Original Article

Determination of sex from various measurements of human sternum and manubrium in Gujarat population

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ABSTRACT

Background: Determination of sex from the skeletal remains is of immense importance in the field of forensic medicine, physical anthropometry and anthropology. Various previous studies have demonstrated sternum as an important tool for the determination of sex.

Aims: Aim of the present study was to establish normal range of values for various dimensions of sternum in the studied population and evaluate the sexual dimorphism in the sternum.

Material & Methods: The present study was conducted at M.P. Shah Govt. Medical College, Jamnagar on Computed tomography scans of a total of 83 adult Gujarati individuals (57 males, 26 females). Various sternal and manubrial linear measurements and indices were measured and analyzed.

Results: It was found in the study that manubrial length, sterna length, manubrial width and combined length of manubrium and sternum were found to be larger in male and the difference was statistically significant. Among the various indices studied, none showed statistically significant difference between male and female. The combined length of manubrium and sternum was found to be the most accurate for determination of sex among all studied parameters, which accurately indentified 24.56% of sterna as male and 11.53% as female by the method of demarking point.

Conclusion: The combined length of sternum and manubrium is the most reliable criteria for the determination of the sex of a sternum. Various indices, defined in relation to manubrium and sternum, were found to be non effective for the determination of sex of a sternum.

Key words: Sex determination, sternum, CT scan, demarking point, Gujarati

INTRODUCTION

The gender determination from the skeletal remains is of very much interest in the field of forensic medicine. To identify the sex of the specimen found, with great accuracy and precision, is of utmost importance. The bones are more resistant to the putrification process that makes it important to study, which in turn helps identify the gender determination criteria. Next to pelvis, human skull is regarded as the most accurate indicator of the sex [1]. But when these bones are missing, recent findings have suggested that sternum and manubrium can act as valuable specimens [1,3-7,9-19].

Manubriosternum is a flat bone that takes part in the formation of the thoracic cage. It is made up of cancellous bone, which, throughout the life, is filled with haemopoietic bone marrow. The manubrium is attached to the body of the sternum at its lower border by the symphysis type of joint, while its upper margin, known as jugular notch, is concave and free. On sides, manubrium contains facets for the articulation of first and half of the second rib. The body of sternum is attached to the manubrium at upper margin while to the xiphoid process by the lower margin. On the lateral margins it contains facets for the articulation of second to sixth/seventh ribs.

The total length of sternum is approximately 17 cm in males and less in females. The ratio between manubrial and mesosternal lengths differs between the sexes [2]. Wenzel [3] was the first to study the sternum for sexual dimorphism. Ashley [4] extensively presented that the sternum is an index of age, sex and height of an individual and its measurements have an influence on the sex and age of that individual in European and African population. Dwight [5] suggested that the male sternum is considerably longer than the female sternum. He also confirmed that the combined length of manubrium and mesosternum, and the total sternal length provide useful guide to the height of an individual. Similarly, Macaluso [1], Osunwoke [6], Selthofer [7], Torwalt [8], Vella [9], Fernadoz [10], etc., studied the sex differentiation in human sternum by studying its various morphometric measurements in various populations.

In India, various researchers have presented their work on the sternum regarding sex determination. i.e. Singh et al [11] [12], Dahiphale et al [13], Gautam et al [14], Puttabanthi et al [15], Kaneriya et al [16], Adhvaryu et al [17], and Mahajan et al [18].

The aim of the present study was to evaluate various sternal parameters and establish the normal values and the sex related differences for the sternum in the Gujarati population.

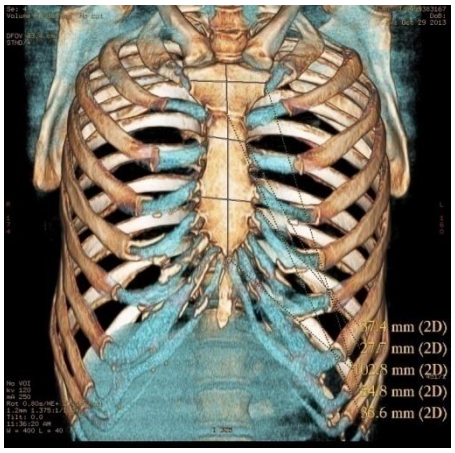
MATERIAL AND METHODS

The present study was conducted on the total of 83 (57 males, 26 females) subjects. The observations were collected from the Department of Radio-diagnosis, M.P. Shah Government Medical College, Jamnagar, Gujarat. The patients who had undergone computed tomography (CT) scan for the conditions other than involvement of sternum were taken in to consideration for the present study. No person was made to undergo a CT scan for the sole purpose of this study.

Subjects aged 18 years and above were included in this study. Subjects with chest trauma, congenital sternal malformation or other anatomical variations were excluded.

For the morphometry of the sternum, following measurements were taken in to consideration (fig -1):

Fig – 1: CT scan image depicting linear measurements of sternum



LENGTH OF MANUBRIUM (ML): It was measured from the centre of suprasternal notch to the centre of the manubrio-sternal junction in mid sagittal plane.
LENGTH OF MESOSTERNUM (SL): It was measured from the centre of manubrio-sternal junction to the centre of sterno-xiphoid junction in the mid sagittal plane.
WIDTH OF MANUBRIUM (MW): It was the distance between the midpoints of the facets for the first costal cartilage on both sides of the bone.
WIDTH OF THE STERNUM AT FIRST STERNEBRA (SW1): It was the distance at the level of line passing from the midpoint between the facet for the second and third costal cartilages on both sides of the bone.
WIDTH OF THE STERNUM AT THIRD STERNEBRA (SW3): It was the distance at the level of line passing from the midpoint between the facet for the fourth and fifth costal cartilages on both sides of the bone.

The above mentioned measurements were further used to calculate various sternal dimensions and indices according to the techniques described by Ashley [4] and McCormick [19].

COMBINED LENGTH OF MANUBRIUM AND STERNUM (CL): It was defined as the summation of length of manubrium and length of sternum.
MANUBRIUM INDEX (MI): It was calculated as the division of MW by ML, multiplied by 100. [MW/ML x 100]
MANUBRIO CORPUS INDEX (MCI) [STERNAL INDEX]: It was calculated by the division of ML by SL, multiplied by 100. [ML/SL x 100]

CORPUS STERNI INDEX (CSI): It was calculated by the division of SW1 by SW3, multiplied by 100. [SW1/SW3 x 100]

The various measurements and indices were tabulated and the mean, standard deviation, coefficient of variation, standard error of mean, range, identification point and demarking points were calculated for each variable.

The identification point:
The identification points were constituted by the lowest value of a variable in males and highest value for the same in females. All the values less than the minimum value for the males were treated as female bone and the bones having values more than maximum value of females were treated as male bones.

The area between these two values is known as overlapping zone. Variable having a broader overlapping zone is thought to be a bad estimator.

The demarking point:
The demarking point was calculated by using ±3SD in mean. Mean±3SD ensured that 99% of the value fall within the range calculated. The minimum value in males was taken as demarking point for female i.e. the value less than this point falls in female category.

These data were tabulated and then analyzed using the IBM SPSS Statistic 20 software package.

RESULTS

The data taken were tabulated and calculated for to find the range of observations, mean, standard deviation, standard error of mean, 95% confidence interval of the difference of mean, Identification and demarking point and overlapping zone.

A total of 83 sterna were measured in the present study. Various measurements, statistical analysis of these measurements, and the indices are shown in Table 1.

Manubrial length, sternal length and manubrial width were found to be significantly higher in males than females. Among the indices calculated, combined length of manubrium and sternum was found to be higher in males than in females; where in the difference was significant for combined length of manubrium. Whereas, manubrio corporal index (sternal index), manubrial index, and corpus sterni index was found to be higher in females; however, all these differences were non-significant. Thereby it could be established that all the indices were higher in males except MCI, MI and CSI.

Identification point, overlapping zone, and demarking point showed significant difference between males and females. Table 2 and Table 3 show identification points, IP%, overlapping zone, % of the bones falling in the overlapping zone, demarking point and DP% in both sexes.

For males, sternal length was found to be most accurate criterion to identify sex by the method of identification point. By using this criterion, 43.86% specimens were correctly identified as male, whereas 28.07% specimens were correctly identified by using the combined length. Manubrial width (1.75%) and manubrial length (1.75%) were found to be least accurate to determine sex by the method of identification point. Overall, 98.25% specimens were falling in the overlapping zone for both of the aforementioned criteria, which again suggest the less accuracy of the criteria for the determination of sex.

By the method of demarking point, combined length of sternum and manubrium was found to be most accurate criteria to identify sex. Overall, 24.56% specimens were correctly classified as male by this criterion. Sternal length was found to classify 21.05% specimens correctly as male. Manubrial length was found to be least accurate (1.75%) for determining sex.

Combined length of sternum and manubrium was found to be most accurate criterion which correctly identified 65.38% specimens as female by the method of identification point. The second most accurate criterion for the same method was the manubrial length which correctly classified 15.39% specimens as female. Manubrial width could not identify any specimen as female by the same method; thus, it was proved to be least accurate criterion. All the female sterna in the study were falling in the overlapping zone for the criterion of manubrial width.

Combined length of sternum and manubrium was found to be most accurate criterion by the method of demarking point. It could correctly identify 11.53% specimen as female. Manubrial length and manubrial width were found to be least accurate, as none of this criterion could correctly identify any sterna as female.

Table 1: Statistical analysis of various sternal measurements (Males- 57; Females- 26)

Variable	Sex	N	Mean±SD (mm)	Standard error of mean (mm)	Mean difference (mm)	P-value*	95% CI	
							Lower	Upper
Manubrial Length	Male	57	45.61±6.70	0.8878	5.39	0.001	2.252	8.516
	Female	26	40.22±6.53	1.2815				
Manubrial width	Male	57	56.42±6.47	0.8567	6.24	0.0001	3.358	9.130
	Female	26	50.18±5.89	1.1559				
Sternal length	Male	57	92.49±10.72	1.4202	16.60	0.0001	12.175	21.034
	Female	26	75.89±8.66	1.6980				
CL	Male	57	138.10±11.63	1.5406	21.99	0.0001	16.639	27.338
	Female	26	116.11±11.08	2.1738				
MCI	Male	57	50.15±10.69	1.4167	-3.57	0.165	-8.650	1.523
	Female	26	53.72±10.69	2.0968				
MI	Male	57	125.92±20.81	2.7565	-1.31	0.796	-11.54	8.903
	Female	26	127.23±21.76	4.2670				
CSI	Male	57	87.80±13.92	1.8439	-0.63	0.856	-7.636	6.369
	Female	26	88.43±15.03	2.9482				

* p-value was measured by t-test & values <0.01=statistically significant, <0.0001=statistically highly significant

Table – 2: range, number and percentage of the sterna falling in overlapping zone and beyond identification point and demarking point for the female sterna

	ML	MW	SL	CL
Identification point (IP)	34.5	41	66.8	119.5
No. Of the sterna falling below IP	4	0	1	17
IP%	15.385	0	3.84615	65.385
Overlapping zone	34.5-62.1	41-72.5	66.8-94.1	119.5-145.7
No. Of the sterna falling in overlapping zone	22	26	25	9
% of sterna in overlapping zone	84.615	100	96.1538	34.615
Actual range	29.4-62.1	41.8-72.5	49.2-94.1	90.7-145.7
Mean±3SD	20.63-59.81	32.51-67.85	49.91-101.87	82.87-149.35
Demarking point (DP)	25.51	37.01	62.33	103.21
No. Of the sterna falling beyond DP	0	0	1	3
DP%	0	0	3.84615	11.538

Table – 3: range, number and percentage of the sterna falling in overlapping zone and beyond identification point and demarking point for the male sterna

	ML	MW	SL	CL
Identification point (IP)	62.1	72.5	94.1	145.7
No. Of the sterna falling beyond IP	1	1	25	16
IP%	1.754	1.7544	43.86	28.07
Overlapping zone	34.5-62.1	41-72.5	66.8-94.1	119.5-145.7
No. Of the sterna falling in overlapping zone	56	56	32	41
% of sterna in overlapping zone	98.25	98.246	56.14	71.93
Actual range	34.5-69.1	41-73.5	66.8-116.4	119.5-165.4
Mean±3SD	25.51-65.71	37.01-75.83	62.33-126.65	103.21-172.99
Demarking point (DP)	59.81	67.85	101.87	149.35
No. Of the sterna falling beyond DP	1	3	12	14
DP%	1.754	5.2632	21.053	24.561

Table – 4: showing the comparison of the findings of the present study with the same of the other researcher for manubrial length, sternal length and combined manubrial and sterna length

RESEARCHER	SEX (No)	ML±SD (mm)	SL±SD (mm)	CL±SD (mm)
Dwight T.(1881)	M (30)	51.8	105.9	-
	F (26)	46.7	89.4	-
Dwight T.(1890)	M (142)	53.7	110.4	164.1
	F (86)	49.4	91.9	141.3
Ashley (African)	M (85)	45.9	96.5	142.6
	F (13)	44.2	82.9	127.1
Ashley (European)	M (378)	52.2	104.7	156.9
	F (168)	47.9	90.8	138.7
Dahiphale (Maharashtra)	M (96)	48.46	94.43	142.20
	F (47)	43.78	70.19	113.87
Gautam RS (Ahmedabad)	M (56)	53	95	149
	F (44)	48	76	124
Selthofer (Croatia)	M (55)	55.2± 3.6	109.7± 14.4	-
	F (35)	52.4± 4.5	94.2± 14	-
Mahajan A (Punjab)	M (98)	57.86± 6.46	115.19± 12.96	173.05± 19.31
	F (55)	46.96± 5.99	93.85± 11.71	140.82± 17.62
Singh J. (north India)	M (252)	52.1± 5.21	94.07± 10.01	145.69± 11.41
	F (91)	47.17± 5.17	78.54± 10.23	124.87± 10.12
Osunwoke (Nigeria)	M (68)	60.7± 10.7	101.3± 13.22	164.6± 19.96
	F (26)	46.0± 6.13	77.9± 7.07	123.3± 11.8
Puttabanthi S (Andhra Pradesh)	M (57)	47.48± 12.03	92.36± 14.03	139.55± 21.09
	F (22)	21.68± 5.96	88.95± 8.93	110.64± 8.13
Adhvaryu A (Saurashtra region)	M (45)	48.95± 4.25	92.11± 9.55	141.06± 10.64
	F (55)	44.03± 4.21	78.28± 7.59	122.31± 9.38
Kaneriya D (Surat)	M (27)	52± 8	98± 18	149± 21
	F (23)	48± 5	78± 9	126± 12
Macaluso PJ (Spain)	M (65)	51.85± 4.74	106.25± 11.05	158.10± 12.7
	F (51)	45.85± 4.76	87.77± 9.61	133.62± 11.22
Present study (Saurashtra region)	M (57)	45.6± 6.7	92.49± 10.72	138.10± 11.63
	F (26)	40.22± 6.53	75.89± 8.66	116.11± 11.08

DISCUSSION

The present study evaluated various sternal parameters in order to establish the normal values and the sex related differences for the sternum in the Gujarati population. The findings suggest that osteometric evaluation of the sternum can be an effective method for identification of sex in the Gujarati population.

In the present study, the manubrium length was comparable to the findings by Ashley et al, Dahiphale et al, and Adhvaryu et al. However, the data were different to those presented by Puttabanthi et al, Selthofer et al, Mahajan et al, and Osunwoke et al.

The sternum length was comparable to the findings by Ashley et al, Jit et al, Gautam et al, Singh et al, and Adhvaryu et al. However, the data were different to those presented by Dahiphale et al, Puttabanthi et al, Paterson et al, Ashley et al, Selthofer et al, Mahajan et al, and Macaluso et al. The differences in findings could be contributed to the regional differences. The comparison of findings by various researchers is presented in table - 4.

Overall, the manubrial length was found to be poor indicator of sex as majority of specimens were falling in to overlapping zone. This finding was in accordance with Dahiphale et al [13], Jit et al [12], Dwight et al [5], Ashley et al [4], Adhvaryu et al [17], and Kaneriya et al [16]. The sternal length was also found to be poor indicator of sex and the finding was in accordance.

Table – 5: showing the comparison of the findings of the present study with the same of the other researcher for manubrial width

RESEARCHER	SEX (No)	MW±SD (mm)
Selthofer (Croatia)	M (55)	52.5± 6.8
	F (35)	45.9± 5
Singh J. (north India)	M (252)	54.91± 5.44
	F (91)	48.31± 5.11
Kaneriya D (Surat)	M (27)	58±8
	F (23)	54±6
Macaluso PJ (Spain)	M (65)	59.78±3.65
	F (51)	51.82±4.34
Present study (Saurashtra region)	M (57)	56.42±6.47
	F (26)	50.18±5.89

with Adhvaryu et al [17]. However, data by Dahiphale et al [13] suggested sternal length as precise indicator of sex determination, which is contradicting the finding of the current study. The mean manubrial width found in the present study was in accordance with the findings of the previous workers as per shown in table – 5.

In the present study, the most reliable method for sex determination was the combined length of sternum and manubrium using demarking point or identification point methods. Of all criteria evaluated, maximum specimens were correctly identified through the combined length of sternum and manubrium. The results from the study can assert the effectiveness of sternum for identification of sex from human remains. The findings from the present study are consistent with previously reported data from various researchers [1,4-7,11,13-18] (as summarized in a table-4).

It was found in the present study that the manubrio corpus index (sternal index) is an inaccurate criterion to determine the sex of a sternum of unknown sex. The difference found in the sternal index between males and females was statistically insignificant. This finding of present study was in accordance to the finding of other worker in south Indian population [15] while it was contrary to the findings of the workers in the Spanish [1], Marathi [13] and north Indian population [11]. Corpus sterni index was found to be ineffective for to determine the sex of a sternum which was in accordance with the findings in the Spanish [1] and Marathi population [13]. Manubrial index also was found to be inaccurate to determine sex of a sternum which was similar to the findings in the Spanish [1] and Croatian population [7].

The sternum of the Gujarati population was found to be smaller than the sternum of European [4], Nigerian [6], Croatian [7] and Spanish population [1]. Among the other regions of India, the sternum of the Gujarati population was found to be smaller than the same of Punjabi population [11]. The sternum of Gujarati population was found to be similar in dimensions to the sternum of Marathi population [13]. The sternum from the males of south Indian population was similar to the sternum of Gujarati males, but the sternum of females of Gujarati population was found to be larger than the sternum of south Indian females [15]. Present study measured the dimension of sternum in Saurashtra region of Gujarat, which was similar to the sternum of the region of Ahmadabad [14] and Surat [16].

CONCLUSION

The result and comparative observation in the present study show that the combined length of sternum and manubrium is the most reliable criteria for the determination of the sex of a sternum. Various indices defined in relation to manubrium and sternum, were found to be non effective for the determination of sex of a sternum. The mean values of the dimensions of the sternum established in the present study should be kept in mind while dealing with the Gujarati population in various fields as forensic medicine, anthropology, anthropometry, orthopaedics and Radio diagnosis.

Finally, given the relatively small size of the study sample, it is further recommended that additional investigations be conducted on other documented Gujarati population samples to confirm the findings of the present research.

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