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The relationship between cadaver, living and forensic stature: A review of current knowledge and a test using a sample of adult Portuguese males

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ABSTRACT

The use of cadaver length and forensic stature as a proxy for living standing height has not been scrutinized in detail. In this paper we present a brief review of the current knowledge on the relationship between cadaver, living and forensic stature; assess the magnitude and nature of the differences between these three measures of stature; and investigate the potential impact of these differences in forensic contexts. The study uses a sample of 84 males who were autopsied in 2008 at the National Institute of Legal Medicine and Forensic Sciences (Porto, Portugal), where stature data were collected from three different sources: cadaver stature was obtained from the corpse prior to autopsy, living stature was obtained from military conscription records and forensic stature was obtained from national citizenship identification card records. Descriptive statistics, ANOVA and linear regression are used to analyze the data. The results show that cadaver stature is the highest measure, followed by forensic and by living stature, and the difference between cadaver and living stature is greater than expected (4.3 cm). Results also show considerable individual variation in the differences between the three measures of stature and that differences decrease with stature, although only slightly. This study has shown that the difference between cadaver and living stature is greater than previously thought and suggests that previously reported correction factors are a minimum rather than a mean correction. Forensic stature is likely to be incorrectly estimated and can jeopardize identification if methods estimate living rather than forensic stature.

1. Introduction

The estimation of stature can be crucial in several research areas in biological anthropology including paleoanthropology, bioarcheology and forensic anthropology. Although the information may be used to address different research questions in each of these major areas, stature has generally been considered one of the most straightforward parameters to estimate from human skeletal remains. A bone measurement is taken, the appropriate regression formula is applied and the estimate is obtained together with the respective prediction interval. In the end, only the first and last steps – measuring the bone and applying the formula – are actually straightforward. The choice of which regression formula to use is less obvious since most methods are sex-specific and/or population-specific and/or century-specific. Much research in stature estimation has focused on population or group differences in stature [e.g. 1–8], but one of the key areas of stature reconstruction that has not been scrutinized is the source of the stature data used to develop the equations for estimating this parameter.

There are three distinct concepts of stature that are directly and/or indirectly relevant when estimating stature from skeletal remains: living stature, forensic stature and cadaver stature. Although the definition of each type of stature data is fairly straightforward, in practice there is a great deal of variation in what is actually measured. As the name suggests, living stature (LS) is the actual stature of a person standing in a standardized position as measured using calibrated equipment such as an anthropometer or stadiometer. Living stature may vary for any one person over the course of a 24 h period with the effects of gravity on the compression of hip joints, knee joints, and especially on the loss

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of thickness of intervertebral discs during the day, and the decompression at night while horizontal [9–16]. Furthermore, LS may change over the course of a person's lifetime with joint compression and cartilage degeneration [17–22]. Living stature has also been referred to as measured stature [e.g. 23].

Forensic stature (FS) is defined here as the documented stature of an individual as it appears on official government issued documents such as passports, driver's licenses and identity cards of various types. The difference between LS and FS can range from negligible to significant because there is a great deal of variation through time and in different jurisdictions in when and how FS is collected. In some jurisdictions, stature data appearing on government issued documents is actually measured, while in others it is simply self-reported. Forensic stature may or may not actually match LS since FS can be self-reported on application forms, is not always measured before the issuing of the documents and, if measured, it may or may not be collected using calibrated equipment in a standardized manner. Additionally, in a forensic investigation, data on stature can also be reported by relatives when filling the missing-persons reports [24–26]. Similarly, stature reported by others will likely show some discrepancy to the measured stature [27]. As with LS a significant amount of time in years may have elapsed between when the FS was documented and time of death.

Cadaver stature (CS) has a technical definition and is also a descriptive term. What is often referred to as cadaver stature is the length of the cadaver taken prior to autopsy in a supine position. A non-technical, but descriptive use of the term cadaver stature refers to various attempts by researchers to recreate LS from cadavers [28]. For example, Terry [29] developed a pivoting table to measure a cadaver in a "standing position" to estimate LS more precisely and accurately. The differences between CS and LS, particularly when CS is measured in a supine position, have been attributed to several factors as the lessening/flattening in the lying position of the curvature of the spine and a possible decompression in some joints, the loss of muscle tone "resulting in abnormal subsidence of parts and favoring tendencies of the limbs to fall into unnatural positions" [29, p. 435], as opposed to the compression of intervertebral soft tissue while standing [12,30,31].

It is conventional wisdom in physical anthropology, forensic anthropology and legal medicine that CS is greater than LS, but the exact relationship between these two measures of stature is poorly understood. The Scientific Working Group for Forensic Anthropology [32, section 4, p. 3] expresses this concern most clearly: "Some stature estimation techniques are based on samples using cadaver length, not living stature. Depending on the manner the cadaver was measured and adjustments in the techniques to approximate living stature, the stature estimation may be inaccurate." One approach that has been used to address this issue of living stature data is to collect LS from live volunteers and to collect long bone lengths from x-rays or CT scans [e.g. 4,33–41]. While potentially solving one problem related to the accurate and precise measurement of LS, using conventional radiography creates an equally significant problem of error in the measurement of long bones [42]. There are significant differences in the measurements taken from dry bone versus radiographs due to difficulties in locating landmarks, subtle differences in positioning specimens during X-rays and distortion related to compressing a three dimensional object into two dimensions [43,44]. There is some evidence that using CT-scans can minimize these problems [38,41]. To the best of our knowledge the only methods that rely on direct measurements of dry long bones and actually living standing stature is that by Olivier [45] and, in part, Trotter and Gleser [46,47]. However, both studies have problems with their samples. Olivier collected data from ethically questionable sources and Trotter and Gleser sampled a very narrow demographic.

Although the relationship between LS and FS has been investigated [23], the relationship between CS and LS or FS has not been considered in a systematic way. In fact, there has been no direct investigation of the relationship between LS and CS, probably because it is very difficult to find a sample where living, forensic and cadaver stature have been measured on the same individuals. In this paper we present a brief review of the current knowledge on the relationship between cadaver, living and forensic statures; we assess the magnitude and nature of the differences between these three measures of stature; and we investigate the potential impact of these differences in forensic contexts. Unlike other investigations of the relationships between these measures of stature, we use a sample from Portugal where all three stature measurements are known for each individual in the sample.

1.1. Background: previous correction factors of cadaver stature

Our current understanding of the relationship between LS and CS stems from the early attempts by physical anthropologists at devising methods for stature estimation from skeletal measurements. The only source of information available for these early researchers was measurements of long bones collected from fresh cadavers after autopsy and supine stature measured from those same cadavers before autopsy. Consequently, in various cases including several widely used and foundational studies, formulae were developed from long bone length regressed on CS [2,7,46,48–50]. Several authors, though, have noted that CS is greater than LS and have proposed a correction factor to convert CS into LS [30,46,48]. The most often cited and utilized correction factor was proposed by Trotter and Gleser [46], who recommended subtracting 2.5 cm from CS. However, others have proposed different correction factors or even none at all. Manouvrier [30] concluded that CS is on average 2 cm greater than LS. Similarly, Correa [51] found a mean difference of 2 cm between cadaver and living stature in a Portuguese sample. Pearson [48] found that CS is 1.2 cm greater than LS for males and actually 2 cm smaller for females. More recently, Bidmos [25] found CS to be 1.9 cm and 4.1 cm greater than LS, in white and black males respectively. Dupertuis and Hadden [49], on the other hand, did not find a noticeable difference between CS and LS and did not apply any correction. Similarly, Hauser et al. [7], Sarajlić et al. [34] and Petrovečki et al. [35] do not correct cadaver stature because they consider that stature measured with the cadaver in a supine position and in *rigor mortis* does not differ from living stature, due to muscular contraction and absence of extension of intervertebral discs. However, there are reasons to suspect that this may not be necessarily the case. A summary of the mean differences found between CS and LS in the various studies can be found in Table 1.

The disagreement regarding the proposed correction factors may result from the different approaches taken to measure CS and LS as well as the mathematical approach used to calculate the difference between the two. Trotter and Gleser [46] used stature data from the Terry Collection, which were taken on cadavers that were placed in a standing position using a pivoting table [29]. In

Table 1
Differences between cadaver (CS) and living stature (LS) reported in the literature (cm).

Source	Males	Females
Trotter and Gleser [46]	+2.5	–
Manouvier [30]	+2.0	+2.0
Correia [51]	+2.0	+2.0
Pearson [48]	+1.2	−2.0
Bidmos [25]	+4.1/−1.9[a]	+8.5/+2.9[a]
Dupertius and Hadden [49]	0.0	0.0

[a] "Black"/"White" individuals.