# An Autopsy Based Study of Sexual Dimorphism of Adult Human Sterna

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## Abstract

Creation of an individual's biological profile is of extreme importance and depends on age, sex and stature. The cranial and pelvic bones are important in identifying the sex of an individual. However, loss of complete bones or bones getting destroyed renders it impossible to use them for such estimations. However, since such sex-specific bones are hard to find at each and every scene, forensic experts are left with no choice but to depend on less sexually dimorphic elements of the human skeleton such as the sternum.

This study was conducted in subjects that were subjected to medicolegal autopsy. The deceased aged 18 years and above, of either sex, were included in study. The deceased with evidence of trauma and surgery to the anterior chest wall, generalized bone diseases, observable deformities over the sternum were excluded. The analysis of 300 sterna was carried out to study sexual dimorphism in sternum using different parameters such as width of suprasternal notch, width of sternum at level of fourth rib, posterior curved length of sternum, manubrio-corpus index and length of sternum.

***Key words*** *– Sexual dimorphism, sternal measurements, sternum.*

## Introduction

In forensic medicine, characterization of the biological profile of a deceased includes investigating the individual's age, sex, stature etc. Although pelvic and skull bones are known to be best identifiers of an individual's sex, relying on only these two bones for sexual dimorphism is limiting, considering their fragile nature or instances of their unavailability. Therefore, intensive research work has been performed and confirmed the potential use of sternum to detect sexual dimorphism. Moreover, manubrium and sternum are reported to have a high recovery rate as it resists the effects of putrefaction and decomposition for a long period of time.

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Sex estimation from sternal remains relies on factors of sexual dimorphisms, such as length and proportion differences of the manubrium, corpus sterni and combined length of manubrium and mesosternum between males and females.[1] Sexual dimorphism has been considered in sex estimation from sternum, specifically with the application of Hyrtl's law which stipulates the length of a female's manubrium to exceed half the length of the corpus sterni, while those of the male sterna are, at least double the manubrium length.[2] This study of sexual dimorphism in adult human sterna is also carried out to compare and analyse the sternal measurements among both genders.

## Materials and Method

This autopsy study was conducted in the mortuary at the department of forensic medicine, Topiwala National Medical College, Mumbai after obtaining permission from the institutional ethics committee.

This study was conducted in subjects that were subjected to medicolegal autopsy. The deceased aged 18 years and above, of either sex, were included in study.

The deceased with evidence of trauma and surgery to the anterior chest wall, generalized bone diseases, observable deformities over the sternum were excluded. During the period of November 2014 to August 2016, 150 (50%) sterna of males and 150 (50%) of females were studied. The preliminary data, in each case, was collected from the inquest report and hospital indoor paper records in admitted cases.

During the autopsy 'I' shaped incision was taken from chin to pubis symphyses. The skin over the chest, subcutaneous tissue under the skin and pectoralis muscles on both the sides was separated carefully. The clavicle was disarticulated from sternum and sternum was removed by cutting ribs by their costal cartilage. After removing the sternum from the thoracic cage, the sternal margins that articulate with the cartilages of the first seven pairs of ribs were carefully dissected. The sternum was washed and soft tissue was scraped and direct measurements were taken using a calibrated vernier calliper and measuring tape. After noting the measurements the sternum was placed back in the body. The xiphoid process was not taken into consideration in the present metric study to measure the length of sternum because of the high variability of its length.[3]

The following measurements were taken keeping the bone on a flat surface in anatomical positions:

1. Width of suprasternal notch (WS).
2. Width of sternum at level of 4th rib (WM4).
3. Posterior curved length of sternum (PCL).
4. Distance from suprasternal notch to manubrio-mesosternal junction in midline.(M)
5. Distance from manubrio-mesosternal junction to mesosternal-xiphoid junction in midline.(B)
6. Manubrio – corpus index (MCI) = M / B x 100
7. Length of sternum (in cm) = M+B

Baseline study participant characteristics were described using descriptive statistics like mean and standard deviations. The unpaired 't' test was used to compare the mean values between males & females. Discriminant functional analysis was done to examine the sexual dimorphism in the sternum and how the variables correctly assigned the bones to the proper sex.

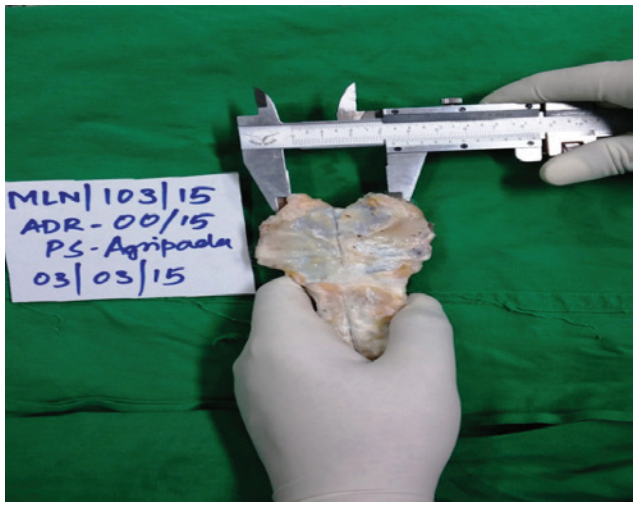


**Figure 1: Measurement of width of suprasternal notch (WS)**


**Figure 2: Measurement of Width of sternum at level of 4th rib (WM4)**

## Findings

**Table 1: Age and Sex-wise distribution**

| Gender | Min. Age (Years) | Max. Age (Years) | Mean Age (Years) | Standard Deviation |
|---|---|---|---|---|
| Males | 18 | 84 | 43.83 | 14.93 |
| Females | 19 | 90 | 39.98 | 18.92 |
| P = 0.0518, using unpaired t-test. | | | | |

In our study, the mean age of males was 43.83 ± 14.93 years and that of females was 39.98 ± 18.92 years.

**Table 2: Comparison of various measurements of sternum**

| Width of suprasternal notch (WS) | | | | | |
|---|---|---|---|---|---|
| Gender | Minimum (mm) | Maximum (mm) | Mean (mm) | Standard Deviation | P value using unpaired t test |
| Males | 20 | 45 | 30.67 | 4.96 | P = 0.0002 |
| Females | 21 | 43 | 28.61 | 4.32 | |
| Width of sternum at the level of 4th rib (WM4) | | | | | |
| Males | 22 | 48 | 33.25 | 5.60 | P < 0.0001 |
| Females | 22 | 40 | 30.19 | 4.56 | |
| Posterior curved length of sternum (PCL) | | | | | |
| Males | 124 | 185 | 140.37 | 12.90 | P = 0.0002 |
| Females | 115 | 185 | 135.1 | 11.09 | |
| Distance from suprasternal notch to manubrio-mesosternal junction in midline of sternum (M) | | | | | |
| Males | 34 | 65 | 42.58 | 5.74 | P = <0.0001 |
| Females | 35 | 60 | 46.06 | 4.66 | |
| Distance from manubrio-mesosternal junction to mesosternal-xiphoid junction in midline (B) | | | | | |
| Males | 83 | 140 | 97.40 | 10.79 | P = <0.0001 |
| Females | 75 | 120 | 87.72 | 8.40 | |
| Manubrio-corpus index (MCI) | | | | | |
| Males | 25 | 61.9047 | 43.91 | 5.32 | P = <0.0001 |
| Females | 40 | 70.5128 | 52.70 | 4.98 | |
| Distance from suprasternal notch to mesosternal-xiphoid junction in the midline (M+B) | | | | | |
| Males | 119 | 188 | 139.98 | 14.40 | P value <0.0001 |
| Females | 110 | 175 | 133.94 | 11.78 | |

The unpaired t-test indicates a significant difference in all the measurements of the sternum amongst males and females.

**Sensitivity and specificity results of parameters used for gender identification**

**Table 3: Sensitivity and specificity analysis of detection test**

| Variable | Cut-off (> for males) | Sensitivity | Specificity | ROC (AUC) & (95% CI) |
|---|---|---|---|---|
| WS | 29.5mm | 60% | 64% | 0.629 (0.566-0.693) |
| WM4 | 31.5mm | 62% | 68% | 0.659 (0.596-0.722) |
| PCL | 137.5mm | 52% | 67% | 0.628 (0.564-0.691) |
| M | NA | NA | NA | 0.297 (0.238-0.356) |
| B | 90.5mm | 63% | 69% | 0.773 (0.721-0.825) |
| MCI | NA | NA | NA | 0.097 (0.012-0.10) |
| M+B | 119.5mm | 99% | 90% | 0.935 (0.90-0.97) |
| The Receiver Operating Curve (ROC) plot values are area under curve (AUC) | | | | |
| > 0.90 = Excellent detective test<br>0.71 - 0.80 = Good detective test<br>0.51 - 0.60 = Poor detective test | | | 0.81 - 0.90 = Very good detective test<br>0.61 - 0.70 = Average detective test<br>≤0.50 = Not to be used as detective test | |

A mean WS in males (30.67 ± 4.96 mm) was more in comparison with that of females (28.61 ± 4.32 mm). In males, the largest WS noted was 45 mm while the smallest was 20 mm in length. In females, the largest observed WS was 43 mm and the smallest WS was 21 mm in length. Similar findings were reported by Mukhopadhyay[4], who studied 35 adult sterna in West Bengal, India, that WS was more in males than females. However he observed that the mean WS in males was 5.71 ± 0.39 cm and that of females was 4.79 ± 0.31 cm which was far greater than the mean WS observed in the present study. The ROC for WS was equal to 0.629 (95% confidence interval (CI) of 0.566-0.693) with 60% sensitivity and 64% specificity. Results of the present study showed that, if WS is greater than 29.5 mm, the cadaver is that of a male whereas if WS is <29.5 mm it belongs to a female.

The mean WM4 in the present study was greater in males (33.25 ± 5.60 mm) than females (30.19 ± 4.56 mm). The largest WM4 in males, was found to be 48 mm as compared to that in females which was 40 mm; while the length of the smallest WM4 was observed to be 22 mm in both the genders. The mean WM4 of males and females studied by Mukhopadhyay[4] were 5.3 ± 0.31 cm and 4.4 ± 0.33 cm respectively. Their findings were more than those found in present study. The ROC for WM4 was equal to 0.659 (95% CI of 0.596-0.722) with 62% sensitivity and 68% specificity. Results of present study showed that, if WM4 is greater than 31.5 mm, the cadaver belongs to a male and if WM4 is <31.5 mm it belongs to a female.

The mean PCL was greater in males (140.37 ± 12.90 mm) as compared to females (135.10 ± 11.09 mm). The maximum length of PCL observed in both the genders was same, i.e. 185 mm. However, the minimum length of PCL in males was noted to be 124 mm and that in females was 115 mm. However Mukhopadhyay[4] noted the mean PCL in males as 22.4 ± 1.01 cm; females as 17.92 ± 0.98 cm which are more than that observed in present study this might be due to regional and ethnic variations in population. The ROC for PCL was equal to 0.628 (95% CI of 0.564-0.691) with 52% sensitivity and 67% specificity. Results of present study showed that, if PCL is greater than 137.5 mm, the cadaver belongs to a male whereas if PCL is <137.5 mm it belongs to a female.

The mean length of manubrium (M) was greater in females (46.06 ± 4.66 mm) as compared to males (42.58 ± 5.74 mm). The distance from suprasternal notch to manubrio-mesosternal junction in midline of sternum ranged from 65 mm (maximum) to 34 mm (minimum) in males and from 60 mm (maximum) to 35 mm in females.

However, the findings observed were in contrast to previous studies where the lengths of the manubrium were reported greater in males rather than females.[1,5,6,7] This might be due to regional and ethnic variations in population. The ROC for length of manubrium was equal to 0.297 (95% CI of 0.238-0.356), hence it cannot be considered as a parameter for sexual dimorphism.

The mean mesosternum length (B) was greater in males (97.4 ± 10.79 mm) as compared to females (87.72 ± 8.4 mm). The distance from manubrio-mesosternal junction to mesosternal-xiphoid junction in midline of sternum ranged from 140 mm (maximum) to 83 mm (minimum) in males and from 120 mm (maximum) to 75 mm (in females). These results are in accordance with the studies of Gautam et al[7] (95 mm males; 76 mm in females), Dahiphale et a5[5] (94.427 mm in males; 70.191 mm in females) Ankit et al[6] (92.11 mm in males; 78.28 mm in females), Hunnargi et al[1] (89.17 mm in males; 72.38 mm in females), Ramadan et a8[8] (100.7 mm in males; 85.1 mm in males) and Puttabanthi et al[9] (92.36 mm in males; 88.95 in females). The ROC was equal to 0.773, with 95% confidence interval 0.721-0.825, showing mean mesosternum length can be considered as a good detective test with 63% sensitivity and 69% specificity. In agreement with previous studies and the results of present study, we agree that the length of mesosternum is a reliable parameter in determining the sex of a deceased.

A highest manubrio-corpus index of 61.91 in male cadavers and 70.51 in female cadavers; and the lowest observed manubrio-corpus index was 25 in male cadavers and 40 in female cadavers. The mean (SD) manubrio-corpus index in males was 43.91 (5.32) and that in females was 52.70 (4.98). Though the samples follow Hyrtl's law and statistically significant gender differences are obvious, sternal indices among males and females shows considerable overlapping. Therefore, the manubrio-corpus index (MCI) is not helpful when applied to detect sexual dimorphism of an individual specimen. Similar conclusions were reported by various researchers, viz. Hunnargi et a1[3], Dahiphale et al[5], Ankit et al[6], Puttabanthi et al[9]. On similar grounds, Ashley[10] and Jit et al[11] also reported the index to be 'unreliable'. Since the ROC for manubrio-corpus index was equal to 0.097 (95% CI of 0.012-0.10), hence it cannot be used as a detective test.

The mean combined length (M+B) observed in the present study was greater in males (139.98 ± 14.40 mm) than females (133.94 ± 11.78 mm). The maximum distance from suprasternal notch to mesosternal-xiphoid junction in midline of male cadavers was 188 mm and in female cadavers was 177 mm. The minimum distance from suprasternal notch to mesosternal-xiphoid junction in midline of male cadavers was 119 mm and in female cadavers was 110 mm. The results obtained in present study are in accordance with those reported by several previous studies.[1,5,6,7,8,9] According to results of present study, the distance from suprasternal notch to mesosternal-xiphoid junction in midline can be considered as an excellent detective test since the ROC curve was equal to 0.935 with 95% confidence interval of 0.90-0.97, 99% sensitivity and 90% specificity.

## Conclusion

Distance from suprasternal notch to mesosternal-xiphoid junction in midline i.e. sternal length can be considered as excellent detective test for sexual dimorphism from sternum. Parameters like width of suprasternal notch (WS), width of sternum at the level of 4th rib (WM4) and the posterior curved length of sternum (PCL) can be considered as average parameters for sexual dimorphism from sternum. Length of manubrium (M) and the manubrio-corpus index (MCI) are not helpful for sexual dimorphism.

It has been observed that detection of sexual dimorphism using sternum is subjected to population diversity. To obtain an excellent detective test to access sexual dimorphism of adult human sterna from different measurements of sternum, a detailed analysis in a larger sample size and closed Indian population is warranted.

**Abbreviations -**

WS - Width of suprasternal notch.

WM4 - Width of sternum at level of 4$^{th}$ rib.

PCL - Posterior curved length of sternum.

M - Distance from suprasternal notch to manubrio-mesosternal junction in midline.

B - Distance from manubrio-mesosternal junction to mesosternal-xiphoid junction in midline.

MCI - Manubrio – corpus index = M / B x 100

M+B - Length of sternum (in cm).

**Conflict of Interest** – None

**Source of Funding** – None

**Ethical Clearance** – Yes

## References

1. Hunnargi SA, Menezes RG, Kanchan T, Lobo SW, Binu VS, Uysal S, et al. Sexual dimorphism of the human sternum in a Maharashtrian population of India: a morphometric analysis. Leg Med 2008;10:6–10.
2. Dwight T. The sternum is an index of sex, height and age. Journal of Anatomy. 1890;24:527-35.
3. Snell RS. Clinical anatomy for medical students. 6th ed. Philadelphia: Lippincott Williams & Wilkins; 2000; p. 47-8.
4. Mukhopadhyay PP. Determination of sex from adult sternum by discriminant function analysis on autopsy sample of Indian Bengali population: A new approach. J Indian Acad Forensic Med 2010. 32(4): 321-4.
5. Dahiphale VP, Baheete BH, Kamkhedkar SG. Sexing the human sternum in Marathwada Region. J. Anat. Soc. India 2002; 51(2):162-7.
6. Adhvaryu AV, Adhvaryu MA, Rathod SP, Chauhan PR, Joshi HG. A study of sexual dimorphism in human sterna. International Journal of Medical Research & Health Sciences. 2013;2(3):577-81.
7. Gautam R, Jadhav G, Gohil B. The human sternum – as an index of age & sex. J Anat Soc India. 2003;52(1):20-3.
8. Uysal Ramadan S, Türkmen N, Dolgun N, Gökharman D, Menezes R, Kacar M et al. Sex determination from measurements of the sternum and fourth rib using multislice computed tomography of the chest. Forensic Science International. 2010;197(1-3):120.e1-120.e5.
9. Puttabanthi S, Velichety S, Padi TR, Boddeti RK, Priyanka JR. Sexing of unknown adult human sterna by metrical analysis. International Journal of Biological and Medical Research. 2012;3(2):1516-9.
10. Ashley G. A comparison of human and anthropoid mesosterna. Am J Phys Anthropol. 1956;14(3):449-65.
11. Jitindar I, Jhingan V, Kulkarni M. Sexing the human sternum. American Journal of Physical Anthropology. 1980;53:217-24.