Metric Methods of Skeletal Sex Determination using the Arm Bones of Two British Medieval Populations

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Abstract: Several studies have stated the importance of devising population-specific metric methods for sex determination. The long bones of the arm have been previously reported as having a high reliability. This paper explores the degree of sexual dimorphism in adult arm bones displayed in two Medieval British populations, one urban and one rural. The urban Gloucester population sample consists of 45 individuals (19 female and 26 male) and the rural Poulton sample of 27 individuals (13 female and 14 male) and were selected from collections housed at Liverpool John Moores University. Measurements of the proximal and distal epiphyses along with maximum length were used on the humerus, radius and ulna. These populations showed sexual dimorphism in every measurement taken. Discriminant function analysis found that all arm bones had very high discriminant accuracies in both populations reaching 91.2% (Gloucester radii) and 95.5% (Poulton radii). It was found that some of the values were significantly different between the populations supporting the necessity for population-specific metric standards.

Keywords: Biological anthropology, Sex determination, Arm bones, Medieval Britain, Metric standards.

INTRODUCTION

Sexual dimorphism is the observable differences between males and females of the same species within the same population. These observable traits enable sex determination which is an important first step in the analysis of human skeletal remains, as in forensic cases it reduces the number of potential individuals by half [1]. It is also important to determine sex in archaeological collections as it enables the demographic reconstruction of the population studied [2]. The degree of sexual dimorphism varies between populations, separated both chronologically and geographically. It is therefore important to use population specific methods when determining sex in human skeletal remains [3]. Morphological methods of sex determination using the pelvis and the skull are routinely used [4]. However if these skeletal elements are not present or fragmented it may not be possible to accurately determine sex, therefore alternative methods should be applied [5, 6].

Metric methods of sex determination have proved highly reliable on several populations using mainly post-cranial long bone measurements. Morphological traits are believed to be more subjective than measurements and therefore require considerable osteological knowledge [7-9]. The use of a single or combined limb bone measurements have shown to be accurate 80-90% of the time [10]. Metric standards of the lower limb have been used extensively for sex determination, however as not all bones may be recovered it is important to utilise other skeletal elements [2, 5]. For example, it has been demonstrated that arm bone dimensions are sexually dimorphic. Various studies have shown a high degree of reliability of metric methods in the determination of sex using the humerus [2, 3, 11-14]. Studies using the radius and ulna have also proved successful [1, 7, 15, 16]. It is therefore important to develop metric sample-specific methods for sex determination using arm bones which can be applied to unidentified remains of archaeological origin [2].

This paper aims to explore the degree of sexual dimorphism in arm bone measurements shown in two British Medieval populations. Several studies have shown differences in the degree of sexual dimorphism displayed in various populations. Some examples are a study comparing the dimorphism of Thai, Chinese and Japanese humeri [12] as well as others using the long bones of the arm in Germans [17] and Greeks [6]. Whilst both the Poulton and Gloucester collections examined in this study are British Medieval, Poulton was a rural community and Gloucester was urban. It is therefore possible that there would be a difference in the degree of sexual dimorphism displayed in the arm bones examined. The present study also aims to examine the similarities and differences between the two populations and develop metric standards for sex determination in the Poulton and Gloucester archaeological samples.

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MATERIALS AND METHODS

The specimens selected for this research are derived from two collections housed at Liverpool John Moores University (LJMU). Both the Poulton and Gloucester skeletal collections are from Medieval church graveyard excavations.

Poulton is a rural hamlet located in Cheshire, which once briefly housed a Cistercian abbey (between c1153-1214CE). Excavation at the site started in 1995 and while the abbey has not been found to this day, the foundations of an ecclesiastical structure believed to be a chapel were discovered. This chapel fell into disuse by the time of the English Civil War and was no longer visible by 1719 CE [18]. The Poulton chapel graveyard excavation is ongoing and has so far yielded over 750 burials. Evidence has suggested that the surrounding site of the chapel has been in use since the Bronze age and that some of the Christian burials pre-date the chapel construction [19].Gloucester is a city in the South West of England. The Gloucester skeletal collection, housed at LJMU, was excavated from the Medieval churchyard of St. Owen in 1989. Over 300 Medieval burials were excavated, the majority of which are on loan to LJMU [20].

Specimens for the study were selected from a database of skeletal remains housed at LJMU. All skeletons had been previously sexed using a combination of morphological methods such as the Phenice method (1969)[21], other pelvic traits as well as cranial morphology [22]. The remains selected had been aged as adult (using epiphyseal closure and dental eruption patterns), with no pathologies noted on the bone used. Arm bones were selected on the basis of their completeness, and intact epiphyses. Where both left and right bones were present, the left bones were analysed in line with anthropological standards [22]. Statistical analysis found that there was no significant difference between left and right bone measurements therefore when the right bone alone was present, this was included in the sampling. Out of the 72 individuals identified, only 36 individuals had all three arm bones intact (22 Gloucester, 14 Poulton). Therefore, individuals with as little as one intact bone were also used.

The Poulton Collection housed at LJMU currently has approximately 650 skeletons. This number is increasing as the excavation is ongoing. However, due to poor preservation of arm bones and the fact that not all skeletons were available for study, only 27 individuals were used for this study, 13 female and 14 males. The Gloucester collection housed at LJMU contains skeletons including sub-adult and non-sexed individuals which were excluded from the current work. This study used a total of 45 adult skeletons, 19 females and 26 males.

The measurements used on the humerus, radius and ulna were the maximum length, proximal and distal mediolateral articular dimensions. The only exception was the vertical head diameter of the humerus.

Humerus

The measurements used had produced high accuracy rates of sex determination in previous studies. The total number of specimens used for humeral measurements can be seen in Table **1**.

The measurements used were maximum humeral length (MHL), Vertical head diameter (VHD) and humeral epicondylar width (HEW).

Maximum Humeral Length (MHL)

The maximum humeral lengths were taken using an osteometric board. This is the distance between the most inferior part of the trochlea and the most superior part of the humeral head [23].

Vertical Head Diameter (VHD)

The vertical head diameter was taken using sliding calipers. It is the distance between the most superior and inferior points of the articular surface [23].

Humeral Epicondylar Width (HEW)

The humeral epicondylar width (also known as the biepicondylar breadth by other authors) was taken using an osteometric board. This is the distance between the most medially protruding part of the medial epicondyle and the most laterally protruding part of the lateral epicondyle [23].

Radius

Radial measurements have also been used successfully for sex determination in past studies. Table **1** shows the number of specimens used in this study.

The measurements used in this study were the maximum radial length (MRL), maximum radial proximal width (MRPW) and the maximum radial distal width (MRDW).

Maximum Radial Length (MRL)

The maximum radial length (MRL)is measured using an osteometric board and is the distance from the most proximal part of the radial head to the most distal part of the styloid [23].

Maximum Radial Proximal Width (MRPW)

Maximum radial proximal width (MPRW), isalso known as the transverse radial head diameter. This measurement is taken using sliding calipers and measures the mediolateral diameter of the radial head [24].

Maximum Radial Distal Width (MRDW)]

The maximum radial distal width is measured using an osteometric board. It is taken at the most mediolateral points on the distal epiphysis. The distal end of the radius is placed parallel with the horizontal plane of the osteometric board [24].

Ulna

The ulna sample size for both populations and each sex is presented in Table **1**.

The measurements used for the ulna were the maximum ulnar length, maximum ulnar proximal width and the maximum ulnar distal width.

Maximum Ulnar Length (MUL)

The maximum ulnar length is the distance from the most inferior of the styloid process to the most superior part of the olecranon. This measurement is taken with an osteometric board [22].

Maximum Ulnar Proximal Width (MUPW)

The maximum ulnar proximal width is the most medial and lateral points on the proximal ulna [24].This measurement is taken using an osteometric board.

Maximum Ulnar Distal Width (MUDW)

The maximum ulnar distal width is measured using sliding calipers and is the distance between the most lateral and medial points of the distal epiphysis [24]. Statistical analysis was carried out using IBM SPSS 21 for descriptive statistics, t-test analysis and discriminant function analysis (DFA). Statistics were viewed as significant at the 95 percentile ($p>0.05$). Percentage

Table 1: Total Number of Measured Humeri, Radii and Ulnae for Both Populations

	Humeri		Radii		Ulnae	
Sex	Gloucester	Poulton	Gloucester	Poulton	Gloucester	Poulton
Females	16	12	17	13	15	10
Males	25	11	18	9	12	12
Total	41	23	35	22	37	22

Table 2: Summary Statistics and T-test Results Comparing Female and Male Values for Gloucester [Measurements in Millimetres]

Gloucester	Humerus			Radius			Ulna		
Variables [mm]	MHL	VHD	HEW	MRL	MRPW	MRDW	MUL	MUPW	MUDW
<u>Females</u>									
Mean	295.75	42.36	57	217.69	19.91	29.25	238.23	24.64	15.92
Standard deviation	17	1.73	2.45	6.86	1.16	2.295	10.01	1.45	1.16
Minimum value	239	38.8	53	207	17.13	22.5	224	22.4	14.12
Maximum value	308	45.2	63	237	21.6	31.5	272	29.5	18.16
<u>Males</u>									
Mean	320.63	46.96	63.38	235.61	22.19	33.19	257.86	28.93	18.81
Standard deviation	18.05	2.87	3.91	13.33	1.57	2.55	11.64	2.29	1.31
Minimum value	270	39.3	52	203	18.14	25.5	242	26	16.9
Maximum value	351	53.4	69	254	25.2	36	280	34	20.8
t-test	-4.288	-5.947	-5.778	-4.581	-4.516	-4.702	-3.739	-5.215	-4.85
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3: Summary Statistics and T-test Results Comparing Female and Male Values for Poulton [Measurements in Millimetres]

Poulton	Humerus			Radius			Ulna		
Variables [mm]	**MHL**	**VHD**	**HEW**	**MHL**	**VHD**	**HEW**	**MHL**	**VHD**	**HEW**
Females									
Mean	295.92	41.31	55.46	220.77	19.24	29.04	239.5	23.1	15.00
Standard deviation	8.32	2.12	3.62	10.92	0.89	1.44	10.17	2.60	1.51
Minimum value	285	38.4	49	204	17.48	27	225	19	11.71
Maximum value	318	45.5	63	247	20.9	32	257	27.5	16.7
Males									
Mean	337.18	47.31	64.82	249	22.79	34.46	265.75	28.21	18.33
Standard deviation	21.89	2.92	5.02	13.86	0.99	2.04	14.83	2.74	1.84
Minimum value	304	42.1	51	235	21	31.5	241	23	15.34
Maximum value	382	50.6	71	279	24.45	38.5	299	32.5	20.91
t-test	-6.018	-5.669	-5.168	-5.346	-8.742	-7.325	-4.738	-4.452	-4.575
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

given in DFA is as the result stated *e.g.* 91% of individuals were correctly classified. Microsoft Excel 2013 was used to calculate sexual dimorphism indices according to the Ricklan and Tobias (1986) formula[25]. The range parameters were calculated from the descriptive statistics, using the minimum male values and the maximum female values.

RESULTS

Descriptive statistics for each measurement are presented in Tables **2** and **3**. The t-test results show that there is a difference in the mean values. Males are generally larger than females in both populations in all measurements. The differences are statistically significant in every measurement in these two populations.

The sexual dimorphism index for each measurement was calculated using a formula after Ricklan and Tobias (1986) [25]. These ratios can be seen in Table **4**. This shows that HEW showed the most sexual dimorphism in the humerus, while for the radius and ulna the maximum radial and ulnar distal width (MRDW, MUDW) were the most dimorphic measurements. These were consistent in both populations. The level of dimorphism displayed was higher in Poulton than Gloucester for every measurement.

Table 4: Sexual Dimorphism Index [SDI] for All Three-Arm Bones in Both Populations

	Variable	Gloucester	Poulton
Sexual dimorphism index [SDI]			
Humerus	MHL	7.76	12.24
	VED	9.80	12.68
	HEW	10.07	14.44
Radius	MRL	7.61	11.34
	MRPW	10.26	15.55
	MRDW	11.87	15.72
Ulna	MUL	7.61	9.88
	MUPW	14.83	18.11
	MUDW	15.36	18.15

Statistical analysis was carried out comparing Poulton females (PF) and Gloucester females (GF), Poulton males (PM) and Gloucester males (GM). This was in order to assess the reliability of these measurements across populations, by testing for significant differences in the males and females between the two populations. These values can be seen in Table **5** where there is a significant difference between males in the two populations for maximum humeral length and maximum radial length. However, there was no significant difference in any of the other male arm bone measurements. The between-population measurements for females were significantly different for the maximum radial proximal width, maximum ulnar proximal width and maximum ulnar distal width.

Table 5: Statistical Differences between Gloucester and Poulton Females and Gloucester and Poultonmales*. Significant Differences Appear in Bold

	Variable	GF vs PF	GM vs PM
Humerus	MHL	t=-0.654 p=0.519	**t=-2.404 p=0.022**
	VED	t=1.405 p=0.172	t=-0.359 p=0.722
	HEW	t=1.415 p=0.172	t=-0.803 p=0.428
Radius	MRL	t=-0.790 p=0.436	**t=-2.471 p=0.021**
	MRPW	**t=2.272 p=0.031**	t=-1.063 p=0.298
	MRDW	t=0.404 p=0.689	t=-1.378 p=0.180
Ulna	MUL	t=0.284 p=0.779	t=-1.579 p=0.128
	MUPW	**t=2.101 p=0.047**	t=0.558 p=0.582
	MUDW	**t=2.091 p=0.048**	t=0.241 p=0.810

t= t-test value, p=probability of a false hit.
*[GF= Gloucester females, GM=Gloucester males, PF= Poulton females, PM= Poulton males].

Ranges for the population measurements can be seen in Table **6**. These measurements were derived using the minimum male and maximum female measurements for each population. The ranges for the Poulton collection are presented in Table **6**. The sample size for this population was smaller than Gloucester and the indeterminate range was greater in this population for six out of 9 measurements.

Combined discriminant function analysis was carried out on the samples. Figure **1** shows the relationship between the variables. The graph shows that measurements for females from both populations are closely related and are separate to the males from both populations. The male measurements show clearer population-specific clusters. Discriminant function analysis found that 86.1% of cases were correctly classified, using all the measurements.

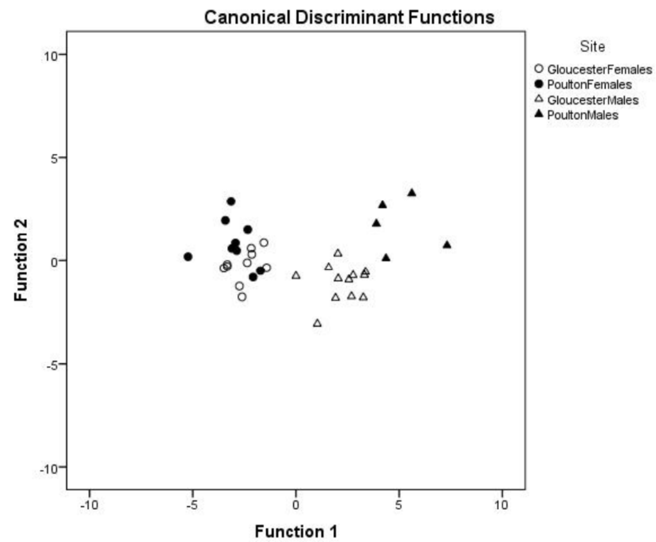

Figure 1: The relationship between males and females from Poulton and Gloucester using combined discriminant function analysis.

Table 6: Ranges Derived from Descriptive Statistics for Gloucester and Poulton using the Minimum Male and Maximum Female Values [Measurements in Millimetres]

		Gloucester			Poulton		
	Variable	Female	Indeterminate	Male	Female	Indeterminate	Male
Humerus	MHL	<296	296-308	>308	<304	304-318	>318
	VHD	<42	42-45.2	>45.2	<42.1	42.1-45.5	>45.5
	HEW	<59	59	>59	<51	51-63	>63
Radius	MRL	<223	223-226	>226	<235	235-247	>247
	MRPW	<20.1	20.1-21.6	>21.6	<20.9	20.9-21	>21
	MRDW	<31	31-32	>32	<31.5	31.5-32	>32
Ulna	MUL	<241	241-248	>248	<241	241-257	>257
	MUPW	<26	26-27	>27	<23	23-27.5	>27.5
	MUDW	<17	17-18	>18	<15.3	15.3-16.7	>16.7

Table **7** shows the results for the stepwise discriminant function analysis carried out on the measurements for the humerus, radius and ulna. They indicate that there were high classification rates for each individual bone in each population.

Table 7: Percentage of Correct Group Classification of Sex Based on Measurements of the Humeri, Radii and Ulnae for each Population using Discriminant Function Analysis

	Gloucester	Poulton
Humerus	95%	91.3%
Radius	91.2%	95.5%
Ulna	92.6%	91.3%

DISCUSSION

The results of the study showed that there was significant sexual dimorphism displayed in both Gloucester and Poulton populations. The degree of sexual dimorphism was greater in the Poulton population than the Gloucester. This may be due to the different activities carried out in urban and rural communities [26]. The amount of physical activity can be inferred by the dimensions of long bones (such as those of the arm), as the greater robusticity of long bones indicates greater activity [27]. Table **1** shows that Gloucester and Poulton females are grouped closer together compared to the males from these populations and that Gloucester males were closest to the female populations. The occupations and division of labour would have been different between the two populations. Medieval Gloucester was a middle-ranking town with an estimated 1377 CE population of 4500 individuals[28]. Occupations within Gloucester included bakery, brewing, and trading[29]. Whereas the main occupation in Medieval Poulton would have likely been farming and agriculture [19]. This may account for the greater level of sexual dimorphism in the Poulton collection as farming would have been labour intensive.

The mean values for maximum radial and ulna length, maximum radial proximal and distal width was lower in the Poulton and Gloucester populations(Tables **2** and **3**) compared to a 2008 study carried out by Barrier and L'Abbe on a modern South African sample[1]. However, as the Poulton and Gloucester collections are remote from other studies geographically and chronologically this was expected. Discriminant function analysis found that when all arm bone measurements were included 86.1% of individuals were classified correctly (Figure **1**). The percentage of correctly classified sex was higher for each population when each bone was individually assessed for sex (Table **7**). The classification was very high for each bone for both populations using stepwise analysis (91.2 -95.5%). However, the bone with the highest rate of classification varied between the populations, with the humerus being greatest for Gloucester and the lowest classification rate on the radius, whereas the radius had the highest classification rate for Poulton.

The measurements used in this study used articular measurements and maximum long bone length. Long bone length showed the least amount of sexual dimorphism for all three arm bones in both populations compared to the mediolateral joint measurements (Table **4**). Charisi *et al*. [6], also found this in their study of a Modern Greek collection. When evaluating differences between males for Gloucester and Poulton, it was found there was a significant difference in the maximum humeral and radial length unlike the other seven measurements. This may be due to the close association between long bone length and stature estimation. This has been observed in previous studies as varying between populations and therefore may affect the results for sex estimation [4, 16, 27]. Analysis comparing males and females from the different populations (Table **5**) showed that there were significant differences between male and females from Poulton and Gloucester in all the measurements. The distal measurements for the humeri, radii and ulnae (HEW, MRDW, and MUDW respectively) were consistently the most sexually dimorphic. This differs from the findings of Charisi *et al*. [2011]. They found that the proximal measurements had the highest sexual dimorphism indexes (VHD, MRPW, and MUPW). This again shows that different results are obtained in different populations.

Humerus

The humerus has been stated as the second best bone for sex determination [30]. Spradley and Jantz [9] compared the reliability of metric variable for various skeletal elements (including the cranium), to determine the most accurate element after the pelvis. They found that the humerus had the highest classification for black Americans using the biepicondylar breadth, head diameter and diameter of the midshaft.

In the present study, there was a significant difference in all measurements taken on the humerus between sexes in both populations (Tables **2** and **3**).

The sexual dimorphism indices showed the HEW as the most dimorphic measurement in both populations for the humerus. This measurement is also known as the biepicondylar breadth. The vertical head diameter was the second most sexually dimorphic humeral measurement for both Gloucester and Poulton. This is consistent with previous studies which found that either the HEW or VHD were the best discriminator for sex using on the humerus [5, 12-14].

Radius

The radius was the best discriminator for sex in the Poulton collection, which had a 95.5% correct classification rate using stepwise analysis (Table **7**). Spradley and Jantz [9] also found that the radius had the highest rate of classification for white Americans, even though they used different measurements than the present study. The MRDW showed the highest degree of sexual dimorphism for both populations (Table **4**). The MRPW also showed a high level of sexual dimorphism. This measurement is similar to the maximum transverse head diameter. Allen *et al.* [15] found that when applied to a Dutch collection this measurement was the most consistent with 85% accuracy. Berrizbeitia [7] found that using multiple aspects of the radial head produced a correct classification rate of 96%. This study found that there was a significant difference in MRPW between Gloucester and Poulton females (Table **5**). This indicates that this measurement is useful when applied on population specific samples.

Ulna

The ulna measurements showed a high rate of correct classification for both populations despite the fact that the ulna did not rank in first place for either population (Table **7**). The MUPW and MUDW showed the highest degree of sexual dimorphism in both populations for all the measurements taken for all the arm bones. However, results for MUPW and MUDW were significantly different between Gloucester and Poulton females (Table **5**). Therefore these measurements are sample specific as were the most accurate radial measurements and show the importance of selecting appropriate parameters when trying to determine sex for unknown individuals.

The range of measurements derived from this study (Table **6**) are similar to the ranges in Mall *et al*. [17]. However, when compared to other studies these ranges vary which emphasises the need for population-specific measurements [31]. Measurement ranges for the vertical head diameter derived from the Terry collection are widely used in metric sex determination [30, 32]. These measurements are similar to those derived from Poulton and Gloucester in Table **6**. However, the Terry measurements are greater than those derived from the present study and if used on the Poulton and Gloucester collections, they may show bias against small males and large females. It is therefore important to select the most appropriate variables when attempting metric methods for sex determination. Further research could be carried out by blind testing the methods used in this study alongside the ranges of measurements in Table **6** to determine whether correct classification is possible. These measurements could then be compared to other studies to determine their accuracy.

CONCLUSION

The Poulton and Gloucester collections represent archaeological undocumented samples, therefore definite sex and age at death are unknown. The skeletons have been previously assessed using morphological methods for sex determination. It is however known that there is a degree of error associated with these methods. Therefore, it is not certain that the previous allocated sex is correct and could affect the accuracy in testing these measurements. Albanese *et al*., [2] stress the importance of drawing up such metric standards and propose a methodology for unidentified individuals from archaeological skeletal collections.

The sample size was relatively small. This was due to poor preservation in the Poulton skeletal collection, and a high proportion of juveniles in this population which were excluded from this study. Therefore, the sample size for Poulton was much smaller than that of Gloucester. Only 9 intact male radii were identified as usable therefore the resulting measurement may not be a fair representation of the population. This could account for the increased indeterminate sex ranges from Poulton (Table **6**). The total skeletons studied was 72 individuals, however of these only 36 individuals had all three arm bones present, this therefore affects the results when assessing the reliability of using combined measurements in relation to these populations.

Sex determination is very important in the study of human remains whether for forensic or archaeological purposes. The results of this research showed that there was a difference between male and female arm bone dimensions in two archaeological populations. The degree of sexual dimorphism displayed was different between these groups. This may be due to the differing lifestyles, occupations and division of labour, between urban Gloucester and rural Poulton.

The long bone lengths were the least sexually dimorphic for both Gloucester and Poulton. There were significant differences between the arm bone lengths in the two populations. Therefore, these measurements would not be a good discriminator for sex. This reiterates the importance of population-specific measurements as there were observable differences between the populations.

The distal articular measurements (HEW, MRDW, MUWD) were the most sexually dimorphic for the humerus, radius and ulna in this research. Proximal articular measurements (VHD, MRPW, MUPW) were also highly dimorphic which supports the findings of previous studies [7, 12-15].

There was a high correct classification rate for all three arm bones in both populations, using step-wise analysis of multiple variants (91.2-95.5%). The humerus was the most dimorphic arm bone for Gloucester and the radius for Poulton, achieving the highest correct classification rates in each population. The ulna was the second-best discriminator in both groups, however it showed the greatest variation between populations. Therefore, the ulna may not be the best bone to use in the future for drawing up metric standards.

Due to the small sample size in the Poulton collection some of the results may be affected. As the excavation at this site is ongoing it may be possible to increase the sample size in future research. Further study and blind testing of these methods and derived parameters can also be carried out.

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REFERENCES

[1] Barrier I, L'Abbé E. Sex determination from the radius and ulna in a modern South African sample. Forensic science international 2008; 179(1): 85. e1-e7.

[2] Albanese J, Cardoso HF, Saunders SR. Universal methodology for developing univariate sample-specific sex determination methods: an example using the epicondylar breadth of the humerus. Journal of Archaeological Science 2005; 32(1): 143-52. https://doi.org/10.1016/j.jas.2004.08.003

[3] Steyn M, İşcan MY. Osteometric variation in the humerus: sexual dimorphism in South Africans. Forensic science international. 1999; 106(2): 77-85. https://doi.org/10.1016/S0379-0738(99)00141-3

[4] İşcan MY. Forensic anthropology of sex and body size. Forensic Science International. 2005; 147(2): 107-12. https://doi.org/10.1016/j.forsciint.2004.09.069

[5] Ahmed AA. Estimation of sex from the upper limb measurements of Sudanese adults. Journal of forensic and legal medicine. 2013; 20(8): 1041-7. https://doi.org/10.1016/j.jflm.2013.09.031

[6] Charisi D, Eliopoulos C, Vanna V, Koilias CG, Manolis SK. Sexual dimorphism of the arm bones in a modern Greek population. Journal of forensic sciences 2011; 56(1): 10-8. https://doi.org/10.1111/j.1556-4029.2010.01538.x

[7] Berrizbeitia EL. Sex determination with the head of the radius. Journal of Forensic Science 1989; 34(5): 1206-13. https://doi.org/10.1520/JFS12754J

[8] Mays S, Cox M. Sex Determination in Skeletal Remains. In: Cox M, Mays S, editors. Human osteology: in archaeology and forensic science: Cambridge University Press 2000. p. 117-30.

[9] Spradley MK, Jantz RL. Sex estimation in forensic anthropology: skull versus postcranial elements. Journal of Forensic Sciences. 2011; 56(2): 289-96. https://doi.org/10.1111/j.1556-4029.2010.01635.x

[10] White TD, Folkens PA. The human bone manual: Academic Press; 2005.

[11] Frutos LR. Metric determination of sex from the humerus in a Guatemalan forensic sample. Forensic science international 2005; 147(2): 153-7. https://doi.org/10.1016/j.forsciint.2004.09.077

[12] İşcan MY, Loth SR, King CA, Shihai D, Yoshino M. Sexual dimorphism in the humerus: a comparative analysis of Chinese, Japanese and Thais. Forensic Science International 1998; 98(1): 17-29. https://doi.org/10.1016/S0379-0738(98)00119-4

[13] Kranioti EF, Michalodimitrakis M. Sexual Dimorphism of the Humerus in Contemporary Cretans—A Population-Specific Study and a Review of the Literature. Journal of forensic sciences 2009; 54(5): 996-1000. https://doi.org/10.1111/j.1556-4029.2009.01103.x

[14] Robinson MS, Bidmos MA. The skull and humerus in the determination of sex: reliability of discriminant function equations. Forensic science international 2009; 186(1): 86. e1-e5.

[15] Allen J, Bruce M, MacLaughlin S. Sex determination from the radius in humans. Human Evolution 1987; 2(4): 373-8. https://doi.org/10.1007/BF02436498

[16] Celbis O, Agritmis H. Estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. Forensic Science International. 2006; 158(2): 135-9. https://doi.org/10.1016/j.forsciint.2005.05.016

[17] Mall G, Hubig M, Büttner A, Kuznik J, Penning R, Graw M. Sex determination and estimation of stature from the long bones of the arm. Forensic science international. 2001; 117(1): 23-30. https://doi.org/10.1016/S0379-0738(00)00445-X

[18] Cootes KVE, M.M. E. The Excavation of Ring-Ditched Two and Three at Poulton, Cheshire, 2010-2013: An Interim Report. 2014.

[19] Emery MM. Poulton-Pulford – 7500BC to 1650AD In: Group

PaPLH, editor. Pulford and Poulton in Cheshire Through the Ages. Bury St Edmunds: Arima Publishing; 2010. p. pp. 5-30.

[20] Atkin M, Garrod A. Archaeology in Gloucester 1989. Transactions of the Bristol and Gloucestershire Archaeological Society. 1990; 108: 185-92.

[21] Phenice TW. A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology. 1969; 30(2): 297-301. https://doi.org/10.1002/ajpa.1330300214

[22] Buikstra J, Ubelaker D. Standards for data collection from human remains. Arkansas Archaeological Survey, Arkansas. 1994.

[23] Moore-Jansen P, Ousley S, Jantz R. Data collection procedures for forensic skeletal material. Report of Investigations. 1994; (48).

[24] Martin R, KS. Lehrbuch der anthropologie. Stuttgart, Germany: Gustav Fischer Verlag; 1959.

[25] Ricklan D, Tobias P. Unusually low sexual dimorphism of endocranial capacity in a Zulu cranial series. American journal of physical anthropology. 1986; 71(3): 285-93. https://doi.org/10.1002/ajpa.1330710304

[26] Ruff C. Sexual dimorphism in human lower limb bone structure: relationship to subsistence strategy and sexual division of labor. Journal of Human Evolution. 1987; 16(5): 391-416. https://doi.org/10.1016/0047-2484(87)90069-8

[27] Larsen CS. Bioarchaeology: the lives and lifestyles of past people. Journal of Archaeological Research. 2002; 10(2): 119-66. https://doi.org/10.1023/A:1015267705803

[28] Hoskins WG. Local history in England: Routledge; 1972.

[29] Holt R. Gloucester in the Century after the Black Death. Transactions of the Bristol and Gloucestershire Archaeological Society. 1985; 103: 149-61.

[30] Bass W. Human osteology: A Laboratory and Field manual. 5th ed: Missouri Archaeological Society; 2005.

[31] Lee JH, Kim YS, Lee U, Park DK, Jeong Y-G, Lee NS, *et al*. Sex determination using upper limb bones in Korean populations. Anatomy & cell biology. 2014; 47(3): 196-201. https://doi.org/10.5115/acb.2014.47.3.196

[32] Stewart TD. Essentials of Forensic Anthropology: Especially as Developed in the United States. Springfield, IL, USA: Charles C. Thomas; 1979.

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