Forensic Science International 206 (2011) 211.e1–211.e8

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Forensic Anthropology Population Data

Skeletal height estimation from regression analysis of sternal lengths in a Northwest Indian population of Chandigarh region: A postmortem study

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ARTICLE INFO

Article history:
Received 6 July 2010
Received in revised form 17 August 2010
Accepted 26 August 2010
Available online 24 September 2010

Keywords:
Forensic anthropology
Stature estimation
Sternal lengths
Total sternal length
Regression analysis
Universal regression formulae

ABSTRACT

Skeletal height estimation from regression analysis of eight sternal lengths in the subjects of Chandigarh zone of Northwest India is the topic of discussion in this study. Analysis of eight sternal lengths (length of manubrium, length of mesosternum, combined length of manubrium and mesosternum, total sternal length and first four intercostals lengths of mesosternum) measured from 252 male and 91 female sternums obtained at postmortems revealed that mean cadaver stature and sternal lengths were more in North Indians and males than the South Indians and females. Except intercostal lengths, all the sternal lengths were positively correlated with stature of the deceased in both sexes ($P < 0.001$). The multiple regression analysis of sternal lengths was found more useful than the linear regression for stature estimation. Using multivariate regression analysis, the combined length of manubrium and mesosternum in both sexes and the length of manubrium along with 2nd and 3rd intercostal lengths of mesosternum in males were selected as best estimators of stature. Nonetheless, the stature of males can be predicted with SEE of 6.66 ($R^2 = 0.16$, $r = 0.318$) from combination of MBL + BL_3 + LM + BL_2, and in females from MBL only, it can be estimated with SEE of 6.65 ($R^2 = 0.10$, $r = 0.318$), whereas from the multiple regression analysis of pooled data, stature can be known with SEE of 6.97 ($R^2 = 0.387$, $r = 575$) from the combination of MBL + LM + BL_2 + TSL + BL_3. The R^2 and F-ratio were found to be statistically significant for almost all the variables in both the sexes, except 4th intercostal length in males and 2nd to 4th intercostal lengths in females. The 'major' sternal lengths were more useful than the 'minor' ones for stature estimation The universal regression analysis used by Kanchan et al. [39] when applied to sternal lengths, gave satisfactory estimates of stature for males only but female stature was comparatively better estimated from simple linear regressions. But they are not proposed for the subjects of known sex, as they underestimate the male and overestimate female stature. However, intercostal lengths were found to be the poor estimators of stature ($P < 0.05$). And also sternal lengths exhibit weaker correlation coefficients and higher standard errors of estimate.

1. Introduction

Being an important component of biological identity, stature estimation has been attempted by various workers using long bones with variable degree of success. But the recovery of long bones from all forensic or bioarchaeological scenarios is a chance factor and can never be guaranteed or the retrieved long bones may not be suitable for the purpose as they may be partially or completely destroyed, fractured, diseased. Hence forensic anthropologists are left with no option other than relying upon the development of some alternate methods of stature estimation using other skeletal elements like skull [1,2], vertebrae/vertebral column [3,4], hand and foot bones [5–7], sacrum [8], scapula [9–11], sternum [12], etc.

Further, it is well documented that there exists some biometrical/proportional relationship between every human bone or body segment and the stature of that individual, which varies between two sexes as well as amongst different populations because of some long-term genetic [13,14], ethnic, secular [14–16] environmental, socio-economic or nutritional factors [17], etc., which, in turn, influence the developmental period of individuals of a particular sex or a population [18,19]. So, population and sex-specific stature estimation equations are needed. Though a number of human bones or body segments have been used for stature estimation in different populations, but sternum has been rarely used in this endeavor.

The total skeletal height of an individual estimated from dead body/corpse is different from the actual living stature because former does not takes into account the rigor mortis changes, the

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doi:10.1016/j.forsciint.2010.08.023

thickness of intervertebral soft tissues and age-dependent deductions in the actual stature of that individual [20–22]. Soft tissue thickness (correction factor) need to be added and ageing factor be subtracted from the total skeletal height to obtain living stature of an individual. The body length of a dead person is about 2.5 cm more than the living stature [13], possibly due to compression of soft tissues between intervertebral discs in a standing person.

As is the case with different geographical zones of world, there is a need to develop separate regression formulae for different bones of human skeleton for different regions of India. Except a preliminary study on a South Indian population by Menezes et al. [12], as per the accessible literature, no other indexed study has been reported for stature estimation from sternal measurements. So the present study was undertaken to formulate regression equations for stature estimation from the total skeletal height predicted from sternal lengths and to compare their accuracy with pooled data formulae, and also to provide alternate means of stature estimation of the adult subjects of Chandigarh zone of Northwest India.

2. Materials and methods

2.1. Population data

With the valid consent of the legal heirs of the deceased, adult sternum was collected from 343 subjects (males, 252; females, 91) who were admitted and died because of various medico-legal causes (198 accidents, 73 poisoning, 42 burns, 30 other reasons) at Nehru Hospital of Postgraduate Institute of Medical Education and Research, Chandigarh, India. The medico-legal postmortem of these cadavers was conducted by the Department of Forensic Medicine of this institute. All the subjects were between the ages of 18 and 94 years. In the present study, only the subjects demographically belonging to five northwest Indian States of Punjab, Haryana, Himachal Pradesh, western part of Uttar Pradesh and Union Territory of Chandigarh were included. The cases of other regions/states were not considered in order to avoid any distortion in the values of the measurements of the studied parameters as people of different zones of India are reported to have different sternal measurements [23–33].

2.2. Methodology

Each sternum was removed as a single piece by giving incisions at sternoclavicular joints and at junctions of all the seven rib costal cartilages. After removal, the standard procedures of cleansing, washing and drying were followed to prepare the freshly removed sternums suitable for the morphometric measurements. While boiling, repeated careful inspection was done to avoid separation of the three pieces of sternum. Sternum showing any skeletal abnormality or deformity, visible pathology or fracture was excluded from the study sample. Due to ethical constraints, each sternum was replaced into the body after taking measurements, without employing any prolonged defatting or drying process. Except body length (in centimeters), all the other measurements were measured in millimeters. Each of the following measurement was taken three times and their average was recorded for analyses and comparisons.

2.2.1. Body/cadaver length (CL)

Before autopsy, the length of each dead body, placed in supine position on a flat and hard-surfaced postmortem table, was measured between the vertex of head and the heel with a steel measuring tape to the nearest 0.1 cm as per the technique used by Nagesh and Kumar [4]. This was taken as postmortem stature of the deceased.

2.2.2. Length of manubrium (LM)

It is the straight distance measured on the anterior surface of the sternum from the centre of suprasternal notch or incisura jugularis (jugular notch) to the centre of manubrio-mesosternal junction (sternal synchondrosis) in mid-sagittal plane (Fig. 1) using Mitutoyo® digital vernier calipers to the nearest millimeter according to the technique prescribed by Ashley [34].

2.2.3. Length of mesosternum (LB)

It is the straight distance measured from the manubrio–mesosternal junction to the mesosterno–xiphoidal junction of the sternum in the mid-sagittal plane (Fig. 1).

2.2.4. Combined length of manubrium and mesosternum (MBL)

It is the straight distance measured from the centre of suprasternal notch or incisura jugularis (jugular notch) to the mesosterno–xiphoidal junction in the mid-sagittal plane (Fig. 1) and taken on the anterior surface of the sternum using Mitutoyo® digital vernier calipers to the nearest millimeter according to the technique prescribed by Ashley [34].

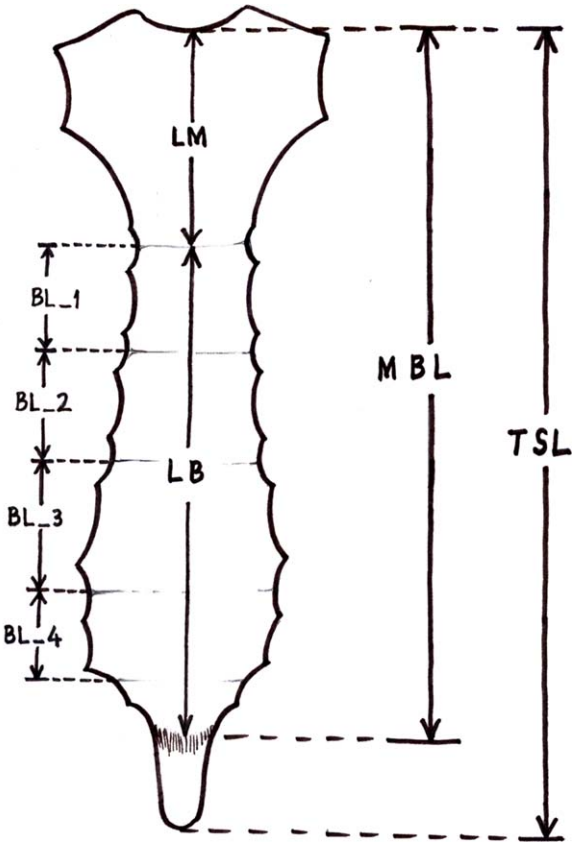

Fig. 1. Illustration of various sternal measurements.

$$\text{Combined length(MBL)} = \text{length of manubrium(LM)} + \text{length of mesosternum(LB)}.$$

2.2.5. Total sternal length (TSL)

It is the total distance measured from the jugular notch to the caudal end of xiphoid process in the mid-sagittal plane (Fig. 1). Because of high variability in xiphisternal shape and length [35,36], this parameter could be measured only in 234 males and 78 female sternums, as in the remaining cases the sternal elements were either fused partially or xiphisternum was absent completely. Hence the missing values of total sternal length of 18 male and 13 female cases were replaced with their respective mean values.

2.2.6. Intercostal lengths of mesosternum (BL)

It is the distance measured between the mid-points of second and third (BL_1), third and fourth (BL_2), fourth and fifth (BL_3) and fifth and sixth (BL_4) costal facets/notches of the mesosternum (Fig. 1). These distances between the consecutive costal notches were measured with the help of spreading caliper with pointed ends. The intercostal length between sixth and seventh could not be recorded correctly in most of the cases (due to its inherent variability) and hence it was not considered for the observations and the final analysis. It may be pertinent to clear here that this measurement is different from that recorded by Torwalt and Hoppa [37] on chest-plate radiographs, who recorded the width of mesosternum mid-way between second and third, third and fourth, fourth and fifth and fifth and sixth costal cartilage notches.

Arbitrarily, first four sternal lengths were considered as 'major' and the last four intercostal lengths as 'minor' sternal lengths as the former lengths are from larger segments of the sternum.

2.3. Statistical analysis

Various statistical descriptives of the sternal lengths were calculated using Statistical Package for Social Sciences 'SPSS 11.5 Version' [38]. The correlation coefficients were calculated to assess any relationship that exists between different