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Forensic Anthropology Population Data

The efficacy of sternal measurements for sex estimation in South African blacks

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ABSTRACT

The correct assessment of sex from the human skeleton is of fundamental importance in forensic medicine and bioarchaeology. In South Africa, unidentified remains are often fragmentary, making it necessary to estimate sex from a variety of skeletal elements. The purpose of the present study was to evaluate the sex discriminating potential of the sternum in black South Africans using standard osteometric techniques. A sample of 123 males and 83 females drawn from the Raymond A. Dart Collection of Human Skeletons and the Pretoria Bone Collection was used. The results demonstrated that all eight sternal variables, including both dimensions and indices, were highly sexually dimorphic in this population. A stepwise discriminant function procedure, which selected corpus sterni length and manubrium width, correctly identified 86.4% of the individuals in the study sample. Additional multivariate discriminant equations incorporating dimensions for either the manubrium or corpus sterni yielded sex prediction rates of 80.6% and 84.5%, respectively. Sternal area, when used in isolation, produced the highest sex classification accuracy with 86.9% of specimens correctly assigned. The remaining single variable functions, which can be applied when well-preserved or complete sterna are not available for analysis, provided classification accuracies ranging from 68.4% to 83.5%. These classification results are comparable to those reported in previous investigations concerning sex estimation of black South Africans for other postcranial elements.

1. Introduction

The estimation of sex is an important first step in developing a biological profile for human skeletal remains as methods of establishing stature and age-at-death are frequently sex dependent. The assessment of this demographic characteristic is more reliable if a complete pelvis and skull are available for analysis; however, this is often not the case in forensic and bioarchaeological investigations, making it necessary to be able to predict sex from a variety of skeletal elements.

The ability to estimate sex from an assortment of different bones is of particular importance in South Africa where unidentified remains are often incomplete or fragmentary due to numerous taphonomic processes, such as animal scavenging, burning, and dismemberment [1–4]. Therefore, recent research to develop osteometric standards for discriminating sex from skeletal remains of black South Africans has focused on the humerus [5], radius and ulna [4], femur [2,3], patella [6], talus [7] and calcaneus [8]. Currently, however, there are no established metric standards for sex prediction from the sternum in this population, although previous studies have shown that this skeletal element exhibits considerable sexual dimorphism and thus provides a reasonably accurate method for discriminating sex in such diverse ethnic groups as Indians [9–12], Nigerians [13], Turks [14], and North American whites and blacks [15,16]. The usefulness of the sternum is further enhanced by the fact that this bone is often present in decomposing or skeletonized remains [15,16].

The objective of the present investigation, therefore, was to develop osteometric standards for estimating sex from the sternum of South African blacks.

2. Materials and methods

The skeletal material utilized in this research was drawn from the Raymond A. Dart Collection of Human Skeletons and the Pretoria Bone Collection, which are housed at the University of the Witwatersrand and University of Pretoria, respectively. The specimens in these documented skeletal series were derived largely from donated and unclaimed bodies of late 19th and 20th century black South Africans and white South Africans of European descent [17,18].

The sterna of 206 black South Africans of known sex (123 males and 83 females) were examined in the present study. This sample was composed of individuals from different local population groups (e.g., Zulu, Sotho, and Xhosa). Although some degree of morphological variation has been observed between these ethnic groups, the subdivisions within the South African black population are disappearing [19–21]. Furthermore, in many forensic situations the local population is not known, and thus a model incorporating a variety of ethnic groups will be of more practical value. The sample used in this investigation included adult individuals between the ages-at-death of 21 and 84 years, with a mean age of 49.51 $\pm$ 13.03 for males and 43.22 $\pm$ 12.12 for females. The recorded dates of death for these specimens ranged

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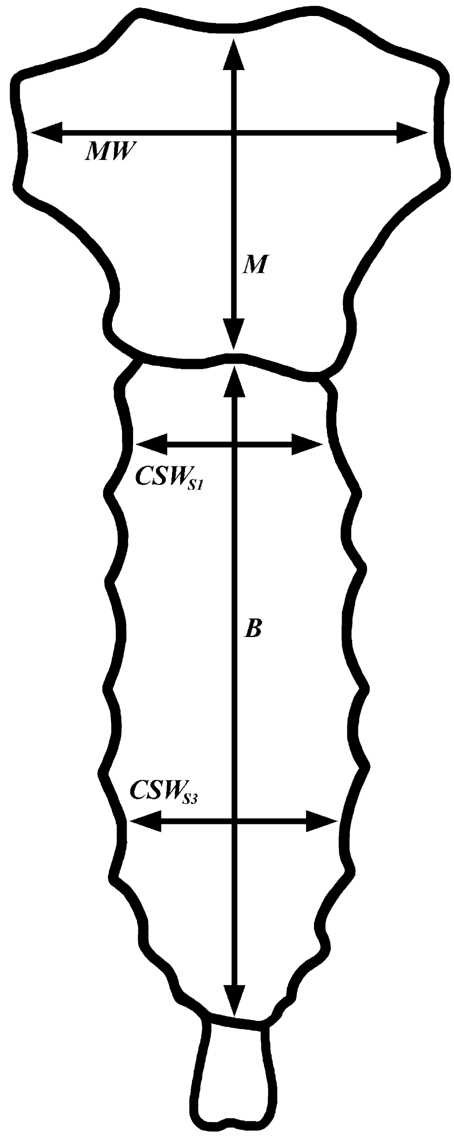

Fig. 1. Linear measurements of the sternum.

from 1961 to 2000. Only specimens with complete ossification of the corpus sterni were included in the analysis. Sectioned bones or those that showed features which would affect measurement, such as pathology, surgical repairs, fractures, or extensive arthritic growths around costal articular surfaces were excluded from the study.

The following linear measurements and indices, as defined in previous publications [10–12,9,22], were examined in the present investigation (Fig. 1):

1. Manubrium length (M): midsagittal distance from the suprasternal (jugular) notch to the manubriosternal junction.
2. Corpus sterni, or sternal body, length (B): midsagittal distance from the manubriosternal junction to the mesoxiphoidal junction.
3. Combined length of the manubrium and corpus sterni (CL): calculated as the sum of M and B (M + B).
4. Manubrium width (MW): distance between midpoints of the facet for first costal cartilage on each side.
5. Corpus sterni width at first sternebra (CSW_{S1}): minimum distance at the level of the line passing from the midpoint between the facet for the second and third costal cartilage on each side.
6. Corpus sterni width at third sternebra (CSW_{S3}): distance at the level of the line passing from the midpoint between the facet for the fourth and fifth costal cartilage on each side.
7. Sternal, or manubrio-corpus, index (SI): calculated as the division of M by B, multiplied by 100 [$(M/B) \times 100$].
8. Sternal area (SA): calculated by multiplying the sum of M and B with the sum of MW, CSW_{S1} and CSW_{S3} divided by three [$(M + B) \times (MW + CSW_{S1} + CSW_{S3})/3$].

In sterna with an ossified xiphoid process, the inferior margin of the two articular demifacets for the seventh costal cartilage along the lateral borders of the corpus sterni (mesosternum) formed the landmark to differentiate the corpus sterni from the xiphoid process, and thus identify the mesoxiphoidal junction [23]. The xiphoid process was not included in this metric study given the naturally high variability of this structure [12,23,24]. Measurements were taken with vernier calipers and recorded to the nearest tenth of a millimeter.

In order to assess the degree of intraobserver error, the sterna of 40 randomly selected individuals, including males and females from both the Raymond A. Dart and Pretoria skeletal collections, were measured a second time after the entire dataset had been collected. Paired-sample t-tests revealed that intraobserver variation was insignificant ($p > 0.05$ for the five dimensions taken with calipers). In addition, the relative technical error of measurement (rTEM), which quantifies the magnitude of random error [25], ranged from 1.1166% to 1.5481%, indicating that errors of precision were small and unlikely to have influenced the results.

Statistical analysis of the data included the calculation of means and standard deviations for all dimensions and indices. After using independent-sample t-tests to establish that a significant difference exists between male and female mean values for each variable, univariate and multivariate discriminant function analyses were conducted. A stepwise procedure, incorporating the five linear sternal dimensions, was performed to select the combination of variables which best discriminates between the two sexes. Additional stepwise discriminant functions were developed for the manubrium and corpus sterni separately to account for the presence or absence of either structure in forensically or archaeologically derived remains. Finally, direct analysis was carried out on each of the variables to obtain formulae (or demarking points) that could be used to sex fragmentary skeletons.

The reliability of each of the functions generated from the stepwise and direct analyses was then assessed using the leave-one-out classification (jackknife) technique. This procedure classifies each individual of a sample by the functions derived for all specimens other than that specimen itself, and thus provides less biased classification estimates for the study sample [26,27]. Although multivariate classification provides an understanding of within sample assignments of every case, the actual affinity of a particular individual may best be evaluated by its posterior probability to be reassigned to its original group [28,29]. The higher the posterior probability, the greater the likelihood of a specimen's correct placement in the reference population [30]. Therefore, posterior probabilities of correct group membership were also employed to measure the effectiveness of the discriminant functions.

The dataset utilized in the present study was also subjected to logistic regression analysis. The benefit of logistic regression is that this technique generally performs as well as or better than discriminant function analysis with fewer statistical assumptions when predicting dichotomous variables such as sex, and the resulting score used to classify an unknown individual also provides a probability value for the allocation [16,31–35]. As with the discriminant analysis, logistic regression methods were utilized to develop univariate and multivariate equations for predicting sex on the basis of sternal dimensions and indices.

3. Results

Descriptive statistics for all sternal variables recorded in both sexes are presented in Table 1. As mentioned previously, a highly significant difference ($p < 0.0001$) was found between males and females for all dimensions and indices, with mean values in males exceeding those in females for all parameters, except sternal index which is larger in females. The greatest differences in mean values, as indicated by t-values, were for sternal area, combined length of the manubrium and corpus sternal, corpus sterni length, and manubrium width. These results demonstrate the presence of marked sexual dimorphism in the sternum of black South Africans, and thus metric analysis of this skeletal element should provide an effective method for the estimation of sex in this population group.

Table 2 provides the discriminant function coefficients for the sex predicting equations generated through stepwise and direct analysis. For Function 1, the five linear dimensions were entered into the stepwise procedure and only two variables were selected: corpus sterni length and manubrium width. When only length and width dimensions of the manubrium were entered into a stepwise analysis (Function 2), both variables were selected. In the stepwise discriminant function for the corpus sterni (Function 3), the selected variables included length and width at the first sternebra (width at the third sternebra was not selected). The remaining functions (Functions 4–11), one for each sternal variable, were generated through the direct approach.