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Stature estimation from sternum length using computed tomography–volume rendering technique images of western Chinese

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ABSTRACT

The objective of the present investigation was to generate linear regression models for stature estimation on the basis of sternum length derived from computed tomography–volume rendering technique (CT–VRT) images for Western Chinese. The study sample comprised 288 individuals of Western Chinese, including 124 females and 164 males, with documented ages between 19 and 78 years, and was randomly divided into two subgroups. The linear regression analysis for the calibration sample data yielded the following formulae: male stature (cm) = 137.28 + 1.99*combined length of manubrium and mesosternum and female stature (cm) = 111.59 + 3.51* combined length of manubrium and mesosternum. Pearson's correlation coefficients for the regression models were r = 0.459 and r = 0.541 for the male and female formulae, respectively. The standard errors of the estimate (SEE) were 4.76 cm for the male equation and 6.73 cm for the female equation. The 95% confidence intervals of the predicted values encompassed the correct stature of all specimen in the validation sample. The regression equations derived from the sternum length in the present study can be used for stature estimation and the length of the sternum is a reliable predictor of stature in Chinese when better predictors of stature like the long bones are not available, and the CT–VRT method may be a practical method for stature estimation.

1. Introduction

Forensic anthropology plays a crucial role in the medico-legal investigation of unidentified skeletonized or decomposed human remains. The estimation of stature is an important component. The most accurate method for reconstructing stature involves the measurement of all skeletal elements that contribute to living height.[1,2] Although highly accurate, this anatomical method cannot be applied in many cases in which human remains have been dismembered or mutilated. As a result, the most commonly alternatives are based on the positive linear relationship between stature and the length of various parts of the body. Several post-cranial elements have been used for the derivation of regression equations for the estimation of stature, such as long bones,[3–8] scapula,[9–11] metacarpals,[12] metatarsals,[13] and vertebral column.[14–17]

Recently, regression equations for stature estimation based on the length of the sternum have been developed from the measurement of digital radiographs,[18] multidetector computed tomography images,[19] however, mostly are recorded from direct measurement of cadavers.[20–24] The rapid technological development of multi-row computed tomography (CT) in the last two decades has resulted in an increase in CT examinations on the whole, the volume rendering technique (VRT) has the advantage of real time operation of the object mass. Currently, the virtual anthropology techniques initiated by the Virtopsy (virtual autopsy) project,[25] which rely on three-dimensional (3D) reconstructions of computed tomography (CT) scans of skeletal remains. Analysts can perform morphological and metric analyses to establish the biological profile from the 3D images,[26] and the data can provide an

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objective and observer-independent method for recording features that are normally difficult to quantify and can allow easy access to reports and data for peer review. Additionally, advantages include no deterioration of data over time, no skeletal preparation, no damage to skeletal material, and potential application to living individuals.[27,28]

Therefore, the primary objective of the present investigation was to generate linear regression models for stature estimation on the basis of sternum length derived from 3D-VRT images in different population groups. This was done due to inherent population differences in various dimensions that are attributed to genetic and environmental factors.[29,30] Furthermore, a test of the utility of sternal measurements to predict stature in Western Chinese was carried out.

2. Materials and methods

The present study was performed with the approval of the ethics committee of the West China Hospital of Sichuan University and all the participants provided written informed consent.

The data used in the present study were obtained from participants undergoing routine examination at the West China Hospital of Sichuan University. The study sample comprised 288 individuals from western China, including 124 females and 164 males, with documented ages between 19 and 78 years (Table 1). Subjects with a history of chronic illness, trauma, physical deformity, or any surgical procedure that might affect stature or sternum dimensions were excluded from the study.

The stature was measured during standing in full extension as the maximum length between the skull vertex and the heel in millimetres. The data collection was conducted during a two-month period between 9:00 am and 10:00 am to avoid the influence of diurnal variation as it affects the standards generated and equations developed for the estimation of stature.[31]

Multidetector CT was carried out on Somatom definition AS 128 slice CT Machine by Siemens Germany Ltd. After obtaining the scout projection, the area of scanning was defined to include the region from fifth cervical vertebra until the first lumbar vertebra. The scanning protocol was as follows: collimation of 1 mm, reconstruction interval of 1 mm, tube voltage of 120 kV, tube current of 110 mA, and scanning time of 0.3 s. Image data were processed on a workstation (Syngo CT 2011A) to obtain volume-rendering technique images.

A 3D reconstructed image was used for assessment. The linear distances from the centre of suprasternal notch or incisura jugularis (jugular notch) to the centre of manubrio-mesosternal junction (sternal synchondrosis) in mid-sagittal plane and the manubrio–mesosternal junction to the mesosterno–xiphoidal junction of the sternum in the mid-sagittal plane were defined as the Length of manubrium (M) and Length of mesosternum (B), respectively (Fig. 1). The manubrium and mesosternum often do not fuse even in later life,[32] and as a result, the Combined length of manubrium and mesosternum was used for statistical analysis.

Fig. 1. Linear measurements (black lines) from 3D-VRT images used to calculate the combined length of manubrium and mesosternum: manubrium length (M) and mesosternum length (B).

All the measurements recorded by the same author twice to minimize the error in measurement, and the results of measurements were made to the nearest 1 mm, the mean value was used for analysis. Mean intra-observer error, calculated following the equation presented by Albanese et al.,[33,34] was less than 1.1% for all dimensions and thus within the acceptable limit (below 2.0–2.5%).

Given that previous studies have demonstrated that stature formulae are not only population-specific but also sex-specific,[23,35,36] separate linear regression equations for estimating stature on the basis of sternum length were then devised for males and females. The study sample was randomly divided into two subgroups. A calibration sample, which consisted of 113 females

Table 1
Sex, age, stature, and combined length of manubrium and mesosternum distribution of the utilized study sample.

Sex group	n	Age (years)			Stature (cm)			Combined length of manubrium and mesosternum (cm)		
		Mean ± Std. deviation	Minimum	Maximum	Mean ± Std. deviation	Minimum	Maximum	Mean ± Std. deviation	Minimum	Maximum
Calibration sample										
Female	113	47.0 ± 12.3	19	78	157.1 ± 6.5	138.9	171.9	12.9 ± 1.0	10.0	15.8
Male	146	48.9 ± 12.1	25	78	166.6 ± 6.3	151.9	185.9	14.8 ± 1.4	9.5	23.0
Validation sample										
Female	11	45.5 ± 8.3	33	59	156.5 ± 3.2	150.0	160.4	12.6 ± 0.9	11.1	14.4
Male	18	47.9 ± 7.7	35	60	168.1 ± 2.5	163.5	171.4	14.8 ± 0.9	13.2	16.3