

**ORIGINAL RESEARCH**

# Gender Determination from Various Measurements of the Humerus- A cadaveric study

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**ABSTRACT**

**Background:** In forensic anthropology, it is very important to determine the sex from the bony remains found at an excavation site or a crime scene. The humerus is a big bone in the upper limb and its condition does not usually deteriorate, which is why the humerus is favored for the determination of sex. This study was conducted to assess different measurements of the humerus for the determination of sex. **Material and methods:** This cross-sectional investigation involved the analysis of 100 humeri, comprising 50 specimens from male cadavers and 50 from female cadavers. The humeri were extracted from adult individuals estimated to be between 25 and 75 years of age, sourced from the anatomy department. Each bone underwent a thorough examination to identify any visible deformities. The research concentrated on six particular measurements: maximum length of the humerus (MLH), maximum diameter of the humeral head (MDH), vertical diameter of the humeral head (VDH), transverse diameter of the humeral head (TDH), condylar breadth (CB), and epicondylar breadth (EB). The maximum length of the humerus was characterized as the distance from the apex of the humeral head to the lowest point on the trochlea. The vertical diameter was assessed as the distance between the highest and lowest points on the articular surface of the humeral head. The transverse diameter was established by measuring the distance between the most anterior and posterior points on the articular surface of the humeral head. Finally, the epicondylar breadth was defined as the distance between the two most laterally extending points on the lateral epicondyles of the humerus. A comparative analysis of the six variables—MLH, MDH, VDH, TDH, EB, and CB—was performed between genders using appropriate statistical tests. **Results:** In this study, the MLH in males and females was  $307.86 \pm 11.19$  mm and  $283.88 \pm 6.78$  mm, respectively. The MDH in males and females was  $43.75 \pm 1.81$  mm and  $40.86 \pm 1.62$  mm, respectively. The VDH in males and females was  $42.54 \pm 1.63$  mm and  $39.88 \pm 1.52$  mm, respectively. The TDH in males and females was  $39.28 \pm 1.82$  mm and  $36.77 \pm 1.49$  mm, respectively. The EB in males and females was  $55.23 \pm 4.60$  mm and  $50.64 \pm 8.27$  mm, respectively. The CB in males and females was  $38.17 \pm 2.22$  mm and  $35.29 \pm 1.08$  mm, respectively. A value that falls below the designated threshold was classified as female, while a value that exceeds this threshold was classified as male. For instance, a maximum humerus length exceeding 289.6 mm is categorized as male, whereas a length below 289.6 mm is categorized as female. The threshold values for MDH, VDH, TDH, EB, and CB are established at 42.6 mm, 41.7 mm, 39.9 mm, 55.4 mm, and 36.5 mm, respectively. **Conclusion:** The findings of this research indicate that the maximum length of the humerus and the vertical diameter of the humeral head are the two critical measurements that provide the greatest accuracy in determining gender from human skeletal remains.

**Keywords:** humerus, males, females

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**INTRODUCTION**

In forensic anthropology, it is very important to determine the sex from the bony remains found at an excavation site or a crime scene. The humerus is a big bone in the upper limb and its condition does not usually deteriorate, which is why the humerus is favored for the determination of sex. The length of various bones in the human body, including the humerus, is a good predictor of gender but the accuracy of the vertical diameter of the head is also

significant in sex determination.<sup>1</sup> Numerous studies have been conducted on the measurements of upper limb bones including the humerus and metric systems devised in Chile<sup>2</sup>, South Africa<sup>3</sup>, Guatemala<sup>4</sup>, the Dart collection<sup>5</sup>, the island of Crete<sup>6,7</sup>, Turkey<sup>8</sup>, Greece<sup>9</sup>, America<sup>10</sup>, and the Eastern Adriatic coast.<sup>11</sup>

Observing morphological characteristics in a full human skeleton allows for straightforward sex estimation.<sup>12</sup> When the entire skeleton is accessible, accurate sex diagnosis should be straightforward; but,

when only a portion of the skeleton is available, assessment becomes increasingly difficult.<sup>13</sup> When skeletal remains are discovered, anthropologists attempt to reconstruct the person's biological profile, which includes estimating sex, age, and height.<sup>14</sup> Because subsequent methods of age and stature determination are largely sex dependent, determining sex is one of the earliest and most basic aspects of assessment.<sup>15</sup> The pelvic girdle, skull, and long bones are the major anatomical regions utilised to determine sex. The pelvis, skull, or other anatomical elements that point to reasonably precise sex judgments are frequently missing. As a result, parameters for other bones, particularly long bones that are frequently discovered in the collection must be developed.<sup>16</sup> This study was conducted to assess different measurements of the humerus for the determination of sex.

## MATERIAL AND METHODS

This cross-sectional investigation involved the analysis of 100 humeri, comprising 50 specimens from male cadavers and 50 from female cadavers. Each bone underwent a thorough examination to identify any visible deformities. The research concentrated on six particular measurements: maximum length of the humerus (MLH), maximum diameter of the humeral head (MDH), vertical diameter of the humeral head (VDH), transverse diameter of the humeral head (TDH), condylar breadth (CB), and epicondylar breadth (EB). The maximum length of the humerus was characterized as the distance from the apex of the humeral head to the lowest point on the trochlea. The vertical diameter was assessed as the distance between the highest and lowest points on the articular surface of the humeral head. The transverse diameter was established by measuring the distance between the most anterior and posterior points on the articular surface of the humeral head. Finally, the epicondylar breadth was defined as the distance between the two most laterally extending points on the lateral epicondyles of the humerus. A comparative analysis of the six variables—MLH, MDH, VDH, TDH, EB, and CB—was performed between genders using appropriate statistical tests.

## RESULTS

**Table 1: Variable comparison between two genders**

Variable	Male	Female
<b>MLH (mm)</b>	307.86 ± 11.19	283.88 ± 6.78
<b>MDH (mm)</b>	43.75 ± 1.81	40.86 ± 1.62
<b>VDH (mm)</b>	42.54 ± 1.63	39.88 ± 1.52
<b>TDH (mm)</b>	39.28 ± 1.82	36.77 ± 1.49
<b>EB (mm)</b>	55.23 ± 4.60	50.64 ± 8.27
<b>CB (mm)</b>	38.17 ± 2.22	35.29 ± 1.08

The MLH in males and females was 307.86 ± 11.19 mm and 283.88 ± 6.78 mm, respectively. The MDH in males and females was 43.75 ± 1.81 mm and 40.86 ± 1.62 mm, respectively. The VDH in males and females was 42.54 ± 1.63 mm and 39.88 ± 1.52 mm, respectively. The TDH in males and females was 39.28

± 1.82 mm and 36.77 ± 1.49 mm, respectively. The EB in males and females was 55.23 ± 4.60 mm and 50.64 ± 8.27 mm, respectively. The CB in males and females was 38.17 ± 2.22 mm and 35.29 ± 1.08 mm, respectively.

**Table 2: Demarking point for males and females**

Variable	Demarking point	Wilks' lambda
MLH (mm)	F<289.6	0.512
MDH (mm)	F<42.6	0.531
VDH (mm)	F<41.7	0.487
TDH (mm)	F<39.9	0.603
EB (mm)	F<55.4	0.617
CB (mm)	F<36.5	0.744

A value that falls below the designated threshold was classified as female, while a value that exceeds this threshold was classified as male. For instance, a maximum humerus length exceeding 289.6 mm is categorized as male, whereas a length below 289.6 mm is categorized as female. The threshold values for MDH, VDH, TDH, EB, and CB are established at 42.6 mm, 41.7 mm, 39.9 mm, 55.4 mm, and 36.5 mm, respectively.

## DISCUSSION

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.<sup>17</sup>

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.<sup>18</sup> But in case the human body is compromised like during wars, mass disasters there is likelihood that pelvis and skull bones are damaged. All these necessitated various studies for the sex determination using other bones.<sup>19,20</sup> This study was conducted to assess different measurements of the humerus for the determination of sex.

The MLH in males and females was 307.86 ± 11.19 mm and 283.88 ± 6.78 mm, respectively. The MDH in males and females was 43.75 ± 1.81 mm and 40.86 ± 1.62 mm, respectively. The VDH in males and females was 42.54 ± 1.63 mm and 39.88 ± 1.52 mm, respectively. The TDH in males and females was 39.28 ± 1.82 mm and 36.77 ± 1.49 mm, respectively. The EB in males and females was 55.23 ± 4.60 mm and 50.64 ± 8.27 mm, respectively. The CB in males and females was 38.17 ± 2.22 mm and 35.29 ± 1.08 mm, respectively. Chaudhary RS et al (2017)<sup>21</sup>

conducted a study 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. 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  $\pm$  S.D. 70.8  $\pm$  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 sternal 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. All the values were higher for males than females. The maximum length of clavicle amongst males was 149.4  $\pm$  7.4 mm and that amongst females were 137.2  $\pm$  9.9 mm. Maximum length of humerus amongst males was 301.8  $\pm$  15.4 mm and that amongst females was 279.9  $\pm$  16.2 mm. Maximum length of ulna amongst males was 248.4  $\pm$  11.9 mm and that amongst females was 226.3  $\pm$  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%). From the above study it can be concluded that upper limb measurements are a reliable tool in the sex estimation of the specimen. Khan MA et al (2020)<sup>22</sup> studied different measurements of the humerus for the determination of sex. This was a cross-sectional study conducted at the Anatomy Department of Nishtar Medical University and Hospital from June 1, 2018, to May 31, 2019. Six measurements, including maximum length of the humerus (MLH), maximum diameter of the head of the humerus (MDH), vertical diameter of the head of the humerus (VDH), transverse diameter of the head of the humerus (TDH), epicondylar breadth (EB), and condylar breadth (CB) were calculated for 122 male humeri and 52 female humeri. These variables were compared between both genders using the student's t-

test. Wilks' lambda test was applied. The demarking point of all these variables was defined as the average of the means of male and female measurements. Correctly identified cases were calculated in the male group, the female group, and the whole study group. Data analysis was done in SPSS v.23.0 (IBM Corp, Armonk, NY).  $P > 0.05$  was statistically insignificant. The differences of MLH, MDH, VDH, TDH, EB, and CB were statistically significant between both the genders ( $p < 0.001$ ). The accuracy of MLH was 85% in the total population. The accuracy of MDH, VDH, and TDH was 76%, 85%, and 76% in the total population, respectively. EB and CB correctly identified 75% and 78% of all the bones. This study shows that maximum humeral length and the vertical diameter of the humeral head are the two most important measurements with the highest accuracy for the determination of gender from the skeletal remains of the human body in the South-East Asian population.

## CONCLUSION

The findings of this research indicate that the maximum length of the humerus and the vertical diameter of the humeral head are the two critical measurements that provide the greatest accuracy in determining gender from human skeletal remains.

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