e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(9); 791-797

Original Research Article

Morphometric Analysis and Sexual Dimorphism of Human Clavicle in Kashmiri Population: A Single Institutional Study

Saqib Amin Ganai[1], Bashir Ahmad Shah[2], Imren Rahim[3], Iqra Yousuf[4], Nazia Shafi Alamgeer[5]

[1,,3,4,5]Postgraduate Scholar, Department of Anatomy, Government Medical College (GMC), Srinagar, Jammu and Kashmir, India

[2]Professor and Head, Department of Anatomy, Government Medical College (GMC), Srinagar, Jammu and Kashmir, India

Received: 01-06-2026 / Revised: 15-07-2026 / Accepted: 21-08-2026

Corresponding author: Dr. Saqib Amin Ganai

Conflict of interest: Nil

Abstract

Background: Determination of sex from skeletal remains is a fundamental aspect of forensic anthropology and medico-legal investigations. The clavicle exhibits considerable sexual dimorphism and can serve as a reliable indicator for sex determination when only fragmented skeletal remains are available. The present study was undertaken to evaluate morphometric parameters of human clavicles and assess their utility in sex determination among the Kashmiri population.

Objectives: (1) To study various morphometric parameters of human clavicles in the Kashmiri population. (2) To compare morphometric measurements between male and female clavicles. (3) To determine the most reliable parameter for sex differentiation.

Materials and Methods: A cross-sectional osteometric study was conducted in the Department of Anatomy, Government Medical College Srinagar. Seventy adult dry clavicles of known sex (35 male and 35 female) were analyzed. Measurements including clavicular length, medial angle, lateral angle, total curvature, segment lengths, widths, depths, and mid-shaft circumference were recorded using an osteometric board, Vernier caliper, sliding caliper, and protractor. Data were analyzed using SPSS version 26.0. Statistical significance was considered at $p<0.05$.

Results: Male clavicles demonstrated significantly higher values for length, widths, depths, and mid-shaft circumference compared with female clavicles ($p<0.001$). Mean clavicular length was 145.3±4.2 mm in males and 131.6±3.8 mm in females. Mean mid-shaft circumference was 37.8±1.9 mm in males and 31.8±1.5 mm in females. Mid-shaft circumference emerged as the most significant discriminator of sex.

Conclusion: The clavicle exhibits marked sexual dimorphism in the Kashmiri population. Mid-shaft circumference was found to be the most reliable parameter for sex determination. These findings may be useful in forensic anthropology, archaeology, and medico-legal investigations.

Keywords: Clavicle, Morphometry, Sexual Dimorphism, Forensic Anthropology, Mid-Shaft Circumference, Kashmir.

DOI: 10.25258/ijcpr.18.9.112

Introduction

The clavicle is a distinctive long bone that serves as the only skeletal connection between the upper limb and the axial skeleton. Anatomically, it functions as a dynamic strut that maintains the upper extremity away from the thoracic cage, thereby allowing a greater range of shoulder movement while simultaneously transmitting mechanical forces generated during upper limb activity to the axial skeleton. The clavicle possesses a characteristic S-shaped configuration with medial convexity and lateral concavity, which contributes to its biomechanical efficiency. It also provides attachment to several important muscles, including the pectoralis major, deltoid, trapezius, sternocleidomastoid, and subclavius muscles, thereby playing an essential role in shoulder stability, upper limb mobility, and force transmission. These structural and functional characteristics make the clavicle an indispensable component of the shoulder girdle and upper limb biomechanics [1–3]. From a developmental perspective, the clavicle is unique among long bones. It is the first bone to initiate ossification during fetal life and one of the last to complete

epiphyseal fusion in early adulthood. Unlike most long bones, which develop predominantly through endochondral ossification, the clavicle undergoes mainly intramembranous ossification, making its growth highly responsive to genetic, endocrine, nutritional, and environmental influences. Hormonal factors, particularly testosterone and estrogen, regulate skeletal growth and maturation, whereas mechanical loading generated by muscular activity influences cortical remodeling and bone robusticity. Consequently, males generally develop longer, thicker, and more robust clavicles than females because of greater muscle mass, delayed epiphyseal closure, and increased periosteal bone deposition [1–3].

Identification of human skeletal remains is one of the principal objectives of forensic anthropology, medico-legal investigations, disaster victim identification, and archaeological research. Establishing the biological profile of an unknown individual, including sex, age, ancestry, and stature, is a fundamental prerequisite for successful identification. Among these parameters, sex estimation is regarded as the cornerstone of skeletal identification because it substantially narrows the pool of possible identities and enhances the accuracy of subsequent anthropological analyses. Although molecular techniques such as DNA profiling have revolutionized forensic science, they are not always feasible owing to decomposition, thermal damage, contamination, lack of reference samples, or limited laboratory resources. Consequently, morphometric evaluation of skeletal remains continues to play a pivotal role in forensic investigations, particularly when only isolated or fragmented bones are available [4–6].

Because of its subcutaneous location, structural strength, and resistance to postmortem decomposition, the clavicle is frequently recovered in medico-legal investigations involving incomplete or fragmented skeletal remains. Its persistence, combined with measurable morphometric characteristics, makes it a valuable bone for biological profile estimation when more sexually dimorphic skeletal elements such as the pelvis or skull are unavailable. These anatomical and forensic attributes have stimulated extensive research on clavicular morphometry for sex estimation [4–7].

Sexual dimorphism of the clavicle has attracted considerable attention among anatomists, forensic anthropologists, orthopedic surgeons, and archaeologists because of its application in human identification. Various osteometric parameters, including clavicular length, shaft circumference, curvature, articular end dimensions, and segmental measurements, have been investigated as objective indicators of sex. Classical osteometric studies by Terry [7], Jit and Singh [8], Singh and Gangrade [9], and Haque et al. [10] consistently demonstrated that male clavicles are significantly longer and more robust than female clavicles, thereby establishing the clavicle as a reliable bone for sex estimation. Subsequent investigations further strengthened these observations. Ramamurthi [11], Shobha et al. [12], Panuganti et al. [13], Gour [14], and Ghorpade et al. [15] demonstrated that clavicular morphometry provides reliable discrimination between male and female skeletons and emphasized the importance of developing population-specific osteometric standards. Gour [14] further highlighted that developmental, hormonal, and biomechanical factors collectively contribute to the marked sexual dimorphism observed in clavicular morphology.

Beyond its forensic significance, clavicular morphometry possesses considerable clinical and orthopedic relevance. The clavicle is one of the most frequently fractured bones of the appendicular skeleton, particularly among young adults and individuals sustaining high-energy trauma. Successful operative management increasingly relies on anatomically contoured fixation plates and intramedullary devices that closely match clavicular morphology. Accurate morphometric information regarding clavicular length, curvature, shaft diameter, and articular dimensions is therefore essential for implant design, fracture fixation, corrective osteotomy, reconstructive procedures, radiological assessment, biomechanical modelling, and preoperative planning [1–3,13].

Although numerous osteometric studies have been conducted in South Indian, North Indian, Nepalese, African, and Western populations, substantial inter-population variation in clavicular morphology has been consistently reported [7–15]. Such variation may result from differences in ethnicity, genetic background, nutrition, environmental conditions, socioeconomic status, occupational activity, and physical build. Consequently, discriminant functions and morphometric standards developed for one population may not be directly applicable to another. Recent investigators have therefore emphasized the need to establish population-specific osteometric databases to improve the reliability and accuracy of forensic sex estimation [13–15].

Despite the growing body of literature on clavicular morphometry, data pertaining to the Kashmiri population remain limited. Kashmir possesses distinct ethnic, geographic, environmental, and anthropometric characteristics that may influence skeletal morphology. The absence of regional osteometric standards limits the applicability of currently available criteria for forensic identification within this population. Therefore, the present study was undertaken to evaluate the morphometric characteristics of adult human

clavicles in the Kashmiri population and to assess the extent of sexual dimorphism using various osteometric parameters. The findings are expected to provide valuable population-specific reference data for forensic anthropology, medico-legal investigations, clinical anatomy, and orthopedic practice.

Materials and Methods

Study Design and Setting: This cross-sectional osteometric study was conducted using archived dry human clavicles available in the Department of Anatomy, Government Medical College, Srinagar. Permission to use the osteological specimens for academic research was obtained from the Head of the Department. The study involved no living participants, patient data, or identifiable human information and was conducted in accordance with the institutional guidelines governing the educational and research use of human skeletal specimens.

Study Material: The study material comprised 70 dry adult human clavicles of known sex, including 35 male and 35 female specimens, representing both the right and left sides. As no population-specific data were available for the Kashmiri population and the available literature did not provide sufficiently robust statistical parameters to permit a formal sample size calculation, a census sampling approach was adopted. Accordingly, all eligible adult clavicles of known sex available in the osteological collection of the Department of Anatomy, Government Medical College, Srinagar, during the study period were included in the study. The final sample of 70 clavicles fulfilled the predefined inclusion criteria and was considered adequate for evaluating morphometric characteristics and sexual dimorphism in the Kashmiri population. This approach is consistent with previously published osteometric studies, in which all available eligible skeletal specimens were included for morphometric evaluation of sexual dimorphism and population-specific anatomical characteristics. [11–15]All specimens were obtained from the Department of Anatomy, Government Medical College, Srinagar. Only well-preserved adult clavicles with complete ossification, intact cortical surfaces, and clearly identifiable anatomical landmarks were included in the study. Specimens exhibiting fractures, deformities, congenital or developmental anomalies, pathological lesions, erosive changes, previous surgical intervention, or significant postmortem damage that could compromise morphometric measurements were excluded to ensure the accuracy and reliability of the data.

Morphometric Measurements: All morphometric measurements were performed using a standardized protocol. Maximum clavicular length was measured using an osteometric board as the straight distance between the most medial point of the sternal end and the most lateral point of the acromial end. Angular measurements were obtained by tracing the contour of each clavicle on graph paper and identifying the deepest points of the medial and lateral curvatures. The medial angle, lateral angle, and total curvature angle were subsequently measured using a standard protractor.

The clavicle was further divided into medial, middle, and lateral segments for segmental analysis. Linear dimensions including segment lengths, widths, and depths were measured using a digital Vernier caliper with an accuracy of 0.01 mm. Width measurements were recorded at the sternal end, medial curvature, narrowest part of the shaft, conoid tubercle, and acromial end. Similarly, anteroposterior depths were measured at corresponding locations. Mid-shaft circumference was determined at the midpoint of the clavicular shaft using a flexible non-elastic measuring tape and was subsequently verified with caliper-based measurements whenever necessary. All measurements were obtained in millimeters except angular measurements, which were recorded in degrees.

Measurement Procedure: Prior to morphometric assessment, each clavicle was carefully oriented in the standard anatomical position on a flat horizontal surface. All measurements were obtained using predefined anatomical landmarks and standardized osteometric techniques described in anthropological literature. To minimize observational bias and ensure uniformity, all measurements were performed by the same investigator using identical measuring instruments throughout the study period. Each morphometric parameter was measured independently on three separate occasions, and the arithmetic mean of the three measurements was used for statistical analysis.

All measuring instruments were calibrated before the commencement of data collection and periodically throughout the study to ensure measurement accuracy and reproducibility.

Quality Assurance: To assess the reproducibility of the measurement protocol, a randomly selected subset of clavicles was remeasured by the same investigator after a two-week interval.

The repeated measurements demonstrated minimal variation, indicating good intra-observer

consistency and reproducibility. Standard anatomical landmarks and validated osteometric techniques described in previous anthropological and forensic studies were consistently followed throughout the investigation to ensure methodological uniformity and facilitate comparison with published literature.

Statistical Analysis: The collected data were entered into Microsoft Excel and subsequently analyzed using IBM SPSS Statistics version 26.0 (IBM Corporation, Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation (SD), minimum value, maximum value, and range. The normality of data distribution was assessed using the Shapiro–Wilk test. Comparisons between male and female clavicles were performed using the independent samples Student's t-test. Side-wise comparisons between right and left clavicles within each sex were also performed using the independent samples Student's t-test where appropriate. A p-value <0.05 was considered statistically significant.

Results

A total of 70 adult human clavicles were examined, comprising 35 male and 35 female specimens. Morphometric analysis demonstrated statistically significant sexual dimorphism in the majority of measured parameters.

Male clavicles exhibited greater dimensions than female clavicles across most linear measurements, indicating a more robust skeletal morphology in males.

The mean clavicular length was significantly higher in males (145.3 ± 4.2 mm) compared to females (131.6 ± 3.8 mm), with a mean difference of approximately 13.7 mm (Table 1). Side-wise analysis revealed that the left clavicle was marginally longer than the right in males, whereas in females the right clavicle was marginally longer than the left. The mean medial angle showed no statistically significant difference between males (154.1 ± 3.7°) and females (154.3 ± 3.5°), whereas the lateral angle was significantly greater in females (148.5 ± 3.3°) than in males (143.7 ± 3.4°). Consequently, the total curvature angle was significantly higher among female clavicles (302.8 ± 5.1°) compared with male clavicles (297.9 ± 5.0°) (Table 2).

Segmental analysis demonstrated significant sex-related differences in all three clavicular segments. The mean inner segment length was 56.6 ± 2.2 mm in males and 49.8 ± 2.1 mm in females. Similarly, the middle segment measured 53.9 ± 2.3 mm in males compared with 50.3 ± 2.0 mm in females, while the outer segment measured 37.2 ± 1.7 mm and 31.4 ± 1.5 mm in males and females, respectively (Table 2). These findings indicate consistently greater segmental dimensions among male clavicles.

Analysis of clavicular width measurements further demonstrated marked sexual dimorphism. The mean width at the inner end was significantly greater in males (22.5 ± 1.0 mm) than females (20.0 ± 0.9 mm). Likewise, the width at the inner angle, least width, and width at the outer end were significantly larger in males. The mean least width was 11.5 ± 0.6 mm in males compared with 9.3 ± 0.5 mm in females.

Although width at the conoid tubercle was slightly greater in males (14.3 ± 0.8 mm) than females (14.0 ± 0.7 mm), the difference was relatively small compared with other morphometric parameters (Table 2). Depth measurements followed a similar pattern. The mean depth at the inner end was 22.7 ± 1.1 mm in males and 19.7 ± 1.0 mm in females. At the midshaft, mean depth measured 10.0 ± 0.5 mm in males compared with 9.2 ± 0.4 mm in females.

Depth at the conoid tubercle and outer end also demonstrated significantly higher values in males than females (Table 2). Among all measured variables, mid-shaft circumference exhibited the most pronounced sexual dimorphism. Male clavicles showed a mean mid-shaft circumference of 37.8 ± 1.9 mm, whereas female clavicles demonstrated a mean value of 31.8 ± 1.5 mm, yielding a difference of approximately 6 mm between the sexes (Table 2). This parameter showed the highest discriminatory value for sex determination and emerged as the most reliable osteometric indicator in the present study.

Discussion

Sex determination from skeletal remains is one of the most important components of forensic identification and forms the basis for subsequent estimation of age, stature, and ancestry. Although the pelvis and skull remain the most reliable skeletal elements for sex assessment, isolated bones such as the clavicle become particularly valuable in cases involving fragmented, decomposed, or incomplete human remains [4–6]. The present study evaluated morphometric characteristics of 70 adult clavicles from a Kashmiri population and demonstrated significant sexual dimorphism in most of the measured parameters.

In the present study, male clavicles were significantly longer than female clavicles, with mean lengths of 145.3±4.2 mm and 131.6±3.8 mm, respectively. The observed difference of approximately 13.7 mm indicates substantial sexual dimorphism. These findings are comparable with those reported by Panuganti et al. [13] in a South Indian population, who documented mean clavicular lengths of 142.5 mm in males and 128.5 mm in females. Similar observations were reported

by Ramamurthi [11] from Coimbatore, Tamil Nadu, who found mean clavicular lengths of 13.78±0.73 cm in males and 12.90±1.03 cm in females. Likewise, Gour [14] from Maharashtra reported mean clavicular lengths of 14.42±0.70 cm and 12.70±0.02 cm in males and females, respectively. The consistency of these findings across geographically distinct populations supports the role of clavicular length as a reliable indicator of sexual dimorphism.

Table 1: Morphometric Measurements of Human Clavicles

Measurements	Male Right (n=18) Mean±SD	Male Left (n=17) Mean±SD	Male Total (n=35) Mean±SD	Female Right (n=18) Mean±SD	Female Left (n=17) Mean±SD	Female Total (n=35) Mean±SD
Length (mm)	144.8±4.0	145.8±4.3	145.3±4.2	132.0±3.9	131.2±3.7	131.6±3.8
Medial Angle (°)	152.1±3.4	156.2±3.8	154.1±3.7	154.0±3.5	154.6±3.6	154.3±3.5
Lateral Angle (°)	143.0±3.2	144.5±3.6	143.7±3.4	150.2±3.4	146.8±3.2	148.5±3.3
Total Curvature (°)	295.1±4.8	300.7±5.2	297.9±5.0	304.2±5.3	301.4±5.0	302.8±5.1
Inner Segment (mm)	56.9±2.4	56.2±2.1	56.6±2.2	49.5±2.0	50.2±2.1	49.8±2.1
Middle Segment (mm)	53.7±2.3	54.1±2.4	53.9±2.3	50.4±2.0	50.1±2.1	50.3±2.0
Outer Segment (mm)	37.6±1.8	36.8±1.7	37.2±1.7	31.6±1.5	31.2±1.6	31.4±1.5
Width at Inner End (mm)	22.3±1.1	22.7±1.0	22.5±1.0	20.2±0.9	19.8±1.0	20.0±0.9
Width at Inner Angle (mm)	12.7±0.8	12.4±0.7	12.6±0.7	10.0±0.6	9.8±0.6	9.9±0.6
Least Width (mm)	11.7±0.7	11.2±0.6	11.5±0.6	9.4±0.5	9.2±0.5	9.3±0.5
Width at Conoid Tubercle (mm)	14.5±0.9	14.2±0.8	14.3±0.8	13.9±0.7	14.1±0.8	14.0±0.7
Width at Outer End (mm)	19.8±0.9	20.2±1.0	20.0±0.9	17.3±0.8	17.1±0.8	17.2±0.8
Depth at Inner End (mm)	22.5±1.2	22.9±1.1	22.7±1.1	19.8±1.0	19.5±1.0	19.7±1.0
Depth at Middle (mm)	10.1±0.5	10.0±0.5	10.0±0.5	9.2±0.4	9.1±0.4	9.2±0.4
Depth at Conoid Tubercle (mm)	10.7±0.6	10.5±0.5	10.6±0.5	9.8±0.5	9.7±0.4	9.8±0.4
Depth at Outer End (mm)	10.8±0.6	10.6±0.6	10.7±0.6	8.3±0.4	8.1±0.4	8.2±0.4
Mid-shaft Circumference (mm)	38.2±1.8	37.4±1.9	37.8±1.9	32.0±1.4	31.6±1.5	31.8±1.5

Table 2: Comparison of Morphometric Measurements between Male and Female Clavicles

Parameter	Male (n=35) Mean±SD	Female (n=35) Mean±SD	p-value
Length	145.3±4.2	131.6±3.8	<0.001
Medial Angle	154.1±3.7	154.3±3.5	0.812
Lateral Angle	143.7±3.4	148.5±3.3	<0.001
Total Curvature	297.9±5.0	302.8±5.1	<0.001
Inner Segment	56.6±2.2	49.8±2.1	<0.001
Middle Segment	53.9±2.3	50.3±2.0	<0.001
Outer Segment	37.2±1.7	31.4±1.5	<0.001
Width at Inner End	22.5±1.0	20.0±0.9	<0.001
Width at Inner Angle	12.6±0.7	9.9±0.6	<0.001
Least Width	11.5±0.6	9.3±0.5	<0.001
Width at Conoid Tubercle	14.3±0.8	14.0±0.7	0.048
Width at Outer End	20.0±0.9	17.2±0.8	<0.001
Depth at Inner End	22.7±1.1	19.7±1.0	<0.001
Depth at Middle	10.0±0.5	9.2±0.4	<0.001
Depth at Conoid Tubercle	10.6±0.5	9.8±0.4	<0.001
Depth at Outer End	10.7±0.6	8.2±0.4	<0.001
Mid-shaft Circumference	37.8±1.9	31.8±1.5	<0.001

Analysis of clavicular curvature revealed relatively limited sexual variation compared with linear dimensions. The mean medial angle was 154.1±3.7° in males and 154.3±3.5° in females, showing no statistically significant difference. However, females demonstrated a greater mean lateral angle (148.5±3.3°) than males (143.7±3.4°), resulting in a higher total curvature in females (302.8±5.1°) compared with males (297.9±5.0°). Similar observations have been reported by Panuganti et al. [13], suggesting that angular parameters are less reliable than linear measurements for sex estimation and may have limited forensic utility when used independently.

Segmental measurements of the clavicle also exhibited marked sexual dimorphism. The mean medial segment measured 56.6±2.2 mm in males and 49.8±2.1 mm in females, while the middle

segment measured 53.9±2.3 mm and 50.3±2.0 mm, respectively. Similarly, the lateral segment measured 37.2±1.7 mm in males compared with 31.4±1.5 mm in females. These findings indicate that male clavicles are proportionately larger throughout their entire length rather than demonstrating enlargement confined to a particular region. Such differences may be attributed to greater skeletal growth and increased biomechanical demands associated with male musculature [1–3].

Width and depth measurements further confirmed significant sexual dimorphism. The mean width at the inner end was 22.5±1.0 mm in males compared with 20.0±0.9 mm in females, while the least width measured 11.5±0.6 mm and 9.3±0.5 mm, respectively. Likewise, the mean depth at the inner end was 22.7±1.1 mm in males and 19.7±1.0 mm in females. These findings are supported by the study of Ghorpade et al. [15], who examined 120 clavicles and reported significantly greater sternal end breadth in males (22.85±2.15 mm) than females (19.42±1.98 mm), along with larger acromial end breadth measurements in males (20.15±1.85 mm) compared with females (17.65±1.72 mm). The greater width and depth observed among males may reflect enhanced cortical bone deposition and adaptation to increased muscular loading [1–3].

Among all measured parameters, mid-shaft circumference demonstrated the highest degree of sexual dimorphism. The mean mid-shaft circumference in the present study was 37.8±1.9 mm in males and 31.8±1.5 mm in females, representing a mean difference of approximately 6 mm. This finding is in close agreement with the observations of Haque et al. [10] in a Nepalese population, who reported mean circumferences of 37.1 mm in males and 30.5 mm in females. Similarly, Shobha et al. [12] from North Karnataka documented values of 37.0 mm and 30.3 mm respectively. Earlier studies by Jit and Singh [8] in the Amritsar region and Singh and Gangrade [9] from Varanasi also demonstrated significantly greater mid-shaft circumferences in males than females. Terry [7], studying American White individuals, likewise reported comparatively larger clavicular dimensions among males. Despite population-based differences in absolute measurements, all studies consistently identify mid-shaft circumference as one of the most reliable osteometric parameters for sex determination.

The findings of the present study are further corroborated by Ghorpade et al. [15], who reported mean mid-shaft circumferences of 39.22±3.10 mm in males and 32.45±2.85 mm in females. Their discriminant function analysis demonstrated an overall classification accuracy of 86.7% using mid-shaft circumference alone and 88.3% when combined with clavicular length. These observations emphasize the superior discriminatory power of mid-shaft circumference and support its use as a primary parameter in forensic sex estimation.

The pronounced sexual dimorphism observed in the clavicle may be explained by genetic, hormonal, nutritional, and biomechanical influences. Testosterone promotes periosteal bone formation, increases muscle mass, and enhances cortical bone thickness, resulting in larger and more robust clavicles in males. Conversely, estrogen accelerates epiphyseal fusion and limits longitudinal skeletal growth, contributing to comparatively smaller clavicular dimensions in females. Furthermore, the clavicle serves as an attachment site for several powerful muscles, including the pectoralis major, deltoid, trapezius, sternocleidomastoid, and subclavius muscles. Greater mechanical loading generated by these muscles in males may stimulate bone remodeling and increase shaft circumference, thereby contributing to sexual dimorphism [1–3,14].

The minor differences observed between the present Kashmiri population and previously studied Indian, Nepalese, and Western populations may be attributable to variations in ethnicity, genetic background, nutritional status, occupational activity, socioeconomic factors, and environmental influences. Such population-specific variation highlights the necessity of developing regional osteometric standards rather than relying on discriminant functions derived from geographically distinct populations [10–15].

The present study possesses several strengths. It is the first osteometric investigation to comprehensively evaluate sexual dimorphism of the clavicle in the Kashmiri population using multiple morphometric parameters, thereby providing valuable region-specific baseline data for forensic anthropology, medico-legal practice, and clinical anatomy. Standardized osteometric techniques were employed for all measurements, minimizing observer-related variability and enhancing the reliability of the findings. Furthermore, the inclusion of a wide range of linear, angular, segmental, width, depth, and circumference measurements allowed a comprehensive assessment of clavicular morphology and facilitated comparison with previously published studies from different populations. However, certain limitations should be acknowledged. The study was conducted on a relatively small sample of dry adult clavicles obtained from a single institution, which may limit the generalizability of the findings to the entire Kashmiri population. Information regarding age, occupation, handedness, nutritional status, and lifestyle factors, which may influence clavicular

morphology, was not available. In addition, advanced statistical methods such as discriminant function analysis and validation using an independent external sample were not performed. Future studies involving larger multicentric samples, three-dimensional imaging techniques, and population-specific discriminant function models are warranted to improve the accuracy and applicability of clavicular morphometry for forensic sex estimation in the Kashmiri population.

Conclusion

The present study demonstrated significant sexual dimorphism in the clavicles of the Kashmiri population. Male clavicles exhibited significantly greater length, width, depth, and mid-shaft circumference than female clavicles. Among all measured parameters, mid-shaft circumference was found to be the most reliable indicator for sex determination. The findings may aid forensic anthropologists, anatomists, archaeologists, and medico-legal experts in identifying sex from isolated clavicular remains.

References

1. Standring S, editor. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 41st ed. London: Elsevier; 2016.
2. Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy. 8th ed. Philadelphia: Wolters Kluwer; 2018.
3. Drake RL, Vogl AW, Mitchell AWM. Gray's Anatomy for Students. 4th ed. Philadelphia: Elsevier; 2020.
4. White TD, Black MT, Folkens PA. Human Osteology. 3rd ed. San Diego: Academic Press; 2012.
5. Buikstra JE, Ubelaker DH, editors. Standards for Data Collection from Human Skeletal Remains. Fayetteville (AR): Arkansas Archeological Survey; 1994.
6. Bass WM. Human Osteology: A Laboratory and Field Manual. 5th ed. Columbia (MO): Missouri Archaeological Society; 2005.
7. Terry RJ. The clavicle of the American White and Negro. Am J Phys Anthropol. 1932;16(3):351-380.
8. Jit I, Singh S. The sexing of the adult clavicles. Indian J Med Res. 1966;54(6):551-557.
9. Singh S, Gangrade KC. The sexing of adult clavicles: Demarking points for Varanasi zone. J Anat Soc India. 1968;17:89-100.
10. Haque MK, Mansur DI, Krishnaswamy A, Karki RK, Sharma K. Morphometric analysis of clavicle in Nepalese population. Kathmandu Univ Med J (KUMJ). 2011;9(35):193-197.
11. Ramamurthi KS. Morphometric analysis of adult human clavicles in South Indian population. Int J Anat Res. 2016;4(3):2758-2762.
12. Shobha R, Suresh R, Shailaja S. Morphometric analysis of clavicle and its role in sex determination in North Karnataka population. Indian J Clin Anat Physiol. 2019;6(2):163-168.
13. Panuganti S, Reddy HM, Poojari M, Shrish P, Kumar JA. Morphometric analysis of adult human clavicles and assessment of sexual dimorphism in South Indian population. Int J Anat Res. 2022;10(3):8370-8375. doi:10.16965/ijar.2022.151.
14. Gour J. Sexual diamorphism of clavicle in Maharashtra population. Int J Acad Med Pharm. 2025;7(4):814-816. doi:10.47009/jamp.2025.7.4.153.
15. Ghorpade MV, Onkar DP, Tabhane MK, Matey SS. Comparative morphometric analysis of the clavicle in male and female human cadavers: Implications for forensic identification. Bioinformation. 2026;22(1):465-469.