Stature estimation based on vertebral morphometry by dual energy X-rays absorptiometry imaging in Italian females

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Abstract

Anthropological profile in forensic context includes the assessment of parameters as ancestry, sex, age and stature of an individual by the analysis of skeletal remains. Stature can be estimated from decomposed and fully or partially skeletonized remains by means of anatomical or mathematical methods applied on the whole skeleton or single bones. Many authors calculated regression formulae for the living stature estimation by these methods, in particular based on a population similar to the remains recovered. Long bones are commonly used for stature estimation, but, when they are missing, methods involving different parts of the skeleton are needed. In this preliminary study we measured heights of the vertebral bodies in a female Caucasian Italian population, evaluated by images of morphometric X-ray absorptiometry based on dual-energy X-ray absorptiometry in living subjects investigated for routine diagnostic purposes. Thoracic and lumbar segments of the spine were measured and statistical analysis was performed, thus obtaining regression formulae for estimated living stature from thoraco-lumbar spine segments (T_6-T_{12}, L_1-L_4 and T_6-L_4). We propose this method for stature evaluation in physical or forensic anthropology when the spine is available and long bones are missing.

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Introduction

The process of forensic identification requires an anthropological profile based on the assessment of parameters as ancestry, sex, age, stature, etc. Anthropologists can estimate the stature of an individual from decomposed and fully or partially skeletonized remains by means of anatomical or mathematical methods,[1-6] based on the whole skeleton[1,3,7,8] or single bones.[9-18] Regression formulae for the living stature estimation have been developed by these methods. Since stature is a population-related parameter, a method based on the same population of the remains is suggested by many Authors.[18-21] In the present study we investigated by morphometric X-ray absorptiometry (MXA) based on dual-energy X-ray absorptiometry (DEXA) some vertebral morphometric parameters and their possible correlations with stature in subjects of a female Caucasian Italian population. Our method can be applied in physical or forensic anthropology when the spine is available and long bones are missing.

Materials and Methods

We measured vertebral body height in a sample of Caucasian population of Italian origin. All the subjects underwent on DEXA-MXA examination for routine clinical purpose, since this examination is applied to evaluate density anomalies occurring with age, specially in women. DEXA is a technique commonly used to measure mineral density in bone metabolic diseases and it utilises two X-ray beams with different energy levels for calculating the different absorptions of soft tissues and bone. It is considered to be the most reliable densitometric technique as for spatial resolution, precision, and accuracy.[22] MXA is a low-radiation technique used for the identification of vertebral deformities, based on DEXA. The examination was performed by hologic QDR discovery scanner in MXA mode for the vertebral fracture assessment (VFA).

The sample included 255 females. We excluded from the statistical analysis 46 subjects with vertebral collapses or deformities. Hence, the final investigated population consisted of 209 subjects.

For each subject the age and the ancestral information (to confirm Caucasian-Italian ancestry) were acquired and the stature was measured in standing position (from the floor to the vertex) by a stadiometer.

DEXA-MXA examination generates images of the trunk in the mid-sagittal plane with semi-automatic measurements of anterior-middle-posterior height and allows an evaluation of the morphological normality of each vertebral body (Figure 1). In the images we considered the anterior height of each vertebra of the thoraco-

lumbar spine segments (T_6-T_{12}, L_1-L_4 and T_6-L_4). The anterior height was the one less affected by morphologic artifacts. Cervicothoracic C_1-T_5 segments and L_5 vertebra were excluded because of their superimposition with other anatomical structures, in DEXA images, that prevented accurate measurements.

A regression analysis was performed in order to obtain the regression formulae for each spine segment and the overall T_6-L_4 segment. Pearson's correlation (r coefficient) and coefficient of determination (R^2) were obtained to evaluating the strength of the association between the measured living stature and vertebral height.

Results

We calculated the average age and stature of the population investigated, resulting respectively in 65.5 years and 155.8 cm. A linear regression analysis was performed (Figures 2-4) and a formula was obtained for each spine segment (T_{6-12}; L_{1-4}; T_6-L_4) in order to estimate the living stature (H) in cm and the standard deviation (SD). The obtained coefficient of determination (R^2) reveals how well data fit a statistical model and Pearson correlation coefficient (r) evaluates the degree of linear dependence between the stature and the vertebral measurements. We obtained the following formulae:

T_{6-12} SEGMENT (1)
H=0.389 (T_{6-12}) + 104.636
SD=± 5.45 cm
r=0.5; R^2=0.2

L_{1-4} SEGMENT (2)
H=0.401 (L_{1-4}) + 114.893
SD=± 5.7 cm
r=0.4; R^2=0.2

T_6-L_4 SEGMENT (3)
H=0.257 (T_6-L_4) + 95.704
SD=± 5.32 cm
r=0.5; R^2=0.2

Discussion

In forensic contexts it may occur that incomplete human remains are recovered and long bones – commonly used for stature

Vertebral Evaluation:

Vertebrae	Impression
T4	Normal
T5	Normal
T6	Normal
T7	Normal
T8	Normal
T9	Normal
T10	Normal
T11	Normal
T12	Normal
L1	Normal
L2	Normal
L3	Normal
L4	Normal

Vertebral Assessment:

	Height (mm)			Percent Deformation		
Vertebrae	Post	Mid	Ant	Wedge	Biconcave	Crush
T4	17.7	17.4	18.5	0.0%	2.1%	4.3%
T5	17.2	14.6	14.8	13.9%	15.5%	0.0%
T6	18.2	15.9	15.7	13.9%	12.9%	0.0%
T7	18.1	17.1	16.2	10.4%	5.4%	0.0%
T8	18.8	15.7	15.8	16.2%	16.4%	0.0%
T9	19.5	17.4	19.4	0.8%	10.8%	0.0%
T10	20.8	18.9	18.8	9.6%	9.1%	0.0%
T11	23.4	20.3	20.9	10.7%	13.2%	0.0%
T12	24.7	21.6	23.5	4.9%	12.5%	0.0%
L1	25.1	23.5	25.3	0.0%	6.4%	0.6%
L2	25.5	23.3	26.2	0.0%	8.4%	2.6%
L3	27.4	24.2	25.5	7.2%	11.9%	0.0%
L4	25.1	24.3	24.6	1.9%	3.0%	0.0%
Std Dev	1.0	1.0	1.0	5.0%	5.0%	5.0%

Figure 1. Morphometric X-ray absorptiometry image.

estimation – are missing; therefore some alternative method is required. The spine has been investigated by many authors for stature assessment and vertebral measurements can be considered a reliable parameter to calculate the height in the living.[23] In this study we decided to investigate the Caucasian Italian population, since a stature estimation method based on the spine in a local population is missing.

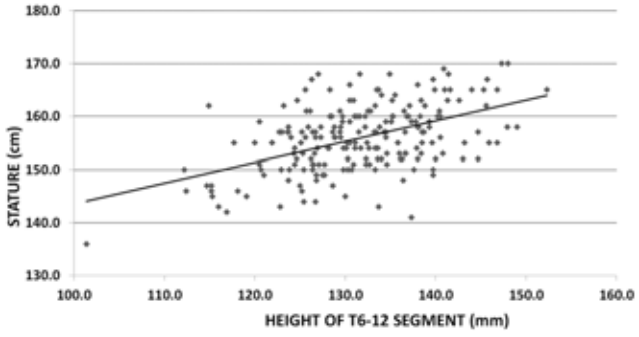

Figure 2. Linear regression analysis for stature estimation from the thoracic T_6-T_{12} segment.

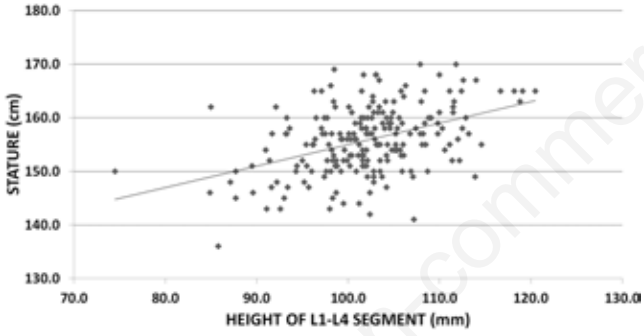

Figure 3. Linear regression analysis for stature estimation from the lumbar L_1-L_4 segment.

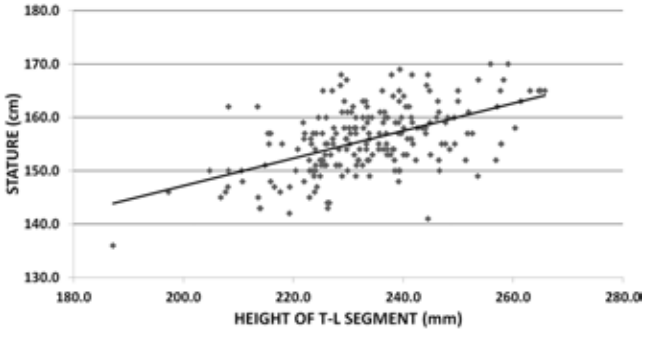

Figure 4. Linear regression analysis for stature estimation from the sum of both thoracic T_6-T_{12} and lumbar L_1-L_4 segments (T-L segment).

Positive and negative aspects emerged. For each segment we obtained a quite uniform point cloud (Figures 2-4) and the standard deviation is compatible with the one obtained by methods not based on long-bones (that still remain the best standard for stature estimation when those bones are recovered).[10,19] Another positive aspect is also the size of the female sample.

A negative aspect is that the average age of the female sample is high, hence most of the women reached menopause. Such situation is characterized by a higher incidence of osteoporosis and some vertebral pathology, which could affect bones not evaluated in this study and influence the stature. The last negative aspect is the low value of coefficient of determination (R^2) and Pearson correlation coefficient (r), which means that the equations can partially predict the living stature. That could be due to the features of the investigated population, that includes subjects with too high average age. With the increasing in age a decreasing in stature, well documented in literature, also occurs.[24-26]

Conclusions

Further studies should be made to ensure or exclude the reliability of vertebral segments for a stature estimation purpose or to extend the analysis also to a male population.

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