Sexual Dimorphism in Humerus: A Study on Egyptians

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Abstract:
The present study aims to detect the possibility of sex discrimination from humeral measurements in Egyptians. One hundred normal right humeri were taken from one hundred cadavers (54 males and 46 females) above 20 years of age and belong to the Egyptian population. Six measurements of maximum length, vertical head diameter, midshaft circumference, minimum midshaft diameter, maximum midshaft diameter and epicondylar breadth were taken for each humerus. The measurements were statistically analyzed. The results revealed that the measurements of males were significantly higher than those of females ($P < 0.001$). Maximum length was the most discriminating variable in sex determination with 90% rate of accuracy, followed by midshaft circumference (86%) then minimum midshaft diameter (82%). Combination of two variables revealed that minimum midshaft diameter with epicondylar breadth gave the highest rate of accuracy for correct sex prediction with accuracy rate of 88%. The results of the study can help in the prediction of sex from the humerus in Egyptians when other human remains, suitable for sex determination, are not available.

Introduction:
The facility for personal identification, at present, is making rapid progress because of development of the polymerase chain reaction (PCR) and stereolithography.[1,2]
Determination of sex is a very important component of any human skeletal analysis. Sex estimation in complete human skeletons is usually easy by observation of morphological traits.[3]
Sex discriminatory functions obtained for each bone are very useful in mass disasters and criminal cases of multiple human burials, where charred bodies, scattered, mixed or incomplete remains are recovered. Since osteometric methods for the determination of sex from the skeleton are population specific, researches from around the world have conducted studies to establish group-specific standards of assessment.[4]
Many bones have been previously used for the identification of sex, and such studies emphasize that sexual dimorphism starts to appear after puberty.[5] The humerus has rarely been tapped as a site for sex determination, though it has often demonstrated even greater accuracy than other long bones such as the femur.[6,7]
In Egypt, different bones, including the patella, have been used for sex determination with great success depending on osteometric methods.[7] On the other hand, little is known about sexual dimorphism in humerus among Egyptians. Therefore, the purpose of this research is to establish metric standards for the determination of sex from the humerus in Egyptians.

Material and Methods:
The present work was carried out on 100 right humeri (54 males and 46 females) belonging to the Egyptian population. They were collected from Anatomy & Embryology Departments in Tanta, Alexandria and Menoufia Faculties of Medicine over 3 years. The bone samples were dissected and extracted from the adult cadavers.
Samples with any pathological changes, fractures or non-union of epiphysis of head were excluded.
The collected bones were soaked in a saturated solution of sodium chloride for 4-6 weeks, then boiled in water with a pinch of sodium carbonate for 20-25 minutes. All adherent soft tissues were removed and the bones were dried for 2 days.[9]
Six dimensions were taken for each humerus (to the nearest millimeter) using an osteometric board, sliding caliper and steel tape. Measurements included maximum length (VI), vertical head diameter (V2), midshaft circumference (V3), minimum midshaft diameter (V4), maximum midshaft diameter (V5) and epicondylar breadth (V6) as shown in fig. (1).

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The student's T. test was used to determine the mean, standard deviation (SD), standard error (SE) and the variance for each variable in both sexes. The T and P values were estimated, and the level of significance was 0.05. Data were also statistically analyzed by using the main from SPSS program, version 6 (1988).[10]

The distance between sex means (d/s) was also determined from the ratio of the mean difference and the mean standard deviation, to demonstrate the overlap between male and female samples.[11] The following formula was used:

$$d / s = \left(Xm - Xf\right)\sqrt{\left(nM\ s^2 M + nF\ s^2 F\right)/\left(nM + nF\right)}$$

(Xm-Xf= means, nM, nF= examined samples; s^2M, s^2F variance).

Cut off level, the value which maximize the sum of sensitivity and specificity, was determined for each variable by using the Receiver Operating Characteristic (ROC) curve.[12] Various combinations to the measurements from VI to V6 were also analyzed by the ROC curves. Then, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy for each variable, separately and in combination, were detected.

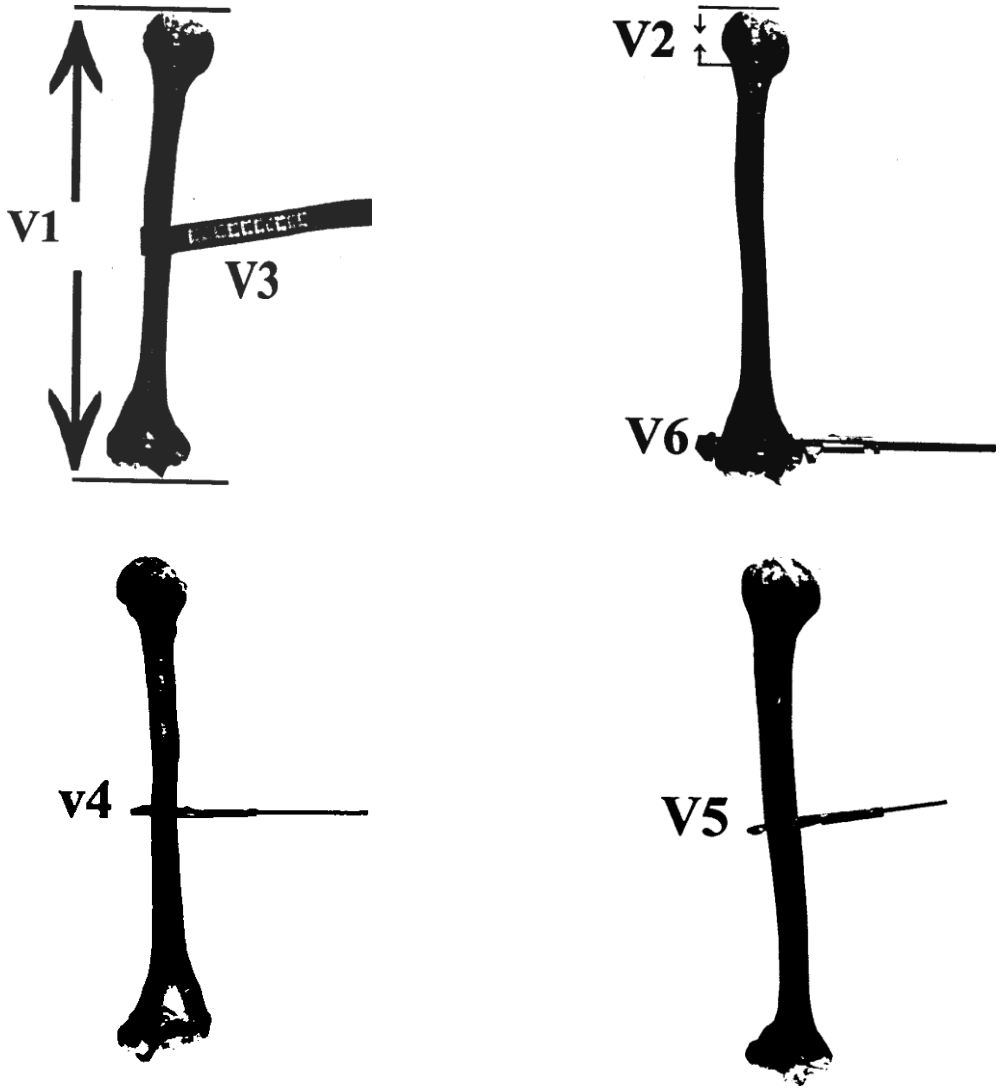


Fig. (1): The six measurements of the humerus.

Results:

The results of descriptive statistical analysis are represented in table (1) revealing the mean, standard deviation, standard error and variance of each variable. The t values for comparison between males and females and their significance are given. Also, the distance between sex means (d/s) are recorded.

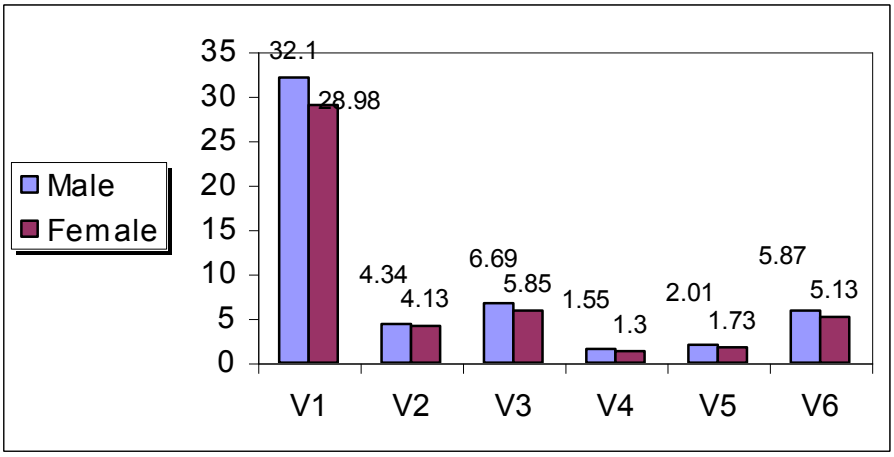
Table (I): Descriptive statistical analysis of the humeral measurements.

Variable	Males (n-54)				Females (n=46)				t	p	d/s
	Mean	±SD	SE	Var.	Mean	±SD	SE	Var.			
V1	32.10	1.58	0.21	2.49	28.98	1.45	0.21	2.09	10.35	<0.001	2.07
V2	4.34	0.48	0.06	0.23	4.13	0.40	0.06	0.16	2.37	<0.05	0.47
V3	6.69	0.48	0.07	0.23	5.85	0.43	0.06	0.19	9.09	<0.001	1.83
V4	1.55	0.15	0.02	0.02	1.30	0.13	0.02	0.02	8.95	<0.001	1.77
V5	2.01	0.18	0.03	0.03	1.73	0.17	0.03	0.03	7.85	<0.001	1.62
V6	5.87	0.43	0.06	0.18	5.13	0.43	0.06	0.18	8.57	<0.001	1.74

Table (I) shows that the mean values of males are significantly higher than those of females in all measurements ($P < 0.001$). Standard deviations denote that males exhibit more variability than females in all variables.

The maximum length (VI) is the measurement with the greatest sex difference (d/s= 2.07), followed by the midshaft circumference (V3) with d/s= 1.83, the minimum midshaft diameter (V4) with d/s= 1.77, epicondylar breadth (V6) with d/s= 1.74 and, vertical head diameter (V2) with d/s= 0.47. The mean values of the six measurements in males and females are illustrated in fig. (2).

Fig. (2): Bar chart for mean values of male and female humeral measurements.



The efficiency of sex determination from each variable was tested using the ROC curves to detect their cut off values. Measurements equal to or higher than the cut off levels would indicate a male individual, and lower values a female individual. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and the accuracy for each variable are shown in table (2).

Table (2): The cut off values, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of humeral measurements.

Variable	Cut off	Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %
V1	30.25	88.9	91.3	92.3	87.5	90.0
V2	4.35	51.9	65.2	63.6	53.6	58.0
V3	6.40	81.5	91.3	91.7	80.8	86.0
V4	1.45	74.1	91.3	90.9	75.0	82.0
V5	1.85	81.5	78.3	81.5	78.3	80.0
V6	5.35	88.9	78.3	82.8	85.7	74.0

Table (2) shows that the accuracy of sex measurements ranges from 58% to 90%. The maximum length (VI) is the first for sexual dimorphism with the highest accuracy rate for sex prediction (90%). Midshaft circumference (V3) comes next with accuracy of 86%, followed by minimum midshaft diameter (V4) with accuracy of 82%, maximum midshaft diameter (V5) with accuracy of 80%, epicondylar breadth (V6) with 74% accuracy and finally vertical head diameter (V2) with 58% accuracy.

Also from table (2) it is clear that maximum length is the most sensitive variable for identification of male individuals (88.9%) and it has also the highest rate of negative predictive values (87.5%). It is followed by epicondylar breadth (sensitivity = 88.9% and NPV = 85.7%). Also maximum length is found to be the most specific variable for determination of female sex (91.3%) and it has also the highest rate of positive predictive value (92.3%).

Variety of combinations between each two different variables were tested in order to make them more useful and are shown in table (3).

Table (3): Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of different combinations of humeral measurements.

Combination	Sensitivity%	Specificity%	PPV %	NPV %	Accuracy%
V1&V2	100.0	56.5	73.0	100.0	80.0
V1&V3	92.6	82.6	86.2	90,5	88.0
VI&V4	92.6	82.6	86.2	90.5	88.0
V1&V5	96.3	73.9	81.3	94.4	86.0
V1&V6	96.3	73.9	81.6	94.4	86.0
V2&V3	88.9	65.2	75.0	83.3	78.0
V2&V4	85.2	60.9	71.9	77,8	74.0
V2&V5	88.9	60.9	72.7	82,4	76.0
V2&V6	100.0	47.8	69.2	100.0	76.0
V3&V4	81.5	87.0	88.0	80.0	84.0
V3&V5	88.9	78,3	82.8	85.7	84.0
V3&V6	100.0	65.2	77,1	100.0	84.0
V4&V5	85.2	73.9	79.3	81.0	80.0
V4&V6	96.3	78.3	83.9	94.7	88,0
V5&V6	100.0	65.2	77.1	100.0	84.0

It is obvious that combination between VI & V2, V2 & V6, V3 & V6 and V5 & V6 gave 100% sensitivity to male sex and 100% negative prediction for females. Meanwhile, combination between V4 & V6, VI & V3 and VI & V4 gave the highest rate of accuracy (88%). This is followed by combination between VI & V5 and VI & V6 (86% each). Combination between V2 & V4 gave the lowermost rate of accuracy (74%).

Discussion:

It is essential to identify sex from different bones of the body other than the skull or pelvis. Many studies have set osteometric standards for sexual dimorphism.[4] In addition, populations have different morphological and metric manifestations in both sexes.[13]

Therefore, it is necessary to have population specific standards from skeletal collections.[14]
This study aimed to determine sex using different measurements of humerus belonging to Egyptian population.
All the cases in this study were above 20 years as this is the age of epiphyseal union of head of humerus and its shaft with no further growth in bone length.[5]

The results revealed that the mean values of male measurements were significantly higher than those of females. For example, the mean value of maximum length (VI) was 32.10±1.58 and 28.95±1.45 in males and females respectively. The sexual difference of humeral measurements was previously discussed by Iscan et al. (1998)[15] who studied sexual dimorphism of the huemrus among Chinese, Japanese and Thai populations. They found that the mean values of VI were 31.37±1.646 and 28.36±1.368 in Chinese, 29.74±1.042 and 27.69±1.71 in
Japanese, 30.06±1.565 and 27.89± 1.367 in Thai. Sex difference in humeral measurements was explained by Black (1998)[16] ,who proposed that differential bone remodeling exists between males and females in addition to the development of more cortical bone during adolescence in males.

The present study revealed that the maximum length (VI) was the measurement with the greatest sex difference (d/s= 2.07). The reliability of sex determination from each variable was tested by ROC curves analysis ,and the maximum length (VI) was found to be the most sensitive one (88.9%) with the highest rate of accuracy (90%). This was followed by midshaft circumference V3 (86% accuracy), then minimum midshaft diameter V4 (82% accuracy). On the contrary, Iscan et al. (1998)[15] found that the most effective single dimension, as determined by direct discriminant analysis, were vertical head diameter (V2) in the Chinese (81%) and epicondylar breadth (V6) in the Japanese and Thais (90% and 93% respectively). Also, Wu (1989)[6] reported greatest dimorphism in proximal and distal bone dimension during his study on northeastern Chinese. He found that humeral head diameter was the most sex discriminator (84%).

France, (1983)[7] ,concluded that proximal and distal measurements are likely to be more accurate because these areas are subjected to greater functional or occupational stress. Also, Gray and Wolfe (1980)[17] stated that stature based sexual dimorphism peaks in societies that are at the extremes of protein consumption, both high and low. In addition, DiBennardo and Taylor (1982)[18] suggested that shape measurements are of major significance for correct diagnosis of sex because the functional demands of weight bearing and musculature affect circumferential measurements more than length.

Combination of the more sex differentiating measurements provided higher rate of accuracy. Combination of minimum midshaft diameter and epicondylar breadth (V4 & V6) gave the highest rate of accuracy (88%) and seemed to be the most reliable one. This is followed by combination of maximum length and midshaft circumference (VI & V3) and combination of maximum length and minimum midshaft diameter (VI & V4) with accuracy rate of 88% for each. On the contrary, Iscan et al. (1998)[15] selected four variables for the Chinese and Japanese and three variables for the Thais. The only dimensions common to all groups were epicondylar breadth and vertical head diameter, while maximum length was only a factor in the Chinese. They found that the highest rate of accuracy was 86.8% in Chinese, 92.4% in Japanese and 97.1% in the Thais.
The degree and distribution of sexual dimorphism varies both within and between different regions. Therefore, most skeletal biologists agree that interpopulation difference necessitates the development of regionally specific standards for the identification of sex.
This study underscores the need for population specific techniques not only for medicolegal investigations, but also for the study of population affinities and factors affecting bone configurations.

It must be noted that patterns of sexual dimorphism differ between populations, and that the results obtained could not have similar accuracy if applied to different ethnic groups. This study confirms the reliability of sex identification from the humerus and the reported results can be considered a valid support for medicolegal investigations involving skeletal remains of Egyptians.

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