TECHNICAL NOTE

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Race Determination of Fragmentary Crania by Analysis of the Cranial Base

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ABSTRACT: The cranial base can be used to determine the race of fragmentary skulls. An initial study used 8 measurements taken from 100 crania in the Terry Collection. The sample was divided equally by race and sex. Five regression models were formulated that predicted correctly the race of the sample with 70 to 86% accuracy. In a separate test, a control sample of 20 skulls, also drawn from the Terry Collection but not involved with formulating the regression equations, was correctly classified with 75 to 90% accuracy.

KEYWORDS: physical anthropology. musculoskeletal system, human identification

In 1962, Giles and Elliot [*1*] noted that the skull "provides more indication of race than any other skeletal part." But while encouraged by the utility of the skull for making racial determinations, they noted the difficulty involved in quantifying objectively those features that suggest racial affinity. In response to this difficulty, they offered a discriminant function technique that could objectively classify the sociological race of an individual based on eight cranial measurements. The measurements consisted of glabello-occipital length, maximum width, basion-bregma height, basion-nasion distance, basion-prosthion distance, bizygomatic diameter, prosthion-nasion height, and nasal breadth. Using a sample of American blacks and whites from the Terry and Todd collections and American Indians from the Indian Knoll site, Giles and Elliott [*1*] correctly predicted back the race (that is, white, black, or Indian) in 82.6% of the males and 88.1% of the females from the same sample from which they developed the discriminant functions.

Although the Giles and Elliot technique provides good results, its use is limited. The required measurements can only be obtained from intact or largely intact skulls. The same handicap exists for Giles and Elliot's [*2*] technique for determining sex.

Since not all forensic skulls are intact, a technique that is applicable to fragmentary crania is needed. This paper presents the results of a study of the feasibility of using the cranial base to determine race. The study is an outgrowth of recent work by the author[2] that suggests the

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[2]T. D. Holland, "Sex Determination by Multiple-Regression Analysis of the Cranial Base," unpublished Master's thesis, Department of Anthropology. University of Missouri-Columbia, 1985.

cranial base, especially the area of the occipital condyles and foramen magnum, is effective in identifying sex.

Sample

Two samples, both drawn from the Terry Collection,[3] were used in the study. Both samples consisted of equal numbers of blacks and whites between the ages of 20 and 50. The collector's assignment of race to an individual was made in light of social, legal, and morphological considerations, and while these classifications are of value in segregating individuals into socially important categories, they should not be regarded as accurate measures of genetic affinity. The samples consisted of equal numbers of males and females, and all crania with pathologies or abnormal growth that would have affected normal development of the skull's base were removed. Sample 1 ($N = 100$) was used to formulate the regression equations shown in Table 2. The second sample ($N = 20$), not used in formulating the regression models, served as a control.

Measurements

The following eight measurements were taken from the sample skulls. Each measurement was made with vernier sliding calipers graduated to 1 mm. Fractions were expressed to one decimal place.

Length of Occipital Condyle

Maximum length of (left) condyle as measured along its long axis from the ends of the articular surface [*3*].

Width of Occipital Condyle

Maximum width of (left) condyle as measured from the articular edges along a line perpendicular to the length [*3*].

Minimum Distance Between Condyles

Minimum distance between the lateral edges of the articular surfaces of the condyles perpendicular to the mid-sagittal plane.

Maximum Distance Between Condyles

Maximum distance between the lateral edges of the articular surfaces of the condyles perpendicular to the mid-sagittal plane.

Maximum Interior Distance Between Condyles

Maximum distance between medial margins of condyles perpendicular to the mid-sagittal plane.

[3]The Terry Collection is the property of the Department of Anatomy, Washington University School of Medicine, St. Louis, MO and is currently on indefinite loan to the Smithsonian Institution, Washington, DC.

TABLE 1—*Sample 1 statistics.*

Category	Age	Length of Condyle, mm	Width of Condyle, mm	Minimum Distance, mm	Maximum Distance, mm	Maximum Interior Distance, mm	Length of Foramen Magnum, mm	Width of Foramen Magnum, mm	Length of Basilar Process, mm
				MEANS					
White female	40.0	23.9	11.4	18.0	50.3	45.1	34.7	30.4	25.4
White male	40.3	25.7	12.6	20.0	52.9	46.3	38.0	31.8	27.2
Black female	35.2	21.8	11.8	18.2	46.9	41.3	34.6	28.4	28.0
Black male	35.5	25.0	13.1	22.0	50.5	44.0	37.1	31.1	30.0
				STANDARD DEVIATIONS					
White female	6.52	2.89	1.17	2.00	3.94	3.48	2.73	2.27	1.98
White male	6.74	2.80	1.41	3.29	3.43	2.89	2.50	1.99	1.84
Black female	6.80	1.95	1.00	2.26	3.06	3.87	3.09	2.56	2.27
Black male	5.80	2.00	1.74	4.44	3.11	2.78	2.22	1.84	3.73

Length of Foramen Magnum

Maximum length of the foramen magnum as measured from basion to opisthion along the mid-sagittal plane [*4*].

Width of Foramen Magnum

Maximum width of foramen magnum as measured perpendicular to the mid-sagittal plane [*4*].

Length of Basilar Process

Maximum length of the basilar process as measured from basion to hormion [*4*].

Twenty percent of the sample was remeasured after a period of three days to determine measurement replicability. All eight measurements had an average error of less than 3.0%, with measurements of the foramen magnum providing the most accurate remeasurements. Sample statistics are listed in Table 1.

Regression Equations

The regression models were constructed using the MINITAB package [*5*] (REGRession program; MINITAB release 81.1). This procedure is functionally equivalent to simple linear discriminant function analysis [*6*]. Calculations were made on the University of Missouri's IBM 3081-D system computer. Race was treated as the criterion variable and was coded as 0 for white, 1 for black. The resulting equations produced individual regression scores on a continuum bounded by 0 and 1 (approximately), with 0.5 as the sectioning point. Scores less than 0.5 classify white individuals, and scores greater than the sectioning point indicate black individuals. By comparing the predicted race with the recorded race, the accuracy of each equation could be calculated [*7*].

Five regression equations are shown in Table 2. These five were selected for their reliability in predicting race and for their applicability to fragmentary skulls. Also included in the

TABLE 2—*Multiple-regression equations for predicting the race of fragmentary crania.*

Equation number Number of measurements	1 6	2 5	3 5	4 4	5 3
Length of occipital condyle	−0.0224	...	−0.0095	−0.0420	...
Width of occipital condyle	...	...	...	0.0806	...
Minimum distance between condyles	0.0345	0.0338	0.0347	...	0.0239
Maximum distance between condyles	−0.0236	−0.0329	−0.0063	...	...
Maximum interior distance between condyles	−0.0161	−0.0159	−0.0428	...	−0.0536
Length of foramen magnum	...	...	...	0.0284	...
Width of foramen magnum	−0.0185	−0.0200	−0.0201	−0.0650	...
Length of basilar process	0.0777	0.0756	...	...	0.0712
Constant	0.669	0.706	2.87	1.48	0.425
Sectioning point	0.5	0.5	0.5	0.5	0.5
Percent accuracy Group 1 (N = 100)	86.0	82.0	72.0	70.0	80.0
Percent accuracy Group 2 (N = 20)	90.0	85.0	75.0	75.0	80.0

table is the number of measurements required for the particular equation. To use the table, the value of the required measurement (in millimetres), is multipled by the appropriate coefficient located opposite the measurement designation. The sum of the products, added to the appropriate constant, is the regression score. The last two rows of Table 2 indicate the accuracy of the equation in predicting the race of the two sample groups. The results of the tests are shown in Figs. 1 and 2.

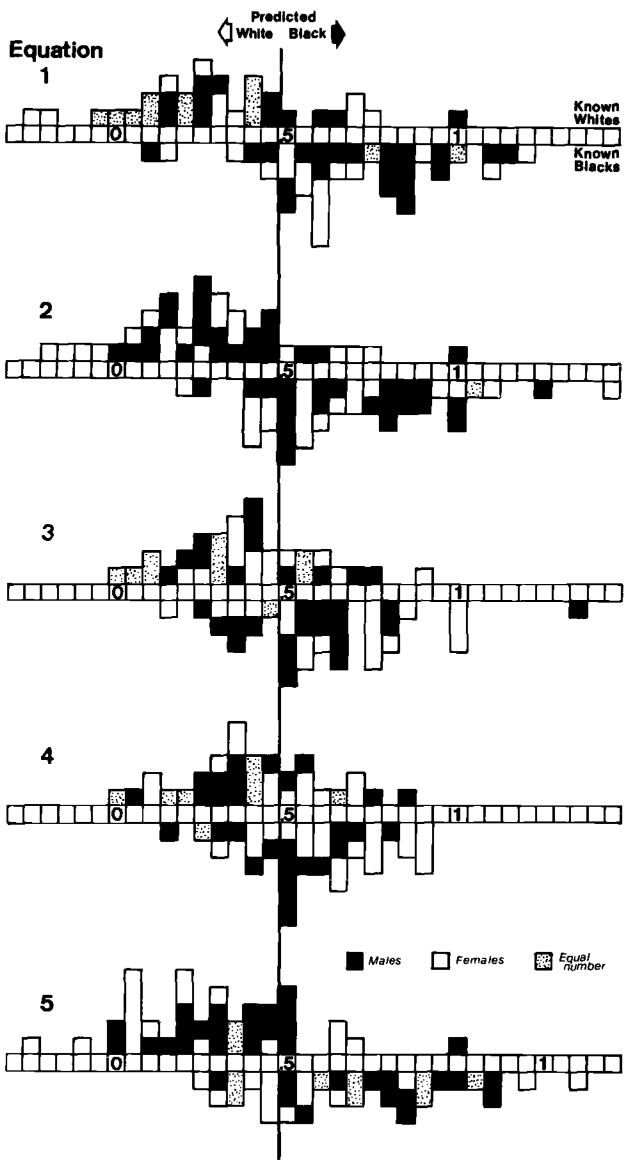

FIG. 1—*Distribution of regression scores for Group 1.*

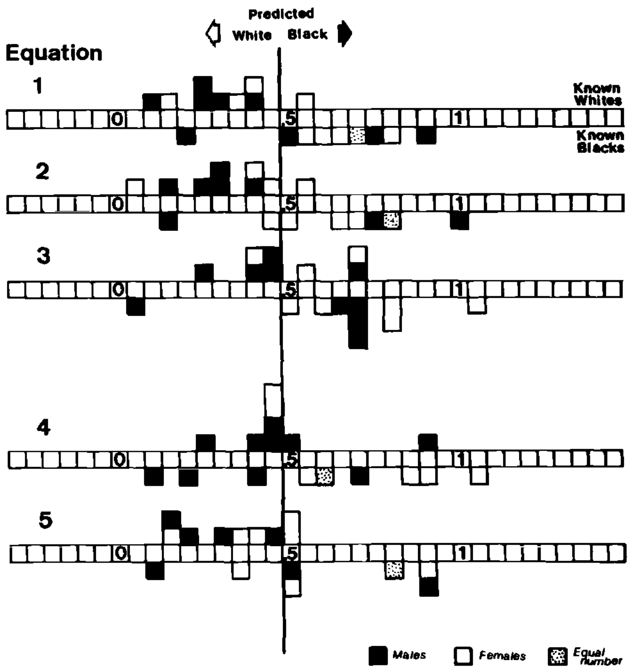

FIG. 2—*Distribution of regression scores for Group 2.*

Summary

As Figs. 1 and 2 illustrate, the cranial base appears to have some use in determining race. While the technique applied here may be less accurate than that proposed by Giles and Elliot [*1*], it may be more applicable in cases where the skull is fragmentary. Furthermore, the sex of the case need not be known.

Although the technique proved effective in determining the race of dissection room individuals, more work should be done before this technique can be used with confidence for forensic science cases. The Terry Collection, like most dissection room assemblages, exhibits several biases. In general, the collection consists of older individuals and is predominantly male. In addition, individuals in such collections are commonly indigents from the lower economic classes. In particular, the Terry Collection is composed of individuals from a limited geographic area, essentially St. Louis, MO.

Several of the biases could be controlled for by the careful selection of the specimens. For example, selecting only individuals between the ages of 20 and 50 eliminated the age bias. Likewise, the selection of equal numbers of males and females of both races controlled for any sex and race biases. But while the demographic aspects of the sample could be controlled, the biases introduced by sampling a localized, indigent population could not. The extent to which these factors influenced diet, and thereby normal growth, is unknown. For this reason, larger samples, preferably drawn from several geographic regions, should be tested. Until such testing takes place, the technique presented here should be applied with appropriate caution.

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