



Study of Sexual Dimorphism of Human Sternum in Indian Population

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Abstract

Aim: To study the sternum and its anatomical pattern and variation in population to show the sternum as one of the bone of sexual dimorphism.

Material and Method: Two hundred and two adult human sternum of known age and sex were studied. Statistical analysis was done on the basis of length of manubrium, length of mesosternum, combine length of manubrium and mesosternum, breadth of first sternebra, breadth of third sternebra.

Result: After analysis of all statistically significant parameter, the percentage of identified bone for male was 89.7% and for female was 82.4%.

Conclusion: The study will be useful in deciding the sex of unknown sample in future and often required in medicolegal cases.

Key Words: Sternum, Sternebra, Mesosternum, Manubrium, Dimorphism.

Introduction

The study of sexual dimorphism in the morphology of skeletal remains is beneficial to multiple areas of biological anthropology. It is capable of throwing light upon the significant similarities and differences existing between individuals and groups by the study of sexual dimorphism. Determination of sex is one of the vital aspects for forensic medicine. Human body shows destructive effects of post mortem putrefaction and decomposition. The osseous skeleton is the only structure to resist this effect for long time. The human skeleton maintains its morphological features long after the soft tissues have been destroyed and are useful for sexing the

individual and its racial characteristics. When all the soft tissue have disappeared and only the skeleton remains, the sex of the unidentified bones must be determined by the presence of secondary sexual characteristics of the bones. Teeth and bones, being composed of tissue more resistant than any others to the effects of degradation are of utmost importance in the process and often serve as a key tool in forensic identification.

According to Parikh¹, reliable information can be obtained from specific bones like skull, hip bone, sacrum, first cervical vertebra, mandible, clavicle, sternum, long bones, ribs etc. The sexual dimorphism seen between the males and females in the anthropometry of body parts including the

soft tissue and bones can be explained by Stansfield's postulate of "evolutionary biology" (1977) which hypothesizes that the genotypic and phenotypic variance is inversely proportional to the intensity of stabilizing selection. This can explain the difference in the morphology of adult human males and females.

Almost all elements of human skeleton show some degree of sexual dimorphism and it is apparent that all the bones of skeleton do not have the same importance in determining the sex. In case of well-preserved complete skeleton, it is easy to identify the sex. But in badly preserved or scanty material, the chances of mistake increase greatly. Krogman²(1962) noted the accuracy of sex identification based on the study of complete skeleton and found it to be 100%, whereas the figures for the other bones were as follows:-

So according to Krogman²(1962) the accuracy of sexing of bony material is as follows

- | | | |
|----|-------------------|------|
| 1) | Entire skeleton - | 100% |
| 2) | Skull and pelvis- | 98% |
| 3) | Pelvis alone - | 95% |
| 4) | Skull alone - | 90% |
| 5) | Long bones - | 80% |

Taylor in his book of Medical Jurisprudence has stated that, the accuracy of sexing various bones using statistical analysis, is as follows

- | | | |
|----|-------------------|--------|
| 1) | Skull and femur - | 97.35% |
| 2) | Coccyx + sacrum - | 97.18% |
| 3) | Pelvis - | 95% |
| 4) | Skull alone - | 91.38% |
| 5) | Femur - | 39.84% |
| 6) | Atlas - | 31.18% |

From these findings one can determine the sex of unknown identity above 90% from skull, sacrum and pelvis. Thus from above knowledge none of bones can give 100% identification.

Material and Methods

In the present study, 202 adult human sterna of known sex were studied; which were dried and not having any damage anywhere on the bone. Bones selected were completely ossified; pathologically deformed and fractured bones were

discarded. Care was taken to avoid damage to the bones. The sampling data was made at random. Bones were obtained for study from various government medical colleges of Maharashtra.

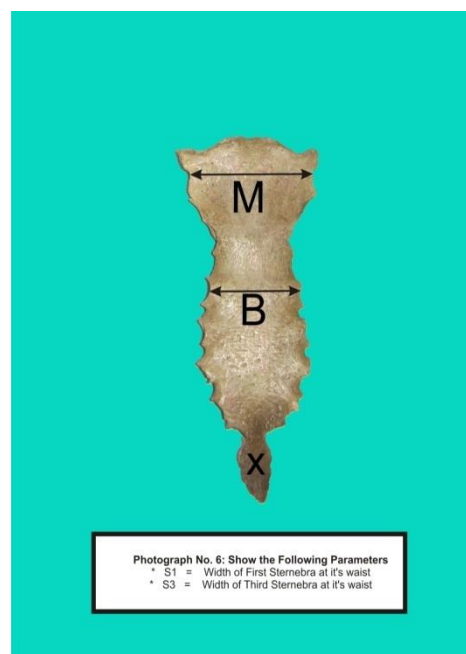
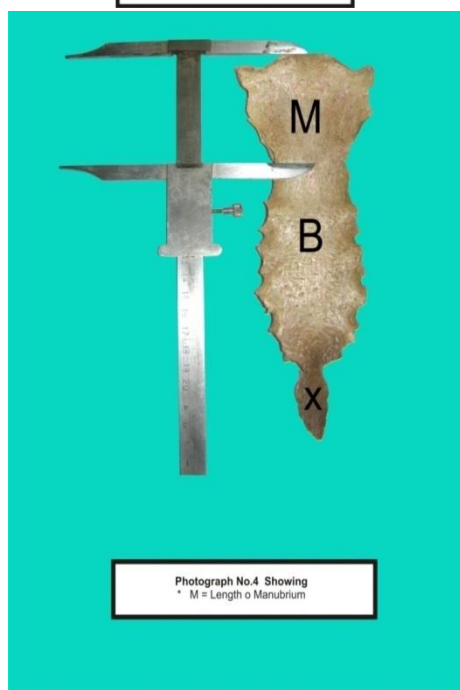
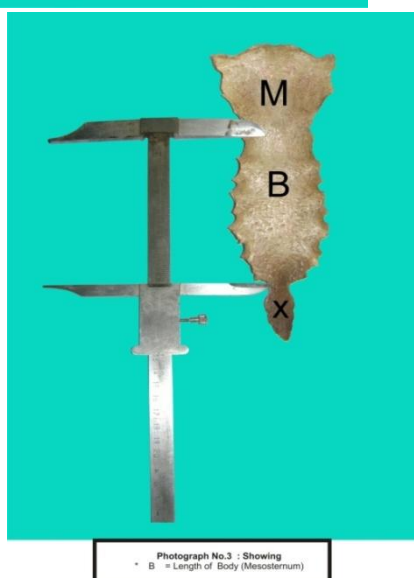
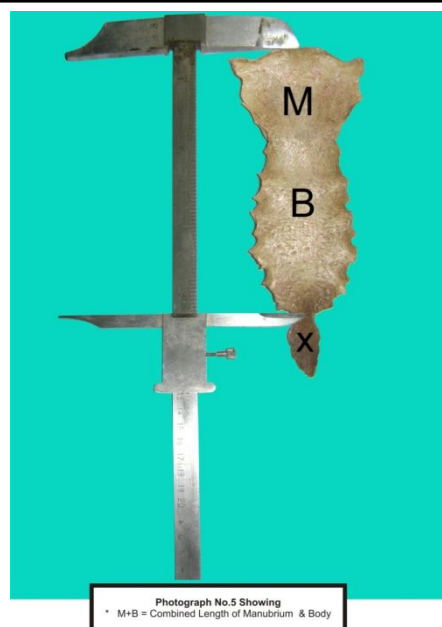
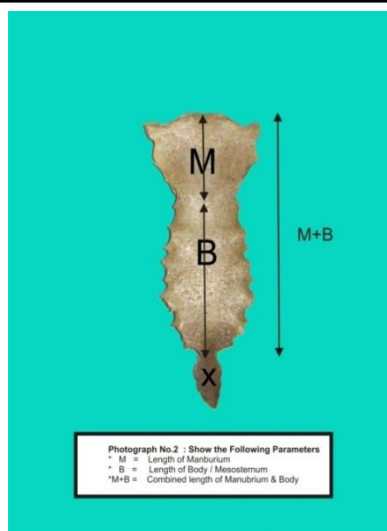
Instruments: Following instruments were used for present study:

- 1) Sliding Vernier Calliper.
- 2) Standardized flexible steel tape.

With the help of stainless steel Verniercalliper, various parameters considered in this study were measured personally and sufficient care was taken to avoid manual error. Metrical data from sternum was obtained and recorded in millimetres according to technique described below,

- 1) **M = Length of manubrium (X_1)** - With the help of Verniercalliper length of manubrium was measured from suprasternal notch to manubrio-mesosternal junction in midline.
- 2) **B = Length of mesosternum (X_2)** - With the help of Verniercalliper length of mesosternum was measured from manubrio-mesosternal junction to meso-xiphoid junction in the midline.
- 3) **M+B = Combined Length of manubrium and mesosternum (X_3)**
- 4) **S_1 = Breadth of first sternebra at its waist (X_4)**
With the help of Verniercalliper breadth of first sternebra was taken at its waist.
- 5) **S_3 = Breadth of third sternebra at its waist (X_5)**
With the help of Verniercalliper breadth of third sternebra was taken at its waist.

Data obtained was analysed statistically and 't' test was applied to see if sexual differences in the means were significant or not. From the obtained values, demarking points were calculated on the lines of Jit I and Singh(1966) and percentage of bones identified in relation to each parameter.



Observations

Two hundred and two human sterna were studied in the present study. The data obtained was analyzed statistically to find out the mean, standard deviation, calculated range, demarking point, identification point and the percentage beyond demarking and identification point. 't' test is applied. The results of observed values of each parameter are shown in tables 1 to 5 respectively. All the parameters were taken in millimeters.

Table No. 1: Statistical analysis of length of Manubrium.

| Sr. | Statistical Measurements | Male | Female | t test |
|-----|-----------------------------------|-----------|-----------|--------------------------------------|
| 1 | Number of cases | 117 | 85 | 10.3 P<0.01 Highly significant |
| 2 | Mean | 51.44 | 43.93 | |
| 3 | S.D. | 4.74 | 5.54 | |
| 4 | Range | 42-71 | 31-56 | |
| 5 | Calculated Range (Mean \pm 3SD) | 37.2-65.7 | 27.3-60.6 | |
| 6 | Demarking Point | > 60.6 | <37.2 | |
| 7 | % Beyond Demarking Point | 3.41% | 14.11% | |

Demarking point for male sternum is > 60.6mm and that for female sternum is < 37.2mm. On the basis of demarking point only 3.41% male sternum and 14.11% of female sternum can be identified with 100% accuracy. Ashley³(1956) observed that the difference in the mean length of manubrium in male and female sterna was 1.7mm in African and 4.3mm in European sterna. If the length of manubrium is above 60.6mm, the bone is male and below 37.2mm it is female. 37.2 – 60.6mm is the range of overlap where the sex could not be determined. 3.41% male and 14.11% female sterna do not overlap hence could be identified.

Table No. 2: Statistical analysis of length of Mesosternum

| Sr. | Statistical Measurements | Male | Female | P value |
|-----|-----------------------------------|------------|----------|------------------------------------|
| 1 | Number of cases | 117 | 85 | 10.76 p<0.01 Highly significant |
| 2 | Mean | 89.2 | 72.39 | |
| 3 | S.D. | 9.67 | 12.42 | |
| 4 | Range | 63-120 | 41-93 | |
| 5 | Calculated Range (Mean \pm 3SD) | 60.2-118.2 | 35.1-110 | |
| 6 | Demarking Point | >110 | <60.2 | |
| 7 | % Beyond Demarking Point | 1.70% | 14.11% | |

Demarking point for male sternum is > 110 mm and that for female sternum is < 60.2 mm. On the basis of demarking point only 1.70% male sternum and 14.11% of female sternum can be identified with 100% accuracy. Jit I⁴ (1980) found that the average length of mesosternum in North Indian female was 16.75mm shorter than male, which could be statistically highly significant. But only 29.55% female and 50% male specimens can be identified with certainty. Dwight⁵ (1890) observed that mean length of mesosternum in

female was 18.5mm shorter than male. Paterson⁶ (1904) found that the difference between the two means was 12.7mm.

Table No. 3: Statistical analysis of combined length of Mesosternum and Manubrium

| Sr. | Statistical Measurements | Male | Female | t test |
|-----|-----------------------------------|-----------|------------|---------------------------------------|
| 1 | Number of cases | 117 | 85 | 13.01 P<0.01 Highly significant |
| 2 | Mean | 140.65 | 116.32 | |
| 3 | S.D. | 10.21 | 16.11 | |
| 4 | Range | 110-168 | 77-138 | |
| 5 | Calculated Range (Mean \pm 3SD) | 110-171.3 | 67.9-164.6 | |
| 6 | Demarking Point | >164.6 | <110 | |
| 7 | % Beyond Demarking Point | 0.85% | 31.76% | |

Demarking point for male sternum is > 164.6 mm and that for female sternum is < 110 mm. On the basis of demarking point only 0.85% male sternum and 31.76% of female sternum can be identified with 100% accuracy. Jit I (1980) found that the combined length is extremely useful in determining the sex of North Indian sterna. The average length of female sterna was 20.06mm shorter than that of male, which is statistically highly significant. The co- extensive range lies between 131 – 140 mm. From this 72.12% male and 62.50% female sterna can be sexed correctly, and he derived “the 136 rule” for the North Indian sterna by which 86% male and 78 % female sterna could be sexed. According to him the combined length of manubrium and mesosternum was extremely useful in determining the sex of North Indian sternum.

Table No. 4: Statistical analysis of breadth of first sternebra at its waist.

| Sr. | Statistical Measurements | Male | Female | T test |
|-----|-----------------------------------|-------------|-----------|--------------------------------------|
| 1 | Number of cases | 117 | 85 | 5.33 P<0.01 Highly significant |
| 2 | Mean | 26.98 | 23.59 | |
| 3 | S.D. | 4.27 | 4.65 | |
| 4 | Range | 20-40 | 18-41 | |
| 5 | Calculated Range (Mean \pm 3SD) | 14.16-39.80 | 9.64-37.5 | |
| 6 | Demarking Point | >37.5 | <14.16 | |
| 7 | % Beyond Demarking Point | 1.70% | 0% | |

Demarking point for male sternum is > 37.5 mm and that for female sternum is < 14.16 mm. On the

basis of demarking point only 1.70% male sternum and no female sternum can be identified with 100% accuracy. Hunnargi SA⁷ (2008) observed average breadth of first sternebra at its waist in male was 27.81mm and the same in female was 25.10mm, with a difference of 2.71mm which was statistically significant. She observed that all male and female bones fall within overlapping zone so no bone could be identified by using this parameter.

Table No. 5: Statistical analysis of breadth of 3rd sternebra at its waist.

| Sr. | Statistical Measurements | Male | Female | t test |
|-----|-----------------------------------|-------------|-----------|--------------------|
| 1 | Number of cases | 117 | 85 | 7.10 |
| 2 | Mean | 32.19 | 26.08 | P<0.01 |
| 3 | S.D. | 6.50 | 5.24 | Highly significant |
| 4 | Range | 20-61 | 19-41 | |
| 5 | Calculated Range (Mean \pm 3SD) | 12.67-51.70 | 10.4-41.8 | |

Ambike⁸ (1996) found that average breadth of third sternebra at waist was 26.01mm in male and 29.15mm in female, with a difference of 3.14mm. 96.29% of male and 96.34% female bones fall within overlapping zone, so this parameter was not found to be useful in sex determination of sternum. In the present study the mean breadth is 32.19mm in male and 28.08mm in female. The difference between the two means is 6.11mm which is statistically highly significant. Only 5.13% male sterna and no female sterna could be identified beyond the demarking point. The range of overlapping zone is 12.7 – 41.8mm where sex could not be determined

Discussion

Great majority of anthropometric observations are “measurements” carried out by internally accepted techniques. The methods of recording the principle observations are established for all skeletal elements and the proportions are expressed as indices. By taking into account various parameters of sternum; merits and demerits of each measurement were discussed by considering average value (mean), its definitive value for male and female, statistical significance and by comparing it with other workers.

Length of Manubrium (M):

According to Dwight⁷ (1890), variations in the length of manubrium in the two sexes was very slight. On the basis of absolute differences in the average length of manubrium in the two sexes, Ashley⁴ (1956) came to the conclusion that the manubrium in European female was definitely shorter than the male, but the percentage of the specimen lying in the opposite sex were very high. Ashley⁴ (1956) observed that the difference in the mean length of manubrium in male and female sterna was 1.7mm in African and 4.3 mm in European sterna. If the length of manubrium is above 60.6 mm, the bone is male and below 37.2 mm it is female. 37.2 – 60.6 mm is the range of overlap where the sex could not be determined. 3.41% male and 14.11% female sterna do not overlap hence could be identified

Length of Mesosternum (B):

Ashley⁴ (1956) found the female mesosternum to be shorter by about 13mm in both cases of European and African specimens. His observation showed that the length of mesosternum of all European female specimens fall in the range of male. However, in 23/380 male European sterna the length was more than 120 mm, which was maximum length recorded in the female mesosternum.

Jit I⁵ (1980) found that the average length of mesosternum in North Indian female was 16.75 mm shorter than male, which could be statistically highly significant. But only 29.55% female and 50% male specimens can be identified with certainty.

Dwight⁷ (1890) observed that mean length of mesosternum in female was 18.5 mm shorter than male. Paterson⁸ (1904) found that the difference between the two means was 12.7 mm. This parameter was considered to be useful to determine sex by Jit I and also found to be useful in the present study, which determines 34.83% males and 35.55% female sterna correctly.

Combined Length of Manubrium and Mesosternum (M+B):

Ashley⁴(1956) recorded average combined length of manubrium and mesosternum in European sterna to be 156.9 mm in male and 138.7 mm in female, giving an absolute difference of 18.2 mm in average. By “trial and error method” he concluded that the combined length of 149mm was dividing line between two sexes. According to him “the 149 rule” was applicable to 76.7% male and 80.4% female European sterna, similarly for African sterna he arrived at “the 136 rule” which was applicable to 77.6% male and 84.6% female sterna. But the coextensive range of the two sexes in European sterna extends from 126 – 171mm and therefore any sternum of unknown sex having combined length within this range cannot be sexed with certainty. The coextensive range covers 90.2% male and 91.1% female sterna.

Jit I⁵ (1980) found that the combined length is extremely useful in determining the sex of North Indian sterna. The average length of female sterna was 20.06 mm shorter than that of male, which is statistically highly significant. The co- extensive range lies between 131 – 140 mm. From this 72.12% male and 62.50% female sterna can be sexed correctly, and he derived “the 136 rule” for the North Indian sterna by which 86% male and 78 % female sterna could be sexed. According to him the combined length of manubrium and mesosternum was extremely useful in determining the sex of North Indian sternum.

Hunnargi SA¹² (2008) observed that combined length of manubrium and mesosternum in male was 141.16 mm and that in female was 117.25 mm. The difference between two mean was 23.91 mm which was statistically significant. The co-extensive range 120 – 140. A cut of value had been derived by halving the co-extensive range which came to be “the130 rule”.

If the combined length is more than 164.6mm then the bone is male and if less than 110mm then it is female. The range of overlapping zone is 110 – 164.6mm where sex could not be determined,

Breadth of First Sternebra at Its Waist (S1)

Considering breadth as a parameter previous workers measured maximum breadth of all sternebra, but they found no significant correlation between breadth and sex. Jit I⁵ (1980) observed that average breadth of first sternebra at its waist was 27.45 mm in male and 24.32 mm in female, giving an absolute mean difference of 3.13 mm which was statistically significant. Also, he observed that measurements of all bones fall within the range of other sex almost completely, hence they were found to be useless in sexing the sternum. Hunnargi SA¹² (2008) observed average breadth of first sternebra at its waist in male was 27.81 mm and the same in female was 25.10 mm, with a difference of 2.71 mm which was statistically significant. She observed that all male and female bones fall within overlapping zone so no bone could be identified by using this parameter.

In the present study the mean value of breadth of first sternebra at its waist is 26.98 mm in male and 23.59 mm in female, with the difference of 3.39 mm which is statistically significant. But the percentage of specimens lying in the range of opposite sex is very high. Only 1.70% male can be identified from the demarking point and no any female can be identified by demarking point . The range of overlapping zone is 14.2 – 37.5 mm where sex could not be determined,

Breadth of Third Sternebra at Its Waist (S3):

Jit I⁵(1980)found that average breadth of third sternebra at its waist was 32.58 mm in male and 29.19 mm in female sterna, the absolute mean difference of 3.39 mm which was statistically significant, but measurement of all the bones fall within the range of other sex. Thus, breadth of sterna as a parameter was not useful in sexing the sternum.

Ambike¹¹(1996) found that average breadth of third sternebra at waist was 26.01mm in male and 29.15 mm in female, with a difference of 3.14 mm. 96.29% of male and 96.34% female bones fall within overlapping zone, so this parameter

was not found to be useful in sex determination of sternum.

In the present study the mean breadth is 32.19 mm in male and 28.08 mm in female. The difference between the two means is 6.11 mm which is statistically highly significant. Only 5.13% male sterna and no female sterna could be identified beyond the demarking point. The range of overlapping zone is 12.7 – 41.8mm where sex could not be determined,

Summary and Conclusion

The present study is carried out on 202 adult human sterna of unknown sex. The parameters studied were length of manubrium (M), length of mesosternum (B), combined length (M+B), width of first sternebra (S1), width of third sternebra (S3). As first part of analysis, all these parameters were subjected to routine statistical method by applying 't' test and obtaining 'P' values. Out of these parameters, length of manubrium, length of mesosternum, combined length M+B, width of first sternebra, width of third sternebra were statistically significant.

The demarking points for identification of sex were worked out by using formula $\text{mean} \pm 3 \text{ SD}$ and overlapping zones were observed. This will be useful in deciding the sex of unknown sample in future, which is often required in medicolegal cases.

Univariate statistical test (t test) was applied to metrical data obtained to assess whether the difference between means of each parameter were statistically significant or not. Thus maximum 18.8% - male and 31.76% - female can be identified as male and female respectively by using univariate statistical analysis.

After application of multivariate analysis to all statistically significant parameters, the percentage of identified bones for male was 89.7% and for female was 82.4 %. Thus percentage of identified bones increases from 18.80% to 89.7% for male while for female percentage of identified bones

increases from 31.76% to 82.4% after application of multivariate analysis.

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