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Cephalo-facial analysis to estimate stature in a Sudanese population

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ABSTRACT

Medico-legal practitioners are often confronted with dismembered remains from which they need to develop a biological profile to establish identity. Accurate estimation of stature is an initial, crucial component of any meaningful medico-legal evaluation. However, sometimes only cephalo-facial remains are available. The most accurate statistical estimations of biological attributes are based on population-specific standards. Therefore, this study assessed the ability to estimate stature using 15 cephalo-facial measurements in 240 Sudanese adults (120 men, 120 women) aged 18–25 years. Stature and cephalo-facial measurements of men were significantly higher than those of women. Most of the measurements were significantly correlated with stature ($p < 0.05$), with better correlations for women than for men. The accuracy of stature estimation using sex-specific simple and stepwise multiple regression equations ranged from ±52.53 to ±60.28 mm. This study provides new forensic standards for stature prediction in a Sudanese population. However, the equations should be used with caution in forensic cases when the more reliable body parts (e.g., limbs) are not available for human identification.

1. Introduction

Identification of skeletal remains or mutilated bodies is of the utmost importance in medico-legal practice. In addition to sex, age, and ancestry, stature is a biological parameter that characterizes individuals and is required to establish a biological profile [1]. Estimation of these parameters accelerates the analysis of human remains by narrowing the pool of victims to match and provides more definitive markers for final confirmation.

Two methods (anatomical and mathematical) are generally used to estimate stature, depending on the completeness and condition of remains. The anatomical method sums the superior-inferior measurements of skeletal remains to estimate stature, while the mathematical method involves extrapolation of living stature from one or multiple bones/parts [2]. Among the mathematical methods used to estimate stature, such as regression and multiplication factors, regression analysis is considered the best and most reliable method [3].

Adult stature results from complex interactions between genetic and environmental factors such as nutrition, climate, and health status during growth and development [4]; these same factors result in differences in body proportion, size, and shape between populations. Moreover, craniometric measurements, particularly those of the jaw, midface, and cranial base, are different between individuals as well as populations [5]. Growth (change in size) and development (change in shape) constitute an ontogenetic trajectory that is determined by the onset and offset of growth and development, growth rate, and initial measurement [6]. Although regularities in developmental systems produce similarities in phenotypes between populations, the mechanisms yielding specific cephalo-facial differences between populations is not yet fully understood [5,7]. The main attribute might be the differences in development rates and timing, which can be determined primarily by the needs of the associated non-skeletal structures [8]. Therefore, the equations to estimate stature should be population-specific [9]; furthermore, the use of contemporaneous standards improves the accuracy of the biological profile. However, population-specific standards might not be available for medico-legal practitioners, either due to a lack of representative documented skeletal collections or published statistical reports [10].

Abbreviations: BIGB, bigonial breadth; BIZB, bizygomatic breadth; CBB, cranial base breadth; HHC, horizontal head circumference; HV, head vault; MFB, minimum frontal breadth; MFH, morphological facial height; MHB, maximum head breadth; MHL, maximum head length; NB, nasal breadth; NH, nasal height; PEL, physiognomic ear length; PEW, physiognomic ear breadth; PFH, physiognomic facial height; UFH, upper facial height.

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The majority of contemporary inhabitants of Sudan, which is located in northeastern Africa, have a unique mixed genetic background because of immigration from the Arabian Peninsula and the local African populations. The lack of complete records, such as fingerprints and antemortem dental records, and the economic constraints for conducting DNA analysis in the presence of civil war and tribal clashes necessitate alternative methods of identification. Moreover, the increased possibility of finding only partial human remains in mass disasters, airplane crashes, war, and crimes warrant alternative stature-estimating standards that use different body parts. However, there is no documented skeletal collection that can be used as a database in Sudan. Consequently, a relative rarity of established morphometric standards are available to estimate biological attributes. However, various body parts in the Sudanese population have been assessed for their ability to estimate stature [11,12], sex [13–16], and intralimb reconstruction [17].

Although the ability to estimate stature using anthropometric techniques with different parts of the body, such as the upper [11,18] and lower [12,19] limbs, has been evaluated, these body parts might not always be available for forensic analysis; at times, only the head or a portion of the head is provided to the medico-legal examiner. In these cases, stature has to be estimated from the available body part, and for this purpose, the cephalo-facial region has been a focus of study in medico-legal and forensic practice owing to its high utility in estimating sex and ancestry [10,20,21]. However, there is a relative paucity of published literature assessing the use of the skull or its parts through either direct measurement of bones or radiological or anthropometric measurements in living humans. Furthermore, these studies have been conducted in limited populations (Indians [22,23], Japanese [24], Indo-Mauritians [25], Nepalese [26], Turkish [27], and Italians [28]). Further limitations are the restriction to only men or cadavers of a broad age range, which could affect stature. The findings have been inconclusive, with some authors reporting good results using these measurements to estimate stature, such as in adult Gujjar men in northern India (standard error of the estimate [SEE] ± 37.26–58.20 mm) [22], and other authors indicating that cephalo-facial measurements are not recommended for estimating stature, such as in Indo-Mauritians ($r = -0.079$–0.494 among men and $r = -0.012$–0.382 among women) [25] and Turkish men ($r = 0.012$–0.229) [27]. Furthermore, anthropometric studies on the use of cephalo-facial/cranial dimensions to estimate stature in Africans, Arabs, or a mixed Arab-African population are extremely limited, although Fully's method was used to estimate stature from the skulls of indigenous South Africans, from Raymond Dart's collection, resulting in correlations of 0.40–0.54 (SEE ± 43.7–62.4) [29].

Because there are currently no population-specific standards for estimating stature from cephalo-facial measurements in the Sudanese population, the primary aims of the present study were to assess the relationship between cephalo-facial measurements and stature in Sudanese Arab subjects and to devise regression formulae for reconstruction of stature from these measurements.

2. Materials and methods

2.1. Sample

Measurements were conducted with 240 healthy Sudanese Arab students (120 men; 120 women) aged 18–25 years at the University of Khartoum. Because they were originally from different localities of Sudan, the sample is representative of the contemporary population of Sudanese Arabs. Only individuals without any medical history of maxillofacial deformity, congenital anomalies, malignancy, trauma, chronic diseases, or surgery that might affect the cephalo-facial measurements or stature were included.

Subjects were required to provide informed, written consent before participation. Approval to undertake this research project was received from the ethical committee of the Faculty of Medicine, University of Khartoum. Each subject completed a questionnaire containing basic demographic questions.

2.2. Measurements

Stature and 15 cephalo-facial measurements were performed by the same investigator using standard anthropometric instruments in a well-lit room and the procedures and definitions described by Vallois [30] and Kolar and Salter [31]. Each measurement was repeated twice, and the mean value was recorded in mm.

Stature was measured with a stadiometer (Seca 217, Seca GmbH & Co. KG, Hamburg, Germany), while the subject stood barefoot on the flat platform with their heels in close contact and touching the base of the vertical board, trunk braced along the vertical board with arms placed on the sides of the thighs, and eyes looking straight ahead. Each subject's head was positioned in the Frankfurt plane, and the projecting horizontal sliding bar was moved to the vertex for the measurement.

The subjects were required to sit on a bench for the 15 cephalo-facial measurements:

- Maximum head length (MHL) was measured as the direct distance from the most prominent anterior point at the glabella to the most prominent posterior point of the occiput (opisthocranion) in the midline using a digital spreading caliper.
- Maximum head breadth (MHB) was measured as the direct distance between the most lateral points of the parietal bones (euryons) perpendicular to the sagittal plane of the head using a digital spreading caliper.
- Horizontal head circumference (HHC) was measured as the circumference of the vault from glabella to glabella in the plane of the maximum length with a measuring tape.
- Head vault (HV) was measured as the direct measurement between the right and left tragi with a measuring tape passing over the vertex.
- Cranial base breadth (CBB) was measured as the direct distance between the superior margins of the tragi using a digital spreading caliper.
- Minimum frontal breadth (MFB) was measured as the direct distance between the two fronto-temporal points using a digital spreading caliper.
- Bizygomatic breadth (BIZB) was measured as the maximum distance between the two zygomatic arches, i.e., zygion to zygion, using a digital spreading caliper.
- Bigonial breadth (BIGB) was measured as the maximum distance between the two most posterior, inferior, and lateral points on the external angles of the lower jaw, i.e., gonion to gonion, using a digital spreading caliper.
- Nasal height (NH) was measured as the distance from nasion to the subnasal point (where the nasal septum joins the upper lip) using a digital sliding caliper.
- Nasal breadth (NB) was measured as the maximum distance between the most prominent points on the lateral aspect of the ala nasi using a digital sliding caliper.
- Morphological facial height (MFH) was measured as the straight distance from the nasion to the lowest point on the lower border of the mandible in the mid sagittal plane (gnathion) using a digital sliding caliper.