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Demographic Change and Forensic Identification: Problems in Metric Identification of Hispanic Skeletons*

ABSTRACT: The United States (U.S.) population structure is currently in a state of flux with one of the most profound changes being the increasing number of people referred to as Hispanic. In the U.S., much of the identification criteria for a biological profile are based on American Black and White individuals from anatomical collections. Using metric data from the Forensic Anthropology Data Bank (FDB), this paper will attempt to explore several issues that forensic anthropologists face when confronted with Hispanic remains. These will involve estimation of sex, height, and ancestry, the initial components of a biological profile. Discriminant function analyses indicate that American White criteria provide poor estimations of sex when applied to Hispanics and that ancestry estimation of Hispanic crania is difficult. Additionally, a new linear regression equation is presented that estimates stature for Hispanic individuals, although population specific criteria are still needed for Hispanic individuals from diverse geographical origins.

KEYWORDS: forensic science, forensic anthropology, Hispanic, sex, stature, ancestry

One of the greatest challenges faced by forensic anthropologists is to keep up with the changing demographic structure of the populations with which they are confronted. It is from this population that forensic cases are drawn. Forensic anthropology is a worldwide discipline with a main goal of providing a biological profile of an unknown individual or individuals found in a forensic context. The initial components of the biological profile include the estimation of age, sex, ancestry, and stature. In the United States (U.S.), much of the identification criteria for a biological profile are based on American Black and White individuals from late 19th and mid 20th century anatomical collections, with the exception of FORDISC 2.0, which provides estimations of sex, ancestry, and stature from recent U.S. forensic anthropological cases.

The U.S. population structure is currently in a state of flux with one of the most profound changes being the increasing number of people referred to as Hispanic. The term Hispanic is a social construct with no precise genetic meaning and is defined by the U.S. Census Bureau as an individual originating from Mexico, Puerto Rico, Cuba, South or Central America, or other Hispanic/Latino origins (1). In other words, the term Hispanic is based on a linguistic definition of Spanish-speaking peoples. Although Hispanic individuals have distinct ethnicities and cultures that vary from country to country, once inside the U.S., they are referred to as Hispanic, regardless of their country of origin.

The U.S./Mexico border is a gateway for many individuals from Mexico, Latin America, and Central America to enter the U.S. for work, health care, and education. However, Ross et al. (2) suggested that Cubans make up Florida's largest Hispanic community and that the unique population history of Cubans makes them more similar to American Blacks. Additionally Ross et al. further suggested that the designation of Hispanic does not capture the unique and complex population structure of Cubans, in that Cubans are less likely to have genetic Native American ancestry. Whereas individuals originating from Mexico, Central, and Latin America derive genes primarily from Spanish and Native American sources, in coastal geographic regions African ancestry is prevalent (3–5).

This paper will use the socially constructed term Hispanic to refer to individuals of Spanish-speaking origin. According to the U.S. Census Bureau, more than one in eight people are of Hispanic origin, yet there are only few identification criteria based on Hispanic samples (6–8). The majority of Hispanics in the U.S. originate from Mexico, followed by Central and South America forming the next largest group, many of whom enter the U.S. via Mexico (1). Data comparing 1990 and 2000 census results for Hispanics show that the Southeast experienced the largest influx of Hispanics in absolute terms (1). It exceeds the Northeast by a factor of five, the Midwest by a factor of three, and the West by a factor just less than one and a half (1). The West's percent increase is larger because of lower population density and because of the already large Hispanic population size (1).

These changes mean that forensic anthropologists in regions other than the West and Southwest will see increasing numbers of Hispanics in their forensic case load. As the country grows and diversifies, forensic anthropology must do the same. The biological profiles generated by forensic anthropologists require both expertise in the field and personal experience, although some aspects of the profile, such as sex estimation from long bones, stature estimation, and ancestry estimation also rely on metric data. The formulae used by forensic anthropologists are only as good as the data that are used to derive them.

Unfortunately, data from Hispanics have not accumulated at a rate proportional to their representation in the U.S. population, now ranking as the largest minority population in the U.S. (http://

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www.census.gov/Press-Release/www/releases/archives/population/006808.html). Additionally, there are no collections of Hispanic skeletons equivalent to the Terry and Todd collections for American Blacks and Whites. The Forensic Anthropology Data Bank (FDB) relies on data submission by anthropologists world-wide to provide the most up-to-date identification criteria. The FDB has assembled information from over 150 Hispanic skeletons, predominantly from the southwest and Mexico. While the southeast is likely to encounter Hispanic individuals from other geographic regions including Cuba and Puerto Rico, data from this region are not available.

Hispanic skeletons are difficult to recognize, especially by those with little experience. Even if they are recognized, there are few metric criteria available which allow quantification of visual assessments. Using metric data derived from Hispanic skeletons predominantly from the southwest U.S. and Mexico, we will attempt to explore several issues that forensic anthropologists face when confronted with Hispanic remains. These will involve estimation of sex, height, and ancestry, the initial components of a biological profile.

Sex estimation is usually the first component when creating a biological profile. When os coxae are available, one can presumably estimate the sex of Hispanics as well as any other group. While some might be tempted to look at the skull for a sex assessment, Hispanic crania are often misclassified as female because of their smaller size and more gracile nature than other groups such as American Blacks and Whites (9). Moreover, using postcranial estimators of sex has been found to be more reliable than the skull (10). However, no population-specific metric criteria exist for sexing Hispanic skeletons. More often, it is White or Native American criteria that are applied to southwest Hispanics or other Hispanics. When an innominate is unavailable, one often relies on metric sexing using dimensions of the humerus or femur. Humeral head diameter and biepicondylar diameter of the humerus have been shown to effectively sex Whites and Blacks (10,11).

Stature is also an important component of a biological profile, and unfortunately stature information for Hispanic individuals for forensic anthropological cases is severely lacking. Population specific stature estimation formulae for various Hispanic groups (Mexican, Cuban, and Puerto Rican) do not exist because of lack of skeletal reference data. However, Trotter (8) published stature formulae derived from Mexican and Puerto Rican Korean war casualties. Genoves also published a stature formula that is often applied to Hispanics, although the formula was designed for unmixed indigenous Mexican populations.

In addition to estimates of sex and stature, in the U.S., ancestry estimation plays an important role in the biological profile. There are several methods of ancestry estimation with the most widely used methods likely being anthroscopic or craniometric. Craniometric data have been shown to estimate ancestry with a high degree of accuracy (12). However, when confronted with Hispanic remains, ancestry estimation accuracy declines (9). This decline may be because Hispanic individuals can have differing degrees of Native American, European, and African ancestry (3).

Platymeria, the medio-lateral elongation of the subtrochanteric region of the femur, has also been put forth as a feature that discriminates Whites from Native Americans (13). Gilbert and Gill argued that the platymeric form of American Indians differentiates them from Whites (13). Using a more geographically diverse sample, Wescott (14) found results that generally agree with Gilbert and Gill regarding the use of platymeria in ancestry when discriminating Native Americans from American Blacks and Whites. He also found that American Indians are platymeric, American Blacks and Whites are eurymeric, and southwest Hispanics intermediate. Because FDB Hispanics likely have substantial American Indian ancestry, one would predict that they would be more platymeric than American Whites.

Using the available Hispanic data, this paper will explore the problems associated with applying American White criteria to sex, stature, and ancestry estimation for Hispanic individuals.

Materials

To keep up with the changing nature of the American population, recent forensic samples from the FDB are used along with data from the National Health and Nutrition Examination Survey (NHANES). The FDB is unique because it continues to store data from individuals derived from the populations for which it is used. While it is representative of the U.S. population, it does present a Southeastern bias. Samples used in the following analyses include American Blacks, American Whites, Native Americans, Hispanics, and Guatemalan Mayans.

Only American Blacks and Whites born after 1929 were used in subsequent analyses to minimize cranial and postcranial secular changes (15,16). The modern Native American sample also comes from the FDB; however, eliminating individuals born prior to 1930 would make the sample too small for analysis. Birth years for this sample range from 1902 to 1951.

The majority of Hispanic data was collected at the Pima County Office of the Medical Examiner (PCOME) in Tucson, Arizona. The PCOME receives an unusually large number of border crossing fatalities, and several data collection trips to the PCOME in late July of 2004 and 2005 provided data for purposes of updating the FDB. Thus, this sample will be referred to as the FDB Hispanic group and is not representative of the entire U.S. Hispanic population. Instead, the FDB Hispanic sample represents primarily U.S./Mexico border crossers. It is ideal to obtain data from other parts of the U.S. with large Hispanic populations. However, at present, data are not available or have not accumulated in large numbers from other geographic areas in the U.S.

Inevitably, there are a number of problems with the use of border crossing fatalities, the primary one being that they are less likely to be positively identified than others, and they are also more likely to be male. As previously discussed, the term Hispanic refers to many different culturally and geographically distinct areas encompassing Mexico, Latin America, Central and South America. The FDB Hispanic sample used in this paper is either positively identified or contextually identified. The positively identified individuals include cases submitted to the FDB and most are from New Mexico, Texas, and Mexico.

The contextually identified individuals are either circumstantially identified or are from U.S. border crossing fatalities found by immigration officers patrolling the border. Of the border crossing fatalities, only individuals with enough soft tissue present to indicate a positive identification of sex were used. The remains of the U.S./Mexico border crossing are likely from individuals from Mexico, Latin America, or Central America (1). For the purpose of this paper, the positively identified Hispanics (and thus self-identified) and U.S. border crossing fatalities are referred to as FDB Hispanics. A separate sample from the PCOME is used as a test class sample for ancestry estimation using craniometric data. This test sample did not have enough soft-tissue present for a positive sex assessment and was sexed using pelvic morphology.

The Guatemalan Mayan sample comes from the Forensic Anthropology Foundation of Guatemala (FAFG); this is a recent forensic sample and consists predominantly of males. The context is modern Mayan, from Rabinal and Comalapa, and some have been positively identified. The FAFG works with members of the indigenous communities to locate mass graves that resulted from human rights violations during Guatemala's Civil War. Once a location is determined, the FAFG excavates the area; any human remains are excavated and a full forensic anthropological work up is done to aid in the identification of the individuals. While sex is sometimes assessed by skeletal morphology, clothing, context, and personal items are in support of these assessments. It is not uncommon for family members to be present during the exhumations and to recognize a family member's personal belongings and clothing, therefore strengthening the sex assessment.

In addition to evaluating stature using published formulae, the NHANES data set was also used to evaluate general trends in stature for Hispanic groups. The NHANES data set, provided by the National Center for Health Statistics (http://www.cdc.gov/nchs/nhanes.htm), was collected during 1971–2002 for the purpose of assessing the health and nutritional status of the current U.S. population. The NHANES data set uses self-reported country of origin for Hispanic individuals.

Methods

Sex Estimation

A discriminant function analysis (DFA) in SAS 9.1 (17) was used to test sex estimation of FDB Hispanics using criteria derived from the American White samples. Because the Guatemalan sample only contains a few females and the Native American sample is too small for use in the DFA, these groups were not used. The use of the American White sample represents the sexing criteria that most forensic anthropologists are faced with when determining sex metrically (12). Humeral head diameter, humeral epiphyseal breadth, and femoral head diameter have been shown to be the most effective postcranial metric discriminators of sex for both American Blacks and Whites (10); therefore these criteria were used to estimate the sex of FDB Hispanics.

Stature Estimation

Currently there are only two stature formulae for use with Hispanic samples, Trotter (8) and Genoves (7). The Trotter and Genoves stature formulae were applied to the FDB Hispanic sample with known forensic or cadaver statures (n = 29). The forensic statures are either self-reported or were reported on missing persons' reports. The cadaver statures were taken after death, measuring the individual from head to heel. Using the FDB Hispanic sample with known statures and an associated femur length, a linear regression equation was derived using SAS 9.1 (17). This regression equation was then used on the FDB Hispanic femur lengths, used to derive the equation. (This paper was submitted prior to the release of FORDISC 3.0 which contains stature formulae for the Hispanic individuals used in this analysis.) Because the Guatemalan Mayan sample does not contain any known stature information, they were not used for the purpose of stature estimation.

The NHANES data set was plotted using smoothing loess plots in S-PLUS (18) so as to view any differences in overall stature between American Whites and Blacks, Puerto Ricans, Cubans, and Mexicans. If differences in stature exist between these groups, especially between Hispanic groups, population specific estimations of stature are necessary for forensic purposes.

Ancestry Estimation

Ancestry estimation is evaluated using craniometric variables and the platymeric index (PI). Craniometric data are commonly used to estimate ancestry with a high degree of accuracy (12). A stepwise selection method was used to find the best subset of craniometric variables that discriminated between FDB Hispanics and American Whites. These variables were then used in a cross-validated canonical DFA for FDB Hispanics, Guatemalan Mayans, American Blacks, and American Whites to assess overall classification rates for each group.

The PI was calculated for Native Americans, American Blacks, American Whites, FDB Hispanics, and Guatemalan Mayans by dividing subtrochanteric anterior–posterior diameter by the medio-lateral diameter and multiplying by 100 (19). A PI <84.9 is indicative of platymeria, a PI between 85 and 99.9 is considered eurymeric, and a PI of 100 or greater is considered stenomeric (20). An analysis of variance (ANOVA) was performed to test for differences among the sex-specific means of each group using SAS 9.1 (17).

Results

Sex Estimation

Humeral head diameter and biepicondylar breadth from the FDB American White sample provide a poor estimate of sex based on the cross-validated DFA results (Table 1). It is evident that postcrania of Hispanics are smaller in size than American Whites, especially males. Biepicondylar diameter sexes 90% of the American White sample correctly, although when applied to FDB Hispanics, it identifies too many males as females, yielding a success rate of only 67% for males and only 83% for females. FDB American White humeral head diameter provides an overall correct classification of 89% for American Whites; when the same criteria is applied to FDB Hispanics 100% of females are correctly identified, yet only 47% of FDB Hispanic males are correctly identified for sex. Using femur head diameter from the FDB American Whites, 61% of Hispanic males are sexed correctly and 100% of females are again correctly assigned.

Stature Estimation

Smoothing loess plots of the NHANES data for standing height demonstrate that American Whites and Blacks are taller than FDB Hispanics, Cubans, and Puerto Ricans (Figs. 1 and 2). Additionally, there is variation among the Hispanic groups with FDB Hispanics and Puerto Ricans exhibiting shorter stature than Cubans. Further, plots of sitting height reveal that male and female American Whites display higher values for sitting height than all other groups, and Puerto Ricans the lowest sitting height (Figs. 3 and 4).

Differences displayed in the plots of NHANES data suggests that population specific stature formulae are needed. This need was

TABLE 1—*Sex estimation of FDB Hispanics using American White reference data from the FDB.*

Measurement	Female, n	Female Correct (%)	Male, n	Male Correct (%)
Humeral head diameter	10	100	34	47
Humeral epicondylar breadth	12	83	33	67
Femoral head diameter	7	100	36	61

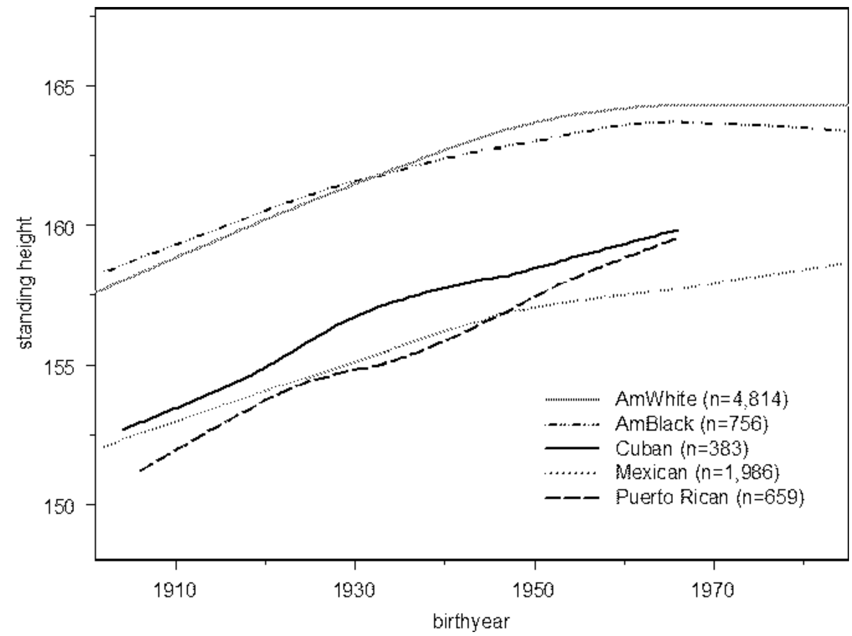

FIG. 1—*Male standing heights reported in the NHANES data set.*

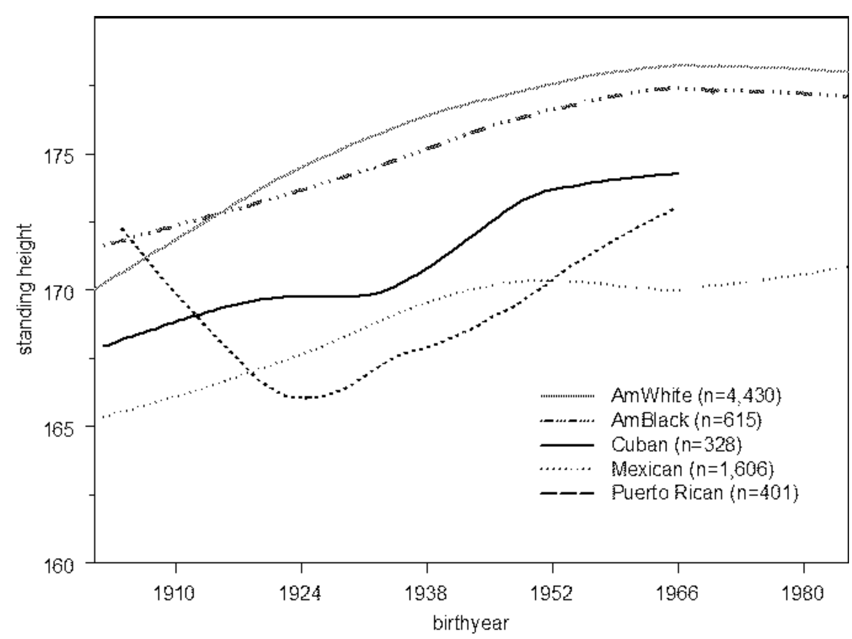

FIG. 2—*Male standing heights reported in the NHANES data set.*

previously pointed out by Trotter (8) who published stature formulae derived from Mexican and Puerto Rican Korean War casualties. Genoves's (1) stature criteria are often applied to Hispanics, but were designed for indigenous Mexican populations with no European admixture. Table 2 presents the mean stature estimations from Trotter, Genoves, and FDB.

Ancestry Estimation

The variables selected by the stepwise selection method are presented in Table 3. A canonical plot was generated that shows the differences among groups (Fig. 5). The first axis differentiates Guatemalan Mayans and American Whites, with FDB Hispanics intermediate on the axis. American Blacks are differentiated on the second axis. The structure coefficients indicate that American Whites have overall larger, taller vaults, and overall narrower faces, and smaller orbits than Mayans. American Blacks are differentiated based on maxillary prognathism in addition to an overall wider mid-facial region and larger interorbital distances. MANOVA results indicate that all groups have significantly different means at the $p < 0.0001$ level.

Variables selected for the DFA are presented in Table 4. The DFA allocates only 45% of southwest Hispanics into their group (Table 5). The PCOME test sample was run against the DFA. Only 10 of 21 individuals in the test sample were classified as FDB Hispanic, with posterior probabilities ranging from 0.4 to 0.8 (Fig. 6).

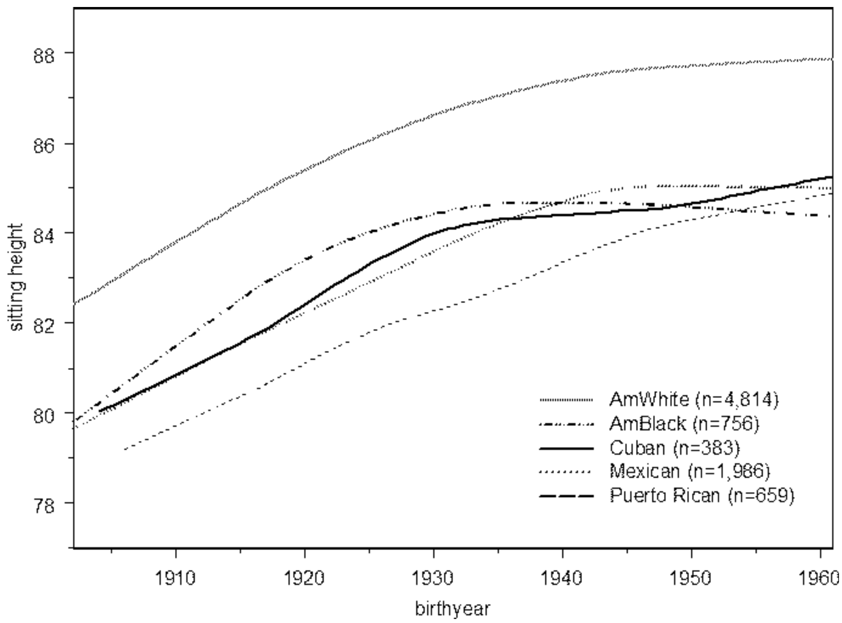

FIG. 3—*Female sitting heights reported in the NHANES data set.*

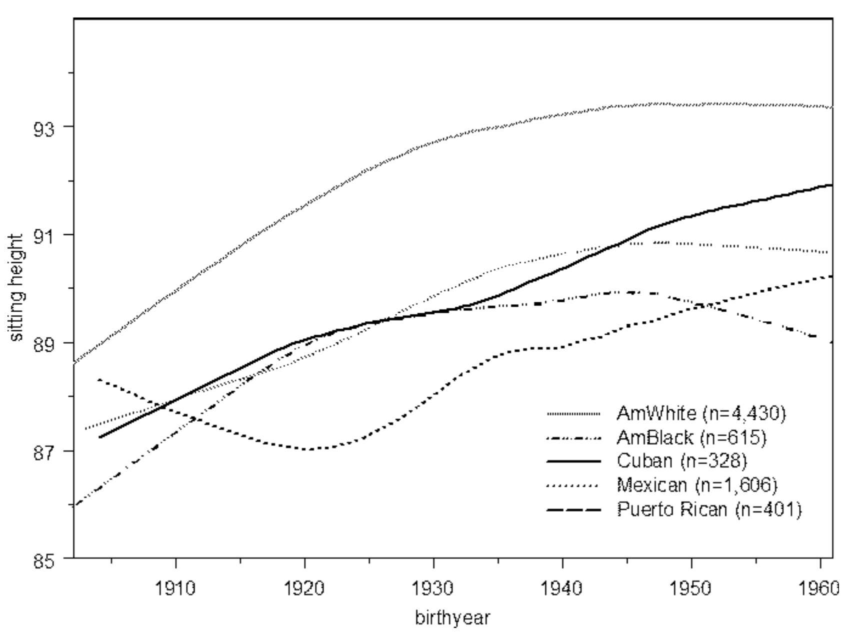

FIG. 4—*Male sitting heights reported in the NHANES data set.*

TABLE 2—*Mean values for stature formulae.*

Formula	*n*	Mean	SD	Minimum	Maximum
FDB*	29	169.90	5.434	161	185
Trotter	29	168.97	6.115	159	186
Genoves	29	168.38	5.647	159	184

FDB, Forensic Anthropology Data Bank.
*Equation for FDB Hispanic stature: stature = (femur length in mm × 0.2196) + 70.85.

Of the remaining test sample four were classified as Black, four as Guatemalan Mayan, and three classified as American White. However, when FDB Hispanics and Americans Whites are the only groups in the analyses, the percentages correct jump to 81% and 87% respectively with posterior probabilities ranging from 0.7 to 1.0.

TABLE 3—*Variables used in canonical analysis.*

GOL	XFB	NPH	IML	ZMB	FRC	OCC
BNL	ZYB	NAS	NLB	FMB	FRS	OCS
BBH	AUB	OBH	MAB	EKB	PAC	BAR
XCB	BPL	NDS	DKB	WMH	PAS	BRR

Table 6 indicates that recent forensic Native Americans and FDB Hispanics show no tendency towards platymeria, with the exception of the extremely small sample of Guatemalan Mayan

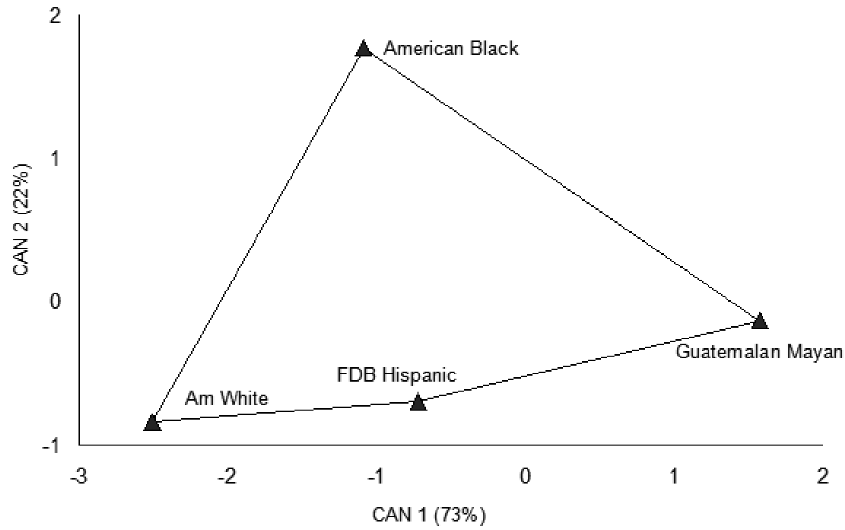

FIG. 5—*Canonical plot of FDB Hispanics, Guatemalan Mayans, and American Blacks and Whites.*

TABLE 4—*Variables used in DFA analysis.*

GOL	BNL	ZMB	BAR
NPH	XML	OBH	NLB
OBB	ZYB	NDS	PAS
PRR	EKB	XCB	DKB

TABLE 5—*DFA results for calibration sample (cross-validated)**.

Group	*n* Correct	Total *n*	Percentage Correct
FDB Hispanic	28	62	45
Guatemalan Mayan	55	69	80
American Black	55	78	71
American White	166	203	82

FDB, Forensic Anthropology Data Bank.

*When only Mexican-Americans and American Whites are included in analysis, percentages correct are 81% and 87%, respectively.

females. The ANOVA results indicate that the group means for the PI are significantly different for the males. Although the *p*-value is significant for females, the only group that exhibits platymeria is the Guatemalan Mayan female sample.

Discussion

It is difficult to determine sex metrically on FDB Hispanics. Females are nearly always assigned to the appropriate sex, although too many males are classified as females. Therefore, sexing criteria derived from American Whites cannot be applied to FDB Hispanics with the same success rate. The Trotter, Genoves, and FDB stature formulae all provide similar mean stature estimations. While these stature formulae might work well for some Hispanic individuals, the plots of the NHANES data set suggest that population specific formulae are needed for different Hispanic groups. Mexicans with post 1945 birth-years are shorter in stature than Puerto Ricans and Cubans. Further, differences displayed in sitting height reinforce the need for population specific stature equations by showing differences in lower limb proportionality. Trotter's (8) stature formula for Mexicans and the regression equation derived from FDB Hispanics provide the best possible stature formulae. The apparent marginal overestimation of stature derived from the FDB could either be the result of postcranial secular change or due to differences found in the overestimation of reported stature versus actual measured stature (21).

Ancestry estimation of Hispanic individuals based on a DFA using a four group analysis provides low classification rates.

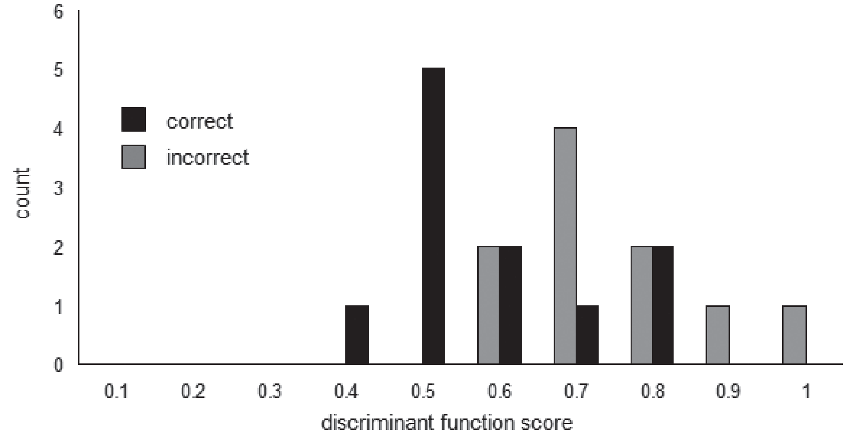

FIG. 6—*Discriminant function scores for FDB Hispanic test sample.*

TABLE 6—*Platymeric indices of groups from the FDB*.*

Platymeric Index						
Group	Sex	*n*	PI	SD	Minimum	Maximum
American Indian	F	2	96	11.31	88	104
	M	7	90.85	6.28	81	100
American Black	F	45	89.68	12.01	75	129
	M	77	90.36	9.05	78	119
FDB Hispanics	F	9	96.66	10.16	81	113
	M	36	93.11	12.03	68	123
Guatemalan Mayan	F	3	79	4.58	74	83
	M	83	86.01	9.53	61	133
American White	F	139	88.66	10.49	41	129
	M	239	89.41	8.81	65	125

*ANOVA results: Male F = 3.98, df = 4, $p = 0.0035$; female F = 2.18, df = 4, $p = 0.0730$.

Although low, they are better than chance alone which in this case would be 25%. When using a DFA, interpretation of the posterior probabilities is important. Posterior probabilities evaluate the probability of group membership based on the assumption that the unknown individual is from one of the populations (22). When running a positively identified sample through a DFA, and using an appropriate reference sample, posteriors of 0.8 or higher would indicate a good classification. Figure 6 shows the number of correct and incorrect classifications and associated posterior probabilities. Notice that the majority of correct classifications are 0.5. This means that they are just as likely to belong to another group, in other words they are not strong classifications.

Further, based on the PIs presented in Table 6, platymeria does not appear to be a good tool for ancestry estimation in modern forensic cases. This result is surprising in view of the strong arguments made for its utility in discriminating Whites from Native Americans (13,14). If it has a strong genetic component, a hybrid population such as Hispanics should be intermediate. In fact what we see is that Hispanics are even less platymeric than Whites. The results from our small sample of recent Native Americans suggest that they differ from earlier Native Americans in expressing no platymeria. However, it may be useful in distinguishing prehistoric and historic Native Americans from American Whites but has no utility in modern forensic practice.

Determination of ancestry for FDB Hispanics, as well as other Hispanic groups, is complicated by hybrid populations that could be thought of as arriving from previously hybridized populations. Classifications based on cranial discrete traits are largely more subjective and are unlikely to separate closely related groups of individuals. Classifications based on metric data require a careful examination and interpretation of posterior probabilities. Analyses using geometric morphometric methods are known to discriminate better among similar groups and may become more widespread because more researchers are beginning to use this technology in forensic anthropology.

Conclusions

A biological profile initially consists of sex, age, ancestry, and stature. When faced with remains of FDB Hispanics, if the pelvis is not available, the accuracy of metric sex determination declines considerably. Both visual and metric sex estimation of the skull may also be quite misleading for southwest Hispanic crania because they tend to be smaller and more gracile than other groups. However, if ancestry is able to be assessed as Hispanic, sex may become more accurate if population-specific sex estimates are derived. Plots of the NHANES data illustrate the need for population specific stature formulae for Hispanics from different geographic areas.

Stature estimation for southwest Hispanics can be obtained with Trotter's (8) stature formulae or the regression formula reported from the FDB. Ancestry is difficult to estimate for FDB Hispanic individuals given the diverse genetic admixture in the population. Platymeria is not a good tool for ancestry estimation in modern forensic cases; however it may be useful in distinguishing prehistoric and historic Native Americans from American Whites. Ross et al. found that Cubans were more similar to American Blacks and suggested that they have little or no Native American ancestry (2). The canonical variates analysis suggests that FDB Hispanics do contain biological Native American ancestry as indicated in Fig. 5. The FDB Hispanic sample is intermediate between American Whites and the Guatemalan Mayan sample, which can be considered a Native American sample.

Our methods and reference samples are the key when it comes to keeping up with America's changing demographics for purposes of skeletal identification. As demonstrated in this paper, we are only just beginning to understand the complexity and biological variation among southwest Hispanics and other Hispanic groups.

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