Dimorphism of the Radial Head and its Potential for Sex Determination

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Abstract

The present study assesses the degree of sexual dimorphism in the human radial head diameter, as an indicator of overall body size, and the accuracy of sex estimates based on this measurement. The study utilized 199 White females and 170 White males from the Hamann-Todd Collection (Cleveland Museum of Natural History, Cleveland, OH).

Analysis of covariance (ANCOVA) allowed testing for group differences after correction for body size. Cross-validation of sex classification through discriminant function analysis shows that radial head diameter, is a sex indicator showing accuracies comparable to those of the femoral and humeral head diameters. Furthermore, it is argued that, due to the simplicity of the measurement and its reliability as a sex indicator, it should be included in the standard measurements set.

Introduction

Sex estimation is a vital component of a decedent's biological profile. Traditionally, it has been observed that features of the pelvis and cranium hold the greatest potential for accurate sex assessment of skeletonized human remains. Additionally, certain dimensions of the long bones are thought to be highly reliable indicators of sex, in particular, the maximum diameters of the humeral and femoral heads. It was realized early on that the size of articular surfaces, including the femoral and humeral head and the curvatures of the transverse diameter of these surfaces, provide highly reliable indicators of sex (Dwight, 1905). In general, females tend to have smaller joints and, subsequently, smaller articular surfaces than males.

This is related to the ability of the articular surfaces to reflect in vivo mechanical loadings and therefore body mass (Ruff, 1990; Scott, 1990), as body mass is the best indicator of overall sexual dimorphism (Anderson, 1994).

Consequently, recent studies have focused on the primary predictors of body weight or muscular mass. The femoral and humeral head diameters are good predictors of weight and thus have provided accuracies in sex determination in the 90% range (DiBennardo and Taylor, 1979; Dittrick and Suchey, 1986; Iscan and Miller-Shaivitz, 1984a; MacLaughlin and Bruce, 1985).
The conjoining articular surfaces of the distal humerus are listed among the best sex estimators (France, 1988).

Singh *et al.* (1974) discriminated sex in an Indian population utilizing measurements of the radius that included; the head, tuberosity and midshaft circumferences, distal end width, length, and bone weight. The radial head circumference did not provide an accurate estimator of sex while weight, length, and distal end width measurements provided some discriminatory ability. Still, Berrizbeitia (1989) obtained correct classification rates of 96% including radial head measurements in her analysis.

More recently, Mall *et. al.* (2001) uses discriminant function analysis to sex a European population using a variety of measurements of the long bones of the arm. This study included the maximum radial head diameter in its analysis and achieved 88.57% correct classification.

No epiphyseal measurements of the radius are included among the 29 standard long bone variables (Buikstra and Ubelaker, 1994) that are nowadays routinely employed to assess sex, through canonical variate analysis, in forensic settings (Jantz and Ousley, 2005).

The purpose of the present study is to assess the potential for sex estimation from the maximum radial head diameter, as compared to the standard set of radial measurements currently used in forensic and bioarchaeological settings, as well as to two of the best stand-alone long bone sex estimators: the maximum head diameters of the femur and humerus.

Methods

A sample of White females (n=199) and White males (n=170) from the Hamann-Todd collection (Cleveland Museum of Natural History) were randomly selected for inclusion in the study. The sample ranged in age from 19 to 93 years old. The variables considered were: *maximum diameter of the femoral head, maximum diameter of the humeral head, maximum diameter of the radial head, maximum radial length, radial A-P diameter at mid shaft, and radial M-L diameter at mid shaft*, (all as defined by Buikstra and Ubelaker, 1994, and to the nearest mm). Only left bones were measured and individuals with damaged or pathological skeletal elements potentially affecting these measurements were not utilized. The maximum radial head diameter was taken by holding the calipers' beam parallel to the proximal most articular surface of the radial head and then rotating the jaws of the calipers around the head to obtain the maximum measurement to the nearest mm (Berrizbeitia, 1989).

Performance of radial head diameter as compared to all standard variables was first assessed through two forward-stepwise canonical variate analyses, using all variables (Table 1), and all radial variables, respectively. Prior probabilities were considered identical for both sex groups. In these analyses, variable performance was assessed in terms of rank order of entrance into the canonical function.

Additionally, discriminant functions for sex estimation were obtained for radial, femoral, and humeral head diameters, and the ability of each of these areas to diagnose sex was compared in terms of percent correct classification rates for each of the obtained discriminant functions.

Analysis of Covariance (ANCOVA) of radial head diameter on maximum radial length, with sex as the grouping variable, served to assess the existence of allometric sex differences in radial head morphology, as opposed to mere body mass dimorphism.

Results

Canonical Variate Analysis

The maximum diameter of the radial head was the first variable to enter the analysis (Table 2). The maximum radial length and the maximum humeral head diameter were excluded by the analysis. The resulting discriminant functions rendered a 95.4% correct classification (Table 3).

Table 1. Unstandardized canonical coefficients for stepwise discriminant function analysis including all measurements

Canonical Discriminant Function Coefficients

	Function 1
fem hd diam	.173
rad hd diam	.294
rad A-P mid diam	.542
rad M-L mid diam	-.214
(Constant)	-17.458

Unstandardized coefficients

Table 2. Variables Entered/Removed for stepwise discriminant function analysis including all measurements

Variables Entered/Removed[a,b,c,d]

		Wilks' Lambda				Exact F			
Step	Entered	Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	rad hd diam	.374	1	1	247	414.189	1	247	.00
2	rad A-P mid diam	.312	2	1	247	270.925	2	246	.00
3	fem hd diam	.292	3	1	247	198.132	3	245	.00
4	rad M-L mid diam	.279	4	1	247	157.329	4	244	.00

At each step, the variable that minimizes the overall Wilks' Lambda is entered.
a. Maximum number of steps is 12.
b. Maximum significance of F to enter is .05.
c. Minimum significance of F to remove is .10.
d. F level, tolerance, or VIN insufficient for further computation.

As expected from the previous analysis, radial head diameter was also the first variable to enter when only radial variables were considered. The three "standard" radial measurements also entered the analysis. This function achieved a 94.5% correct classification rate (Table 4).

Table 3. Classification results for discriminant function analysis including all measurements

Classification Results[b,c]

			Predicted Group Membership		
		sex	1	2	Total
Original	Count	1	125	11	136
		2	1	125	126
	%	1	91.9	8.1	100.0
		2	.8	99.2	100.0
Cross-validated[a]	Count	1	124	12	136
		2	1	125	126
	%	1	91.2	8.8	100.0
		2	.8	99.2	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
b. 95.4% of original grouped cases correctly classified.
c. 95.0% of cross-validated grouped cases correctly classified.

Table 4. Unstandardized canonical coefficients for discriminant function analysis including all measurements of the radius.

Canonical Discriminant Function Coefficients

	Function 1
rad hd diam	.430
rad A-P mid diam	.528
rad M-L mid diam	-.150
rad max Lnth	.013
(Constant)	-16.152

Unstandardized coefficients

Discriminant Function Analyses

The univariate discriminant function estimated from the radial head diameter rendered higher percent correct classification rates (92.5%)(Tables 5 and 6) than those obtained for the femoral head diameter (88.9%) and the humeral head diameter (88.8%). All discriminant function performed slightly better in classifying female individuals.

Table 5. Classification results for discriminant function analysis of the maximum radial head diameter

Classification Results[a]

			Predicted Group Membership		
		sex	1	2	Total
Original	Count	1	127	21	148
		2	3	171	174
	%	1	85.8	14.2	100.0
		2	1.7	98.3	100.0

a. 92.5% of original grouped cases correctly classified.

Table 6. Coefficients for discriminant function analysis of the maximum radial head diameter

Canonical Discriminant Function Coefficients

	Function 1
rad hd diam	.671
(Constant)	-14.837

Unstandardized coefficients

Analysis of Covariance

The analysis of covariance (ANCOVA) did not reveal significant sex differences in the allometric relationship between radial head diameter and maximum length, neither in slope nor in intercept (Figures 1 and 2). Therefore, sexual differences on radial head diameter appear to reflect sexual dimorphism exclusively in terms of body mass.

Figure 1. Regression lines of maximum radial head diameter on maximum radial length for both groups

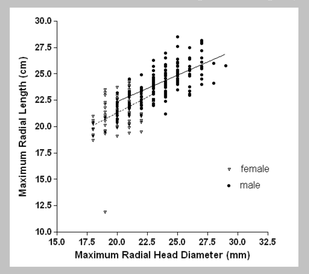
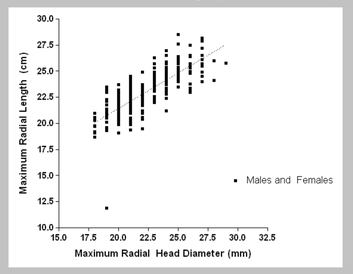


Figure 2. Pooled regression line of maximum radial head diameter on maximum radial length (after ANCOVA results)



Conclusions

- The maximum diameter of the radial head can be used as a reliable measurement to estimate sex in modern American "White" populations, rendering percent correct classifications above 90% when used as a stand-alone estimator.
- The ability of this measurement to discriminate between sexes is as strong as those of the femoral and humeral head diameters; measurements often relied upon for sex estimation.
- ANCOVA results indicate that sex differences in the maximum radial head diameter appear to be influenced only by overall body mass rather than by differential growth trajectories resulting in different allometric patterns in males and females.

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