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Forensic Anthropology Population Data

Measurements of the talus in the assessment of population affinity☆

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ABSTRACT

As part of their routine work, forensic anthropologists are expected to report population affinity as part of the biological profile of an individual. The skull is the most widely used bone for the estimation of population affinity but it is not always present in a forensic case. Thus, other bones that preserve well have been shown to give a good indication of either the sex or population affinity of an individual. In this study, the potential of measurements of the talus was investigated for the purpose of estimating population affinity in South Africans. Nine measurements from two hundred and twenty tali of South African Africans (SAA) and South African Whites (SAW) from the Raymond A. Dart Collection of Human Skeletons were used. Direct and step-wise discriminant function and logistic regression analyses were carried out using SPSS and SAS. Talar length was the best single variable for discriminating between these two groups for males while in females the head height was the best single predictor. Average accuracies for correct population affinity classification using logistic regression analysis were higher than those obtained from discriminant function analysis. This study was the first of its type to employ discriminant function analyses and logistic regression analyses to estimate the population affinity of an individual from the talus. Thus these equations can now be used by South African anthropologists when estimating the population affinity of dismembered or damaged or incomplete skeletal remains of SAA and SAW.

1. Introduction

In order to establish the identity of an individual from his or her skeletonized remains, forensic anthropologists by the nature of their work are expected to build a biological profile of the individual. This process involves the estimation of age and stature as well as estimation of sex and population affinity/ancestry [1–3]. The estimation of biological parameters like sex [4–11], age [12–18] and stature [19–26] often requires the use of population specific osteometric standards. Therefore, accurate estimation of these parameters are based on prior knowledge of the population affinity of the individual whose skeletal elements are being analyzed. The population affinity of an individual can be estimated using either the morphological or the metrical method.

A number of studies have been conducted using certain morphological traits from the skull and the pelvis in the assignment of population affinity [1,2,27]. However, this method has been shown to be subjective which requires a certain degree of expertise on the part of the examiner. Therefore, the use of more objective quantifiable metric methods are often used [5]. One of the metrical methods that is widely used is discriminant function analysis. Consequently, discriminant function equations have been formulated from measurements of the skull [28–30] and postcranial skeleton [31–33]. Since these bones are not always present for analysis in forensic cases, it became necessary to assess the usefulness of other bones especially the tarsal elements, which are often well preserved in forensic cases, in the estimation of population affinity.

The talus is a key foot bone as it disseminates forces from the whole body to the rest of the foot. It is also a bone that survives well due to post-mortem and taphonomic changes [34]. The potential of the talus and the calcaneus in the estimation of sex and estimation of stature has been investigated from different ancestries [34–44]. Most of these studies have used discriminant function equations as a statistical tool due to its analytical power to distinguish between similar groups. However, very little is known about the potential of

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measurements of tarsal elements in the estimation of population affinity. To date only two studies have shown the usefulness of calcaneal measurements using discriminant function analysis in the estimation of population affinity [45,46]. Since no previous study has investigated the potential of the talus in the assignment of population affinity, it is the aim of this study to assess the usefulness of talar measurements in the estimation of population affinity in South Africa using both discriminant function and logistic regression analyses.

2. Materials and methods

2.1. Materials

The data set for this study was obtained from a sample of tali in the Raymond A. Dart Collection of Human Skeletons, which is housed in the School of Anatomical Sciences at the University of the Witwatersrand, Johannesburg, South Africa [47]. There are four main population groups that are officially recognized in South Africa namely: (a) South African Africans (SAA), (b) South African Coloured, (c) South African Whites (SAW), and (d) South African of Indian or Asian Extract ancestry (Indian or Asian) [47,48].

For the purpose of the current study, the South African African (SAA) and South African White (SAW) population groups were selected as they represent about 80% and 9% of the population of SA, respectively, in the latest general census [48]. Moreover, these two groups are also the largest groups with regards to representation in the Raymond A. Dart Collection of Human Skeletons [47]. The SAA population group consists of various tribes or chiefdoms, which include the Tswana, Sotho, Pedi, Zulu, Xosa, Tsonga, Venda and few other smaller groups. Previous studies have shown that there are no significant osteometric differences between these groups [49,50]. Consequently they were considered to be a single homogenous group. The SAW population group on the other hand consists of migrants from Western Europe mainly from the Netherlands, France, Germany and the United Kingdom [51]. It has been shown that their osteometric characteristics are different from those of their counterparts in Europe due mainly to admixture with each other and local South African groups, which has possibly changed their genetic make-up [51].

This study is based on a random sample of 220 tali, equally distributed based on sex and population affinity. The age of death ranged from 20 to 70 years for the SAA group and 19 to 76 years for the SAW population. The left talus was used in all cases and those that were considered abnormal or found to be fractured (broken with evidence of healing) were excluded from the study.

2.1.1. Measurements

On each talus, nine variables as described by Martin and Knussman [52] were measured (in millimeters) using a vernier caliper. These are talar length (tl), width of the talus (tw), talar height (th), length of the trochlea (trl), breadth of the trochlea (trb), head–neck length (hnl), height of the head (hh), length of the posterior articular surface for the calcaneus (lpas), and the breadth of the posterior articular surface for the calcaneus (bpas). These nine tali variables as illustrated in Fig. 1 were used as main predictors of population affinity of an unknown skeleton.

2.1.2. Statistical analysis

There are a range of statistical techniques that can be used in the development of models for assignment of population affinity. Descriptive statistics were conducted to calculate the mean values and standard deviations for each of the nine tali measurements. F-statistics were used to compare the mean values of the tali measurements between SAA and SAW groups. After establishing that significant osteometric differences exist between the two population groups using the F statistic, the data was then subjected to discriminant function analysis (DFA) and logistic regression analyses (LRA). The DFA and LRA were used to classify each of the unknown skeletons into SAA or SAW by predicting its membership into these mutually exclusive groups using all or some of the nine tali measurements. The resulting models will provide predictive probabilities of population affinity (probability of an unknown skeleton to be a member of either group). The DFA and LRA are widely used statistical methods for categorizing data [53], both methods were compared based on their predictive accuracies.

2.1.3. Model assessment and validity

One of the objectives of this study is to generate models that can accurately assign an unidentified talus using the predictive probability of group membership via either the DFA or LRA model. In order to achieve this, there is a need for a model that consists of few explanatory variables (parsimonious) and high predictive power (high percent concordant value). The percent concordant (C-statistics) or area under receiver (AUC) operating characteristic (ROC) curve [54] was used to assess the ability of the models to discriminate the group membership (population affinity) of an unknown skeleton. A model with a C-statistic ranged 70% to 79% is considered to provide acceptable discrimination, 80% to 89% gives an excellent discrimination while a value above 90% is outstanding [54].

All the nine measurements listed above were tested for intra-observer repeatability using the concordance correlation coefficients of reproducibility [55] by two of the authors (MB and MD). Twenty tali, consisting of five males and five females from the SAA, and five males and five females from the SAW, were used for this purpose. The values of these coefficients being in the range of 0.90–0.99 (Table 1) were within the internationally accepted standards [56].

The reliability of the two predictive models from DFA and LRA were assessed using the “leave-one-out” classification procedure. IBM SPSS Statistics for Windows, Version 22.0 [57] software was used for the DFA, while SAS 9.3 Software Version 6 of the SAS System for Windows [58] was used for the LRA. All inferences were based on a 5% significant level. All talar variables were initially tested for normality using Shapiro Wilk test [59].

3. Results

Descriptive statistics including means and standard deviations of male and female measurements are presented in Tables 2 and 3 respectively. South African Whites (SAW) males showed significantly ($p < 0.05$) higher mean values for most of the measurements compared to South Africa Africans (SAA) males as indicated by the F-statistics (Table 2). No significant population difference was observed in the mean value of tw and lpas. In the female group, the SAW sample displayed significantly higher mean values for all measurements compared with the SAA sample with the exception of bpas (Table 3).

Our results indicated that both DFA and LRA are appropriate because all the variables are normally distributed. The results from the DFA and the LRA using different formulations for male and female South Africans are presented in Tables 4 and 5 respectively. For the male data, both DFA and LRA selected trl, hnl and hh as having the best discriminating abilities for predicting population affinity with average accuracy of 80.9% and 90.0% respectively.

Skeletons are classified as SAW if the DFA score is greater than 0.000 and SAA if the score is less than or equal to 0.000. Function F2 (Table 4) was obtained from the stepwise DFA of all length measurements while functions F3 and F4 were formulated from the direct analyses of various combinations of measurements that displayed significant population differences in their mean values.