sex prediction equations; arm bones; ancient Greek populations

1. INTRODUCTION

Sex and age at death determination are the principal questions considered during the anthropological investigation of exhumed human remains. Accurate sex determination from skeletal remains is of utmost importance in archaeological studies. The skeletal study of archaeological material is the only detailed source of demographic information on ancient populations and investigating demography is crucial for the reconstruction of the social structure of past societies. Furthermore, since rates of growth, development, and degeneration vary according to sex, without accurate sex determination, age at death cannot be accurately estimated as well. This is also the case for stature and body mass estimation.

Non-metric (morphologic) and metric methods are commonly used for sex determination. Although molecular techniques like DNA fingerprinting have a greater degree of reliability, they are complicated, invasive, highly expensive and time consuming (Rösing *et al.*, 2007). Therefore, the analysis of skeletal morphology will remain essential for the identification process (Kemkes-Grottenthaler, 2001). Non-metric methods are based on the visual assessment of sexually dimorphic features and produce good results when bones are intact (Krishan *et al.*, 2016). However, many of these features are difficult to measure and are greatly influenced by subjectivity (Steyn *et al.*, 2004; Kemkes-Grottenhaler *et al.*, 2002). Consequently, they show high inter and intra observer errors, classification difficulties and problems in analysis (Krishan *et al.*, 2016). Metric methods, on the other hand, are based on measurements, utilize different statistical methods in order to derive models for assessing sex (Işcan and Miller-Shaivitz,1984a, b; Asala, 2001) and their numerical results are easier to assess and interpret (Pretorius *et al.*, 2005). The statistical methods applied for sexing could involve simple proportions, limiting points, identification points, sectioning points, demarking points, logistic regression analysis and discriminant function analysis. The model's accuracy will probably vary depending on the statistical method (Dabbs and Moore-Jansen, 2010).

Archaeological skeletal remains are rarely found and excavated intact. Therefore, metric methods are considered more appropriate for assessing sex since the accuracy of non-metric methods decreases in cases of fragmented bones. Additionally, sex prediction equations should be used only when the sample is known to come from the same population from which the functions were derived (Ubelaker *et al.*, 2002; Ramsthaler *et al.*, 2007; Dabbs and Moore-Jansen, 2010), since the expression of sexual dimorphism is population specific (Rösing *et al.*, 2007). The aim of this study is to test the application of sex prediction equations, which were produced using measurements from the arm bones of a modern Greek population, in ancient Greek skeletal remains.

Figure 1. Map of the studied sites.

2. MATERIALS AND METHODS

Five human skeletal collections from different regions of Greece were used in the present study (Fig. 1). The Theban population is dated from the Mycenaean (1600-1400 BC) period and derives from the southwest citadel of Cadmeia. The excavation was conducted in 2003 by Eleni Kountouri and consists of 14 individual graves. The Corfu population derives from Almyros site, which is located in north Corfu, and is dated from the Archaic to Roman period (610 BC–200 AD). The excavation was conducted in 1988 by Preka-Alexandri and a total of 32 skeletons were exhumed. Excavations in Edessa started in 1987 and were conducted by Anastasia Chrisostomou. Our sample from Edessa was unearthed in 1989 from the police plot and is dated to the Roman period (31 BC–324 AD). The skeletal material of Edessa consists of 37 individual graves, 3 double graves and 1 triple grave. The Ancient Corinth population used in the current research is dated from the Geometric period to early Christian times (900 BC-700 AD) and consists of three properties: Rota, Soukouli and Deli. The excavation was conducted from 1960 to 2004 by the Inspectorate for Pre-historical and Classical Antiquities of Corinth. Although in total 115 individuals were exhumed from 74 graves where one or more individuals were buried, only 5, 4 and 17 individual graves from Soukouli, Deli and Rota properties respectively could be used for the needs of the current research and are dated from the late Archaic period to early Christian times (500 BC-

500 AD). Finally, the sample from Agia Triada Thebes derives from the west citadel of Cadmeia and is dated to the Medieval period (1300-1400 AD). The excavation was conducted from 1986 to 1990 by Marilena Vavouri and consists of 27 individual graves. Regarding all five archaeological assemblages, only individual burials were selected and only adult individuals without any evidence of pathology or hyper-development were used. All skeletal collections are currently housed at the Department of Animal and Human Physiology (Faculty of Biology, National and Kapodistrian University of Athens) under the supervision of Dr. M.E. Chovalopoulou with the appropriate permission granted by former associate professor (retired) Dr. Sotiris Manolis.

Table 1. **Charisi's et al. (2010) sex predicting equations used in the present study.**

DF Equation	*Bone*	*Side*	*Constant*	*ML*	*VHD/MPW*	*HEW/MDW*
FI	*Humerus*	*Left*	*- 64.4297*	*0.00031*	*0.75645*	*0.55083*
F2	*Humerus*	*Right*	*- 68.3179*	*0.03400*	*0.69295*	*0.47795*
*F3**	*Humerus*	*Left*	*- 64.4262*		*0.75658*	*0.55084*
*F4**	*Humerus*	*Right*	*- 63.2281*		*0.81097*	*0.48332*
F5	*Radius*	*Left*	*- 66.6076*	*0.09206*	*1.74226*	*0.34817*
F6	*Radius*	*Right*	*- 59.7476*	*0.08319*	*1.69590*	*0.21441*
*F7**	*Radius*	*Left*	*- 64.4662*	*0.09933*	*2.07841*	
*F8**	*Radius*	*Right*	*- 58.9050*	*0.08900*	*1.90695*	
F13	*Humerus*	*Left*	*- 37.1895*	*0.12076*		
F14	*Humerus*	*Left*	*- 48.0799*		*1.09569*	
F15	*Humerus*	*Left*	*- 51.5386*			*0.91044*
F16	*Humerus*	*Right*	*- 36.7429*	*0.11837*		
F17	*Humerus*	*Right*	*- 47.2795*		*1.07591*	
F18	*Humerus*	*Right*	*- 46.0255*			*0.80501*
F19	*Radius*	*Left*	*- 43.9440*	*0.19804*		
F20	*Radius*	*Left*	*- 53.1841*		*2.61492*	
F21	*Radius*	*Left*	*- 37.4700*			*1.24119*
F22	*Radius*	*Right*	*- 40.9148*	*0.18156*		
F23	*Radius*	*Right*	*- 47.7878*		*2.34768*	
F24	*Radius*	*Right*	*- 29.8596*			*0.99116*
F25	*Ulna*	*Left*	*- 46.7395*	*1.90864*		
F27	*Ulna*	*Left*	*- 16.1512*			*1.02121*
F28	*Ulna*	*Right*	*- 52.5638*	*0.21251*		
F30	*Ulna*	*Right*	*- 14.4582*			*0.89476*

ML, maximum length; VHD, vertical head diameter; HEW, humeral epicondylar width; MPW, maximum proximal width; MDW, maximum distal width.

**Stepwise discriminant function analysis.*

The equations for predicting sex (Table 1) were produced from Charisi and her colleagues in 2010 (Charisi *et al.*, 2010) using the modern, human skeletal reference collection of the Biology Department of the University of Athens, known as the ''Athens Collection'' (Eliopoulos *et al.*, 2007). Eight measurements were taken, three measurements from both humerus and radius and two measurements from the ulna, according to well-known sources (Martin and Saller, 1957; Moore-Jansen *et al.*, 1994; Buikstra and Ubelaker, 1994) and include maximum lengths and epiphyseal widths. More specifically, regarding the humeral dimensions, the maximum humeral length (MHL), the vertical head diameter (VHD) and the humeral epicondylar width (HEW) were used. Correspondingly, the maximum radial length (MRL), the maximum radial proximal width (MRPW) and the maximum radial distal width (MRDW) were taken. Finally, regarding the ulnar dimensions, the maximum ulnar length (MUL) and the maximum ulnar distal width (MUDW) were used. A standard osteometric board was used for measuring maximum lengths and a Mitutoyo® Digimatic Caliper (Chengdu Tengqiang Industry Co., Ltd, Sinchuan, China) for the epiphyseal widths. Sex determination of the archaeological sample was conducted using primarily morphological criteria of the pelvis, such as the ventral arc, the subpubic concavity, the medial aspect of ischiopubic ramus, the greater sciatic notch and the preauricular sulcus (Buikstra and Ubelaker, 1994). In cases where the os caxae were not available, sex determination was conducted using morphological criteria of the cranium, such as the supraorbital ridges and the mastoid processes (Buikstra and Ubelaker, 1994).

3. RESULTS

In order to investigate the inter-observer reliability, both the second and the third author took all measurements. The mean difference between the two observers was 0,8mm regarding the measurements taken with the standard osteometric board and 0.3mm regarding the measurements taken with the caliper.

The total sample size as well as the sample size of total humeri, radii and ulnae, are given in table 2. Descriptive statistics for each measurement include the number of specimens, the mean value, the minimum and maximum values, the standard deviation, as well as the standard error (Tables 3–5).

Table 2. Sample sizes of individuals and measured bones from the archaeological assemblages.

Sample		N	Sample		N
	Males	38		*Males*	16
Individuals	*Females*	36	*Left radii*	*Females*	18
	Total	***74***		***Total***	***34***
	Males	23		*Males*	20
Left humeri	*Females*	19	*Right radii*	*Females*	13
	Total	***42***		***Total***	***33***
	Males	21		*Males*	11
Right humeri	*Females*	23	*Left ulnae*	*Females*	9
	Total	***44***		***Total***	***20***
				Males	12
			Right ulnae	*Females*	8
				Total	***20***

Table 3. **Summary statistics for left and right humerus (number of specimens, mean, minimum and *maximum* value, SD and SE). Mean, minimum and maximum values in mm.**

		N[1]	Mean[1]	Minimum[1]	Maximum[1]	Std. Deviation[1]	Std. Error[1]
MHL							
Ancient Corinth	*Males*	*5 / 7*	*307.2 / 314.71*	*291.00 / 292.00*	*344.00 / 342.00*	*22.00 / 16.32*	*9.84 / 6.17*
	Females	*2 / 1*	*294.5 / 287.00*	*281.00 / -*	*308.00 / -*	*19.09 / -*	*13.50 / -*
Corfu	*Males*	*5 / 3*	*315.20 / 303.00*	*284.00 / 289.00*	*370.00 / 318.00*	*32.38 / 14.52*	*14.48 / 8.38*
	Females	*1 / 4*	*263.00 / 287.75*	*- / 270.00*	*- / 306.00*	*- / 14.75*	*- / 7.37*
Agia Triada Thebes	*Males*	*1 / 1*	*320.00 / 345.00*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*5 / 5*	*310.80 / 307.00*	*277.00 / 283.00*	*342.00 / 344.00*	*26.09 / 27.39*	*11.66 / 12.25*
Edessa	*Males*	*5 / 6*	*313.00 / 321.50*	*300.00 / 309.00*	*333.00 / 340.00*	*12.58 / 13.93*	*5.63 / 5.69*
	Females	*5 / 8*	*293.00 / 298.16*	*272.00 / 270.00*	*310.00 / 320.00*	*15.87 / 18.33*	*7.09 / 6.48*
Thebes	*Males*	*1 / 0*	*272.00 / -*	*-/-*	*-/-*	*-/-*	*-/-*

	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
VHD							
Ancient Corinth	*Males*	*5 / 7*	*43.18 / 44.13*	*41.20 / 39.98*	*47.88 / 46.58*	*2.70 / 2.47*	*1.21 / 0.93*
	Females	*0 / 2*	*- / 39.43*	*- / 37.96*	*- / 40.9*	*- / 2.07*	*- / 1.47*
Corfu	*Males*	*4 / 2*	*40.02 / 39.59*	*38.52 / 39.18*	*41.18 / 40.00*	*1.10 / 0.57*	*0.55 / 0.41*
	Females	*1 / 4*	*36.90 / 38.52*	*- / 36.30*	*- / 40.99*	*- /2.48*	*- / 1.24*
Agia Triada Thebes	*Males*	*2 / 1*	*45.61 / 50.65*	*45.52 / -*	*45.70 / -*	*0.12 / -*	*0.08 / -*
	Females	*4 / 3*	*43.46 / 41.86*	*38.28 / 36.50*	*50.97 / 50,58*	*6.25 / 7.62*	*3.12 / 4.4*
Edessa	*Males*	*3 / 4*	*45.53 / 44.41*	*43.36 / 42.02*	*48.64 / 46.48*	*2.76 / 1.84*	*1.59 / 0.92*
	Females	*5 / 8*	*39.74 / 38.65*	*37.44/34.83*	*42.25 / 41.68*	*2.41 / 2.59*	*1.39 / 0.98*
Thebes	*Males*	*1 / 0*	*41.06 / -*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 1*	*-/ 34.85*	*-/-*	*-/-*	*-/-*	*-/-*
HEW							
Ancient Corinth	*Males*	*7 / 6*	*61.14 / 60.83*	*50.00 / 57.00*	*75.00 / 64.00*	*7.69 / 2.99*	*2.90 / 1.22*
	Females	*4 / 1*	*53.25 / 51.00*	*50.00 / -*	*60.00 / -*	*4.71 / -*	*2.35 / -*
Corfu	*Males*	*5 / 4*	*54.40 / 54.75*	*50.00 / 51.00*	*56.00 / 58.00*	*2.60 / 3.30*	*1.16 / 1.65*
	Females	*2 / 4*	*52.50 / 56.00*	*52.00 / 47.00*	*53.00 / 68.00*	*0.70 / 8.98*	*0.50 / 4.49*
Agia Triada Thebes	*Males*	*1 / 2*	*58.00 / 62.00*	*- / 59.00*	*- / 65.00*	*- / 4.24*	*- / 3.00*
	Females	*4 / 5*	*59.40 / 58.00*	*55.00 / 51.00*	*65.00 / 65.00*	*3.64 / 5.29*	*1.63 / 2.36*
Edessa	*Males*	*6 / 6*	*60.66 / 61.75*	*54.00 / 55.00*	*69.00 / 69.00*	*5.20 / 4.68*	*2.12 / 1.91*
	Females	*7 / 9*	*55.00 / 54.00*	*49.00 / 45.00*	*59.00 / 59.00*	*3.31 / 4.82*	*1.25 / 1.60*
Thebes	*Males*	*1 / 0*	*56.00 / -*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*

[1] *left side / right side*

MHL: maximum humeral length; VHD: vertical head diameter; HEW: humeral epicondylar width.

In most cases males have higher values than females. However, in all arm bones there were measurements in which females exhibited higher values than males. More specifically, females from Agia Triada Thebes as well as Corfu have higher humeral epicondylar width (HEW) values than males in the left and right humerus respectively.

Regarding the radial variables, females exhibit higher maximum radial proximal width (MRPW) and maximum radial distal width (MRDW) values in the left radius in Edessa and Agia Triada Thebes respectively. Most exceptions are found in the ulna. Ancient Corinth males as well as Agia Triada Thebes males have lower maximum ulnar length (MUL) values in the left and right ulna respectively. Additionally, both Ancient Corinth and Corfu females exhibit higher maximum ulnar distal width (MUDW) values in the left ulna. The maximum ulnar distal width (MUDW) of the right ulna has lower values in Agia Triada Thebes males.

Table 4: Summary statistics for left and right radius (number of specimens, mean, minimum and maximum value, SD and SE). Mean, minimum and maximum values in mm.

		N¹	Mean¹	Minimum¹	Maximum¹	Std. Deviation¹	Std. Error¹
MRL							
Ancient Corinth	*Males*	*7 / 4*	*255.00 / 239.4*	*217.00 / 219.00*	*354.00 / 259.00*	*45.70 / 15.66*	*17.27 / 7.00*
	Females	*1 / 4*	*202.00 / 232.50*	*- / 213.00*	*- / 248.00*	*- / 15.15*	*- / 7.57*
Corfu	*Males*	*2 / 2*	*216.00 / 217.50*	*210.00 / 211.00*	*222.00 / 224.00*	*8.48 / 9.19*	*6.00 / 6.50*
	Females	*1 / 1*	*202.00 / 199.00*	*-/-*	*-/-*	*-/-*	*-/-*
Agia Triada Thebes	*Males*	*1 / 2*	*230.00 / 241.50*	*- / 227.00*	*- / 256.00*	*- / 20.50*	*- / 14.50*
	Females	*4 / 3*	*226.50 / 241.66*	*199.00 / 237.00*	*244.00 / 248.00*	*19.29 / 5.68*	*9.64 / 3.28*
Edessa	*Males*	*6 / 7*	*240.33 / 237.71*	*219.00 / 212.00*	*258.00 / 259.00*	*13.73 / 16.86*	*5.60 / 6.37*
	Females	*7 / 4*	*215.00 / 214.50*	*189.00 / 208.00*	*230.00 / 223.00*	*14.18 / 6.24*	*5.36 / 3.12*
Thebes	*Males*	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
MRPW							
Ancient Corinth	*Males*	*4 / 7*	*23.50 / 21.85*	*20.00 / 19.00*	*29.00 / 29.00*	*4.04 / 3.43*	*2.02 / 1.29*
	Females	*1 / 1*	*18.00 / 21.00*	*-/-*	*-/-*	*-/-*	*-/-*
Corfu	*Males*	*2 / 2*	*19.00 / 19.00*	*18.00 / 18.00*	*20.00 / 20.00*	*1.41 / 1.41*	*1.00 / 1.00*
	Females	*1 / 1*	*18.00 / 18.00*	*-/-*	*-/-*	*-/-*	*-/-*
Agia Triada Thebes	*Males*	*1 / 2*	*22.00 / 25.00*	*- / 22.00*	*-/ 28.00*	*- / 4.24*	*- / 2.51*
	Females	*3 / 3*	*20.00 / 20.00*	*17.00 / 18.00*	*24.00 / 22.00*	*3.60 / 2.00*	*2.08 / 1.15*
Edessa	*Males*	*5 / 6*	*21.00 / 20.66*	*19.00 / 15.00*	*23.00 / 23.00*	*1.58 / 2.94*	*0.70 / 1.20*
	Females	*5 / 3*	*23.26 / 19.33*	*18.00 / 18.00*	*42.34 / 21.00*	*10.67 / 1.52*	*4.77 /0.88*
Thebes	*Males*	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
MRDW							
Ancient Corinth	*Males*	*6 / 6*	*30.83 / 32.00*	*21.00 / 27.00*	*35.00 / 35.00*	*5.11 / 2.82*	*2.08 / 1.15*
	Females	*0 / 3*	*- / 30.66*	*- / 25.00*	*- / 36.00*	*- / 5.50*	*- / 3.17*
Corfu	*Males*	*2 / 1*	*28.50 / 28.00*	*27.00 / -*	*30.00 / -*	*2.12 / -*	*1.50 / -*
	Females	*1 / 1*	*26.00 / 27.00*	*-/-*	*-/-*	*-/-*	*-/-*
Agia Triada Thebes	*Males*	*1 / 2*	*32.00 / 35.00*	*- / 33.00*	*- / 37.00*	*- / 2.82*	*- / 2.00*
	Females	*4 / 3*	*32.75 / 30.00*	*29.00 / 27.00*	*38.00 / 35.00*	*4.50 / 4.35*	*2.25 / 2.51*
Edessa	*Males*	*6 / 6*	*33.83 / 31.66*	*30.00 / 26.00*	*37.00 / 35.00*	*2.92 / 3.07*	*1.19 / 1.25*
	Females	*5 / 3*	*28.80 / 28.66*	*26.00 / 27.00*	*31.00 / 31.00*	*1.92 / 2.08*	*0.86 / 1.20*
Thebes	*Males*	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*

¹ *left side / right side*
MRL: maximum radial length; MRPW: maximum radial proximal width; MRDW: maximum radial distal width.

Throughout all populations examined the descriptive statistics show higher values for right and left side interchangeably for both sexes. In order to test for bilateral asymmetry, all ancient Greek samples were pooled and only individuals who had both right and left corresponding measurements were used. The results for bilateral assymetry are presented in table 6, where no statistically significant asymmetry was found.

Table 5: Summary statistics for left and right ulna (number of specimens, mean, minimum and maximum value, SD and SE). Mean, minimum and maximum values in mm.

		N[1]	Mean[1]	Minimum[1]	Maximum[1]	Std. Deviation[1]	Std. Error[1]
MUL							
Ancient Corinth	*Males*	*4 / 4*	*252.00 / 260.25*	*240.00 / 245.00*	*262.00 / 281.00*	*11.66 / 16.56*	*5.83 / 8.28*
	Females	*1 / 1*	*253.00 / 226.00*	*-/-*	*-/-*	*-/-*	*-/-*
Corfu	*Males*	*1 / 1*	*226.00 / 231.00*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*1 / 1*	*218.00 / 222.00*	*-/-*	*-/-*	*-/-*	*-/-*
Agia Triada Thebes	*Males*	*0 / 1*	*-/ 246.00*				
	Females	*2 / 2*	*234.00 / 256.50*	*218.00 / 251.00*	*250.00 / 262.00*	*22.62 / 7.77*	*16.00 / 5.50*
Edessa	*Males*	*4 / 5*	*258.75 / 260.40*	*242.00 / 239.00*	*279.00 / 279.00*	*15.23 / 17.74*	*7.61 / 7.93*
	Females	*4 / 4*	*228.28 / 232.75*	*213.00 / 223.00*	*246.00 / 249.00*	*14.40 / 12.12*	*7.20 / 6.06*
Thebes	*Males*	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
MUDW							
Ancient Corinth	*Males*	*4 / 4*	*17.75 / 20.00*	*16.00 / 19.00*	*19.00 / 21.00*	*1.25 / 1.15*	*0.62 / 0.57*
	Females	*1 / 0*	*19.00 /-*	*-/-*	*-/-*	*-/-*	*-/-*
Corfu	*Males*	*1 / 1*	*15.00 / 16.00*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*1 / 1*	*16.00 / 16.00*	*-/-*	*-/-*	*-/-*	*-/-*
Agia Triada Thebes	*Males*	*1 / 1*	*18.00 / 19.00*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*2 / 2*	*17.50 / 21.00*	*16.00 / 18.00*	*19.00 / 24.00*	*2.12 / 4.24*	*1.50 / 3.00*
Edessa	*Males*	*4 / 5*	*20.50 / 20.20*	*20.00 / 18.00*	*21.00 / 21.00*	*0.57 / 1.30*	*0.28 / 0.58*
	Females	*5 / 4*	*16.80 / 17.25*	*16.00 / 16.00*	*18.00 / 18.00*	*0.83 / 0.95*	*0.37 / 0.47*
Thebes	*Males*	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*
	Females	*0 / 0*	*-/-*	*-/-*	*-/-*	*-/-*	*-/-*

[1] *left side / right side*
MUL: maximum ulnar length; MUDW: maximum ulnar distal width.

The correct classification rates for each measurement are given in table 7 and range from 47.37% for the F27 equation to 74.19% for the F17 equation. Regarding the humeral sex prediction equations, the bones of the right side always reach a higher classification accuracy than the bones of the left side, while in case of the radial sex prediction equations the reverse applies. The exceptions concern the sex prediction equations which include all the radial measurements as well as the radial distal width. It is worth mentioning that in the case of maximum length the most sex dimorphic element is the left radius (68.97%). In the cases of vertical head diameter or maximum proximal width, the most sex dimorphic element appears to be the right humerus VHD (74.19%), whereas in the case of epicondylar width or maximun distal width, the most sex dimorphic bones are the right radius and the right humerus achieving 72.0% and 71.05% correct classification respectively.

4. DISCUSSION

According to the results of Charisi and her colleagues in 2010, the arm bones of Greek populations are suitable for the determination of sex in skeletal samples.

Regarding bilateral asymmetry, Charisi et al. (2010) found that although in most cases measurements from the right side were slightly higher than those on the left side, there was no statistically significant asymmetry between them with the exceptions of the MRL and maximum ulnar proximal width (MUPW) in females. Although the power of the tests is expected to be low due to the small sample size, our results suggest that there is no statistically significant bilateral asymmetry in any measurement of the bones examined.

Table 6. Test results for bilateral asymmetry for humerus, radius, and ulna.

		t	df	p value [1]
MHL	*Males*	-0,769	18	0,452
	Females	-0,535	16	0,6
VHD	*Males*	-0,146	12	0,887
	Females	0,067	8	0,948
HEW	*Males*	-0,678	26	0,504
	Females	-0,448	26	0,658
MRL	*Males*	-0,222	26	0,826
	Females	-0,286	10	0,781
MRPW [2]	*Males*	70		0,907
	Females	14		0,493
MRDW	*Males*	-0,411	24	0,685
	Females	0,094	10	0,927
MUL	*Males*	-0,366	8	0,724
	Females	-0,306	6	0,77
MUDL	*Males*	-0,703	10	0,498
	Females	0	6	1

[1] Statistically significant difference at level of 95.0% of confidence interval.

[2] Mann-Whitney U test results

According to a number of studies, the existence of bilateral asymmetry in the arm bones is caused by the preferential use of one arm for everyday tasks (Roy et al., 1994; Cuk et al., 2001). Other researchers (Lanyon, 1980; Lieberman et al., 2001; Ruff, 2003) have suggested that some of the bone dimensions are genetically determined. Based on Trinkaus et al. research (1994), bilateral asymmetry is best observed in the diaphyses and especially their circumference or other cross-section characteristics. Therefore, Charisi et al. (2010) suggest that the absence of bilateral asymmetry in the Greek sample could be due to the measurements taken for their project.

Although Charisi et al. (2010) found no statistically significant bilateral asymmetry, they created sex-predicting equations for right and left side sexually dimorphic traits separately, in order to maximize the amount of information obtained, especially from incomplete skeletons. In the modern Greek population, all mean values were higher in males than in females and the differences were statistical significant (Charisi et al., 2010). Due to the small sample size of the individual ancient Greek populations, no statistical test for sexual dimorphism could be conducted. Additionally, pooling the ancient Greek samples would not be appropriate due to issues relating to secular change in stature, which is also present in the modern Greek population (Bertsatos and Chovalopoulou, 2017). However, the SD values in ancient populations with sufficient male and female individuals suggest that there may be significant differences between sexes in most arm bones measurements.

The cross-validated correct classification rates for the modern Greek population ranged between 87% for the left ulna using the ML and MPW measurements to 95.7% for the right humerus when all three measurements are utilized (Charisi et al., 2010). Additionally, according to Charisi's et al. results (2010), the humeral sex prediction equations' accuracy rates were highest in the right side. Our results are consistent with Charisi et al. (2010) regarding the right side's highest accuracy rates of the humeral sex prediction equations. However, in the ancient Greek populations, the correct classification rates were lower for all arm bones (Fig. 2). It is worth mentioning that ancient Greek populations under study were not used separately for testing the reliability of the sex prediction equations, due to the small sample size of each population. Additionally, we were not able to test the reliability of the sex prediction equations containing the MUPW measurement, which was not available due to the poorly preserved skeletal material. When comparing the variables' mean values of the ancient and the modern Greeks, we notice that ancient Greek males have equal or lower values, with the exception of the left MRL as well as the right and left MUDW, while in the case of females the reverse applies, with the exception of the right VHD variable. These observations could account for the low correct classification rates of the ancient Greek populations. However, the small sample size doesn't allow for definitive conclusions.

There are many factors contributing to the degree of sexual dimorphism, such as diet (Stini, 1969; Steyn & Işcan,1999; Frutos, 2005), physical activity patterns (Steyn & Işcan,1999; Carlson et al., 2007) and genetic background (Steyn & Işcan,1999; Frutos, 2005). According to Gray and Wolfe (1980), groups with excessive or deficient intake of protein tend to express lower sexual dimorphism, while an intermediate intake of protein leads to a more pronounced sexual dimorphism. Additionally, the division of labor between males and females also affects sexual dimorphism, since the various forces exerted on bones are responsible for their size (Ruff, 1987; Steyn & Işcan, 1999). Unfortunately, due to the lack of dietary data for the ancient Greek populations under study along with the poor bone preservation, which does not allow scoring of the entheseal changes for activity markers, no comparison of sexual dimorphism between the ancient and modern Greek populations could be made.

Regarding the maximum length's sex-prediction equations of all arm bones, for the modern Greek population, the right ulna has the highest accuracy rate (90.4%). Correspondingly, both radii (94.6–

94.1% left and right, respectively) have the highest accuracy rate regarding the vertical head diameter / MPW, whereas both humeri (92.0–90.1% left and right, respectively) regarding the epicondylar width / MDW (Charisi et al., 2010). Our results are consistent with Charisi et al. (2010), only in the case of the right humerus with regard to the epicondylar width / MDW variables.

According to France (1983), the mechanical stress received by the epiphyses during loading is higher than that on the diaphysis and causes them to increase in size. Additionally, genetic factors are mainly related to bones' length (Cowgill & Hager 2007; Blackburn, 2011) Therefore, it is expected the epiphyseal dimensions to be more discriminating between the two sexes, which is the case for our population samples as well as Charisi's et al. (2010). However, according to other studies, the reverse applies especially in diaphyses' cross-section (Auerbach & Ruff, 2006; Carlson et al., 2007). No measurements of the diaphyses were obtained for Charisi's et al. research (2010) and therefore no verification could be performed.

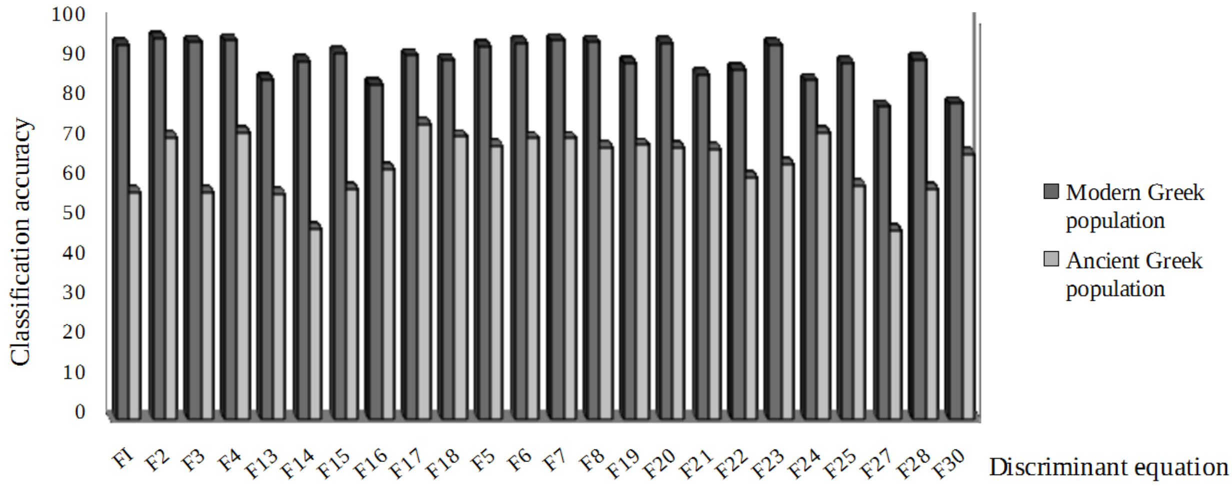

Figure 2. Comparison of classification accuracies between modern and ancient Greek populations.

Table 7. Classification accuracies on arm bones of the archaeological assemblages.

Humeral Discriminant Functions*

Population	FI	F2	F3	F4	F13	F14	F15	F16	F17	F18
Ancient Corinth	*3/4*	*2/4*	*3/4*	*3/5*	*3/7*	*1/5*	*8/11*	*4/8*	*5/9*	*8/8*
Corfu	*1/5*	*3/6*	*1/5*	*3/6*	*4/6*	*1/5*	*2/7*	*5/7*	*4/6*	*4/8*
Agia Triada Thebes	*3/5*	*3/4*	*3/5*	*3/4*	*3/6*	*4/6*	*2/6*	*4/6*	*3/4*	*4/7*
Edessa	*5/6*	*9/10*	*5/6*	*9/10*	*7/10*	*5/6*	*10/13*	*9/14*	*10/11*	*11/15*
Thebes	*0/1*		*0/1*		*0/1*	*0/1*	*0/1*		*1/1*	
Total sample	*12/21*	*17/24*	*12/21*	*18/25*	*17/30*	*11/23*	*22/38*	*22/35*	*23/31*	*27/38*
(%) Prediction of Total Sample	*57.14*	*70.83*	*57.14*	*72*	*56.67*	*47.83*	*57.89*	*62.86*	*74.19*	*71.05*

Radial Discriminant Functions*

Population	F5	F6	F7	F8	F19	F20	F21	F22	F23	F24
Ancient Corinth	*3/4*	*2/4*	*3/4*	*2/4*	*7/8*	*4/5*	*4/6*	*5/9*	*5/8*	*6/9*
Corfu	*1/3*	*1/2*	*1/3*	*1/2*	*2/3*	*1/3*	*1/3*	*1/3*	*1/3*	*1/2*
Agia Triada Thebes	*2/3*	*4/5*	*2/3*	*3/5*	*2/5*	*3/4*	*3/5*	*2/5*	*4/5*	*4/5*
Edessa	*5/6*	*5/6*	*6/7*	*7/8*	*9/13*	*7/10*	*9/11*	*9/11*	*6/9*	*7/9*
Thebes										
Total sample	*11/16*	*12/17*	*12/17*	*13/19*	*20/29*	*15/22*	*17/25*	*17/28*	*16/25*	*18/25*
(%) Prediction of Total	*68.75*	*70.59*	*70.59*	*68.42*	*68.97*	*68.18*	*68*	*60.71*	*64*	*72*

Sample

Ulnar Discriminant Functions*

Population	**F25**	**F27**	**F28**	**F30**
Ancient Corinth	*2/5*	*4/5*	*4/5*	*4/4*
Corfu	*1/2*	*0/2*	*1/2*	*1/2*
Agia Triada Thebes	*1/2*	*1/3*	*0/3*	*1/3*
Edessa	*6/8*	*4/9*	*6/9*	*6/9*
Thebes				
Total sample	*10/17*	*9/19*	*11/19*	*12/18*
(%) Prediction of Total Sample	*58.82*	*47.37*	*57.89*	*66.67*

** correct classification / valid samples (N)*

Discriminant equations by Charisi et al. 2011

5. CONCLUSIONS

According to our results, humeral as well as radial measurements can be considered adequately reliable for sex determination of ancient skeletal remains. More specifically, the humeral vertical head diameter, its combination with the humeral epicondylar width as well as the maximum radial distal width, achieve a classification accuracy over 72%. On the contrary, ulnar measurements cannot be considered adequate for sex determination of ancient skeletal remains, since the highest correct classification achieved was only 66.7% from the maximum ulnar distal width measurement. However, further research on larger archaeological samples is required to address whether the different correct classification results may reflect differences in the expression of sexual dimorphism of the particular traits examined and how secular change in stature among other confounding factors between modern and past populations may be contributing to these differences.

REFERENCES

Asala, S. (2001). Sex determination from the head of the femur of South African whites and blacks. *Forensic Science International*, 117(1-2), 15-22.

Auerbach, B. M., & Ruff, C. B. (2006). Limb bone bilateral asymmetry: variability and commonality among modern humans. *Journal of Human Evolution, 50*(2), 203-218.

Bertsatos, A., & Chovalopoulou, M. E. (2017). Secular change in adult stature of modern Greeks. *American Journal of Human Biology*, e23077.

Blackburn, A. (2011). Bilateral asymmetry of the humerus during growth and development. *American Journal of Physical Anthropology, 145*(4), 639-646.

Buikstra, J., & Ubelaker, D. (1994). Standards for data collection from human remains. Arkansas: Arkansas Archaeological Survey.

Carlson, K. J., Grine, F. E., & Pearson, O. M. (2007). Robusticity and sexual dimorphism in the postcranium of modern hunter-gatherers from Australia. *American Journal of Physical Anthropology, 134*(1), 9-23.

Charisi, D., Eliopoulos, C., Vanna, V., Koilias, C. G., & Manolis, S. K. (2010). Sexual Dimorphism of the Arm Bones in a Modern Greek Population. *Journal of Forensic Sciences*, 56(1), 10-18.

Cowgill, L. W., & Hager, L. D. (2007). Variation in the development of postcranial robusticity: an example from Çatalhöyük, Turkey. *International Journal of Osteoarchaeology, 17*(3), 235-252.

Cuk, T., Leben-Seljak, P., & Stefancic, M. (2001). Lateral asymmetry of human long bones. *Variability and Evolution*, 9,19-23.

Dabbs, G. R., & Moore-Jansen, P. H. (2010). A Method for Estimating Sex Using Metric Analysis of the Scapula. *Journal of Forensic Sciences*, 55(1), 149-152.

Eliopoulos, C., Lagia, A., & Manolis, S. (2007). A modern, documented human skeletal collection from Greece. *HOMO - Journal of Comparative Human Biology*, 58(3), 221-228.

France, D. L. (1983). *Sexual dimorphism in the human humerus*. Ph.D. dissertation, Boulder (CO), University of Colorado.

Frutos, L. R. (2005). Metric determination of sex from the humerus in a Guatemalan forensic sample. *Forensic Science International, 147*(2-3), 153-157.

Gray, J. P., & Wolfe, L. D. (1980). Height and sexual dimorphism of stature among human societies. *American Journal of Physical Anthropology, 53*(3), 441-456.

Işcan, M. Y., & Miller-Shaivitz, P. (1984a). Determination of sex from the femur in Blacks and Whites. *Collegium Antropologicum,* 8(2), 169–175.

Işcan, M. Y., & Miller-Shaivitz, P. (1984b). Determination of sex from the Tibia. American Journal of Physical Anthropology, 64(1), 53-57.

Kemkes-Grottenthaler, A. (2001). The reliability of forensic osteology — a case in point. *Forensic Science International*, 117(1-2), 65-72.

Kemkes-Grottenthaler, A., Löbig, F., & Stock, F. (2002). Mandibular ramus flexure and gonial eversion as morphologic indicators of sex. *HOMO - Journal of Comparative Human Biology*, 53(2), 97-111.

Krishan, K., Chatterjee, P. M., Kanchan, T., Kaur, S., Baryah, N., & Singh, R. (2016). A review of sex estimation techniques during examination of skeletal remains in forensic anthropology casework. *Forensic Science International,* 261.

Lanyon, L. E. (1980). The influence of function on the development of bone curvature. An experimental study on the rat tibia. *Journal of Zoology, 192*(4), 457-466.

Lieberman, D. E., Devlin, M. J., & Pearson, O. M. (2001). Articular area responses to mechanical loading: effects of exercise, age, and skeletal location. *American Journal of Physical Anthropology, 116*(4), 266-277.

Martin, R., & Saller, K. (1957). Lehrbuch der Anthropologie: in systematischer Darstellung mit besonderer berucksigtigung der anthropologischen Methoden. Stuttgart: Fischer.

Moore-Jansen, P. H., Ousley, S. D., & Jantz, R. L. (1994). Data collection procedures for forensic skeletal material. Knoxville: Forensic Anthropology Center, Dept. of Anthropology, University of Tennessee. Report no. 48.

Pretorius, E., Steyn, M., & Scholtz, Y. (2005). Investigation into the usability of geometric morphometric analysis in assessment of sexual dimorphism. *American Journal of Physical Anthropology*, 129(1), 64-70.

Ramsthaler, F., Kreutz, K., & Verhoff, M. A. (2007). Accuracy of metric sex analysis of skeletal remains using Fordisc® based on a recent skull collection. *International Journal of Legal Medicine*, 121(6), 477-482.

Rösing, F., Graw, M., Marré, B., Ritz-Timme, S., Rothschild, M., Rötzscher, K., . . . Geserick, G. (2007). Recommendations for the forensic diagnosis of sex and age from skeletons. *HOMO - Journal of Comparative Human Biology,* 58(1), 75-89.

Roy, T. A., Ruff, C. B., & Plato, C. C. (1994). Hand dominance and bilateral asymmetry in the structure of the second metacarpal. *American Journal of Physical Anthropology, 94*(2), 203-211.

Ruff, C. (1987). Sexual dimorphism in human lower limb bone structure: relationship to subsistence strategy and sexual division of labor. *Journal of Human Evolution, 16*(5), 391-416.

Ruff, C. (2003). Ontogenetic adaptation to bipedalism: age changes in femoral to humeral length and strength proportions in humans, with a comparison to baboons. *Journal of Human Evolution, 45*(4), 317-349.

Steyn, M., & Işcan, M. (1999). Osteometric variation in the humerus: sexual dimorphism in South Africans. *Forensic Science International, 106*(2), 77-85.

Steyn, M., Pretorius, E., & Hutten, L. (2004). Geometric morphometric analysis of the greater sciatic notch in South Africans. *HOMO - Journal of Comparative Human Biology*, 54(3), 197-206.

Stini, W. A. (1969). Nutritional stress and growth: Sex difference in adaptive response. *American Journal of Physical Anthropology, 31*(3), 417-426.

Trinkaus, E., Churchill, S. E., & Ruff, C. B. (1994). Postcranial robusticity inHomo. II: Humeral bilateral asymmetry and bone plasticity. *American Journal of Physical Anthropology, 93*(1), 1-34.

Ubelaker, D. H. (2002). Application of Forensic Discriminant Functions to a Spanish Cranial Sample. Retrieved June 18, 2017, from https://www.fbi.gov/about-us/lab/forensic-science-communications/fsc/july2002/ubelaker1.htm