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Forensic Anthropology Population Data

Assessing the use of the anatomical method for the estimation of sub-adult stature in Black South Africans

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ABSTRACT

Stature estimation is rarely attempted in sub-adults due to the general lack of available standards as a result of the dearth of sufficiently large sub-adult skeletal collections with known demographic information. To overcome this problem sub-adult research mainly relies on modern imaging modalities. In the current study Magnetic Resonance Imaging (MRI) scans were used to assess the use of the anatomical method for stature estimation in sub-adults. A total of 53 Black South African sub-adult males (n = 24) and females (n = 29) aged between 10 and 17 years participated in the study by voluntarily completing a full-body MRI scan. A stadiometer was used to measure living stature prior to all MRI scans. Skeletal elements that contribute directly to stature were measured from the MRI scans using OsiriX and summed to compute the total skeletal height. Total skeletal height was calculated using the diaphyseal, maximum and physiological long bone lengths and correlated to living stature using Pearson's correlations. Subsequently least squares regression equations were generated for the estimation of sub-adult stature. Results indicated strong, statistically significant positive correlations between living stature and total skeletal heights in sub-adult males, females and a combined sex sample. The regression equations were characterized by small standard error of estimates which are comparable to that reported for Black South African adults. Based on these results the anatomical method can be used to accurately describe living stature in Black South African sub-adults. This method is therefore encouraged as it will add valuable information when dealing with unknown sub-adult skeletal remains.

1. Introduction

Two methods are available for the estimation of stature from skeletal remains: the mathematical method, which includes stature:bone ratios and regression analyses, and the anatomical method [1,2]. The mathematical method is considered to be the most commonly used method as it allows for the estimation of stature from a single bone or a combination of bones [3]. The stature estimation equations generated using the mathematical method are, however, sex and population specific and should not be applied to populations other than the population from which it was derived [2,4,5].

The anatomical method, also known as Fully's method [6], is described as the most accurate stature estimation method, benefitting from the inclusion of all the skeletal elements that contribute directly to stature [1,7,8]. Measurements collected from these bones are summed to generate the total skeletal height to which a soft tissue correction factor is added to produce an estimate of living stature [6]. The soft tissue correction factor was initially believed to be independent of sex and population affinity [1,8], however, a number of recent publications have questioned this [9–12].

The mathematical and anatomical methods are well defined for stature estimation relating to adult skeletal remains; however, stature estimation from sub-adult skeletal remains is rarely attempted [13,14]. This is due to a general lack of available literature and standards, related to the shortage of sufficiently large sub-adult skeletal collections with known demographics, available for research [14,15]. Research on sub-adult stature estimation is further encumbered by individual and population differences in growth and development as well as the allometric

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growth of bones, which causes considerable change in body proportions throughout life [16–20].

To date only the mathematical method has been explored for stature estimation from sub-adult skeletal remains. This includes work by Feldesman [21] on the femur:stature ratio as well as a number of studies that have computed regression equations for sub-adult stature estimation from several skeletal remains, including the length of the second metacarpal [55] and lengths of various upper and lower limb long bones [22–29].

The anatomical method has not yet been described for stature estimation in sub-adults; however, a method comparable to that described by Dwight in 1894 is available (as cited by Lundy [1]). Kondo et al. [13] aimed to estimate stature from the well preserved skeletal remains of an immature Neanderthal skeleton. The authors reconstructed and re-articulated the skeleton using casts derived from the original skeletal remains, while missing bones and/or bone sections were restored with paraffin wax. The curvature of the vertebral column as well as the intervertebral distances, joint cartilage thicknesses and the missing talus-and-calcaneus complex were established from photographs and radiographs of modern sub-adults. Stature was measured directly from the reconstructed skeleton and adjusted to incorporate the shrinkage associated with the use of casts. Finally, a soft tissue correction factor of 10 mm, representing the scalp and sole thicknesses was also added. The authors asserted that this is an accurate method for sub-adult stature estimation as it eliminates proportional differences observed between different body parts and between various populations [13]. The veracity of this assertion based on a method developed for a single sub-adult Neanderthal requires further investigation in which a larger sample size is utilized.

Due to the scarcity of information available on sub-adult stature estimation, the aim of this study was thus to assess the use of the anatomical method for stature estimation in Black South African sub-adults.

2. Materials and methods

2.1. Participants

Due to the paucity of sub-adult skeletal collections available for research [14,15] living participants were recruited to partake in this study by completing a full body Magnetic Resonance Imaging (MRI) scan. MRI scans were specifically chosen for this study for three reasons. Firstly, it affords the opportunity to study the internal structures of living individuals including the musculo-skeletal system. Secondly, participants are not unduly exposed to harmful ionizing radiation [30–33]. Lastly, skeletal measurements collected from MRI scans have been found to be as accurate and reliable as measurements collected from CT scans (with radiation about 250 times more than MRI) and dry bones [31–33].

Black South African sub-adult males and females from the greater Johannesburg area were invited to voluntarily participate in this study. Informed assent and consent was obtained from the participants and their parents or legal guardians, prior to participation. Black South Africans were selected for this study as they constitute the largest population group in South Africa [34]. The skeletal remains from this population also make up a greater number of forensic anthropological cases compared to other South African groups as documented by Bernitz et al. [35]. The participants represented various South African tribes, including Venda, Ndebele, Xhosa, Sepedi, Zulu, Sotho, Tswana and Tsonga. However, a large number of participants self-identified as "South African" or "Black" and as such no tribal distinctions were made. This is in line with reports by Franklin et al. [36] who found that tribal sub-classifications in South Africa are disappearing.

Only sub-adults aged between 10 and 17 years were invited to participate in this study. This age range was of specific interest due to the general lack of research related to stature estimation in adolescents [21]. Additionally, the lower age limit was selected to ensure an increased sample size, as research has shown that more than 50% of participants aged 5 years and older, successfully completed MRI scans [37,38]. It has also been found that sedation is not required for MRI scans for individuals 6 years and older [31]. An upper age limit of 17 years was set, as fusion between long bone diaphyses and epiphyses usually occur around the age of 18, signifying the end of long bone growth [39].

Standard MRI exclusion criteria were adhered to. Pregnant female participants and those with any metal implants or devices were excluded from the study [40]. In addition, participants who have had any nutritional deficiencies, growth related diseases, skeletal abnormalities or reported broken or fractured bones were also excluded.

Ethical clearance (Clearance Certificate Number — M110414) was granted by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, South Africa.

2.2. Methods

2.2.1. Magnetic Resonance Images (MRI) scans

A 1.5-T Phillips Entera MR Scanner, housed at the Department of Radiology, Wits-Donald Gordon Medical Centre was used for the collection of MRI scan images. The examinations were carried out with participants in the supine position and commenced with a sagittal T1-weighted survey scan (TR between 3000–4000, 130 mm slice thickness). This was then followed by 3 mm T2-weighted MOBI track scans using three stations. It should be noted that T2-weighted scans were preferred as it produces images that allow for easier differentiation between the long bone epiphyses and the growth plates [30]. A sagittal sequence was taken from the head to the pelvis which was then followed by a coronal sequence from the pelvis to the heel. The sagittal and coronal MOBI track stations were subsequently fused together on a workstation and the images saved to a digital versatile disc (DVD).

A total of 67 volunteers participated in the study. However, a number of participants did not successfully complete the MRI scan. The sample size was further reduced by the exclusion of poor quality scans, some of which were as a result of movement of participants during the scanning process while others were due to technical errors. The final sample size available for analyses consisted of 53 sub-adults (24 males and 29 females).

2.2.2. Anthropometry

Living stature of each participant was measured in the morning prior to the MRI scan. This was done in order to avoid the effect of diurnal variation of stature as reported by Siklar et al. [41]. Living stature data was collected according to the stipulations of the World Health Organization with the participant standing in an upright position and the head in the Frankfort horizontal plane. Measurements of height (living stature) were collected with a stadiometer and recorded to the nearest 0.1 cm [42].

Anthropometric data were collected from the MRI images using OsiriX which is a freely available image processing software [43]. As per convention, long bone measurements were taken on the left side but were supplemented with data from the right where required [44]. All the skeletal elements that contribute directly to stature were measured on MRI scans as described by Moore-Jansen et al. [45] and Raxter et al. [8], with some modifications as suggested by Bidmos and Manger [11] and Brits et al. [12]. A number of sub-adult specific skeletal measurements were also collected as described by Fazekas and Kósa [26] and Buikstra and Ubelaker [44]. The inclusion of these measurements became