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Sex estimation from the patella in an African American population

Tanya R. Peckmann[a,*], Brooke Fisher[b]

[a] Department of Anthropology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada
[b] Forensic Sciences Program, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

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ABSTRACT

The skull and pelvis have been used for the estimation of sex for unknown human remains. However, in forensic cases where skeletal remains often exhibit postmortem damage and taphonomic changes the patella may be used for the estimation of sex as it is a preservationally favoured bone. The goal of the present research was to derive discriminant function equations from the patella for estimation of sex from an historic African American population. Six parameters were measured on 200 individuals (100 males and 100 females), ranging in age from 20 to 80 years old, from the Robert J. Terry Anatomical Skeleton Collection. The statistical analyses showed that all variables were sexually dimorphic. Discriminant function score equations were generated for use in sex estimation. The overall accuracy of sex classification ranged from 80.0% to 85.0% for the direct method and 80.0%–84.5% for the stepwise method. Overall, when the Spanish and Black South African discriminant functions were applied to the African American population they showed low accuracy rates for sexing the African American sample. However, when the White South African discriminant functions were applied to the African American sample they displayed high accuracy rates for sexing the African American population. The patella was shown to be accurate for sex estimation in the historic African American population.

1. Introduction

In humans, the patella is the largest sesamoid bone in the body. It articulates with the femur and covers and protects the anterior articular surface of the knee joint. The patella develops in the tendon of the quadriceps femoris muscle and is ossified from a single center.[1] The patella functions primarily as an anatomic pulley for the quadriceps muscle. It increases the lever arm of the extensor mechanism allowing for more effective knee flexion and thus increasing quadriceps strength by 33%–50%.[1] The patella is also resistant to postmortem and taphonomic changes and is therefore valuable for the estimation of sex in unknown human remains.[2]

The estimation of sex is an important part of the biological profile as it provides for a better understanding of other elements of the biological profile, as the estimation of stature and age at death are sex dependent. The estimation of sex is more reliable when a full skeleton is available for analyses. However, incomplete or fragmentary human remains are often found during a forensic recovery especially in cases of mass disasters and human rights investigations. Forensic anthropologists use both morphological and metric methods for the estimation of sex when complete or fragmentary remains are found. Morphological methods are subjective and their accuracy is dependent on observer experience while metric methods use statistical analyses to objectively validate results.[3]

The most commonly used metric method for sex estimation is discriminant function analysis.[4] Discriminant function equations for sex estimation have been shown to be population-specific.[5,6] Variation in sexual dimorphism has been found even within small geographic areas therefore requiring the development of population-specific discriminant function equations.[7–9] Currently, there are no patellar discriminant function equations available for the estimation of sex for an African American population. The goals of this research are to (1) test the accuracy of discriminant functions developed on a Black South African,[10] White South African,[13] and Spanish[11] population for use with an African American population for estimating sex from the patella, and (2) develop population-specific discriminant function equations for the patella from an African American population. The Black South African[10] data were used as they are genetically similar to the African American population. The White South African[13] and Spanish[11] samples were used as they are genetically dissimilar to the African American population. Also, the Black South African,[10] White South African,[13] and Spanish[11] data were the only published discriminant functions available for comparison that employed the same variables as the current research.

* Corresponding author. Saint Mary's University, Department of Anthropology, 923 Robie Street, Halifax, Nova Scotia B3H 3C3, Canada.
E-mail addresses: tanya.peckmann@smu.ca (T.R. Peckmann), brookfisher@trentu.ca (B. Fisher).

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Table 1
Description of measurements.

Measurement	Description[a]
Maximum height (MAXH)	Greatest distance between the base and the apex.
Maximum breadth (MAXB)	Greatest distance between the medial and the lateral sides.
Maximum thickness (MAXT)	Greatest distance between the anterior and the posterior sides.
Lateral articular facet breadth (LAFB)	Distance between the lateral edge of the patella and the median ridge of the articular facet.
Height of articular facet (HAF)	Maximum height of articular facet on the posterior aspect of the patella.
Medial articular facet breadth (MAFB)	Distance between the medial edge of the patella and the median ridge of the articular facet.

[a] (Modified from Dayal and Bidmos 2005).

2. Materials and methods

This study used 200 individuals (100 males and 100 females) of an African American population from the Robert J. Terry Anatomical Skeleton Collection housed at the National Museum of Natural History (NMNH), Smithsonian Institute in Washington, D.C. Age at death ranged between 20 and 80 years of age. Demographic information was known for each individual, i.e. sex, year of birth, age at death. The African American collection consists of individuals whose birth dates range from 1828 to 1943 and death dates range from 1924 to 1962. Therefore, these skeletal remains represent an historic population.

Following the protocol of Dayal and Bidmos (2005), six variables from the patella were recorded using a standard Vernier caliper to the nearest 1/100 of a millimeter (Table 1, Figs. 1–3). A comparison of the measurements taken from 20 paired patellae showed no statistically significant side differences with all $p > .05$. Therefore only the left patella was measured. In cases where the left patella showed evidence of trauma, damage, pathological changes, or was absent measurements of the right patella were recorded. Intra- and inter-observer error rates were calculated by re-measuring 30 randomly selected patellae (15 males and 15 females) for each measurement variable. These sample sizes are appropriate as previous studies have shown that a subsample of 10%–20% of the total population should be used to test for intra- and inter-observer error.[12] There were two observers. The intra- and inter-observer measurements were collected one week apart.

All statistical analyses were performed using Graphpad Prism 7 and the SPSS 22.0 software program with a level of significance $\alpha = 0.05$ and Bonferonni-adjusted level of significance $\alpha = 0.008$. Parametric (normally distributed) data were analyzed using a paired *t*-test and non-parametric (not normally distributed) data were analyzed using a paired Wilcoxon test. Descriptive statistics were obtained for each measurement. Males and females were analyzed separately. Using a two-sample *t*-test for the parametric data and a Mann-Whitney *U* test for the non-parametric data the mean values of the six measurements were compared between the sexes to determine if statistically significant differences existed. The Black South African,[10] White South African,[13] and Spanish[11] discriminant functions were applied to the African American sample to determine their accuracy for sex classification. Population-specific discriminant functions were created for the African American population. The variables were subjected to direct and stepwise discriminant function analyses. The African American mean patellae measurements were compared with other populations: White South Africans,[13] Black South Africans,[11] Thai,[14] Japanese,[15] Southern Italian,[16] Medieval German,[17] and Spanish.[11]

All data were tested for normality. The six measurements were separated into groups (i.e. male and female) to ensure that each sex was accurately represented. The Kolmogorov-Smirnov (KS) test was used to evaluate normality of the data with a significance level of $\alpha = 0.05$. For males and females, all six measurements were normally distributed. The two sample t-tests were selected as the appropriate statistical test because the sample was randomly and independently selected, the variances were similar for the measurements, and the data exhibited a normal distribution.

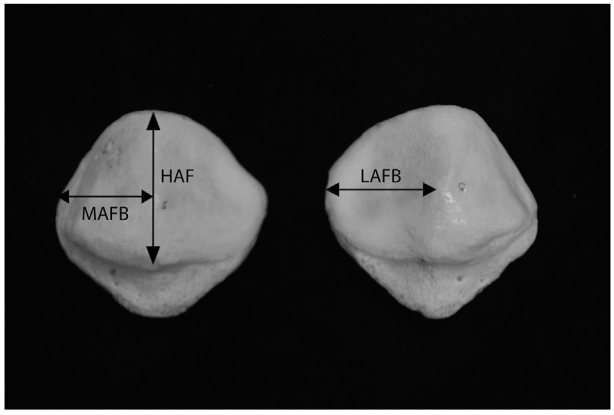

Fig. 1. Patellar measurements: lateral articular facet breadth (LAFB), height of articular facet (HAF), medial articular facet breadth (MAFB) (photo by A. Rozendaal).

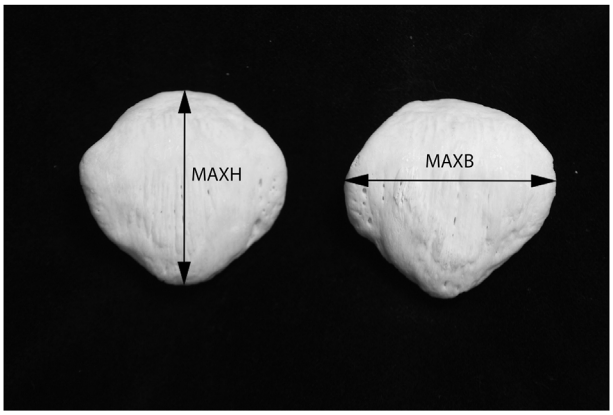

Fig. 2. Patellar measurements: maximum height (MAXH), maximum breadth (MAXB) (photo by A. Rozendaal).

Fig. 3. Patellar measurement: maximum thickness (MAXT) (photo by S. Scott).

3. Results

3.1. Intra- and inter-observer error rates

When examining the intra- and inter-observer error rate, there were