J Indian Acad Forensic Med. 2021 Apr-Jun; 43(2): 118-121
doi:10.5958/0974-0848.2021.00031.2

ORIGINAL ARTICLE

Correlation of cadaveric stature with posterior curve length of sternum in Mewat Region of Haryana: A comparative analysis of SPSS with machine learning

Ashish Tyagi[1], Piyush Bhardwaj[2], Hitesh Chawla[1]
1 Department of Forensic Medicine, Shaheed Hasan Khan Mewati Government Medical College, Nalhar, Nuh, Haryana, India
2 Centre of Advanced Computational Solutions and Department of Molecular Biosciences, Lincoln University, Christchurch, New Zealand

Abstract
The aim of the present study was to develop a population specific regression formula for estimating cadaveric length from posterior curve length of fresh sternum and compare the linear regression results of SPSS and machine learning. Cadaveric length and posterior curve length (PCL) of the sternum were measured from 74 dead bodies (39 males and 35 females) aged between 18 and 95 years from known corpses during medico-legal autopsies. Cadaveric stature and PCL was greater in males as compared to females ($p<0.001$). Regression equations and correlation coefficients were derived for PCL by SPSS and machine learning, which were Y=122.79+2.504(PCL) and Y= 122.98+2.49(PCL), respectively, with correlation coefficients of 0.609 and 0.606, respectively. Individual regression equations were also formulated for males and females separately with significant correlation. The standard error of estimate and R square model were also derived. Cross validating linear regression results of SPSS with machine learning showed almost similar results. The study suggests that posterior curve length of sternum in relation with post-mortem or cadaveric stature shows regional or geographic variation, a moderately positive correlation and relatively low reliability in estimating cadaveric stature, and thus, has limited forensic value.

Keywords
Fresh sternum; Posterior curve length; Cadaveric stature; Correlation; Regression equation; Machine learning.

Introduction

One of the four important attributes of identification is stature estimation. Most of the studies conducted previously in this regard were from long bones but in case of fractured, dismembered, mutilated or diseased remains other bones also comes in to play like bones of hand, feet, sternum, vertebrae etc. 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.[1-3] Soft tissue thickness i.e. correction factor also needs to be added and ageing factor needs to be taken into consideration to obtain living stature of an individual.[4]

The present study was conducted to estimate the stature of an individual from the sternum which is a superficial bone and can be easily procured from cadavers without much damage during the autopsy procedure.[5] Owing to these factors, the sternum was selected for this study and as an identifying unit of stature. Most of the earlier researchers in this regard have confined their studies to stature estimation of a single sex. But only a few studies such as the present one have taken both the sexes into consideration and have derived a regression equations for both sexes. After undertaking a thorough search of the available literature, this preliminary study which is perhaps the first ever work to be done on correlation of cadaveric stature with sternum posterior curve length by using machine learning also as a tool for analysis was piloted. The present study was designed to develop a population specific regression formula to correlate the stature of an individual with the posterior curve length of the sternum in the Mewat region of Haryana.

Corresponding Author
Dr. Ashish Tyagi (Associate Professor)
Email: drashishfm@gmail.com,
Mobile: +91-8222880085

Article History
Received: 18th July, 2020; Accepted: 9th April, 2021

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 rural south Haryana, for medico-legal autopsy between October, 2019 and May, 2020. The studied sample comprised the sterna of 74 adult individuals of age 18 to 95 years, including 39 males and 35 females of Mewat, Haryana. All participants of the study were positively identified at the time of post-mortem examination via personal identification documents to confirm their identity and date of birth. Ethical approval for the study was taken from the Institutional Ethics Committee and informed consent from the relatives of the deceased. All the sternum samples which were fractured, charred, diseased or deformed due to congenital or acquired causes were excluded from the study.

The length of the dead body or cadaveric 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 sternoclavicular joint and the sternal margins that articulate with the first seven pairs of ribs were carefully cut at the costosternal junction. After removing the sternum from the thoracic cavity it was cleaned and soft tissues were separeted from the bone. Posterior curve length of sternum was measured to the nearest using standard measuring tape. Measurements were taken keeping the fresh sternum bone on a flat surface and posterior curve length (PCL) was measured between suprasternal notch and the xiphoid process. The distance between the inferior point of the jugular notch and the inferior point of the xiphoid process was recorded. Three readings were taken and an average of the results was recorded. After taking all the measurements the bone was not preserved beyond the autopsy and was subsequently returned to the body. All data were recorded in an Excel spreadsheet and tabulated.

The data was analyzed using SPSS version 20.0 to derive a linear regression equation for estimation of cadaveric stature. Pearson's correlation coefficient was calculated to assess the correlation between stature and length of the sternum and Student t test was used to evaluate the significance. P value less than 0.05 was considered significant. The hypothetical regression equation is represented as Stature (S) = a + bX, where 'a' is the regression coefficient of the dependent variable (i.e., stature), 'b' stands for the regression coefficient of slope or independent variable (posterior curve length) and 'X' is the mean length. The R^2 and standard error of estimate (SEE) were calculated to assess the significance of regression. R^2 determines the degree of association of correlation that exists between PCL and the cadaveric stature/length. The standard error of estimate measures the accuracy of estimated figure, smaller is its value, better will be the estimates and vice-versa. Stature was estimated from the derived regression equations and was compared with the actual postmortem stature of the cadavers to assess the accuracy of the formulae.[4]

Similar to the SPSS analysis, R^2 value, regression coefficient of slope, correlation coefficient and regression coefficient of dependent variable were estimated by implementing linear regression algorithm (in python version 3.7) via a machine learning approach. Results obtained from machine learning method were then compared against the SPSS outcomes to cross validate the prediction of stature.

Results

The present study comprised of 74 samples of sterna with 39 male and 35 female samples. Test of normality (Kolmogorov-Smirnov test and Shapiro Wilk test) were done to demonstrate the normal distribution of samples taken from the same population. The significance (2-tailed) value for PCL for sternum was 0.06 and 0.195 respectively, which were >0.05, and thus establishes the fact that both male and female samples were normally distributed and taken from same population.

The stature of male and female cadavers ranged from 149cm - 181cm and 148cm-171cm, respectively. The posterior curve length of the male and female sterna ranged from 12-21cm and 13-20 cm, respectively. The mean length of the sterna formed 9.8% and 9.7% of the mean stature of the cadavers in males and females, respectively. The mean values of the cadaveric stature and the posterior curve length of the sternum are shown in Table 1.

Table 1: Descriptive statistics of posterior curve length (PCL) and stature of study subjects (cm)

Variables	Mean ± SD (cm)		
	Males (n = 39)	**Females (n = 35)**	**Total (n = 74)**
Cadaveric stature	167 ± 6.87	158.09 ± 6.15	162.85 ± 7.89
PCL	16.5 ± 2.08	15.43 ± 1.55	16.00 ± 1.92

PCL = posterior curve length of the sternum

Table 2: Regression models to estimate stature using the posterior curve length of the sternum

Method	Linear regression equation	R	R^2	SEE (years)
SPSS	Y=122.79 + (2.504 x PCL)	0.609	0.37	6.31
Machine learning	Y= 122.98 + (2.49 x PCL)	0.606	0.368	4.98

PCL = posterior curve length of the sternum; Y = stature; SEE = standard error of the estimate

Table 3: Result of linear regression equation for the present study

	Linear Regression model	R	R^2	SEE (years)
Male	Y=134.55+ (1.967 x PCL)	0.596	0.355	5.59
Female	Y=125.85+ (2.090 x PCL)	0.526	0.277	5.31
Total sample	Y=122.79+ (2.504 x PCL)	0.609	0.370	6.31

PCL = posterior curve length of the sternum; Y = stature; SEE = standard error of the estimate

Statistically significant correlation (p-value < 0.001) was observed between the posterior curve length of the sterna of males, females, and the total study population with the cadaveric stature. Coefficient of correlation (R) was observed to be 0.596 in males, 0.526 in females, and 0.609 in the total population.

Simple linear regression analysis was used to predict stature based on posterior curve length (PCL) of sternum (Table 2). The regression model developed was: Y=122.79 + (2.504 x PCL) with R^2 of 0.370. PCL was measured in centimetres and it was observed that the average stature increases by 6.24 cm for each 1 cm of PCL. The standard error of estimate for the regression model was 6.31. By applying the standard error 6.24, we can determine the stature of an individual with 68%

confidence. If we multiply the standard error of estimate by 2, stature can be estimated with 95% confidence.

To cross-validate our prediction of stature based on the PCL of sternum, we performed linear regression algorithms via a machine learning approach in python (Table 2). Observed results were almost similar to the results from SPSS analysis. The regression equation obtained was Y=122.98 + (2.49 x PCL) with R^2 of 0.368 and correlation coefficient of 0.606.

Table 3 shows bivariate regression analysis of both sexes for estimating stature on the basis of sterna posterior curve length. The standard error of estimate (SEE) in both the sexes was found to be higher, i.e., around 5-6 cm for almost all the variables. The linear regression analysis between post-mortem stature/cadaver length and the sternal posterior curve length in both the sexes was found to be significant.

Table 4: Comparison of the results of present study with the those in literature

Studies	R	R^2	SEE (years)	Linear regression model
Menezes et al.[7] (South Indian population)	0.638	0.407	5.64 (M)	Y=117.784 + (3.429 Sternal length)
Menezes et al.[8] (South Indian population)	0.639	0.408	4.11(F)	Y=111.599+(3.316×Length of the sternum)
Choudhary et al.[15] (Bengali population)	0.636 (M)	0.404	2.94 (M)	Y=137.58+1.15*sternal length
	0.843 (F)	0.711	2.230 (F)	Y=120.47+1.81*sternal length
Singh et al.[4] (Northwest Indian population)	0.318 (M)	0.101	6.83 (M)	Y= 138.93 + 0.20(MBL)
	0.318 (F)	0.101	6.65 (F)	Y = 128.85 + 0.22(MBL)
Manoharan et al.[9] (South Indian population)	0.78	0.608	4.8 (M)	Y=93.6+5.1* (MBL)
Jit et al.[10] (South Indian population)	0.629 (M)	0.396	5.97 (M)	Y=117.091+(3.41xsternal length)
	0.598 (F)	0.958	5.26 (F)	Y=115.059+(3.27x sternal length)
Marinho et al.[11] (Portugal population)	0.329	0.11	6.59	Y = 135.322 + 0.160 (Sternal Length)
Tumram et al.[12] (Central Indian population)	0.55	0.302	7.4 (M)	Y=90.65+4.8* total sternal length
Yonguc et al.[13] (Turkish population)	0.850	0.521	0.045	Y=111.198+ 0.370 (MBL)
Baraw et al.[14] (Delhi population)	0.872	0.770	3.5	Y=91.51+3.5 (PCL)
Present study using SPSS	0.609	0.370	6.31	Y=122.79+ (6.24 x PCL)
Using machine learning	0.606	0.368	4.98	Y= 122.98 + (2.49 x PCL)

PCL = posterior curve length of the sternum; MBL: combined length (manubrium+mesosternum)

Discussion

For many years anthropometric techniques are being used in forensic practice for estimation of stature. Every racial or ethnic group needs a different linear regression equation, and region wise studies are very essential as racial or ethnic variations arise in different geographic regions.[6] With the increasing frequency of mass disasters and crimes involving dismembered or mutilated bodies, estimation of stature from such remains has created problems in ascertaining identity of some victims as methods of estimating stature from the skeleton are mostly based on the long bones of the lower and upper extremities. Sternum is one of the bones that could be used to determine stature, when the body is recovered in such mutilated or dismembered state with absence of limbs.[7-8]

Earlier studies have dealt with stature estimation from a dry sternum.[7-10] Recently, various researchers (Table 5) used the fresh sterna for stature estimation to determine its applicability in forensic practice.[11-14] The present work consisted of direct measurement of the sternum in autopsy cases. Also the use of regression analysis to correlate with stature is a well established method in anthropological studies. In its natural position the inclination of the sternum is oblique from above, downward and forward. It is slightly convex in front and concave behind.[5,10,15] So we considered the posterior curved length of sternum as one of the variables in the present investigation.[5] Direct measurement in autopsy cases is more accurate and reliable than other works of morphometry with radiography and digital measurement.[5] In this study we wished to provide an alternative means to the estimation of stature with measurements of fresh sterna, namely when maceration cannot be carried out, due to time constraints for example, or when a fresh or decomposed mutilated cadaver is being identified.[14]

The observations of the present study showed that posterior curve length of sternum has a moderate positive correlation with cadaveric stature which also corresponds to that reported by other researchers from India and abroad (Table 4).[7-14] However, interpretations of the present study also concur with the findings of Singh et al.[4], Marinho et al.[11] and Tumram et al.[12], that sternal lengths are comparatively less correlated with stature and are thus, comparatively less reliable for stature estimation. Not only is the correlation between sternum posterior curve length and cadaveric stature comparatively less, but the standard error of the estimate is relatively large, resulting in confidence intervals for cadaveric stature which are also large and of limited use to discriminate between individuals of similar stature. Use of multiple bone lengths for stature estimation was found to be better than single bone length as R^2 or coefficient of determination was found higher in multiple regression analysis than simple linear regression.[4,11]

Another important consideration while scrutinizing different stature estimation methods is that they are not universally applicable and several studies have demonstrated that a model developed from a specific population may not give as reliable estimates when applied to another.[11] This results mostly from differences in body proportions and differences in proportions between stature and bone size, that result from differences in environmental conditions during growth which affect these proportions.[1-4,11]

One of the few limitations of the present study was the small sample size. This can be rectified by a larger study group to examine the applicability of the results for use in forensic practice. Also more variables should be analysed for garnering more accuracy. The result of this study when compared to different geographical population yielded a varied predictive value. This regional variation concurs with previous studies also. Another lacuna of study could be the soft tissue adherence to the wet sternum bone sample which could have lead to lower accuracy in morphometry, however, it was uniform and minimal throughout.

In the present study, we also implemented basic linear regression as machine learning algorithm so as to cross validate or support the outcomes from SPSS analysis. The linear regression results calculated from both the systems appeared to be almost similar with standard error of estimate slightly lower in machine learning than the SPSS system result. However, the limited amount of data in this study restricted us from using machine learning approaches extensively. However, in future machine learning methods such as K-nearest neighbour, support vector machines, regression trees and random forest can be utilised to predict using large datasets.

Conclusion

Forensic anthropology is a good predictor of various collaborations that can be adjunctive in the process of identification. The studies which are conducted on a specific ethnic group can be an addition to the existing database of studies of various populations around the world so that a large international database is made available which can be of use in practical forensic investigation. Stature is one of the main tools for identification of unknown dead bodies. Apart from long bones which are mostly studies for this purpose other bones like sternum can also be used for estimating stature only when long bones are not available, as sternal PCL exhibits comparatively weaker correlation coefficients with cadaveric stature and higher standard error of estimate in regression analysis. This measurement and method of calculating cadaveric stature can be used, if immediate estimation is required, as the sternum is easily removed and dissected from a relatively fresh or badly decomposed body.

Ethical clearance: A prior approval was obtained from the Institutional Ethics Committee

Conflict of interest: None to declare

Source of funding: None to declare

References

1. Trotter M. Estimation of stature from long bones. In: T.D. Stewart, editor. Personal Identification in Mass Disasters. Washington DC: National Museum of Natural History; 1970.p. 71–84.
2. Galloway A. Estimating actual height in the older individual, J Forensic Sci. 1988;33: 126–36.
3. Adams BJ, Herrmann NP. Estimation of living stature from selected anthropometric (soft tissue) measurements: applications for forensic anthropology. J Forensic Sci. 2009;54: 753–60.
4. Singh J, Pathak RK, Chavali KH. Skeletal height estimation from regression analysis of sternal lengths in a Northwest Indian population of Chandigarh region: A postmortem study. Forensic Sci Int. 2011;206(1-3):211.e1-8.
5. Mukhopadhayay PP. Determination of sex from adult sternum by discriminant function analysis on autopsy sample of Indian Bengali population: A new approach. J Indian Acad Forensic Med.2010; 32(4):321-3.
6. Telkka A. On the prediction of human stature from the long bones. Acta Anat (Basel) 1950:9;103–17.
7. Menezes RG, Kanchan T, Kumar GP, Rao PPJ, Lobo SW, Uysal S, et al. Stature estimation from the length of the sternum in South Indian males: A preliminary study. J Forensic Leg Med. 2009; 16(8):441–3.
8. Menezes RG, Nagesh KR, Monteiro NP,Kumar GP, Kanchan T, et al. Estimation of stature from the length of the sternum in South Indian females. J Forensic Leg Med. 2011;18:242-5.
9. Manoharan C, Rajesh R, Dhanalakshmi V. Morphometric study of human sternum to determine the stature in males- an autopsy study. Indian J Forensic Community Med. 2015;2(2):91-4.
10. Jith S, Hussain JAP, Kumar V, Siddapa SC, Mohanty SK. Estimation of stature from the length of the sternum: an autopsy based study. J Indian Acad Forensic Med. 2018; 40(1):81-4.
11. Marinho L, Almeida D, Santos A, Cardoso HFV. Is the length of the sternum reliable for estimating adult stature? A pilot study using fresh sterna and a test of two methods using dry sterna. Forensic Sci Int. 2012; 220(1-3):292.
12. Tumram NK, Parchake SB, Bardale R, Dixit P. Estimation of height from the length of the sternum in an adult Indian population. Med Sci Law. 2016;56(1):46-52.
13. Yonguc GN, Kurtulus A, Adiguzel OBE, Unal I, Demir S, Acar K. Estimation of stature and sex from sternal lengths: An autopsy study. Anat Sci Int. 2015;90(2):89-96.
14. Baraw R, Pradhan M, Singh A. Correlation of Posterior Curve Length of Sternum and Stature: A Postmortem Study in Delhi Population. Int J Med Toxicol Forensic Med. 2017; 7(3):159-164.
15. Chowdhuri S, Mukhopadhayay P. Estimation of stature from radiological measurement of sternal length with corroboration in living individuals a study in contemporary Bengali adults. J Indian Acad Forensic Med. 2015; 37(4):388-91.