Original Article

Sex Determination Using Sternal Morphometry: Application of Discriminant Function Analysis and Hyrtl's Law in Forensic Anthropology

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Abstract

Background: Sex determination is crucial in forensic anthropology, especially for fragmented remains. The sternum, with its distinct sexual dimorphism, serves as a key parameter for estimation. This study measured the manubrium, mesosternum, and their combined length, analyzing the data statistically. The reliability of discriminant function analysis and Hyrtl's Law in classifying male and female sterna was assessed. **Materials and Methods:** A total of 78 human sterna (33 males, 45 females) were analyzed. The length of the manubrium (X1), mesosternum (X2), and their combined length (X3) were measured and compared between sexes. Discriminant function analysis was applied to classify sterna. **Results:** Males exhibited significantly greater mesosternum length (mean: 109.4 mm) and combined length (mean: 155.6 mm) than females (103.9 mm and 148.2 mm, respectively; $p < 0.05$), while manubrium length showed no significant difference. The Manubrio-Corpus Index was not a reliable discriminator ($p = 0.123$). Discriminant function analysis demonstrated moderate diagnostic accuracy, with sensitivity of 58.9% and specificity of 69.2%, indicating greater reliability in classifying male sterna. The PPV was 86.03%, suggesting a high probability of correctly identifying male sterna, while the NPV was 40.3%, reflecting lower certainty in female classification. Hyrtl's Law showed a high conformity in males (87.87%) but was less applicable to females (24.4%), reinforcing the presence of sexual dimorphism in sternal morphology. **Conclusion:** The findings confirm consistent sexual dimorphism in sternal morphology, with male sterna exhibiting greater classification accuracy. While discriminant function analysis proves effective, its reliability in female classification remains limited, necessitating population-specific reference standards.

Keywords: Sternal morphology, sex determination, discriminant function analysis, Hyrtl's Law, forensic anthropology, skeletal dimorphism.

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Introduction

The determination of sex from skeletal remains plays a vital role in forensic investigations, particularly when dealing with unknown, decomposed, or fragmented human bodies. Accurate identification of sex, along with age estimation, is crucial in medico-legal cases and bioarchaeological research. When a complete skeleton is available, sex can be identified with nearly 100% accuracy. However, when only the skull or pelvis is present, the accuracy drops to approximately 90%. In cases where neither of these structures is available, sex determination becomes significantly more challenging, relying on secondary skeletal elements such as the sternum (İşcan, 1986).[1] The sternum, a flat bone of the anterior thoracic wall, has been widely studied for its potential role in sex estimation due to its resistance to decomposition and putrefaction over time (Ashley, 1956).[2] Early research on sternal morphometry dates back to Wenzel (1788), who first observed sexual dimorphism in the ratio between the lengths of the manubrium and mesosternum. Subsequent studies by Fiegel (1837), Ashley (1956) and Osunwoke E et al., (2010) further validated these findings, establishing the sternum as a reliable indicator for sex determination.[2-4] Ashley's "Rule of 149" proposed that if the combined length of the manubrium and mesosternum exceeded 149 mm, the sternum belonged to a male; if less than 149 mm, it belonged to a female.[2] However, this rule was found inapplicable to African populations, leading to the introduction of the "Rule of 136" (Ashley, 1956).[2] The anatomical structure of the sternum consists of three main components: the manubrium (prosternum), the body (mesosternum), and the xiphoid process (metasternum). The mesosternum, composed of four sternebrae, plays a key role in forensic analysis due to its measurable differences between sexes. Generally, male sterna are longer (approximately 17 cm) compared to female sterna, and the ratio of manubrial to mesosternal length differs significantly between the sexes (Sharma 2019).[5] Furthermore, the sternum exhibits a highly vascular trabecular bone structure encased in a compact cortical layer, with the manubrium being the thickest part. It also contains red bone marrow, which may persist throughout life (Jaiswal R et al., 2019).[4] Numerous studies have examined sexual dimorphism in the sternum across

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different populations, including American, African, and European groups, as well as regional Indian populations such as North Indian, Maharashtrian, and Gujarati cohorts.[4,5] Despite some variations, the sternum remains a valuable skeletal element for sex estimation, particularly in forensic and anthropological contexts where other primary bones are absent. Given its forensic significance, this study aims to analyze the morphometric variations of the sternum for sex determination, contributing to the refinement of existing methods and improving accuracy in forensic casework.

Materials and Methods

This study was conducted on human sterna obtained at the Department of Anatomy, Government Medical College (GMC), Srinagar. A total of 78 human sterna were included in the study, comprising 45females and 33 male specimens. These samples were selected based on specific inclusion and exclusion criteria to ensure the accuracy and reliability of the findings.

Inclusion Criteria:

- Sterna obtained from cadavers or autopsy cases with no visible pathological deformities.
- Specimens from individuals aged 10 years and above to ensure complete skeletal development.

Exclusion Criteria:

- Deformed, diseased, or fractured sterna.
- Specimens exhibiting any anomalies that could interfere with accurate morphometric assessment.

The sternum was carefully excised from the cadavers by sectioning the costal cartilages near the costo-chondral junction to ensure complete and intact removal of the bone. The extracted sterna were then cleaned and prepared for morphometric analysis. The following measurements were recorded using a Vernier caliper, ensuring precision in millimeters:

Length of Manubrium (M) (X1): The distance from the suprasternal notch to the manubrio-mesosternal junction in the midline.

Length of Mesosternum (B) (X2): The distance from the manubrio-mesosternal junction to the mesosterno-xiphoidal junction in the midline.

Combined Length of Manubrium and Mesosternum (X3): The sum of the lengths of the manubrium and mesosternum (M + B).

Manubrio-Corpus Index (X6): Calculated using the formula:

X6= (Length of Mesosternum (B)/Length of Manubrium (M)) ×100.

All measurements were taken using a Vernier caliper, a precise instrument designed for measuring internal, external, and depth dimensions. The caliper provides both metric and English scales, allowing for accurate assessment of sternum dimensions. To minimize interobserver error, all measurements were taken by the same examiner and recorded twice to ensure reliability and consistency. The collected morphometric data were analyzed statistically to determine the differences between male and female sterna. Descriptive statistics, including mean and standard deviation, were calculated for each parameter. We applied the independent t-test after confirming that all assumptions were met. Additionally, discriminant function analysis was performed using Wilks'Lamda formula to classify male and female sterna based on key morphometric measurements.

Results

In this section, the results of the study will be described.

Table 1 A: Various Length Measurements (mm) of the Sterna in Males and Females

Parameter	Male (Mean ± SD)	Range (mm)	Female (Mean ± SD)	Range (mm)	p-value	Cases in Overlapping Zone (%)
Length of Manubrium (X1)	47.5 ± 5.9	35 – 61	44.8 ± 6.9	33 - 55	0.073	Male: 7 (15.6%) Female: 24 (72.7%)
Length of Mesosternum X2)	109.4 ± 12.1	88 – 130	103.9 ± 11.5	70 - 126	0.044*	Male: 13 (28.8%) Female: 23 (69.7%)
Combined Length (X3)	155.6 ± 15.2	125 – 182	148.2 ± 15.9	102 - 168	0.042*	Male: 18 (40.9%) Female: 15 (45.45%)

[Table 1] presents various measurements of the sternum in males and females. The length of the manubrium (X1) ranged from 35–61 mm in males and 33–55 mm in females, with mean values of 47.5 mm and 44.8 mm, respectively. The length of the mesosternum (X2) was significantly greater in males (mean: 109.4 mm) compared to females (mean: 103.9 mm, p = 0.044). Similarly, the combined length of the manubrium and mesosternum (X3) was higher in males (mean: 155.6 mm) than in females (mean: 148.2 mm, p = 0.042).

Table 1B: Comparison of Manubrio-Corpus Index (X6) Between Males and Females

Parameter	Male (Mean ± SD)	Range (mm)	Female (Mean ± SD)	Range (mm)	p-value	Cases in Overlapping Zone (%)
Manubrio-Corpus Index (X6)	44.1 ± 7.8	32 - 61	41.5 ± 6.9	32.5 - 53	0.123	Male: 4 (8.8%) Female: 6 (18.1%)

The Manubrio-Corpus Index (X6) showed no significant difference between sexes (p = 0.123). The percentage of cases in the overlapping zone varied across parameters, with higher overlap observed in females, particularly for X1 (72.7%) and X2 (69.7%), compared to males. The statistical analysis of sterna based on Hyrtl's Law revealed a notable difference between male and female specimens.

Among the 33 male sterna, 29 (87.87%) conformed to Hyrtl's

Law, whereas only 11 (24.4%) of the 45 female sterna exhibited compliance (fig 1). This indicates a significantly higher adherence to Hyrtl's Law in male sterna compared to female sterna, suggesting a potential sexual dimorphism in sternal morphology.

Table 2: Showing age group wise and sex wise distribution of total cases

Age Group (Years)	I (10-20)	II (20-30)	III (30-40)	IV (40-50)	V (50-60)	VI (60-70)	VII (70-80)	Total
Male Sternum	8	10	8	2	4	1	0	33
Female Sternum	10	15	9	6	1	2	1	45
Total	18	25	17	8	5	3	2	77

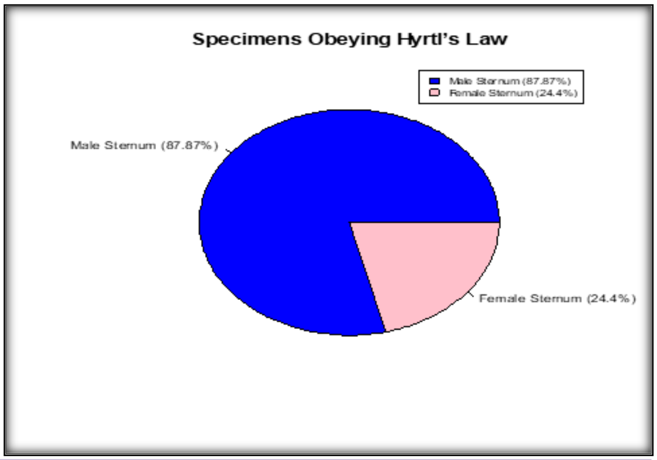

Figure 1: Specimen Obeying Hyrtl's Law

[Table 2] depicts the distribution of sterna across different age groups indicated that the majority of specimens were from younger individuals, particularly in the 20-30 years and 10-20 years' age groups. This trend suggests that sternal specimens from older individuals were less commonly available, likely due to factors such as decreased preservation, lower autopsy rates, or natural population demographics. A comparison between sexes shows that female sterna were more frequently observed than male sterna (45 vs. 33), with the highest representation in the 20-30 years' age group (15 cases in females vs. 10 in males). In contrast, male sterna were less frequently represented in older age groups, with no cases in the 70-80 years' category. This suggests a possible age-related decline in the availability of male specimens.

Table 3A: Combined Length of the Sternum in Males

Interval of Sternum (mm)	Male Sternum (Frequency)
105 – 114	1
115 – 124	3
125 – 134	5
135 – 144	5
145 – 154	8
155 – 164	10
165 – 174	1
Total	33

Table 3B: Combined Length of the Sternum in Females

Interval of Sternum (mm)	Female Sternum (Frequency)
95 – 104	3
105 – 114	1
115 – 124	2
125 – 134	4
135 – 144	14
145 – 154	11
155 – 164	10
Total	45

The combined length of the sternum in males and females showed a distinct distribution across different length intervals [see Table 3A and 3B]. In males, the majority of specimens (10 cases) fell within the 155–164 mm range, followed by 145–154 mm (8 cases). In contrast, female sterna were more frequently observed in the 135–144 mm (14 cases) and 145–154 mm (11 cases) intervals. Notably, female sterna tend to be shorter, with some specimens in the 95–104 mm range, which was absent in males as shown in [Table 3A]. This distribution highlights a general trend of longer sternum lengths in males compared to females.

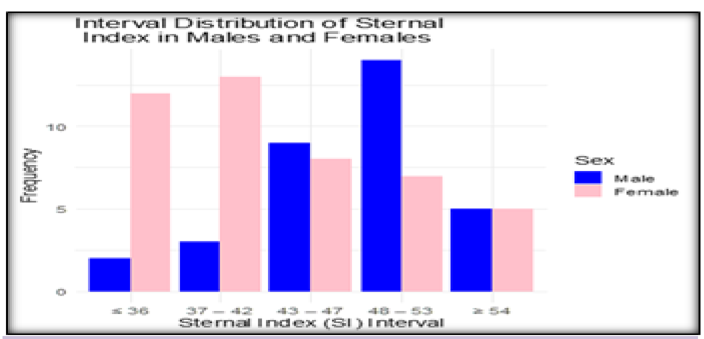

Figure 2: Interval Distribution of Sternal Index in Males and Females

Among the male specimens (n = 33), the majority (14 cases) fell within the SI interval of 48–53, followed by 9 cases in the 43–47 range, 5 cases in the ≥54 range, 3 cases in the 37–42 range, and only 2 cases in the ≤36 range. In contrast, among the female specimens (n = 45), the highest number (13 cases) was observed in the 37–42 range, followed by 12 cases in the ≤36 range, 8 cases in the 43–47 range, 7 cases in the 48–53 range, and 5 cases in the ≥54 range [Figure 2]. This distribution suggests that males tend to have a higher sternal index compared to females.

Discriminant function analysis was conducted to distinguish between male and female sterna using specific sternal measurements, following Wilks' formula. The centroid for males in the discriminant function analysis was determined as the mean of the discriminant function scores for all male cases. The discriminant function score (D) for each male case was calculated using the following equation:

$D=(2.348\times X1) + (2.697\times X2) + (-3.302\times X3)$

X_1 = Manubrium length

X_2 = Mesosternum length

X_3 = Combined length of the manubrium and mesosternum

The centroid for males was determined by calculating the mean of all discriminant function scores for the male group, using the formula:

Male centroid= $\frac{\Sigma D_m}{N_m}$

where N_m represents the total number of male cases. A similar approach was applied to the female group to compute the female centroid. The cut-off centroid, serving as the classification threshold, was calculated as the average of the male and female centroids:

Cut-off centroid = { -0.049+ (-0.120)}/2=-0.08

A sternum with a discriminant function score greater than −0.08-0.08 was classified as male, while a scoreless than −0.08- was classified as female. The diagnostic performance of the discriminant function analysis was assessed by calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The analysis demonstrated a sensitivity of approximately 58.9%, indicating the proportion of correctly identified male sterna, and a specificity of around 69.2%, representing the proportion of correctly classified female sterna. Additionally, the positive predictive value (PPV) was 86.03%, reflecting the probability that a sternum classified as male truly belonged to a male, while the negative predictive value (NPV) was 40.3%, indicating the probability that a sternum classified as female was truly from a female. These results highlight the discriminant function's ability to distinguish between male and female sterna with moderate accuracy.

Discussion

The present study provides valuable insights into the morphometric variations of the sternum, specifically focusing on the lengths of the manubrium, mesosternum, and their combined measurement in males and females. Our findings indicated that the mean length of the manubrium in males was 47.5 mm, while in females, it was slightly lower at 44.8 mm. The mesosternum exhibited a mean length of 109.4 mm in males and 103.9 mm in females, with a total sternum length (manubrium + mesosternum) measuring 155.6 mm in males and 148.2 mm in females as shown in [Table 4].

Table 4: Comparative Analysis of Sexual Dimorphism in Sternal Measurements by Different Researchers

Authors	Sex (M-Male, F-Female)	No. of Specimens	Manubrium (M) Mean Length (mm)	Diff in Mean (mm)	Mesosternum (B) Mean Length (mm)	Diff in Mean (mm)	Manubrium + Mesosternum (M+B) Mean Length (mm)	Diff in Mean (mm)
Present study (2025)	M	33	47.5	2.7	109.4	5.5	155.6	7.4
	F	45	44.8	-	103.9	-	148.2	-
Jaiswal R et al. (2019)	M	46	46.26	3.26	107.08	2.4	153.87	5.407
	F	19	43	-	104.68	-	147.68	-
Puttabanthi et al. (2012)	M	57	47.48	25.8	92.36	3.41	139.55	28.91
	F	22	21.68	-	88.95	-	110.64	-
Mahajan et al. (2009)	M	98	57.86	10.9	115.19	21.34	173.5	32.23
	F	55	46.96	-	93.85	-	140.82	-
Gautam et al. (2003)	M	56	53	5	95	19	149	25
	F	44	48	-	76	-	124	-
Dahipale et al. (2002)	M	96	48.42	4.64	94.43	24.23	142.82	29.32
	F	47	43.78	-	70.19	-	113.87	-
Jit et al. (1980)	M	312	51.73	3.31	95.35	16.75	147.08	20.06
	F	88	48.42	-	78.6	-	127.02	-
Ashley (1956) (European)	M	378	52.2	4.3	104.7	13.9	159.8	18.2
	F	168	47.9	-	90.8	-	138.7	-
Ashley (1956) (African)	M	85	45.9	1.7	96.5	13.6	142.6	15.5
	F	13	44.2	-	82.9	-	127.1	-
Paterson (1904)	M	310	52	4.7	103.7	12.7	-	-
	F	126	47.3	-	91	-	-	-
Dwight (1890)	M	142	53.7	4.3	110.4	18.5	164.1	22.8
	F	86	49.4	-	91.9	-	141.3	-
Strauch (1881)	M	200	-	-	110	20	-	-
	F	-	-	-	90	-	-	-
Dwight (1881)	M	30	51.8	5.1	105.9	16.5	-	-
	F	26	46.7	-	89.4	-	-	-

These findings align with the well-documented pattern of sexual dimorphism, where males consistently exhibit longer sternum components than females. When compared to Jaiswal et al. (2019), who reported a mean manubrium length of 46.26 mm in males and 43.0 mm in females, our study demonstrates slightly higher values for both sexes.[4] Similarly, their mesosternum lengths (107.08 mm in males and 104.68 mm in females) were marginally lower than ours. However, the consistency remains evident- males had greater sternal dimensions than females in both studies. The minor variations observed may be attributed to regional and genetic differences, as well as environmental influences. A more pronounced discrepancy was observed in the study by Puttabanthi et al. (2012), where they reported a significantly lower mean manubrium length in females (21.68 mm) compared to males (47.48 mm).[6] While their male values align closely with our findings, the exceptionally low female measurements deviate from the expected pattern and from other studies. This suggests possible methodological inconsistencies or anatomical variations specific to their study population. Despite this, the trend of males having greater sternal dimensions remains consistent across studies. Mahajan et al. (2009) reported notably higher sternal measurements, with the manubrium measuring 57.86 mm in males and 46.96 mm in females, and the mesosternum reaching 115.19 mm in males and 93.85 mm in females.[7] While the absolute values differ from our findings, the male-to-female ratio follows the same consistent trend of larger sternal dimensions in males. The variation in absolute measurements may be due to differences in genetic background, nutritional factors, or secular trends in skeletal growth. Further consistency was observed in studies conducted across different ethnic populations. Ashley (1956) reported a higher mean manubrium length in a European cohort (52.2 mm in males and 47.9 mm in females), while an African cohort exhibited measurements (45.9 mm in males and 44.2 mm in females) closer to our findings.[2] Similarly, Jit et al. (1980) documented manubrium lengths of 51.73 mm in males and 48.42 mm in females, which, although slightly higher, follow the established pattern of males having larger dimensions than females. Historical studies by Dwight (1890, 1881) and Strauch (1881) also support this trend.[9-11] Dwight (1890) recorded a mean mesosternum length of 110.4 mm in males, which is closely aligned with our findings, emphasizing the persistence of sexual dimorphism in sternal morphology over time.[9] While absolute measurements vary across different studies, the overarching trend of males having longer sternal components remains consistent across different populations, time periods, and methodological approaches. The observed differences across studies can be attributed to a combination of genetic diversity, ethnic variations, nutritional status, and secular trends in skeletal growth. Methodological variations, including sample selection and measurement techniques, may also contribute to the minor discrepancies in reported values. However, the consistency across studies in the male-female dimensional differences reinforces the robustness of sexual dimorphism in sternum morphology.

Table 5: Conformity to Hyrtl's Law in Sex Determination of the Sternum Across Various Studies

S. No	Observer	Year	Sex	No. of Specimens	% Obeying Hyrtl's Law
1	Present Study	2025	M	33	87.87%
			F	45	24.4%
2	Jaiswal R et al.	2019	M	46	89.13%
			F	19	21.05%
3	Puttabanthi et al.	2012	M	57	94.73%
			F	22	4.54%
4	Atal et al.	2008	M	56	89.20%
			F	44	75%
5	Dahipale et al.	2002	M	96	31.08%
			F	47	100%
6	Jit et al.	1980	M	312	52.20%
			F	88	88.64%
7	Narayan &Verma	1958	M	126	34.12%
			F	27	81.48%
8	Ashley (European)	1956	M	378	52.90%
			F	171	69.30%
9	Ashley (African)	1956	M	85	64.70%
			F	13	69.20%
10	Krause	1897	M	-	65%
			F	14	43%
11	Patermoller	1890	M	55	-
			F	33	-
12	Dwight	1890	M	142	59.10%
			F	86	60.40%

The present study assessed the applicability of Hyrtl's Law in determining the sex of the sternum and found that 87.87% of male sterna conformed to the law, whereas only 24.4% of female sterna followed the expected classification. These findings highlight a high accuracy of Hyrtl's Law in identifying male sterna but a lower reliability when applied to female sterna. Our results are consistent with those of Jaiswal et al. (2019), who reported a similar conformity rate of 89.13% for males, though their female conformity rate was slightly lower at 21.05%.[4] This suggests that while Hyrtl's Law effectively classifies male sterna across different populations, its applicability to female sterna remains inconsistent. A higher degree of male conformity was also observed in Puttabanthi et al. (2012) (94.73%) and Atal et al. (2008) (89.20%), further reinforcing the reliability of the law for male sternum classification.[6,12] However, Puttabanthi et al. reported an extremely low adherence of 4.54% in females, which is even lower than our findings.[6] This stark difference in female classification suggests potential anatomical variations among different populations and highlights the limitations of applying a single morphological criterion universally. Interestingly, Dahipale et al. (2002) reported 100% adherence among female specimens, a finding that contrasts sharply with most other studies, including ours.[13] This anomaly may be due to differences in sample selection, measurement techniques, or inherent population-specific morphological differences. Conversely, their male conformity rate was only 31.08%, suggesting a possible reversal of trends in that particular study population. Studies conducted in earlier decades, such as Jit et al. (1980), Ashley (1956), and Narayan & Verma (1958), presented mixed results.[2,8,14]. Jit et al. found that 52.20% of male specimens followed Hyrtl's Law, with a much higher female conformity rate of 88.64%, indicating a trend opposite to our findings.[8] Similarly, Ashley's European cohort (1956) showed 52.90% conformity in males and 69.30% in females, whereas his African cohort reported 64.70% in males and 69.20% in females.[2] These findings highlight the variability in sternal morphology across different ethnic backgrounds and reinforce the notion that Hyrtl's Law may not be universally applicable, particularly for female classification. The discrepancies observed across different studies may be attributed to several factors ethnic, genetic, nutritional, environmental factors variations, and methodological differences. These findings underscore the need for population-specific reference values and caution against the universal application of Hyrtl's Law in forensic and anthropological investigations. Further research with larger, ethnically diverse sample sizes and standardized measurement protocols is essential to refine the accuracy of sternal-based sex determination techniques.

The present study applied discriminant function analysis to classify male and female sterna using specific sternal measurements. A classification threshold of −0.08 was established, where sterna with discriminant function scores above this value were categorized as male, while those below it was classified as female. The analysis demonstrated a sensitivity of 58.9% and a specificity of 69.2%, indicating that male sterna were classified with relatively higher accuracy than female sterna. Additionally, the positive predictive value (PPV) was 86.03%, meaning that a sternum classified as male had a high probability of being truly male, while the negative predictive value (NPV) was 40.3%, reflecting a lower certainty in female classification. These findings emphasize the consistent diagnostic ability of discriminant function analysis in sex determination, particularly for male sterna, while highlighting the inherent challenges in accurately classifying female sterna. Our findings align closely with those of Jaiswal et al. (2019), who also employed multivariate discriminant analysis and correctly classified 61.5% of sterna using a classification threshold of −0.106.[4] The sensitivity in their study (56.5%) was slightly lower than ours (58.9%), while their specificity (73.7%) was marginally higher than ours (69.2%). These small differences suggest that both studies demonstrate moderate diagnostic accuracy, reinforcing the consistent performance of discriminant function analysis across different datasets. Notably, both studies observed that male sterna were classified with greater reliability than female sterna, which is a recurring pattern in sex classification research. Earlier studies, such as those by Penrose (1947) and Jit et al. (1980), reported significantly higher classification accuracies, where 89% of male and 82% of female sterna were correctly identified using multivariate analysis.[8,15] Compared to our sensitivity (58.9%) and specificity (69.2%), these older studies showed superior classification performance. The difference may be attributed to methodological variations, differences in sample selection, or population-specific skeletal morphology. Furthermore, secular trends in skeletal growth, influenced by nutrition, healthcare, and environmental factors, could contribute to the observed differences in classification accuracy between historical and contemporary studies. Similarly, Dahiphale et al. (2002) reported that on the application of multivariate discriminant analysis, their accuracy increased to 92% for males and 87% for females, which is significantly higher than the classification rates observed in our study and Jaiswal et al.'s study.[4,13] These results suggest that multivariate techniques consistently improve classification accuracy, but the extent of improvement may vary based on sample composition, genetic diversity, and measurement methodology. Across multiple studies, including ours, male sterna are consistently classified with greater accuracy than female sterna. This trend is largely due to sexual dimorphism, as male sterna exhibit greater robustness and predictable growth, whereas female sterna show more variability influenced by hormonal factors. Ethnic and population-specific differences further contribute to variations in classification accuracy, as seen in Ashley's (1956) study comparing European and African populations.[2] Methodological differences, including measurement techniques and sample selection, may also account for discrepancies, with older studies often reporting higher classification success due to more homogeneous samples. Additionally, secular trends in skeletal development, driven by changes in nutrition and lifestyle, may affect the applicability of historical classification models, highlighting the need for ongoing refinement in sex determination methods.

Conclusion

The present study reinforces the consistent sexual dimorphism in sternal morphology, with male sterna exhibiting greater classification accuracy than female sterna. Our findings align with previous research, demonstrating moderate diagnostic accuracy using discriminant function analysis, with greater reliability in identifying male sterna. While Hyrtl's Law effectively classified male sterna, its applicability to female classification remained inconsistent, reflecting trends observed in earlier studies. Variations in sample composition, ethnic diversity, measurement methodologies, and secular trends may contribute to discrepancies in classification accuracy across different populations. Among the parameters assessed, the length of the manubrium emerged as a strong discriminator for female sterna, while the combined length of the manubrium and mesosternum proved to be the most reliable parameter for sex determination. This combined measurement demonstrated the highest discriminatory power, reinforcing its utility in forensic and anthropological applications. Despite inherent challenges in female classification, the diagnostic consistency of discriminant function analysis underscores its relevance in forensic investigations. Future research should focus on population-specific reference standards, larger ethnically diverse samples, and refined statistical methodologies to enhance the accuracy of sternum-based sex determination.

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Conflicts of interest

There are no conflicts of interest.

References

1. Işcan MY. Osteometric analysis of sexual dimorphism in the sternal end of the rib. J Forensic Sci. 1985;30(4):1090-9. PMID: 4067537.
2. Ashley GT. The human sternum: the influence of sex and age on its measurements. Cape Times Limited; 1956.
3. Osunwoke E A, Gwunireama I U, Orish C N, Ordu K S, Ebowe I. A study of sexual dimorphism of the human sternum in the southern Nigerian population. Journal of Applied Biosciences 2010;26:1636-9.
4. Jaiswal R. Sternum as an index for determination of sex. Int J Anat Res. 2019;7(4.2):7070-9.
5. Sharma SV, Kumar N, Jahan S, Sharma HB. To Correlate the Age And Gender Between Living Female Children And Adult Through Measurement Of Different Segment Of Sternum Bone In North Population Of India. Int J Anat Res 2019,7(2.2):6556-60.
6. Puttabanthi S, Subhadra D, Tirupati R et al., Sexing of unknown adult human sterna by metrical analysis. Int J Biol Med Res. 2012;3(2):1516-9.
7. Mahajan A, Batra APS, Khurana BS, Sharma SS. Sex determination of human sterna in North Indians. J Punjab Acad Forensic Med Toxicol 2009;9(1):12–5
8. Jit I, Jhingan V and Kulkarni M. Sexing the human sternum. American Journal of Physical Anthropology 1980; 53:217-24.
9. Dwight T. The sternum as an index of sex and age. J Anat. 1881;15:327-30.
10. Dwight T. The sternum is an index of sex, height and age. Journal of Anatomy. 1890;24:527-35
11. Strauch M. Anatomische Untersuchungen über das Brustbein des Menschen mit besonderer Berücksichtigung der Geschlechtsverschiedenheiten: Inaug.-Diss. Universität Dorpat; 1881.
12. Atal DK, Murari A, Naik SK. Role of sternal index in determination of gender. Indian J. Forensic Med. Pathol. 2008;3:3-4.
13. Dahiphale V P, Baheete B H, Kamkhedkar S G. Sexing The Human Sternum In Marathwada Region. J Anat.Soc. India 2002;51(2):162-7.
14. Narayan D, Verma HC. 1958. Sternal index for male and female in U.P. Journal of Anatomical Society of India, 7: 71-2
15. Penrose LS 1947 Some notes on discrimination. Annals of Eugenics 13: 228-37.
16. Gautam RS, Shah GV, Jadav HR, Gohil, B.J. The Human Sternum – as An Index of Age & Sex. Anat. Soc. India 2003;52(1):20-23.
17. Paterson AM. The human sternum. Williams & Norgate; 1904.
18. Krause W. Ueber das weibliche sternum. Int Mschr Anat Physiol. 1897;14:21-6.