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Forensic Anthropology Population Data

Sex estimation using dimensions around the nutrient foramen of the long bones of the arm and forearm in South Africans

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ABSTRACT

South Africa has had an increase in rates of crime, interpersonal violence and homicide since the introduction of democracy in 1994. Forensic osteological standards was lacking for South Africans of different population groups necessitating the generation of new standards for forensic identification of individuals from skeletal remains. For these reasons, there is a concerted demand for methods of identifying skeletal remains with sex being amongst the most important of the biological characteristics required. The nutrient foramen has been used to estimate sex in lower limb long bones with much accuracy but this has not been demonstrated in the upper limb long bones. The aim of this study was to develop osteometric standards for sex estimation from measurements around the nutrient foramen of the arm and forearm bones of South Africans of different population affinities. A total of 660 bones consisting of humeri, radii and ulnae of black South Africans and white South Africans were assessed for sex estimation using dimensions related to the nutrient foramen. Sex was correctly classified with a range of 84–85% for the humerus and 83–88% for the arm bones. The study showed that length measurements were more sexually dimorphic than width dimensions in South Africans, as length was consistently selected as the best predictor of sex in all bones. However, the average accuracy increased when length was used in combination with measurements related to the nutrient foramen. In conclusion, the dimensions of upper limb long bones that are directly related to the nutrient foramen are sexually dimorphic and are useful in the estimation of sex in South Africans, with the highest accuracy shown in the white South African population group.

1. Introduction

The nutrient foramen (NF) is a macroscopically visible opening that is formed as a result of penetration of the periosteal bud containing the nutrient artery on the bone during development [1,2]. Structurally, the nutrient foramen has a slightly raised edge where it originates, and a well-marked groove leading up to it. It is an easily identifiable landmark on the surface of long bones and measurements around it have been shown to express some degree of sexual dimorphism in these bones [3–9].

The estimation of sex from osteometric traits and dimensions is an integral part of building of the biological profile of an individual from their recovered skeletal remains. In addition, a forensic anthropologist will also estimate age and stature, as well as the population group to which the individual belongs [10,11]. It has been observed that the estimation of the biological sex of an individual is a pertinent component of development of the biological profile, since failure to establish this characteristic will further compound the difficulty in ascertaining the ancestry and estimation of age in a forensic setting [11,12]. In addition, estimating the sex of an unknown individual will theoretically reduce the possible number of victims by half as it excludes all individuals of the opposite sex [13].

There is an increased need for translational methods of human identification from skeletal remains considering the growing crime rate in South Africa [14]. Presently, crime and violence in South Africa has been identified to be a severe problem. The recent report of the annual crime statistics for 2015 showed a significant increase compared to that documented in 2003 [15]. In fact, South Africa has one of the highest rate of interpersonal violence with an intentional homicide rate of 31.8/100 000 population [16,17]. Since

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estimation of sex is amongst the most important of the biological markers necessary for human identification in forensic cases, efforts have been made by various researchers to establish osteometric standards for this purpose, using different bones of the human skeleton.

The pelvis, which is designed for parturition and the cranium are recognized as the most conventional and reliable parts of the skeleton for sex estimation [3,9,11,18–20]. However, the pelvis and cranium may be susceptible to damage and fragmentation and may not be present for evaluation in cases of dismemberment, which may make metrical and non-metrical assessment of bones in forensic cases quite challenging [3,9,11,18,21]. Therefore, there has been an increased demand for the use of alternative methods of sex estimation, with increments in the use of long bones for reliable sexing estimates [19]. It has been shown that long bones of the skeleton are generally well preserved during forensic cases and easier to define metrically, making them reliable skeletal materials for sex estimation [18,22].

Dimensions of long bones of the upper limb have been shown to have considerable levels of accuracy in sex estimation in different population groups including South Africans [12,14,23], Germans [10], Japanese [22], Guatemalans [18], Turks [24], Scottish [11] and Greeks [25]. In addition, a number of dimensions associated with the nutrient foramina of lower limb bones have been shown to be sexually dimorphic in different population groups [3,5–9,23]. However, there is a paucity of studies investigating sexual dimorphism using measurements around the nutrient foramen of the bones of the arm and the forearm in any of the South African population groups. It is, therefore, the purpose of this study to develop osteometric standards for sex estimation from measurements around the nutrient foramen of the humerus, radius and ulna of South Africans of different ancestry.

2. Materials and methods

The study utilised a total of 660 bones (228 humeri, 214 radii and 218 ulnae) which were obtained from the Raymond A. Dart Collection of Human Skeletons housed in the School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg [26]. Ethical clearance (ethics number W-CJ-140604-1) was granted and covered by the Human Tissue Act (No. 65 of 1983) and the National Health Act (No. 61 of 2003) on the use of human specimens for teaching and research. The distribution of the sample with respect to sex and ancestry is as shown in Table 1.

Only intact humeri, radii and ulnae of individuals whose ages at the time of death ranged between 21 and 65 years were selected. Bones of individuals who were classified as black South African (South African African or SA African) and white South African (South African White or SA White) in the catalogue of the Raymond A. Dart Collection were included. These two population groups were selected because they represent about 80% and 9% respectively of the population of South Africa in the latest general census [15]. In addition, these ere the two largest groups with regards to representation in the Raymond A. Dart Collection of Human Skeletons [26].

Table 1
Distribution of sample.

	Humerus		Radius		Ulna	
	Males	Females	Males	Females	Males	Females
[a]Black South African	65	59	62	52	62	55
[b]White South African	56	48	53	47	56	45

[a] Black South African (SA African).
[b] White South African (SA White).

The black South African population group consists of various tribes including the Zulu, Xosa, Sotho, Tswana, Pedi, Venda and a few other groups. Studies by De Villiers [27] and Lundy [28] for example have shown that there are no significant osteometric differences between these groups. Therefore, they were considered to be a single homogenous group. The white South African population group on the other hand consists of migrants from Western Europe mainly from the Netherlands, France, Germany and the United Kingdom [29]. It is well documented that the osteometric dimensions of white South African are different from those of other nationalities in Europe. The reason for the observed difference is due mainly to admixture of white South African with each other and local groups which has possibly changed their genetic make-up [29].

A total of five parameters were measured on each bone. These measurements are defined below using standard methods as described by Iscan and Miller-Shaivitz [30] and Brauer [31]:

A. Maximum length measurements using a laboratory osteometric board:
   1. The maximum length of the humerus (maxlhum): This measurement was taken from the most proximal aspect of the humeral head to the most distal point of the trochlea.
   2. The maximum length of the radius (maxlrad): This is the linear distance from the most proximal point of the radial head to the distal end of the styloid process radius.
   3. The maximum length of the ulna (maxluln): The linear distance between the most proximal aspect of the olecranon process to the distal end of the styloid process of ulna.

B. Proximal end to nutrient foramen measurements: This is the linear distance from the most proximal end of the humerus (penfhum), radius (penfrad) or ulna (penfuln) to the nutrient foramen. These were taken using a digital sliding calliper.

C. Circumference at nutrient of foramen: These measurements were taken at the level of the nutrient foramen of the humerus (circhum), radius (circrad) and ulna (circuln) with masking tape and then quantified on a measuring ruler by following the contours of the bone.

D. Antero-posterior diameter: These were taken using a digital sliding calliper.
   1. Humerus (apdhum): This is the linear distance from the anterior border to the posterior surface of the humerus taken at the level of the nutrient foramen.
   2. Radius (apdrad): The linear distance between the anterior border/anterior oblique line to the posterior surface of the radius at the level of the nutrient foramen.
   3. Ulna (apduln): This is the distance between the anterior surface and the posterior border.

E. Mediolateral diameter: These measurements were also taken using a digital sliding calliper.
   1. Humerus (mldhum): This is the distance between the medial and lateral borders of the humerus at the level of the nutrient foramen.
   2. Radius (mldrad): This measurement was taken from the interosseous border to the lateral surface of the radius at the level on the nutrient foramen.

F. Ulna (mlduln): The distance between the medial and interosseous borders at the level on the nutrient foramen.

All the measurements for each of the bones were repeated on 15 bones to assess the intra-observer repeatability. The reliability of the measuring technique was evaluated using the concordance correlation coefficient of reproducibility [32]. Subsequent data collected were analyzed using the Statistical Product and Service Solutions (SPSS version 23) software program. The descriptive statistics including mean and standard deviations were obtained