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Sex Determination with the Head of the Radius

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ABSTRACT: Analysis of a sample of 1108 radii corresponding to 567 black and white North Americans in the Terry Collection at the Smithsonian Institution demonstrates that the diameter of the radial head is an accurate sex discriminator for human remains. A simple "radial-head method" of sex determination consists of measuring the maximum and minimum diameters of the head and comparing such measurements with the test cutoff points. The subject is female when the maximum radial head diameter (either left or right) is less than or equal to 21 mm, and male when the maximum diameter (either left or right) is greater than or equal to 24 mm. The same decisions apply to the minimum diameters of 20 mm or less and 23 mm or more, respectively. When the maximum diameter is 23 mm or the minimum is 22 mm, the subject is more likely male; when the maximum diameter is 22 mm or the minimum is 21 mm, the subject is more likely female. The sample frequency of any one of these latter diameters is never more than 16%.

Cross-validation of the method with a sample of 50 pairs of radii of the Terry Collection, different from the original specimens, resulted in 92% sexing accuracy when using the left radius singly, 94% accuracy when using the right radius singly, and 96% accuracy when using both radii jointly.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, sex identification, sex determination, radius, radial head method, sexual dimorphism, forensic anthropology

A basic problem in physical and forensic anthropology is determination of the sex of incomplete and fragmentary skeletal remains. In the absence of the pelvic bones and the skull, the diameter of the femoral head is generally the most used criterion, even though it is not as precise as the pelvic method. Other methods reported in the literature employ diverse measurements of the scapula, the sternum, the humerus, the radius, and the tarsal bones; although generally not very precise, such methods can be useful in determining sex when the principal indicators mentioned above are unavailable, excessively fragmented, or otherwise indistinct.

The objectives of this study are to show that the diameter of the head of the radius can be used to identify the sex of human remains with a high degree of accuracy and to develop a systematic method for this purpose.

The idea that the heads of the long bones can be used as sex discriminators can be traced at least as far back as the first decade of this century, when Dwight [1] stated: "it is very evident that the differences between the bones of the arm and thigh in the matter of length are much less important sexually than those of the diameters of the heads." According to

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Stewart [2], "Jose Pons of Barcelona, Spain, tried out the method first (1955) on several dimensions of the femur. . ."

A study by Singh et al. [3] used the radius as a trait to discriminate sex in Indian populations. Criteria included length, distal end width, and weight of male and female radii, as well as the circumferences of the head, tuberosity, and midshaft region. A method of "demarking points" was developed for determining sex with each of these measurements. It was found that "weight, length and distal end width [are] good discriminating factors for the identification of sex in both males and females" [3]. When applied to the circumference of the head of the radius, the demarking-point method determines sex in 34% of the right radii, and in 40% of the left radii.

Materials and Methods

All radii used are from the Terry Collection at the Smithsonian Institution. The collection consists of the skeletal remains of approximately 1600 modern black and white individuals; males predominate, as do blacks. All are documented by race, sex, age, and cause of death.

The diameters of the proximal ends (heads) of both right and left radii of each individual were measured using the blunt end of a sliding caliper (Gneupel). The results were rounded to the nearest whole millimetre. Both maximum and minimum diameters were obtained by rotating the caliper around the head. The age, sex, and race of the individuals in the sample were recorded after measurement by using the identification number to retrieve the information from the Terry Collection files.

The original sample consisted of 609 individuals. Sampling stopped when at least 100 individuals of each racial-sexual subgroup had been measured; the least numerous subgroup is white females. Some individuals were later discarded from the sample on the basis of one or more of the following criteria: age less than 21 years at death, to ensure skeletal maturity; non-U.S. nationals; race other than white or black; damaged radial heads; obvious pathological conditions, such as fractures, osteophytes, porosity, and eburnation.

The final study sample, totaling 567 individuals, has the following composition: 324 (57%) males, of which 152 (47%) are white and 172 (53%) are black, and 243 (43%) females, of which 103 (42%) are white and 140 (58%) are black. Overall, 255 (45%) individuals are white and 312 (55%) are black. The mean age of the females is 55 years (whites, 61; blacks, 52), and the mean age of males is 46 (whites, 53; blacks, 31). Data on both radii are not available for all individuals in the sample.

Results

The basic sample statistics presented in Table 1 indicate that there are no significant statistical differences between the mean diameters of the left and right radial heads (unpaired) of any given subgroup. Furthermore, the table strongly suggests that there are significant differences between the diameters of the radii of the two sexes. The mean differences between male and female radial head diameters range from 3.1 to 3.5 mm, depending on which of the four measurements are compared. These differences are generally twice as large as the standard deviations within any subgroup.

Table 2 summarizes the results of the "tests of differences between means" for the maximum diameters of the right radial heads of males and females in the sample. The tests indicate that the differences between means are statistically significant, that is, that the heads of male radii are definitely larger than those of female radii for both races. Similar results were obtained for the three other measurements of the radial head diameter.

Table 3 compares the relative percentage distributions, adjusted for missing observations, for the maximum diameter of the head of the right radius for black females and males. The choice of this particular diameter measurement and racial subgroup for the purpose of this example is arbitrary.

TABLE 1—Basic sample statistics: radial head diameter of sample population radii (in millimetres).

Diameter	Whites		Blacks	
	Male	Female	Male	Female
Left, maximum				
No. of observations	152	98	171	139
Mean	24.21	20.74	24.89	21.42
S.D.	1.74	1.74	1.54	1.26
Range	20-30	12-26	20-30	18-25
Left, minimum				
No. of observations	149	97	165	137
Mean	23.03	19.71	23.64	20.51
S.D.	1.68	1.65	1.53	1.19
Range	19-29	12-24	18-28	17-24
Right, maximum				
No. of observations	151	99	170	136
Mean	24.23	20.74	24.78	21.29
S.D.	1.65	1.57	1.48	1.30
Range	20-29	14-26	19-29	19-27
Right, minimum				
No. of observations	146	96	165	135
Mean	22.91	19.79	23.55	20.33
S.D.	1.56	1.43	1.47	1.25
Range	19-27	13-25	18-28	17-25

TABLE 2—Tests of differences between means of female and male radii maximum diameter of the head of the right radius.

Basic Statistics	Whites		Blacks	
	Females	Males	Females	Males
No. of observations	99	151	136	170
Mean	20.74	24.23	21.29	24.78
S.D.	1.581	1.569	1.300	1.478
S.E.	0.158	0.134	0.111	0.113
Pooled Variance Estimate				
	Whites		Blacks	
<i>F</i> -Test for variance	N.S. ^a		N.S. ^a	
Diff. between means	3.49		3.49	
<i>T</i> -value	16.72		21.63	
Degrees of freedom	248		304	
2-tail probability	< 0.001		< 0.001	
1-tail probability	< 0.001		< 0.001	

^aThe variance of the white females was compared with that of the white males and no significant differences were detected by the *F*-test. However, when a similar test was performed for the black specimens, slight heterogeneity at or near the 5% level was detected. Since the loss of power is known to be so slight under this condition (Cochran [4]; Brown and Forsythe [5]), a Student's *t*-test rather than a Welch's test of the means was used for consistency of presentation among the races.

TABLE 3—Percentage distribution of maximum right radial head diameter for black females and black males.

Observed Diameter, mm	Adjusted Relative Percentage Distribution			Proportional Distribution of Observed Diameters According to Sex	
	(1) Black Females, %	(2) Black Males, %	(3) Both Sexes, %	(4) Black Females, %	(5) Black Males, %
19	8.1	0.6	4.4	93.1	6.9
20	16.2	0.0	8.1	100.0	0.0
21	36.0	1.2	18.6	96.8	3.2
22	24.3	3.5	13.9	87.4	12.6
23	11.0	11.2	11.1	49.5	50.5
24	3.7	21.8	12.8	14.5	85.5
25	0.0	35.9	18.0	0.0	100.0
26	0.0	15.3	7.7	0.0	100.0
27	0.7	7.1	3.9	9.0	91.0
28	0.0	2.4	1.2	0.0	100.0
29	0.0	1.2	0.6	0.0	100.0

The first two columns of Table 3 give the relative percentage distributions of the maximum diameter of the right radial head for black males and females. For the sake of simplicity, Column 3 assumes a "50-50" distribution of males and females in the black population of North America. The same assumption applies to Columns 4 and 5, also derived from Columns 1 and 2, which show the proportional distribution of each observed diameter between the two sexes. For example, the 22-mm diameter corresponds with black females in 87.4% of the observations and with black males in 12.6% of the observations.

The information in Columns 1 and 2, presented graphically in Fig. 1, shows the very strong sexual dimorphism of the maximum diameter of the right radial head in black males and females. Figure 1 indicates that, among black North Americans, right radial heads with diameters of 24 mm or more are predominantly male, and those with diameters of 21 mm or less are predominantly female. Indeed, at least 85% of the sample observations of any one of these diameters are either male or female, as indicated by Columns 4 and 5 of Table 3.

The 23-mm diameter occurs with almost equal frequency in both sexes and is thus the least discriminating measurement; however, it occurs in only 11.1% of the observations.

Inspection of Fig. 1 shows that, for blacks, the maximum right radial head diameter of 23 mm is the appropriate sectioning point for sex identification purposes. Radii with diameters greater than 23 mm are identifiable as males, and radii with diameters less than 23 mm are identifiable as females. The sex of radii with maximum diameters of 23 mm is not determinable in blacks using this type of analysis.

Table 4 summarizes the results of the analysis as applied to maximum and minimum diameters of the right and left radial heads in the sample. The table indicates that, in general, one sex predominates by at least 80% for any given radial head measurement. The exceptions, indicated with an asterisk, range from 22 to 23 mm for the maximum diameters and from 21 to 22 mm for the minimum diameters. However, their frequency is never more than 16%.

Discussion

Using the 80% cutting point for classifying the diameters by sex, Table 4 indicates that, for both races, sex is correctly identified in at least 83% of all radii with maximum head diameters of 21 mm or less and 24 mm or more, and in at least 82% of all radii with mini-

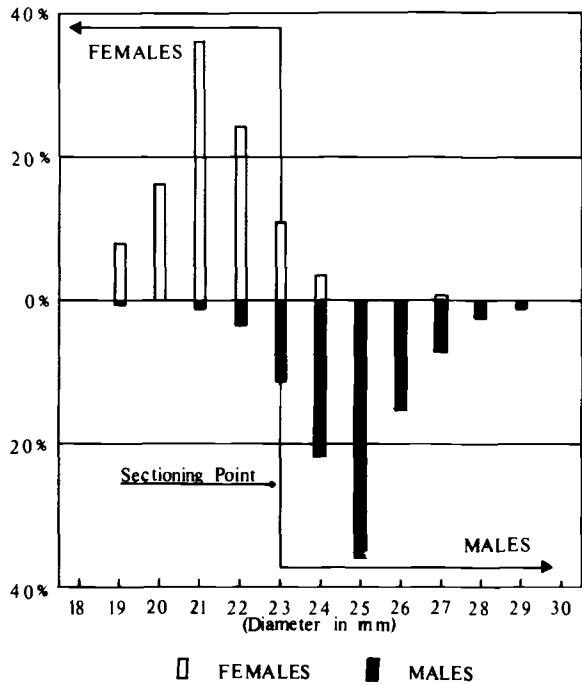


FIG. 1—Adjusted relative frequencies of right radial head maximum diameter in blacks.

um head diameters of 20 mm or less and 23 mm or more. Furthermore, several diameters allow for correct identification of 90 or even 100% of observations.

For whites, sexual ambiguity is highest for a 22-mm maximum diameter and for a 21-mm minimum diameter, although the former is more likely to correspond with females. Also, a maximum right radial head diameter of 23 mm is somewhat ambiguous in whites, although with 78.7% male predominance it nearly satisfies the 80% classification criterion.

For blacks, sexual ambiguity is highest for a maximum diameter of 23 mm and for a minimum diameter of 22 mm, both of which are almost evenly distributed between males and females.

These results show the strong sexual dimorphism of the diameter of the radial head and suggest that it can be used to determine sex more accurately than with any other method currently in use, except those based on the pelvis. Thus, the diameter of the radial head can provide a reliable alternative for sex determination under forensic or archeological conditions when the pelvic bones are missing, fragmented, or otherwise indistinct. As with any other method, this approach is complementary to other types of analyses, and all available evidence should always be applied in determining the sex of skeletal remains.

These results can be generalized and combined for both racial groups into a simple radial-head method of sex determination for North American black and white populations, as indicated in Table 5. The subject is considered female if the maximum diameter is less than or equal to 21 mm or the minimum diameter is less than or equal to 20 mm. The subject is considered male if the maximum diameter is greater than or equal to 24 mm or the minimum diameter is greater than or equal to 23 mm. Table 5 also provides the more likely decision associated with the ambiguous diameters. Figure 2 presents the same decision method in graphic form.

TABLE 4—Sample results of radial head analysis of sex determination classification of observations by predominant sex.

Observed Diameter, mm	Whites			Blacks		
	Predominant Sex	Percent Classified	Sample Frequency, %	Predominant Sex	Percent Classified	Sample Frequency, %
Right, maximum						
21—	F	92-100	40.0	F	93-100	31.1
22	F	58.8 ^a	12.0	F	87.4	13.9
23	M	78.7 ^a	14.3	M	50.5 ^a	11.1
24+	M	86-100	33.7	M	85-100	44.0
Left, maximum						
21—	F	90-100	38.4	F	96-100	28.9
22	F	67.1 ^a	16.0	F	84.5	13.2
23	M	83.6	9.5	F	59.7 ^a	14.5
24+	M	90-100	36.3	M	83-100	43.5
Right, minimum						
20—	F	90-100	41.5	F	89-100	31.6
21	F	53.8 ^a	12.6	F	85.2	12.2
22	M	80.1	15.8	F	50.6 ^a	15.4
23+	M	87-100	30.1	M	92-100	40.9
Left, minimum						
20—	F	92-100	41.0	F	82-100	27.4
21	F	52.4 ^a	14.8	F	92.4	15.8
22	M	83.2	9.3	M	52.2 ^a	14.6
23+	M	91-100	35.0	M	83-100	42.2

^aLess than 80% of observations of this diameter correspond to one sex.

TABLE 5—Radial head method of sex determination for North American blacks and whites.

Observed Diameter, mm	Decision ^a (Maximum Diameter)	Observed Diameter, mm	Decision ^a (Minimum Diameter)
21—	F	20—	F
22	U/F	21	U/F
23	U/M	22	U/M
24+	M	23+	M

^aF = female; U/F = uncertain, more likely female; M = male; U/M = uncertain, more likely male.

Conclusion

The method was tested against a different sample of 50 pairs of radii in the Terry Collection. The sample consisted of 30 (60%) males, of which 20 (67%) were black and 10 (33%) were white, and of 20 (40%) females, of which 7 (35%) were black and 13 (65%) were white. The mean female age was 59 years (whites, 62; blacks, 50), and the mean male age was 50 (whites, 64; blacks, 42). The maximum and minimum diameters of each radial head were used separately and then jointly. Cross-validation in this manner resulted in 92% sexing

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