Original Article

Anthropometric Study of Clavicle with Its Significance in Sex Determination- A Radiological Study

Varsha Suresh[1], Chandni Gupta[2], Vikram Palimar [1], Prakashini K[3], Manjula Anil Kunder[4], Purnima Adhikari[2], Bhukya Nom Kumar Naik[2]

ABSTRACT

Objectives

Sex determination is an important aspect of forensic anthropometry. The shape of the clavicle can offer indications about a person's age, and gender. This study aims to explore the effectiveness of the clavicle bone in determining an individual's sex and to develop a specific equation for predicting sex using X- ray and CT scan images.

Materials and Methods

The study was conducted using X-rays and CT scans of 131 adults. The samples were distributed into three different age groups: 21-40, 41-60, and 61-80 years. Eleven parameters of the clavicle were measured using clinical imaging software. Statistical analysis was performed on the collected parameters.

Results

The clavicles were found to be longer in males than in females. The best parameter for predicting males in the age group 21-40 years was the lateral angle of the right clavicle with an accuracy of 74.4%. The best parameter for predicting females in age group 21-40 years was the max. length of left clavicle with an accuracy of 74.4%. The best parameter for predicting both males and females in age group 41-60 years was the max. length of left clavicle with an accuracy of 85.7%. The best parameter for predicting both males and females in age group 61-80 years was the max. length of the left clavicle with an accuracy of 76.9%.

Conclusion

The results and the equation obtained for the various age groups in this study will help the forensic Anthropologist in identification of sex where the clavicle bone is retrieved from a crime scene.

Keywords

Clavicle, Sex; CT scan; X ray; Anthropometry

INTRODUCTION

Anthropometry is made of two different words- human and measurement. It involves systematically collecting various measurements from the human body and establishing a correlation between them. Forensic anthropometry is a prominent branch of anthropometry that examines skeletal remains to help in criminal investigations.[1]

Sex determination is an important aspect of forensic anthropometry. It involves analyzing skeletal remains to determine whether they belong to a male or female. This process relies on differences in the morphology of bones, which tend to vary between the sexes due to biological and hormonal influences. Sex assessment serves several purposes in a forensic setting, including unknown body identification, preparing a biological profile of the missing individual or suspects, and comprehending demographic details in case of war, genocide, and other humanitarian crises. An inaccurate evaluation of an individual's sex can affect the accuracy of other characteristics such as age and

1. Department of Forensic Medicine and Toxicology, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India, 576104
2. Department of Anatomy, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India, 576104
3. Department of Radiodiagnosis, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India, 576104
4. Department of Community Medicine, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India, 576104

Correspondence

Dr. Vikram Palimar, MBBS, MD, Professor and Head Department of Forensic Medicine, KMC Manipal, India 576104, E-mail: vpalimar@gmail.com, vikram.palimar@manipal.edu

Bangladesh Journal of Medical Science Vol. 25 No. 03 July'26

DOI: https://doi.org/10.3329/bjms.v25i3.90569

height. Using the pelvic bones alone yields an accuracy of around 95%. When only the skull bones are used, the accuracy is about 90%. However, when the pelvic and skull bones are utilized together, the accuracy increases to approximately 98%.[2] The skull and pelvic bones are typically utilized to determine sex in studies, but there are instances, such as mass disasters, decomposition, or mutilation where these bones may be unavailable. So, further studies should be done to examine the significance of other bones in sex determination.

Recent studies have investigated the use of clavicles in determining sex. The clavicles are of considerable importance in anthropometry due to a variety of factors. The shape of the clavicle can offer indications about a person's age, and gender. It is somewhat impervious to environmental factors and deterioration, and as a result, is well-maintained for a longer duration.[3] The bone shows morphological differences and bilateral asymmetry, likely due to genetics, hormones, lifestyle activities, growth, or work-related pressures.[4] The clavicle fuses later than other skeletal parts, making it useful for estimating age. Additionally, later-growing skeletal elements are often sexually dimorphic compared to those that grow early.[5] Various parameters of the clavicle, such as volume, curvature, angles, and length measurements, have displayed varying levels of accuracy for sex determination. Also, the anthropometric dimensions of the bones vary among different races and geographical regions.[6]

Previous studies on sex determination involved using real bones collected during autopsies or from various sites. The bones were manually measured using instruments, which were time-consuming and raised ethical and religious considerations. However, recent studies have shown that multiple radiological techniques, including X-rays and CT scans of the bones, can serve as alternatives. The measurement of three-dimensional bone images in CT scans can be easily performed by individuals with limited expertise in the field. The utilization of CT scans enhances precision and consistency when contrasted with conventional techniques that involve actual bones.[5] Radiological techniques also provide a rapid processing time, higher clarity, and resolution which helps the investigators to go through a large amount of data efficiently. Limited differences were observed across the data sources, and there was a high level of agreement among the observers, indicating that CT images can be relied upon for obtaining osteometric measurements.[7]

Earlier studies have provided strong evidence of sexual dimorphism in clavicles in various populations, but they are generally done manually or on 3D reconstruction images on bones. So, the present research aims to investigate the effectiveness of the clavicle bone in determining an individual's sex and to develop a specific formula for predicting sex.

MATERIALS AND METHODS

Study type: Observational study

Sample size: 131 pairs of clavicles were studied belonging to age groups of 21 – 80 years.

Sample size was calculated using effect size 0.6, power 80%, error 0.05 and 5% significance.

Using the formula: $n = z2 \times \sigma 2 / d2$

Where,

n=Sample needed

z= Value of normal standard distribution

σ= Standard deviation

d=Absolute precision

Study period: April 2023 to April 2024.

Inclusion criteria

Radiological images of patients belonging to 21-80 years

Exclusion criteria

Radiological images of patients less than 21 years and greater than 80 years

Patients who had a history of malignancies, bone or connective tissue diseases, arthritis, abnormalities, fractures, or surgery in the clavicle.

The current research was carried out after obtaining the Institutional Ethical committee clearance (IEC:492/2023).

The patient IDs were collected from the Medical Records Section. The patient IDs were categorized into three age groups i.e, 21-40yr, 41-60yr and 61-80yr. Sample distribution gender wise is shown in Table 1. Every patient's medical record was opened, and clinical imaging software InstaRISPACS was utilized to view the radiographic images, and the software's tools were utilized to measure the parameters.

The following parameters were measured on clavicles:[8-10] **(Fig. 1-3)**

1. Maximum length of clavicle: The linear distance between the furthest points of the sternal and acromial articular ends of the clavicle is measured.
2. Midshaft maximum diameter: At the midpoint of the bone shaft, the maximum diameter is measured.
3. Midshaft minimum diameter: At the midpoint of the bone shaft, the minimum diameter of the bone is measured.
4. Maximum breadth of sternal end: The maximum anterior to the posterior length of the sternal end of the clavicle is measured.
5. Maximum breadth of acromial end: The maximum anterior to the posterior length of the acromial end of clavicle is measured.
6. Depth of medial curvature: The perpendicular distance between the deepest point of the medial curvature and a tangent that links the most posterior point of the medial end to the summit of the posterior edge of the lateral curvature.
7. Depth of lateral curvature: Perpendicular distance between the deepest point of the lateral curvature and a tangent that links the most anterior point of the lateral end to the summit of the anterior edge of the medial curvature.
8. Radius of the medial curvature: Radius of the optimal circle that fits correctly in the contour of the medial curve.
9. Radius of the lateral curvature: Radius of the optimal circle that fits correctly in the contour of the lateral curve.
10. Medial angle/sternal angle: It is the angle formed between the sternoclavicular end and the clavicle shaft. It involves drawing one line tangential to the sternal end of clavicle and another tangential to bone shaft, then measuring the angle formed between the two lines.
11. Lateral angle/acromial angle: It is the angle formed between the acromioclavicular end and the clavicle shaft. It involves drawing one line tangential to the acromial end of clavicle and another tangential to the bone shaft, then measuring the angle formed between the two lines.

Seven out of the eleven parameters, such as the maximum length of clavicle, midshaft maximum diameter, depth of medial and lateral curvatures midshaft minimum diameter, and maximum breadth of the sternal and acromial, were measured using the ruler tool on X-ray scans.

The remaining four parameters - radius of the medial curvature, radius of the lateral curvature, medial angle, and lateral angle, were measured on 3D CT images of the clavicles. The radii of the medial/lateral curvature were measured using the elliptical annotation tool and the medial/lateral angles were measured using the angle annotation tool. These measurements were then recorded on an Excel sheet and subsequently subjected to statistical analysis.

Statistical analysis

The following tests were carried out using the statistical software 'Jamovi'. The Shapiro-Wilks test was done for normality. Comparison of right and left clavicle was done using Students t-test for normally distributed parameters and for non- normally distributed parameters using Wilcoxon sign rank test. Comparison of right and left clavicle between the groups was done using Students t-test for normally distributed parameters and for non- normally distributed parameters using Mann-Whitney U test. Gender wise comparison was done using Students' t-test for normally distributed and Mann-Whitney U test for non-normally distributed parameters. Sex determination was done using logistic regression analysis.

Ethical Approval

Institutional ethical clearance was taken. Approval no: (492/2023).

RESULTS

The study involved 131 pairs of clavicles (74 males and 57 females) which were divided into three age groups: Group 1 (21-40 years), Group 2 (41-60 years), and Group 3 (61-80 years).

Descriptive Statistics of all Parameters of Right and Left Clavicles are shown in Table 2. On comparing right and left clavicle it was noted that there is a significant difference in the measurements of the max. acromial breadth (p-value-0.013), radius of lateral curvature (p-value-0.024), and medial angle (p-value-0.013) between the right and left clavicles for both sexes.

Descriptive Statistics of Parameters of Right and Left Clavicles of all 3 age groups are shown in Table 3. Comparison of right and left parameters within each age group using Students' t-test (normally distributed) and Wilcoxon sign rank test (non-normally distributed) is shown in Table 4. From the table it can be noted that in group 1, there is a statistically significant difference

in the max. acromial breadth (p-value-0.002), radius of medial curvature (p-value-0.026), and radius of lateral curvature (p-value-0.007) between right and left clavicles. In Group 2, there is a statistically significant difference in the medial angle (p-value-0.008) and lateral angle (p-value-0.015) between the right and left clavicles. In Group 3, the radius of lateral curvature (p-value-0.041) shows a statistically significant difference between the right and left clavicles.

Comparison of parameters between two groups using Student's t-test (normally distributed) and Mann-Whitney U test (non-normally distributed) is shown in Table 5. From the table it can be noted that between Groups 1 and 2, the right and left radius of medial curvature (p-value-<0.001), right and left radius of lateral curvature (0.027 and 0.002 respectively), right and left medial angle (p-value- <0.001), and right and left lateral angle (p-value- <0.001) show a statistically significant difference. Between Group 2 and 3, the left max. acromial breadth (p-value-0.02), right medial angle (p-value-0.014), right and left lateral angle (p-value-0.001 and 0.047 respectively), and left depth of medial curvature (p-value-0.045) show a statistically significant difference. Between Groups 1 and 3, the right max. length (p-value-0.012), right and left midshaft min. diameter (p-value-0.024 and 0.007 respectively), right and left radius of medial curvature (p-value-<0.001), right and left lateral radius (p-value-<0.001), left medial angle (p-value-0.003), right and left lateral angle (p-value <0.001), and left midshaft max. diameter (p-value-0.037) showed a statistically significant difference between the two groups.

Descriptive Statistics of all Parameters of Male and Female Clavicles is shown in Table 6. On comparing all parameters between males and females it was noticed that right and left max. length of the clavicle (p-value-<0.001), right and left midshaft min. diameter (p-value- <0.001), left sternal breadth (p-value-<0.001), right and left acromial breadth (p-value-<0.001), right lateral depth (p-value-0.018), right and left medial depth (p-value-0.023 and 0.03 respectively), and right and left midshaft max. diameter (p-value-<0.001) showed a statistically significant difference between male and female clavicles.

Descriptive Statistics of Parameters of Male and Female Clavicles of all 3 Age Groups is presented in Table 7. Comparison of all parameters among the sexes within each group using Students' t-test (normality distribution) and Mann-Whitney U test (non-normality distribution) is shown in Table 8. From the table it can be noted that in Group 1, right and left max. length (p-value-0.037 and <0.001 respectively), right midshaft min. diameter (p-value-0.016), right and left acromial breadth (p-value-0.011 and <0.001), right lateral radius (p-value-0.043), and right lateral angle (p-value-0.017) show statistically significant differences between the sexes. In Group 2, the right and left max. length (p-value-<0.001), right and left midshaft min. diameter (p-value-<0.001), right and left sternal breadth (p-value-0.038 and <0.001 respectively), right and left acromial breadth (p-value-0.026 and 0.012 respectively), left medial radius (p-value-0.030), right medial angle (p-value-0.015), right medial depth (p-value-0.011), right and left midshaft max. diameter (p-value- <0.001) shows statistically significant differences among the sexes. In Group 3, the right and left max. length (p-value-0.008 and <0.001 respectively), right and left midshaft min. diameter (p-value-0.015 and <0.001 respectively), left sternal breadth (p-value-0.008), left acromial breadth (p-value-0.040), right lateral depth (p-value-0.006), right and left midshaft max. diameter (p-value-0.009 and <0.001 respectively) shows statistically significant differences between sexes.

Comparison of all parameters between sexes and among two groups using Students' t-test (normally distributed) and Mann-Whitney U test (non-normally distributed) is shown in Table 9. From the table it can be noted that when comparing Groups 1 and 2, right and left max. length (p-value- <0.001), right and left midshaft min. diameter (p-value- <0.001), left sternal breadth (p-value-<0.001), right and left acromial breadth (p-value- <0.001), right lateral angle (p-value-0.024), left medial depth (p-value-0.033), and right and left midshaft max. diameter (p-value- <0.001) shows statistically significant differences among the sexes and the two groups. When comparing Groups 2 and 3, right and left max. length (p-value-<0.001), right and left midshaft min. diameter (p-value- <0.001), left sternal breadth (p-value-<0.001), right and left acromial breadth (p-value- <0.001), right lateral depth (p-value-0.001), right medial depth (p-value-0.006), and right and left midshaft max. diameter (p-value- <0.001) shows statistically significant differences among the sexes and the two groups. When comparing Groups 1 and 3, right and left max. length (both <0.001), right and left midshaft min. diameter (p-value-<0.001), left sternal breadth (p-value-0.016), right and left acromial

breadth (p-value-0.001 and <0.001 respectively), right lateral radius (p-value-0.025), left lateral angle (p-value-0.048), and right and left midshaft max. diameter (p-value-0.003 and 0.002 respectively) shows statistically significant differences between the sexes and the two groups.

Sex determination using logistic regression analysis

Logistic regression was used to recognize the best parameter for identifying males and females separately for each age group.

GROUP-1 (21-40 years) **(Fig. 4)**

The best parameter for predicting males in the 21-40 age category was found to be the lateral angle of the right clavicle. The p-value was 0.025 and the overall accuracy was 74.4%.

Equation: log [0.5/1-0.5] = 15.104 + -0.103(Right Lateral Angle)

The cut-off value for the right lateral angle that corresponds to a 0.5 probability of being male is 146.64°. When the right lateral angle is less than 146.64°, the model predicts a higher possibility of being female. When the right lateral angle is more than 146.64°, the model predicts a higher possibility of being male. When the right lateral angle = 146.64°, the model predicts an equal probability of being male or female.

The best parameter for predicting females in the 21-40 age category was found to be the maximum length of the left clavicle. The p-value was 0.003 and the overall accuracy was 74.4%.

Equation: log [0.5/1-0.5] = -13.038 + -0.988(Left max. length of clavicle)

The cut-off value for the left max. length of clavicle that corresponds to a 0.5 probability of being male is 13.196cm. When the left max. length of clavicle is less than 13.196 cm, the model predicts a higher possibility of being female. When the left max. length of clavicle is more than 13.196 cm, the model predicts a higher possibility of being male. When the left max. length of clavicle = 13.196 cm, the model predicts an equal probability of being male or female.

GROUP-2 (41-60 years) **(Figure: 5)**

The best predictor for both males and females in the 41-60 age category was found to be the maximum length of the left clavicle. The p-value was <0.001 and the overall accuracy was 85.7%.

Equation: log [0.5/1-0.5] = -27.66 + 2.03(Left Max. Length of Clavicle)

The cut-off value for the left max. length of clavicle that corresponds to a 0.5 probability of being male is 13.625 cm. When the left max. length of clavicle is less than 13.625 cm, the model predicts a higher possibility of being female. When the left max. length of clavicle is more than 13.625 cm, the model predicts a higher possibility of being male. When the left max. length of clavicle= 13.625 cm, the model predicts an equal probability of being male or female.

GROUP-3 (61-80 years) **(Figure: 5)**

The best predictor for both males and females in the 61-80 age category was found to be the maximum length of the left clavicle. The p-value was 0.003 and the overall accuracy was 76.9%.

Equation: log [0.5/1-0.5] = -13.22 + 1.01(Left Max. Length of Clavicle)

The cut-off value for the left max. length of clavicle that corresponds to a 0.5 probability of being male is 13.089 cm. When the left max. length of clavicle is less than 13.089 cm, the model predicts a higher possibility of being female. When the left max. length of clavicle is more than 13.089 cm, the model predicts a higher possibility of being male. When the left max. length of clavicle = 13.089 cm, the model predicts an equal probability of being male or female.

DISCUSSION

Several studies reveal the advantages of using anthropometric measurement as a means for examining the variants in human population and as a critical element of forensic science for criminal investigations.[11] Distinguishing sex, race and age of the unidentified skeleton still has been the most difficult task in forensic investigations.[12] Some studies have shown that the clavicle can be used to determine sex quite reliably, achieving rates of accurate classification of approximately 96%.[3] Thus, clavicle is a very good bone which can be utilized for sex determination.

Upon comparison of clavicle lengths amongst males and females, it was observed that both the right and left clavicles exhibited greater mean lengths in males (14.33 and 14.63cm, respectively) than in females (12.89 and 12.68cm, respectively). This finding aligns with previous studies by Demir U et al. (Males- 14.25(right), 14.50cm (left) and Females- 12.94 (right), 13.12cm

(left)), KC S et al. (Males- 16.17 (right), 16.10cm (left) and Females- 11.20 (right) ,10.65cm (left)), Patted S et al. (Males- 14.96cm, females 13.54cm), Yang JCS et al. (Males- 15.6cm, females 14.3cm), Adieb N et al. (Males- 16.01(right), 16.25cm (left) and Females- 15.56 (right), 160.03cm (left)), Mediavilla E et al. (Males- 14.99cm, Females 13.18cm), Qiu X et al. (Males- 15.29cm, Females 13.56cm), Daruwalla ZJ et al. (Males- 15.23cm, Females 14.03cm), Panuganti P et al. (Males- 14.25cm, Females 12.85cm), and Datta D et al. (Males- 13.88 (right), 14.04cm (left) and Females- 11.9 (right), 12.02cm (left)).[2-4, 9-10, 13-17]

The mean clavicle length in males was found to be 14.48cm and for females, it was 12.78cm. Various studies in India have reported different clavicular lengths such as Sehrawat JS et al. for the Northwest Indian region (Male: Right 14.91; Left 15.24cm & Females: Right 13.47; Left 13.77cm), Panuganti P et al. for the South Indian region (Males: 14.25 cm & Females: 12.85cm), Singh G et al. for Eastern Odisha zone (Males:14.30cm & Females: 12.79cm), and Kumar A et al. for Haryana zone (Males:15.19cm & Females: 13.62cm).[16,18-20] These variations in clavicular length among individuals in India and other populations may stem from internal factors like ethnic backgrounds, racial origins, or genetic variances.[4] Additionally, external factors such as occupation, diet, or environmental conditions could also play a significant role.[21]

Variations in length can also be observed in populations across various countries like the South Nigerian population by Udoaka AI and Nwokediuko AU (Males: 15.28cm and Females: 14.5cm), Turkish population by Bozdag M et al. (Males: 15.48cm and Females: 13.91cm), Chinese population by Yang JCS et al. (Males: 15.60cm and Females: 14.30cm) and Greek population by Papaioannou VA et al. (15.39cm and Females: 13.70cm).[13, 22-24] These differences might be due to racial and ethnic variations.

An overall comparison of the right and left clavicles of both genders revealed that the mean length of the left clavicle (13.78cm) is greater than that of the right clavicle (13.70cm). This finding agrees with the studies conducted by Patted S et.al. (right-14.15cm and left-14.35cm), Adieb N et.al. (right-15.78cm and left-16.14cm), Mediavilla E et.al. (right-14.09cm and left-14.27cm), Qiu X et.al. (right-14.35cm and left-14.49cm), Daruwalla ZJ et.al. (right-14.32cm and left-14.52cm), Panuganti P et.al. (right-13.53cm and left-13.56cm), Datta D et.al. (right-12.89cm and left-13.03cm), Sehrawat JS et.al (right-14.19cm and left-14.50cm), and Chavda H et.al. (right-14.22cm and left-14.51).[3,9,10,14-18,25] (Table 10)

Other parameters such as midshaft min. diameter (Males-1.11cm and Females-0.91cm), midshaft max. diameter (Males-1.20cm and Females-1.02cm), max. breadth of sternal end (Males-2.32cm and Females-2.10cm), and max. breadth of the acromial end (Males-1.12cm and Females-0.96cm) shows higher values in males than in females. Similar results were also found in studies done by Yang JCS et.al. midshaft max. diameter (Males-1.40cm and Females-1.20cm), max. breadth of sternal end (Males-2.50cm and Females-2.30cm), and max. breadth of the acromial end (Males-2.60cm and Females-2.20cm), Papaioannou V et.al. midshaft min. diameter (Males-1.02cm and Females-0.86cm), midshaft max. diameter (Males-1.33cm and Females-1.12cm), max. breadth of sternal end (Males-2.74cm and Females-2.29cm), and max. breadth of the acromial end (Males-1.84cm and Females-1.60cm), and Eboh DEO et.al. midshaft max. diameter (Males-1.14cm and Females-0.92cm), max. breadth of sternal end (Males-1.70cm and Females-1.62cm), and max. breadth of the acromial end (Males-0.83cm and Females-0.77cm), and Qiu X et.al. midshaft max. diameter (Males-1.27cm and Females-1.02cm), max. breadth of sternal end (Males-2.41cm and Females-2.02cm), and max. breadth of the acromial end (Males-2.51cm and Females-2.03cm).[13,14,24,26]

In this study, right and left max. length of the clavicle (both <0.001), right and left midshaft min. diameter (both <0.001), left sternal breadth (<0.001), right and left acromial breadth (<0.001), and right and left midshaft max. diameter (<0.001) showed a statistically significant difference between males and females. These findings are supported by the studies of Eboh D et.al., Sehrawat JS et.al. and Qiu X et.al. found that the length, sternal and acromial widths, and midshaft width showed a significant p-value (<0.05).[14,18,26] However, Kc S et al. reported that while most parameters showed significant differences, except the length and midshaft diameter.[4]

Curvature-related parameters, such as right (males-5.83, females- 5.66cm) and left radius of medial curvature (males- 5.84, females- 5.39cm), left radius of lateral curvature (males- 6.05, females- 6.03cm), right (males- 0.79, females- 0.71cm) and left depth of lateral curvature (males- 0.75, females- 0.70cm), and right

(males- 0.77, females- 0.69cm) and left depth of medial curvature (males- 0.76, females- 0.66cm) exhibit higher values in males than females. However, the right radius of lateral curvature (males- 6.21, females- 6.44cm) shows greater values in females than in males. These findings align with the studies by Patted S et.al. radius of medial curvature (males- 5.13, females- 4.74cm), radius of lateral curvature (males- 3.56, females- 3.26cm), depth of lateral curvature (males- 1.14, females- 1.07cm), and depth of medial curvature (males- 1.92, females- 1.62cm) and Yang JCS et.al. radius of medial curvature (males- 7.50, females- 6.80cm), radius of lateral curvature (males- 3.40, females- 3.70cm), depth of lateral curvature (males- 1.30, females- 1.00cm), and depth of medial curvature (males- 1.70, females- 1.50cm).[9,13]

The study found statistically significant differences between sexes for the right depth of lateral curvature (0.018) and right and left depth of medial curvature (0.023 and 0.03 respectively). Patted S et.al. reported a significant difference in the depth of medial curvature (0.000). Yang J et.al. shows that medial depth (<0.001), medial radius (<0.05), and lateral depth (<0.05) are significant. Qiu X et.al. reported that the medial radius and medial and lateral depth showed a significant p-value (<0.05). Panuganti P et.al. showed that the depth of the inner and outer ends had a significant difference between sexes (<0.0001).[9,13,14,26]

Angle-related parameters including, right (males- 144.78, females- 147.01°) and left medial angles (males- 145.92, females- 147.77°) and right (males- 147.34, females- 150.36°) and left lateral angles (males- 147.88, females- 151.26°) showed greater values in females than males. Daruwalla Z et.al. also reported that all angles were greater in females as compared to males. Sharma RK et.al. found that only the left lateral (males- 150.04, females- 149.72°) and medial angle (males- 153.72, females- 150.68°) showed higher values in males while the right lateral (males- 139.29, females- 148.48°) and medial angle (males- 143.68, females- 152.00°) values were greater in females. Panuganti P et.al. showed that the all angles were greater in females except left medial angle ((males- 157.00, females- 154.00°).[15,16,27]

This study found that neither medial nor lateral angles showed a significant difference among sexes (p value>0.05). A similar outcome was reported by Sehrawat JS et.al. who found that both medial and lateral angles were less sexually dimorphic than the other parameters and not statistically significant. Panuganti P et.al. found that there was no significant difference in medial angles, but lateral angles showed a statistically significant difference (0.0001) between the sexes. Contrarily, Datta D et.al. and Sharma RK et.al. indicated that both medial and lateral angles showed significant p-values (<0.05).[16-18,27]

Thus, from the results, it can be concluded that the clavicle bone exhibits sexual dimorphism as there are differences in the mean values of several parameters between the sexes. The mean values of most parameters are higher in male clavicles than in female clavicles. Several explanations have been proposed to explain sexual dimorphism. Some suggest that the influence of the male sex hormone, testosterone in males, or the inhibitory effect of estrogen in females may cause the clavicle bone to attain a greater length in males as compared to females.[8,28] Development patterns and puberty also differ between the genders. In males and females, the clavicle reaches most of its length (four-fifths) by ages 12 and 9, respectively, allowing males a longer growth period, which may contribute to its larger length. Height is also shown to have a positive correlation with clavicular length. Generally, the female skeletons are found to be about 20% shorter than the males which in turn can result in a shorter clavicle with a smaller radius of curvature, which causes the bone to be more curved.[10,26] External factors, such as diet, work-related activities, and lifestyle, can also affect the length of the bone.[28]

The study also shows that certain parameters show that there is a significant difference in the measurements of the max. acromial breadth (p value-0.008), radius of lateral curvature (p value-0.024), and medial angle (p value-0.013) between the right and left clavicles of both genders. The remaining parameters do not show a notable variation. Qiu X et.al. reveals no significant differences in length, width, and curvature measurements between the right and left sides. Similarly, Daruwalla Z et.al. also reveals no significant differences in length between sides. However, Eboh et al. states there is a significant difference in length, sternal, acromial, and mid-length diameter (<0.001) between sides.[14,15,26]

In this study, the mean values of the medial and lateral angles (146.72 and 149.35° respectively) are greater in the left clavicles than the right clavicles (145.75 and 148.65° respectively). Similar results were obtained by Adieb N. et al. medial angle (right-158.25, left-

158.80°), lateral angle (right-147.70, left- 153.65°) in an Egyptian population, where they concluded that the smaller angles in the right clavicle result in a greater curvature, leading to a shorter right clavicle.[10]

The study accurately confirms the existence of bilateral asymmetry between the right and left clavicles. A popular theory supporting this is the role of hand dominance. Generally, most individuals are dominant in their right hand. The constant and regular movement of that arm causes the bone to wear away with time. This results in the greater curvature of the bone which in turn causes the clavicle to be shorter on the right side rather than the left.[15]

Using Logistic regression analysis, the right lateral angle was found to be the best parameter for predicting males in the 21-40 age group (Overall accuracy-74.4%). For females in the 21-40 age group the max. length of the left clavicle was considered the best parameter with an overall accuracy of 74.4%. For males and females in the 41-60 and 61-80 age groups, the max. length of the left clavicle was the best parameter for predicting sex with an overall accuracy rate of 85.7% and 76.9% respectively. These results are comparable to those of Eboh D et al. which indicate the left clavicular length shows an overall accuracy of 74.3% (Males: 74.1% & Females: 74.4%). Other studies with similar results include Singh A et al. with an overall accuracy of 75% (Males: 80% & Females: 70%) and Mohammed S et al. which indicated that the left clavicular length alone produces an accuracy rate of 64%. A study by Sehrawat JS et.al. shows that the lateral angle had a sex accuracy of only 61.2% (Males: 59.5% & Females: 66.2%).[8,18,19,26]

Certain authors have indicated higher accuracy rates using clavicular length. Bozdag M et al. indicated an overall accuracy of 84.9% (Males 83.1% & Females: 86.4%) while Mediavilla E et al. reports that right max. length shows an accuracy of 80% and 92% for males and females respectively and the left length of clavicle shows an accuracy of 80% and 90% for males and females respectively. On the contrary, Kamdi D et al. reported that by only using clavicular length 0-4.35% of male and female bones can be identified and Balwir TK et al. found that the length of the bone could be used to identify 12.68% and 8.30% of male and female clavicles respectively.[3,23,29,30]

This study is important in the field of forensic anthropology, particularly in cases where the clavicle bone is retrieved from a crime scene. By measuring key parameters of the clavicle, these values can be inserted into a formulated equation to provide a probabilistic determination of the bone's sex. The study highlights the effectiveness of radiological methods for forensic anthropological studies and suggests it as a replacement for the traditional methods.

CONCLUSION

The result of this study conclusively demonstrates that the clavicle bone exhibits both morphological differences between males and females and bilateral asymmetry. The clavicles were found to be longer in males than in females. Among both genders, the left clavicle was found to be greater in length than the right.

Statistically significant differences between the male and female clavicles were observed in several parameters including, the right and left max. length of the clavicle, right and left midshaft min. diameter, left sternal breadth, right and left acromial breadth, right lateral depth, right and left medial depth, and right and left midshaft max. diameter.

The best parameter for predicting males in the age group 21-40 years was the lateral angle of the right clavicle (Overall accuracy: 74.4%). The best parameter for predicting females in age group 21-40 years was the max. length of left clavicle (Overall accuracy: 74.4%). The best parameter for predicting both males and females in age group 41-60 years was the max. length of left clavicle (Overall accuracy: 85.7%). The best parameter for predicting both males and females in age group 61-80 years was the max. length of the left clavicle (Overall accuracy: 76.9%)

This study proves the usefulness of the clavicle bone and radiological methods for sex determination studies. It could also be beneficial in different fields including anatomy, forensic sciences, anthropology, and radiology.

Limitations and future scope of the study

- In the study, all the parameters were not measured using a single radiological method.
- Further studies can be performed using additional clavicular parameters like midshaft circumference. Larger sample sizes can also be considered for future studies. Similar radiological studies can be carried out in other populations across India.

Acknowledgements

Declarations

We state that all authors have read and approved the final version of the article

Consent for publishing

Not applicable

Competing interest

The authors declare that they have no competing interests

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not for-profit sectors".

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author's contributions

VP, CG: Conceptualization, Methodology, Resources, Software, Writing - review & editing. VS: Data curation, Project administration, writing original draft. CG, PK: Supervision, Validation, Visualization, Writing - review & editing. MAK, PA, BNKN: Formal analysis. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Table 1: Descriptive Statistics of Age Groups by Sex

Age Group	Sex	N	Mean ± SD
Group-1 (21-40yrs)	Male	28	27.11 ± 4.79
	Female	15	32.07 ± 6.17
Group-2 (41-60yrs)	Male	24	47.42 ± 6.13
	Female	25	52.40 ± 5.26
Group-3 (61-80yrs)	Male	22	69.23 ± 5.33
	Female	17	70.82 ± 6.28
		Total: 131	

Table 2: Descriptive Statistics of all Parameters of Right and Left Clavicles

Parameters	Mean ± SD (cm)
Max. Length Right	13.70 ± 1.47
Max. Length Left	13.78 ± 1.57
Midshaft Min. Diameter Right	1.02 ± 0.21
Midshaft Min. Diameter Left	1.02 ± 0.18
Sternal Breadth Right	2.22 ± 0.36
Sternal Breadth Left	2.24 ± 0.43
Acromial Breadth Right	1.08 ± 0.22
Acromial Breadth Left	1.02 ± 0.17
Medial Radius Right	5.76 ± 2.15
Medial Radius Left	5.64 ± 1.97
Lateral Radius Right	6.31 ± 1.72
Lateral Radius Left	6.04 ± 1.57
Medial Angle Right	145 .75 ± 8.52°
Medial Angle Left	146.72 ± 7.78°
Lateral Angle Right	148.65 ± 8.73°
Lateral Angle Left	149.35 ± 9.66°
Lateral Depth Right	0.75 ± 0.17
Lateral Depth Left	0.73 ± 0.19
Medial Depth Right	0.74 ± 0.19
Medial Depth Left	0.71 ± 0.19
Midshaft Max. Diameter Right	1.12 ± 0.20
Midshaft Max. Diameter Left	1.13 ± 0.19

Table 3: Descriptive Statistics of Parameters of Right and Left Clavicles of all 3 age groups

Parameters	Mean ± SD (cm)		
	Group-1	Group-2	Group-3
Max. Length Right	14.14 ± 1.50	13.62 ± 1.52	13.33 ± 1.26
Max. Length Left	14.16 ± 1.56	13.68 ± 1.64	13.49 ± 1.44
Midshaft Min. Diameter Right	1.05 ± 0.17	1.05 ± 0.25	0.96 ± 0.17
Midshaft Min. Diameter Left	1.07 ± 0.15	1.02 ± 0.19	0.97 ± 0.17
Sternal Breadth Right	2.24 ± 0.32	2.17 ± 0.41	2.25 ± 0.33
Sternal Breadth Left	2.26 ± 0.37	2.22 ± 0.51	2.22 ± 0.40
Acromial Breadth Right	1.11 ± 0.23	1.04 ± 0.21	1.10 ± 0.22
Acromial Breadth Left	1.01 ± 0.20	1.00 ± 0.15	1.08 ± 0.16
Medial Radius Right	7.82 ± 2.15	4.72 ± 1.42	4.78 ± 1.02
Medial Radius Left	7.55 ± 1.81	4.63 ± 1.21	4.80 ± 1.31
Lateral Radius Right	5.58 ± 1.29	6.40 ± 2.07	7.00 ± 1.34
Lateral Radius Left	5.30 ± 1.17	6.31 ± 1.65	6.52 ± 1.60
Medial Angle Right	149.66 ± 5.80°	141.66 ± 9.00°	146.58 ± 8.32°
Medial Angle Left	150.84 ± 4.98°	144.25 ± 7.51°	145.30 ± 8.89°
Lateral Angle Right	139.84 ± 8.46°	151.49 ± 4.44°	154.80 ± 4.49°
Lateral Angle Left	139.32 ± 8.73°	153.36 ± 5.41°	155.37 ± 5.15°
Lateral Depth Right	0.75 ± 0.17	0.74 ± 0.17	0.78 ± 0.20
Lateral Depth Left	0.73 ± 0.20	0.69 ± 0.16	0.78 ± 0.19
Medial Depth Right	0.73 ± 0.17	0.71 ± 0.16	0.78 ± 0.24
Medial Depth Left	0.70 ± 0.19	0.68 ± 0.15	0.78 ± 0.22
Midshaft Max. Diameter Right	1.14 ± 0.16	1.13 ± 0.25	1.08 ± 0.18
Midshaft Max. Diameter Left	1.16 ± 0.16	1.13 ± 0.21	1.08 ± 0.18

Table 4: Comparison of right and left parameters within each age group using Students' t-test (normally distributed) and Wilcoxon sign rank test (non-normally distributed)

Parameters	P-Value		
	Group-1	Group-2	Group-3
Max. Length Right Max. Length Left	0.43	0.66[a]	0.52[a]
Midshaft Min. Diameter Right Midshaft Min. Diameter Left	0.43	0.62	0.89[a]
Sternal Breadth Right Sternal Breadth Left	0.57	0.49[a]	0.76[a]
Acromial Breadth Right Acromial Breadth Left	0.002*	0.37	0.63[a]
Medial Radius Right Medial Radius Left	0.02*	0.69[a]	0.57
Lateral Radius Right Lateral Radius Left	0.007*	0.77[a]	0.04*
Medial Angle Right Medial Angle Left	0.07	0.008*	0.95
Lateral Angle Right Lateral Angle Left	0.39	0.01*[a]	0.70
Lateral Depth Right Lateral Depth Left	0.62	0.21	0.90[a]
Medial Depth Right Medial Depth Left	0.44[a]	0.35	0.91[a]
Midshaft Max. Diameter Right Midshaft Max. Diameter Left	0.47	0.61	0.96[a]

*P value <0.05- Significant

[a] denotes normally distributed variables

Table 5: Comparison of parameters between two groups using Student's t-test (normally distributed) and Mann-Whitney U test (non-normally distributed)

Parameters	P-Value		
	Group 1&2	Group 2&3	Group 1&3
Max. Length Right	0.09	0.45	0.01*
Max. Length Left	0.13	0.65	0.06
Midshaft Min. Diameter Right	0.72	0.15	0.02*
Midshaft Min. Diameter Left	0.22	0.24	0.007*
Sternal Breadth Right	0.41[a]	0.39[a]	0.92
Sternal Breadth Left	0.48	0.78	0.57
Acromial Breadth Right	0.06	0.11	0.79[a]
Acromial Breadth Left	0.98	0.02*[a]	0.07
Medial Radius Right	<0.001*	0.98	<0.001*
Medial Radius Left	<0.001*	0.77	<0.001*
Lateral Radius Right	0.02*[a]	0.12[a]	<0.001*
Lateral Radius Left	0.002*	0.57	<0.001*
Medial Angle Right	<0.001*[a]	0.01*	0.05[a]
Medial Angle Left	<0.001*	0.31	0.003*
Lateral Angle Right	<0.001*[a]	0.001*	<0.001*[a]
Lateral Angle Left	<0.001*[a]	0.04*	<0.001*
Lateral Depth Right	0.63	0.30	0.60
Lateral Depth Left	0.49	0.06	0.30
Medial Depth Right	0.52	0.26	0.52
Medial Depth Left	0.48	0.04*	0.20
Midshaft Max. Diameter Right	0.73	0.43	0.17
Midshaft Max. Diameter Left	0.33	0.33	0.03*

*P value <0.05- Significant

[a] denotes normally distributed variables

Table 6: Descriptive Statistics of all Parameters of Male and Female Clavicles

Parameters	Sex (M/F)	Mean ± SD (cm)
Max. Length Right	M	14.33 ± 1.41
	F	12.89 ± 1.11
Max. Length Left	M	14.63 ± 1.37
	F	12.68 ± 1.05
Midshaft Min. Diameter Right	M	1.11 ± 0.19
	F	0.91 ± 0.17
Midshaft Min. Diameter Left	M	1.11 ± 0.16
	F	0.91 ± 0.13
Sternal Breadth Right	M	2.26 ± 0.34
	F	2.16 ± 0.38
Sternal Breadth Left	M	2.38 ± 0.43
	F	2.05 ± 0.36
Acromial Breadth Right	M	1.15 ± 0.23
	F	0.99 ± 0.17
Acromial Breadth Left	M	1.09 ± 0.17
	F	0.94 ± 0.15
Medial Radius Right	M	5.83 ± 197
	F	5.66 ± 2.38
Medial Radius Left	M	5.84 ± 1.89
	F	5.39 ± 2.07
Lateral Radius Right	M	6.21 ± 1.67
	F	6.44 ± 1.78
Lateral Radius Left	M	6.05 ± 1.67
	F	6.03 ± 1.45
Medial Angle Right	M	144.78 ± 8.83°
	F	147.01 ± 7.99°
Medial Angle Left	M	145.92 ± 8.16°
	F	147.77 ± 7.18°

Parameters	Sex (M/F)	Mean ± SD (cm)
Lateral Angle Right	M	147.34 ± 9.76°
	F	150.36 ± 6.91°
Lateral Angle Left	M	147.88 ± 10.52°
	F	151.26 ± 8.12°
Lateral Depth Right	M	0.79 ± 0.19
	F	0.71 ± 0.14
Lateral Depth Left	M	0.75 ± 0.22
	F	0.70 ± 0.14
Medial Depth Right	M	0.77 ± 0.21
	F	0.69 ± 0.14
Medial Depth Left	M	0.76 ± 0.22
	F	0.66 ± 0.13
Midshaft Max. Diameter Right	M	1.20 ± 0.19
	F	1.02 ± 0.17
Midshaft Max. Diameter Left	M	1.21 ± 0.18
	F	1.02 ± 0.15

Table 7: Descriptive Statistics of Parameters of Male and Female Clavicles of all 3 Age Groups

Parameters	Sex (M/F)	Mean ± SD (cm)		
		GROUP-1	GROUP-2	GROUP-3
Max. Length Right	M	14.50 ± 1.55	14.61 ± 1.29	13.79 ± 1.25
	F	13.47 ± 1.17	12.66 ± 1.03	12.73 ± 1.03
Max. Length Left	M	14.73 ± 1.50	14.95 ± 1.17	14.16 ± 1.32
	F	13.09 ± 1.07	12.46 ± 0.97	12.62 ± 1.11
Midshaft Min. Diameter Right	M	1.10 ± 0.16	1.20 ± 0.22	1.02 ± 0.17
	F	0.96 ± 0.17	0.90 ± 0.19	0.89 ± 0.15
Midshaft Min. Diameter Left	M	1.10 ± 0.17	1.16 ± 0.13	1.06 ± 0.15
	F	1.02 ± 0.09	0.88 ± 0.14	0.84 ± 0.10
Sternal Breadth Right	M	2.25 ± 0.31	2.30 ± 0.39	2.23 ± 0.35
	F	2.22 ± 0.35	2.06 ± 0.41	2.27 ± 0.33
Sternal Breadth Left	M	2.29 ± 0.36	2.48 ± 0.50	2.37 ± 0.43
	F	2.21 ± 0.38	1.97 ± 0.38	2.03 ± 0.27
Acromial Breadth Right	M	1.17 ± 0.24	1.11 ± 0.24	1.17 ± 0.23
	F	1.00 ± 0.16	0.96 ± 0.15	1.01 ± 0.19
Acromial Breadth Left	M	1.08 ± 0.19	1.05 ± 0.14	1.13 ± 0.16
	F	0.87 ± 0.13	0.94 ± 0.15	1.02 ± 0.14
Medial Radius Right	M	7.56 ± 1.77	4.90 ± 1.38	4.65 ± 0.99
	F	8.32 ± 2.78	4.54 ± 1.46	4.95 ± 1.06
Medial Radius Left	M	7.37 ± 1.70	5.02 ± 1.27	4.78 ± 1.36
	F	7.90 ± 2.02	4.27 ± 1.05	4.82 ± 1.27
Lateral Radius Right	M	5.29 ± 1.16	6.80 ± 2.14	6.75 ± 1.09
	F	6.13 ± 1.38	6.03 ± 1.96	7.33 ± 1.58
Lateral Radius Left	M	5.07 ± 1.15	6.72 ± 1.72	6.57 ± 1.63
	F	5.73 ± 1.11	5.91 ± 1.52	6.46 ± 1.59
Medial Angle Right	M	148.98 ± 6.16°	138.17 ± 8.18°	146.63 ± 8.50°
	F	150.94 ± 5.00°	145.01 ± 8.60°	146.50 ± 8.33°
Medial Angle Left	M	150.62 ± 5.10°	142.51 ± 7.24°	143.66 ± 9.63°
	F	151.24 ± 4.92°	145.91 ± 7.52°	147.72 ± 7.59°
Lateral Angle Right	M	137.62 ± 8.01°	151.55 ± 4.83°	155.11 ± 3.70°
	F	143.98 ± 7.91°	151.43 ± 4.14°	154.40 ± 5.44°
Lateral Angle Left	M	137.61 ± 8.67°	153.85 ± 4.82°	154.44 ± 6.04°
	F	142.50 ± 8.19°	152.89 ± 5.99°	156.57 ± 3.53°
Lateral Depth Right	M	0.75 ± 0.19	0.78 ± 0.17	0.85 ± 0.21
	F	0.75 ± 0.11	0.70 ± 0.16	0.68 ± 0.12
Lateral Depth Left	M	0.77 ± 0.22	0.69 ± 0.20	0.81 ± 0.21
	F	0.67 ± 0.12	0.68 ± 0.12	0.75 ± 0.16
Medial Depth Right	M	0.73 ± 0.18	0.77 ± 0.15	0.84 ± 0.28
	F	0.72 ± 0.13	0.66 ± 0.15	0.70 ± 0.14
Medial Depth Left	M	0.74 ± 0.21	0.71 ± 0.17	0.84 ± 0.26
	F	0.64 ± 0.14	0.65 ± 0.13	0.70 ± 0.13
Midshaft Max. Diameter Right	M	1.16 ± 0.16	1.28 ± 0.21	1.15 ± 0.18
	F	1.09 ± 0.16	0.99 ± 0.20	1.00 ± 0.13
Midshaft Max. Diameter Left	M	1.17 ± 0.18	1.28 ± 0.17	1.86 ± 0.17
	F	1.16 ± 0.15	0.98 ± 0.14	0.95 ± 0.09

Table 8: Comparison of all parameters between the sexes within each group using Students' t-test (normality distribution) and Mann-Whitney U test (non-normality distribution)

Parameters	P-Value		
	Group-1	Group-2	Group-3
Max. Length Right	0.03*	<0.001*	0.008*[a]
Max. Length Left	<0.001*[a]	<0.001*	<0.001*
Midshaft Min. Diameter Right	0.01*	<0.001*	0.01*[a]
Midshaft Min. Diameter Left	0.19	<0.001*	<0.001*[a]
Sternal Breadth Right	0.76	0.03*	0.86
Sternal Breadth Left	0.39	<0.001*	0.008*[a]
Acromial Breadth Right	0.01*	0.02*	0.05
Acromial Breadth Left	<0.001*	0.01*[a]	0.04*[a]
Medial Radius Right	0.16	0.30	0.55
Medial Radius Left	0.29	0.03*[a]	0.85
Lateral Radius Right	0.04*[a]	0.19[a]	0.19
Lateral Radius Left	0.07[a]	0.09[a]	0.85
Medial Angle Right	0.24	0.01*	0.96[a]
Medial Angle Left	0.60	0.08	0.33
Lateral Angle Right	0.01*[a]	0.92[a]	0.63
Lateral Angle Left	0.07	0.52[a]	0.13
Lateral Depth Right	0.51	0.05	0.006*[a]
Lateral Depth Left	0.37	0.86[a]	0.41
Medial Depth Right	0.84[a]	0.01*	0.22
Medial Depth Left	0.32	0.24	0.05[a]
Midshaft Max. Diameter Right	0.15	<0.001*	0.009*[a]
Midshaft Max. Diameter Left	0.94	<0.001*	<0.001*[a]

*P value <0.05- Significant
[a] denotes normally distributed variables

Table 9: Comparison of all parameters between sexes and between two groups using Students' t-test (normally distributed) and Mann-Whitney U test (non-normally distributed).

Parameters	P-Value		
	Group 1&2	Group 2&3	Group 1&3
Max. Length Right	<0.001*	<0.001*	<0.001*
Max. Length Left	<0.001*	<0.001*	<0.001*
Midshaft Min. Diameter Right	<0.001*	<0.001*	<0.001*[a]
Midshaft Min. Diameter Left	<0.001*	<0.001*	<0.001*
Sternal Breadth Right	0.04	0.12	0.98
Sternal Breadth Left	<0.001*	<0.001*	0.01*[a]
Acromial Breadth Right	<0.001*	<0.001*	0.001*[a]
Acromial Breadth Left	<0.001*	<0.001*[a]	<0.001*[a]
Medial Radius Right	0.20	0.72	1.00
Medial Radius Left	0.06	0.12	0.97
Lateral Radius Right	0.69	0.57[a]	0.02*
Lateral Radius Left	0.90	0.14[a]	0.19
Medial Angle Right	0.07	0.06	0.70[a]
Medial Angle Left	0.43	0.05	0.52
Lateral Angle Right	0.02*	0.36	0.14
Lateral Angle Left	0.16	0.77	0.04*
Lateral Depth Right	0.27	0.001*	0.15
Lateral Depth Left	0.44	0.52	0.31
Medial Depth Right	0.05	0.006*	0.38
Medial Depth Left	0.03*	0.05	0.10
Midshaft Max. Diameter Right	<0.001*	<0.001*	0.003*
Midshaft Max. Diameter Left	<0.001*	<0.001*	0.002*

*P value <0.05- Significant
[a] denotes normally distributed variables

Table 10. Showing comparison of present study with other studies.

Parameters	Gender (M/F)	Mean (cm) (Present study)	Demir U et al [8]	KC S et al [12]	Adieb N et al [1]	Datta D and Anand C [7]	Sharma RK et al [22]	Patted S et al [19]	Mediavilla ER et al [15]	Qiu X et al [20]	Daruwalla ZJ et al [6]	Panuganti P et al [17]	Sehrawat JS and Pathak RK [21]	Chavda H et al [5]
Country		India	Turkey	Nepal	Egypt	Malaysia	India	India	Spain	China	Ireland	India	India	India
Max. Length Right	M	14.33	14.25	16.17	16.01	13.88		14.15	14.09	14.35	14.32	13.53	14.19	14.22
	F	12.89	12.94	11.20	15.56	11.90								
Max. Length Left	M	14.63	14.50	16.10	16.25	14.04		14.35	14.27	14.49	14.52	13.56	14.50	14.51
	F	12.68	13.12	10.65	16.03	12.02								
Medial Angle Right	M	144.78			158.25		143.68							
	F	147.01					152.00							
Medial Angle Left	M	145.92			158.80		153.72							
	F	147.77					150.68							
Lateral Angle Right	M	147.34			147.70		139.29							
	F	150.36					148.48							
Lateral Angle Left	M	147.88			153.65		150.04							
	F	151.26					149.72							

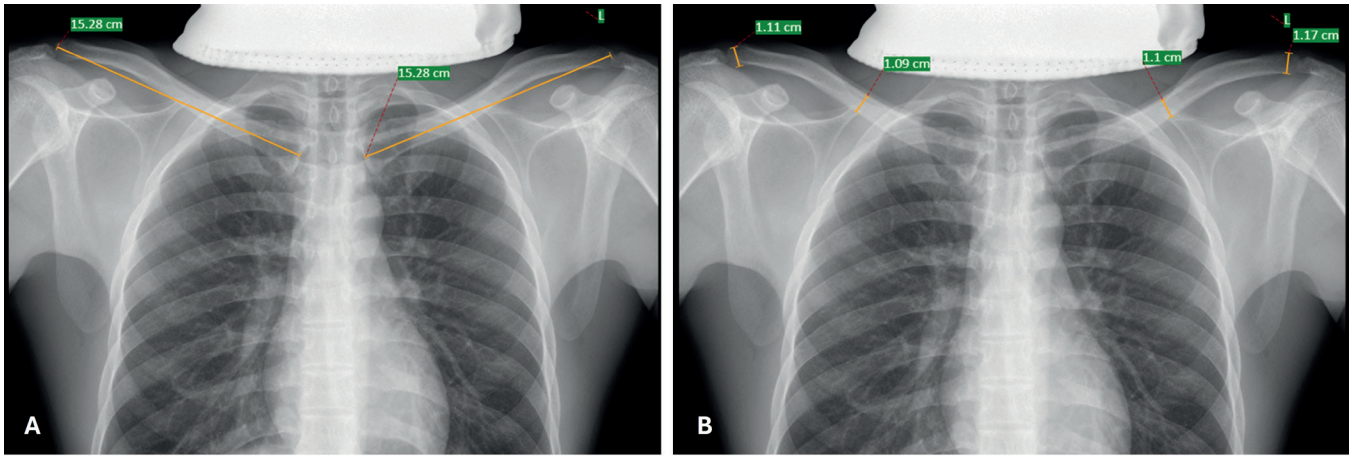

Figure 1. A. Measuring the Maximum Length of the Clavicle using X-ray scan. B. Measuring the Maximum breadth of the Acromial End and Midshaft Minimum Diameter of the Clavicle using an X-ray scan.

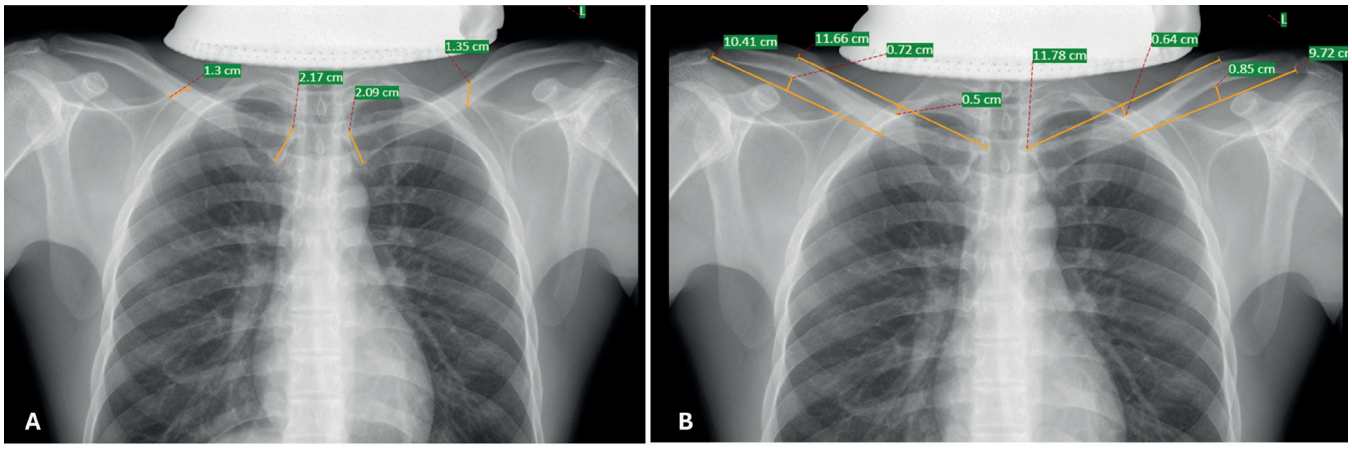

Figure. 2. A. Measuring the Maximum Breadth of the Sternal End and Midshaft Maximum Diameter of the Clavicle using an X-ray Scan. B. Measuring the Depths of Lateral and Medial Curvatures of the Clavicle using an X-ray Scan.

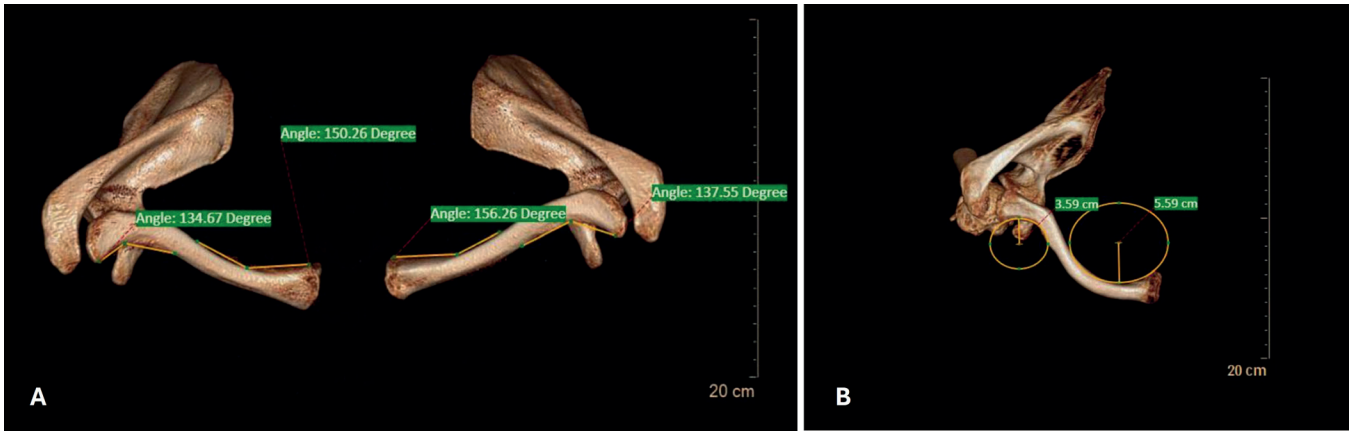

Figure 3. A. Measuring the Lateral and Medial Angles of the Clavicle using a CT scan. B. Measuring the Radius of Lateral and Medial Curvatures of the Clavicle using a CT scan.

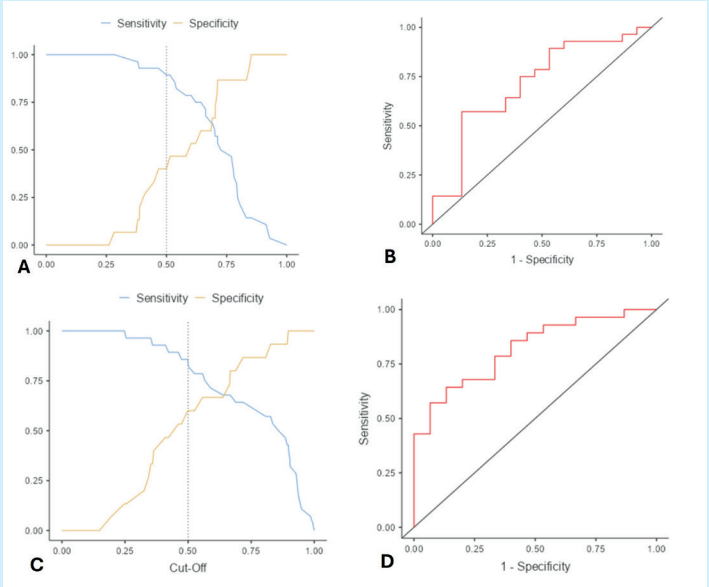

Figure 4. A. Cut-off Plot for Right Lateral Angle (Male: 21-40years). B. ROC curve for Right Lateral Angle (Male: 21-40years). C. Cut-off Plot for Left Max. Length of Clavicle (Female: 21-40years). D. ROC curve for Left Max. Length of Clavicle (Females: 21-40years).

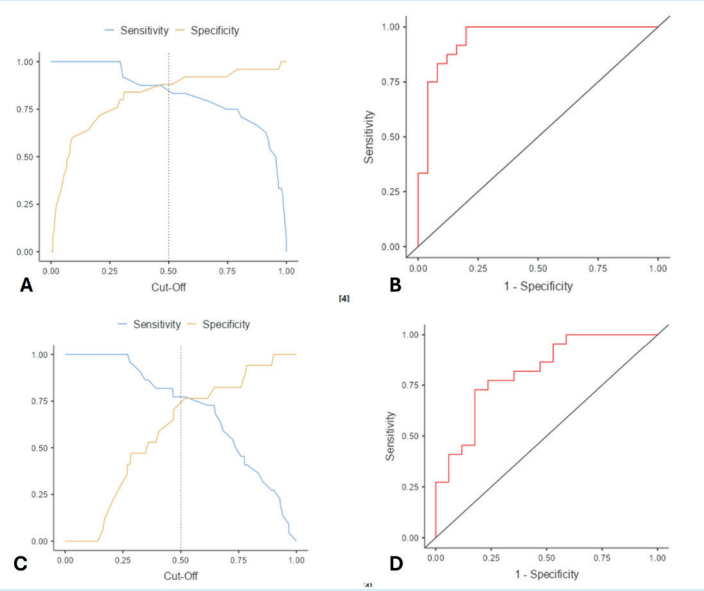

Figure 5. A. Cut-off Plot for Left Max. Length of Clavicle (Male & Female: 41-60 years). B. ROC curve for Left Max. Length of Clavicle (Male & Female: 41-60 years). C. Cut-off Plot for Left Max. Length of Clavicle (Male & Female: 61-80 years). D. ROC curve for Left Max. Length of Clavicle (Males & Females: 61-80 years).

REFERENCES

1. Krishnan K. Anthropometry in Forensic Medicine and Forensic Science-'Forensic Anthropometry'. *The Internet Journal of Forensic Science*. 2006; **2**(1):41-42. https://doi.org/10.5580/1dce
2. Demir U, Etli Y, Hekimoglu Y, Kartal E, Keskin S, Yavuz A, et al. Sex estimation from the clavicle using 3D reconstruction, discriminant analyses, and neural networks in an Eastern Turkish population. *Leg Med.* 2022; **56**:102043. https://doi.org/10.1016/j.legalmed.2022.102043
3. Mediavilla ER, Pérez BP, González EL, Sánchez JAS, Fernández ED, Sáez AS. Determining sex with the clavicle in a contemporary Spanish reference collection: A study on 3D images. *Forensic Sci Int.* 2016; **261**:163. e1-. e10. https://doi.org/10.1016/j.forsciint.2016.01.029
4. Kc S, Shrestha S, Acharya S, Bhandari KR. Clavicle Morphometry for Sexual Dimorphism and Bilateral Asymmetry: Radiographic Assessment. *J Nepal Health Res Counc*. 2020;**18**(3):448-452. https://doi.org/10.33314/jnhrc.v18i3.2534
5. Torimitsu S, Makino Y, Saitoh H, Sakuma A, Ishii N, Yajima D, et al. Sex assessment based on clavicular measurements in a modern Japanese population using multidetector computed tomography. *Forensic Sci Int*. 2018; **285**:207. e1-e5. https://doi.org/10.1016/j.forsciint.2017.10.009
6. Akhlaghi M, Moradi B, Hajibeygi M. Sex determination using anthropometric dimensions of the clavicle in Iranian population. *J Forensic Leg Med*. 2012;**19**(7):381-385. https://doi.org/10.1016/j.jflm.2012.02.016
7. Stull KE, Tise ML, Ali Z, Fowler DR. Accuracy and reliability of measurements obtained from computed tomography 3D volume rendered images. *Forensic Sci Int*. 2014; **238**:133-140. https://doi.org/10.1016/j.forsciint.2014.03.005
8. Mohammed S, Ahmidan M, Wasef M, Ali M, Gad AMA. Identification of Sex from Clavicle Bone Morphometry through 3D CT in Libyan Population. *The Egyptian Journal of Hospital Medicine*. 2023;**90**(2): 3534-3539. https://doi.org/10.21608/ejhm.2023.291965
9. Patted SM, Kumar A, Halawar RS. Morphometric Analysis of Clavicle and Its Medullary Canal: A Computed Tomographic Study. *Indian J Orthop*. 2020; **54**:283-291. https://doi.org/10.1007/s43465-020-00223-2
10. Adieb N, Messih A El, Shaaban MH, Youakim F, Fahim MA, Youakim MF. Curvatures and Medullary Canal of the Clavicle Among an Egyptian Population: A Three-Dimensional Computed Tomography Study. *Egyptian Journal of Anatomy*. 2017;**40**(1):120-129. https://doi.org/10.21608/ejana.2017.5717
11. Okoro GO, Igabari JN, Owhefere GO. A Morphometric Study of Nasal Index among Owo Indigenes of Ondo State, Nigeria. *International Journal of Human and Health Sciences*, 2024;**8**(2): 165-169. doi:http://dx.doi.org/10.31344/ijhhs.v8i2.638. https://doi.org/10.31344/ijhhs.v8i2.638
12. Al Timimi AHU, Hameed Al Khafaji TG, Oglah Albaaj FS, Hasan HA, & Alam MK. Identification of gender by radiographic analysis of mental foramen in a sample of Iraqi patients. *Bangladesh Journal of Medical Science*, 2022;**21**(1):79-83. https://doi.org/10.3329/bjms.v21i1.56330 https://doi.org/10.3329/bjms.v21i1.56330
13. Yang JCS, Lin KJ, Wei HW, Tsai CL, Lin KP, Lee

PY. Morphometric analysis of the clavicles in Chinese population. *Biomed Res Int.* 2017; 2017:1-5. https://doi.org/10.1155/2017/8149109

14. Qiu XS, Wang XB, Zhang Y, Zhu YC, Guo X, Chen YX. Anatomical study of the clavicles in a Chinese population. *Biomed Res Int*. 2016; 2016:1-5. https://doi.org/10.1155/2016/6219761
15. Daruwalla ZJ, Courtis P, Fitzpatrick C, Fitzpatrick D, Mullett H. Anatomic variation of the clavicle: A novel three-dimensional study. *Clinical Anatomy*. 2010;**23**(2):199-209. https://doi.org/10.1002/ca.20924
16. Panuganti PK, Venkateshwar MR, Poojari MS, Shrish P, Kumar JA. Morphometry and Sexual Dimorphism of the Human Clavicle in South Indian Population. *International Journal of Anatomy and Research*. 2022;**10**(1):8283-90. https://doi.org/10.16965/ijar.2021.205
17. Datta D, Anand C. Study of Morphometry of Clavicle-Length and Angles. *Int Arch BioMed Clin Res.* 2021;**7**(2): HA1-HA3.
18. Sehrawat JS, Pathak RK. Variability in anatomical features of human clavicle: Its forensic anthropological and clinical significance. *Translational Research in Anatomy*. 2016;**3-4**:5-14. https://doi.org/10.1016/j.tria.2016.08.001
19. Singh G, Das S, Shamal S, Patra M. Gender variation of clavicle in eastern Odisha. *International Journal of Anatomy and Research*. 2020;**8**(1):7386-7389. https://doi.org/10.16965/ijar.2020.109
20. Kumar A, Sharma L, Archana, Kaushik G, Saini N, Soni RK, et al. Estimation of Sex by Applying Discriminant Function Analysis on Osteo-metric Parameters of Clavicle in Population of Haryana. *Journal of Forensic Science and Medicine*. 2023;**9**(2):106-111. https://doi.org/10.4103/jfsm.jfsm_42_22
21. Sushmita S, Kuntal M, Sharmistha B, Hasi D. Morphometric Study of Clavicle of Eastern Indian Population. *Indian Journal of Basic and Applied Medical Research*. 2018;**7**:295-307.
22. Udoaka AI and Nwokediuko AU. Radiologic evaluation of clavicular morphology in southern Nigerians. *Int. J. Morphol*. 2013;**31**(1);94-99. https://doi.org/10.4067/S0717-95022013000100014
23. Bozdag M, Er A, Kranioti E, Basa CD, Oztop B, Kacmaz E, et al. Sex estimation in a modern Turkish population using the clavicle: a computed tomography study. *Australian Journal of Forensic Sciences.* 2022;**54**(2):187-198. https://doi.org/10.1080/00450618.2020.1781255
24. Papaioannou VA, Kranioti EF, Joveneaux P, Nathena D, Michalodimitrakis M. Sexual dimorphism of the scapula and the clavicle in a contemporary Greek population: Applications in forensic identification. *Forensic Sci Int*. 2012;**217**(1-3): 231.e1-231.e7. https://doi.org/10.1016/j.forsciint.2011.11.010
25. Chavda HS, Khatri CR, Varlekar PD, Saiyad SS. Morphometric analysis of clavicles in Gujarat Morphometric Analysis and Sex determination from Clavicles in Gujarati Population. *NJIRM.* 2013;**4**(6):18-22.
26. Eboh DEO, Ishicheli GK. Sex determination using Radiographic Anthropometric dimensions of the clavicle in an Igbo population of Nigeria. *Int. Journal of Forensic Medical Investigation*. 2019;**5**(1):52-60.
27. Sharma RK, Aneja PS, Saxena AK. Determination of Sex of Adult Human Clavicle by Curves and Angles. *Global Journal for Research Analysis*. 2017;**6**(8):83-84.
28. Kaewma A, Sampannang A, Tuamsuk P, Iamsaard S. Morfometría de las Clavículas en una Población Isan-Thai como Guía para la Determinación del Sexo. *International Journal of Morphology.* 2017;**35**(1):172-177. https://doi.org/10.4067/S0717-95022017000100028
29. Balwir TK, Gajbe U, Br S, Anjankar S, Gawali R, Anjankar V. Determination of Sex by Discriminant Linear Regression Analysis of Clavicle in Vidarbha Region. *Ann Med Health Sci Res.* 2021;**11**; S3:150-152.
30. Kamdi DA, Gayatri D, R. Sherke DA, Krishnaiah DM, Chaitanya MK. Morphometric Parameters and Sex Determination of Clavicle in Telangana Region. *IOSR Journal of Dental and Medical Sciences.* 2014;**13**(10):01 https://doi.org/10.9790/0853-131010105

REFERENCES

1. Min, H. J., & Kim, K. S. 2021. Primary Non-Hodgkin's lymphoma originating from the massetermuscle. *Bangladesh Journal of Medical Science* 2021;**20**(1),181-6. https://doi.org/10.3329/bjms.v20i1.50367 https://doi.org/10.3329/bjms.v20i1.50367
2. Stein SA and Wartofsky L, Primary Thyroid Lymphoma: A Clinical Review. *J Clin Endocrinol Metabol* 2013;**98**: 3131-8. 10.1097/00000478-200005000-00001. https://doi.org/10.1210/jc.2013-1428
3. Derringer, GA, Thompson LD, Frommelt RA et al. Malignant Lymphoma of the Thyroid Gland: A Clinicopathologic Study of 108 Cases. *Am J Pathol.* 2000;**24**: 623-39.10.1046/j.1365-2559.1996.268311.x. https://doi.org/10.1097/00000478-200005000-00001
4. Pedersen RK and Pedersen NT. Primary non-Hodgkin's lymphoma of the thyroid gland: a population-based study. *Histopathology* 1996; **28**:25-32.10.1016/j.prp.2020.152819 https://doi.org/10.1046/j.1365-2559.1996.268311.x
5. Travaglino A, Pace M, Varricchio S et al. Clinical features associated with high pathological grade in primary thyroid lymphoma. *Pathol Res Pract*. 2020;**216**:152819.1007/s12070-020-02088-1 https://doi.org/10.1016/j.prp.2020.152819
6. Khanal P, Lageju N, Adhikari B. Diffuse Large B-Cell Lymphoma of Thyroid: A Case Report and Review of Literature. *Indian J Otolaryngol Head Neck Surg*. 2022;**74**:2287-90.10.1089/thy.2006.16.983 https://doi.org/10.1007/s12070-020-02088-1
7. Ota H, Ito Y, Matsuzuka F, et al. Usefulness of ultrasonography for diagnosis of malignant lymphoma of the thyroid. *Thyroid*. 2006;**16**:983-7.10.1007/s12070-022-03326-4 https://doi.org/10.1089/thy.2006.16.983
8. Manda S, Tummidi S, Shankaralingappa A et al. Primary Thyroid Lymphoma Diagnosed on Rapid Onsite and Cytology: A Rare Case Report. *Indian J Otolaryngol Head Neck Surg*. 2023;**75**:1040-44. 10.1016/j.hoc.2020.05.002 https://doi.org/10.1007/s12070-022-03326-4
9. Chuen,C. S., Lazim, N. M., Haw et al. Approach for paediatric cervical lymphadenopathy: Tuberculosis versus lymphoma. *Bangladesh Journal of Medical Science*,2019; **18**(1): 149-52. 10.3329/bjms.v18i1.39567. https://doi.org/10.3329/bjms.v18i1.39567
10. Navarro A, Beà S, Jares P et al. Molecular Pathogenesis of Mantle Cell Lymphoma. *Hematol Oncol Clin North Am*. 2020;**34**:795-807. 10.1002/ccr3.4104 https://doi.org/10.1016/j.hoc.2020.05.002
11. Pongas GN, Alderuccio JP, Chapman JR et al. Mantle cell lymphoma involving the thyroid gland. *Clin Case Rep*. 2021;**9**(9):e04104. 10.1182/blood-2018-03-791392 https://doi.org/10.1002/ccr3.4104
12. Maddocks K. Update on mantle cell lymphoma. *Blood*. 2018;**132**(16):1647-56. 10.1155/2017/6749801 https://doi.org/10.1182/blood-2018-03-791392
13. Siddiqui UM, Rao SN, Galera PK et al. Mantle Cell Lymphoma in the Thyroid: A Rare Presentation. *Case Rep Pathol*. 2017;**67**:49801. 10.1155/2017/6749801. https://doi.org/10.1155/2017/6749801