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Forensic Anthropology Population Data

Dimensions around the nutrient foramina of the tibia and fibula in the estimation of sex

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ABSTRACT

Sex estimation from skeletal remains is one of the key components in establishing a biological profile and consequent identification of an individual in a forensic and medico-legal practice. The use of dimensions around the nutrient foramen in instances where long bones may be fragmented and damaged is of benefit due to the fact that the nutrient foramen is easily identifiable and may be preserved on the shaft of long bones. This study is an investigation of the usefulness of various measurements around the nutrient foramen of the tibia and fibula of South Africans in an attempt to develop osteometric standards for sex estimation. The sample included 206 tibiae and 204 fibulae of South African Africans (SAA) and South African whites (SAW) procured from the Raymond A. Dart Collection of Human Skeletons based at the University of the Witwatersrand. Sex was correctly classified for the tibia with an accuracy ranging between 79–82% in SAA and 84–88% in SAW, with the circumference at the level of the nutrient foramen as the single best predictor of sex in both populations. An accuracy ranging from 69 to 74% in SAA and 70–77% in SAW was observed for the combined measurements on the fibula. The current study confirms the usefulness of measurements around the nutrient foramen of the tibia in the assignment of sex. However functions of the fibula generally performed poorly and should be used with caution.

1. Introduction

One of the scope of practice of forensic anthropologists is the building of the biological profile of an individual from skeletal remains. This process involves the establishment of what is sometimes referred to as the "big four" [1]. These include the estimation of stature, age, ancestry and sex. While non-metrical and metrical methods are well established for the estimation of sex from human skeletons, the latter is more widely used because it is more objective and easily applicable compared to the former. Consequently a lot of attention has been devoted in the past few years to the development of population specific osteometric standards that can be used for the estimation of sex.

Discriminant function and logistic regression equations have been derived worldwide from measurements of the skull [2–7], vertebrae [8–11], pelvis [12,13], hand [14–18] and foot bones [19–24] with various degrees of accuracies. In addition, a lot of work has been carried out on the usefulness of intact long bones of upper and lower limbs [25–33] in different parts of the world. Similar studies have also been carried out in South Africa, a country which has one of the highest crime rates in the world [34]. In these studies, local osteometric standards for the estimation of sex were generated for measurements of the skull [35–37], sternum [38], lumbar vertebra [39], pelvis [40], patella [41,42], tarsals [43,44] and long bones of the upper and lower extremities [45–48]. Since long bones are sometimes recovered in various states of fragmentation, some authors have therefore focussed their attention on the derivation of equations from measurements on the shaft and around the proximal and distal ends of long bones [49–51].

An important feature of long bones is the presence of the nutrient foramen. This is a macroscopically visible opening that is formed in the developmental stages of long bones [52]. The nutrient foramen has been described structurally as having a slightly raised edge where it originates and is therefore an easily identifiable landmark on the surface of long bones [53–55]. Few

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studies have shown that selected measurements around nutrient foramen are sexually dimorphic [56–62]. A similar study was conducted on the tibiae of South Africans by Steyn and Iscan [45]. Three of the measurements of the tibia around the nutrient foramen in combination with other measurements of the tibia and femur were used in the formulation of discriminant function equations with acceptably high average accuracies [45]. Recently, the usefulness of measurements around the nutrient foramina of the humerus, radius and ulna of South Africans were assessed. It was shown that these measurements are not only sexually dimorphic but the derived discriminant function equations have high average accuracies in correct sex assignment [63].

To date, no study has shown the usefulness of measurements around the nutrient foramina of the fibula in the estimation of sex in South Africa. It is, therefore, the purpose of this study to investigate the usefulness of various measurements around the nutrient foramen of the tibia and fibula of South Africans. In addition, this study also aimed to develop osteometric standards for sex estimation from measurements around the nutrient foramen of these bones.

2. Materials and methods

Following the approval and granting of ethical clearance waiver (ethics number W-CJ-140604-1) by the School of Anatomical Sciences in accordance with the Faculty of Health Sciences Human Ethics Committee. A total of 206 tibiae and 204 fibulae were obtained from the Raymond A. Dart Collection of Human Skeletons [64]. This is one of the largest collections of human skeletons in the world and it is housed in the School of Anatomical Sciences of the Faculty of Health Sciences at the University of the Witwatersrand, Johannesburg. Table 1 shows the distribution of the sample with respect to sex and ancestry. In this study, only intact bones of individuals classified as South African Africans (black South Africans) and South African Whites (white South Africans) in the catalogue of the Raymond A. Dart Collection and whose ages at the time of death ranged between 21 and 65 years were selected. Specimens with notable pathological and curatorial damage were excluded from the study.

These two population groups were selected because they both currently represent about 90% of the population of South Africa [65]. In addition, these two population groups represent the largest groups with regards to representation in the Raymond A. Dart Collection of Human Skeletons [64]. The black South African population group or South African African (according to the official classification of population groups in South Africa) consists of various tribes including the Ndebele, Zulu, Sotho, Tswana, Pedi, Xhosa, Tsonga, Venda and Swazi. Previous work on the skull and postcranial skeletons of this group by De Villiers [66] and Lundy [67] have shown that there are no significant osteometric differences between these tribal groups. Consequently, these groups were therefore considered to be a single homogenous group.

The South African White population group or white South African consists of migrants from Western Europe mainly from the Netherlands, France, Germany and the United Kingdom [45]. It has been shown that the osteometric dimensions of white South Africans are different from those of other nationalities in Europe due mainly to admixture of white South Africans within and between other native population groups which has possibly changed their genetic make-up [45].

Table 1
Distribution of sample.

	Tibia		Fibula	
	Males	Females	Males	Females
SAA[a]	56	55	54	54
SAW[b]	42	53	53	43

[a] South African Africans or black South Africans.
[b] South African Whites or white South Africans.

A total of eight parameters as defined below based on standard methods as described by Iscan and Miller-Shaivitz [68] and Brauer [69] were measured on both bones:

A Tibial measurements:

1) Proximal end of tibia to nutrient foramen (penftib): This is the linear distance from the most proximal end of the tibia to the nutrient foramen. This was taken using an L shaped square stainless ruler, from the intercondylar eminence of tibia to the inferior border of the foraminal opening if the foramen was directed upward or the superior border of the foraminal opening if the foramen was directed downward.
2) Circumference at nutrient foramen (circtib): This measurement was taken at the level of the nutrient foramen of the tibia with a standard measuring tape by following the contours of the bone.
3) Antero-posterior diameter at nutrient foramen (apdtib): This is the linear distance from the anterior border to the posterior surface of the tibia taken at the level of the nutrient foramen using a digital sliding calliper (Mitutoyo Corporation, calibrated to 0.01 mm).
4) Mediolateral diameter at nutrient foramen (mldtib): This is the distance between the medial and lateral borders of the tibia at the level of the nutrient foramen taken using a digital sliding calliper (Mitutoyo Corporation, calibrated to 0.01 mm).

B Fibular measurements:

5) Proximal end of fibula to nutrient foramen (penffib): This is the linear distance from the most proximal end of the fibula to the nutrient foramen. This was taken using an L shaped square stainless still ruler, from the apex of the head of fibula to the inferior boarder of the foraminal opening if the foramen was directed upward and the superior border of the foraminal opening if the foramen was directed downward.
6) Circumference at nutrient foramen (circfib): This measurement was taken at the level of the nutrient foramen of the fibula with a standard measuring tape by following the contours of the bone.
7) Antero-posterior diameter at nutrient foramen (apdfib): This is the linear distance from the anterior border to the posterior surface of the fibula taken at the level of the nutrient foramen using a digital sliding calliper (Mitutoyo Corporation, calibrated to 0.01 mm).
8) Mediolateral diameter at nutrient foramen (mldfib): This is the distance between the medial and lateral borders of the fibula at the level of the nutrient foramen taken using a digital sliding calliper (Mitutoyo Corporation, calibrated to 0.01 mm).

Generally, it is advised that anthropologists should provide an objective evidence of the reliability of their measuring technique. This is important in the establishment of the fact that the data collected are free of measuring errors. Various methods including standard deviations of differences, standard error of measurements, technical error of measurements and coefficient of reliability [70] have been suggested for this purpose. In the present study, the concordance correlation of reproducibility [71] was used because it is both a measure of precision and accuracy of the measuring technique. A test sample of 20 bones were measured and re-measured two days apart. A coefficient of