Stature of Caucasian Elderly Estimated by Scapula Length from Chest X-Ray

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Abstract—**Stature is an important biological characteristic considered in the clinical activities. Height (h)is frequently hard to measure in the elderly population or in people with skeletal deformities and vertebral fractures. Furthermore it represents also a key point in forensic evaluations.**

Our aim was to provide an equation in order to predict human height based on the Longitudinal Scapular Diameter(LSD) measured through a Chest X-ray (CX) in an elderly Italian population.

We enrolled 60 patients (age > 65 years) who underwent a standard CX. An average LSD was obtained on the basis of the measurements of left and right scapula. Stature was measured in standard conditions by a calibrated stadiometer in all patients. A linear predictive model was employed to estimate stature by LSD.

The predictive equation for stature estimation [cm] from LSD [cm] was: h=2.969*LSD+116.7. The linear regression was significant (p < 0.01) and the correlation coefficient was 0.75.

In order to assess the performance of the proposed model, we compared our results with the values obtained in the same population with a largely employed approach, i.e., the Chumlea's method.

Considering the whole population, the mean error using LSD equation was 4.4 cm *vs* 4.6 cm from Chumlea's.

The proposed linear relationship between human height and LSD measured by CX can be considered valid in elderly patients, showing comparable results to the Chumlea's method.

I. INTRODUCTION

In clinical practice, measurement of human height is of particular interest because it is an anthropometric index necessary to different activities, important in the evaluation of[1]:

- body surface, essential for a large number of drug posology;
- nutritional status;
- theoretical respiratory function values;
- physical functions (some performance indexes, such as the *six-minute-walking test*, consider individual height values).

However, human height is frequently challenging to measure in elderly people because of their inability in standing upright or even because of skeletal deformities like vertebral fractures, which could misrepresent results obtained by a standard stadiometer.

An equation for the estimation of stature of elderly patients (age 60-90) is presently available and is based on knee height [2]. This method, provided by Chumlea et al., presents a margin of error around ± 6 cm and requires a good experience in identifying tibia landmarks.

Stature estimation represents also a key point in forensic evaluation because it is an important component of biological identity. Together with sex, age and ancestry, height can be evaluated from the skeleton, thanks to a proportional correlation[3]: this helps forensic scientist to establish height on the basis of skeletal remains after natural disasters, war crimes or any other condition with an elevated number of cadavers [4].

In the present study we focused on a paired short bone: scapula. This choice is motivated firstly by its negligible morphological change during life-time and secondly because of its useable and rapid measurement from a standard CX.

Our aim was to calculate a predictive equation of human height starting from the LSD measured through a CX in an elderly Italian population. Moreover we wanted to compare the performance of the equation with the one coming from Chumlea's method.

II. MATERIALS AND METHODS

A. Materials

From September 2012 to September 2013, 60 elderly patients (30 males and 30 females; mean age 74 years) who underwent a standard CX during recovery in our institution were included in the study. Exclusion criteria were: age < 65 years; inability/strife in standing upright (which impedes not only standard CX execution but also a correct measurement of height with the stadiometer); history of skeletal diseases or bone fractures; vertebral deformities (*Wall-Occipit distance*>7 mm); knee or ankle deformities (which impede an accurate measurement of tibia length); impossibility in identifying all scapula margins in posterior-anterior CX view.

A standard CX exam was obtained in each subject (orthostatic position; posterior-anterior and latero-lateral

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Figure 1. Left knee height measurement with a sliding caliper according to the Chumlea's method.

views in inspiratory breath-hold) with both scapulae completely included in the exams.

We measured the height of each patient using standard stadiometer; each patient stood barefoot with arms stretched out from the body, keeping the head in the Frankfurt horizontal plane [5]. Each measurement was carried out twice to reduce operator errors. Then we calculated the stature predicted by the Chumlea's equation [2], based on the measurement of the left knee height with the patient standing supine; this was considered as the distance from the sole of the foot to the anterior surface of the thigh with ankle and knee each flexed to a 90° angle, measured with a sliding caliper (Fig. 1).

B. Methods

After completion of sampling, we analyzed CX images of each patient. The LSD, corresponding anatomically to the distance between the end of the inferior scapular angle and the superior margin of the coracoid process (Fig. 2a), was measured in centimeter for each scapula in the posterior-anterior view CX, obtaining an average LSD value from right and left scapula in each subject (Fig.2b). Measurements were made by two different radiologists, respectively with 5 and 3 years of experience in the field of CX imaging, in order to estimate the dependence of the measurement on the operator. The LSD values were measured on digital images with electronic calipers; the data considered in this study were the mean of the two measurements and these were highly reproducible with a maximum difference of 2 mm (not relevant on the final results).

C. Statistical Analysis

Simple regression analysis has been carried out to analyze the correlation between the height estimated with LSD (h_{LSD}) and the height measured (h_M); the same analysis was performed using the Chumlea's predictive height (h_C). Moreover, the differences between these values have been analyzed by the Bland-Altman method. Finally, the differences between the

estimated heights (h_{LSD} and h_C) and the measured ones (h_M) and their mean values have been calculated considering all 60 patients.
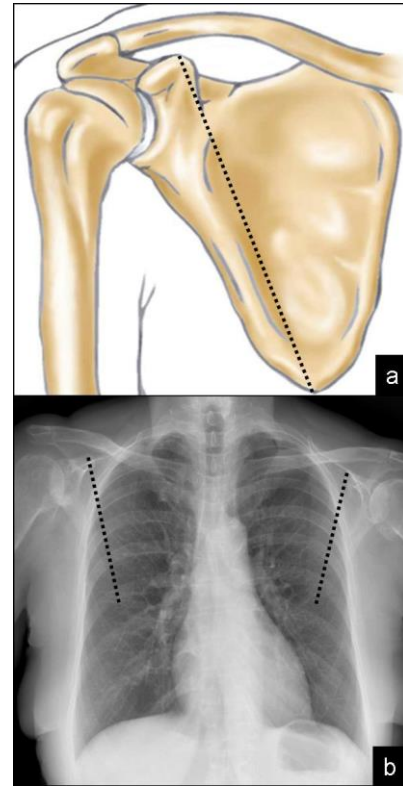

Figure 2. a\ Drawing of right scapula showing the anatomical markers for the LSD, i.e. the distance between the end of the inferior scapular angle and the superior margin of the coracoid process (dotted line); b\ Standard postero-anterior projection CX of a 67 years old man with the the left and right LSD measurements (dotted lines).

III. RESULTS

As shown in Fig.3, simple correlations between h_{LSD} and h_M and between h_C and h_M were found.
The values of h_{LSD} have been estimated by calculating the best fitting line between LSD and height (h_M). This equation is:

$$h_{LSD} = 2.969 \cdot LSD + 116.7 \qquad 1$$

Both h_{LSD} and LSD are expressed in cm.

As shown in Fig. 3 and in Table I, there is significant correlation between both h_C and h_{LSD} and h_M ($\rho<0.01$).

Moreover, the slopes of the two best fitting lines (0.999 and 1.03 for LSD and Chumlea, respectively) are close to the unity, showing absence of under or overestimations. The absolute value of the differences between the estimated and measured heights, $|\Delta h|$ for all patients are shown in Fig. 4.

As shown in Fig. 4, the differences are comparable using the two methods for stature estimation: using Chumlea's equation in the 87% of cases the difference is lower than 9 cm, while using the proposed equation based on the dimension of the LSD this requirement is fulfilled in the 90% of cases. Moreover, the mean absolute difference considering

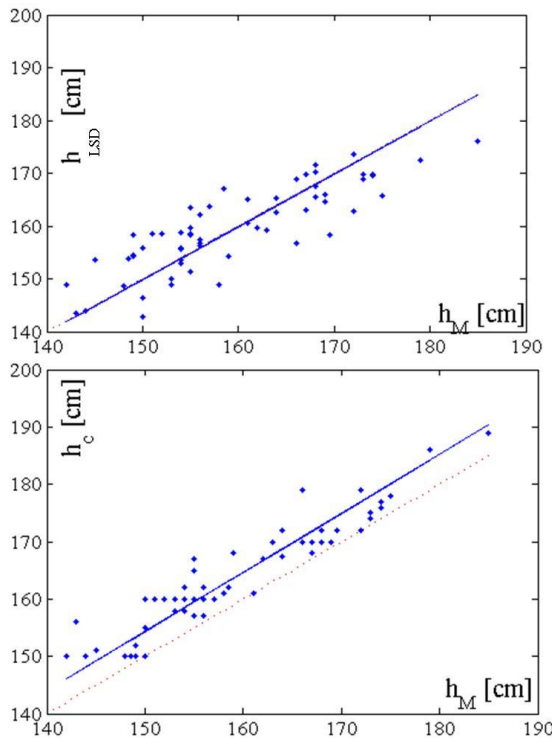all 60 patients is also comparable: 4.6 cm with Chumlea vs 4.4 cm with LSD.

Figure 3. Simple regression between the height directly measured and height estimated by LSD (h_{LSD}) and by Chumlea equation (h_c). The line of equality is also reported (red lines).

TABLE I.   STATURE ESTIMATION EQUATION, CORRELATION COEFFICIENT (R) AND SIGNIFICANCE FOR LSD AND CHUMLEA'S METHODS

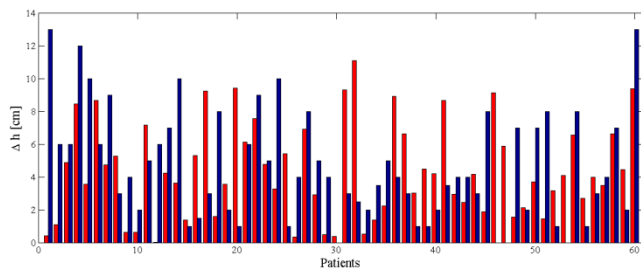|	Table Column Head		
	Equation	*R*	*ρ*
LSD	$h_{LSD}=0.999 \cdot h_M$	0.75	<0.01
Chumlea	$h_c= 1.03 \cdot h_M$	0.92	<0.01

Figure 4. Absolute values of difference between measured and height estimated by LSD (red bars) and by Chumlea equation (blue bars).

IV.   DISCUSSION

Stature estimation is important in many fields of medicine both in research and in daily practice [1]. During the aging process, height measurement declines 0.5 – 1.5 cm/ decade due to loss in vertebral corpus and shrinkage in intervertebral discs [6]. Because measuring of the body height in elderly is difficult, it must be performed by indirect ways [7]. Stature estimation from single bones can be a useful tool, in order to analyze morphological skeletal diseases or measure height in bedconstrained or elderly patients [8]. In literature, several authors have proposed formulae for stature estimation based on measurements of the lengths of different long bones [9-11] and various short bones, such as the sternum [12]. All these studies have been performed on samples of population derived mostly from a single country; because of the strong influence of genetic and environmental components on skeletal development, an equation derived from a certain population will not be suitable for another originating from a different nation; in some cases, *in vivo* studies have been carried out estimating bones length using anthropometric instruments, which are not as precise as direct bone measurement [8]. Chumlea et al. [2,6] suggested a knee-heel length based equation as a surrogate measurement of standing height. However, these equations were derived from North-America healthy people. The validity of these formulae in other population is uncertain [13] and this method presents a margin of error around ± 6 cm.

To achive accurate standard measurements *in vivo*, some authors have applied radiology in the field of anthropometry, measuring the bones of interest with radiographs [14] or CT scanner [15].

In our study we collected data from a sample of elderly patients who underwent a standard CX for cardiac or respiratory evaluation during recovery in our institution.

The radiological exams were performed with patients standing always upright and at the same distance from the X-ray source, according to the standard radiological norm; this reduces measurement errors due to differences in patient positioning and image magnification.

We focused our attention on scapula, a pair short bone, because another study [15] previously demonstrated that this bone could be correlated with stature estimation by CT scan imaging; in that study the authors assessed that longitudinal scapular length provides better results in comparison to the transverse scapular length. In this study we do not analyze the transverse scapular length because it is difficult to measure precisely on CX; however the correlation coefficients of the longitudinal scapular diameter with height are similar for both males and females (i.e., 0.75 *vs* 0.74 for male and 0.70 for female).

Our study is the first in an Italian population to derive an equation for stature estimation by applying a CX imaging technique, which is a useable rapid and low dose radiological exam, usually needed in elderly people. Moreover, scapula measurements by standard CX could be standardized because the anatomical landmarks are easy to locate with a high reproducibility.

In this paper we provide a predictive equation for stature estimation based on the measurement of longitudinal scapular diameter (expressed in cm): 2,969*LSD +116,7, which presents a mean error in our elderly population of 4.4 cm; this

value is comparable to the values provided by the reference method (i.e. the Chumlea's equation, 4.6 cm).

The main limitation of our paper is that we used the same dataset for training and final analysis. This is due to the limited number of subjects enrolled; in future studies we will enlarge the sample population and this will increase also the significance of our results. Another limit could be represented by the patient position during CX acquisition; even if performed in standard conditions according to the radiological norm, small variations in the position are unavoidable and so the precision of LSD measurement could be altered; a solution could be to evaluate different CX of the same patient to assess the reproducibility of the measurement, however this is not in accord with ethical standards because it would imply unjustified radiation exposure. Finally, in the clinical practice, it must be considered that the present study has been performed on standard CX and so our results are not appliable to bed constrained patients receiving CX because in that cases the skeletal proportion are altered.

V. CONCLUSIONS

Our study confirms that scapula can be used for stature estimation in elderly subjects. Predictive equation based on CX scapula length can be considered a valid approach to estimate human height in elderly patients. This finding is confirmed by the provided results, which are comparable to the ones obtained with the Chumlea's method.

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