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ORIGINAL ARTICLE

Estimation of cadaveric stature from sternal measurements: An autopsy-based study

Ashish Tyagi[1], Devinder Kumar Atal[1], Shrabana Kumar Naik[2]

1 Department of Forensic Medicine, Shaheed Hasan Khan Mewati Government Medical College, Nalhar, Nuh (Haryana), India
2 Department of Forensic Medicine, Lady Hardinge Medical College (New Delhi), India

Abstract

The aim of this study was to estimate cadaveric/post-mortem stature from dry sternum measurements by deriving regression equations. This study included dry intact sterna from 56 males and 44 females, aged more than 25 years, obtained during medico-legal autopsies. Stature and three sternal lengths i.e. length of the manubrium (ML), Mesosternal length (MSL) and combined sternal length (MBL), of each cadaver were measured. Stature and all measured sternal lengths were greater in males compared to females ($p<0.001$). Most of the sternal lengths were positively correlated with stature in sexes except male MSL and MBL. MBL had the highest correlation coefficient (0.525). On the other hand, the stepwise multiple linear regression equation derived from the combination of ML, MSL and MBL had the higher R2 value (R2 = 0.337) for cadaveric stature estimation. These findings suggested that measured sternal lengths can be used for estimation of sex. However, MSL and MBL measurements were found to be the most reliable sternal lengths for estimating sex. Our results revealed that sternum morphometry although shows moderate positive correlation with the cadaveric stature but is not a reliable tool for estimating stature when other skeletal bones are not available.

Keywords

Sternum; Cadaveric stature; Anthropometry; Correlation; Regression equation.

Introduction

One of the main information recovered from the bones is stature estimation which is one of the four main attributes of identification. Different morphometrical analysis of long and short bones helps us to estimate the stature of an individual by their individual correlation coefficients and regression analysis. Every racial or ethnic group need a different linear regression equation, and region wise studies which are very essential as racial or ethnic variations arise in different geographic regions.[1]

The total skeletal height of an individual estimated from dead body/corpse is different from the actual living stature because living stature does not takes into account the post-mortem changes like rigor mortis, intervertebral soft tissues thickness and age-dependent deductions in the actual height of that body.[2-4] Apart from long bones other bones like bones of hand, foot, vertebrae, sternum have also showed significant results in stature estimation of an unidentified corpses. Sternum is one of the few bones which is superficial and doesn't require much dismembering of body for its removal and thus used freely for anthropological purposes. Many researchers have used dry and fresh sternum morphometry for different forensic usage. The objective of the present investigation was to generate linear regression models for cadaveric stature estimation on the basis of different sternum measurements in North Indian population.

Corresponding Author
Dr. Devinder Kumar Atal (Associate Professor)
Email: devinder.atal@gmail.com,
Mobile: +918222880085

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Material and Methods

The material used in the present study was obtained from dead bodies brought to the mortuary of Department of Forensic Medicine of a tertiary care hospital and teaching institute of North India, for medico-legal autopsy during a period of one and a half year. The studied sample comprised of dried sterna of 100 adult individuals of age more than 25 years, including 56 males and 44 females. All of the study samples were positively identified at the time of post-mortem examination through police papers and personnel identification documents. Ethical approval for the research was obtained from the Institutional Ethical Committee and written informed consent was taken from the relatives of the deceased. All the sternum samples which were fractured, charred, diseased, or with deformities either congenital or acquired were excluded from the study.

The length of the dead body or cadaveric/post-mortem stature was measured, using a measuring tape, from the vertex of the cranium to the base of the heel with the body being placed in a supine position on the autopsy table.

Sternum was removed from the deceased by making a standard routine linear midline incision from chin to upper border of pubic symphysis. The clavicles were separated at the sterno-clavicular joint and the sternal margins that articulate with the first seven pairs of ribs were carefully cut at the costo-sternal junction. After removing the sternum from the thoracic cavity it was cleaned and soft tissues were scraped from the bone which was then allowed to macerate by immersing it in soap water for two weeks. After this the sternum samples were transferred to a setup containing plain water. Subsequent to all the wet maceration, the sterna were cleaned and dried at room temperature. The following parameters were measured using the Helio's dial callipers which gives accurate reading, upto 1/100 of mm.

- Manubrial Length (ML): Midline distance from the suprasternal notch to manubrio-mesosternal junction.
- Mesosternal Length (MSL): Length of mesosternum measured from manubrium-mesosternum junction to mesosternum-xiphoid process junction.
- Combined Length (MBL): Combined length of manubrium and mesosternum i.e. Manubrial length + Mesosternal length

Measurements were taken keeping the sternum bone on a flat surface. Three readings were taken and an average of the results was recorded. All data were recorded in an Excel spreadsheet and tabulated.

The data was analyzed using SPSS version 20.0 to derive linear regression equations for estimation of stature. Pearson's correlation coefficient was used to assess the correlation between stature and length of the sternum, and, Student t test was employed to test significant differences, if any. P value <0.05 was considered significant. Both simple and multiple linear regression analyses were derived using different sternal lengths to estimate stature of the study population. R^2 and standard error of estimate (SEE) were calculated to assess the significance of regression.[5]

Results

The present study comprised of 100 sterna with 56 male and 44 female samples. Test of normality (Kolmogorov-Smirnov test and Shapiro-Wilk tests) were done to demonstrate the normal distribution of samples. The Sig. (2-tailed) value for all sternum lengths: the manubrial length (ML), mesosternal length (MSL) and combined length (MBL) was 0.095 and 0.204, respectively (p-value >0.05). Hence, both male and female samples were normally distributed.

The stature of male and female cadavers ranged from 152cm - 180cm and 148cm -170cm, respectively. The manubrial length (ML), mesosternal length (MSL) and combined length (MBL) of males ranged from 38-52 mm, 79-109 mm, and 119-159 mm respectively, and for females, ranged from 36-49 mm, 62-91 mm, and 100-134 mm respectively. All measurements (stature and sternal lengths) were significantly higher (p<0.001) in males as compared to females (Table 1). The mean values of each of the parameters along are depicted in Table 1.

Statistically significant correlation was observed between all the sternal lengths and the stature. The correlation coefficients for all these lengths for both the sexes are shown in Table 2. Table 2 also shows the bivariate linear regression analysis for estimating stature using the different sternal lengths for both the sexes. For males, females, and the total sample, manubrial length showed the least standard error of the estimate for their regression models (Table 2).

Table 3 shows the results for stepwise multiple regression analysis applied individually to the studied sternal lengths. It was observed that in males, R^2 increased gradually with increase in the number of variables up to the last step of regression with MSL being most significant and MBL the least.

Table 1: Descriptive statistics of stature, manubrial length, mesosternal length, combined length and stature of study subjects

Parameters	Mean ± SD		
	Males (n=56)	**Females (n=44)**	**Total (n=100)**
Cadaveric stature (cm)	167.86 ± 5.96	159.09 ± 5.57	164.00 ± 7.23
ML (mm)	45.74 ± 2.98	41.20 ± 3.31	43.74 ± 3.85
MSL (mm)	100.27 ± 6.24	78.35 ± 6.26	90.62 ± 12.58
MBL (mm)	145.90 ± 7.67	119.29 ± 8.84	134.20 ± 15.58

ML = manubrial length; MSL = mesosternal length; MBL = combined length

Table 2: Linear regression models to estimate stature using sternal lengths

Sternal length	Sample	R	R^2	Linear regression model	SEE(mm)
ML	Male	0.205	0.042	Y=149.12+ 0.410(ML)	5.88
	Female	0.212	0.045	Y=144.36+0.357(ML)	5.51
	Total	0.490	0.240	Y=123.78+ 0.920(ML)	6.34
MSL	Male	-0.036	0.001	Y=171.30-0.034(MSL)	6.01
	Female	0.047	0.002	Y=155.83+0.042(MSL)	5.63
	Total	0.525	0.276	Y=136.64+0.302(MSL)	6.19
MBL	Male	-0.059	0.003	Y=174.55-0.046(MBL)	6.00
	Female	0.106	0.011	Y=151.09+0.067(MBL)	5.60
	Total	0.522	0.272	Y=131.49+0.242(MBL)	6.20

ML = manubrial length; MSL = mesosternal length; MBL = combined length; SEE = standard error of the estimate

Table 3: Stepwise multiple regression models to estimate stature using sternal lengths

Sternal length	R	R^2	Regression model	SEE (mm)
MSL	0.525	0.276	Y=136.64+0.302(MSL)	6.19
MSL+ML	0.359	0.308	Y=125.26+0.206(MSL)+0.459(ML)	6.07
MSL+ML+MBL	0.244	0.337	Y=125.77+0.820(MSL)+1.041(ML) -0.608(MBL)	5.98

ML = manubrial length; MSL = mesosternal length; MBL = combined length; SEE = standard error of the estimate

Table 4: Summary table of previous studies

Studies	Sternal length	Sex	R	R^2	Model	SEE (mm)
Singh et al.[5] (2011)	ML	M	0.191	0.04	Y=154.38 + 0.26 (ML)	7.08
		F	0.217	0.06	Y=141.17 + 0.32 (ML)	6.82
	MSL	M	0.255	0.07	Y=150.90 + 0.18 (MSL)	6.97
		F	0.229	0.05	Y=144.02 + 0.16 (MSL)	6.83
	MBL	M	0.318	0.10	Y=138.93 + 0.20(MBL)	6.83
		F	0.318	0.10	Y = 128.85 + 0.22(MBL)	6.65
Yonguc et al.[14] (2014)	ML	M	0.656	0.353	Y=141.192 + 0.602 (ML)	0.103
		F	0.670	0.448	Y=120.276 + 0.827 (ML)	0.173
	MSL	M	0.746	0.314	Y=125.320 + 0.408 (MSL)	0.076
		F	0.372	0.138	Y=134.845 + 0.261 (MSL)	0.123
	MBL	M	0.850	0.521	Y=111.198 + 0.370 (MBL)	0.045
		F	0.740	0.547	Y=95.139 + 0.449 (MBL)	0.077
Tumram et al.[10] (2015)	ML	M	0.44	0.197	Y=130.84 +6.44 (ML)	7.9
	MSL	M	0.25	0.06	Y=135.55 +2.53 (MSL)	8.5
	MBL	M	0.55	0.302	Y=90.65+ 4.8(MBL)	7.4
Jit et al.[11] (2018)	MBL	M	0.629	0.396	Y=117.091+3.41 x (MBL)	5.97
		F	0.598	0.358	Y=115.059+3.27(MBL)	5.26
Present study	ML	M	0.205	0.042	Y=149.12+ (0.410 x ML)	5.88
		F	0.212	0.045	Y=144.36+ (0.357 x ML)	5.51
	MSL	M	-0.036	0.001	Y=171.30+ (-0.034 x MSL)	6.01
		F	0.047	0.002	Y=155.83+ (0.042 x MSL)	5.63
	MBL	M	-0.059	0.003	Y=174.55+ (-0.046 x MBL)	6.00
		F	0.106	0.011	Y=151.09+ (0.067 x MBL)	5.60

ML = manubrial length; MSL = mesosternal length; MBL = combined length; SEE = standard error of the estimate

Discussion

Accurate identification of skeletal remains depends on the type and condition of bone available. Numerous studies have been conducted to estimate stature using various skeletal remains. The accuracy of stature estimation was found highest with long bones.[2, 3] However, few researchers also estimated stature using small bones and reported high levels of accuracy.[4] Various statistical tools have been utilised to increase the accuracy of identification.

Many researchers found it convenient to study the sternum for estimation of cadaveric stature, as it is easily procured during autopsy without causing any external disfigurement to the subject.[6] In the present study, we assessed the correlation between the sternal measurements and cadaveric stature in a north Indian population and linear regression equations were derived for the estimation of cadaveric stature.

Most of the previous studies were conducted using either fresh or dry sterna. Majority of researcher measured the straight length of anterior surface of sternum. In the present study, dry sterna were used and straight length of sterna was measured using Helio's dial calliper.

Menezes et al. [7,8], Singh et al.[5], Marinho et al.[9], Tumram et al.[10] and Jit et al. (2018)[11] concluded that the sternum can be utilised to estimate stature only when long bones are not available. The sternal lengths exhibit weaker correlation coefficients with stature and higher standard errors of estimate.

In the present study, all the measurements showed higher mean values in males than females, which supports the finding of sexual dimorphism for most measured lengths (Table 1). Similar to the study conducted by Singh et al.[5], the use of multiple bone lengths for stature estimation was found to be better than a single bone length. The R^2 was found to be higher for multiple regression analysis as compared to simple linear regression (Table 3).

Cadaveric Stature**:** The mean stature in the present study (Table 1) was found to be 167.86±5.96 in males and 159.09±5.57 in females, respectively. Menezes et al.[7, 8], Nagesh and Kumar[12], Rastogi et al.[13], Younguc et al.[14], and Jit et al.[11] also observed cadaveric statures within same range their studies.

In present study, there was a significant correlation between cadaveric stature and Manubrial Length (ML) for both males and females. The correlation coefficient was comparable to the study by Singh et al.[5] However, other researchers reported more positive correlation coefficients in their studies (Table 4). The standard error of estimate in almost all the studies ranges from 5 to 7. The standard error of estimate in the current study is also in between 5 to 6.

There was a positive correlation between cadaveric stature and Mesosternal Length (MSL) in females. However, negative correlation was observed in males. Other researchers found higher correlation coefficients in both sexes when compared to the present study (Table 4). The standard error of estimate in almost all the studies ranges between 5 to 8, which was also observed in the this study.

There was a positive correlation between cadaveric stature and Combined Length (MBL) in females. However, negative correlation was seen in males. Other researchers reported a strong correlation coefficient in both sexes as compared to this study (Table 4). The standard error of estimate in almost all the studies ranges from 5 to 7, which was also observed in this study.

The current study is limited to the north Indian population and thus its applicability is limited to this population alone. In order to increase the accuracy and specificity, studies with large sample size and different geographical distribution should be carried out. Also, the present study is of limited use in cases of estimation of cadaveric stature from non-macerated sterna and stature estimation in living individuals. Many researchers have also used the sternum for stature estimation in living beings by different radiological techniques i.e. X-ray[15] and CT scans.[16]

Conclusion

Based on the observations and results of different sternal measurements, it can be concluded that mean cadaveric stature and other sternal lengths were higher in males than females. On applying linear regression analysis, there was a significant correlation between cadaveric stature and ML measurement in males except in the case of MSL and MBL sternal lengths, whereas in female samples significant correlation seen for all measurements. The correlation coefficient in the present study is comparatively less as compared to other studies.

So, we conclude that the sternal measurement is not statistically significant for estimating cadaveric stature as compared to other long bones. However, these measurements could be used to determine stature in the absence of other significantly correlated bones.

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