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TECHNICAL NOTE

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Discriminating Sex in South African Blacks Using Patella Dimensions*

ABSTRACT: For many years, sex determination has been carried out on skeletal remains to identify individuals in forensic cases and to assess populations in archaeological cases. Since it has been shown that not all bones are found in a forensic case, discriminant function equations should be derived for all bones of the body to assist in sex determination. Numerous studies have shown the usefulness of bones of the lower extremity (e.g. femur, tibia) in sex determination using discriminant function analysis, but the use of patella measurements has not been extensively investigated for this purpose. It is therefore the aim of this study to derive discriminant function equations for sex determination from measurements of the patella of South African blacks as represented in the Raymond A. Dart Collection of Human Skeletons. A total sample of 120 (60 male, 60 female) patellae were measured using six measurements. The Statistical Product and Service Solutions (SPSS) program was used to derive the equations. Stepwise and direct analyses were performed with the highest rate of classification of 85% thereby making the patella useful for sex determination. Thus, the proposed equations derived from this study should be used with caution and only on the South African black population group.

KEYWORDS: forensic science, forensic anthropology, discriminant function, sexing, patella, South African blacks

For many years, sex has been determined from skeletal remains either for archaeological (1) or forensic (2) purposes. Morphological and metrical features of some bones that display sexual differences have been described (2). These include the pelvis (3–6), the cranium (7–13), bones of the upper (14–15) and lower limbs (16–23), and even fragments of bones (24–29). Recently, there has been an increased interest in the use of metrical methods in sex assignment. The most commonly used metrical method is discriminant function analysis (30), which has been described by the authors in previous studies (16–17). Nearly every bone has been subjected to discriminant function analysis (16) but not much literature has been found on the usefulness of measurements of the patella in the determination of sex using this method.

Forensic anthropologists often do not have the luxury of being presented with complete skeletons for analysis in personal identification. As most forensic cases presented to forensic anthropologists are not always complete, other bones could be used for sex determination (e.g., the patella). The patella is the largest sesamoid bone that develops within the quadriceps femoris muscle tendon. It is a roughly triangular, flat bone that has an articulating facet for the distal anterior end of the femur (31). As the shape and size of the patella relies on the strength of the muscle mass it could be suggested that stronger muscle masses could alter the shape and size of this bone. Since it has been shown that females have a smaller build compared to males, it would be expected that some measurements of the patella would display sexual dimorphism.

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The patella is a small compact bone that does not undergo too many postmortem changes and therefore can be retrieved complete and used for such purposes (32). Few studies have shown the usefulness of the patella in sex determination. One such study conducted by Gunn and McWilliams (33) assessed sexual dimorphism of patellae obtained from the Todd Collection using volumetric analysis. This involved submerging the patella into a container of water and using the displacement method in calculating the volume of the bone. The highest average accuracy in correct sex classification obtained in this study was 88% for "Europids."

Introna and co-workers (32) also attempted to assess the usefulness of the patella in sex determination by subjecting some measurements of the patella of a known contemporary Southern Italian population to discriminant function analysis. The highest classification rate of 83.3% was achieved in this study. A similar study was conducted by Bidmos and co-workers (34) in South Africa. They (34) were able to derive discriminant function equations for sex determination using the patella of South African whites. Since it has been shown that discriminant function equations derived for skeletal analysis are population specific, it is the aim of this study to evaluate whether measurements of the patella of South African blacks, as represented by the Raymond A Dart Collection of Human Skeletons display sexual differences using discriminant function analysis.

Materials and Methods

Data were collected from skeletal remains obtained from the Raymond A Dart Collection of Human Skeletons, which is housed in the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg. A total of 120 (60 male, 60 female) patellae of South African blacks were measured. The age range was between 18 and 70 years. As it has been previously shown that there are no statistically significant intertribal differences in osteometric dimensions of the South African black population group (8,35), data were collected from two large groups namely the Zulu and Xhosa tribes.

A simple random sampling technique was used in the selection of the sample. In all cases, only the left patellae were measured and patellae that showed any signs of pathology or abnormality were excluded from the study. The measurements taken from each patella included:

1. Maximum height (MAXH)—the greatest distance between the base and apex.
2. Maximum breadth (MAXB)—the greatest distance between the medial and lateral sides.
3. Maximum thickness (MAXT)—the greatest distance between the anterior and posterior surfaces.
4. Height of articular facet (HAF)—maximum height of the articular facet on the posterior aspect of the patella.
5. Medial articular facet breadth (MAFB)—distance between the medial edge of the patella and the median ridge of the articular facet.
6. Lateral articular facet breadth (LAFB)—distance between the lateral edge of the patella and the median ridge of the articular facet.

All measurements were adapted from Martin and Knussman's (36) definitions and were taken using a digital vernier caliper. Measurements were taken by both authors and inter- and intra- observer errors were assessed using the concordance correlation coefficient of reproducibility (37).

The Statistical Product and Service Solutions (Version 8; SPSS Inc., Chicago ILL) program was used to analyze all the data. Descriptive statistics, which included means and standard deviations, were obtained for all measurements. After establishing that a significant difference exists between male and female mean values for each of the measurements using the F-statistic, the data were subjected to discriminant function analyses. For a description of the method, we refer to our previous studies on the talus (16,17).

The equations that were derived were tested using different methods. Firstly, the validity of each of the functions was tested using the "leave-one-out" classification procedure (16,20). Thereafter two test samples were used. Test sample 1 consisted of 10 individuals from the Zulu and Xhosa tribes, while Test sample 2 consisted of 10 individuals from the Soto and Tswana tribes.

Results

The mean and standard deviation for each of the six measured variables in both sexes are presented in Table 1. Comparison of means using the F-statistic showed significant differences ($p < 0.0001$) in the male and female mean measurements, with males showing higher mean values than females. This indicates sexual dimorphism of the measured variables. The average of the male and female mean values for each variable (demarking point) is shown in Table 2. These variables are arranged in decreasing order of average accuracies in correct classification.

TABLE 1—*Descriptive statistics (measurements in mm).*

Variable	Sample Size	Male Mean	Male SD	Female Mean	Female SD	*F-statistic	*P-value
MAXH	60	41.22	3.12	36.48	2.23	91.70	0.000
MAXB	60	43.34	2.54	38.97	2.90	77.11	0.000
MAXT	60	20.56	1.42	18.20	1.71	67.65	0.000
HAF	60	29.56	2.96	27.86	2.73	10.70	0.001
MAFB	60	18.38	1.94	16.34	1.61	39.32	0.000
LAFB	60	25.31	2.07	22.91	2.10	39.77	0.000

* All significant at $P < 0.05$.

TABLE 2—*Demarking points (in mm) for sex differentiation.*

Measurements	Demarking Points	Average Accuracy %
MAXB	females < 41.16 < males	80.0
MAXH	females < 38.85 < males	79.2
MAXT	females < 19.38 < males	77.5

When all six measurements were subjected to stepwise analysis, only two variables (MAXH and MAXB) were selected (Table 3). A discriminant function equation can be formulated from these two variables using the unstandardised coefficients and constant as presented in Table 3. The percentage average accuracy in correct classification using this equation is 81.7%. A second equation was derived from the stepwise analysis of articular facet measurements (MAFB, LAFB and HAF). The two variables selected were LAFB and MAFB with an average accuracy of 78.3% (Table 3).

The coefficients and constants from the direct discriminant function analysis of all variables (function 1), the best three individual variables obtained from the use of demarking points (function 2), breadth dimensions (function 3) and height dimensions (function 4) are presented in Table 4. The percentage average accuracies for these functions ranged from 78.3% to 85%.

The validity of the functions derived in Tables 3 and 4 was assessed using the "leave-one-out" classification. While the average accuracies before and after validation for most functions remained unchanged, the other functions showed a drop in correct classification accuracy that ranged between 0.8% (function 2, Table 3) and 3.3% (function 1, Table 4). Generally, females were more correctly classified than males.

The average accuracies in correct sex classification (Table 5) from independent samples ranged between 60% and 80%.

Discussion

Measurements taken on most bones in the body have been shown to present with higher mean values for males compared to females. The patella follows a similar pattern in the present study. The two most sex differentiating variables in the present study were maximum breadth and maximum height. This finding is consistent with earlier studies by Introna et al. (32) on a southern Italian sample and Bidmos et al. (34) on South African whites. However the percentage average accuracies obtained from these individual measurements in the present study are higher than those obtained by Introna et al. (32), but lower compared to that obtained by Bidmos et al. (34) for maximum height.

The range of average accuracies obtained from individual variables is lower than that of combinations of variables in the present study (Tables 2–4). This therefore shows that discriminant function equations obtained from combination of variables are more useful in the determination of sex from measurements of the patella. This is in agreement with the previous study on the patella in which Introna et al. (32) obtained a higher range of average accuracies for combinations of variables (76.3–83.8%) than individual variables (62.7–78.8%). However the average accuracies from combinations of variables from the present study (78.3–85%) is higher than that

TABLE 3—*Stepwise discriminant function analysis.*

	Variables	Unstandardized Coefficient	Standardized Coefficient	Wilk's Lambda	Structure Point	Centroids	Sectioning Point	Average Accuracies (%) O	C
1	MAXH	0.242	0.656	0.606	0.878	M = 0.997	0.000	81.7	79.1
	MAXB	0.193	0.528	0.562	0.803	F = −0.997			
	Constant	−17.373							
2	LAFB	0.329	0.684	0.616	0.735	M = 0.782	0.000	78.3	77.5
	MAFB	0.381	0.680		0.731	F = −0.782			
	Constant	−14.529							

In function 1, discriminant function equation (y) = (0.242 × MAXH) + (0.193 × MAXB) − 17.373.
For this function, DFS greater than 0 indicates male, DFS less than 0 indicates female.
O = original classification.
C = cross validation.

TABLE 4—*Direct discriminant function analysis.*

Functions	Variables	Unstandardized Coefficient	Standardized Coefficient	Wilk's Lambda	Structure Point	Centroids	Sectioning Point	Average Accuracies % O	C
1	MAXH	0.215	0.584	0.480	0.848	M = 1.031	0.000	85.0	81.7
	MAXB	0.161	0.440		0.776	F = −1.031			
	MAXT	0.179	0.281		0.725				
	LAFB	−0.064	−0.134		0.558				
	MAFB	0.020	0.036		0.554				
	HAF	0.018	0.052		0.290				
	Constant	−17.791							
2	MAXB	0.138	0.376	0.484	0.782	M = 1.023	0.000	85.0	83.3
	MAXH	0.215	0.583		0.855	F = −1.023			
	MAXT	0.181	0.284		0.730				
	Constant	−17.541							
3	MAXB	0.256	0.700	0.598	0.984	M = 0.814	0.000	80.0	78.3
	LAFB	0.075	0.156		0.707	F = −0.814			
	MAFB	0.160	0.286		0.703				
	Constant	−15.148							
4	MAXH	0.352	0.954	0.554	0.984	M = 0.889	0.000	78.3	77.5
	HAF	0.064	0.182		0.337	F = −0.889			
	Constant	−15.515							

In function 4, discriminant function equation (y) = (0.352 × MAXH) + (0.064 × HAF) − 15.515.
For this function, DFS greater than 0 indicates male, DFS less than 0 indicates female.
O = original classification.
C = cross validation.

TABLE 5—*Validity of functions on independent samples.*

Functions	Original Accuracy	Cross Validation: Independent Sample 1	Independent Sample 2	Combined Independent Sample
Function 1 (Table 2)	80.0	60.0	80.0	70.0
Function 2 (Table 2)	79.2	70.0	70.0	70.0
Function 1 (Table 3)	81.7	70.0	70.0	70.0
Function 1 (Table 4)	85.0	70.0	70.0	70.0
Function 2 (Table 4)	85.0	70.0	60.0	65.0
Function 3 (Table 4)	80.0	70.0	60.0	65.0

obtained by Introna et al. (32) but compares well with that obtained for South African whites (34). Similar comparisons could not be made between the present study and that of Gunn and McWilliams (33) because of the difference in methods used in sexing. While they (33) used the amount of volume of water displaced in sex differentiation, we used linear measurements of the patella in discriminating between the sexes.

From forensic contexts, preservation of the skeleton is highly variable and all bones may be recovered intact. However, in some cases the patella is one of the few bones that are recovered intact because it is compact. Some of the equations that have been derived in the present study from measurements of the patella have shown it to be useful for sex determination. In South Africa, the average accuracies obtained from the use of humerus (14), calcaneus (23), and talus (17) of South African blacks are higher than those obtained from the present study, thereby making these bones more useful than the patella as sex assessors. In cases where these bones (humerus, calcaneus and talus) are not available for sex determination, the equations derived from the present study may be useful.

The validity of these equations was tested on two independent samples of patellae obtained from different tribes of the South African black population. The result revealed lower average accuracies than the original classification in both samples. The reasons for the differences in average accuracies between the original and independent samples are thought to include the following: (1) the tribal differences that might exist within the South African black population group that has always been treated as a single homogenous group and (2) the possibility of variation in age distribution that differences could exist between the original sample and the independent sample. However, as the test sample is too small, further conclusions cannot be drawn from it.

We propose that the equations from the present study should be used with caution in forensic cases when only the patella is available for sex determination and should be limited to the South African black population group.

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