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RESEARCH ARTICLE

Radiographic morphometric study of the normal distal humerus in adult Egyptians

Abdelmonem Awad Hegazy
Department of Anatomy and Embryology, Faculty of Medicine, Zagazig University, Egypt.

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Abstract

Determination of sex from the skeleton is of great importance in medicolegal investigations. The available literatures about the dimensions of distal humerus were scanty, especially for Egyptians. This study aimed to establish metric standards for assessment of sex determination from the radiographs as well as to investigate whether bilateral asymmetry exists in the distal humerus. The study included measurements of the distal humerus from 132 (60 males and 72 females) radiographs of normal elbows of 100 adult healthy Egyptian subjects. Thirty-two (16 males and 16 females) of whom were volunteers; and the two humera were radio-graphed. There were statistically significant sex differences in all investigated values, except the trochlear inclination angle. Also, there was symmetry in measurements of the right and left humera in the volunteers. It was concluded that the distal humerus is an effective bone for the estimation of sex even in a fragmentary state.

Introduction

Determination of sex from the skeleton is of great importance in medicolegal investigations (1,2). Invariably anatomists, forensic anthropologists and medico-legal experts are asked to examine fragmented skeletal remains and generate data which would facilitate establishing their identity (3). It is sometimes a difficult task, especially in the absence of the pelvis (4). Therefore most of the long bones have been subjected to statistical and morphological analysis for the purpose of determining sex. Presence of sex differences in the carrying angle at the elbow, renders the bones forming the joint to be possible skeletal elements for sexual dimorphism. The adult female has a wider angle, which results in a greater lateral deviation of the forearm on the arm (5).

Populations differ in size and proportions of human bones; and these differences affect the metric assessment of sex (6). The extent of sexual variations among Egyptians has not been quantified; and no standards for dimensions have been introduced for the distal humerus. Therefore, the purpose of this study was to evaluate normal anatomy in adults to establish metric standards for assessment of sex from the radiographs of the distal humerus in Egypt. This might be of help for increase of the reliability of forensic analysis, as well as for surgical repair of this bone. Also, another aim of the study was to ascertain whether bilateral asymmetry exists in the distal humerus.

Material and Methods

132 radiographs of normal elbows of 100 adults were studied. The study included anteroposterior radiographs taken from two groups of subjects. The first group included 64 radiographs of normal elbows for 32 healthy Egyptian subjects (16 females and 16 males), all of whom were volunteers. All enrolled subjects consented to participate in the study after explanation of the aim and the procedures of the work. Their average age was 30 years (range: 23-50) and 38 years (range: 22-62) for females and males respectively. Individuals who had trauma history, fractures or metabolic disorders were excluded from the study. Images of the two elbows in each subject were taken. The X-rays were obtained in TechnoScan Centers, Zagazig, Egypt. The second group included 68 radiographs of normal elbow of non volunteers (40 females and 28 males). The images were obtained for various reasons such as soft tissue injuries, muscle pain and contralateral comparison following elbow injury. The radiographs were excluded if pathology affecting the anatomy of the elbow was present or if the radiograph was deemed unacceptable. The ages

ranged from 25 to 59 years, mean age was 33 years. Image of one side for each subject was available. They were 32 right and 36 left elbows. They were explored in the radio-diagnostic department of Zagazig university hospitals.
The selected radiographs were evaluated by the author of the study together with an experienced radiologist. The following measurements were investigated in each radiograph (Table 1, Figure 1):

1. Epicondylar breadth (ECB).
2. Trochlear breadth (TB).
3. Trochlear constriction (TC).
4. Medial epicondylar breadth (MEB).
5. Angle of trochlear inclination (TIA).

Radiographs were randomly ordered to minimize observer recall bias. Then, all images were reexamined two weeks after the first examination. Additionally, two indices using the ratios of TB and MEB to the ECB were calculated. The following formulae were used for these indices:
- Index 1: TB/ECB×100
- Index 2: MEB/ ECB×100

Statistical analysis including mean, standard deviation (SD) and *t*-test was done to assess any gender differences existed. In order to ascertain whether bilateral asymmetry exits, the available 32 pairs of radiographs of the volunteers were subjected to a paired *t*-test (7). A *P*-value <0.05 was considered to be statistically significant.

Table (1) Definitions of anatomic parameters of the body of the first sacral vertebra (S1)

Parameter	Abbreviation	Definition
Epicondylar breadth	ECB	The maximum transverse distance between tips of the two epicondyles.
Trochlear breadth	TB	The maximum transverse distance between lateral and medial ends of trochlea.
Trochlear constriction	TC	The distance between the lowermost point on the upper border of trochlea to the uppermost point on its lower border.
Medial epicondyle breadth	MEB	The maximum transverse distance between tip of the medial epicondyle to the medial end of trochlea.
Trochlear inclination angle	TIA	The angle between an imaginary transverse line and a line passing along the lower border of trochlea, passing from the uppermost point on its lower border.

(A) (B)

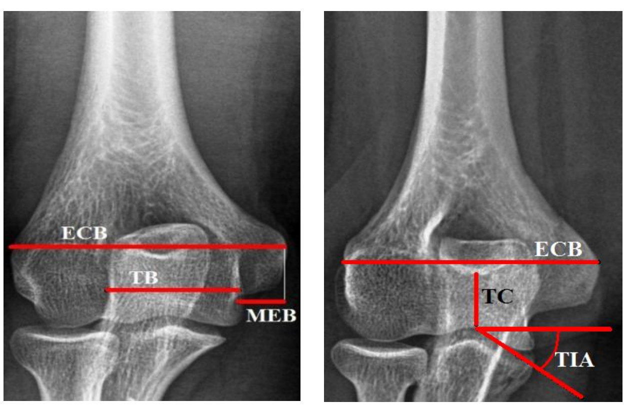

Figure (1) Anteroposterior views of right elbows. A) A male radiograph showing epicondylar breadth (ECB), trochlear breadth (TB) and medial epicondylar breadth (MEB), extending from the edge of trochlea to the tip of medial epicondyle (marked by the vertical white line). B) A female radiograph showing ECB, trochlear constriction (TC) and trochlear inclination angle (TIA)

Results

Replication of measurements was satisfactory; repeated measurements were very similar. Morphologically, the distal humerus was seen to have larger trochlea and smaller medial epicondyle in males than in females (Figure 1). The investigated data are summarized in table 2. Statistical comparison of measured values in males and females in this study showed extremely statistically significant differences for the investigated metric data. The male values were larger than that of females in all investigated measurements, except the MEB. Meanwhile, the differences in TIA were considered to be not statistically significant (*P* =0.8303); the angle was about 36º in both sexes (Figure 2). In regard to the investigated indices, they showed extremely statistically significant differences between males and females, but index 1 showed higher value in males than in females whilst the reverse occurred with index 2. Comparing the measurements in the distal humerus of the right and left elbows in the available sample of the first group (No. 32 subjects), no significant side differences were identified (Table 3).

Table (2) Statistical analysis of the investigated measurements and indices in males and females

	Males (No. 60)			Females (No. 72)			MGD	SE	95% CI	*P*-value
	Mean	±SD	Range	Mean	±SD	Range				
ECB (mm)	58.80	±9.20	50-83	48.88	±5.48	40-62	9.92	1.294	7.36 to 12.49	<0.0001
TB (mm)	28.28	±5.19	22-40	19.63	±2.77	14-25	8.66	0.708	7.26 to 10.06	<0.0001
TC (mm)	14.17	±2.38	11-20	11.39	±0.99	9-14	2.78	0.308	2.17 to 3.39	<0.0001
MEB (mm)	10.20	±2.41	6-13	11.51	±2.07	8-16	-1.31	0.390	-2.08 to -0.54	=0.0010
TIA (º)	35.62	±7.31	15-43	35.85	±4.96	24-49	-0.23	1.073	-2.35 to 1.89	=0.8303
Index 1 (TB/ECD×100)	48.23	±4.62	38-54	40.44	±5.12	31-53	7.79	0.857	6.09 to 9.48	<0.0001
Index 2 (MEB/ECD×100)	17.08	±2.91	11-22	23.51	±2.61	20-29	-6.43	0.481	-7.38 to -5.48	<0.0001

SD=Standard deviation, MGD=Difference between mean of two groups, CI=Confidence interval, SE=Standard error of difference

Table (3) Statistical analysis of the investigated measurements of the right and left humera of the first group "volunteers"

	Right humerus (No. 32)		Left humerus (No. 32)		MGD	SE	95% CI	*P*-value
	Mean	±SD	Mean	±SD				
ECB (mm)	55.59	±11.41	55.47	±11.21	0.13	2.827	-5.53 to 5.78	=0.9649
TB (mm)	25.03	±6.92	25.38	±6.37	-0.34	1.663	-3.67 to 2.98	=0.8369
TC (mm)	12.91	±2.70	13.06	±2.41	-0.15	0.635	-1.42 to 1.11	=0.8087
MEB (mm)	11.09	±2.32	11.03	±2.30	0.06	0.573	-1.08 to 1.21	=0.9121
TIA (º)	38.47	±3.83	38.75	±3.49	-0.28	0.916	-2.11 to 1.55	=0.7598

SD=Standard deviation, MGD=Difference between mean of two groups, CI=Confidence interval, SE=Standard error of difference

Table (4): The means of ECB in previous studies and the current one.

Author/s	Year	Nationality	Type of materials	No. of specimens		Mean (mm)	
				Males	Females	Males	Females
İşcan et al. (6)	1998	China	Dry bones	41	33	60.4	52.3
		Japan	Dry bones	44	35	59.8	52.1
		Thailand	Dry bones	70	34	60.3	52.1
Steyn and İşcan (8)	1999	South Africa- Black	Dry bones	40	43	61.4	53.3
		South Africa- White	Dry bones	55	48	64.3	55.9
Mall et al. (1)	2001	Germany	Dry bones	64	79	66	58
Frutos (11)	2005	Guatemala	Dry bones	68	50	58.3	49.3
Kshirsagar et al. (3)	2009	India- Marathwada	Dry bones	142	70	58.5	53
Robison and Bidmos (2)	2009	South Africa- Dart	Dry bones	48	48	62.68	54.43
		South Africa- Pretoria	Dry bones	48	48	64.18	55.86
		South Africa- Pretoria	Dry bones	36	36	62.61	55.02
Charisi et al. (19)	2011	Greece	Dry bones	111	93	61.45	53.53
Patil et al. (20)	2011	India- South Indians	Dry bones	54	46	58.7	51.3
Bašić et al. (21)	2013	Croatia	Dry bones	80	35	63.53	56.74
Current study	2013	Egypt	Radiographs	60	72	58.80	48.88

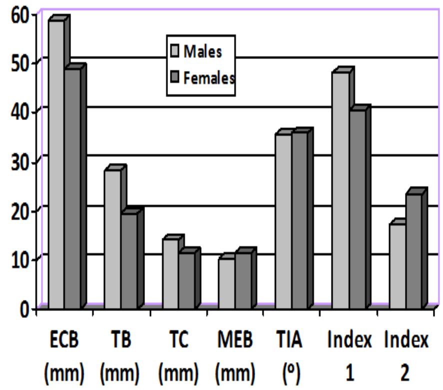

Figure (2) Histogram of the means of the investigated measurements and indices in males and females

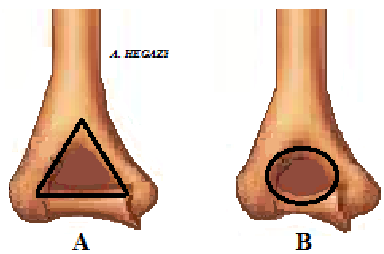

Figure (3) Diagrams showing the posterior distal humerus; A) The triangular olecranon fossa in males, marked by dark triangle. B) The oval olecranon fossa in females, marked by dark circle.

Discussion

The recovery of the identity of unknown body needs a simple and easy way for biological profiling. As the human remains are usually not complete, it is essential to have sex determination techniques applicable to different parts of the body (8). In this study, the radiographs of the distal end of humerus were examined that represent a simple method for investigations for both skeletal and fleshy remains. The use of radiographs instead of the actual bones allows investigation of semi-decomposed bodies without needs for special preparation, such as maceration (9). Also, X-ray films enable the investigator to take the measurements more easily, especially in case of irregular bones such as the lower end of humerus.

The current results revealed that the investigated dimensions of male humerus were significantly higher than those of females, except for MEB. This is in general agreement with other studies (6,10). Devi, et al. (10) added that the vertical head diameter was the most discriminating variable in sex determination, followed by the epicondylar breadth (ECB). İşcan et al. (6) showed a presence of significant metric differences in humerus between three different populations "Chinese, Japanese and Thais" that might affect sex determination from the skeleton but the only dimension exhibiting no significant population differences was ECB with a mean of about 60 mm in males and 52 mm in females. In the current Egyptian sample of population, ECB showed statistically significant differences between males "mean: 58.80" and females "mean: 48.88" (*P*-value <0.0001). The differences in the means might be due to differences of populations, and/or the materials used; skeletal samples in their study and radiographs in the current study. However, similar results obtained from dry bones were reported in another study; ECB mean in males = 58.3 mm, and in females=49.3 mm (11). Table 4 summarizes the means of ECB results in some previous studies and the current work.

Rogers (12) suggested a visual method for sexual determination of the posterior distal humerus, depending on the hypothesis that its morphology reflects the formation of the carrying angle at the elbow. Three visual (non-metric) determinations of sex were used to assess the skeletal sex (12-14). They were olecranon fossa shape, angle of medial epicondyle and trochlear extension. The authors stated that the olecranon fossa appears to be roughly triangular in males; whilst in females it is oval in shape. The male medial epicondyle extends parallel to the table when placed posterior side up; but in females, it clearly curves upwards from the parallel plane of the table. Finally, the medial edge of trochlea extends more than the lateral edge in males; but in females the lateral and medial edges are almost similar in extension or more symmetrical. The current finding may add to these visual features that there is a larger TB and smaller MEB in males than in females. Also, there was a statistically significant sex difference in length of TC (mean in males:14.17, mean in females: 11.39 and *P*-value: <0.0001). This finding might reflect the differences in the olecranon fossa shape noticed in previous studies (12,13); that the decrease of length of TC in females renders the fossa to take the more or less diamond or oval shape (figure 3).

Traditionally the long bones of lower limbs are used to drive standards for sex determination (15-17). However, many studies showed that the humerus is as dimorphic as the femur and tibia (1-3,6,8,12,18-21). With the exception for ECB, these studies investigated variables in humerus other than that investigated in the current study. In this study, the distal end of humerus sharing in the carrying angle was investigated. It was found that both TB and MEB show statistically significant sex differences, with *P*-values of <0.0001 and =0.0010 respectively. The noticed larger values of TB in males might reflect their larger musculoskeletal system than in females (18). To alleviate the possible magnification errors of radiography, some data were converted into ratios (or percentages). This will standardize the measurements, irrespective of the magnification power. Index 1 that is the percentage of TB to ECB showed extremely statistically significant sex differences (mean in males: 48.23 and in females 40.44). Similarly, index 2 that is MEB to ECB showed significant sex differences (*P*- value: <0.0001), but with larger values in females than in males. On the other hand, the only measure that didn't show sex differences in the investigated parameters was the TAI (*P*- value =0.8303). This might exclude the possibility of trochlear inclination as a cause for sex differences found in the 'carrying angle'. This angle is caused partly by projection of the medial trochlear edge c.6 mm beyond its lateral edge and partly by the obliquity of the superior articular surface of the coronoid, which is not orthogonal to the shaft of the ulna (22).

In regard to the comparison between the right and left humera, there were no significant statistical differences in all investigated values. This might make the one of them to be a standard reference for the other, in case of its repair in theatre or in investigation at autopsy. This result is consistent with a previous study on Greek population (19). In contrast to these findings, Kshirsagar et al. (3) reported that ECB in left humerus (mean: 60.2 mm) was larger than that of right side (mean: 57.7 mm) in males, but the reverse occurred in females (mean in females: 52.2 mm; mean in males: 54.1 mm).

Conclusions

The results of this study suggest that the distal humerus could be used quite reliably for assessment of sex in forensic contexts in Egypt. It can give high classification accuracy, especially when all measures were taken and applied jointly.

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References

1. Mall G, Hubig M, Buttner A, Kuznik J, Penning R, Graw M. Sex determination and estimation of stature from long bones of the arm. Forensic Sci. Int. 2001;117:23-30.

2. Robison MS, Bidmos MA. The skull and humerus in the determination of sex: Reliability of discriminant function equations. Forensic Science International, 2009;186:86.e1-86.e5.

3. Kshirsagar SV, Chavan SK, Makhani CS, Kamkhedkar SG. Sexual dimorphism of humerus: A study in Marathwada region. Indian Journal of Forensic Medicine and Pathology, 2009;2(4):145-151.

4. Sembian U, Muhil. M, Srimathi.T, Muthukumar.T, Nalina Kumari.SD**.** A study of sexual dimorphism in femora of rural population of South Tamilnadu, India. Journal of clinical and diagnostic research. 2012,6(2):163-165.

5. Snell RS. Clinical Anatomy by Regions, 9th ed., pp 32-33,408-410. 2012, Lippincott Williams & Wilkins.

6. 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.

7. Faragher B. Essential Statistics for Medical Examinations. 2nd Ed., PasTest Ltd., Knutsford Cheshire, 2005, Pp: 32-81.

8. Steyn M, İşcan MY. Osteometric variation in the humerus: sexual dimorphism in South Africans. Forensic science international, 1999;106:77-85.

9. Kranioti EF, Bastir M, Meseguer AS, Rosas A. A geometric-morphometric study of the cretan humerus for sex identification. Forensic science international, 2009;189:111.e1-111.e8.

10. Devi S, Raichandani L, Kataria SK, Raichandani S, Dhuria S. Osteometric study of sex determination by the epiphyseal ends of humerus in Western Rajasthan sample. International journal of biomedical sciences, 2013;4(6):279

11. Frutos LR. Metric determination of sex from the humerus in a Guatemalan forensic sample. Forensic science international, 2005;147:153-157.

12. Rogers TL. A visual method of determining the sex of skeletal remains using the distal humerus. J Forensic Sci 1999;44(1):57-60.

13. Vance VL, Steyn M, L'Abbe EN. Nonmetric sex determination from the distal and posterior humerus in black and white South Africans. J Forensic Sci 2011;56(3):710-714.

14. Vance VL, Steyn M. Geometric morphometric assessment of sexually dimorphic characteristics of the distal humerus. HOMO - Journal of Comparative Human Biology,2013;64(5):329-40.

15. Kieser JA, Moggi-Cecchi J, Groeneveld HT. Sex allocation of skeletal material by analysis of the proximal tibia. Forensic Sci. Int. 1992;56:29-36.

16. İşcan MY, Yoshino M, Kato S. Sex determination from the tibia: standards for contemporary Japan. J. Forensic Sci. 1994;39:785-792.

17. İşcan MY, Ding S. Sexual dimorphism in the Chinese femur. Forensic Sci. Int. 1995;74:79-87.

18. Smith F, Smith P. Musculoskeletal differences between males and females. Sports Medicine & Arthroscopy Review, 2002;10(1):98-100.

19. Charisi D, Eliopoulos C, Vanna V, Koilias CG, Manolis SK. Sexual dimorphism of the arm bones in a Greek population. Journal of Forensic Sciences, 2011;56(1):10-18.

20. Patil G, Kolagi S, Ramadurg U. Sexual dimorphism in the humerus: A study on South Indians. Journal of clinical and diagnostic research, 2011;5(3):538-541.

21. Bašić Ž, Anterić I, Vilović K, Petaros A, Bosnar A, Madžar T, Polašek O, Anđelinović Š. Sex determination in skeletal remains from the medieval Eastern Adriatic coast – discriminant function analysis of humeri. Croat Med J,2013;54(3):272-278.

22. Standring S, Ellis H, Healy JC, Johnson D, Williams A. Gray's Anatomy: The anatomical basis for clinical practice, 39th ed., Elsevier Churchill Livingstone, 2005, pp. 853-863.