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TECHNICAL NOTE

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Evaluation of Purkait's Triangle Method for Determining Sexual Dimorphism*

ABSTRACT: The identification of sex from the skeleton is an important demographic assessment in medicolegal investigations. Rama Purkait developed a method for estimating sex using measurements from a triangle defined by three points on the proximal end of the femur using skeletal material from Bhopal, India. This method was tested with measurements on 200 Indo-European and African American adult femora from the Terry collection using discriminant function analysis to determine if Purkait's method was valuable for determining sex in Americans. A side-by-side analysis was conducted of Purkait's "triangle method" and the maximum diameter of the femoral head to determine their relative value in assessing sexual dimorphism. In the study sample a single variable from Purkait's method provided 85.5% prediction accuracy, similar to 87% for the head diameter. Combining threshold values for a single variable from Purkait's method and the femoral head diameter raised the predictability to greater than 90% for both sexes.

KEYWORDS: forensic science, forensic anthropology, sex determination, femur

The ability to determine sex from isolated bones and bone fragments is a necessity in medicolegal investigations. The evaluation of sexual dimorphism in the skeleton is generally based on two factors, size difference with males being generally larger than females, and function-related differences, particularly in the pelvis. These factors reflect the biological differences between males and females and varying levels of stress and strain on the bones during development which lead to differences in both size and morphology. Because a pelvis is not always present, it is important to be able to determine sex from other skeletal elements (1,2). The use of the femur for sexual determination has been documented in numerous studies including those by İşcan and Miller-Shaivitz (3), Holliday and Falsetti (4), and Asala (5).

Traditionally, when the proximal end of the femur is the only portion of bone available for analysis, the maximum vertical diameter of the head is utilized for determining sex (1). A second method was recently developed by Purkait (6) and involves measurements taken of areas of muscle origin and insertion. Multiple methods for sexual estimation utilizing a single bone are valuable in increasing the likelihood of accurately determining sex.

Materials and Methods

This study sample utilized 200 dry, adult femora from the Terry collection, of which 100 were male and 100 were female. The sample was further partitioned between African Americans (AA) and European Americans (EA) with 50 EA males, 50 AA males, 50 EA females, and 50 AA females. These specimens were selected at random from the collection. Neither pathological nor abnormal bones were included in this sample. An additional 40 specimens (10 from each group) were measured to be used as validation samples on any statistical procedures developed.

The Terry collection contains the skeletal remains of over 1700 dissecting room cadavers that were assembled at Washington University Medical School, St. Louis, MO, and transferred to the Smithsonian Institution in Washington, DC. The Terry collection is composed of individuals originating from the lower socioeconomic groups and is therefore not representative of all individuals from society. Additionally, the sample is not contemporary as the dates of birth of the individuals represented in the sample range from 1822 to 1943.

In measuring, the femur was placed on a flat table with both condyles touching the surface and the posterior aspect facing the observer. Purkait's triangle (6) is defined by the most lateral projecting point on the femur head (A), the most medially projecting point on the greater trochanter (B), and the most posteromedial point on the lesser trochanter (C) (Fig. 1). The maximum vertical diameter of the head was also measured with the femur on a table in this manner. This measurement was conducted on the articular surface of the head and the bone was rotated until the maximum distance was obtained (7). The distances between each point (AB, AC, and BC) and the maximum vertical diameter of the head were measured to the nearest 0.01 mm using a Mitutoyo Digimatic Caliper (Mitutoyo America Corporation, Aurora, IL). Purkait (6) conducted a paired *t*-test and determined that there was no significant bilateral variation at 0.05 levels. As such, right femora were used for measurement except in instances where there was a pathological or abnormal condition in which case the left femur was utilized.

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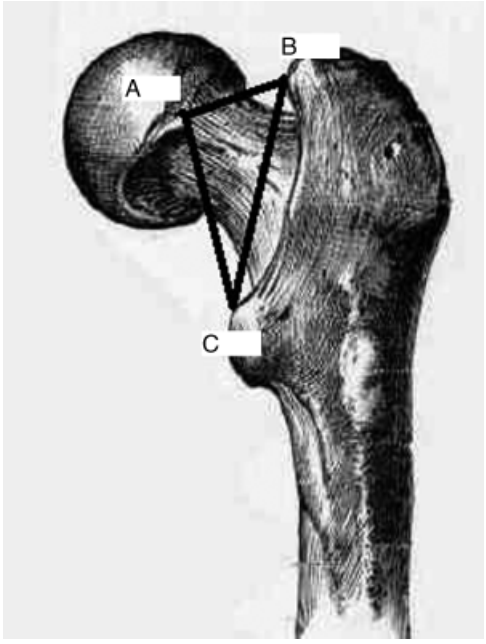

FIG. 1—*Triangle of Purkait at the proximal end of the femur.*

Statistical analysis of the data included the calculations of means and standard deviations for each variable (Excel spreadsheet functions) divided by sex and population. To further determine which variables were useful in discriminating the femora by sex, discriminate function analysis was performed using SPSS 13.0 graduate student edition software (SPSS Inc., Chicago, IL). To test the consistency of prediction accuracy, the data were subjected to a Jackknife procedure, which recalculates the discriminate function analysis, while sequentially removing one of the samples and averages the results over all of the Jackknifed values (8). Using the discriminant function it was possible to classify femora as male or female with a certain degree of accuracy. However, using the data from which the discriminate function was generated to test the discrimination biases the estimate in favor of those variables initially used. Therefore, the discrimination function was repeated using 40 additional femora (20 males and 20 females) measured and not included in the original sample. Finally, a simple threshold was developed using the nadir of the male and female distributions and this was tested for its ability to discriminate samples based on sex. Note: due to multiple statistical tests on the same dataset the Bonferroni correction for multiple tests was performed to determine an appropriate level of α.

TABLE 2—*Classification accuracy using Purkait's threshold values on the Terry sample.*

Measure	Male (%)	Female (%)	Total (%)
AB	54.00	85.00	69.00
AC	64.00	80.00	72.00
BC	65.00	99.00	82.00

Results

The descriptive statistics are presented in Table 1 for the four variables examined. While all variables show differences between males and females, the means for AB and AC for males and females are within one standard deviation of each other. Though statistically significant differences could be detected, they were not thought to be terribly predictive in sexual discrimination.

Initial attempts were made to classify the Terry samples using Purkait's threshold values of 31.6, 44.8, and 55.9 mm for AB, AC, and BC, respectively. The results are shown in Table 2. The low accuracy of male classification using Purkait's threshold values required the development of criteria specific for the Terry samples. A discriminant function analysis was conducted using the Terry samples to specifically test the four variables on the Terry samples. The results for correct classification using these discriminant function analyses and the significance of the discriminate function analysis are given in Table 3. Table 3 contains the accuracies of prediction for each function as well as accuracies for combined functions. There were no significant differences between the accuracy of the Purkait function and the Terry collection, after correction for the number of tests performed. BC was shown to be the best predictor of the Purkait's triangle variables (85.5%) with the maximum vertical head diameter slightly better (87%). Neither the inclusion of AB or AC nor both in combination with BC yielded a significant improvement over BC in the discriminant function analysis. In a step-wise analysis all of the discrimination was contributed by BC. Additionally, all of the following were tested, and none of them were found to be significant predictors of sexual dimorphism: angles defined by AB, AC, and BC; total sides of triangle and area of triangle (data not presented). To see if any of these variables were useful in discriminating population of origin, the analysis was repeated dichomotomized on population of origin. None of the variables were significant discriminators ($F(4/195) = 2.0085$, $p < 0.095$). This latter analysis also indicated that there was no significant interaction of sex and population of origin.

TABLE 1—*Descriptive statistics for male, female, European American (EA) and African American (AA) samples for each of the variables under study.*

	AB		AC		BC		Head Diameter	
Population	Male	Female	Male	Female	Male	Female	Male	Female
EA								
Mean	34.15	26.80	45.95	42.07	57.46	48.83	49.40	42.80
SD	6.00	4.68	5.61	4.21	3.93	4.17	3.08	2.24
AA								
Mean	30.03	27.80	46.56	39.91	58.15	47.67	48.14	42.39
SD	5.49	3.58	7.12	4.92	6.39	4.60	3.15	2.39
Total								
Mean	32.09	27.30	46.26	40.99	57.81	48.25	48.77	42.60
SD	6.08	4.17	6.39	4.69	5.29	4.41	3.17	2.32

SD, standard deviation.

TABLE 3—*Accuracy of classification and discriminant function analysis of the Terry collection data.*

Measure	Male (%)	Female (%)	Total (%)	Jackknife (%)	*F*	df	*p*
AB*	70.00	68.00	69.00	69.00	42.151	1/198	<0.001
AC*	67.00	74.00	70.50	70.50	44.272	1/198	<0.001
BC*	83.00	88.00	85.50	85.50	192.672	1/198	<0.001
AB*+AC*	70.00	80.00	75.00	74.00	42.458	2/197	<0.001
AB+BC*	84.00	90.00	87.00	86.50	100.83	2/197	<0.001
AC+BC*	85.00	90.00	87.50	87.00	96.293	2/197	<0.001
AB+AC+BC*	84.00	90.00	97.00	86.50	66.954	3/196	<0.001
Head diameter*	85.00	89.00	87.00	87.00	247.135	1/198	<0.001
Diameter*+BC*	88.00	92.00	90.00	89.50	146.63	2/197	<0.001

*Individual values significant after Bonferroni's correction $\alpha' = 0.05/25 = 0.002$.

Based on these data, only BC proved to be a useful discriminator for the Terry collection samples with an 85.5% accuracy which is not significantly different from the 87% accuracy using the diameter alone. Combining BC and the diameter together marginally raised the accuracy to 90%. Based on the discriminate analysis threshold values were determined using BC and diameter. The threshold value for BC was determined to be 53.00 mm and for diameter 45.70 mm. The accuracy for threshold values versus discriminant function analysis is detailed in Table 4. The threshold value for the diameter is similar to that found in İşcan and Miller-Shaivitz's (3) previous study. All samples were scored using threshold values. Analyses were performed using individual threshold values and both threshold values. Though the overall prediction accuracy increased to 93.4% (Table 5) using concordance for both threshold values the increase was not significantly different from the individual threshold values for BC (86.0%) or diameter (87.0%). Further, though there is heterogeneity among populations and sex in the rate of accuracy the differences are also not statistically significant ($\chi^2 = 13.840$, 15 df, $p = 0.538$). The 40 additional femora not included in the determination of the threshold values were tested using the threshold values. These results are given in Table 6. The results were not significantly different from the original series of 200.

TABLE 4—*Accuracy using threshold value versus discriminate function.*

Method	Male	Female	Total
Discriminate BC+diameter (%)	88.00%	92.00%	90.00%
N	100	100	200
Threshold BC*+diameter (%)†	91.500%	95.30%	93.4%
N	82	85	167

*Threshold BC value = 53.00 mm.
†Threshold diameter value = 45.70 mm.

TABLE 6—*Accuracy using threshold values on 40 additional femora not included in original sample.*

Measure	Male	Female	Total
BC	80.00% (20)	80.00% (20)	80.00% (40)
Diameter	90.00% (20)	100.00% (20)	95.00% (40)
BC+diameter	93.75% (16*)	100.00% (16*)	96.68% (32)

*Only samples concordant for both threshold values are included, discordant samples were considered inconclusive.

Discussion

Osteometric analysis of postcranial skeletal remains with the use of discriminant function analysis statistics is one of the most common ways of estimating sex in unidentified remains. The use of this method also reveals population variation by comparing tests of formulas derived from one group with another. The comparison of these different studies on different populations allows for a valid assessment of population variability.

This study evaluated a relatively new sexual dimorphism method in order to examine the population variability in the femora from the Terry collection and Purkait's sample, which consisted of middle-class Central Indian males. The measurement from the point projecting most medially on the greater trochanter and the highest point on the lesser trochanter (BC), was determined to be valuable in estimating sex using the proximal end of the femur, particularly in combination with the maximum vertical diameter of the head. The prediction accuracy using discriminant function analysis for BC alone was found to be 85.5%. Similar results (87%) were found using the more traditional maximum vertical

TABLE 5—*Results of sex classification using threshold values for BC from Purkait's triangle, maximum head diameter, and both.*

	Males			Female				
Threshold	EA	AA	Total	EA	AA	Total	Total	
BC correct	46	38	84	45	43	88	172	
N	50	50	100	50	50	100	200	
Percent correct	92.00	76.00	84.00	90.00	86.00	88.00	86.00	
Diameter correct	45	40	85	45	44	89	174	
N	50	50	100	50	50	100	200	
Percent correct	90.00	80.00	85.00	90.00	88.00	89.00	87.00	
BC+diameter correct	42	33	75	41	40	81	156	
N	44	38	82	42	43	85	167	
Percent correct	95.45	86.84	91.46	97.62	93.02	95.29	93.41	
Ambiguous	6	12	18	8	7	15	33	16.50%

diameter of the head. Using discriminant function analysis of the two variables in combination, the accuracy was 90% and even higher (93.4%) using threshold values when individuals where BC and diameter measurements produced conflicting results were excluded. The use of two measures of sex dichotomy slightly improved the precision of determination of sex; however, discordant samples reduced the total number of samples that could be classified, limiting the usefulness of this approach.

The measured values in the Terry Collection taken in this study were found to be smaller than those from Purkait's study, however, the results are within one standard deviation, and thus the biological meaning of these differences is unclear. More studies should be conducted on different populations using contemporary samples in order to determine general discriminant functions and threshold values based on population variability and to further document human variation in this aspect of the anatomy. Further, the possible differences in the predictive ability to determine sex on skeletal remains from different populations needs to be confirmed by additional studies on contemporaneous populations of multiple origins. Future studies of this nature should also include intraobserver and interobserver error studies to determine whether these results can be reliably reproduced.

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