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Testing assumptions of the Gilbert and Gill method for assessing ancestry using the femur subtrochanteric shape

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Abstract

In 1990, Gilbert and Gill proposed a simple metric technique using femoral subtrochanteric anteroposterior and mediolateral diaphyseal diameters for discriminating between Native American and American Black and White femora in medicolegal and bioarchaeological contexts. However, there are several inherent assumptions in the method that may affect its validity. The assumptions include minimal sexual dimorphism, temporal and geographical homogeneity within populations, and that differences between populations in femoral subtrochanteric size and shape are primarily due to genetic variation. In this study, these assumptions are tested using femora from seven populations (African, American Black, American White, Australian, Native American, Hispanic, and Polynesian). The results indicate that sexual dimorphism and geographical and temporal heterogeneity in proximal femur diaphyseal shape within Native Americans are not great enough to significantly affect the validity of the Gilbert and Gill method (GGM). Variation between populations is most likely due to combined genetic and environmental factors, but differences in proximal femur shape between Native Americans and American Blacks/Whites are sufficient to allow accurate discrimination between these groups. Caution, however, must be taken during investigations

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where populations other than Native Americans or American Blacks/Whites are present, and therefore, the GGM may have limited forensic anthropological application in many parts of the world.

Introduction

Determination of ancestry from skeletal remains is a critical component in most forensic anthropological and historic bioarchaeological investigations, but it is also a difficult and controversial task (Brace, 1995; Kennedy, 1995; Montagu, 1942; Sauer, 1992; Shipman, 1994; St. Hoyme and İşcan, 1989; Williams et al., 2005). Traditionally, craniofacial features are scrutinized by biological anthropologists to determine ancestry (Bass, 1995; Giles and Elliot, 1962; Krogman and İşcan, 1986; Stewart, 1979), but when the skull is absent or badly damaged, techniques that make use of other skeletal elements are necessary. Gilbert and Gill (1990) proposed a simple metric technique, requiring only femoral subtrochanteric anteroposterior and mediolateral dimensions, for distinguishing Native American femora from those of historic and contemporary American Blacks and Whites. They observed that at the subtrochanteric region of the femoral diaphysis, Native Americans exhibit a relatively anteroposteriorly flattened (platymeric) cross-section, while American Blacks and Whites have a more circular (eurymeric) cross-section (Fig. 1). Plotting the subtrochanteric anteroposterior diameter (APD) against the mediolateral diameter (MLD), Gilbert and Gill (1990) visually determined a sectioning line that placed 100% of the American Black and White femora on the right side of the line and 61% of the Native American femora to the left (Fig. 2). While the precision of the sectioning line proposed by Gilbert and Gill (1990) was only moderate for Native Americans, Gill and Rhine (1990) showed that by adjusting the sectioning line, the Gilbert and Gill method (GGM) could correctly classify 78% of Native Americans

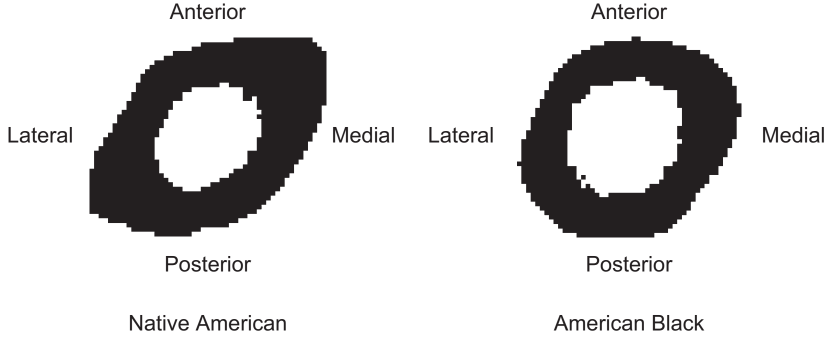

Fig. 1. Left femur subtrochanteric cross-sections of a Native American and American Black showing shape differences.

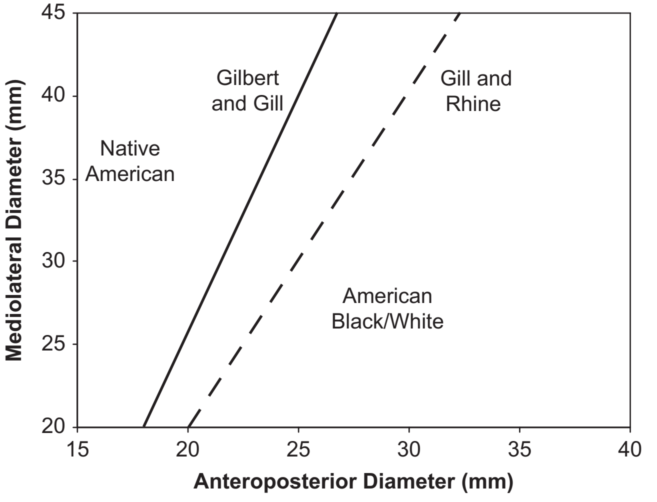

Fig. 2. Graph illustrating the Gilbert and Gill (1990; solid line) and Gill and Rhine (1990; dotted line) sectioning points. Gilbert and Gill (1990) found that 61% of Native Americans fell to the left of the solid line and 100% of American Blacks and Whites fell to the right. For the adjusted Gill and Rhine (1990) sectioning line, 78% of Native Americans were to the left and 85% of American Blacks and Whites were to the right of the dotted line.

and 85% of American Whites (Fig. 2). American Blacks were not used in the study by Gill and Rhine (1990).

The GGM has appeal, but it is also plagued with potential inherent problems that could affect its validity. The appeal of the GGM is that it appears to distinguish between Native American and American Black/White femora with a reasonable degree of accuracy, requires very little equipment (sliding calipers), can be conducted on complete and incomplete or fragmented bones, and can be used in both forensic anthropological and historic bioarchaeological investigations. The potential problems with the GGM are that subtrochanteric measurements may have high intra- and interobserver errors (see Adams and Byrd, 2002; Wescott, 2005 for discussion), and investigators must accept several inherent assumptions: (1) there is little or no sexual dimorphism in femur subtrochanteric size and shape, (2) ancestral groups are temporally homogeneous in proximal femur morphology, (3) ancestral groups are geographically homogeneous in proximal femur morphology and (4) proximal femur shape differences between Native Americans and American Blacks and Whites are primarily due to genetic variation. However, anthropological research over the past several decades suggests that many of these assumptions may be incorrect, which has the potential to affect the validity of the GGM.

Ruff (1995) showed that the first assumption of little or no sexual dimorphism in proximal femur morphology may be incorrect. He argued that the sexual dimorphism in proximal femur diaphyseal shape reflects sex differences in pelvic morphology. In order to give birth, females have a relatively wider pelvis than males.

As a result, females place greater mediolateral bending loads on the proximal femur, causing them to develop more pronounced platymeria than males (Ruff, 1995).

The assumption of temporal homogeneity is also dubious because numerous studies have shown a temporal trend in femoral diaphyseal shape and robusticity, especially at midshaft, due to changes in activity patterns through time (Rockhold, 1998; Ruff, 1987; Ruff et al., 1984, 1993). Rockhold (1998) found a significant decrease in subtrochanteric APD and MLD from 1840 to 1970 among American Blacks and Whites, but no significant change in diaphyseal shape. Since the GGM uses both size and shape of the proximal femur, Rockhold (1998) study suggests the validity of the method could be affected regarding American Blacks and Whites. Furthermore, Ruff et al. (1984) observed that femoral subtrochanteric shape in Native Americans is more circular (i.e., more eurymeric) among agricultural males than among earlier hunter–gatherer males along the Georgia coast. Females also show a similar, although not statistically significant, trend. The results suggest that Native American males may not be temporally homogeneous due to changes in subsistence strategy. Consequently, the accuracy of the GGM at distinguishing between Native Americans and American Blacks/Whites may be reduced depending on the subsistence strategy practiced by Native American groups.

The third assumption that groups, especially Native Americans, are geographically homogeneous in proximal femur morphology is also suspect. The Native American sample used by Gilbert and Gill (1990) was composed entirely of skeletons from the Northern Great Plains. Research by (Gill and Rhine, 1990 and Wescott, 2001, 2005), however, showed that Northern Plains Native American groups are more platymeric than are Native Americans from other geographical regions. This suggests that sampling bias may have contributed to the success of the GGM. That is, Gilbert and Gill (1990) used the most platymeric Native American group to represent all Native Americans.

The fourth assumption that differences between Native Americans and American Blacks and Whites in proximal femur shape are due to genetic variation is difficult to assess. Gill and colleagues (Gilbert and Gill, 1990; Gill and Rhine, 1990; Gill, 2001) have argued that differences in proximal femur shape between groups are primarily due to genetic variation. This claim is at least partially supported by Miller (1995) and Lovejoy et al. (2002) who have asserted that population differences in proximal femur shape appear in early childhood, and therefore probably have a strong genetic component. However, there is also evidence that differences between groups in femur subtrochanteric shape result from the interaction of genetic and environmental factors. Wescott (2006a), for example, showed that femur subtrochanteric shape is established early in life—around 4–5 years of age. However, he contended that the early establishment of subtrochanteric shape is probably due to biomechanical stresses associated with children learning to walk and developing a mature gait pattern. Wescott (2006a) argued that differences between groups in subtrochanteric shape likely reflect differences in body physique during growth, especially hip breadth relative to femur length, which may have a strong environmental component. Additionally, the growing body of biomechanical research on long bone cross-sectional architecture suggests that differences in the proximal femur between Native Americans and American Blacks and Whites may reflect diversity in physical activities rather than genetic differences. There is a significant body of experimental, clinical, and anthropological evidence demonstrating that long bone diaphyseal cross-sectional size and shape reflects mechanical loads placed on the bone during life (for an overview see Curry, 1984; Frost, 2003; Martin et al., 1998; Ruff, 1999). The biomechanical research suggests that most of the within and between group variation in subtrochanteric shape is associated with physical activity rather than genetics. Geographical, temporal, and sexual variation therefore may reflect differences in terrain relief (Ruff, 1999), subsistence strategy (Bridges, 1989, 1995; Larsen, 1981, 1997; Larsen and Ruff, 1994; Ruff, 1987, 2000), terrestrial mobility levels (Larsen, 1997; Ruff, 2000), and sexual division of labor (Ruff, 1987, 2000).

The purpose of this paper is five-fold. First, sexual dimorphism in femoral subtrochanteric size and shape is examined within seven populations. Second, temporal homogeneity is investigated among American Blacks, American Whites, and Native Americans. Third, geographical homogeneity among Native Americans in proximal femur shape is tested. Native Americans are used to test the assumption of geographical homogeneity because they are the only large geographically diverse sample used in the study. Fourth, the genetic versus environmental contributions to subtrochanteric shape are examined. This is accomplished by reviewing the literature and examining variation within and between samples of African, American Black, American White, Australian, Hispanic, Native American, and Polynesian femora. Finally, the validity of using the proximal femur to assess ancestry is tested using femora from individuals of known ancestry.

Materials and methods

Femur subtrochanteric APD and MLD (Moore-Jansen et al., 1994; Zobeck, 1983), measured to the nearest millimeter, were obtained for individuals from seven groups (Table 1): African ($N = 31$), American Blacks ($N = 320$), American Whites ($N = 668$), Australians ($N = 147$), Hispanics ($N = 41$), Native Americans ($N = 1695$), and Polynesians ($N = 179$). Only adults (complete epiphyseal closure) with no evidence of fractures or infection of the femur were used. Left femora were preferentially used but right femora were used for individuals with a missing or damaged left femur to increase the sample size.

The femoral data used in this study came from multiple sources. The African sample was collected by one of the authors (DW) at the American Museum of Natural History and represents populations from North, South, and West Africa. American Black and White femora, which were measured by multiple researchers, come from the Terry Collection (Trotter, 1981), Forensic Data Base (FDB) (Ousley and Jantz, 1996, 1998), and historic archaeological sites (Wescott, 2001). The Hispanic sample is from the FDB and no specific information is available regarding ancestry. However, craniometric evidence suggests at least some Native American ancestry (Spradley et al., 2008). The Australian sample was collected on skeletons

Table 1. Sample size and description

Group	♀ *N*	♂ *N*	*N*	Description
African	3	28	31	American Museum of Natural History collection
American Black	137	183	320	Terry collection, Forensic Data Bank, archaeological sites
American White	265	403	668	Terry collection, Forensic Data Bank, archaeological sites
Australian	62	85	147	George Murray Black collection
Hispanic	7	34	41	Forensic Data Bank
Native Americans	808	887	1695	University of Tennessee/Smithsonian database
Geographical Regions	795	864	1659	
Central Plains (CP)	149	155	304	Northern plains border to Arkansas River
Eastern Prairie (EP)	36	22	58	East of Mississippi River
Great Basin (GB)	38	54	92	Desert basin of Nevada and Utah
Gulf Coast (GC)	43	55	98	Texas Gulf Coast
Northern Plains (NP)	394	449	843	North of Nebraska/South Dakota border
Southern Plains (SP)	58	61	119	South of Arkansas River
Southwest (SW)	77	68	145	Utah, Colorado, New Mexico, Arizona
Temporal Periods	639	712	1351	
Pre-Woodland (PWD)	15	22	37	7000 B.C. to A.D. 500; Paleoamerican and Archaic
Woodland (WD)	69	72	141	1000 B.C. to A.D. 950; Woodland
Village (VIL)	266	286	552	A.D. 1000–1700; Primarily horticultural groups
Historic (HIST)	289	332	621	1700–1850; Proto-historic and historic groups
Polynesian	108	71	179	Hawaii—Snow collection

from the George Murray Black collection (Brown, 2004) and downloaded from Dr. Peter Brown's website (http://www-personal.une.edu.au/~pbrown3/resource.html). The Native American sample comes from the University of Tennessee/Smithsonian Institution (UT/SI) postcranial database, which includes femora from historic and prehistoric archaeological sites from the American Great Basin, Great Plains, Southwest, and Southeast (see Wescott (2001) for a detailed description of the sample). The Polynesian sample was drawn from Hawaiian skeletons measured by Dr. Charles Snow (Snow, 1974). As with all compiled data, interobserver error has the potential to create noise in the data. However, a previous study (Wescott, 2005) showed that the interobserver error in these data is nominal and has no significant effect on the validity of analyses of proximal femur shape.

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Analyses of the data were conducted using raw measurements and the platymeric index (PI), which was calculated by dividing APD by MLD and multiplying by 100 (Bass, 1995; Brothwell, 1981). Individuals with anteroposteriorly flattened proximal diaphyses ($PI \leqslant 84.9$) are considered platymeric, those with circular diaphyses ($85 \leqslant PI \leqslant 99.9$) are eurymeric, and individuals with a PI above 99.9 are stenomeric. Individual variation in the PI ranges from approximately 55 to 125, but population means generally range from 75 to 95 (Brothwell, 1981).

Several statistical analyses were performed on the femoral data using SAS. First, males and females were compared within the seven groups. Sex-specific variation among the seven populations was then examined. Analysis of variance (ANOVA) was used to evaluate group differences, and Tukey's multiple comparison tests were employed to control for Type 1 error and discover which populations, if any, differ. Temporal variation was examined in American Blacks and Whites and Native Americans using linear regression and ANOVA. Since year of birth is known for most of the American Blacks and Whites, temporal variation in these groups was investigated using linear regression by examining secular changes in femur diaphyseal size and shape for individuals born between 1830 and 1983. Temporal variation in Native Americans (Table 1) was investigated by dividing the sample into four temporal periods (Pre-Woodland, Woodland, Village, and Historic). Differences between temporal periods in APD, MLD, and PI were tested using ANOVA and Tukey's multiple comparison tests. Geographical variation was examined among Native Americans by dividing the sample into seven geographical regions or subsamples (Table 1). Finally, the effectiveness of the GGM at separating Native Americans from American Blacks and Whites was evaluated using discriminant function analysis and a PI sectioning point.

Results

Sexual dimorphism and among group comparisons

Summary statistics for the seven groups are presented in Table 2 by sex. Overall, there is significant sexual dimorphism in all populations for APD ($F = 149.8$; $p < 0.0001$) and MLD ($F = 144.8$; $p < 0.0001$), but not in the PI ($F = 1.26$; $p = 0.2616$). These results demonstrate that the proximal femora of males and females differ only in size. That is, at subtrochanteric level, males have larger but similarly shaped femoral diaphyses as females. The sample size for African and Hispanic females is very small and the results for these groups should be viewed with caution. However, the sexual dimorphism in the African and Hispanic samples follows the same pattern seen in other groups.

The results also clearly show that Polynesians, Native Americans, and Australians are on average platymeric, while the other groups are eurymeric (Table 2, Fig. 3). Africans are on the borderline with females slightly eurymeric and males slightly platymeric, however the sample size is small. Polynesians have the most platymeric

Table 2. Summary statistics by group and sex

Group	Sex	*N*	APD[a]		MLD[a]		PI	
			Mean[b]	SD	Mean[b]	SD	Mean	SD
African	F	3	21.8	3.2	25.5	0.4	85.2	11.5
	M	28	24.3	3.2	28.9	2.8	84.3	8.6
American Black	F	137	26.2	2.2	28.5	2.5	92.7	10.8
	M	183	28.7	2.4	31.8	2.6	90.6	8.5
American White	F	265	25.3	2.4	28.4	2.2	89.5	9.4
	M	403	28.7	2.5	31.9	2.7	90.3	8.9
Australian	F	62	21.8	2.6	27.7	2.5	79.2	6.3
	M	85	25.3	2.2	30.7	3.1	80.5	7.3
Hispanic	F	7	25.3	2.4	29.1	1.7	86.7	5.7
	M	34	27.3	2.4	31.0	3.2	89.2	13.4
Native American	F	808	23.4	2.3	30.6	2.5	76.9	8.8
	M	887	26.3	2.4	33.4	2.8	79.2	10.0
Polynesian	F	108	21.3	1.7	30.4	2.0	70.1	5.0
	M	71	23.6	1.9	33.5	2.7	71.4	5.5

[a]Statistically significant sexual dimorphism in all populations.
[b]In millimeters.

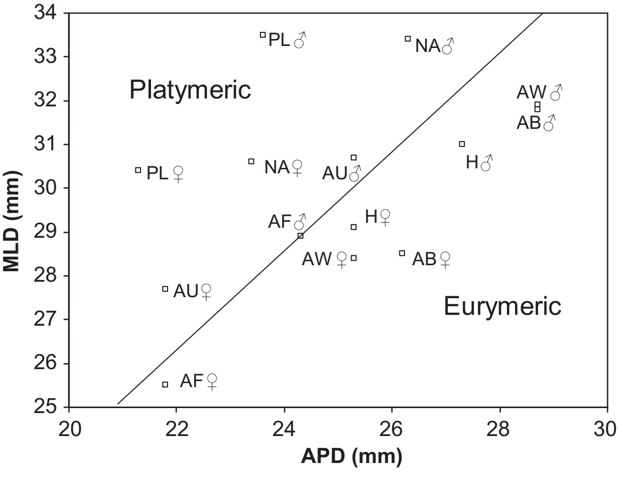

Fig. 3. Plot of mean APD and MLD for each of the seven groups by sex [African (AF), American Black (AB), American White (AW), Australian (AU), Hispanic (H), Native American (NA), and Polynesian (PL)].

femora and differ appreciably from all other groups. American Blacks, on the other hand have the most eurymeric femora, but do not differ significantly from Africans, American Whites, or Hispanics.

Temporal homogeneity

Temporal homogeneity was examined in American Blacks and Whites by examining secular changes among individuals with birthdates ranging from the 1830s to 1980s and in Native Americans by dividing the sample into temporal groups. The platymeric index has decreased slightly (slope $= -0.0002$, $r^2 = 0.0067$) in American Blacks and increased a small amount (slope $= 0.00008$, $r^2 = 0.0011$) in American Whites over the last 150 years (Fig. 4). However, the change in PI is not significant for American Blacks ($F = 1.91$, $p = 0.1683$) or Whites ($F = 0.71$, $p = 0.4000$).

As seen in Table 3, there is a slight decrease in the PI among Native Americans from the Pre-Woodland to the Historic period, but only the earliest period differs significantly. When males and females are pooled, the later three periods (Woodland, Village, and Historic) are significantly more platymeric (PI: $F = 4.26$; $p = 0.0054$) than the earliest period (Pre-Woodland) due to a significantly larger MLD ($F = 5.15$; $p = 0.0015$). There is not a significant temporal pattern in APD ($F = 0.94$; $p = 0.4194$). Sex-specific analyses show that females from the Pre-Woodland period exhibit a significantly smaller MLD ($F = 4.35$; $p = 0.0017$) and consequently a larger PI ($F = 4.97$; $p = 0.0020$). Males from the Pre-Woodland period differ significantly from the other temporal periods only in MLD ($F = 3.48$; $p = 0.0156$). There are no significant differences between the Woodland, Village, or Historic periods in any of the variables.

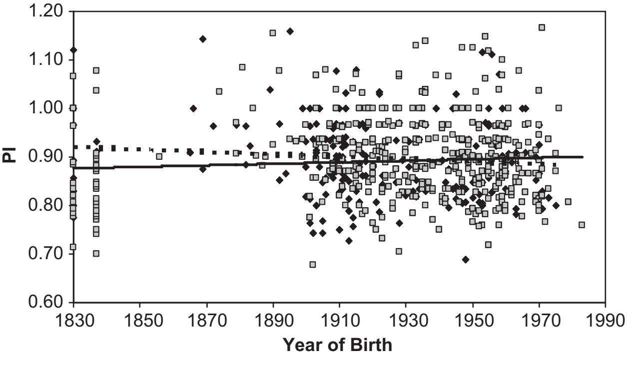

Fig. 4. Secular change in the platymeric index of American Blacks (diamonds) and Whites (squares). The PI has decreased in American Blacks (dashed line) and increased American Whites (solid line) through time, but the change is not significant for either group.

Table 3. Summary statistics for Native Americans by temporal period and sex

Period[a]	Sex	APD		MLD		PI	
		Mean	SD	Mean	SD	Mean	SD
PW	F	22.8	3.0	[b]29.6	2.4	[b]81.2	14.9
	M	26.3	1.6	[b]31.9	3.2	83.3	10.1
WD	F	23.1	2.4	30.8	3.0	75.4	8.1
	M	26.1	2.6	33.4	3.0	78.6	10.2
VIL	F	23.7	2.1	30.9	2.6	77.1	8.8
	M	26.2	2.2	33.9	2.9	77.8	9.1
HIST	F	23.0	2.2	30.9	2.1	74.7	7.2
	M	26.2	2.2	33.7	2.7	78.2	10.2

[a]See Table 1 for abbreviations and sample size.
[b]Significantly different ($p<0.05$) from other temporal periods.

Table 4. Native American platymeric index means by geographical region

	Sex	Geographical region[a]						
		CP	EP	GB	GC	NP	SP	SW
Mean	F	79.0	79.0	81.1	78.1	[b]74.3	82.2	[b]76.4
SD		8.3	9.1	9.9	6.9	7.3	11.4	8.8
Mean	M	84.0	79.4	82.0	84.5	[b]75.7	83.3	79.6
SD		12.4	8.2	9.3	9.3	7.9	8.7	9.7

[a]See Table 1 for list of abbreviations and sample sizes.
[b]Statistically significant ($p<0.05$) difference from all other groups. NP and SW females differ from other groups but not from each other.

Geographical homogeneity

Within Native Americans there is some geographical heterogeneity in femoral subtrochanteric shape (Table 4). American Northern Plains males exhibit significantly greater platymeria than males from other geographical regions. Among females, the PI is significantly smaller in the Northern Plains and Southwest, but there are no significant differences between Northern Plains and Southwestern females. Differences in PI among the other geographical regions are insignificant for both males and females.

Effectiveness of GGM for determining ancestry

The within-population range of individual variation in proximal femur size and shape is considerable, making discrimination between the seven populations nearly

Table 5. Classification of ancestry using the platymeric index

Group	Sex	PI < 83		PI ≥ 83	
		No.	(%)	No.	(%)
Native American	Female	660	82	148	18
	Male	631	71	256	29
	Combined sex	1291	76	404	24
American Black	Female	27	20	110	80
	Male	39	21	144	79
	Combined sex	66	21	254	79
American White	Female	67	25	198	75
	Male	82	20	321	80
	Combined sex	149	22	519	78

impossible. For example, American Black femora could not accurately be distinguished from femora of American Whites or Hispanics. Similarly, Native Americans could not accurately be separated from Polynesians or Australians. However, to test Gilbert and Gill's assertion that subtrochanteric shape can be used to discriminate between Native Americans and American Blacks/Whites, a discriminant function with cross-validation was run using APD and MLD as variables. Blacks and Whites were pooled since they do not differ significantly in subtrochanteric size or shape. Seventy-two percent of Native American males and 82% of Native American females were correctly classified. Among the pooled American Black/White group, 79% of males and 77% of females were correctly classified. The PI alone was also found to be extremely valuable for distinguishing between Native Americans and American Blacks and Whites (Table 5). A PI of 83 as a sectioning point was determined to provide the greatest discriminating ability in this study. Individuals with a PI less than 83 were classified as Native American and those equal to or above the sectioning point were classified as American Black/White. Seventy-six percent of Native Americans, 79% of American Blacks, and 78% of American Whites were correctly classified when sexes were combined (Table 5).

Discussion

Gilbert and Gill (1990) proposed a simple and relatively accurate method for distinguishing between the skeletons of Native Americans and American Blacks/Whites using proximal femur shape, but several untested assumptions threatened its validity when applied outside the American Northern Great Plains. In this study, several of the assumptions embedded in the GGM were identified and examined to determine if and how they affect its validity. These assumptions include little or no sexual dimorphism in proximal femur diaphyseal shape, geographical and temporal homogeneity within groups in diaphyseal shape, and the primacy of genetics influencing diaphyseal shape.

Sexual dimorphism

Ruff (1995) discovered significant sexual dimorphism in the cross-sectional properties of the femoral diaphysis at the subtrochanteric region. Likewise, we found that females are in general more platymeric than males, but not at the level of statistical significance. Significant size differences between males and females were found in diaphyseal diameters (APD and MLD), but not in shape (PI). The results of this study likely differ from those of Ruff (1995) because he examined cross-sectional properties, which take into account not only the external shape but also the internal architecture and size of the shaft. Since there is no significant sexual dimorphism in proximal femur shape using the PI, the assumption of no sexual dimorphism embedded in the GGM is not violated and should have little or no effect on the validity of the method.

Temporal homogeneity

The assumption of temporal homogeneity is not violated for American Blacks and Whites but is violated for Native Americans. However, the significant temporal change in subtrochanteric shape among Native Americans does not appear to have a major effect on the validity of the GGM. The Pre-Woodland group (Paleoamerican and Archaic) was significantly less platymeric than later groups. However, the latter three groups also contain a large number of Northern Great Plains and Southwestern groups, which are significantly more platymeric than Native Americans from other geographical areas, suggesting that the slight decrease could be due to sampling error. Regardless, the slight temporal variation is not great enough to affect the validity of the GGM. Even Pre-Woodland Native American groups are notably more platymeric than American Blacks/Whites.

Geographical homogeneity

The assumption of geographical homogeneity was tested using Native Americans since this was the only sample used with substantial geographical diversity. Native Americans are not geographically homogeneous in subtrochanteric shape. Northern Plains populations, the group Gilbert and Gill (1990) used to represent all Native Americans, are significantly more platymeric than are Native Americans from other geographical regions. This would indicate that geographical differences could have an effect on the validity of the GGM. However, regardless of geographical region, Native Americans are more platymeric than other populations examined, except for Polynesians. As a result, geographical heterogeneity among Native Americans does not appear to affect the validity of the GGM, which only compares Native Americans to American Blacks and Whites.

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Genetic versus environmental contributions

The genetic versus environmental (biomechanical) influences on proximal femur diaphyseal shape is a controversial topic (Lovejoy et al., 2003; Wescott, 2006b). Differences among groups in diaphyseal shape may be related to genetic variation, environmental diversity, or both. Gill and colleagues (Gilbert and Gill, 1990; Gill and Rhine, 1990; Gill, 2001) contended that differences between groups in proximal femur shape are primarily due to genetic variation, while Ruff and colleagues (Ruff, 2000; Ruff et al., 1984) contended that mechanical usage greatly affects diaphyseal shape and size. The results of this study will not settle the issue, but they do provide some insight.

No attempts have been made to examine the proportion of genetic and environmental influence on subtrochanteric shape, but Miller (1995) and Lovejoy et al. (2002) assert that proximal femur shape is established relatively early during growth and development—well before the children place any significant biomechanical loads on their femora. These authors have argued that the early establishment of diaphyseal shape at the subtrochanteric level suggests that platymeria is controlled more by genetics than by biomechanics or other environmental influences. Lovejoy and colleagues (Lovejoy et al., 2002, 2003; Ohman and Lovejoy, 2001, 2003) argued that femur diaphyseal shape is greatly influenced by the shape of the growth plate during femoral growth and development. Since the shape of the growth plate is known to be controlled by regulatory genes, Lovejoy et al. (2002) contended that the shape of the diaphysis must be under strong genetic influence. However, in a study examining age related changes in femur subtrochanteric size and shape of subadults, Wescott (2006a) discovered that subtrochanteric shape is established around the time children develop a mature gait pattern and then remains fairly static through adulthood. This ontogenetic pattern was found in Native Americans as well as American Blacks and Whites. Wescott (2006a) argued that differences between Native Americans and American Blacks and Whites in subtrochanteric shape were likely due to differences in hip breadth relative to femur length between the groups. Since Native Americans have shorter femora relative to hip breadth compared to American Blacks/Whites, Native Americans place greater mediolateral stress at the subtrochanteric region during bipedal locomotion than American Blacks/Whites. As a result, Native Americans tend to develop more platymeric proximal femoral diaphyses. However, body build can be the result of both genetic and environmental factors (Bogin, 1999).

In concordance with Lovejoy and colleagues, the results of this study also hint at a strong genetic component to subtrochanteric shape (Lovejoy et al., 2002, 2003; Ohman and Lovejoy, 2001, 2003). The results of this study show that in a broad sense, populations of Asian ancestry are more platymeric than those of African or European ancestry. These results are consistent with those of Gill (2001) and Voulgaris (1999) who found that Chinese and Polynesians from Easter Island, respectively, are extremely platymeric. Even though there is probably some geographical and temporal heterogeneity in all populations due to skeletal plasticity, as discovered among Native Americans in this study, it appears that genetics plays a

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role in determining proximal femur diaphyseal shape. For example, while there is considerable individual variation in the PI, over 75% of Native Americans are platymeric, regardless of subsistence strategy, geographical location, or terrain type (Wescott, 2005). On the other hand, only about 25% of American Blacks and American Whites are platymeric.

Validity of the Gilbert–Gill method

While race or ancestry is socially or bureaucratically constructed and usually based on the history of migration in a region, the estimation of ancestry from skeletal remains is often critical in forensic anthropological and historical bioarchaeological investigations (Brace, 1995; Cox et al., 2006; Kennedy, 1995; Sauer, 1992; Shipman, 1994; Weiss and Fullerton, 2005; Williams et al., 2005). The GGM is an easy and relatively accurate method for discriminating between Native Americans and American Blacks and Whites. As pointed out by Gill and Rhine (1990), the sectioning line provided by Gilbert and Gill (1990) is imprecise, but approximately 76% of Native Americans and 78% of American Blacks/Whites can be correctly classified using an appropriate PI sectioning point or a discriminant function that includes APD and MLD. With the addition of femur head size and femur maximum length in the discriminant function, Wescott (2005) showed the classification rate increases to as high as 87%. Consequently, this simple method for estimating ancestry should be extremely valuable to investigators conducting historic bioarchaeological studies in the United States, where the ancestry of the skeleton is generally restricted to one of these three groups. However, the GGM may be of less value to forensic anthropologists because the ancestry of the unidentified skeleton may not be limited to these groups and admixture is possible. It is feasible that the GGM could be used by forensic anthropologists to assess if a skeleton is of Asian ancestry or not, but more accurate assessment of ancestry is probably not achievable using the proximal femur. For example, it was impossible to reliably distinguish between American Blacks, American Whites, Hispanics, and Africans. Likewise, Native Americans frequently were classified as Polynesian or Australian using this method. Therefore, we recommend that investigators do not use the GGM for comparisons of groups other than those it was developed on, i.e., Native Americans and American Blacks and Whites.

Conclusions

Several assumptions embedded in the method proposed by Gilbert and Gill (1990) for estimating ancestry were examined. The results show that sexual dimorphism (not observed) and geographical and temporal heterogeneity (both observed) in proximal femur diaphyseal shape within Native Americans is not great enough to significantly affect the validity of the GGM. The results also suggest that variation between populations may have a strong genetic component. However, regardless of whether diaphyseal shape is more genetically or environmentally determined, the differences in proximal femur shape between Native Americans and American Blacks/Whites are sufficient to allow accurate discrimination between these groups. However, caution must be taken during investigations where populations other than Native Americans or American Blacks/Whites are present. As a result, the GGM may have limited forensic anthropological application in many parts of the world.

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