Anthony B. Falsetti,[1] *Ph.D.*

Sex Assessment from Metacarpals of the Human Hand

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ABSTRACT: Discriminant functions designed for the determination of sex from metacarpal measurements are presented. Three samples of metacarpal specimens were employed in the analysis; one consisting of 212 individuals from the Terry Collection, one of 33 individuals from the Royal Free Medical School in London, and finally, 40 individuals from the Forensic/Donated Collection, Maxwell Museum of Anthropology, University of New Mexico, all of whom had documented sex. Five measurements designed to characterize the size and shape of the human metacarpal were taken on all five digits. Based on the Terry Collection, significant metric differences attributed to race were found for digits I and III, and thus functions could only be derived for the three remaining metacarpals. Sex discriminant functions derived from the Terry Collection for digits II, IV, and V provide correct classification of 92.0, 86.26, and 84.37 percent. The resulting three linear equations were then independently applied to the Royal Free Medical School and Forensic/Donated samples to validate the accuracy of the original functions. Percentage of correct classification for each of the test samples varies.

KEYWORDS: physical anthropology, sex estimation, metacarpals, discriminant functions, musculoskeletal system

Forensic anthropologists are often asked to determine the sex of unidentified human remains. Krogman and Işcan [*1*], and others report that close to 100% accuracy can be attained by visual examination if the entire skeleton is present for analysis. However, the completeness of human remains can vary greatly due to preservation circumstances, animal activity, and very often recovery proficiency. Frequently, the skull and pelvis are absent or damaged, and the determination or prediction of sex must be made from other skeletal elements [*2–6*].

Recently, Scheuer and Elkington [*2*] described a multiple regression method for sex determination from the metacarpals and first proximal phalanx of the human hand based on a cadaver sample (n = 60) of white British subjects. Their study reported accuracy of 74% to 94% using various combinations of six measurements of metacarpals and the first proximal phalanx when evaluated on a second sample (n = 20). The present investigation attempts to broaden the extent of sex determination from metacarpals using a larger documented calibration sample (n = 212) from North America and two independent modern test populations.

Materials

The metric data for this study were obtained from three skeletal collections. The Terry Collection, Smithsonian Institution, Washington, DC, sample consists of 212 individuals, 109 males and 103 females, of known sex and race. Five measurements were taken on both hands. However, only those from the left are used in this analysis. Data from the cadaver sample from the Royal Free Medical School, London, UK, were taken from Musgrave [*7*]. This sample consists of 33 individuals of known sex, and is composed of white subjects of British ancestry. Measures were reported for both right and left metacarpals. After tests for quantitative differences between right and left hand morphometrics showed no significant dissimilarity, data from both the right and left hand are pooled for this sample. The sample from the Forensic/Donated Collection from the Maxwell Museum of Anthropology, University of New Mexico, Albuquerque, NM, consists of 40 individuals of known race and sex and only measures from the left hand are used.

Methods

The measurements which define the size and shape of the metacarpal are presented in Fig. 1. (1) Midline, interarticular, or functional length is measured from the midline of the proximal articular surface to the midline of the distal articular surface. *A* to *B*. (2) Breadth across the distal aspect or head is measured from the **most** lateral to medial point in the medio-lateral plane. *C* to *D*. (3) The breadth of the proximal base is measured from the **most** lateral to medial point in the medio-lateral plane. *E* to *F*. (4) The medio-lateral breadth of the midshaft is measured in the medial lateral plane at midshaft. *G* to *H*. Finally, the (5) anterio-posterior breadth of the midshaft is taken at 90 degrees from the M-L dimension, in the anterior posterior plane. These measurements are all recorded in millimeters.

The utility of linear discriminant analysis for deriving classification functions is dependent on satisfying the assumption of multivariate normality of the data and the equality of variance-covariance matrices [*8,9*]. In other words, the distribution of each variable within each of the classes, in this case race and sex, must be normal. Not only do levels of sexual dimorphism vary within the skeleton by population, but these differences are evident in hand morphology between human groups [*10,11*]. Because the intent of this analysis is to provide sex discriminant functions, it was necessary first to determine whether or not levels of sexual dimorphism vary between whites and blacks. Therefore, before the calculation of discriminant functions, data from the Terry Collection were tested for significant racial differences in hand morphology.

The original 212 individuals from the Terry Collection, may be broken out into subsamples consisting of 51 black males, 56 black females, 58 white males, and 47 white females. Tests were accomplished by means of Two-Way ANOVA using both sex and race as class and interaction variables, as well as by directly examining the variance-covariance matrices. Significant differences between

[1]Forensic Anthropologist, National Museum of Health and Medicine, Armed Forces Institute of Pathology, Washington, DC.

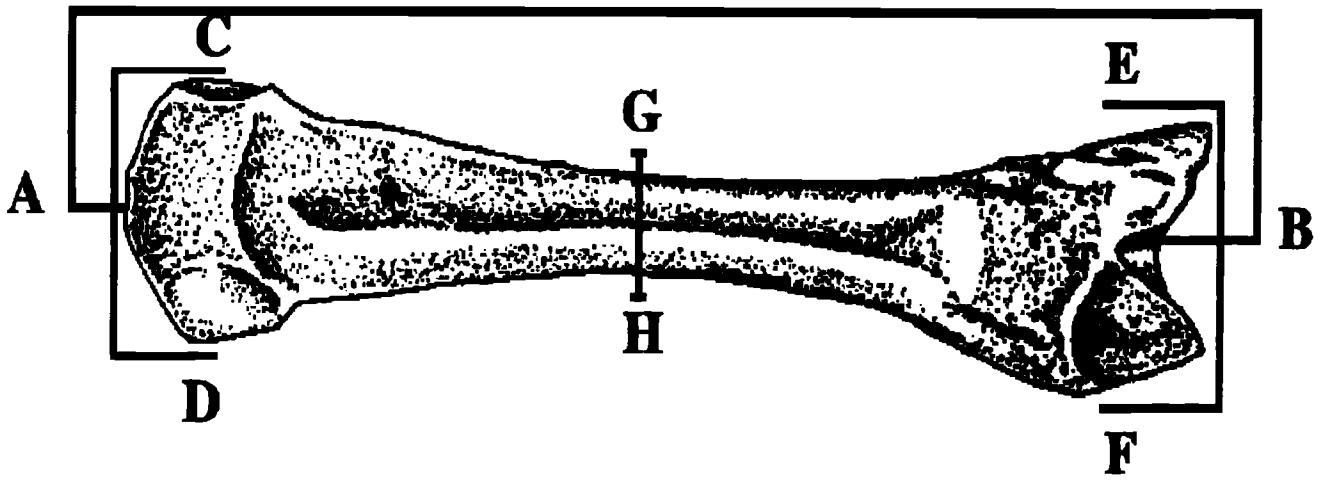

FIG. 1—*Measurements used in this study.* A-B *interarticular length.* C-D *medio-lateral breadth of distal aspect, or head. E-F medio-lateral breadth of proximal aspect, or base.* G-H *medio-lateral breadth of the midshaft.* I-J *(not shown) anterior-posterior breadth at midshaft. Taken from Musgrave* [7] *and Martin* [12]. *Figure 1 modified from Meadows and Jantz* [11].

the races for all five measurements were found for metacarpals I, and III, and thus these measurements cannot be used to generate functions which are blind to racial morphology. Linear discriminant analysis, using cross-validation classifications, was then performed on the pooled sample for digits II, IV, and V using the PC SAS package Version 6.08 for Windows.

Results

Results of the discriminant analysis for sex on the pooled-race sample for digits II, IV, and V are presented in Table 1. Correct classification, which is the number of individuals misidentified divided by the total number of individuals subtracted from 100, ranges from a high of 92.0 percent to a low of 84.37 percent. In this sample, the second digit provides the best discrimination between the sexes, using all five measures, at 92.0 percent. The percentage of correct classification drops off somewhat with the remaining digits, the third digit 86.8 percent, and the fifth at 84.37 percent.

The correct classification percentages are based on the linear equations' ability to segregate the calibration sample. In order to demonstrate whether or not these rather favorable results can be reproduced, the functions for digits II, IV, and V were applied independently to both the cadaver and donated/forensic samples.

Cadaver Sample

The application of the sex discriminant functions to the sample from the Royal Free Medical School is presented in Table 2.

TABLE 1—*Discriminant functions for sex: Terry Collection.*[a]

Variable	Digit II		Digit IV		Digit V	
Articular Length	−0.183		−0.0418		−0.004	
A-P Breadth	1.423		1.464		0.848	
M-L Breadth	0.573		−0.416		0.17	
Proximal Breadth	1.84		0.981		1.22	
Distal Breadth	0.631		1.038		0.787	
Constant	−41.481		−31.342		−30.68	
% Correct	92.0		86.26		84.37	
Mean Discriminant Score	Male	Female	Male	Female	Male	Female
	8.85	7.53	6.7	5.81	6.52	5.73

[a]Sectioning Point = 0. Values greater than zero indicate a male, values less than zero are female.

TABLE 2—*Application of Terry Functions for sex assessment: Royal Free Medical School Collection.*

Digit	Terry Collection % Correct	Royal Free Collection % Correct	Mean Discriminant Score Male	Female
II	92.0	57.58	10.66	9.04
IV	86.26	84.85	6.68	5.80
V	84.37	70.0	7.25	6.39

Correct classification of the cadaver sample ranges from a low of 57.58 percent to a high of 84.85 percent. The fourth digit provides the best classification power in this sample, while the second is a very poor discriminator for sex. The poor classification using the second digit from this sample may be seen by examining the differences in mean discriminant scores (Tables 1 and 2) between the collections. For the Terry Collection, males and females have much lower mean scores than those from the Cadaver sample. Therefore, the functions ability to correctly determine sex from this digit is undermined. Conversely, the similarity of mean discriminant scores for the fourth digit explain the comparable percent of correctly sexed. Overall there is a conspicuous decrease in correct classification percentages from the calibration sample.

Forensic/Donated Sample

The results of applying the discriminant functions for digits II, IV, and V to the forensic/donated sample are in Table 3. Correct

TABLE 3—*Application of Terry Functions for sex assessment: UNM Forensic/Donated Collection.*

Digit	Terry Collection % Correct	Forensic/Donated % Correct	Mean Discriminant Score Male	Female
II	92.0	77.50	10.29	8.36
IV	86.26	80.00	6.26	5.16
V	84.37	85.00	6.62	5.70

classification ranges from 77.4 percent to 85.0 percent. The fifth digit provides the best discrimination between the sexes, using all five measurements, at 85.0 percent. The percentage of correct classification drops off somewhat with the remaining digits, the third at 80.0 percent, and the second at 77.4 percent. Again, there is a noticeable decrease in percent of correct classification, however the percentage for digit V remains constant between the Terry and UNM Forensic/Donated. This may be inspected further by examining the corresponding mean discriminant scores for each sex by digit (Tables 1 and 3). These two collections, at least for digits II, IV, and V, share fairly similar mean scores. Thus, there is a greater overall consistency in correct classification percentages between the Terry Collection and the University of New Mexico Donated/Forensic.

Discussion and Conclusions

The objective of this investigation is to modify methods for sex determination from the metacarpals of the human hand. It employs a large calibration sample of North American whites and blacks so that it may better represent the variation in North American populations [*11*]. Further, the equations provided for digits II, IV, and V are based on a pooled-race sample after testing for race-sex differences established that digits I and III exhibit differing levels of sexual dimorphism. Thus, the equations for metacarpals II, IV, and V may be applied to metacarpals of unknown population affinity. Additionally, the second digit shows a wide range of metric variation in size and shape between these populations.

The results derived from the forensic/donated collection are encouraging because this sample represents actual forensic anthropology cases. The percentages for correct classification; 77.0% digit II, 80.0% digit IV, and 85% digit V, are slightly higher than those reported by Scheuer and Elkington [*2*]. However, they [*2*] report an actual correct sex determination for metacarpal I of 94%. In this analysis, metacarpal's I and III showed significant differences in morphology by race and thus could not confidently be used to develop discriminant functions. Scheuer and Elkington's [*2*] results were not tested directly, however, the range in variability of correct classification percentages derived from Musgrave's [*7*] British cadaver sample, and the low percentage of correct classification suggests that population-specific functions such as theirs should be applied with caution.

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Address requests for reprints or additional information to
Anthony B. Falsetti, Ph.D.
National Museum of Health and Medicine
Armed Forces Institute of Pathology
Washington, DC 20306-6000
Fax (202) 782-3573