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Original communication

Estimation of sex from the upper limb measurements of Sudanese adults

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ABSTRACT

Sex estimation is the first biological attribute needed for personal identification from mutilated and amputated limbs or body parts in medical-legal autopsies. Populations have different sizes and proportions that affect the anthropometric assessment of sex. Relatively few published works assess the accuracy of sex estimation from soft tissue measurements of upper limb parts, except for the hand and its components, but these studies involve a limited range of global populations. The current study aimed to assess the degree of sexual dimorphism in upper limb measurements and the accuracy of using these measurements for sex estimation in a contemporary adult Sudanese population. The upper arm length, ulnar length, wrist breadth, hand length, and hand breadth of 240 right-handed Sudanese subjects (120 males and 120 females) aged between 25 and 30 years were measured by international anthropometric standards. Demarking points, sexual dimorphism indices and discriminant functions were developed from 200 subjects (100 males and 100 females) who composed the study group. All variables were sexually dimorphic. The ulnar length, wrist breadth and hand breadth significantly contributed to sex estimation. Forearm dimensions showed a higher accuracy for sex estimation than hand dimensions. Cross-validated sex classification accuracy ranged between 78.5% and 89.5%. The reliability of these standards was assessed in a test sample of 20 males and 20 females, and the results showed accuracy between 77.5% and 90%. This study provides new forensic standards for sex estimation from upper limb measurements of Sudanese adults.

1. Introduction

Sex estimation, which is the first biological attribute needed in the identification process of unknown human remains, is essential for constructive profiling. Sex estimation roughly halves the pool of possible victim matches and enables the application of the most appropriate standard to estimate other sex-dependent individual attributes, e.g., age and stature.[1,2] Sex can be estimated with morphological and metric techniques applied to the human skeleton.[1] While it is widely understood that traditionally the skull and pelvis have been considered most reliable for sex determination,[1] many recent articles (e.g., Barrier and L'Abbe,[3] Papaioannou et al.,[4] Srivastava et al.,[5] and Salus et al.[6]) have examined postcranial skeletal accuracy and reliability in sex determination.[1] The increased likelihood of pelvic and skull absence when body integrity is compromised, such as during mass disasters, wars, traffic accidents, and assault cases, and the likelihood of recovering separated limbs necessitate the determination of the primary indicators of identification from limb parts.[5,7] In addition, comparison of skull and postcrania sex discrimination has shown that the postcrania metrics provide better estimates of sex than non-metric and metric traits of the skull.[5,8]

Anthropometry is the science of measurements of the size, weight and proportions of the human body and skeleton.[9] Anthropometry is considered to be a multifaceted technique to investigate sexual dimorphism; anthropometry has high precision and validity and is practical and quantifiable by discriminant and regression analyses.[3,10] Additionally, anthropometry provides sex estimation standards from contemporary living populations and overcomes some limitations inherent in osteometric skeletal collections, e.g., wrong recording, dynamicity of the population, and lack of collections in some countries.

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A number of studies have addressed the issue of sex determination based on osteologic and radiologic examination of upper limb bones.[3,4,11–16] However, an extensive literature review revealed a relative scarcity of published research assessing the accuracy of sex estimation from soft tissue measurements of most of upper limb parts; furthermore, the most studied part is the hand and its parts, but these studies involve a limited range of global populations, e.g., India, Turkey, Egypt, and West Australia. Therefore, sex estimation from soft tissue measurements remains a relatively novel approach in forensic anthropology.[17] Kanchan and Rastogi[18] studied hands dimensions, as well as hand and palm indices, among North and South Indian population to assess sexual dimorphism, and they reported that hand dimensions are better discriminators than indices and concluded that hand breadth is the most sexually dimorphic dimension. Similar findings were found in the Rajput population from northern India.[19] The sex identification prospective of hand length and breadth were explored in Indo-Mauritian population and reliability was proved.[20] Ishak et al.,[17] evaluated the accuracy of using anthropometric hand measurements for sex estimation in a contemporary adult Western Australian population, and they found that hand breadth and length are the most significant contributors to sex discrimination.

Few published studies report on sex estimation using other parts of live upper limbs, except for the hand and its parts.[21,22] Aye[23] assessed the usefulness of arm bone dimensions in sex assignment. He measured the wrist circumference, arm span and arm length, derived a discriminant stepwise function using the wrist and arm span and obtained average accuracy between 81.1 and 89%. According to sources cited by Holman and Bennett,[24] the wrist breadth was the most sexually dimorphic trait among living Eskimos, as well as unlike-sex dizygotic twins and unrelated adults from New York City.

The geographical localization of Sudan in northeastern Africa and the presence of the Nile has enhanced migrations of Arabs, Turks, and Copts to Sudan. These migrations resulted in a unique admixture of Arabs and local African populations, e.g., Nubians, in the majority of contemporary Sudan inhabitants. In response to the glaring shortage of Sudanese identification system standards due to the lack of records such as fingerprints, antemortem dental records and the high cost of DNA analysis, Sudanese limbs were explored to assess the possibility of use for stature and sex estimation. Reports indicate sexual dimorphism among Sudanese limbs and argue that limbs can be used for stature and sex estimation.[25–27] There currently are no population-specific standards for sex estimation from Sudanese upper limb measurements in spite of the escalating excessive violent crimes, civil war and tribal conflicts, and difference in the skeletal biology and body proportions of Sudanese compared with other populations, even the Egyptians and others in close proximity.[25,27] Hence, the aims of this study are to explore sexual dimorphism of Sudanese upper limb measurements and provide population specific standards and posterior probabilities for sex assignment of unknown subjects based on these measurements. These standards would provide a sex estimation method for forensic investigators confronted with disarticulated or incomplete human upper limb parts. In addition, this research will provide valuable data for further comparison with other Arab people living in Sub-Saharan regions or individuals with a mixed genetic background including African descent in the Arabian Peninsula.

2. Materials and methods

2.1. Sample

A total of 240 normal, healthy Sudanese Arab volunteers, 120 males and 120 females, were recruited in the Khartoum teaching hospital over four weeks. Subjects were required to sign a consent form and complete a questionnaire with basic demographic data and general questions, e.g., handedness. The subjects were between 25 and 30 years of age; the mean age for males was 27.8 $\pm$ 1.3 and females was 27.6 $\pm$ 1.4, and all subjects were right-handed. No subjects had a history of chronic illness, trauma, physical deformity, or any surgical procedure that might affect upper limb dimensions. The study received approval from the ethical committee of the Faculty of Medicine, University of Khartoum.

2.2. Measurements

Using standard anthropometric instruments, five upper limb dimensions of each subject were measured in centimeters to the nearest millimeter. The existence of a significant directional asymmetry in upper limb dimensions associated with dominance, has been suggested in various studies.[28,29] Therefore, all upper limb measurements were taken on the left side.[30,31] Necessary precautions were taken while measuring the subjects. The instruments were checked regularly for accurate readings. All measurements were obtained in a well-lit room and repeated in triplicate, and the means of the measurements were recorded. These measurements included the parameters detailed in the following sections.

2.2.1. Upper arm length

Upper arm length was measured with a Harpenden anthropometer (Holtain Ltd, Crosswell, UK) and considered to be the distance between the marked inferior border of the acromion process to the external superior border of the head of the radius.[30]

2.2.2. Ulnar length

The subjects were asked to flex their elbow to 90° and extend their fingers in the direction of the long axis of the forearm. Then, ulnar length was measured with a Harpenden anthropometer as the direct distance between the most proximal point of the olecranon process and the styloid process.[32]

2.2.3. Wrist breadth

Wrist breadth was taken with a digital sliding caliper (Mitutoyo, Japan) as the distance between the ulnar and radial styloid processes.[30]

2.2.4. Hand length

The subjects were instructed to sit and place their left hand on a flat, hard horizontal surface with the thumb abducted and the other four extended and adducted. Then, hand length was taken with a digital sliding caliper as the straight distance between the midpoints of the distal crease of the wrist to the most anterior projection of the skin on the middle finger.[33]

2.2.5. Hand breadth

Hand breadth was taken with a digital sliding caliper as the distance between the most lateral point on the head of the second metacarpal bone and the most medial point on the head of the fifth metacarpal bone.[34]

2.3. Statistical analysis

The data were randomly split into two categories: 200 Subjects (100 male, 100 female) were used as the study group, and 40 subjects (20 male, 20 female) were used as test group validation. The statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS), version 14 (SPSS Inc., Chicago, IL). A study to assess the precision and reliability of acquiring upper limb measurements was conducted prior to primary data collection. The