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Research Article

MORPHOMETRIC STUDY OF STERNUM FOR DETERMINATION OF SEX

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ABSTRACT
Determination of sex from human skeletal remains for forensic and medico-legal purpose is an integral part. Study of the sternum as an individual parameter for determination of sex has been attempted by various workers. The material for the present study consists of 50 (27 Male, 23 Female) sterna obtained from the cadavers. The sterna were removed from the cadavers by sectioning the costal cartilages just besides the costochondral junction. Cases belonging to age more than 15 years were only considered. The lengths of the manubrium in the male sterna vary from 35 mm to 71 mm. The Mean was calculated and found to be 52 mm. The Standard Deviation (S.D.) for the length of the manubrium for males is ± 8. The lengths of manubrium in the female sterna vary in the range of 41 mm to 61 mm. The Mean is 48 mm and the S.D. is ± 5. The lengths of the body in male sterna were in the range of 59 - 133 mm. The Mean is 98 mm and S.D. ± 18. The lengths of the body in female sterna were in the range of 56 - 96 mm. The combined lengths (M+B) in the male cases are in the range from 101-191 mm. The combined lengths in the female cases are in the range from 98 -150mm. the sternal indices for males are in range of 38 – 77 mm. while the female cases are in the range 46 – 78 mm. The widths of the manubria of male sterna were in the range of 38 – 72 mm. The widths of the Manubria of female sterna were in the range of 42-68 mm with Mean 54 mm. The widths of the body of the sterna in males were in the range 21 - 62 mm . The widths of the body of the sterna in females were in the range 24 - 51 mm .

Key Words: *Manubrium, Mesosternum, Manubrio-sternal, Sternal Index, Width Index*

INTRODUCTION
Determination of sex from human skeletal remains for forensic and medico-legal purpose is an integral part. Still perfect identification of sex from human skeleton remains relatively a difficult task. About 90% accuracy can be achieved if the specimen includes skull or pelvis. Study of the sternum as an individual parameter for determination of sex has been attempted by various workers. First recorded data is by Wenzel (1788) he described the difference in the ratio between the length of manubrium and that of mesosternum in both sexes. It was followed by Fiegel, 1837; Dwight, 1890; Ashley, 1956).
In present study all existing parameters are used for determination of sex by study of known sex. In which parameters like length of manubrium, length of body, width of manubrium, width of body are recorded. Sternal index and width index are derived from this data in relation to sex. This data base of measurement and indices are statistically analyzed and conclusions are drawn.

MATERIAL AND METHODS
The material for the present study consists of 50 (27 Male, 23 Female) sterna obtained from the cadavers brought for medico-legal postmortem examination at Dept. of Forensic Medicine, Govt. Medical College, Surat. The sterna were removed from the cadavers by sectioning the costal cartilages just besides the costochondral junction. Cases belonging to age more than 15 years were only considered. Deformed, diseased and fractured sterna were not included in the study.
After maceration and cleaning of sterna i.e. all the remains of the muscle and ligaments from the sterna, they were dried at room temperature. Examination was carried out on these dry bones as described.

Measurements of the manubrium and the body of the sternum were taken by a sliding vernier caliper. (a)Measurements of Lengths of the Manubrium and the body of the sternum: A rectangular wooden board measuring 25 x 15 cm. was taken. Another "L" shaped wooden block having length and breadth equal to that of the rectangular board was fixed to the board so that it exactly remained at the edge of one long arm and one short arm of the rectangular board.

The sternum taken for measurement was placed on this board in relation with smaller arm and long arm. The readings were taken by the vernier caliper. (i)Length of the Manubrium:-Distance between the inner edges of the block and the manubrio-sternal line in the median plane was measured.(M) (ii) Length of the Body:- Distance between the manubrio-sternal line and the lowest point of the 4th sternebrae. (B)

(b) Combined Length of sternum:-The combined Length (L) was calculated L = M+B

(C) Width of the Manubrium and the body of the sternum:- The sternum was kept on the board the maximum width of the manubrium (W1) was measured. In the same way, maximum width of the body (W2) was measured.

Figure 1: Measurement of width of Manurium.

(d) Calculation of Indices:-The values obtained were used for calculating the following indices for each case, according to the formula shown against them.

Manubrio-Corpus OR the Sternal Index = M / B X 100
Width Index = W2/W1 x 100
The data obtained were analyzed statistically to find the 'Mean' and the Standard Deviation (S.D.) for each of the above measurement and indices in both the sexes. A 'Z' Test was then applied to see if the sexual diffrence in the means were significant.
Standard deviation (S.D.) in the observations of present study was calculated from the formula:-

$$S.D. = \sqrt{\frac{\Sigma(X - \overline{X})}{N}}$$

Where X = observed value

$\bar{X} = Mean\ of\ observed\ value$

N = No. of observations
Formula for the Z test-

$$Z = \frac{Observed\ difference\ between\ two\ means}{\sqrt{\frac{SD1^2}{N1} + \frac{SD2^2}{N2}}}$$

Where SD1=Male SD
SD2=Female SD
N1=No. of male sternum
N2=No. of female sternum

Following are the confidence limits for the Z test:-
If Z value is < 2 i.e. p > 0.05 = Not significant.
If Z value is > 2 i.e. p < 0.05 = Significant.
If Z value is > 2.56 i.e. p < 0.01 = Highly significant.

RESULTS AND DISCUSSION

(i)Length of the Manubrium: (M)
The lengths of the manubrium in the male sterna vary from 35 mm to 71 mm. The Mean was calculated and found to be 52 mm. The Standard Deviation (S.D.) for the length of the manubrium for males is ± 8. The lengths of manubrium in the female sterna vary in the range of 41 mm to 61 mm. The Mean is 48 mm and the S.D. is ± 5. 'Z' test has been applied on the results, and found to be Z=2.16 which is >2. The test shows that the difference in the Mean is statistically significant.
(ii) Length of the body of Sternum: (B)
The lengths of the body in male sterna were in the range of 59 - 133 mm.The Mean is 98 mm and S.D. ± 18. The lengths of the body in female sterna were in the range of 56 - 96 mm. The Mean is 78 mm and S.D. ± 9. 'Z' test has been applied on the results obtained and Z = 5.07 which is >2. So the test is significant.
(iii) Combined Length of the Manubrium and the body of Sternum:
The combined lengths (M+B) in the male cases are in the range from 101-191 mm. The Mean is 149 mm and the S.D. is ± 21. The combined lengths in the female cases are in the range from 98 -150mm.The Mean is 126 mm and the S.D. is ± 12. After application of 'Z' test on the results Z=4.84 which is >2. Hence the combined length of the sternal body and manubrium in males and females is significant.
(iv) Sternal Index or the Manubrio-corpus Index:-The sternal index is calculated by M/B x 100. According to Hyrtl the index is less than 50 in males and more than 50 in females. In the present study the sternal indices for males are in range of 38 – 77 mm while the female cases are in the range 46 – 78 mm. The Mean for Sternal Index in males is 55 mm with S.D. ± 11 and for females is 63 mm with S.D. ± 9. Out of 27 cases studied only 10 males cases (37.03%) followed the Hyrtl's law. While in females, 22 of

23 cases obeyed the Hyrtl's law (95.65%). After application of 'Z' test on the results Z is (-2.83) which is <2. Hence, the difference in the Mean is statistically not significant.
(v) Width of the Manubrium:

The widths of the manubria of male sterna were in the range of 38 – 72 mm with Mean 58 mm and S.D. ± 8. The widths of the Manubria of female sterna were in the range of 42-68 mm with Mean 54 mm and SD ± 6. The difference in the Mean is statistically significant. After application of 'Z' test on the results, Z=2.02 which is >2. Hence the difference in the Mean is statistically significant.

(vi) Width of the Body of the Sternum:-
The widths of the body of the sterna in males were in the range 2 1 - 6 2 m m with Mean 39 mm and S.D. ± 9. The widths of the body of the sterna in females were in the range 2 4 - 5 1 m m with Mean 35 mm and S.D. ± 7. The difference in the Mean is statistically significant. After application of 'Z' test on the results Z=1.77 which is <2.

(vii)Width Index**:-** W2/ W1x 100. The range of the width index in the males was 44 -97 mm while for the female it was 49 – 100 mm. The Mean for the males was 67 mm and for the female was 66 mm. After application of 'Z' test on the results Z = 0.27 which is < 2.The difference in the Means was statistically not significant. So the width index tried in the study is of no value for the determination of sex.
(a) LENGTH:
(i) Length of Manubrium [M]

According to Inderjit (1986), the lengths of manubrium in males were in the range of 41 mm to 73 mm and in females, 39 mm to 61 mm. while in present study, lengths of manubrium in male were in the range of 35 mm to 71 mm and in female 41 mm to 61 mm. This shows similarity between present study and that of Inderjit. The values for the females for the length of the manubrium overlap with those for the males. This is observed in almost all female cases. Thus the lengths of the manubrium in males and females cases show higher percentage of cases of one sex falling in the range of the other sex. The minimum length of a male manubrium sterni in this study is 35 mm. No sternum with less than 35 mm length was of a male case. Same way, no female sterna had the length of manubrium more than 61 mm so all the sterna above 61 mm would be of male. These results were further worked out by using the method of Demarking Points. Demarking Points include all cases by using the formula [Mean ± 3 S.D.] The demarking points found for Males :-(28 – 76)mm. and for Females:-(33 – 63) mm. This range included all cases. Thus, any sternum with length of manubrium less than 28 mm would be of a female, while any sternum having length of manubrium more than 63 mm would be of a male. However, the range of the length of manubrium in female cases overlaps almost in the length of manubrium in male cases. So, the length of the manubrium cannot be used as a parameter for the determination of sex.
(ii) Length of Body of Sternum (Mesosternum) [B]
According to Inderjit (1986), lengths of Mesosternum were in range from 74mm to 122mm in male, and in the range from 59mm to 95 mm in female. While, in present study, lengths of Mesosternum were in range from 59mm to 133mm in male and in range from 56mm to 96mm in female. This shows similarity in female specimen between present study and that of Inderjit. The minimum length of the body of sternum in male cases in this study is 59 mm. No sternum with body length less than 59 mm was of male hence it can be deduced that all sterna having body length less than 59 mm are of females. Same way, the maximum length of the body of sternum in females is 96 mm. No sternum with body length more than 96 mm was found in females. So all the sternum having body length more than 96 mm are of males. However, this study does not include all the possible sternal body lengths in both the sexes. These were calculated statistically by using the Demarking Points. (Mean ± 3 S.D.), which include all cases.

Table 1: Various measurements of the Sterna in both sexes

Sr. No.	measurement	sex	Range in mm		Mean in mm	S. D.	Level of significance for diff between Means		No. of Cases falling within the range of other sex	% of Cases falling within the range of other sex
			Min	max						
1	Length of Manubrium(M)	Male	35	71	52	8	Z=(2.16)	P<0.05	22	81.48%
		Female	41	61	48	5			all	100%
2	Length of Body of Sternum(B)	Male	59	133	98	18	Z=(5.07)	P<0.01	14	51.85%
		Female	56	96	78	9			all	100%
3	Combined Length (C=M+B)	Male	101	191	149	21	Z=(4.84)	P<0.01	14	51.85%
		Female	98	150	126	12			22	95.65%
4	Sternal Index (M/B × 100)	Male	38	77	55	11	Z=(-2.83)	P>0.01	19	70.37%
		Female	46	78	63	9			all	100%
5	Width of Manubrium(W1)	Male	38	72	58	8	Z=(2.02)	P<0.05	25	92.59%
		Female	42	68	54	6			all	100%
6	Width of Body of Sternum(W2)	Male	21	62	39	9	Z=(1.77)	P>0.05	25	92.59%
		Female	24	51	35	7			all	100%
7	Width Index (W2/W1 × 100)	Male	44	97	67	13	Z=(0.27)	P>0.05	26	96.29%
		female	49	100	66	13			all	100%

Demarking Points found for the length of the body of sternum for males are (44 -152) mm and for females are (51- 105) mm. It can be said that any sternum having the length of body less than 44 mm would be a female; while any sternum having the length of body more than 105 mm would be from a male.

Thus, the length of the body of sternum can be used for determination of sex.But still higher number of cases of one sex fall within the range of the other sex so it cannot be considered to be conclusive within that range.

(iii) Combined Length of the Manubrium & Body of Sternum [M+B]

According to Inderjit (1986), the combined lengths (M+B) were in the range from 131mm to 180mm in male cases and 107mm to 140mm in female cases. The Combined lengths in male cases were in range from 101 mm to 191mm and 98mm to 150mm in females. This shows that observation in present study differs from that of Inderjit in male specimen but similarity is seen in case of female cases. In present study, the minimum combined length in male cases is 101 mm. So any sterna having combined length less than 101 mm will be of female. The maximum combined length in female cases is 150 mm. So any sterna having combined length more than 150 mm will be of male. The Demarking Points for the combined length for male cases are 86mm- 212 mm and for females are 90 mm - 162 mm.

However using the Demarking Points it can be safely said that any sternum with a combined length less than 86 mm would be of a female, while any sternum with a combined length more than 162 mm would be of a male.

(iv) Sternal Index or Manubrio - Corpus Index [M/B x 100]

Table 2: Showing Hyrtl's law:-[M/B x 100 =< 50 implies Male AND M/B x 100 > 50 implies Female]

Sr. No.	observer	Sex	No. of Cases	% obeying Hyrtl's Law
1	Dwight (1890)	M	142	59.10
		F	86	60.40
2	Ashley(1956)- African	M	85	64.70
		F	13	6.20
	Ashley -European	M	378	52.90
		F	171	69.30
3	Narayan & Verma (1958)	M	126	34.12
		F	27	81.48
4	Inderjit	M	312	31.08
		F	88	88.64
5	Present Study	M	27	37.03
		F	23	95.65

The present study is in accord with the fact put forward by Ashley and Inderjit that the sternal index is not a reliable parameter for the determination of sex. However, in all the female cases the law follows in

higher percentage of cases; so if by other examinations sex comes out to be of female then this can be a supportive finding. But no weight age can be given on the sternal index alone.

Table 3: Sexual Difference recorded by various workers in the length of Manubria, Mesosterna & Combined length of manubria & mesosterna

Sr. No.	Name of Worker	Sex	No. of Speci-men	Manubrium (M) in mm		Mesosternum (B) in mm		Combined Length (B) in mm	
				Mean	Difference in Means	Mean	Difference in Means	Mean	Difference in Means
1	Dwight (1881)	M	30	51.80	5.10	105.90	16.50	---	---
		F	26	46.70		89.40		---	
2	Dwight (1890)	M	142	53.70	4.30	110.40	18.50	164.10	22.80
		F	86	49.40		91.90		141.30	
3	Ashley (1956)-Africans	M	85	45.90	1.70	96.50	13.60	142.60	15.50
		F	13	44.20		82.90		127.10	
4	Ashley – Europeans	M	378	52.20	4.30	104.70	13.90	156.00	18.20
		F	168	47.90		90.80		138.70	
5	Inderjit (1985)	M	312	51.73	3.31	95.35	16.75	147.08	20.06
		F	88	48.42		78.60		127.02	
6	Present Study	M	27	52	4	98	20	149	23
		F	23	48		78		126	

Regarding mean length of the manubrium, Dwight (1890) got 51.8 for males and 46.7 for females. Ashley (1956) in his European series got 52.2 for males and 47.9 for females. Inderjit (1986) working on Indian sterna got 51.73 for males and 48.42 females. In present study it is, 52 for males and 48 for females. The difference in the S.D. can be attributed to varying nos. of cases. The length of the body as observed by all the western workers exceeded 100 mm in males and that for female was around 90 mm. This can be explained by larger stature of their population. The length of the body as observed by Inderjit in Indian cases was 95.35 for males and 78.60 for females. The present study gives 98 for males and 78 for females. These results are consistent with those of Inderjit. The combined length of the manubria and mesosterna as studied by Dwight (1890) was 164.1 for males and 141.3 for females. Ashley's (1956) work on European population had 156.9 for males and 138.7 for females. Inderjit (1986) got 147.08 for males and 127.02 for females. The present study shows 149 for males and 126 for females.

(b) WIDTH:

According to Inderjit (1986), sexing of the sternum from the width of the sternebrae 1 and 3 at the body were found to be useless because measurements of sternebrae 1 and 3 in one sex fall within the range of other sex completely. So in present study, for sexing of the sternum, other criteria of the Width has been used are:

Maximum width of Manubrium [W1]

In present study the width of manubria of male sterna was in the range of 38mm to 72mm. Mean was 58mm and S.D was ± 8. While in female sterna, the width of manubria were in the range of 42mm to

68mm and Mean was 54mm and S.D. was ± 6. The minimum width of manubrium was 38mm in male sterna, so no sterna with less than 38 mm width would be of male case. Same way, maximum width of manubrium of female sterna was 68 mm. So no sterna with width more than 68mm would be of female. These results were further worked out by using Demarking Point method. The demarking points were in Male: 34mm to 82mm. and for Female: 36mm to 72mm. This range includes all cases. However, the range of the width of manubrium in male cases overlaps almost full range of female cases. Hence, the parameter of width of manubrium cannot be used for determination of sex.

Maximum width of Body of the Sternum [W2]

In present study the widths of body of sterna in male cases were in the range from 21 mm to 62mm. Mean was 39mm and S.D. was ± 9. While in the female cases were in the range from 24mm to 51mm. Mean was 35mm and S.D. was ±7. The minimum width of body of sterna was 21mm in male sterna, so no sterna with less than 21 mm width would be of male case. Same way, maximum width of body of sterna in female was 51 mm. So no sterna with width more than 51mm would be of female. These results were further worked out by using Demarking Point method. The demarking points were in Male: 12mm to 66mm. and for Female: 14mm to 56mm. This range includes all cases. However, the range of the width of Body of Sternum in male cases overlaps almost full range of female cases. Hence, the parameter of width of manubrium cannot be used for determination of sex.

Width Index [W2/W1 x 100]

The range of the width index in the males was 44 -97 while for the females it was 49 - 100. The Mean for the males was 67 and for the female it was 66. After application of 'Z' test on the results Z = 0.27 which is <2.The difference in the Means was statistically not significant. So the width index is of no value for the determination of sex.

Shahin *et al.,* (2009) studied 115 (75 Male, 40 Female) Adult Sterna from Maharashtrian Population, and found that although Sternal Index was significantly higher in Female Population, Analysis suggests that sex determination cannot be made conclusively from the sternal index in the Maharashtra region of western India. The study further concluded that the applicability of Hyrtl's law in sex determination is limited.

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