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Method for Estimating Height in People using Multivariable Statistics

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dAbstract

Determining the sex, age, height, and race of the subject is the initial phase in the identification of bone remains, as a background, it allows to build a biological profile of an individual, which is the first step for identification when it is not possible to use conventional methods based on fingerprints or identification guided by the recognition of features and/or clothing. The aim of this study was to evaluate Carrea’s method for determining height from the dimensions of temporal maxillary pieces and, in a second step, to propose a mathematical method. A regression equation was determined to allow the correct estimation of height in 58, 3% of the cases with ±5cm and in 98.2% with ±10cm, which is a practical tool for estimating height that must be supported by other methods.

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1. Introduction

The biological profile of human beings can be obtained from different types of bones, the most commonly used being: pelvis, skull, long bones (femur, tibia, humerus, radius), cervical vertebrae, clavicle, sternum, ribs,}

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calcaneus, metatarsals, among others [1] [2] [3]. Height is considered exclusive to the human species, since animals do not assume a physiological habitual upright posture, and their dimensions depend on various segments of the skeleton, such as the cephalic, spinal (height of the spine), pelvic, and lower limbs, each contributing to the individual's height in consideration of age, sex, race, socioeconomic and psychosocial conditions, and finally historical trends [4] [5] [6] [7].

For [8], the estimation of height is an important parameter in the identification of bone remains during forensic examinations. In recent years, several methods have been proposed for the estimation of height. These include anatomical reconstruction and the regression equation based on long bones. The first method is preferable because it takes into account the total height of the skeleton and therefore provides more accurate estimates, but cannot be applied to incomplete remains [9].

And the second method is a metric relation of the length of the bone to the total length of the body. However, different populations require different equations because they have different body proportions. To avoid this, an average femoral height is used (proportion of the different equations) which will provide an adequate estimate of height with a margin of error of 5 cm [1]. The most reliable methods for estimating height when there are just bone remains require the preservation of these long bones, but very often this is not possible, so the development of alternative methods is necessary [10].

In this scenario, forensic dentistry is used as a discipline that applies stomatological knowledge for the correct examination, handling, evaluation, and presentation of oral-dental tests in the interest of Labor, Civil, and Criminal law [11], being relevant to use the available dental elements, since dental tissue can resist extreme conditions of degradation, such as exposure to high temperatures, humidity, and excessive pressure. The high mineral content of dental tissues, especially enamel, is responsible for their hardness and strength, thus allowing the identification of human bodies [12].

In 1920, Ubaldo Carrea developed a mathematical method for calculating the subject's height from the dental dimensions [13]. Carrea begins with the mesiodistal diameters of a lower central, lateral, and canine incisor, whose sum in millimeters constitutes an arc of circumference that encompasses these three teeth. The string of this arch and the so-called lower radius-string are the fundamental measurements of the so-called dental diagram proposed by Carrea [15]. This method has been evaluated by different authors without conclusive results on the usefulness of the method, despite its successful use in procedures of public interest such as the identification of Josef Mengele in Brazil [16].

This method was also evaluated in the maxilla, with negative results [17], with 54% success rate reported for a sample of the Chilean population [18]. Despite the low performance in the maxilla, it is necessary to develop methods to estimate the height of a subject, from individual dental dimensions and in this dental arch, especially considering that the jaw detaches from the skull and is often lost. Additionally, there are no studies that evaluate these methods in children, despite the relative stability of the dimensions of the dental elements once erupted. With these antecedents, the purpose of this study is to evaluate Carrea's method in temporary dentition and to propose, by means of multivariate statistics, mathematical models for the estimation of height in children from the dimensions of temporary teeth.

2. Method

The sample was integrated by 112 pediatric patients between 34 and 82 months of age, both sexes, who attended the dental evaluation, who, together with their parents or caregivers, were informed of the nature of the study and provided a written proof of their adherence. Patients with erupted central, lateral incisors, and upper temporal canines were included. Patients with dental agenesis or supernumerary pieces, with extensive coronary destruction or fractures of the pieces to be evaluated were not considered. Once the sample was selected, each patient's actual height was determined [1].

Subsequently, the mesiodistal diameters of the central, lateral incisor, and upper temporal canine were measured using a caliper, whose sum in millimeters constituted the arc referred to by Carrea. The radius-string was also established, determined by a straight line between the mesial margin of the central incisor and the distal margin of
the canine respectively (Formula). The reliability of the measurements was calculated using the re-measurement method [4].

\[
\text{Maximum height: } \text{arch (mm)} \times 6 \times 3.1416 \times 10 / 2 \\
\text{Minimum height: radius-string (mm)} \times 6 \times 3.1416 \times 10 / 2
\]

Once both measurements were obtained, the mathematical model proposed by Carrea was applied (Fig. 1), and the estimate was compared with the real height.

\[\text{Fig. 1. Scheme of the arch (Red) and radius-string (blue) in the maxilla [5]}\]

3. Results

The average height was 114 cm (SD 0.088). The minimum height was 96 cm and the maximum height was 128 cm. The mean arc was 16.62 (SD 0.83) on the right side and 17.14 (0.83) on the left side, while the right string radius was 18.58 (SD 0.79) and the left string radius 18.42 (SD 1.09). The interclass correlation coefficient was 0.93. Carrea's method was negative in all cases, so a multivariate linear regression was performed to calculate height from the dimensions of the temporal dentition. Multivariate linear regression in maxilla. Linear regression of the maxillary arch and maxillary radius-string data was performed both on the right side. When determining the regression equation, it was observed that the determination coefficient was too low \((r^2 = 0.0088)\), so it was decided to exclude extreme cases (children aged 34.47 and 82.12 months) from the analysis.

With this, the analysis group was made up of 98 individuals of 62 and 74 months. Multivariate linear regression was performed with the data of right maxillary arch, right maxillary radius-string as independent variables and height in mm as dependent variable.

The resulting equation was:

\[\text{Height} = 1357.457 + (\text{Arch} \times -8.584) + (\text{Radius-String} \times -1.894)\]

The \(r^2\) value was 0.028. In order to evaluate the practical usefulness of the method, cross validation of the data was carried out, getting to determine that the formula height ±5 cm allowed to estimate the height in 58, 3% of the cases, whereas the formula height ±10cm allowed to estimate the height in 98,2% of the cases.

Conclusions

Forensic anthropology employs reconstructive methods to establish the identity of deteriorated corpses or fragments of corpses by determining age, height, sex and race, as basic and principal elements of legal medical identification. Over the years, the determination of the height of human remains for identification purposes has been entrusted almost exclusively to methods based on the measurement of long bones. However, there are cases in
which these osseous pieces are not available and, therefore, these methods are not applicable. It is in these situations in which a method that estimates height from dental measurements is useful, such as the one proposed by Ubaldo Carrea, who relied on odontometry, pointing out that the teeth are proportional to the set of the arch, the head and the subject in general.

This study concludes that the Carrea method is not applicable to the temporal maxillary dentition, which is consistent with the low results obtained by Gajardo et al. and Lima et al. The inefficiency of this method may be due to the fact, as proposed by Carrea, that the facial and height proportions are always based on the mandible, starting from Bonwill's Mandibular triangle [6]. The proportion of 6 string radii determine the side of this triangle and 7 string radii determine the external triangle, which extrapolates the facial dimensions and from which the formula for the determination of height in adults is derived [1].

A greater accuracy was found when applying a multivariate linear regression with 58.3% accuracy when considering a range of ±5 cm and 98.2% accuracy with a range over the formula of ±10cm. The described mathematical model can be used in diverse situations, since the maxilla, which is attached to the skull, presents a lower index of fracture in comparison with the mandible in traumatic deaths, thus helping in its use with all its dental components, however, this method must be complemented with other techniques for the estimation of the height.

References
