Correlation between various Measurements of Sternum with Stature - An Autopsy based Study

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Abstract

The sternum is of crucial significance while estimating body stature. Dwight, in the late 19th century, discussed potential use of the sternum for estimation of the stature. Various researchers have shown that the sternum may be of use in stature assessment merely when long bones are not obtainable. The study was conducted to analyse the correlation between the stature and various measurements of the sternum. The posterior curved length, length of manubrium, length of mesosternum and length of sternum were measured in 300 adult sterna. The mean length of a cadaver (Stature) was observed to be greater in males (162.34 ± 8.03 cm) as compared to females (156.53 ± 8.50 cm). A positive moderate correlation (R ranging from 0.332 to 0.647) was observed between various measurements of sternum with stature in both the genders. Sternal length shall be considered as a better parameter over other sternal measurements for estimating the stature. However the application for utilizing the sternum for stature estimation should be restricted to the population sample for and from which they have been developed.

Keywords: *Stature estimation; sternum; posterior curved length of sternum; forensic anthropology.*

Introduction

Estimation of stature is an essential component in the estimation of an individual's identity from mutilated or dismembered or fully skeletonised remains in forensic casework. Karl Pearson (1899) and thereafter Trotter and Gleser (1952) derived regression equations for estimating the stature using long bones which are being used worldwide for a long period of time.[1,2] A number of other bones like skull, metacarpals, metatarsals, scapula, lumbar vertebrae and sacrum have also been used for the estimation of stature.[3,4,5,6,7,8] The osseous skeleton of the sternum is the structure which is observed to resist the effects of putrefaction and decomposition for a long period of time.

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The sternum is of crucial significance while estimating body stature. Dwight, in the late 19th century, discussed potential use of the sternum for estimation of the stature.[9] Various researchers have shown that the sternum may be of use in stature assessment merely when long bones are not obtainable. Recent studies have led to the development of regression equations for the estimation of stature in several different population groups. Menezes RG et al.[10,11] and Singh J et al.[12] have assessed the usefulness and the importance of macerated sternum in the estimation of stature in two different Indian adult populations.

The present study was conducted to analyse the correlation between the stature and various measurements of the sternum and to derive regression equations for the estimation of stature in males and females.

Materials and Method

This study was conducted after the ethical clearance from institute's ethics committee for academic research projects in deceased that were subjected to medicolegal

autopsy at a post-mortem centre attached to a medical college in Mumbai, India. The deceased aged 18 years and above, of either sex without trauma to sternum were included in the study. During the study period from November 2014 to August 2016, 300 adult sterna were examined. Primary data, in each case, was collected from the inquest report and hospital indoor paper records in admitted cases.

During the autopsy, the deceased was put in a supine position on a flat, hard-surfaced autopsy table, with the knee and hip joints extended, and the neck and feet in a neutral position after breaking the rigor mortis. The cadaveric length (stature) was measured from the vertex up to the heel using a steel measuring tape. 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 soft tissue was scraped and measurements were taken using a measuring tape. The posterior curved length of the sternum (PCL), length of manubrium (M), length of mesosternum (B), length of sternum (S) were noted keeping the bone on a flat surface. 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.[13]

Study parameters were described using descriptive statistics like mean, standard deviations and p-values. The correlation between the various measurements of the sternum and stature analysed by calculating Pearson's correlation coefficient, coefficient of determination and standard error of estimate using SPSS v16.0 (SPSS, Inc., Chicago, IL).

Results

In the study, 300 adult intact sterna were examined, 150 (50%) were of males and 150 (50%) of females. The mean age of males was 43.83 ± 14.93 years and that of females was 39.98 ± 18.92 years. A p-value of 0.0518 indicates no significant difference between the mean age of males and females. The mean length of a cadaver (Stature) was observed to be greater in males (162.34 ± 8.03 cm) as compared to females (156.53 ± 8.50 cm). The mean of all the sternal measurements was greater in males as compared to females except that of the length of manubrium (M). P-value <0.05 in all parameters indicates a significant difference in sternal parameters between males and females **(Table 1).**

Table 1 Study population and descriptive statistical data for various measurements of sternum

Variables	**Males N=150**		**Females N=150**		**P value**
	Range	**Mean±S.D**	**Range**	**Mean±S.D**	
Age (years)	18-84	43.83±14.93	19-90	39.98±18.92	0.0518
Stature (cm)	145-178	162.34±8.03	134-175	156.53 ±8.50	<0.0001
PCL (mm)	124-185	140.37±12.90	115-185	135.10±11.09	0.0002
M (mm)	34-65	42.58±5.74	35-65	46.06±4.66	<0.0001
B (mm)	83-140	97.40±10.79	75-120	87.72±8.40	<0.0001
S (mm)	119-188	139.98±14.40	110-175	133.94±11.78	<0.0001

PCL – Posterior curved length of sternum, M – Length of manubrium, B - Length of Mesosternum, S - Sternal length.

Table 2 Linear regression equations for stature estimation from various sternal measurements in males (N=150) and females (N=150).

Group	Variables (mm)	R	R2	Adjusted R2	SEE (cm)	Regression equations Stature (cm) =aX+b	P value
Male	PCL	0.424	0.179	0.174	7.294	=0.264×PCL+ 125.33	<0.0001
	M	0.332	0.110	0.104	7.595	=0.464×M + 142.58	.000033
	B	0.380	0.144	0.139	7.448	=0.283×B+ 134.82	<0.0001
	S	0.417	0.173	0.168	7.319	=0.232×S +129.83	<0.0001
Female	PCL	0.628	0.394	0.390	6.639	=0.481×PCL+ 91.525	<0.0001
	M	0.569	0.323	0.319	7.016	=1.037×M + 108.786	.000033
	B	0.561	0.315	0.310	7.062	=0.567×B+ 106.779	<0.0001
	S	0.647	0.418	0.414	6.506	=0.468×S +129.93842	<0.0001

R- Pearson's correlation coefficient

R^2 - Coefficient of determination

SEE - Standard error of the estimate,

aX+b -'a' is the regression coefficient of slope or independent variable (sternal lengths), 'X' is the sternal measurement and 'b' is the regression coefficient of intercept/or dependent variable (stature).

Positive moderate correlations were observed for posterior curved length of the sternum (PCL), mesosternal length (B), sternal length (S) and manubrial length (M) with stature in males and females. The correlation coefficient (R) was observed to be higher in females than that in males for all sternal measurements. In males better correlations for PCL (R = 0.424) and sternal length (R = 0.417) were found than that of length of manubrium (R = 0.332) and length of mesosternum (R = 0.380) with significant p values. In females better correlations for PCL (R = 0.628) and sternal length (R = 0.647) were found than that of length of manubrium (R = 0.569) and length of mesosternum (R = 0.561) with significant p values **(Table 2).** Simple linear regression analysis was done for the different sternal lengths to derive regression formulae for estimation of stature. The R^2 (Coefficient of determination) and standard error of estimate (SEE) were calculated to assess the significance of a regression as shown in **Table 2.** R^2 determines the degree of association of correlation that exists between sternal measurements and the stature, higher the value of R^2, better the regression equation as a predictive device. The SEE estimate measures the accuracy of the estimated figure, smaller is its value, better will be the estimates.

Discussion

The mean length of male cadavers (162.34 ± 8.03 cm) was observed to be more as compared to that of females (156.53 ± 8.50 cm). The study population, sample size and mean length of cadaver (Stature) observed in the other Indian studies is charted in **Table 3**. The mean length of male cadavers observed by Singh J et al.[12], Menezes RG et al.[10,11], Ranjith Raj VP et al.[14] and Saraf A et al.[15] is comparatively on the higher side than that observed by Tumram NK et al.[16], Baraw R et al.[17] and in the present study. The mean length of female cadavers is observed to be relatively similar in all the studies except that of Saraf A et al.[15] **(Table 3).**

Table 3 - Study population, sample size and mean length of cadaver (Stature) observed in the Indian studies.

Source and study population	**Sample Size (N) and mean length of cadaver (Stature) in cm ± SD**			
	Male		Female	
Menezes RG et al. (South India)	N=35	166.47 ± 7.22	N=40	155.88 ± 5.27
Singh J et al. (Northwest India)	N=252	168.1 ± 7.19	N=91	156.3 ± 6.98
Tumram NK et al. (Central India)	N=92	160.8 ± 8.8	-	-
Baraw R et al. (Delhi)	N=50	162.76 ± 7.3	N=50	156.14 ± 7.3
Ranjith Raj VP et al. (South India)	N=50	171.2285	-	-
Saraf A et al. (South India)	N=50	166.90 ± 3.20	N=50	164.4 ± 3.50
Present Study (Mumbai)	N=150	162.34 ± 8.03	N=150	156.53 ± 8.50

Table 4- Sternal measurements and correlation coefficients observed in various Indian studies.

Source	**Parameters**	**Sternal measurements Mean±SD**		**(R)**	
		Male	**Female**	**Male**	**Female**
Menezes RG et al.	S	14.20±1.34 cm	14.12±1.07 cm	0.638	0.639
Singh J et al.	M B S	52.1±5.21 mm 94.1±10.01 mm 145.7±11.41 mm	47.2.1±5.17 mm 78.5±10.23 mm 124.9±10.12 mm	0.191 0.255 0.318	0.237 0.229 0.318
Tumram NK et al.	M B S	4.65±0.086 cm 9.89±0.125 cm 14.59±1.441 cm	- - -	0.44 0.25 0.55	- - -
Baraw R et al.	PCL*	20.41±1.64 cm	18.27±1.64 cm	0.809	0.755
Ranjith Raj VP et al.	S*	19.2342 cm	-	0.941	-
Saraf A et al.	M B S	48.80±6.47 mm 86.05±13.86 134.86±15.87	43.0±5.91 78.13±15.05 121.14±17.77	0.367 0.853 0.894	0.680 0.747 0.859
Present Study	M B S PCL	42.58±5.74 mm 97.40±10.79 mm 139.98±14.40 mm 140.37±12.90 mm	46.06±4.66 mm 87.72±8.40 mm 133.94±11.78 mm 135.10±11.09 mm	0.332 0.380 0.417 0.424	0.569 0.561 0.647 0.628

R - Pearson's Correlation Coefficient, *Measurements include xiphoid process.

Menezes RG et al.[10,11] observed a higher correlation coefficient and a lower standard error of the estimate for regression models in macerated and dried sterna. Singh J et al.[12] obtained a correlation coefficient value of 0.316 for males and 0.328 for females for regression models which were based on the sternal length taken from dry bone specimens. Saraf A et al.[15] in their study observed that the stature correlated best with the combined length of sternum, among males (R=0.894), females (R=0.859) as compared to manubrium and mesosternum. All these studies[10,11,12,15] suggested that stature can be estimated from sternum with reasonable accuracy and also concluded that sternum may be of vital importance for stature estimation if long bones are not available. Yonguc G et al.[18] in Turkey observed moderate to strong correlation (R ranging from 0.372 to 0.850) and suggested that the sternal lengths can be used for estimation of sex. They also stated that a sternum is a useful tool for estimating stature when other skeletal bones are not available **(Table 4).**

Baraw R et al. [17] in their study measured PCL of the sternum in fresh and dry samples of the sternum and observed correlation coefficient of 0.872 and 0.610 respectively. They concluded that PCL of sternum acts as an alternative to estimate stature in Delhi population. Ranjith Raj VP et al.[14] observed a correlation coefficient of 0.9410. They concluded that the length of the sternum is a strong correlating factor to the stature of South Indian adolescent male population and it is useful for anthropologists and medico-legal experts for stature estimation. Baraw R et al.[17] and Ranjith Raj VP et al.[14] observed strong correlation coefficients in their study while in both the studies the sternal measurements were taken including the xiphoid process which has high variability in its length.[13] However, Marinho Let al.[19] reported a correlation of 0.329 on fresh sterna sample in a male which also includes the xiphoid process. They also argued that sternal length has inadequate forensic value and comparatively low dependability in determining stature from mutilated human skeletal remains, either skeletonised or fresh **(Table 4).**

Tumram NK et al.[16] derived linear regression equations by measuring manubrium, mesosternum and the total sternal length. The regression model provided a correlation coefficient of 0.55. The study concluded that sternal length in relation to body stature shows a moderate positive correlation and relatively low reliability in estimating stature, and has limited forensic value.

In the present study, positive moderate correlation (R ranging from 0.332 to 0.647) was noted between PCL of the sternum, sternal length, manubrial length and mesosternal length with stature in both the genders. Sternal length is the most significant predictor for stature among male gender and female. However, the accuracy of prediction is higher among females compared to males [R2=41% vs 17%]. The PCL of the sternum showed correlation coefficient of 0.424 in males and 0.628 in females, it was 0.872 in the study of Baraw R et al.[17] including the xiphoid process **(Table 4).** Overall all the sternal lengths display relatively moderate correlation coefficients with stature and relatively high standard errors of estimate in regression analysis **(Table 2)**.

Conclusion

Many researchers have shown that the sternum may be of use in stature assessment merely when long bones are not obtainable. Sternum carries ethnic variations, in view of gross population variation in metropolitan cities; the observations derived from multiple studies are of meagre significance. The application for utilizing the sternum for stature estimation should be restricted to the population sample for and from which they have been developed. Sternal length shall be considered as a better parameter over posterior curved length, the length of manubrium and length of mesosternum for estimating the stature if at all being used.

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Ethical approval: The study was conducted after the ethical clearance from Institute's Ethics Committee for Academic Research Projects vide approval letter number ECARP 2014-57. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of interest statement: The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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