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Sex and Race Determination of Crania by Calipers and Computer: A Test of the Giles and Elliot Discriminant Functions in 52 Forensic Science Cases

The sex and race of unidentified skeletons must sometimes be determined by medical examiners or crime laboratory personnel who have no formal training in physical anthropology. Their diagnoses, based on a hasty review of the chapter on skeletal identification in a forensic pathology textbook or on old lecture notes from a homicide seminar, are often wrong. Such knowledge cannot always substitute for the skilled eye and practiced judgment of a physical anthropologist who, in the course of his career, may have examined hundreds of skeletons.

About 15 years ago, Giles and Elliot [*1*] published in this journal a set of discriminant functions (DF) for the diagnosis of sex and race from eight cranial measurements. Taken with simple calipers from precisely defined landmarks, these measurements can be accurately obtained after a little practice. The mathematics involved are sufficiently straightforward that the diagnoses of sex and race, in the form of numerical DF scores, may be computed in minutes either by hand or on a small calculator. In tests of these functions carried out on independent samples drawn from the same skeletal collections (Terry, Todd, and Indian Knoll) from which they were derived, sex and race were correctly assessed in about 85% of the cases [*1,2*]. This success rate approximates that of experienced anthropologists (at least those who have dared publish their results!) in sexing and racing crania by inspection [*3,4*].

Clearly, the method offers a promising tool to forensic scientists as it allows nonanthropologists to determine the sex and race of unknown crania with about the same degree of confidence as the expert. The simplicity of the technique and the ease with which it lends itself to computer programming also make it potentially useful in mass disasters, where relatively inexperienced personnel may be required to identify large numbers of bodies within a short time [*5,6*]. This need was dramatically illustrated in the recent Boeing 747 collision at Tenerife in which about one third of the 217 U.S. fatalities went to their graves unidentified. Thus, in addition to being the largest aviation disaster in history, the Tenerife crash has been characterized as a "forensic disaster" [*7*].

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The purpose of this paper is to evaluate the effectiveness of the Giles and Elliot discriminant functions in a series of actual forensic cases.

Materials and Methods

A linear discriminant function is a function that weights a set of metric characters in such a way that the members of one taxon have higher values of the function than those of another. Applied to an unknown specimen, the function assigns it to one taxon or the other with a minimum chance of error (see Refs *1,2,5,6,8-11*[4] for mathematical treatment and applications). In the present context, the "unknown" is an unidentified cranium, its "characters" are eight linear measurements, assignable taxa are "male" and "female" for sex and "white," "black," and "American Indian" for race.

The first function of the set provided by Giles and Elliot [*1*] uses five measurements in millimetres and appropriate weighting coefficients to diagnose sex:

$$\begin{aligned} DF = {} & 1.16\,(\text{cranial length}) + 1.66\,(\text{basion-nasion length}) + 3.98\,(\text{bizygomatic breadth}) \\ & - 1.00\,(\text{basion-prosthion length}) + 1.54\,(\text{prosthion-nasion height}) \end{aligned}$$

The sectioning point of this function is 891.12. If the DF score of a specimen is less than 891.12, it is considered female; if the DF score is greater than 891.12, it is classified as male.

Two DF, each using all eight cranial measurements, are used to diagnose race. The first assigns the specimen a DF score along a "white-black" axis; the second assigns a DF score along a "white-Indian" axis. Using the white-black axis as the ordinate and the white-Indian axis as the abscissa, the scores are plotted on a graph divided into "white," "black," and "Indian" zones by the DF sectioning points (Fig. 1). Race is determined by the zone within which the point plotted for the unknown specimen falls.

The procedure is used to determine the race of crania of both sexes. However, the weighting coefficients of the measurements used to determine race for males differ from those used for females. These coefficients and the sectioning points of the DF are given in Table 1.

The test sample used in the present study was drawn from more than 75 complete human skeletons submitted since 1967 to the senior author's laboratory for identification. Two criteria were used in selecting a specimen to test the DF used to diagnose sex:

1. The cranium was sufficiently intact and undeformed to allow the required measurements to be taken accurately.
2. The sex of the specimen was known, having been established by either positive identification of the individual or unambiguous, noncranial evidence, such as pelvic morphology, soft tissues, or associated artifacts (such as clothing or jewelry).

Using these criteria, we selected 52 intact crania of known sex from our total case series. The sex and race of these crania are given in Table 2. In the preponderance of males (77%) and whites (64%), our test sample is probably a fair representation of the skeletal cases examined in U. S. forensic science laboratories. American Indians (17%) are somewhat overrepresented, reflecting the rather large Indian population of Oklahoma, the state from which most of the cases were submitted.

To test the race DF, we required specimens of known race and sex. A review of the case histories of the 52 known-sex crania revealed some in which race could not be firmly documented. For instance, the sex of several could be confidently diagnosed from the pelvis or associated artifacts but no corresponding noncranial evidence was available to determine race. Elimination of such cases reduced the sample to be used in testing the race DF to 42.

[4]C. C. Snow and S. Pinski, unpublished results, 1978.

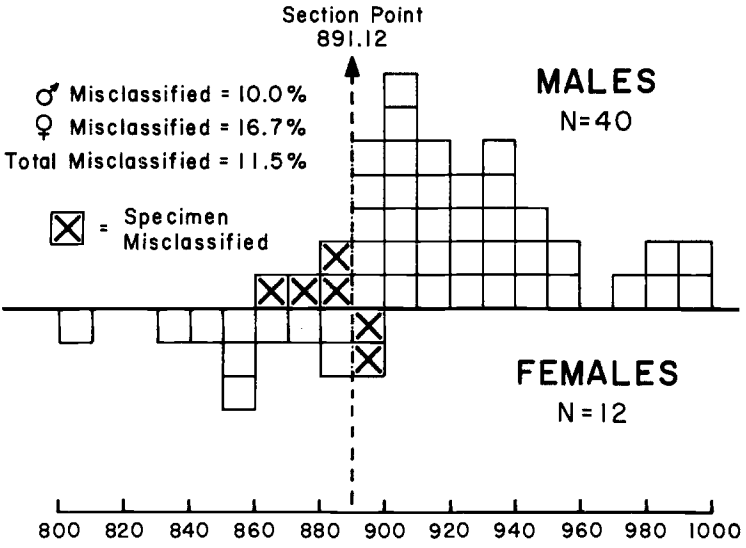

FIG. 1—*Distribution of DF scores of 52 crania of known sex.*

TABLE 1—*Coefficients and sectioning points of Giles-Elliot DF for racial diagnosis of crania* [1].

	Male		Female	
Measurement	White-Indian	White-Black	White-Indian	White-Black
Glabella-occipital length	−0.25	1.60	−1.04	1.28
Cranial breadth	−1.56	−1.90	−5.41	−1.18
Basion-bregma	0.73	−1.79	4.29	−0.14
Basion-nasion	−0.29	−4.41	−4.02	−2.34
Basion-prosthion	0.10	3.06	3.05	1.74
Bizygomatic breadth	1.75	−0.10	5.62	0.38
Prosthion-nasion	−0.16	2.59	−1.00	−0.01
Nasal breadth	−0.84	10.56	−2.19	2.45
Sectioning point[a]	22.28	89.27	130.10[b]	92.20[b]

[a] If DF score is lower than the sectioning point, the specimen is diagnosed as white. In plotting DF scores, white-black function is ordinate, white-Indian is abscissa.

[b] Due to a typographical error these sectioning points were erroneously reported as 13.01 and 9.22 in the original Giles and Elliot publication in 1962.

TABLE 2—*Sex and race distribution of 52 crania used in present study, where sex was known for all 52 crania and sex and race were known for 42.*

Race	Males	Females	Total
White	20	7	27
Black	8	0	8
Indian	5	2	7
Unknown	7	3	10
Totals	40	12	52

All measurements were taken with sliding and spreading calipers, following the definitions provided by Giles and Elliot [*1,6*].

In our laboratory, we have programmed a plotter-equipped Model 9820 Hewlett-Packard minicomputer with the Giles and Elliot DF. Input consists of the eight cranial measurements of the unknown cranium. From these, the computer first calculates the sex DF score, which is plotted on a univariate scale divided into "male" and "female" segments by the sectioning point. On the basis of its diagnosis of sex, the computer then selects the appropriate race DF and plots the racial diagnosis of the specimen. Examples of the final output are shown in Fig. 1.

In this experiment, we have assumed that the observer is a nonanthropologist with sufficient anatomical knowledge to locate the necessary landmarks and take the eight specified measurements on an unidentified cranium. From this point on, he relies entirely on the DF to provide the diagnosis of both sex and race of the specimen. How well would he do? Do the Giles and Elliot DF perform as well in actual forensic science work as they did in tests of the skeletal collections from which they were derived? How well, in other words, can the calipers and computer match the skilled judgment of an experienced anthropologist? Having explored these questions, we will comment on possible sources of error and make some recommendations for improvements in the DF.

In the statistical comparisons of data presented below, tests of independence were made by Fisher's Exact Test for 2 by 2 contingency tables and G tests for 2 by 3 contingency tables [*9*]. Unless an exact probability level is given, the term "statistically significant" implies $P < 0.05$.

Results

Determination of Sex

The DF for sex determination correctly assessed 46 of the 52 crania of our series (Table 3). The function misdiagnosed 4 of the 40 males and 2 of the 12 females. Since this difference is not statistically significant ($P = 0.85$), the function appears to work about equally well on crania of both sexes.

In a test of this function carried out on 1022 (551 males, 471 females) white, black, and Indian crania, including 300 white and black crania used in its derivation, Giles and Elliot [*1*] found that it correctly diagnosed sex in 82.9% of the specimens. The percentage of successful sex diagnoses in our much smaller sample is 88%. The difference is not statistically significant.

Determination of Race

Race was correctly determined by the DF in 30 of the 42 crania of known sex and race (Table 4 and Fig. 2). The diagnoses were correct in 25 of the 33 males and 5 of the 9 females of this group. As this difference is not statistically significant ($P = 0.43$), the ability of the functions to determine race appears to be independent of sex.

When the sexes are considered together (Table 4), 22 of 27 whites and 7 of 8 blacks were correctly diagnosed. In contrast, 6 of the 7 Indians were misclassified. A G test of independence on the 2 by 3 matrix represented in Table 4 was highly significant ($G = 12.61$, 2 degrees of freedom, $P < 0.005$). This finding indicates that the ability of the functions to diagnose race correctly is not independent of the actual race of the individual. Fisher's Exact Tests carried out on the white-black, white-Indian, and black-Indian components of the series show probabilities of $P = 0.80$, $P = 0.017$, and $P = 0.004$, respectively. Clearly, the Indian subsample is responsible for the observed deviation.

The two-phase diagnostic mode in which the computer automatically selects the race

TABLE 3—*Distribution of correct and incorrect sex DF diagnoses by the known sex* (n = *52*) *and race* (n = *42*) *of 52 crania.*

		Known Sex				
		Male		Female		
Race	*n*	Correct	Incorrect	Correct	Incorrect	Correct, %
White	27	18	2	5	2	85.2
Black	8	7	1	0	0	87.5
Indian	7	5	0	2	0	100.0
Unknown	10	6	1	3	0	90.0
Totals	52	36 (90.0%)	4	10 (83.3%)	2	88.5

discriminant functions consistent with its initial diagnosis of sex can occasionally lead to error. This happens when the computer misdiagnoses sex; as a result, the racial diagnosis is carried out by a function inappropriate to the actual sex of the specimen. In our series, 5 of the 42 known-race crania were misclassified by the sex DF and, therefore, were racially diagnosed by inappropriate functions. Despite this, race was correctly diagnosed for four of these five crania. Thus the DF failed to diagnose both sex and race correctly in only 1 of the 42 cases. When rediagnosed with their appropriate race functions, the race of each of the five missexed crania was correctly determined.

In their test of the race DF, Giles and Elliot [*1*] found that they correctly diagnosed 85.1% of the 1022 (187 whites, 221 blacks, 614 Indians) crania. In contrast, only 30 of 42 specimens, or 71%, of our series were correctly identified by race. This difference is statistically significant ($P < 0.025$). However, dropping the 7 Indian crania from our series gives 29 correct racial assignments out of 35, or 83%, which compares well with the results of the original study.

In summary, our data suggest that the race DF perform well in diagnosing white and black crania but poorly in Indians.

Discussion

The overall effectiveness of the Giles and Elliot DF in correctly assigning sex on the basis of cranial dimensions is amply confirmed by this study. Black and white crania are also correctly diagnosed racially in about 83% of cases, further supporting the original study. The obvious deficiency of the method lies in its consistently erroneous racial diagnoses of American Indian crania.

The black and white crania used to derive the Giles-Elliot functions were from the Terry and Todd collections. Both collections were accumulated from dissecting room cadavers of two midwestern medical colleges during the first part of this century. Although, like all such series, they are far from a truly random sample, they are at least broadly representative of the present Caucasoid and Negroid elements of the U.S. population. It is therefore reasonable to expect that DF derived from crania of these collections would perform well in distinguishing sex and race of black and white crania encountered in a series of U. S. forensic science cases.

No comparable collections of recent American Indian crania of known sex exist. For their base sample of Indian subjects, Giles and Elliot were forced to rely on prehistoric crania from Indian Knoll, Kentucky. This collection is from the burial ground of a group of semisedentary hunter-gatherers; it is currently radiocarbon dated at about 3450 B.C. [*1*]. One unavoidable difficulty in using archaeologically derived specimens is that sex is not independently documented; instead, it must be diagnosed by examination of the

TABLE 4—*Distribution of correct and incorrect race DF diagnoses in 42 crania of known sex and race.*

		Known Sex						
		Male		Female		Both Sexes		
Race	*n*	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect	% Correct
White	27	17	3	5	2	22	5	81.5
Black	8	7	1	0	0	7	1	87.5
Indian	7	1	4	0	2	1	6	14.3
Totals	42	25 (77.8%)	8	5 (55.6%)	4	30 (71.4%)	12	...

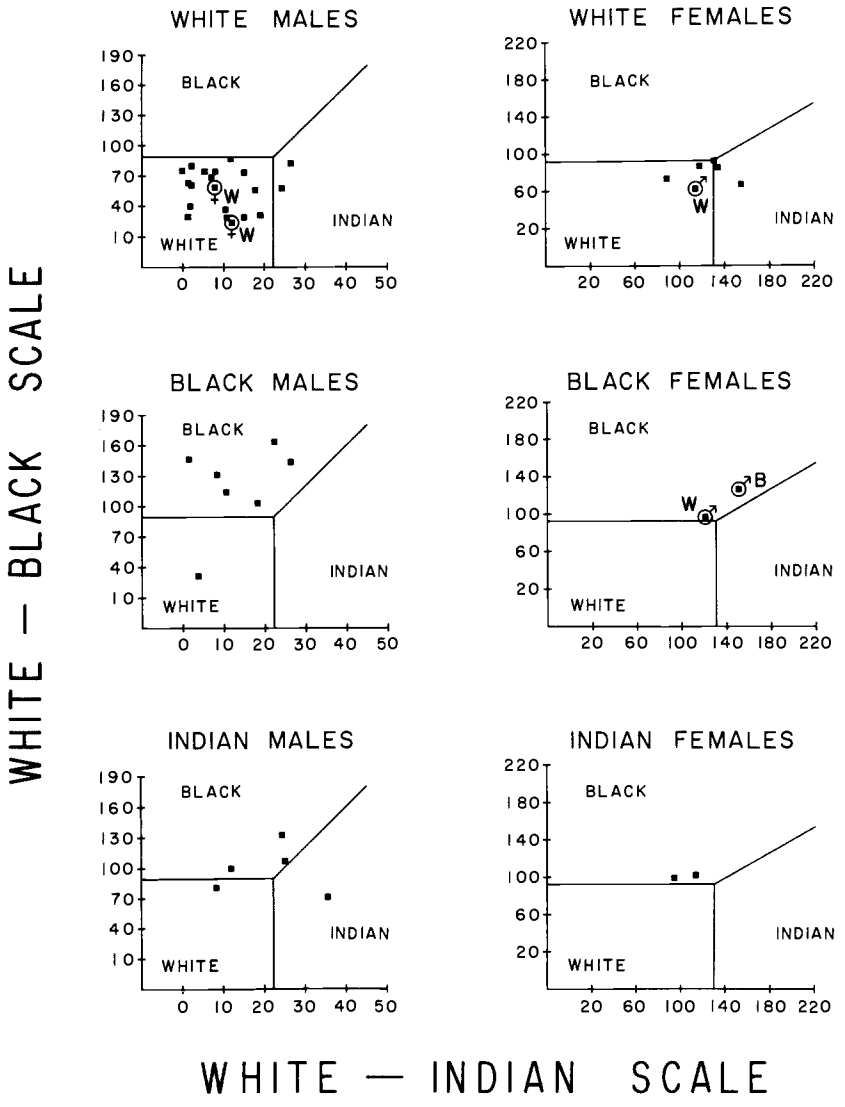

FIG. 2—*Distribution of race DF scores of 40 crania of known race. Points encircled by sex indicators are specimens misclassified by the sex DF: two white females were misclassified as males but correctly classified as to race by the male race DF.*

skeletons themselves (in a few instances the diagnoses may be supported by grave goods indicative of sex). Yet morphological sexing, however skillfully performed, is subject to some error—perhaps 1 to 2%—even when based on the complete skeleton. Therefore, it is likely that at least a few of the Indian Knoll crania used by Giles and Elliot to develop their DF had been missexed originally.

Another deficiency of the Indian Knoll collection as a basis for developing DF applicable to modern racial taxa is its temporal remoteness—more than 5000 years—from the present population of North American Indians. Morphological alteration in craniofacial dimensions caused by genetically based microevolutionary factors or changing functional demands induced by dietary shifts is possible over such a long time and, indeed, has been well documented in many populations. Also, it is probable that the Indian Knoll collection

was from a comparatively small, geographically circumscribed breeding population. Even if temporal changes are discounted, it is doubtful that the Indian Knoll people adequately represent the biological diversity of a population inhabiting an entire continent.

A further factor probably contributing to the misdiagnosis of Indians by the discriminant functions is racial admixture. The influx of white and black genes has been strong in recent generations of American Indians, particularly in Eastern and Southern tribes. Today, individuals of fully Indian genetic heritage are a minority in many tribes. Persons with as little as one eighth Indian ancestry may be carried on tribal rolls, but their medical, military, and police records used for identification purposes seldom reflect non-Indian admixture and simply list them as Indian. To the extent that cranial morphology is affected by racial hybridization, some influence on the effectiveness of the DF to assess correctly the race of such individuals must be expected. In one of our cases, for example, the decedent was classified Indian in personal documents but was actually three fourths white. The DF correctly classified her cranium as white. Thus, the computer, like the eye of the anthropologist assessing race from the cranium, can deal only with the biological reality of the specimen and cannot discern the arbitrary and nebulous boundaries of race as defined by society. However, the brain of the anthropologist is (or at least should be) aware of these boundaries, which perhaps gives him a slight advantage over the machine. For instance, if a cranium were submitted from an area of eastern Oklahoma where many people of one eighth and one fourth Indian ancestry are carried on tribal rolls, an anthropologist would not dogmatically exclude a possible Indian decedent merely on the basis that the specimen is morphologically Caucasoid.

In short, the DF for racial diagnosis effectively distinguished the white and black crania of our forensic science series. They did not, however, perform well in diagnosing American Indian crania, probably because the Indian Knoll collection is not a good representation of the North American Indian population as it exists today. If tests on a more extensive series of Indian crania should confirm our findings, the definition of new functions based on a more recent and more demographically representative sample of the present North American Indian population is to be recommended. Until such a redefined function is available, one should be hesitant in excluding a possible American Indian decedent solely on the basis of a diagnosis of white or black made by the function. Naturally, the risk of such an error is larger in areas such as the southwestern United States, where American Indians are likely to compose a significant proportion of forensically examined skeletons.

What are the more general problems encountered in sex and race determination by this method? Some glimpse of them can be obtained by examination of a few of the crania of our series misdiagnosed by the functions. Three factors, at least, seem to contribute to the errors we observed: cranial size, age at death, and pathology.

Regarding the first, it is clear that overall size of the specimen is a major component of variability in the characters used by Giles and Elliot to define these functions (a principal components analysis carried out on a correlation matrix of these characters in our series of 52 cases supports this contention). In the determination of sex, for instance, the function is more likely to diagnose a large skull as male and a small one as female. The function, in other words, recognizes the fact that, in general, male crania tend to be 5 to 15% larger than female. Construction of the function eliminates correlation between the measurements and makes relative rather than absolute the contribution of each measurement's size difference, so the choice of measurements or the number of them do not, by themselves, accentuate the magnitude of difference solely attributable to absolute size variation between the two sexes' crania. But dimorphic sexual traits not reflected in the measurements may be of great value in some cases.

The effect of size is illustrated by the cranium of a 36-year-old black male missexed by the function. The DF score of this specimen is 869.8—about 21 units below the function sectioning point of 891.12. The cranial measurements used in the function are generally

small in this specimen, as is evidenced by their strongly negative Z scores, which express their deviation from the means of the corresponding measurements of the black male crania used in computing the function [2]. This is shown in Table 5, which gives the measurements and their respective Z scores. In fact, only one of the five measurements used by the function, basion-prosthion, approximates the mean. This measurement, however, is also the only one of the five that is negatively weighted by the function (third column of Table 5); that is, the larger the value of basion-prosthion, the smaller the DF score and, hence, the more "female" the specimen.

The two final columns of Table 5 show the amounts, in both absolute and percentage values, by which any single measurement would have to be altered to provide a DF score equal to the sectioning point of the function. Thus, glabella-occipital length would have to be increased by at least 18.4 mm, or 10.4% of its value, for the specimen to be classified correctly as male. The same general observation holds for the other positively weighted measurements of the function: each, assuming the others were held constant, would have to be increased by about 5 to 20% to increase the DF score sufficiently to exceed the sectioning point and, hence, result in a diagnosis of male. Thus its small size plays a significant role in the misdiagnosis of this cranium as female.

On the other hand, this specimen displays a number of morphological traits not evaluated by the DF that clearly categorize it as male. For instance, three traits alone—the strongly developed supraorbital brow ridges, nuchal crest, and mastoid processes—are so typically masculine that, to an experienced eye, they far outweigh mere cranial size as indicators of sex.

Age can also affect the diagnosis of sex by the DF. Giles [*12*] showed that, in adults of both sexes, the DF scores of the function used in sex determination tend to increase with age. This age-related shift toward higher DF scores might be expected to result in some female crania being erroneously diagnosed as male by the function. It seems likely that this increase in DF score is a result of the generalized 4 to 5% expansion in cranial dimensions that occurs between the third and eighth decades of life [*13,14*].

Perhaps an example of the effect of age is provided by the oldest female of our series, a 64-year-old white homicide victim. Her cranium is diagnosed as male by the DF, the score being 895.1. This exceeds the sectioning point (891.12) by only four units. Her cranial measurements and the Z scores expressing their deviation from the means for white females [2] are shown in Table 6. All four of the positively weighted measurements exceed their respective means by nearly one standard deviation. A reduction in any one of these measurements by 2 to 4 mm would reduce the DF score below the sectioning point and thus result in a correct diagnosis. For instance, a decrease in glabella-occipital length by

TABLE 5—*Cranial measurements, Z scores, DF coefficients, and DF score distances from sectioning point (mm Δ = absolute, % Δ = percentage difference) of a 36-year-old black male classified as female by the Giles and Elliot DF.*

Measurement	mm	Z score[a]	DF Coefficient	mmΔ[b]	%Δ[c]
Glabella-occipital length	176	−1.54	1.16	18.38	10.4
Basion-nasion	96	−1.15	1.66	12.84	13.4
Bizygomatic breadth	126	−1.36	3.98	5.36	4.3
Basion-prosthion	103	0.01	−1.00	−21.32	−20.7
Prosthion-nasion	70	−0.74	1.54	13.84	19.8

[a] Standardized normal deviate [$Z = (x - \bar{x})/SD$], where $\bar{x}$ and SD are mean and standard deviation of black male crania used in deriving DF (see Ref 2, Table 1) and x is measurement of specimen.

[b] Change in measurement (in mm) for specimen DF score to equal sectioning point of DF [mmΔ = (SP − DF)/coefficient].

[c] mmΔ expressed as percentage of specimen measurement (%Δ = mmΔ/x × 100).

TABLE 6—*Cranial measurements, Z scores. DF coefficients, and DF score distances from sectioning point (mm Δ = absolute, %Δ = percentage difference) of a 64-year-old white female classified as male by the Giles and Elliot DF.*

Measurement	mm	*Z* Score[a]	DF Coefficient	mmΔ[b]	%Δ[c]
Glabella-occipital length	178	0.99	1.16	−3.41	−1.9
Basion-nasion	99	0.91	1.66	−2.39	−2.4
Bizygomatic breadth	127	0.84	3.98	−0.99	−0.8
Basion-prosthion	89	−0.26	−1.00	3.96	4.4
Prosthion-nasion	70	0.89	1.54	−2.57	−3.7

[a] Standardized normal deviate from means of white female crania used in deriving discriminant functions (see Ref 2, Table 1).

[b] Change in measurement (in mm) for specimen DF score to equal sectioning point of discriminant function [mmΔ = (*SP* − *DF*)/coefficient].

[c] mmΔ expressed as percentage of specimen measurement (%Δ = mmΔ/x × 100).

only 3.41 mm—a change of −1.9%—would reduce the DF score to the sectioning point. Israel [*14*] reports an average increase of 3.6%, or about 6 to 8 mm in cranial length, over a two-decade period in 26 adult females of the Fels longitudinal population sample. Assuming a change of this magnitude had occurred in our 64-year-old specimen, her glabella-occipital length would have been about 172 mm at age 44. Thus her DF score would be reduced to 888.14, about three units below the sectioning point, and thereby she would be correctly classified as female.

Examination of this cranium reveals that many of the subjectively evaluated traits used by the physical anthropologist to diagnose sex are distinctly feminine. Among these are the slightly developed supraorbital ridges, sharply defined orbital margins, relatively small dentition, and generally gracile cranial architecture. Taken together, these features outweigh the function's diagnosis in assessing the sex of this specimen.

If this age effect is confirmed by further analysis, it is possible that the efficiency of the DF could be improved by a systematic adjustment of the sectioning point based on the estimated age at death of the unknown cranium.

Alterations in craniofacial dimensions induced by pathological change or altered functional demands might also be expected to influence sex or race diagnosis by DF. A possible example of this influence is provided by the cranium of a 44-year-old white male of our series. It was diagnosed correctly as male but misclassified as Indian.

The DF score of the white-Indian function of the specimen was 26.15, exceeding the sectioning point of 22.28 by four units. Table 7 gives the eight cranial measurements of this cranium and other related statistics. Three measurements, glabella-occipital length, basion-bregma height, and bizygomatic breadth, are characterized by large positive *Z* scores, an indication that they strongly exceed the means of the white male crania used by Giles and Elliot [*2*] to develop their DF. One of these three measurements, glabella-occipital length, has a small, negatively weighted DF coefficient; the remaining two are positively weighted. Of these last two, bizygomatic breadth carries a function coefficient of 1.75, almost double that of basion-bregma height. Thus, compared to the other measurements, a relatively small increase in bizygomatic breadth results in a strong positive increase in the DF score. In assigning a large weight to bizygomatic breadth, the function gives statistical recognition to the biological fact that, in general, broadly flaring cheekbones are a distinctively Mongoloid racial trait. In the specimen under consideration, a reduction of 2.3 mm in bizygomatic breadth, or a change of −1.6%, would be sufficient to reduce its DF score below the sectioning point value of 22.28 and thereby correctly classify it as white.

TABLE 7—*Cranial measurements, Z scores, DF coefficients, and DF score distances from male white-Indian sectioning point (mm Δ = absolute, % Δ = percentage difference) of a 44-year-old white male classified as Indian by the Giles and Elliot DF.*

Measurement	mm	Z Score[a]	DF Coefficient	mmΔ[b]	%Δ[c]
Glabella-occipital length	191	1.41	−0.25	15.48	8.10
Cranial breadth	141	−0.33	−1.56	2.48	1.76
Basion-bregma	142	1.41	0.73	−5.30	−3.73
Basion-nasion	102	0.34	−0.29	13.34	13.08
Bizygomatic breadth	138	1.15	1.75	−2.21	−1.60
Basion-prosthion	97	0.24	0.10	−38.70	−39.90
Prosthion-nasion	73	0.50	−0.16	24.19	33.13
Nasal breadth	24	−0.13	−0.84	4.61	19.20

[a] Standardized normal deviate from means of white male crania used in deriving discriminant functions (see Ref *2*, Table 1).

[b] Change in measurement (in mm) for specimen DF score to equal sectioning point of discriminant function [mmΔ = (*SP* − *DF*)/coefficient].

[c] mmΔ expressed as percentage of specimen measurement (%Δ = mmΔ/x × 100).

The skeleton of this individual was found in an isolated soybean field in southern Louisiana in 1969. Examination of the cranium revealed two symmetrically placed, well-healed surgical burrholes on the coronal suture about 6 cm on each side of the midline. In size and location they resembled those commonly made in transcranial prefrontal lobotomies, a finding suggesting that the subject might have had a history of mental illness. Another peculiarity was the extreme and irregular dental attrition along with some signs on the anterior teeth of accidental or deliberate dental mutilation, a pattern of dental damage typically observed in extreme bruxomania.

These findings contributed to the final identification of the victim—a chronic schizophrenic who had escaped from a state mental hospital in California about a decade before the discovery of his skeleton [*15*]. This man had undergone a prefrontal lobotomy in 1949. His medical and dental records revealed a long history of bruxism coupled with a habit of chewing on gravel, nails, and other hard objects. This information was supported by transcripts of several psychiatric examinations in which the observer noted that the patient constantly and audibly ground his teeth. Former wardmates of the subject were interviewed and several stated that they were often kept awake at night by the sounds of his nocturnal bruxism.

In addition to the dental wear, this cranium displayed several osteological peculiarities attributable to bruxism. Particularly evident were the robustly developed attachments for the insertion of the masseters and internal pterygoids on the mandibular angle, the strong gonial eversion, and the laterally flared coronoid processes. On the cranial vault, the temporal lines were exceptionally well developed. The areas of masseter origin along the inferior borders of the zygomatic arches were accentuated and extended well onto the external surfaces of the zygomata. These features are indicative of a strongly developed masticatory musculature and are typical of primitive peoples whose rough diets and use of teeth in the preparation of hides and cordage impose heavy stress on the dentition. However, in the present case, this hypertrophy is clearly the result of the subject's excessive bruxism. It is also shown metrically in the gonio-condylar index (bigonial breadth/bicondylar breadth × 100), which in this subject has a value of 89.9. Olivier [*16*] gives normal values of this index as about 81 in blacks and 84 in whites but notes that in Eskimos, a people characterized by robustly developed masticatory complexes, it may attain a value of 91.

Along with the stress-induced changes in the masticatory apparatus, this cranium

displays unusually strong lateral flaring of the zygomatic arches. It seems reasonable to conclude that this finding is also associated with increased masticatory stress. For example, such a lateral displacement might be due to bone remodeling as a result of hypertrophy of the underlying temporal muscles coupled with altered functional demands of bruxism that would give some biomechanical advantage to a more laterally oblique axis of masseter action. In any case the end result would be an increased bizygomatic breadth which, as pointed out above, might have increased the DF score by an amount sufficient to lead to the incorrect diagnosis of Indian.

Summary

Giles and Elliot [*1*] describe a set of discriminant functions for determining sex and race from the cranium. In the present study, we tested these functions in a series of 52 forensic science cases (all of known sex, 42 of known sex and race). Sex was determined correctly in 88%, comparing well with the accuracy of 83.8% reported by Giles and Elliot. The function appears to perform well for both sexes.

The functions for race determination worked well in diagnosing whites and blacks; 29 of the 35 crania (83%) belonging to these races were assessed correctly. However, it misclassified 6 of the 7 American Indians of our series, and the overall percentage of correct diagnoses was lowered to 71%. This figure is about 12% less than the percentage of correctly diagnosed crania reported by Giles and Elliot. It thus appears that the 5000-year-old Indian Knoll crania used by Giles and Elliot in developing their functions do not adequately represent the entire U. S. category of Indian. It seems likely that this shortcoming is due to an as-yet unassessed combination of microevolutionary and functional factors affecting the cranial dimensions used in the functions. The practice of racial characterization by sociological rather than biological criteria in antemortem descriptions—a problem frequently encountered in forensic anthropology—may also contribute to the poor performance of the functions in diagnosing Indians.

It was also observed through examples in our series that overall cranial size, age at death, and certain pathological and functional changes influencing cranial form may lead to misdiagnoses of sex or race, or both, by the DF.

In conclusion, the Giles and Elliot DF provide a useful tool for the determination of sex and race of unidentified crania submitted for forensic science examination. The measurements used in this method can be accurately obtained by individuals who have no formal anthropological training. The computation involved is straightforward and easily programmable on a variety of minicomputers available in many modern forensic science laboratories. Like any other diagnostic method, it is not 100% error-free. Certain deficiencies may be overcome by further refinements of the method. Meanwhile, an awareness of its shortcomings, some of which are pointed out in the present study, will help insure its judicious use and interpretation. As with any good tool, skillful use insures good performance.

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