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The use of computerized tomography in determining stature and sex from metatarsal bones

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ABSTRACT

This study evaluates the efficacy of a radiological method to estimate stature from measurements of the first and second metatarsal taken from a collection of metatarsals of a Portuguese Caucasian population in which the measurements were made directly on the bone. The highest coefficient of determination and the lowest standard error were obtained with the physiological length of the second metatarsal (F2), using the equation $S = 895.4803 + 10.7848F2$. The linear regressions obtained show significant differences between the estimated heights from M1. In addition, we offer a simple method for sex determination based on the maximum length (M1) and width (W1) of the first metatarsal, where $W1 = x_1$; $(M1/W1) = x_2$; $\beta 0 = 55.4767$; $\beta 1 = -2.5796$ and $\beta 2 = -4.6898$. Here we present a method of measurement using computerized tomography that enables population studies using live volunteers without incurring the difficulties of on the bone measurement.

1. Introduction

The determination of sex, age, weight and height can be crucial in forensic identification, and height in life, a basic element in reconstructing the biological profile, can be calculated from skeletal remains [1–9]. Variations between the measured height of the cadaver and height measured in vivo can be as much as 1.5 cm in males and 2 cm in women [1,5–8,10,11]. In cases involving recent and complete cadavers, height measurement can be performed directly on the body, as in a living individual, but when dealing with skeletal fragments different techniques are required. Regression formulae of long bones are the most useful, especially those of the lower limbs (femur and tibia) [1,6,7,10–16]. However, long bones are fragile and, when found, are often fragmented. To overcome this problem several formulae have been developed to enable these fragments to be used in estimating height [8,18–22].

Small bones have proved to be much more resistant to the rigors of time, due in part to the protection offered by footwear and clothing, as well as particular features of their own tissues, [2–4]. These small bones (from either the hand or foot) are easily recovered and contribute more reliable results than fragmented long bones [19–22]. Several studies report stature estimation calculated from indirect measurements of the hand [23], footprints [24–30] and shoe size [31], and in more contemporary studies metatarsals have proved useful in estimating height [32–36].

Together with height, sex determination is also a basic element in the development of a biological profile [37].

In some studies bones have first been measured radiologically on live volunteers [7,11,13], and the results used to obtain useful formulae for later use in the identification of fragmented bodies and skeletonized victims. One of the main advantages of using radiology is the display of skeletal structures without the need to remove the surrounding soft tissue, thereby avoiding body

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mutilation and allowing, if necessary, its use on living individuals. Furthermore, it serves as an extremely useful aid to victim identification by providing virtual face models and global shape analyses for age estimation [39–42].

This study developed regression formulas obtained from CT scan imaging of the first and second metatarsals, using a collection of metatarsals taken from a Portuguese Caucasian population [33,34]. In addition, we offer a simple method for sex determination based on the new measurements. Each formula obtained should only be used within the population from which it was obtained, given that genetic differences between distinct social-geographic areas can alter the relationship between body measurements [15,17].

2. Materials and methods

2.1. Sample

In this study we used a previously published sample [33,34], comprising a collection of the first and second metatarsal of the left foot extracted in 2002 from cadavers within a recent post mortem, measured and identified by sex and age. All subjects were Caucasians of Portuguese nationality and in order to homogenize the sample the authors took into account a number of criteria:

- Age of the individual at the time of death between 20 and 75 years.
- Absence of fractures in the left lower limb.
- Absence of fractures or any other conditions that might cause changes in body height.
- Absence of obvious pathology in the feet, such as ankylosis, deformities or osteophytes.

The sample comprised 90 males (81.8%) and 20 females (18.2%). The mean age of the sample was 46.06 ± 12.07 (males 46.20 ± 12.28 years, females 45.37 ± 11.29 years).

All data were obtained from the original authors [33,34], and the study was approved by ethics committee.

2.2. Measurement of the metatarsals using computerized tomography (CT)

Metatarsals were thawed at room temperature. Two pairs were found to be fragmented and therefore discarded, while the remaining 108 pairs were correctly identified, and grouped on trays for re-measurement by a dental scanner. The images were subsequently digitalized.

The dental scan technique uses computerized tomography (CT), which although developed for use in dentistry, can also be used for the study of small bones or fragments thereof. By means of appropriate software, it enables life-size reconstructions and correct visualization of anatomical structures. For image display, thicknesses from 0.25 to 1.0 mm were used, and in all cases the least possible thickness was taken and then processed by i-CATVision™ 1.9.2.17 software (Imaging Sciences International, Hatfield, PA, US).

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 millimetres. This method is similar to that used in other publications in this same field, and in keeping with common practice, full data is not necessarily published [33,34,36,38,43,44]. The mean intra-observer error, calculated following the equation presented by Albanese et al., was less than 2% [45].

2.3. Description of measurements

Measurements were obtained according to Cordeiro et al. [34] to which an extra dimension of width was added.

M1 – Maximum length of 1st metatarsal – The distance between the tip of the tuberosity and the most distal point of the head (Fig. 1).

M2 – Maximum length of 2nd metatarsal – The distance between the proximal tip and the most distal point of the head (Fig. 4).

W1 – Width of the first metatarsal (W1): straight-line distance between the edge and the medial first metatarsal measured at the middle of diaphysis (Figs. 2 and 3).

F1 – Physiological length of 1st metatarsal – The distance between the deepest point of the proximal articular surface and the most distal point of the head (Fig. 1).

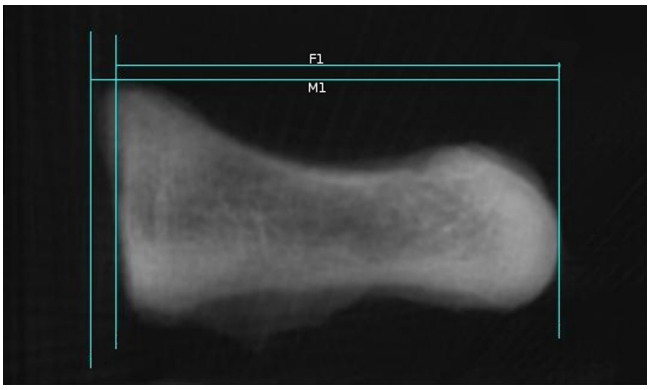

Fig. 1. Maximum (M1) and physiological (F1) length of the first metatarsal.

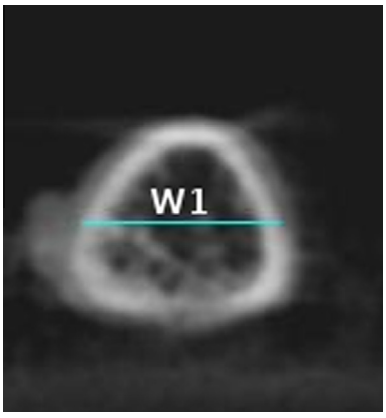

Fig. 2. Width of the first metatarsal (W1), cross-sectional view.

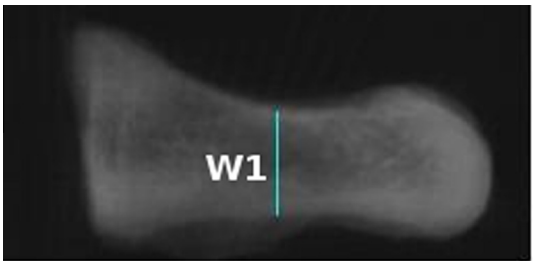

Fig. 3. Width of the first metatarsal (W1), longitudinal view.