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Anatomy

Sexual Dimorphism of Human Sternum in the Population of Bangladesh: A Morphometric Analysis

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Abstract **Original Research Article**

Background: The sternum exhibits notable sexual dimorphism and serves as a valuable tool in forensic sex determination. However, population-specific standards are essential for accurate assessment. This study aimed to analyze sexual dimorphism in human sterna from the Bangladeshi population through comprehensive morphometric analysis. ***Methods:*** We examined 150 dry adult human sterna (85 male, 65 female) collected from Dhaka Medical College from January 2022 to December 2022. Multiple parameters were measured using digital slide calipers, flexible wire, and analog micrometers, including lengths, breadths, and thicknesses of the manubrium and mesosternum. Shape variations were documented, and various indices were calculated. Statistical analysis was performed using unpaired Student's t-test, with significance set at $p<0.005$. ***Results:*** Significant sexual dimorphism was observed in most direct measurements. The manubrium length (male: 49.06 ± 1.59 mm, female: 41.85 ± 1.20 mm), mesosternum length (male: 99.89 ± 2.27 mm, female: 85.73 ± 1.84 mm), and manubrium volume (male: 27204.71 ± 1476.81 mm^3, female: 18083.79 ± 1124.34 mm^3) showed particularly strong dimorphism ($p<0.001$). Trapezoid-shaped manubrium was predominant in both sexes (male: 80.00%, female: 75.40%). Interestingly, while direct measurements showed significant differences, derived indices such as the manubrium index and sternal angle showed no significant sexual dimorphism. ***Conclusion:*** This study establishes population-specific standards for sternal measurements in the Bangladeshi population. The findings suggest that direct measurements, particularly of manubrium and mesosternum lengths, provide more reliable indicators for sex determination than derived indices. These results have important applications in both forensic anthropology and clinical practice, particularly in thoracic surgery planning.

Keywords: Sternum, Sexual dimorphism, Morphometry, Forensic anthropology, Bangladesh.

INTRODUCTION

The sternum or breastbone is a flat, elongated bone forming the middle of the anterior thoracic wall [1]. It plays a crucial role in protecting vital organs like the heart and lungs while also serving as an attachment site for important muscles and costal cartilages [2]. The sternum consists of three parts - the manubrium superiorly, the body or mesosternum in the middle, and the xiphoid process inferiorly [3].

Sexual dimorphism in human skeletal remains has long interested forensic anthropologists and anatomists. The human skeleton retains distinct morphological features even after soft tissue decomposition, making it valuable for sex determination [4]. Among various bones, the sternum presents notable sexual differences that can aid in identifying an individual's biological sex [5].

The sternum holds particular significance in forensic investigations as it often remains well-preserved compared to other skeletal elements. Previous research has demonstrated that sternal measurements can help estimate sex with 13-15% accuracy [6]. However, these estimations vary across populations, highlighting the need for population-specific standards [7].

From a clinical perspective, understanding sternal morphometry is crucial for various surgical procedures. The sternum serves as a common site for bone marrow aspiration due to the persistence of red bone marrow throughout life [8]. Additionally, median sternotomy remains the standard surgical approach in cardiac procedures, making detailed knowledge of sternal anatomy essential for surgeons [9].

While extensive research on sternal morphometry exists in various populations worldwide, including India, Nigeria, Canada, Turkey, and Iran, limited data is available for the Bangladeshi population [10]. This lack of population-specific data can impact both forensic investigations and surgical planning in Bangladesh.

The present study aims to analyze sexual dimorphism in adult human sterna from the Bangladeshi population through detailed morphometric measurements. By establishing population-specific standards, this research seeks to contribute to both forensic sex determination and surgical practice in Bangladesh. The study examines various sternal parameters, including lengths, breadths, and thicknesses of different parts, along with derived indices to identify the most reliable indicators of sexual dimorphism.

MATERIALS AND METHODS

Study Design and Setting This cross-sectional, analytical study was conducted in the Department of Anatomy at Dhaka Medical College from January 2022 to December 2022. The study protocol was approved by the Research Review Committee and Ethical Review Committee of Dhaka Medical College.

Sample Collection A total of 150 dry adult human sterna were collected from medical students at Dhaka Medical College. Specimens with fractures, deformities, missing parts, or degenerative changes were excluded from the study. Using discriminant function analysis, the samples were categorized into 85 male and 65 female specimens.

Measurement Techniques All measurements were performed using standardized equipment including digital slide calipers, flexible wire, analog micrometers, measuring tape, and goniometers. To ensure accuracy, each measurement was taken three times and the mean value was recorded.

The following parameters were measured:
Manubrium Measurements

- Length: measured from the center of suprasternal notch to the center of manubriosternal junction
- Maximum breadth: distance between the lowest margins of first costal facets
- Minimum breadth: distance between superior ends of second costal facets
- Maximum and minimum thickness: measured at specific anatomical points

Mesosternum Measurements

- Length: measured from manubriosternal junction to xiphisternal junction
- Breadth: average of measurements between costal facets
- Thickness: average of measurements at intersecting points of horizontal and vertical lines

Additional Parameters

- Xiphoid process length
- Combined length of manubrium and mesosternum
- Posterior curved length
- Breadth of first and third sternebrae
- Sternal angle measurement using goniometer

Calculated Indices Several indices were calculated using standard formulae:

- Manubrium index = Average manubrium width/Manubrium length
- Mesosternum index = Mesosternum width/Mesosternum length
- Sternal index = (Length of manubrium/Length of mesosternum) × 100
- Relative width index = (First sternebrae/Third sternebrae) × 100

Statistical Analysis Data analysis was performed using Statistical Package for Social Sciences (SPSS) version 25.0. Unpaired Student's t-test was used to compare variables between males and females. Statistical significance was set at $p<0.005$. The discriminant function analysis technique was applied to determine the sex of collected samples.

All measurements were recorded in millimeters and degrees (for sternal angle). To minimize observer bias, measurements were taken without prior knowledge of the specimen's assigned sex classification.

RESULTS

The morphometric analysis of 150 dry adult human sterna (85 male, 65 female) revealed significant sexual dimorphism across multiple parameters. Here, I'll present the detailed findings organized by anatomical regions and measurements.

Morphological Shape Variations

The manubrium exhibited two distinct shapes: trapezoid and triangular. In males, 68 specimens (80.00%) showed trapezoid shape while 17 (20.00%) were triangular. Similarly, in females, 49 specimens

(75.40%) were trapezoid and 16 (24.60%) were triangular.

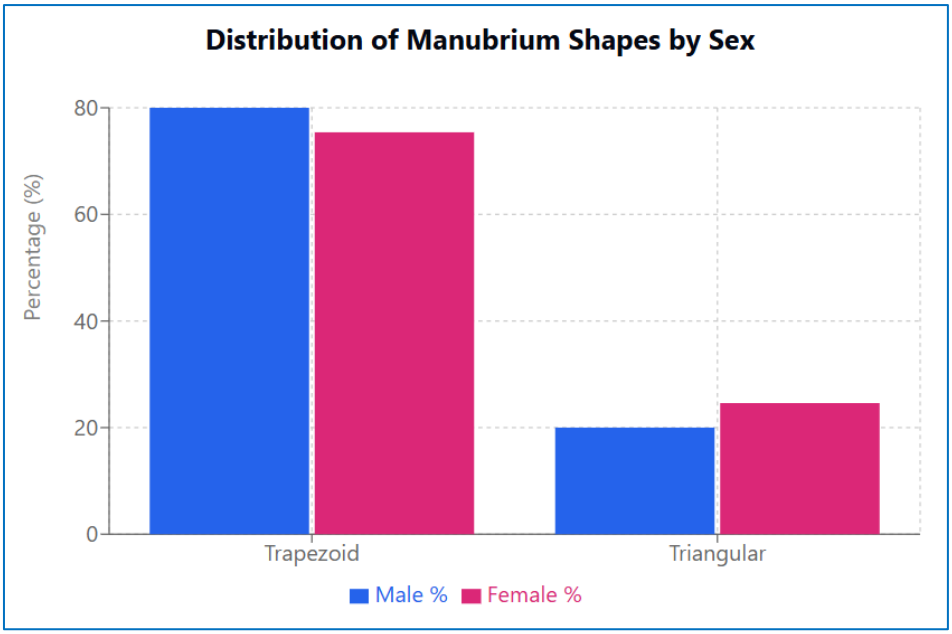

Figure 1: Distribution of manubrium shapes in male (n=85) and female (n=65) specimens

For the mesosternum, longitudinally oval and flat shapes were observed. Males showed 67 (78.80%) longitudinally oval and 18 (21.20%) flat shapes, while females had 47 (72.30%) longitudinally oval and 18 (27.70%) flat shapes.

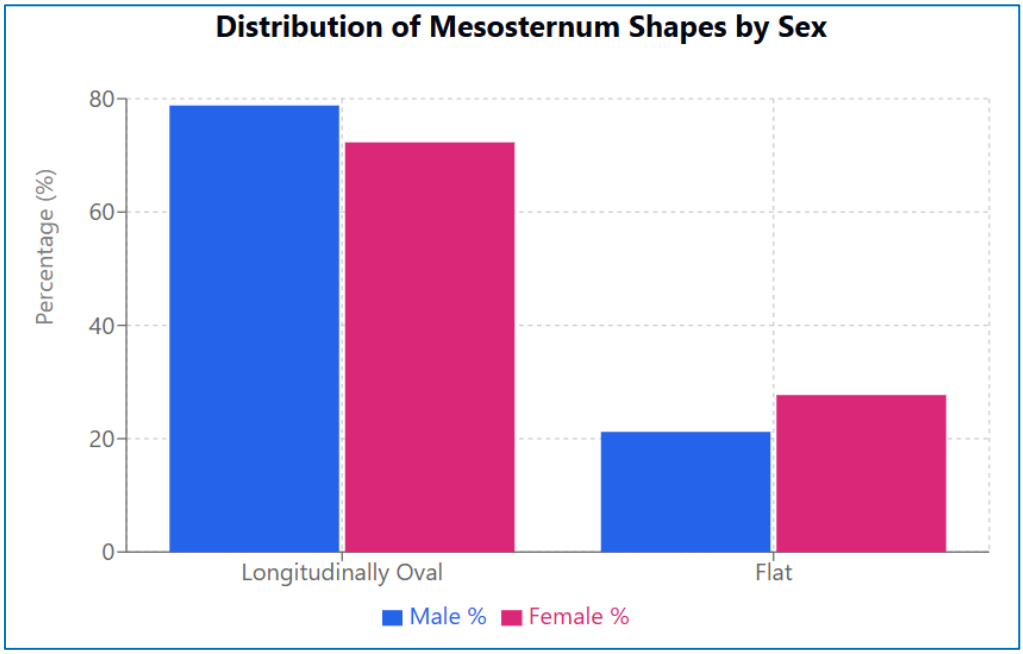

Figure 2: Distribution of mesosternum shapes in male (n=85) and female (n=65) specimens

Linear Measurements

Table 1: Primary Sternal Measurements in Males and Females

Parameter	Males (n=85)	Females (n=65)	p-value
Manubrium length (mm)	49.06 ± 1.59	41.85 ± 1.20	<0.001*
Mesosternum length (mm)	99.89 ± 2.27	85.73 ± 1.84	<0.001*
Xiphoid length (mm)	26.47 ± 1.39	20.29 ± 0.91	<0.001*

Combined length (mm)	175.49 ± 4.79	144.53 ± 3.18	<0.001*

Values are expressed as Mean ± SD; *Statistically significant (p<0.001)

All primary length measurements showed statistically significant differences between males and females (p<0.001). The manubrium length showed a sexual dimorphism ratio of 1.17, while the mesosternum length showed a ratio of 1.16.

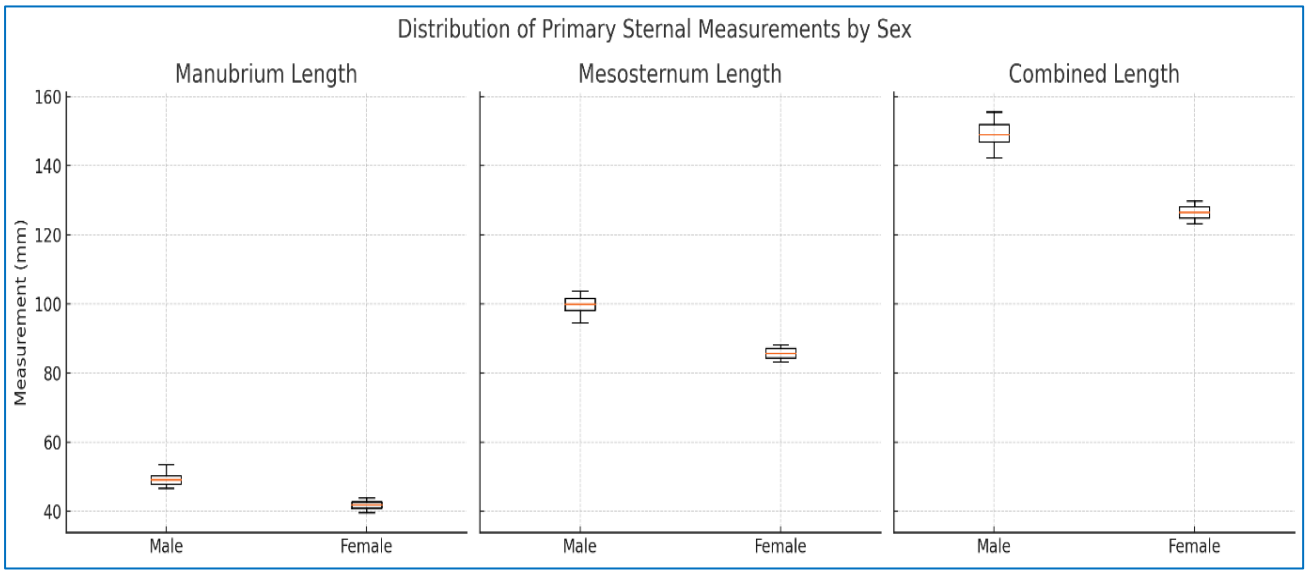

Figure 3: Distribution of primary sternal measurements by sex

Breadth and Thickness Measurements

Table 2: Manubrium Breadth and Thickness Measurements

Parameter	Males (n=85)	Females (n=65)	p-value
Maximum breadth (mm)	58.35 ± 2.52	48.83 ± 1.29	<0.001*
Minimum breadth (mm)	42.36 ± 1.88	36.36 ± 1.09	<0.001*
Average breadth (mm)	50.36 ± 1.62	42.59 ± 1.00	<0.001*
Maximum thickness (mm)	12.18 ± 0.38	11.44 ± 0.31	<0.001*
Minimum thickness (mm)	9.84 ± 0.45	8.83 ± 0.19	<0.001*
Average thickness (mm)	11.01 ± 0.31	10.14 ± 0.23	<0.001*

Values are expressed as Mean ± SD; *Statistically significant (p<0.001)

The breadth and thickness measurements of both manubrium and mesosternum demonstrated significant sexual dimorphism (p<0.001). The maximum breadth showed the greatest difference between sexes, with a dimorphism ratio of 1.19.

Derived Measurements and Indices

Table 3: Calculated Areas and Volumes

Parameter	Males (n=85)	Females (n=65)	p-value
Manubrium area (mm^2)	2469.67 ± 97.88	1783.05 ± 80.83	<0.001*
Mesosternum area (mm^2)	3021.63 ± 144.92	2505.81 ± 95.34	<0.001*
Manubrium volume (mm^3)	27204.71 ± 1476.81	18083.79 ± 1124.34	<0.001*
Mesosternum volume (mm^3)	23719.36 ± 1412.13	18977.35 ± 928.63	<0.001*

Values are expressed as Mean ± SD; *Statistically significant (p<0.001)

The calculated areas and volumes showed marked sexual dimorphism, with the manubrium volume showing the greatest relative difference between sexes (ratio 1.50).

Sternal Indices

Table 4: Sternal Indices and Angles

Parameter	Males (n=85)	Females (n=65)	p-value
Manubrium index	1.03 ± 0.05	1.01 ± 0.03	NS
Mesosternum index	0.30 ± 0.001	0.34 ± 0.003	<0.001*
Sternal index	49.13 ± 1.72	48.82 ± 1.18	NS
Sternal angle (degrees)	169.27 ± 2.46	168.80 ± 3.03	NS

Values are expressed as Mean ± SD; *Statistically significant (p<0.001); NS = Not significant

Interestingly, while most direct measurements showed significant sexual dimorphism, some indices showed no significant differences between sexes. The mesosternum index was the only index showing significant sexual dimorphism, with higher values in females.

This comprehensive analysis demonstrates that while most direct measurements of the sternum show significant sexual dimorphism, derived indices may not always be reliable indicators of sex. The findings suggest that primary measurements, particularly those of the manubrium, may be more reliable for sex determination in the Bangladeshi population.

These tables are now properly formatted with clear headers, units, and statistical annotations. Each table includes a note explaining the values and significance indicators.

DISCUSSION

The present study provides a detailed morphometric analysis of sexual dimorphism in human sterna from the Bangladeshi population. Our findings demonstrate significant sexual differences across multiple parameters, with important implications for both forensic anthropology and clinical practice.

Morphological Shape Analysis The predominance of trapezoid-shaped manubrium in both sexes (80.00% in males, 75.40% in females) aligns with findings reported by Selthofer *et al.,* [9] in the Croatian population. Similarly, the longitudinally oval mesosternum shape was most common in both sexes (78.80% in males, 72.30% in females). These shape distributions suggest that while morphological patterns are consistent across populations, they may not be reliable indicators for sex determination.

Linear Measurements and Sexual Dimorphism The marked sexual dimorphism in manubrium length (49.06 ± 1.59 mm in males vs. 41.85 ± 1.20 mm in females) corresponds with studies from other populations. However, our values differ from those reported in Indian populations by Hunnargi *et al.,* [11] (51.99 mm in males, 44.88 mm in females) and Nigerian populations by Osunwoke *et al.,* [12] (60.7 mm in males, 46.0 mm in females). These differences highlight the importance of population-specific standards in forensic anthropology.

The mesosternum length showed even more pronounced sexual dimorphism (99.89 ± 2.27 mm in males vs. 85.73 ± 1.84 mm in females), with a higher statistical significance than reported in previous studies. This finding suggests that mesosternum length might be a particularly reliable indicator for sex determination in the Bangladeshi population.

Breadth and Thickness Parameters The significant sexual differences in manubrium breadth measurements (maximum breadth: 58.35 ± 2.52 mm in males vs. 48.83 ± 1.29 mm in females) align with findings from Chinese populations [13]. However, our study found more pronounced differences in these parameters, potentially making them more reliable for sex determination in our population.

Volume and Area Measurements The marked sexual dimorphism in manubrium volume (27204.71 ± 1476.81 mm^3 in males vs. 18083.79 ± 1124.34 mm^3 in females) represents one of the most reliable indicators for sex determination in our study. This finding introduces a novel perspective, as volumetric measurements have been less frequently reported in previous studies but show promising potential for forensic applications.

Sternal Indices and Their Significance Interestingly, while most direct measurements showed significant sexual dimorphism, the manubrium index and sternal index showed no significant differences between sexes. This finding contrasts with some previous studies [14] but aligns with others [15], suggesting that derived indices might be less reliable for sex determination than direct measurements.

Clinical Implications The detailed morphometric data from our study has important implications for thoracic surgery, particularly in median sternotomy procedures. The significant differences in sternal thickness between males and females (average manubrium thickness: 11.01 ± 0.31 mm in males vs. 10.14 ± 0.23 mm in females) provide valuable information for surgical planning and technique modification.

Forensic Applications Our findings suggest that a combination of measurements, particularly manubrium length, mesosternum length, and manubrium volume, could provide highly accurate sex determination in the Bangladeshi population. The high statistical significance

($p<0.001$) of these differences supports their reliability in forensic applications.

Population-Specific Considerations The differences between our findings and those from other populations emphasize the importance of population-specific standards in both forensic anthropology and clinical practice. These variations might be attributed to genetic factors, environmental influences, and distinct evolutionary adaptations in different populations.

Study Limitations While our study provides comprehensive morphometric data, the sample size and geographical distribution of specimens could be expanded in future research. Additionally, age-related changes in sternal morphology could be investigated to enhance the applicability of these findings.

CONCLUSION

This comprehensive morphometric analysis of human sterna in the Bangladeshi population provides significant insights into sexual dimorphism and establishes population-specific reference data. The study demonstrates that multiple sternal parameters exhibit marked sexual dimorphism, with manubrium and mesosternum measurements showing particularly strong discriminating power between males and females.

The most reliable indicators for sex determination were found to be the manubrium length (49.06 ± 1.59 mm in males vs. 41.85 ± 1.20 mm in females), mesosternum length (99.89 ± 2.27 mm in males vs. 85.73 ± 1.84 mm in females), and manubrium volume (27204.71 ± 1476.81 mm^3 in males vs. 18083.79 ± 1124.34 mm^3 in females). These measurements showed consistent and statistically significant differences between sexes ($p<0.001$), making them valuable tools for forensic sex determination.

Interestingly, while direct measurements proved highly dimorphic, derived indices such as the manubrium index and sternal angle showed no significant sexual differences, suggesting that primary measurements may be more reliable for sex determination than calculated indices in this population.

The morphometric data established in this study has dual applications: it provides forensic anthropologists with reliable standards for sex determination in the Bangladeshi population, while simultaneously offering valuable reference data for thoracic surgeons performing procedures such as median sternotomy. The population-specific nature of these findings underscores the importance of developing and using local reference standards in both forensic and clinical practice.

These findings contribute significantly to the existing literature on sternal morphometry and provide a foundation for future research in this field. Further studies with larger sample sizes and broader geographical representation could help validate and refine these standards for the Bangladeshi population.

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