Original Research Paper

Reliability of Sternal Index in Sexual Dimorphism In the Haryanvi Population of India

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Abstract

Assessment of sex is one of the most vital determinations to make when it is necessary to establish identity from skeletal remains. Sternal index, also known as manubrio-corpus index is an important and frequently studied parameter from this point of view. Current study was an attempt to know the reliability of sternal index in the differentiation of sex in the population of Haryana of Northern India. A total of 200 adult sterna (comprising of 100 male and 100 female sterna) from unidentified subjects of confirmed sex were studied and sternal index (length of manubrium divided by length of mesosternum multiplied by 100) was calculated for each of them. The values were subjected to univariate and discriminant function analysis and a comparative analysis was made. The study was further tested for the applicability of Hyrtl's law. Though the values of sternal index were found to be significantly higher in females as compare to males, a thorough statistical analysis found sternal index to be an insignificant parameter in the differentiation of sex in the Haryanvi population of India. Hyrtl's law was also found to be inconclusive with a limited applicability.

Key Words: Discriminant function analysis, Hyrtl's law, Identification, Limiting point, Sternum

Introduction:

Determination of the sex and age is the major criterion for identification of an individual in Forensic practice, irrespective of the fact that the person is living or dead. It is necessary to use bone and dental indicators on decomposed bodies for age-at-death assessment, but sex determination is more problematic when the body is skeletonised. To achieve an assignation of sex, the anthropologist uses biological traits of the skeletal system that vary between the sexes for functional reasons. This variation is exhibited in soft and hard tissue. [1] Largely, Forensic anthropology focuses on sexing skeletal remains, with little or no associated soft tissue.

With a growing appreciation for the importance of population specific standards, the literature is replete with morphometric standards for estimating sex from a variety of bones. [2]

While the skull and pelvis are the most sexually dimorphic regions of the human skeleton and traditionally favored when sex is estimated, the sternum is also sexually dimorphic, with recent research demonstrating an overall classification accuracy above 80% in several populations. [3] Study of sternum as an individual parameter for determination of sex has been attempted by various workers.

Sexual dimorphism in human sternum was first noted by Wenzel as early as in 1788 who observed that manubrium of the two sexes is of almost equal length; the mesosternum is proportionately longer in males than in females. [4] This was followed by Fiegel, Hyrtl and Dwight during the 19th century. [5-7] This led to pronunciation of Hyrtl's law that "the manubrium of the female sternum exceeds half the length of the body, while the body in male sternum is, at least, twice as long as manubrium." [6]

Since then a number of anatomists like Strauch and Krause kept on studying the sexual dimorphism of human sterna and suggested that the male sternum is considerably longer than the female and the difference lies in the mesosternal portion of the bone. [8, 9]

An attempt to differentiate sex on the basis of sternal index and the applicability of Hyrtl's law in the same way has been made earlier by various workers across various regions of India and other nations. [7, 10, 11]

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The present study was an attempt to differentiate sex from sternal index and to know its reliability in determination of sex in Haryanvi population of Northern India. The applicability of Hyrtl's law in the sex differentiation was also determined.

Materials and Methods:

A total number of 200 sterna of both sexes were collected from autopsy subjects brought to the mortuary of the Department of Forensic Medicine and Toxicology, PT. B.D. Sharma Post-Graduate Institute of Medical Sciences, Rohtak (Haryana).

Sterna with fused mesosternum or further fusion of sternal segments from unidentified/unknown adult subjects of confirmed sex (100 males and 100 females) were chosen for the study. Sterna showing any pathology, fracture, gross deformity or unfused mesosternum (after maceration process) were excluded from the study.

The measurements were taken by Vernier calipers to the nearest millimeter according to Ashley technique. [10] The morphometric parameters of the sternum were measured for each sternum:

Length of manubrium ML: distance measured on the anterior surface of the sternum from the centre of suprasternal notch (jugular notch) to the centre of manubrio-mesosternal junction (sternal synchondrosis) in mid-sagittal plane, Length of mesosternum BL: distance measured from the manubrio-mesosternal junction to the xiphi-sternal junction of the sternum in the mid-sagittal plane.

After measuring these two parameters, sternal index was calculated for each sternum by using the formula:

Sternal Index (SI) = (ML/BL) × 100

The values thus obtained were statistically analyzed using SPSS version 16.0. Univariate analysis and Fisher's linear discriminant function analysis were used to compare the values for males and females. Applicability of Hyrtl's law on these sterna was also studied along with.

The male identification point is the maximal value of a particular dimension in female bones and for the female bone identification point is the minimum value of a particular dimension in male bones.

The area lying between these points was called overlapping zone. The values of bones lying in this zone were said to have overlapped values. A variable having more overlapping area was not thought to be a good estimator. Demarking points are obtained by calculating the maximum and minimum limits i.e. the range of a particular dimension. Addition of 3 standard deviations to the mean gives the maximum value and subtraction of 3 standard deviations from the mean gives the minimum value. Thus demarking points were obtained above which no female bone could be found and this was the upper calculated range of female bone. Any bone having values more than this was bound to be male.

Similarly from the calculated range of male bones, a demarking point was obtained below which no male bone could be found. Thus, any bone having value less than this was bound to be female. The number of sterna beyond "demarking point" i.e. having value more than the demarking points for males was obtained and the number of bones less than "demarking points" for females was obtained and their percentage was calculated.

Although identification and demarking points can identify sex accurately, but only a small proportion of sterna can be sexed based on these methods as most of the remaining sterna show the measurements in the overlapping zone. Therefore, a limiting point was calculated from the average of male and female identification points. Vast number of male sterna showed value greater than limiting point and the bulk of female sterna showed values lesser than this. In univariate analysis, the mean measurements were compared using unpaired t-test and p values less than or equal to 0.05 were considered to be statistically significant while those less than or equal to 0.001 were highly statistically significant.

Results and Discussion:

1. Manubrio-corpus index/Sternal index:

- **Univariate Analysis:**

The mean value of sternal index was found to be 53.69 ± 9.88 SD for males and 61.56 ± 9.62 SD for females with a statistical highly significant mean difference ($p<0.001$) of -7.87. (Table 1) The values were found to be much higher for females than males similar to observed by various workers previous studies. [11-14]The range was found to be varying between 35.74 to 84.37 in males and 43.65 to 88.20 in females. The lesser value of sternal index in males can be attributed to greater length of mesosternum in males.

Results of further analysis on the basis of identification point, demarking point, limiting point and sectioning point analysis showed that not even a single sternum could be correctly classified on the basis of identification point (Male-88.20, Female-35.74) and demarking point (Male-90.43, Female-24.09) analysis with 100% sterna of each sex falling in overlapping zone of other sex. (Table 2)

With the calculated limiting point of 61.97, 12% of the males and 60% of the females were correctly classified. By "trial and error" method, limiting point of 60 was able to differentiate 20% of the males and 50% of the females which also could not be taken as criteria for differentiation of sex due to poor yield. (Graph 1) Sectioning point of 57.57 was able to differentiate 30% male and 32% female sterna which was very limited and could not be made a basis for sexual dimorphism.

- **Discriminant Function Analysis:**

Discriminant function analysis was used to make study more comprehensive. Fisher's linear discriminant function analysis could classify 70% male and 68% female sterna with an overall yield of 69%. The results of discriminant function analysis were found to be of limited value. (Table 3)

- **Comparative Analysis With Previous Studies:**

The comparison of sternal index with previous studies showed that the present study closely follows the findings of Jit et al and Singh et al study who found statistically highly significant mean difference ($p<0.001$) with overlapping values of nearly 100% for each sex. [11, 13] This similarity may be attributed to the similar demographic, ethnic and population distribution in North Indian subjects.

With a calculated limiting point of 61.97, 12% of male and 60% of female sterna could be classified from which it may be inferred that more of the female sterna could be correctly classified which is also similar to the results of previous North Indian studies. [11, 13]

2. Application of Hyrtl's Law:

A number of workers have applied Hyrtl's law in their studies to find out its reliability in sexual dimorphism from sternum. In the present study 42% of male and 92% of female sterna were found obeying this law. The male sterna obeying the Hyrtl's law were less as compare to American, European and African studies while for female sterna the percentage was much higher.

Thus the results were similar to other Indian studies. (Table 5) When compared to Indian studies, the percentages of male sterna following Hyrtl's law were much higher than most other previous studies while the results were comparable to for female sterna. These all variations and similarities are the result of racial, ethnic and geographic factors that require further exploration and researches.

Conclusion:

After thorough morphometric and statistical analysis and comparison with other studies, it was concluded that although statistical highly significant sex differences exist in sternal index, it cannot be taken as reliable indicator for sex determination on account of large overlapping values (100%) that limits its applicability for individual subject.

Discriminant functional analysis is of limited value and Hyrtl's law is not applicable to the sterna of Haryanvi population.The variations in the sternal index are on account of different geography, ethnic and racial distribution. Further elaborative morphometric studies are required to make sternal index a valuable parameter in sexual dimorphism.

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Graph 1: Cent Percent Overlapping Values of Both Sexes

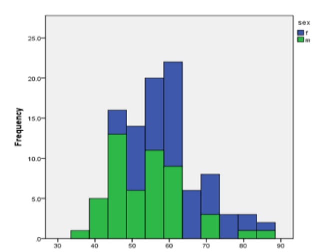

Table 1
Descriptive Statistics: Results of Sternal Measurements and Sternal Index

S. N.	Variables	Male			Female			Mean Diff.	P
		Mean	SD	Range	Mean	SD	Range		
1.	Length of manubrium	48.94	4.70	41.0-61.0	45.42	5.00	36.6-62.0	3.51	<0.001
2.	Length of mesosternum	93.07	13.40	65.1-126.7	74.71	9.00	60.1-100.8	18.36	<0.001
3.	Sternal Index	53.69	9.88	35.74-84.37	61.56	9.62	43.65-88.20	-7.87	<0.001

Table 2
Sternal index: Identification Point, Demarking Point, Limiting Point and Sectioning Point

	Identification Point		Demarking point		Limiting Point		Sectioning Point	
	Value	Overlapping Values (%)	Value	Overlapping Values (%)	Value	Classified (%)	Value	Classified (%)
M	88.20	100	90.43	100		12 (n=12)	57.57	30 (n=30)
F	35.74	100	24.09	100	61.97	60 (n=60)		32 (n=32)

Table 3
Sternal index: Results of Discriminant Function Analysis

Wilk's Lambda	F	t	Coefficient		Constant		Percentage Classified		
0.85	16.27	-4.03	M	F	M	F	M	F	Overall
			0.56	0.64	-15.83	-20.60	70	68	69

Table 4
Comparison of Sternal Index with Other Studies

Study	Sex	Bones	Range	Mean	SD	Overlapping Values (%)
Narayan et al	M	126	31.72-85.33	54.76	9.94	-
	F	27	44.33-80.00	58.98	9.61	-
Jit et al	M	312	35.00-94.00	55.53**	9.57	99.68
	F	88	32.00-88.00	61.80**	10.62	98.86
Dahiphale et al	M	96	36.00-77.00	51.99**	8.34	44.79
	F	47	51.00-91.00	63.01**	8.50	95.74
Hunnargi et al	M	75	36.13-93.06	59.21*	9.85	97.33
	F	40	36.26-88.10	63.31*	9.41	100.00
Atal et al	M	56	38.00-58.00	46.09**	3.750	60.71
	F	44	45.00-62.00	56.70**	3.98	90.91
Singh et al	M	252	39.70-111.76	56.13**	9.39	99.21
	F	91	43.30-88.85	61.23**	11.37	100
Present study	M	100	35.74-84.37	53.69**	4.70	100
	F	100	43.65-88.20	61.56**	5.00	100

SD: Standard Deviation, * $p < 0.05$, ** $p < 0.001$

Table 5
Applicability of Hyrtl's Law as Recorded by Various Workers

Observer	Sex	Subjects	% Obeying the Law
Dwight, 1881 (United States)	M	30	60.00
	F	26	46.20
Dwight, 1890 (United States)	M	142	59.10
	F	86	60.40
Ashley, 1956 (East Africa)	M	85	64.70
	F	13	69.20
1956 (Europe)	M	378	52.90
	F	171	69.30
Narayan & Verma, 1958 (U.P.)	M	127	34.12
	F	27	81.48
Jit et al, 1980 (North West Chandigarh)	M	312	31.08
	F	88	88.64
Dahiphale et al, 2002 (Gujarat)	M	96	52.20
	F	47	100.00
Hunnargi et al, 2008 (Maharashtra)	M	75	18.70
	F	40	95.00
Present study, 2013 (Haryana)	M	100	42.00
	F	100	92.00