Forensic Science International 278 (2017) 409.e1–409.e10

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Forensic Anthropology Population Data

The accuracy of the anatomical method for stature estimation in Black South African females

Desiré Brits[a,*], Paul R. Manger[b], Mubarak A. Bidmos[c,b]

[a] Human Variation and Identification Research Unit, School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa, 2193
[b] School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa, 2193
[c] College of Medicine , Qatar University, Doha, Qatar

ARTICLE INFO

Article history:
Received 5 April 2017
Received in revised form 2 June 2017
Accepted 4 June 2017
Available online 12 June 2017

Keywords:
Forensic anthropology population data
Stature estimation
Anatomical method
Soft tissue correction factor
Magnetic resonance imaging
Black South African females

ABSTRACT

The anatomical method is considered the most accurate stature estimation method, but investigation has shown that it continuously underestimates stature. This underestimation is believed to be related to the use of universal soft tissue correction factors. Therefore, the aim of this study was to assess the accuracy of the soft tissue correction factors in a living population of Black South African females and to subsequently calculate a new soft tissue correction factor, specific for stature estimation in this population group. Thirty Black South African adult females voluntarily participated in this study and underwent a full body Magnetic Resonance Imaging (MRI) scan. Living stature was measured with a stadiometer and total skeletal height (TSH) was calculated from the MRI measurements. Stature was estimated from the TSH of each participant using Fully's (1956) [17], Raxter et al.'s (2006) [38] and Bidmos and Manger's (2012) [5] methods. Results indicated strong, statistically significant positive correlations between living and estimated statures, however, paired t-tests revealed that living stature was significantly underestimated using Fully's and Raxter et al.'s methods, while the method by Bidmos and Manger significantly overestimated stature. A lack of statistically significant correlations between soft tissue correction factors and the total skeletal height was found. Likewise, an absence of statistically significant correlations between age and the estimation error, with and without age adjustments were also observed. A new soft tissue correction factor, specific for stature estimation in Black South African females was calculated. The newly proposed regression equation presented improved stature estimation accuracies for this population group.

1. Introduction

The anatomical method, commonly referred to as Fully's method [17], has repeatedly been described as the most accurate method for stature estimation [29,31,36,3,32]. This is due to the inclusion of the height measurements of all the bones that contribute directly to stature and as such eliminates the inaccuracies introduced by differing body proportions, which is one of the main sources of error of the mathematical method [29,38,32]. The anatomical method is also often used to calculate skeletal height. Subsequently regressions equations are generated for stature estimation from individual bones using the calculated skeletal height, when documented statures are not available [31]. This approach has been used widely in South Africa as cadaveric heights in skeletal collections are often missing [3,10] or inaccurate [28,3].

The accuracy of the anatomical method has previously been tested and reported to be accurate [31]. However, results from recent studies have questioned the accuracy of this method as it has been shown to continuously underestimate stature [22,3,38,32,5]. It has been suggested that the underestimation of stature using the anatomical method is related to the use of the universal soft tissue correction factors as prescribed by Fully [17]. According to Fully [17] this soft tissue correction factor represents all soft tissue that also contribute to stature, such as the scalp, cartilage, vertebral discs, menisci and the fat pad of the foot as well as the curvature of the vertebral column.

* Corresponding author at: Human Variation and Identification Research Unit, School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand, 7 York Road, Park Town, Johannesburg, 2193, South Africa. Fax.: +27 (0)11 717 2422.
E-mail addresses: desire.brits@wits.ac.za (D. Brits), paul.manger@wits.ac.za (P.R. Manger), mbidmos@qu.edu.qa (M.A. Bidmos).

http://dx.doi.org/10.1016/j.forsciint.2017.06.004
0379-0738/

King [22] and Bidmos [3] proposed that the soft tissue correction factors might be population specific, as the observed inaccuracies were more distinct in Black individuals compared to Whites. Bidmos [3] furthermore suggested that the soft tissue correction factor might also be sex specific as inaccuracies were more pronounced in Black females compared to Black males. In contrast, Raxter et al. [38] found that sex and ancestry had no significant effect on the accuracy of stature estimation using the anatomical method, but age was found to be a contributing factor. Raxter et al. [38] also proposed that the underestimations of the anatomical method could in part be related to the vague definitions used to collect the relevant skeletal measurements, as these measurements were not explicitly defined by Fully [17]. A modified anatomical method, based on regression analysis which incorporated a single soft tissue value as well as the effects of age on stature estimation, was put forward [38]. The authors also provided an equation for stature estimation when age is not available [38].

Using the soft tissue correction factors proposed by Fully [17] and Raxter et al. [38], Bidmos and Manger [5] assessed the accuracy of the anatomical method in living Black South African males. The authors found that both Fully's [17] and the revised method by Raxter et al. [38] significantly underestimated stature, on average by 15.8 cm and 14.8 cm respectively, in the studied sample. A new soft tissue correction factor of 25.9 cm was calculated for the Black South African males; a value that was significantly larger than the previously proposed values of 10.5–11.5 cm by Fully [17] and 14.6 cm by Raxter et al. [38]. Bidmos and Manger [5] proposed that these differences were due to the population specificity of the soft tissue correction factors, as earlier suggested by King [22] and Bidmos [3]. The authors also suggested that the soft tissue correction factors could be sex specific. Therefore the aim of this study was to assess the accuracy of the various soft tissue correction factors of the anatomical method, in a living population of Black South African females and to subsequently calculate a new soft tissue correction factor specific for stature estimation in this population group.

2. Materials and methods

2.1. Participants

A plethora of stature estimation publications have been generated from skeletal remains housed in various skeletal collections. These collections are often no longer representative of the current living population due to the effect of secular trends [33,34,13,51]. Therefore, ethical clearance was obtained from the Human Research Ethics Committee—Medical, University of the Witwatersrand (Clearance Certificate No: M110414) to recruit living participants to participate in the current study. The study was verbally described to potential participants and information leaflets along with informed consent forms were given to interested parties. Signing of the informed consent form confirmed their understanding and voluntary participation in the study.

Black South African females were specifically invited to participate in this study as results by Bidmos [3] underlined the magnitude of stature underestimation in this group when using Fully's [17] method. Black South Africans also constitute the largest population group in South Africa [45] and have been shown to fall victim to crime more often than other South African population groups [46]. A recent study by Bernitz et al. [2] showed that more than 70% of forensic anthropological cases comprised Black South Africans, further proof to the vulnerability of this population group to the effects of crime.

The participants included individuals from various tribal affiliations, including mainly Zulu, Xhosa, Tswana, Tsonga as well as Northern and Southern Sotho's. Research has found little intertribal variation amongst Black South Africans [12,11,28,30] and therefore it has been suggested that these individuals be treated as a single homogenous group. In addition, Franklin et al. [15] noted that the tribal subdivisions are disappearing. This was also evident in the current study as a number of participants self-identified as "South African" or "Black". Moreover, in practice, forensic anthropologists will be blind to the tribal affinity of unidentified skeletal remains and as such the pooling of individuals has been suggested for research purposes [15].

Only females between the ages of 19 and 60 years were recruited for this study. The cessation of growth is marked by the fusion of long bone epiphyses to the diaphysis and is typically completed by 18 years of age in females [41]. Furthermore, Trotter and Gleser [50] found an insignificant increase in stature after the age of 18 years. An upper age limit of 60 year was selected as it has been found that the age-related decrease in stature only becomes apparent after approximately 60 years of age [9].

Individuals that were claustrophobic, pregnant or breast feeding, had any skeletal abnormalities or previously broken bones as well as individuals that have suffered from growth related and/or nutritional diseases were excluded from the study. Standard Magnetic Resonance Imaging (MRI) exclusion criteria set out by the Department of Radiology, Wits Donald Gordon Medical Centre, Johannesburg, South Africa as well as those described by Shellock and Spinazzi [43] were also adhered to.

2.2. Methods

2.2.1. Data collection

Participants were invited to complete a full body MRI scan at the Department of Radiology, Wits-Donald Gordon Medical Centre. Prior to the MRI scan the living stature (LS) of each participant was measured, as it has been found that females generally overestimate their own stature [6]. Living stature was measured with a stadiometer on the morning of the MRI scan so as to control for the diurnal loss of stature [23,44,25]. Living stature was measured according to standard anthropometric descriptions to the nearest 0.1 cm. Each participant was asked to change into a hospital gown and to remove their shoes and head gear. Participants were requested to stand upright with their arms at their sides, keeping the head in the Frankfurt horizontal plane [24].

MRI was specifically selected as it is a non-invasive image modality that allows for the reliable and accurate assessment of skeletal remains without exposing participants to harmful ionizing radiation used by computed tomography (CT) scanograms or radiograms [26,14,37]. The MRI scans were taken in the supine position with the head and feet of the participants supported. This was done to ensure that the participants remained in the anatomical position and also to prevent the head and feet from moving during the scan. All MRI scans were collected using a 1.5 T Phillips Entera MR Scanner (Release 3.2, Level 2, 2011-08-11 CE 0344, software version 12.1). T1 weighted survey scans were firstly collected with slide thicknesses of 130 mm and TR between 3000–4000. This was followed by a three station MOBI track scan from the head to the pelvis using a T2 weighted sagittal sequence and from the pelvis to the heel using a coronal sequence, at 3 mm. Following the full body MRI scan the MOBI track stations were fused on a MRI work station and the images transferred to a DVD. A total of 38 participants completed the full body MRI scans. Unfortunately, a number of scans were excluded due to (i) incomplete scans and missing data, (ii) participant movement which affected the quality of the scans and (iii) due to other technical errors. The exclusion of these scans resulted in a final sample size of 30 from which data was collected and subsequently analyzed.