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Estimation of stature from radiologic anthropometry of the lumbar vertebral dimensions in Chinese

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ABSTRACT

The resent study was to assess the relationship between the radiologic anthropometry of the lumbar vertebral dimensions and stature in Chinese and to develop regression formulae to estimate stature from these dimensions. A total of 412 normal, healthy volunteers, comprising 206 males and 206 females, were recruited. The linear regression analysis were performed to assess the correlation between the stature and lengths of various segments of the lumbar vertebral column. Among the regression equations created for single variable, the predictive value was greatest for the reconstruction of stature from the lumbar segment in both sexes and subgroup analysis. When individual vertebral body was used, the heights of posterior vertebral body of L_3 gave the most accurate results for male group, the heights of central vertebral body of L_1 provided the most accurate results for female group and female group with age above 45 years, the heights of central vertebral body of L_3 gave the most accurate results for the groups with age from 20–45 years for both sexes and the male group with age above 45 years. The heights of anterior vertebral body of L_5 gave the less accurate results except for the heights of anterior vertebral body of L_4 provided the less accurate result for the male group with age above 45 years. As expected, multiple regression equations were more successful than equations derived from a single variable. The research observations suggest lumbar vertebral dimensions to be useful in stature estimation among Chinese population.

1. Introduction

Victim identification is one of the most challenge aspects of forensic science. The four main attributes of biological identity that forensic investigators try to determine are sex, age, ethnic background and stature. The estimation of stature using different parts of the body is crucial for formulating a biological profile during the process of personal identification. The estimation of stature standards are based on two major methods: the anatomical method, which requires the presence of a complete skeleton, or the mathematical method, which requires a complete bone and employs regression formulae or multiplication factors to estimate the stature based on the correlation of individual measurements of bones to living statures [1,2].

Researchers have established a relationship between stature and various body parts like head and face [3,4], upper and lower limb bones [5–9], vertebral column [3,10–19], hands [20–26], and feet [25,27–38], the acquired results have concluded that stature can be estimated successfully from various body parts and human bones. The most accurate estimates of body height are obtained when undamaged long bones of known sex and ethnic identity are available. Currently, the stature estimation formulae devised by Trotter and Gleser [39] are the ones most widely used in the fields of forensic science and anthropology. These equations are based on measurements of long bones in the limbs. With these formulae, standard error to estimate living stature was approximately 3 to 5 cm.

However, the presence of a complete skeleton or of a complete long bone may not be feasible when the bodies are dismembered or mutilated in wars, mass disasters, and crimes. Therefore, a practical alternative is to develop new standards that utilize different parts of the skeleton. A few studies have analyzed the stature from vertebral column. Pininski et al. [16] estimated stature from various sacral measurements in South African populations. Torimitsu et al. [17] evaluated the relationship between stature and the length of the sacrum and coccyx using multidetector computed tomography and derived regression equations for stature estimation in the modern Japanese population. Karakas et al. [11] investigated the value of sacrum height in total body height estimation in a contemporary population of adult Anatolian

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Caucasians. Nagesh et al. [12] estimated the stature from different segments of the vertebral column in the South Indian population. Pelin et al. [13] predict living stature from sacral and coccygeal vertebral dimensions in Turkey. Jason et al. [10] estimate stature from the length of cervical, thoracic, lumbar, thoraco-lumbar and cervico-thoraco-lumbar segments of the spine in white and black Americans. Furthermore, Jason and his co-worker's attempt to fit American white and black data to the formulae derived for Japanese but was unsuccessful [10]. The regression formulae derived for stature estimation are population specific [40]. Different formulae need to be derived for different population groups, owing to inherent population differences in various dimensions that are attributed to genetic and environmental factors [41,42]. In Chinese, Zhang et al. [18] estimate the body height from the feasibility of measuring dimensions of cervical vertebrae. Qing et al. [19] establish the mathematical models of stature estimation for female from measurement of lumbar vertebrae.

Therefore, the aim of the present study was to assess the relationship between the radiologic anthropometry of the lumbar vertebral dimensions and stature in Chinese and to develop regression formulae to estimate stature from these dimensions.

2. Subjects and methods

A total of 412 normal, healthy Chinese volunteers, comprising 206 males and 206 females, were recruited for this study from the West China Hospital of Sichuan University. Subjects with a history of chronic illness, trauma, physical deformity, or any surgical procedure that might affect stature or lumbar vertebral dimensions were excluded from the study. We made routine measurements of crown-heel lengths of all participants. The data collection was conducted during a seven-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 [43]. The lumbar vertebral dimensions was measured as recommended by Jason & Taylor [10] and Tibbetts [15], separate measurements were made of the vertebral segments along the anterior surface, the posterior surface and the central of the spine. The lumbar segment was measured from the top of L_1 to the point between L_5 and S_1 (All statistic variables are listed in Table 1). 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 subjects were between 20 and 84 years of age (the mean age of the males as 45.11 ± 12.38, and the mean of females was 44.27 ± 10.85). This age range was chosen to ensure maturity. As previous studies have shown that stature starts to decline after the age of 30 years among black individuals [44], and after the ages of 40 years [45] or 45 years among white individuals [46]. Subgroup analyses were performed to avoid issues of stature reduction, and divided all the participants into four groups, including 117 cases in male group with age from 20 to 45 years and 89 cases with age above 45 years, 116 cases in female participants with age from 20 to 45 years and 90 cases with age above 45 years.

All measurements of lumbar vertebral were recorded from computed radiography (CR). On the images, the length of each vertebral body was measured on the heights of anterior, posterior and central of each lumbar vertebral body (as shown in Fig. 1). 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 0.1 mm. Mean intra-observer error, calculated following the equation presented by Albanese et al. [47,48], was less than 1.6 % for all dimensions and thus within the acceptable limit (below 2.0% and 2.5%).

Table 1
Formulation of the statistic variable.

Variable	Parameter	Variable	Parameter
$\hat{Y}$	Stature	X_9	The heights of central vertebral body for L_3
X_1	The heights of anterior vertebral body for L_1	X_{10}	The heights of anterior vertebral body for L_4
X_2	The heights of posterior vertebral body for L_1	X_{11}	The heights of posterior vertebral body for L_4
X_3	The heights of central vertebral body for L_1	X_{12}	The heights of central vertebral body for L_4
X_4	The heights of anterior vertebral body for L_2	X_{13}	The heights of anterior vertebral body for L_5
X_5	The heights of posterior vertebral body for L_2	X_{14}	The heights of posterior vertebral body for L_5
X_6	The heights of central vertebral body for L_2	X_{15}	The heights of central vertebral body for L_5
X_7	The heights of anterior vertebral body for L_3	X_{16}	Lumbar segment
X_8	The heights of posterior vertebral body for L_3		

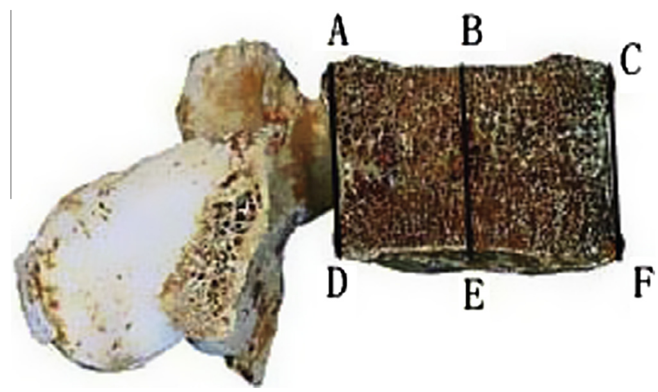

Fig. 1. Measurement of lumbar vertebral body. AD: the height of posterior of lumbar vertebral body; CF: the height of anterior of lumbar vertebral body; BE: the height of central of lumbar vertebral body.

The data were analyzed by using the SPSS (VERSION 13.0 for Windows). For assessing the correlation between the stature and lengths of various segments of the lumbar vertebral column, the Pearson's correlation coefficient was calculated and its significance was tested by Students *t* test. *P* value of less than 0.05 was considered as significant.

3. Results

Descriptive statistics for age, stature and anthropometric measurements of the lumbar vertebral column of all subjects are presented in Table 2.

Table 3 shows the regression equations created for each variable with separation of the sexes and subgroup analysis by age. All measurements presented statistically significant correlation coefficients with stature ($p < 0.01$). When stature was estimated using the equations that involved the dimensions of a single vertebra, the accuracy of stature prediction ranged from 4.370 to 6.010 cm for male, and from 3.723 to 4.912 cm for female. The heights of posterior vertebral body of L_3 gave the most accurate results for total male group, the heights of central vertebral body of L_1 provided the most accurate results for total female group and female group with age above 45 years, the heights of central vertebral body of L_3 gave the most accurate results for the groups with age from 20 to 45 years for both sexes and the male group with age above 45 years. The heights of anterior vertebral body