TECHNICAL NOTE

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Sex Determination by Discriminant Function Analysis of the Petrous Portion of the Temporal Bone

REFERENCE: Kalmey JK, Rathbun TA. Sex determination by discriminant function analysis of the petrous portion of the temporal bone. J Forensic Sci 1996;41(5):865–867.

ABSTRACT: Morphometric variables on the human petrous portion of the temporal bone can provide identification of sex in fragmented skeletal remains. The petrous frequently survives circumstances that cause skeletal fragmentation. Using discriminant function analysis of seven combinations of five variables, up to 74% accuracy can be obtained in determining sex from the petrous portion.

KEYWORDS: forensic science, sex determination, petrous portion, fragmentary remains, physical anthropology, temporal bone, discriminant function

Determining sex in fragmentary adult human remains poses many problems for forensic anthropologists. The typical skeletal indicators of sex, such as those found in the innominates, may frequently be missing or fragmentary, precluding a determination of sex. Other skeletal elements subjected to morphological or statistical analysis may provide sex indicators. Discriminant functions have been developed by anthropologists to enable determination of sex in fragmentary remains: Holland (1–3) developed equations based on the cranial base, Marino (4) analyzed the first cervical vertebra, and Teixeria (5) used the foramen magnum to determine sex.

To provide an additional indicator of sex in fragmentary remains, nine dimensions on the left and right petrous portions of temporal bones from the Terry Collection were analyzed by discriminant functions. The adult petrous portion was chosen as the site to carry out such a technique because of its survivability in fragmentary remains. The petrous survives when other indicators of sex do not because it is one of the hardest bones in the body (6), and it is contained within the cranium that gives it a great deal of protection.

Methods

The individuals used in this study came from the Terry Collection at the Smithsonian Institution, Washington, DC. The sample consisted of 30 females of European ancestry, 36 females of African ancestry, 36 males of European ancestry, and 36 males of African ancestry. It is recognized that secular change has occurred since these individuals were collected and that a more contemporary sample might yield variable results. However, to measure the petrous portion completely, it was necessary that the skulls had been sectioned both sagittally and transversely. No current sectioned sample of sufficient size and documentation was available for analysis. Nine dimensions on both the right and left petrous portions were analyzed by discriminant analysis to determine which combination of the variables offer the best discriminating power to determine sex (Table 1, Fig. 1).

The dimensions were chosen for their prominent or easily identified landmarks and the survivability of such landmarks in fragmentary conditions. Also, the dimensions were chosen to allow at least one measurement on any fragmentation of the petrous. Sliding calipers graduated to one millimeter were used for all measurements, except dimensions HI, D, and F for which a Helios vernier dial caliper was used (values were recorded to the nearest tenth of a millimeter).

Discriminant Analysis

Discriminant function analysis was carried out on the data to discern the sexually dimorphic features on the petrous portion.

TABLE 1—*Description of measurements.**

Measurements		
L	=	Sigmoid sulcus-petrous apex intersection (SS) to the most medial point on the petrous (med. pt.) (sliding caliper)
C	=	SS to posterior (lateral) margin of internal acoustic meatus (IAM) (sliding caliper)
E	=	Posterior margin of IAM to eminentia arcuata (EA). Take measurement on EA at the highest point; if EA is plateau or if it has two peaks at either end then take the measurement in the center (sliding caliper)
HI	=	Height of IAM (taken at center of meatus) (vernier dial caliper)
B	=	Cochlear aqueduct (CA) to EA (sliding caliper)
D	=	CA to superior margin at IAM (center of superior IAM) (vernier dial caliper)
F	=	CA to posterior (lateral) margin of IAM (from Wahl [7]) (vernier dial caliper)
G	=	EA to med. pt. (sliding caliper)
W	=	CA to hiatus of facial canal (sliding caliper)

*Rs and Ls attached to measurements denote right and left side.

Received for publication 28 July 1995; revised manuscript received 11 Oct. 1995 and 25 Jan. 1996; accepted for publication 29 Jan. 1996.

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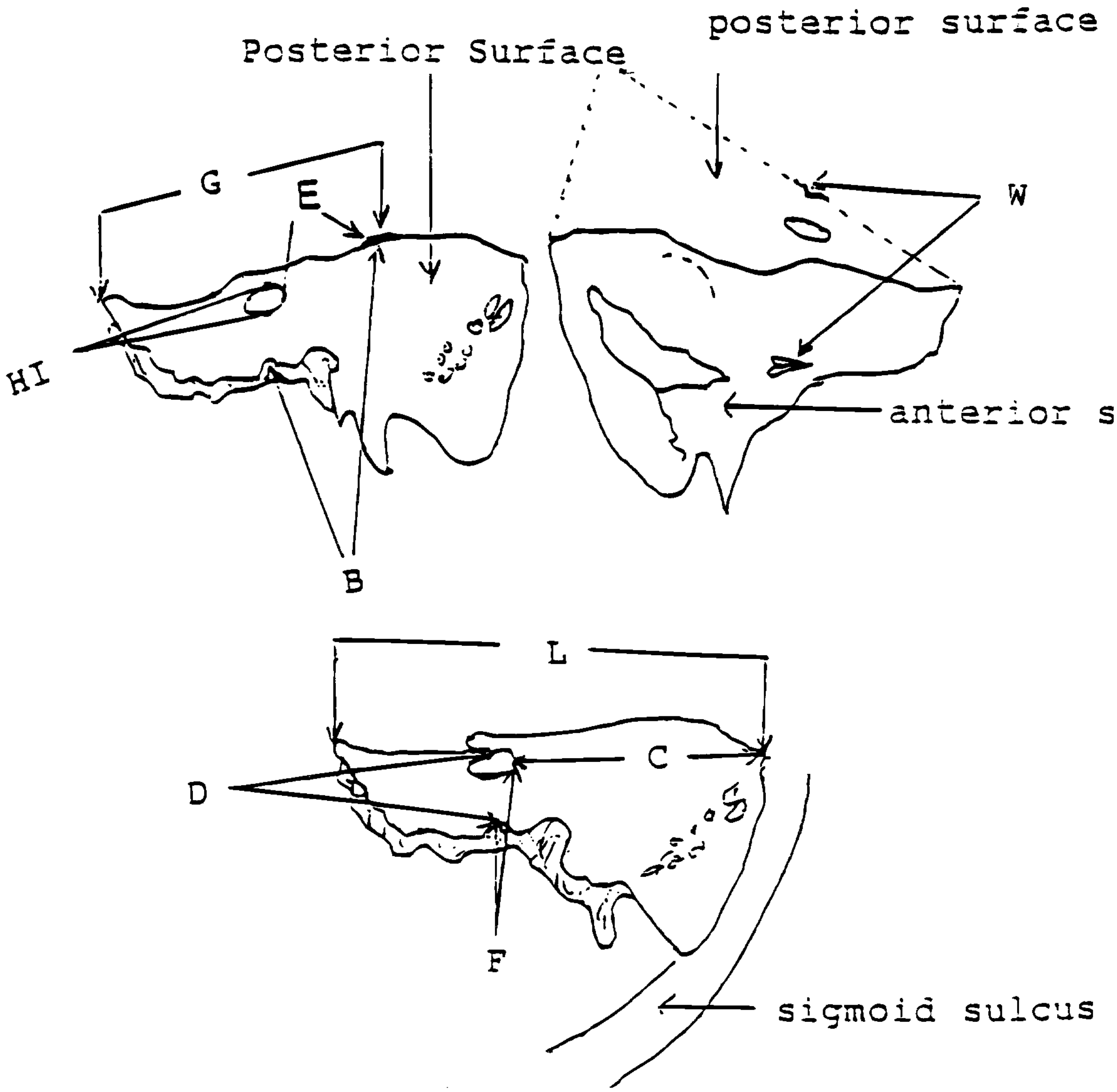

FIG. 1—*Illustration of measurements, viewing right petrous section.*

Discriminant function analysis is a statistical technique that enables the researcher to examine the relationships among two or among more groups based on any number of variables simultaneously (8). By multiplying the discriminant coefficients by the measurements and adding them to obtain the discriminant score, discriminant function analysis condenses a multivariate problem into unvariate simplicity (9).

The discriminant functions were developed from the 138 individuals (one European female had missing values and was not incorporated into the functions) from the Terry Collection using SAS software and then tested for accuracy by cross-validation. Although an outgroup test sample of 18 individuals from the Terry Collection was analyzed and produced accuracies up to 83%, cross-validation was suggested as a way to increase sample evaluation accuracy. Cross-validation, also referred to as jackknifing, produces unbiased accuracy ratings by treating each individual as an out-group. Each individual is tested by a discriminant function created from all the data except that individual (10). The accuracies obtained from cross-validation are reported in Table 2.

All combinations of variables were attempted to provide the best possible accuracy of sex determination. The equations reported were those that were 65% accurate or higher. Less parsimonious equations offering no additional accuracy were not reported.

To use the discriminant functions in this method, the discriminant coefficients in Table 2 are multiplied by the measurements and their products are then added with the constant (*K*) resulting in the discriminant score for the individual in question. The score is then compared to the section point. Males are greater than and females less than all section points. The equations in the unvariate functions (females $< x <$ males) can be used on the raw measurements to determine sex.

There were no statistically significant ancestral differences for the five variables used to determine sex. Therefore, the functions contained herein can be applied without knowledge of ancestry. In forensic practice, if fragmentation is so extensive as to necessitate using this alternative method of sex determination, it is unlikely that ancestral grouping could be determined, thus, making this method ideal for fragmentary remains.

Statistical Analyses and Results

To discern if the petrous portion was sexually dimorphic and on which variables, descriptive and analytical-statistical evaluations

TABLE 2—*Discriminant coefficients, constants, and male and female mean scores.**

Variable, mm	Discriminant Functions 1	2	3	4	5	6	7
LL	0.1756	0.0120	−0.0473				
LR		0.2219	0.1788	0.1816			
DR		0.5888			0.5751		0.8890 female < 8 < male
GR			0.1740	0.1961	0.2328	0.3180 female < 35.43 < male	
DL	0.6643		0.4722				
K	−14.58	−16.74	−16.86	−16.29	−12.88	−11.29	−7.13
Male mean	0.4018	0.5623	0.6046	0.5091	0.5714	0.4361	0.3898
Section point	−0.02	−0.03	−0.03	−0.03	−0.03	−0.02	−0.02
Female mean	−0.4383	−0.6229	−0.6698	−0.5639	−0.6329	−0.4831	−0.4317
Accuracy	70%	72%	74%	71%	73%	66%	69%

*Female < x < male shows raw measurement section points between male and female. K is the constant. Accuracies are from crossvalidation of the entire sample. Example Equation 1: LL in mm(0.1756) + DL in mm(0.6643) + K = score.

were carried out on the measurements. Table 3 shows the male and female means on all of the dimensions used in the discriminant functions. They were found to be statistically significant to less than $p = 0.05$ as tested by two-tailed t-tests. As the means illustrate, the male values are larger than the female values on all variables. Variables C, B, E, and W were not statistically different between the sexes at a p-value below 0.05 and are not reported in Table 3. Dimension GL showed statistically significant differences between ancestral groups of females and was thus not used in the sex functions.

The replicability percent error was calculated using the method in Holland (1). Variables HI and F were the only variables above the threshold of 3.5% error and were not incorporated into the discriminant functions.

Discussion

As shown above, sex determination from the petrous portion may be a valuable tool for forensic anthropologists. This method will allow more information to be gained from fragmentary human remains when the petrous portion is present. This additional information should result in a more exact biological profile of the remains. In addition to possibly being the sole indicator of sex in fragmentary remains, the petrous portion can also be used as a collaborative indicator of sex when several are present. Further discussion on sexual dimorphism in the petrous portion as well as preliminary results on the analysis of archaeological material can be found in Kalmey (11).

As in all morphometric studies, the results are most applicable without reservation to the population from which they came. However, with appropriate caution exercised when applying these data to specimens from other populations, the results may have analytical usage. Continued testing of results with appropriate cases or autopsy samples should help evaluate the results of this initial study. Of course, we welcome reports of results of others' application of the method.

TABLE 3—*Means, standard deviations, and* p-*values.*

Variable	Sex*	Mean	Standard Deviation	p Value
DL†	F	7.94	1.11	0.0001
	M	8.69	1.16	
LL	F	50.52	2.82	0.0014
	M	52.43	3.93	
DR†	F‡	7.54	1.00	0.0000
	M	8.46	1.22	
LR	F‡	49.91	2.85	0.0000
	M	52.69	3.36	
GR	F‡	33.98	3.02	0.0000
	M	36.88	3.25	

*Males $N = 72$, Females $N = 66$.
†R = right; L = left.
‡$N = 65$.

Acknowledgments

Thanks are due to Dr. Richard Meindl, Dr. David Hunt, Pat Lieberson, and Holmes Finch for their assistance during this research and its publication.

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