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Stature estimation from scapular measurements by CT scan evaluation in an Italian population

Francesco Giurazza [a,*], Riccardo Del Vescovo [a], Emilano Schena [b], Roberto Luigi Cazzato [a], Francesco D'Agostino [a], Rosario Francesco Grasso [a], Sergio Silvestri [b], Bruno Beomonte Zobel [a]

[a] Radiology Department, Università Campus Bio-Medico di Roma, Italy
[b] Biomedical Engineering Laboratory of Measurements and Biomedical Instrumentations, Università Campus Bio-Medico di Roma, Italy

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ABSTRACT

This study evaluated the correlation between scapula size and stature and developed standard equations in order to estimate stature by CT scan evaluation.

A total of 200 healthy Italian subjects (100 men and 100 women, mean age 64.2 ± 12.8 years) underwent thoracic CT scan evaluation during pulmonary screening in our department; we measured the stature of each patient with standard anthropometric instruments and then analyzed images to calculate the longitudinal scapular length (LSL) and the transverse scapular length (TSL). The correlation between stature and each parameter measured was analyzed by dividing the population into two groups, males and females, and was examined by simple regression analysis using Pearson's correlation coefficient (*r*).

Each anthropometric variable showed a significant difference between males and females (p value <0.001). The correlation coefficients (*r*-values) were LSL = 0.74 and TSL = 0.51 in males and LSL = 0.70 and TSL = 0.48 in females. In both sexes the *r*-values showed a significant correlation between stature and LSL.

Our study demonstrates that scapulae can be used for stature estimation; in our sample LSL was found to have a better correlation with stature then TSL. $h_m = 4.247 * \text{LSL} + 93.74$ and $h_f = 4.031 - * \text{LSL} + 92.38$ are the formulae that provide the most accurate stature assessment in males and females respectively.

1. Introduction

Stature is one of the most important component of the biological identity that can be evaluated from the skeleton because it has a biological proportional correlation with parts of the human body (head, trunk, arms).

Since 1894 [1], several authors have attempted to develop ways of predicting stature from bone measurements in vivo or from skeletal remains, using formulae derived from multiple or single regression analysis.

For practical reasons, all these studies have been carried out on samples composed of persons with the same genetic and environmental background; since stature is strictly related to these elements, a method obtained in a certain population is applicable only to subjects belonging to the same ethnic group.

This is why authors from different countries who used the same skeletal segments to predict stature obtained different results [2].

In our regression analysis of an Italian sample of 200 subjects we analyzed the relationship between stature and scapula measurements using CT scan images in vivo.

In our previous study [3], we derived regression equations for total skeletal height estimation in the Caucasian population using measurements of femur and skull; however we believe that a formula applying scapula, can be useful in this field especially in cases of chattered bodies, act of terrorism, or disaster victim identification, because in these cases long bones frequently appear fragmented, scattered or mixed together and instead flat and short bones seem to be better preserved.

Few authors have employed radiological techniques in anthropometric studies [2–5]: this instrumental approach allows studies to be performed in vivo and in the anthropometric field it entails significant differences because stature measurement changes after death by approximately 25 mm mainly because of changes to soft tissue, especially intervertebral disc degeneration [6].

* Corresponding author. Address: Radiology Department, Università Campus Bio-Medico di Roma, Via Alvaro Del Portillo 200, 00100 Rome, Italy. Mobile: +39 3381499421; fax: +39 06225411964.
E-mail address: f.giurazza@unicampus.it (F. Giurazza).

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2. Materials and methods

2.1. Materials

From May 2011 to October 2011 we collected a sample of 200 healthy Italian subjects (100 males; 100 females) with a mean age of 64.2 years (SD 12.8; range between 42 and 86 years) who underwent thoracic CT scan evaluation during a pulmonary screening program on heavy smokers, which has been carried out in our institution.

Our exclusion criteria were: scapular, vertebral, pelvis or lower limb fractures; vitamin deficiencies; metabolic-endocrine diseases; lactose intolerance; growth disorders; severe osteoporosis (*T*-score <2.5).

Low dose CT scans (35 mAs; 120 kV) were obtained using Somatom Sensation 64 (Siemens Medical, Enlargen, Germany). A 500 mm topogram was performed between the superior borders of the clavicles and the kidneys with the upper limbs held up beside the head; so scans in spiral mode were executed in inspiratory breath-old and then images were reconstructed with a slice thickness of 1 mm in axial and sagittal planes. After images acquisition was completed, we measured the stature of each patient using standard anthropometric instruments in millimeters; each patient stood barefoot with arms stretched out from the body, keeping the head in the Frankfurt horizontal plane [7]. Each measurement was taken twice to reduce operator errors.

2.2. Methods

After completion of sampling, we analyzed images of each patient and we measured two parameters for both scapulae:

- longitudinal scapular length (LSL): it represents the longitudinal scapular diameter corresponding anatomically to the distance between the end of the inferior scapular angle and the superior margin of the coracoid process (Fig. 1a and b)
- transverse scapular length (TSL): it represents the scapular width and it corresponds anatomically to the distance between the medial scapular margin and the inferior margin of the glenoid cavity (Fig. 1b and c).

In order to improve the measurements repeatability, we have elaborated the 2D CT scan axial images through post-processing volume rendering technique and we have obtained 3D reconstructed bones, so that virtual bones can be aligned and the maximum length of the parameter that is to be measured is in the frontal plane of the screen.

All statistical analyses were performed considering for each parameter the mean value between left and right scapula because we did not identify any significant differences between the two scapulae in each patient.

Our measurement had an estimated error of 2 mm due to slice thickness and were taken by the first author (FG).

3. Statistical analysis

Differences in bone lengths between the two genders were evaluated using Student's *t*-test. The correlation between stature and each parameter measured was performed by dividing the population into two groups, males and females, and was examined by simple regression analysis using Pearson's correlation coefficient (r).

The comparison between the height values estimated using the bone length data (h_e) and the values directly measured on the patient (h_m), and the analysis of their agreement are performed using different methods:

- linear regression, implemented through the mean square error algorithm, to analyze the correlation between h_e and h_m;
- the Bland–Altman approach [8], suggested for assessing the agreement between two methods of clinical measurement, to analyze the agreement between h_e and h_m;
- differences between h_e and h_m calculated for all the 200 patients (100 males and 100 females) and represented by histograms.

All the statistics were analyzed in the MATLAB® (MathWorks, Inc.) environment.

4. Results

4.1. Descriptive statistics

Descriptive statistics which included mean and standard deviation (SD) were obtained for each variable and a comparison between male and female mean values of all the anatomic variables was performed using the t-test and with significant level set at

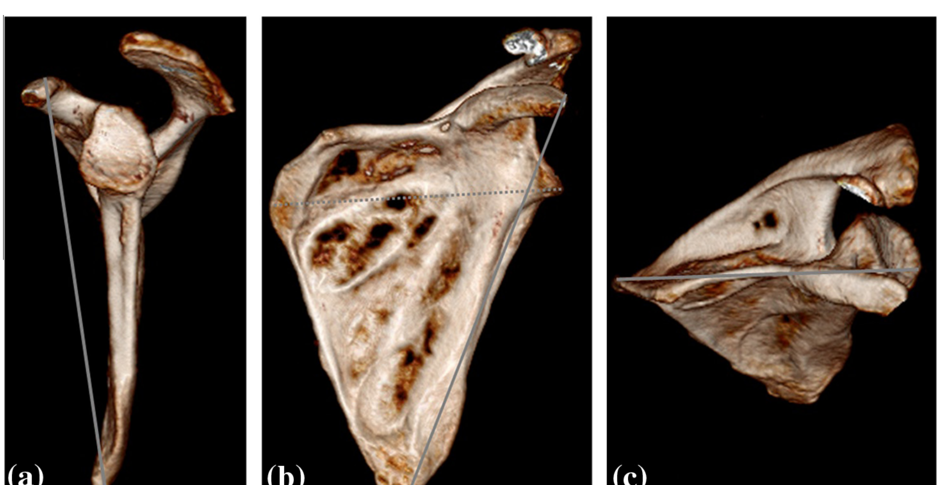

Fig. 1. CT scan imaging with volume rendering reconstruction; (a) LSL in the sagittal plane (continuous grey line); (b) LSL (continuous grey line) and TSL (dashed grey line) in the coronal plane; (c) TSL in the axial plane (dashed grey line). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)