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Original Research Article

Sex Determination Using Measurements of Upper Limb in Cadavers at a Tertiary Care Teaching Centre

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ABSTRACT

Background: Forensic research involves using protocols that cannot be applied in all the cases such as in cases where there is decomposition of the human remain remains due to heat of chemical burns. The branch of science dealing with the measurements of the proportions, size and weight of human skeleton and body is known as anthropometry. Pelvis and skull were considered as the most variable bones of the skeleton amongst males and females. Various studies have been conducted on the sex determination using radiological and osteological examination of bones of upper limb. Humerus has been studied widely for this purpose and various standard measurements have been set amongst different ethnic groups. The aim of present study is to determine sexual dimorphism of upper limb measurements and to establish accurate metric standards for determination of sex, based on measurements of bones of upper limb.

Materials and Methods: The present study was conducted in Department of Forensic Medicine, Teerthanker Mahaveer Medical College & Research Centre, Moradabad, Uttar Pradesh (India) during a period of 2 years. A total of 91 of adult human cadavers aged between 38 to 91 years (mean +/- S.D. 70.8 +/- 12.2 years) were involved in this study. All the measurements were taken using calipers or measuring tapes. The variables that were studied were maximum length of clavicle which was taken as the distance between acromial end and sterna end, circumference at middle of shaft of clavicle, maximum length of humerus which was taken as the distance between trochlea and the proximal extremity of humeral head, maximum diameter of humeral head, epicondylar breadth of humerus , condylar breadth of humerus, transverse diameter of humeral head, vertical diameter of humeral head, maximum length of radius which was taken as distance between styloid process and the proximal extremity of radial head, maximum length of ulna was taken as the distance between styloid process and the proximal extremity of olecranon and least circumference of ulnar shaft was noted. SPSS software was used for statistical analysis.

Results: All the values were higher for males than females. The maximum length of clavicle amongst males was 149.4 +/- 7.4 mm and that amongst females were 137.2 +/- 9.9 mm. Maximum length of humerus amongst males was 301.8 +/- 15.4 mm and that amongst females was 279.9 +/- 16.2 mm. Maximum length of ulna amongst males was 248.4 +/- 11.9 mm and that amongst females was 226.3 +/- 15.2 mm. The gender is to be considered female if the discriminant score is less than the demarcation point and male if the score is more than the demarcation point. If the maximum length of clavicle is less than 143.2 mm than the specimen is to be considered that of a female, if more than this value than male. The diameter of humerus head was a better predictor of sex compared to length of humerus. The worse predictor of sex was circumference of the middle of the shaft of clavicle (60.4%).

Conclusion: From the above study we can conclude that upper limb measurements are a reliable tool in the sex estimation of the specimen.

Keywords: Antrhroprometric, Acromial, Clavicle, Discriminant, Humerus.

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INTRODUCTION

Forensic research involves following specific protocols which have been developed many years ago by the forefathers of this field. But these protocols cannot be applied in all the cases such as in cases where there is decomposition of the human remain remains due to heat of chemical burns. Therefore eye, fingerprints etc cannot be considered as a good interpretation of the patient. Sex estimation is the first factor that is considered for the identification of the human remains. Sex of the individual can be identified by

measurements of human skeleton. The branch of science dealing with the measurements of the proportions, size and weight of human skeleton and body is known as anthropometry.[1] During the initial studies on the skeletal basis of sex identification, pelvis and skull were considered as the most variable bones of the skeleton amongst males and females.[2] But in case the human body is compromised like during wars, mass disasters there is likelihood that pelvis and skull bones are damaged. All this necessitated various studies for the sex determination using other bones.[3,4] Various studies have been conducted on the sex determination using radiological and osteological examination of bones of upper limb. Humerus has been studied widely for this purpose and various standard measurements have been set amongst different ethnic groups.[5-8] The length and vertical head diameter of humerus are good and reliable predictors of gender of the patient.[9,10] Various other bones have also been studied for anthropometric analysis like bones of hand by Ishank[11] and Rastogi[12]. Sex can also be determined by metric analysis of bone but the specificity is less. The aim of present study is to determine sexual dimorphism of upper limb measurements and to establish accurate metric standards for determination of sex, based on measurements of bones of upper limb.

MATERIALS AND METHODS

The present study was conducted in Department of Forensic Medicine, Teerthanker Mahaveer Medical College & Research Centre, Moradabad, Uttar Pradesh (India) during a period of 2 years. A total of 91 adult human cadavers aged between 38 to 91 years (mean +/- S.D. 70.8 +/- 12.2 years) were involved in this study. The upper limb lengths of all the cadavers were noted by removing the right upper limb of all the fresh cadavers. Using a surgical knife, the articulate cartilage was removed from all. Any bones with pathology, fracture or healed fractures were excluded from the study.

All the measurements were taken using callipers or measuring tapes. The variables that were studied were maximum length of clavicle which was taken as the distance between acromial end and sterna end, circumference at middle of shaft of clavicle, maximum length of humerus which was taken as the distance between trochlea and the proximal extremity of humeral head, maximum diameter of humeral head, epicondylar breadth of humerus, condylar breadth of humerus, transverse diameter of humeral head, vertical diameter of humeral head, maximum length of radius which was taken as distance between styloid process and the proximal extremity of radial head, maximum length of ulna was taken as the distance between styloid process and the proximal extremity of olecranon and least circumference of ulnar shaft was noted. All the data was arranged in a tabular form and analysed statistically using SPSS software. The result of the study was expressed as mean +/- standard deviation and t test was applied as a test of significance. A p value of less than 0.05 was taken as significant.

Table 1: Mean length foe each variable amongst the Indian population

VARIABLE (mm)	MALES (mean+/- SD)	FEMALES (mean+/- SD)
Maximum length of clavicle (MLC)	149.4±7.4	137.2±9.9
Circumference in the middle of shaft of clavicle (CMC)	38.2±0.6	35.0±1.1
Maximum length of humerus (MLH)	301.8 ± 15.4	279.9±16.2
Maximum diameter of humerus head (MDH)	46.5±3.2	40.8±2.3
Vertical diameter of humeral head (VDH)	47.2±1.7	39.9±2.5
Transverse diameter of humeral head (TDH)	43.2±3.1	39.1±3.7
Epicondylar breadth of humerus (EB)	58.4±3.6	53.3±3.3
Condylar breadth of humerus (CBH)	43.4±1.9	37.8±2.8
Maximum length of ulna (MLU)	248.4±11.9	226.3±15.2
Least cricumference of ulna shaft (LCU)	37.1±0.6	33.6±0.5
Maximum length of radius (MLR)	229.8±15.6	206.4±11.7

Table 2: discriminant function coefficient of various dimensions of the sample

VARIABLE	DEMARKING POINT (mm)	WILK'S LAMBDA	F RATIO	P VALUE
Maximum length of clavicle (MLC)	F< 143.2<M	0.724	45.876	0.001
Circumference in the middle of shaft of clavicle (CMC)	F< 38.1<M	1.010	0.002	0.871
Maximum length of humerus (MLH)	F< 291.1<M	0.661	71.342	0.003
Maximum diameter of humerus head (MDH)	F< 44.2<M	0.570	101.050	0.001
Vertical diameter of humeral head (VDH)	F< 41.9<M	0.543	103.263	0.002
Transverse diameter of humeral head (TDH)	F< 39.8<M	0.661	68.089	0.000
Epicondylar breadth of humerus (EB)	F< 58.0<M	0.762	45.453	0.001
Condylar breadth of humerus (CBH)	F< 41.3<M	0.641	78.261	0.002
Maximum length of ulna (MLU)	F< 241.1<M	0.637	77.548	0.000
Least cricumference of ulna shaft (LCU)	F< 34.2<M	0.852	23.240	0.000
Maximum length of radius (MLR)	F< 220.7<M	0.611	81.879	0.003

RESULTS

Table 1 illustrates the mean length foe each variable amongst the Indian population. All the values were higher for males than females. The maximum length of clavicle amongst males was 149.4 +/- 7.4 mm and that amongst females were 137.2 +/- 9.9 mm. Maximum length of humerus amongst males was 301.8 +/- 15.4 mm and that amongst females was 279.9 +/- 16.2 mm. Maximum length of ulna amongst males was 248.4 +/- 11.9 mm and that amongst females was 226.3 +/- 15.2 mm. Maximum length of radius amongst males was 229.8 +/- 15.6 mm and that amongst females was 206.4 +/- 11.7 mm. The difference amongst all the values was statistically significant between males and females i.e. p value was less than 0.05. Table 2 shows the discriminant function coefficient of various dimensions of the sample. All the functions are illustrated based on a single variable. The gender is to be considered female if the discriminant score is less than the demarcation point and male if the score is more than the demarcation point. If the maximum length of clavicle is less than 143.2 mm than the specimen is to be considered that of a female, if more than this value than male. If the transverse diameter of humerus is more than 39.8 mm than the specimen is to be considered that of a male otherwise female. Table 3 shows the correctly classified males and females for sex determination based on upper limb size. The diameter of humerus head was a better predictor of sex compared to length of humerus. The worse predictor of sex was circumference of the middle of the shaft of clavicle (60.4%). Transverse diameter of humerus head (81.3%), condylar breath of humerus (81.3%) and maximum length of radius (81.3%) showed nearly same accuracy in estimating the sex.

Table 3: The percentage of correctly classified males and females for sex determination

	CORRECTLY CLASSIFIED PERCENAGE	CORRECTLY CLASSIFIED PERCENAGE	CORRECTLY CLASSIFIED PERCENTAGE
	Male	**Female**	**Average**
Maximum length of clavicle (MLC)	83.5	54.9	76.9
Circumference in the middle of shaft of clavicle (CMC)	58.2	60.4	60.4
Maximum length of humerus (MLH)	83.5	60.3	81.3
Maximum diameter of humerus head (MDH)	82.4	80.2	84.6
Vertical diameter of humeral head (VDH)	86.8	80.2	85.7
Transverse diameter of humeral head (TDH)	82.4	76.9	81.3
Epicondylar breadth of humerus (EB)	75.8	68.1	73.6
Condylar breadth of humerus (CBH)	82.4	80.2	81.3
Maximum length of ulna (MLU)	80.2	79.1	80.2
Least cricumference of ulna shaft (LCU)	69.2	73.6	70.3
Maximum length of radius (MLR)	85.7	71.4	81.3

DISCUSSION

There has been a widespread research in today's era on anthropometric measurements of upper limb particularly hand due to its paucity in literature.[13,14] In most of the times the forensic experts have to conclude about the sex of the patient from single specimen and in these cases upper limb measurements serve as a useful tool in determining sex of the patient. The measurements vary according to many factors like nutrition, environmental and genetic factors.[15,16] In a study conducted by Singh and Singh in Varanasi[7], the mean length of humerus was more in males compared to females. The results of our study are in accordance with their study. The results were also similar to a study conducted by Male et al[17] on German population and Je Hun lee[18] on Korean population. On applying t test in our present study, it clearly demonstrated that all the upper limb measurements were significantly more in males as compared to females. According to our study the demarking point for maximum length of humerus amongst males and females was 291.1 mm. This was lesser when compared to other studies conducted by Kranioti and Michalodimitrakis[19] in which the demarking point was 307.39 mm. According to a study by Iscan and Steyn[20], the demarking point of vertical diameter of humeral head amongst males and females was 46.04mm in South African white population and 40.74 mm in South African Black population. The demarking point in our study came out to be 41.9mm. According to a study by Iscan et al[21], the demarking point of epicondylar breath of humerus amongst Chinese population was 56.80 mm and that amongst Japanese population was 56.40 mm. In our study, the demarking point of the epicondylar breath of humerus was 58.0 mm. According to our study, the percentage accuracy of ulnar length to categorize into male or female was 80.0% and 78.2% respectively. In a study conducted by AA Ahemd et al in 2013[22], the percentage accuracy of ulna to determine sex of the patient was 88.5%, which was higher than our study. In a study conducted by Celbis O et al in 2006 on Turkish corpse, the percentage accuracy of ulnar length to determine sex came out to be 88.8% in males and 95.7% in females. According to our study, humeral length was a better predictor of sex but according to a study conducted by Sakave et al[23] on Japanese population, the reverse was true. The maximum length of humerus could correctly determine the sex of 85.10% of Cretan population, according to a study by AA Ahmed[22]. In our study, 81.3% of the population was correctly identified based on mean length of humerus. Sex estimation of the patient is dependent on the degree of inherent dimorphism in the given population and also on the condition of the specimen provided.[2]

CONCLUSION

From the above study we can conclude that upper limb measurements are a reliable tool in the sex estimation of the specimen. It acts as an asset for medicolegal purposes in cases where DNA analysis cannot be performed because of economic or financial barriers. In cases of mass disasters where only small amount of specimen is available, sex estimation can be performed reliably using upper limb measurements.

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