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Forensic Anthropology Population Data

Stature estimation from the femur and tibia in Black South African sub-adults

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ABSTRACT

Stature estimation can play a role in the positive identification of unknown individuals and as such it is routinely assessed during the examination of adult remains. Unfortunately, this is not a standard procedure when dealing with sub-adult remains due to the general lack of standard procedures for the estimation of sub-adult stature. The aim of this study was therefore to derive regression equations for the estimation of stature in black South African sub-adults. Fifty nine black South African sub-adult males and females, aged 10–17 years, voluntarily participated in the study by undergoing a full body Magnetic Resonance Imaging (MRI) scan. Living stature was measured with a stadiometer and the maximum and diaphyseal lengths of the femur and tibia were measured from the MRI scans using the image processing software OsiriX. Pearson's correlation coefficients and linear least square regression analyses were used to assess the correlations between living stature and the measurements and to generate sub-adult stature estimation equations for males, females and a combined sex sample. Measurements of the femur, tibia and the combined measures thereof showed strong statistically significant positive correlations with living stature, while the obtained regression equations were characterized by low standard error of estimates. The strong correlations and low standard error of estimates are comparable to stature estimation models reported for Black South African adults and therefore these variables can be considered good estimators of sub-adult stature which will contribute valuable information to the biological profile of unidentified sub-adult skeletal remains.

1. Introduction

South Africa is a country plagued by high crime rates [1]. Recent statistics show that approximately 10% of the total number of deaths were recorded as non-natural deaths. Of these non-natural deaths 43.6% affected individuals between 15 and 19 years of age [1]. These bodies are presented to forensic pathologists for post-mortem examination and if the remains are found in a skeletonized or fragmented state, the assistance of forensic anthropologists is sought [2]. Forensic anthropologists assist with the identification of unidentified skeletal remains by compiling an osteobiographic profile that consists mainly of age, ancestry, sex and stature estimates. Of these attributes, stature estimation can contribute to the positive identification or exclusion of an unknown individual and as such it is routinely assessed during the analysis of adult skeletal remains [3]; however, when dealing with sub-adult skeletal remains emphasis is placed on the assignment of age and stature estimation is rarely attempted [4–8]. This is due to the paucity of knowledge related to stature estimation from sub-adults skeletal remains, especially for adolescents [9] and appears to be associated with the difficulties of stature estimation in sub-adults [3] where one is faced with considerable variation in growth and development between individuals and populations, changes in body proportions associated with the growth spurt and the fact that bone growth is allometric [9–11] Additionally, the cartilaginous growth plates and bone epiphyses are rarely preserved [12] and the contribution thereof to bone length and overall stature is unknown and changes throughout growth [4].

Notwithstanding these challenges, a few stature estimation studies from foetal skeletal remains [13–16] and prepubescent sub-adults have been reported [5,13,17–19]. Additionally, a few

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studies have attempted to estimate stature from the skeletal remains of adolescents and include work by Telkkä et al. [13], Feldesman [9] and Ruff [20].

The studies exploring stature estimation in adolescents are based on data collected from longitudinal growth studies, mostly conducted in the early twentieth century [9,20] and utilize the diaphyseal lengths of the major long bones measured from radiographs [9,13,20]. Only the mathematical method, consisting of regression analyses and the femur:stature ratio, have been described for sub-adult stature estimation [9,13,20]. Telkkä et al. [13] described stature estimation in Finnish sub-adults and based on the correlations between diaphyseal long bone measurements and stature, generated stature estimation equations for individuals younger than one, individuals between one and nine years of age and for adolescents aged 10–15 years. Similarly Ruff [20] generated age-specific stature estimation equations for sub-adults aged 1–17 years, based on radiographic data collected from the Denver Longitudinal Growth Study [21–23]. The application of Ruff's [20] equations is hampered by the need for age estimates to the nearest year, which is very difficult to attain when dealing with skeletal remains [16,24]. The errors for the stature estimation equations calculated by Ruff [20] are comparable to that reported for adults while, standard error of estimates presented by Telkkä et al. [13] are higher than adult errors.

Work by Feldesman [9] explored stature estimation in sub-adults aged 8–18 years, by comparing the femur:stature ratios in sub-adults and adults [9]. The results indicated changes in the femur:stature ratio from sub-adults to adults, with statistically significant differences noted between sub-adults aged 8–11 years and adolescents between 12 and 18 years. Sex differences were also noted in the femur:stature ratio for adolescents (12–18 years) and the author suggested the use of a sex-specific ratio for this age group [9]. A number of studies have also assessed the correlation between various body segments and stature, in living adolescents, including measurements of the foot [26–28], fingers [11], forearm [29] and the head [19]; all reporting reasonable stature estimation accuracies.

A few studies have considered the accuracies of sub-adult stature estimation equations with contradictory findings. Cardoso [6] assessed the accuracy of the stature estimation methods described by Telkkä et al. [13] and Feldesman [9] on sub-adult (1–14 years) skeletons, with known demographic information, from Portugal. Results indicated that both methods underestimated stature. These inaccuracies were associated with the stunted growth and proportionally shorter limbs observed in the Portuguese sample related to the low socio-economic background of these individuals [6]. The accuracy of the stature estimation regressions reported by Ruff [20] was assessed by Sciulli and Blatt [25] as well as Sutphin and Ross [7]. Sciulli and Blatt [25] tested the accuracy of the age-specific tibia and radius stature estimation equations on sub-adults with known demographic information, brought to the Franklin County (Ohio) Coroner. Results indicated relatively accurate stature estimates from both the maximum and diaphyseal lengths of the tibia and radius. Sutphin and Ross [7] assessed the accuracy of the stature estimation equations on sub-adult skeletal remains from Chile's General Cemetery. Based on significant bone length and stature differences observed between Chilean and American sub-adults the authors suggested the use of these equations in prepubescent teens, but cautioned against the use in older sub-adult Chileans. These results support the cautionary note by Telkkä et al. [13] Smith [5], Cardoso [6] and Baines et al. [12] who advised against the application of sub-adult stature estimation equations on populations other than the population from which the equations were derived, due to environmental, nutritional, growth and proportional differences observed between populations [5,6,12,13].

The importance of stature estimation for the positive identification of sub-adult skeletal remains has been highlighted by Imrie and Wyburn [30], Warren et al. [31] and Snow and Luke [5] and support the need for more research. Imrie and Wyburn [30] described the age, sex and stature from sub-adult skeletal remains recovered from a hillside in Scotland. The skeletal estimates were compared to the ante-mortem records of a missing sub-adult male and even though considerable time had lapsed between the disappearance of the sub-adult and the time the ante-mortem data was recorded, adjustments to the estimates for this time lapse allowed for a presumptive identification. The importance of stature estimation in the identification of sub-adults from commingled remains was demonstrated by Warren et al. [31]. Using skeletal maturity and stature estimation, sub-adult males were distinguished from an older sub-adult female following an airplane disaster. Likewise, stature estimation played an important role in distinguishing sub-adult females of similar ages as was described by Snow and Luke [5]. Apart from the important contribution to the positive identification of unknown individuals, estimates of stature also provide valuable information regarding growth, socio-economic status, secular change, health and nutrition of sub-adults [7,8,32–34]. The need to estimate stature in sub-adults with disabilities or skeletal abnormalities is also important in clinical settings as seen in pediatric orthopedics and prosthetics [18,24,35].

Adult stature estimation equations cannot be used when dealing with sub-adult remains as it greatly overestimates stature, resulting in inaccurate and unreliable results [9,20,27,29]. Therefore, due to the general lack of standards regarding the estimation of stature in sub-adults, the aim of this study was to assess the correlation between stature and lower limb bone lengths and to subsequently derive regression equations for the estimation of stature in Black South African sub-adults.

2. Materials and methods

2.1. Participants

Ethical approval for this study was obtained from the Human Research Ethics Committee—Medical, University of the Witwatersrand, South Africa (Clearance Certificate Number—M110414) and allowed for the recruitment of living participants. Written informed assent, prior to participation was obtained from participants who were recruited from Afrika Tikkun, Diepsloot, Johannesburg, South Africa. The parents and/or legal guardians of each participant also provided informed consent. Afrika Tikkun is a non-governmental organization that aims to empower children, youth and families through a number of community centers. Afrika Tikkun, Wings of Life Centre, Diepsloot was specifically approached for this study as sub-adults from this community center have previously been involved in research projects [36,37].

Black South African sub-adults were invited and participated in this study by completing a full body Magnetic Resonance Imaging (MRI) scan. The enrollment of Black South Africans for this study was based on the fact that they do not only represent the largest population group in South Africa (79.2%) [38], the skeletal remains from this population group are also more frequently encountered in forensic anthropological cases [39]. Black South Africans consist of individuals from different subgroups including Zulu, Xhosa, Swazi, Sotho to mention a few; however, these tribal subdivisions are disappearing [40]. Previous research has also illustrated no statistically significant differences among these subgroups and as such this group was treated as a homogenous group [41–43].

Sub-adult males and females aged between 10 and 17 years were included in the study. Telkkä et al. [13] illustrated differences in the regression models used for stature estimation in Finnish sub-adults, particularly between the following age groups: younger than one; one to nine; and 10–15 years. Similar reports for linear growth were also noted for infancy, childhood and