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Estimating height from the first and second cervical vertebrae in a Spanish population

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ABSTRACT

One of the roles of forensic anthropology is the identification of skeletal remains and over the years many methods have been developed to obtain specific details of a corpse such as an estimation of age and height. The femur and tibia are ideal for this purpose but unfortunately they are often missing or badly fragmented. For this reason, in this present study, we used the smaller bones of the first and second cervical vertebrae, which are often better preserved than the long bones. Direct measurement of these bones has been found to be misleading, largely due to the remains of a covering of soft tissue, and to overcome this all measurements were taken from tomographic images. The aim of this study is to provide an auxiliary diagnostic method to evaluate the association of different anthropometric measurements taken with tomographic imagery of both the first cervical and second cervical vertebra with body height within a sample of the Spanish population.

Measurements were taken from tomographic images taken with a dental CT of 203 healthy individuals from a Spanish population. The best correlation was obtained in the case of unknown sex using four measurements: two of the first cervical vertebra and two of the second vertebra using the following regression formula $S = 49.02 + 1.02O + 1.58DO + 0.49V + 0.67I$.

All formulae provided statistically significant results and can be applied to any skeletal remains belonging to a Spanish population.

1. Introduction

Forensic anthropology is a branch of forensic medicine that first and foremost attempts to determine the identity of a corpse and then, if possible, the causes, diagnosis and date of death together with all the pertinent surrounding circumstances.

In practice, forensic identification may correspond to a living subject (in cases of missing persons or the identification of fresh corpses or bodies in an advanced state of putrefaction.

There are numerous methods of using a metrical study of skeletal remains to determine chronological age, sex, body height and other characteristics which can be of help in identifying the remains. The best results are provided from the remains of long bones, especially those of the lower limbs (femur and tibia) [1–10]. However, in most cases we do not have long bones or these are fragmented when found, whereas smaller bones, such as metatarsals, are often in a better state of preservation [11], and have been the subject of contemporary studies [12–16]. Following this line of investigation we conducted studies on the spinal column that enable the estimation of height from segments of the spinal column, namely the second cervical vertebra, sacral and coccygeal length [17–20].

Height is a basic element in constructing the biological profile and when remains are found one of the first steps in identification is to obtain the height of the individual in life [3,21–25].

It has been known since the late nineteenth century that there are slight variations between the measured height of the cadaver and height measured in vivo. The corpse is 2.5 cm less than the stature of the living person (the value depends on the time between death and the time of measurement) due to the absence of all soft and cartilaginous parts and intervertebral discs [23]. Hauser [6] mentions an elongation of 1.5 cm in males and 2 cm

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in women. This phenomenon can be explained by the fact that a recumbent body is not compressed by pressure, thus relaxing the intervertebral discs and ligaments, as well as straightening spinal curvature [3,5–7,9,21], hence the height calculated directly on the body is often corrected.

The estimation of height from bones is performed by applying regression formulae to appropriate skeletal samples [26]. The formulae are generally based on correlation coefficients between the length of the long bones and stature. However, this correlation varies widely among major racial groups, and, coupled with differences due to environment, geographical distribution, heredity, socioeconomic development, diet and type of work, it precludes the application of a general formula for all population groups; hence the use of separate regression formulae and the importance of studies in a Spanish population to create unbiased regression formulae applicable to the population under study.

Direct measurement of skeletal remains can produce an error due to the presence of soft tissue remains, and in order to avoid this radiographic methods of identification, covering a wide range of possibilities, have been widely developed. The aim of this study is to evaluate the association of different anthropometric measurements taken with tomographic imagery of both the first cervical vertebra or atlas and the axis or second cervical vertebra with body height within a sample of the Spanish population in order to provide an auxiliary diagnostic method.

To our knowledge, this is the first such study to use the axis (C1) measures to estimate stature in a sample of the Spanish population.

2. Material and methods

2.1. Sample

This work is based on a study of 203 healthy individuals from a Spanish population aged between 15 and 84 who voluntarily participated in the study. The study was approved by the ethics committee.

Any individual with a disease, deformity or bone fracture that might interfere with the measurements was excluded from the study.

All participants were measured for height in millimeters by placing the barefoot volunteer in an upright forward facing position with the back against a ruler and the determined stature was the maximum length between the vertex of the head and the heel of the foot.

2.2. Measuring the odontoids

The odontoid measurements were carried out using the CT Imagery 203 dental Image Tacs, which is somewhat new in this field, since most forensic studies presented are usually based on radiographic images.

All measurements were carried out twice by the same observer at time intervals of a sufficient length to eliminate the possibility of values recorded in the first measurement interfering with those of the second. In this way two sets of measurements were obtained and the mean of each pair of measurements was calculated and recorded in millimeters and used to estimate stature.

Images were taken with a dental CT which is a technique of computed tomography. The device has an X-ray beam cone 23.8 cm wide by 19.2 cm high, with one 360 degree turn and was set at 120 kV and mA 5. The images obtained have a field of view (FOV) of 170 mm, the resolution and scan time depends on the following protocol: resolution of 0.250 with a cycle time of 14.7 s. For image display thickness from 1 to 0.25 mm was used, being taken in all cases minimum thickness cut. Images were exported in DICOM format and then processed with the i-CATVision™ Version 1.9.2.17 software (Copyright© 2004–2008 Imaging Sciences International, Hatfield, PA, USA). For analysis and measurement of each sample linear measurement tool in Multi Planar Reconstruction (MPR) of the software was used.

2.3. Dimensions

Measurements made on both cervical vertebrae are shown in Figs. 1–4:

(A) Measurements of the first cervical vertebra, C1:

- *Height of vertebra* (*V*) measured along the transverse plane of the atlas from the anterior to posterior tubercle (Fig. 1).
- *Interforaminal length* (*I*): measured along the transverse plane of the atlas from the outer edge of the transverse foramen to the outer edge of the contralateral transverse foramen (Fig. 2).

(B) Measurements on second cervical vertebra (C2):

- *Greatest-diameter dens (DO)* measured along the transverse plane of the odonto-axial joint at its widest part (Fig. 3).
- *Height of the odontoid (O)* measured along the sagittal plane from the top of the dens to the uppermost part of the lower formed between the anteroinferior point and the posteroinferior point of the vertebral body (Fig. 4).

2.4. Statistical methods

For statistical analysis we used the *R* environment, whose statistical techniques can be applied and expanded through software from which we obtained the means, standard deviations and linear regression [29]. The Application of Generalized Linear Model (GML) was done by specific software downloaded from the same environment [30].

3. Results

The sample consisted of 203 individuals: 78 males and 125 females. The male sample ($n = 78$) had an average height of 1710.6 mm, with a maximum of 1950 mm and a minimum of 1530 mm. The female sample ($n = 125$) had an average of 1590.4 mm, with a minimum of 1410 mm and maximum of 1800 mm. Table 1 shows the descriptive data of the sample for he four measurements.

Equations were applied to estimate stature for three scenarios, represented in three tables, depending on the sex of the individual and in cases where sex is unknown. (Tables 2–4).

The tables present the linear regression formulae to estimate height for three scenarios.

- Using C1-measures: *V* and *I*
- Using two measures of C2, D*O* and *O*
- Using the four measures: *V*, *I*, D*O*, and *O*

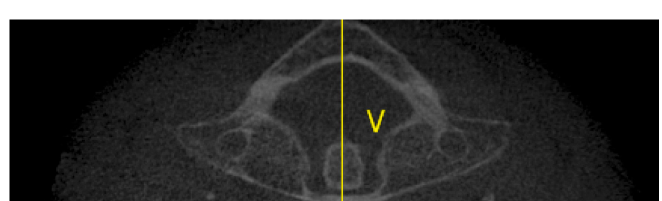

Fig. 1. Height of the vertebra (*V*).