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Metropolitan Forensic Anthropology Team (MFAT) Studies in Identification: 1. Race and Sex Assessment by Discriminant Function Analysis of the Postcranial Skeleton

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ABSTRACT: A case study is presented to demonstrate the utility of the team approach to the identification of human remains, and to illustrate a methodological innovation developed by MFAT. Case 1 represents the first of several planned case studies, each designed to present new methodological solutions to standard problems in identification. The present case describes a test, by application, of race and sex assessment of the postcranial skeleton by discriminant function analysis.

KEYWORDS: pathology and biology, anthropology, odontology, human identification, team approach, discriminant analysis, racing, sexing

The present paper is planned as one of a series of case studies applying new methods developed by the Metropolitan Forensic Anthropology Team (MFAT) for the identification and individualization of human skeletal remains.

The team was organized in 1979 by forensic scientists in the fields of anthropology, odontology, pathology, criminalistics, and computer science, with appointments to several institutions including: The American Museum of Natural History; The John J. College of Criminal Justice, CUNY; Lehman College of CUNY; and the offices of the New Jersey State Medical Examiner, and the Rockland County Medical Examiner of New York State. The team is now based at the Anthropology Department of Lehman College, under the aegis of the Research

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Foundation of the City University of New York, and at the Edwin H. Albano Institute of Forensic Science of the Office of the New Jersey State Medical Examiner. Membership has recently expanded to include forensic specialists from the Office of the Westchester County Medical Examiner of New York State.

The primary objective of MFAT is to develop the study of human identification through research, teaching, and case work. The multi-institutional and interdisciplinary composition of the team provides a broad basis for feedback during the analysis and interpretation of evidence, and has generated several new and efficient paradigms of investigation. These form the basis of this and subsequent reports.

Case Study 1 addresses the problem of race assessment when the customary basis of this assessment, the skull, is damaged or missing. It illustrates and tests by application to a case positively identified by other criteria, discriminant functions recently developed by MFAT personnel [*1,2*] from measurements of the innominate and femur. The latter are recognized as the bones of choice for sex, age at death, and stature assessment (for review see Refs. *3-6*). Furthermore, they are often better preserved than the skull in shot-gun, fire, and blunt trauma victims; are commonly articulated and intact in floaters who have been in water for several weeks; and may aid in individualization when the innominate exhibits scars of parturition [*7-11*]. But though some investigators believe that analysis of the pelvis and femur should permit discrimination between American blacks and whites [*12-17*], racial classification at the level of the individual has been considered unreliable or qualified. Our discriminant functions remedy this situation.

Establishment of Positive Identification

On 15 Oct. 1981 the partially mummified remains of what was later identified as an adult female were discovered in Union City, NJ. Initially non-MFAT personnel were unable to verify a presumptive identification on the basis of dental comparisons. The Prosecutor's Office then requested further analysis, including cause of death, from the State Medical Examiners Office, who referred the case to MFAT personnel on their staff.

Our pathologist determined that facial, cranial, and rib fractures were consistent with a blunt trauma cause of death, and the manner of death was homicide. Furthermore, in contrast to the initial odontological findings, the team forensic dentist was able to positively identify the remains as those of one A. A., on the basis of the following report.

Odontological Analysis

To analyze properly the skull and dentition of the victim, the fractured segments described above had to be reconstructed. This was accomplished in the following manner: the two halves of the maxilla were approximated and luted together. Then the maxilla, with its dentition, were sealed to the lower jaw dentition in the correct centric relationship. The lower jaw with the maxilla attached was related to the skull by fixing the condyles in their correct positions in the glenoid fossae. Thus an appropriate "feel" of the jaw-skull relationship was accomplished.

Although the mid-portion of the maxilla is missing, there is a definite procumbency of the dental arches (common among blacks). All muscle attachments are delicate and smooth (female). The anterior nasal spine is sharp and prominent (caucasoid). The position of the roots in the maxillary arch produce a moderate, corrugated appearance (more common among blacks). Finally, some thin, fine black hairs are still attached to the skull. The combination of these traits suggest a mixed racial origin.

Antemortem X-rays of one A. A., provided by the Hudson County Prosecutors Office, were

compared with postmortem X-rays of the deceased's dentition. The following points of concordance are noted:

1. Upper right and left lateral incisors sites exhibit remodeling and healing in the postmortem skull. Dental history indicates removal of these teeth in 1979.
2. Family gives history of A. A. having missing upper anterior teeth.
3. There is present in the antemortem X-ray of A. A. a halo-like effect of a nutrient canal system in the alveolar bone surrounding the upper left lateral incisor. This can be demonstrated in the postmortem X-ray of the upper left lateral site.
4. The upper left cuspid incisor tip on both antemortem and postmortem X-rays show identical wear notches.
5. The same configuration of incisal edge on the upper right cuspid appears on both sets of X-rays.
6. The lower left first bicuspid root configuration S-shape is similar in both antemortem and postmortem films.
7. The upper right cuspid has the same clinical crown configuration.
8. Age assessment is made as approximately 35 years based on the following: (a) atrophy of the residual edentulous ridges, (b) evidence of advanced periodontal disease with trifurcation involvment and denudation of the buccal plate of bone over the lower anterior teeth, and (c) rotation and drifting of the lower right second bicuspid and right and left third molars.

There is no doubt in this investigator's mind that the deceased was A. A.

Anthropological Analysis

Age—The age of death of A. A. is estimated as in the fourth decade, with the central tendency favoring the middle thirties. The primary criteria for this assessment include the following: the maturation of the pubic symphysis is scored 9 (mean age 33.00, age range 22 to 40 years, standard deviation 9.00 years) according to the method of Gilbert and McKern [*18*]; hypertrophic bone spurs are present on the superior margin of the manubrial facet for the right first rib, and on the antero-inferior border of the right first costal cartilage (suggesting an age beyond the early thirties); cupping is well developed on the anterior ends of the ribs (fourth decade); slight lipping is present on the medial margin of the glenoid socket of the scapula, but is absent from the clavicular facet of this bone (early to middle thirties); slight lipping is also present on some of the thoracic vertebral centra (fourth decade); and the S1-S2 sacral segments have fused (middle twenties, plus). For a review of these and other aging criteria see Refs *2*, *19*, *20*, and *9*.

Closure of the first and second segments of the corpus sterni normally occurs by the age of 30 [*21*]. In the present case, however, we have evaluated the incomplete union at this site in A. A. as anomalous delayed maturation for several reasons: closure is complete on the posterior surface, normally the surface of late union [*21*]; maturation of the sternal joints in general is considered less uniform than in the other joints used for our age estimate [*19*]; persistence of nonunion occurs in a small percentage of individuals [*21*]; and most importantly, the apparent immaturity of this joint in A. A. is at variance with the total aging pattern of her skeleton and dentition.

Hair Analysis—The head hairs appear to be of mixed racial origin. Black characteristics are seen with respect to the pigment granules and their distribution, while the eliptical cross section and relatively straight shaft suggest a superimposed influence of Mongoloid or perhaps white characteristics.

Stature—Living stature is estimated from the femoral length (390 mm) with the regression formula of Trotter and Gleser [*22*] for American white females as 150.13 + 3.72 cm, or about 59 in. tall.

Individualization—Thirteen points of anatomic concordance between the thoracic bones of

Case 1 and the antemortem PA chest X-ray of A. A. are listed in Table 1. The number of points of concordance could have been easily extended.

Each of the 13 points of anatomic similarity was tested by comparison with a large randomly selected skeletal series of females from our laboratories at Lehman College. The entire series of study skeletons (over 20) was excluded as A. A., but we could not exclude Case 1. These 13 points of concordance, therefore, comprise compelling evidence for a positive identification.

Finally, the slight alveolar prognathism, and somewhat masculine square chin of the skull of Case 1 are duplicated in photographic portraits of A. A. provided by the Hudson County Prosecutors Office. These points of concordance were objectified by superimposition of outline tracings of the skull of Case 1 and the photographic portraits of A. A., made with a projection drawing machine (Figs. 1 and 2). A discussion of this method of individualization is planned for a subsequent case study in identification.

Sex and Race—Inspectional analysis of the skull, pelvis, and long bones indicates a female classification for Case 1, and visual inspection of the lower nasal border, alveolar processes of the maxillae and mandible, and the form of the chin, suggest a white, possibly with slight nonwhite admixture. The form of the brain case is entirely white as are femoral features (shaft bowing, development of the pilaster, and maximum length of the femur relative to trunk length [*12,13*]).

Use of Case 1 for Verification of the Discriminant Function Criteria

Listed below are the 15 relevant measurements for Case 1 with the appropriate discriminant function weights for each of the 3 functions necessary for race and sex classification (Table 2). A full description of these measurements is given by DiBennardo and Taylor [*17*].

Each measurement is multiplied by the appropriate weight for each of the three functions, and the products for each function are summed and added to the appropriate constant. For A. A. this gives a discriminant Function 1 score of −3.3, a discriminant Function 2 score of 1.8, and a discriminant Function 3 score of 1.1.

The posterior probability of group membership is computed according to the discussion in Overall and Klett on the uses of canonical variates for classification [*23*]. The discriminant function scores computed above are the canonical variate scores used for classification. One first computes the sum of the squared deviations of the individual's canonical variate scores

TABLE 1—*Points of anatomic concordance between the thoracic bones of Case 1 and the posteroanterior chest X-rays of A. A.*

Skeletal Part	Points of Concordance	Number of Points
Left clavicle	superior border, angles at junctions of middle third of bone with medial and lateral thirds	2
	form of acromial end	1
Right clavicle	inferior border, lateral and medial margins of notch, medial to conoid tubercle	2
Right first rib	form of tubercle and of small nodule on posterior end of the tubercle	2
Right first rib cartilage	hypertrophic bone spur on inferior border	1
Manubrium	hypertrophic bone spur on superior border of first rib facet	1
	form of right clavicular facet	1
	form of jugular notch	1
Left scapula	medial border, notch near inferior angle	1
	form of acromian	1
Total		13

FIG. 1—*Superimposition of the tracings of the skull and the portrait of the missing person (A. A.). frontal view.*

from the mean canonical variate scores for the i^{th} group. The latter are listed below for the black and white male and female groups (Table 3). For A. A., therefore,

$$D_1^2 = (-3.3 - 2.5)^2 + (1.8 - 1.7)^2 + (1.1 - 0.3)^2$$
$$D_2^2 = [-3.3 - (-3.2)]^2 + (1.8 - 1.2)^2 + [1.1 - (-0.4)]^2 \quad \text{and so on}$$

The posterior probability of group membership in group i is given as:

$$P_i = exp(-0.5D_i^2)/[\exp(-0.5D_1^2) + \exp(-0.5D_2^2) + \ldots + \exp(-0.5D_k^2)]$$

where k equals the number of groups (four in our case).

For example, Case A. A.'s posterior probability of membership in Group 2 (white female) is: $P_2 = \exp -0.5(2.62)/\exp -0.5(34.29) + \exp -0.5(2.62) + \exp -0.5(50.94) + \exp -0.5(13.74) = 0.996$. Statistical and inspectional analysis of A. A. are therefore mutually corroborative.

FIG. 2—*Superimposition of the tracings of the skull and the portrait of the missing person (A. A.), lateral view.*

TABLE 2—*The 15 measurements for Case 1 and the multipliers for each variable on the three discriminant functions (DFs).*

Variable	Case A. A. Measurements[a]	DF1	DF2	DF3
Symphyseal angle	127	0.05995	−0.00111	−0.055751
Innominate length	195	0.08364	0.04390	0.04546
Pubic length	69	−0.14578	0.08075	−0.08350
Femoral length	390	0.00493	−0.03512	−0.01044
Iliac height	127	−0.04005	0.08937	−0.12032
Acetabular diameter	50	0.10898	0.04501	0.08871
Sciatic notch height	45	−0.12707	0.03879	0.05862
Oblique pubic ramal length	28	−0.11760	−0.07688	0.11618
Sciatic notch position	23	0.09952	−0.04870	0.02330
Inferior pubic ramal height	15	−0.01450	0.16440	0.15029
Tuberculo-symphyseal length	25	−0.07388	0.01210	−0.07574
Distal diameter of femur	70	0.09048	−0.01179	−0.05310
Femoral circumference	71	−0.00474	−0.07795	0.09750
Carrying angle	80	0.03341	0.14588	−0.02561
Cotylosciatic breadth	35	−0.01507	0.08237	0.05235
(Constant)	...	−18.77931	−21.48789	10.13390

[a] Linear dimensions in millimetres, angles in degrees.

TABLE 3—*Average discriminant Functions 1, 2, and 3 scores for each race and sex grouping.*

Function 1:	white males:	2.24	black males:	2.97
	white females:	−3.19	black females:	−2.02
Function 2:	white males:	1.72	black males:	−1.22
	white females:	1.08	black females:	−1.59
Function 3:	white males:	0.34	black males:	−0.38
	white females:	−0.37	black females:	0.41

Summary and Conclusions

A positive identification of the remains of Case 1 as those of A. A. was achieved by concordance of antemortem and postmortem chest and dental X-rays of the victim. The anthropological and odontological workups of the remains are consistent with our radiologic individualization of them: the skeleton is assessed as that of a gracile, white female, possibly with some black admixture, with a stature of 150 cm (59 in.) and the age at death was estimated as in the fourth decade, with the central tendency favoring the middle thirties; A. A. is described in information provided by the Hudson County Prosecutors Office as a 35-year-old Hispanic female missing person, last seen alive on 29 May 1981, at 2:00 a.m., walking west up the 14th Street Viaduct, from Hoboken toward Jersey City.

Supportive evidence was also provided by hair analysis and by superimposition of outline tracings of the skull of Case 1 and police photographic portraits of A. A.

The positive identification of Case 1 by a diversity of methods afforded the opportunity to test by application our new method for classifying race and sex by multigroup discriminant function analysis of the postcranial skeleton. This method is recommended for race assessment when the skull is missing or damaged, and the conventional statistical and inspectional methods of cranial classification are, therefore, precluded, or produce equivocal results.

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