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Population Variation in Femur Subtrochanteric Shape*

ABSTRACT: Use of proximal femur shape to determine ancestry has appeal, but its validity is problematic because of unaddressed issues associated with skeletal plasticity, within- and between-population variation, sample selection, and interobserver error. In this paper, I inspect within- and between-group variation in proximal femur shape using five groups (American Blacks, American Whites, Hispanics, Native Americans, and Polynesians), and examine the affect of three environmental variables (subsistence strategy, physical terrain, and geographical region). Finally, I consider the validity of using the proximal femur to assess ancestry. The results show that there is significant within-group variation in proximal femur shape. Among Native Americans, both geographical location and subsistence strategy have a significant affect on proximal femur shape. Nevertheless, this study generally verifies the assertion that the proximal femur can be used reliably to distinguish Native Americans from American Blacks and Whites, but its precision may be reduced in some geographical regions.

KEYWORDS: forensic science, forensic anthropology, femur, subtrochanteric shape, platymeria, eurymeria, stenomeria

Categorizing an individual corpse according to race or ancestry is a critical component to any forensic analysis. However, determination of race or ancestry is also perhaps the most controversial (1–10) and difficult task (11–15) facing the forensic anthropologist. Assessment of ancestry is made even more difficult when traditional craniofacial features are absent. In these cases, forensic anthropologists must rely on postcranial bones.

Although several postcranial bones have been examined for their utility in assessing ancestry (16–21), the femur has probably received the greatest attention (17,21–29). Scientists have examined and discovered differences between populations in femoral size (17,21), intercondylar notch morphology (22), anterior shaft curvature (23–26), torsion (27) and subtrochanteric shape (28,29). However, regardless of the method, use of the femur to ascertain ancestry is plagued with potential problems associated with skeletal plasticity, within- and between-population variation, sample selection, and interobserver error. As a result, it is important that forensic anthropologists not only develop methods for determining ancestry but that they also continually test whether one or more of these variables affect its validity.

In this paper I examine proximal femur shape and its validity for assessing ancestry. I investigate within- and between-population variation, including sexual dimorphism, in proximal femur shape of adults among five groups: Native Americans, Polynesians, Hispanics, American Whites, and American Blacks. In addition, I examine the effect of subsistence strategy, terrain type, and geographical region on a large Native American sample in order to determine environmental influence on the shape of the proximal femur. Finally, I evaluate the utility of subtrochanteric shape in separating Native Americans from American Blacks and Whites and discuss how sample selection and interobserver error influences its validity.

Subtrochanteric Shape

Femur subtrochanteric shape is estimated using the platymeric index (PI), which is calculated by dividing the subtrochanteric anteroposterior diameter (APD) by the mediolateral diameter (MLD) and multiplying by 100 ($PI = APD/MLD * 100$) (13). Non-pathological individual variation in the PI ranges from approximately 55 to 125. Individuals with a PI less than 84.9 are platymeric (mediolaterally broad proximal diaphysis), those between 85 and 99.9 are eurymeric (round proximal diaphysis), and individuals with a PI greater than 100 are stenomeric (anteroposteriorly broad proximal diaphysis). Individual variation is considerable, but population means for the PI typically range from 70 to 100 (30). There are no known stenomeric populations.

Population differences in femur subtrochanteric shape have long been noted (31–33), but it has only been in the last several decades that forensic application of subtrochanteric shape has been examined seriously (34). Gill and colleagues (28,29,35,36) argue that subtrochanteric shape can be used effectively to distinguish the femora of historic and prehistoric Native Americans from American Blacks and Whites. They find that the subtrochanteric anteroposterior diameter is generally greater relative to the mediolateral diameter in American Blacks and Whites compared to Native Americans. Blacks and Whites on average have eurymeric proximal diaphyses, whereas Native Americans have platymeric proximal femora. Recently, Clow (37) and Voulgaris (38) discovered that Polynesians from Easter Island also exhibit platymeria, which Gill (34) relies on to suggest that populations of East Asian descent are more platymeric than are populations of African or European descent. This, Gill (34) argues, suggests that all populations of Asian descent are uniformly platymeric.

When employing proximal femur shape to access ancestry, several potential issues arise that could affect its use. First, while femur subtrochanteric shape is likely influenced by genetics (28,34,35,39), there is a significant body of research demonstrating

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the interdependence between long bone diaphyseal size and shape and mechanical stress related to subsistence strategy and physical terrain (40–48). During life, modeling and remodeling modify the basic tubular shape of long bones so that the diameter, shape, and thickness of the cortical bone reflect the manner and magnitude of biomechanical forces. As a result, long bone diaphyseal size and shape may primarily be a reflection of the mechanical stresses placed on the bone due to daily occupational activities and physical terrain. This suggests that the proximal femur is of little value when evaluating ancestry because differences reflect environmental plasticity more than genetic diversity.

Second, there is considerable within-group variation in the proximal femur, especially among Native Americans (49). Some of this within-group variation is manifested as sexual dimorphism, as platymeria may be more common in females than males (40,41,45). Ruff (40, 42) suggests that sexual dimorphism in the proximal femur reflects structural differences between the sexes related to childbirth. Females have relatively greater pelvic width than males and therefore place greater bending stress in the antetorsional (roughly mediolateral) plane of the femoral neck (42). As a result, sex differences in platymeria may reduce its validity in forensic investigations.

Sample selection can also influence the interpretation of within-group variation (50). The Native American sample used by Gill and colleagues (28,29) is primarily composed of skeletons from the American Great Plains and Southwest, but Native Americans are not a genetically homogeneous population, and the use of one or two populations to represent a large geographically and genetically diverse group could be a problem. I found that populations from these regions, especially the Northern Plains, are more platymeric than are Native Americans from other regions of the United States (49). This suggests that the success Gill (28,29) had in separating Native Americans from historic Blacks and Whites may in part be an artifact of sampling bias, as his Native Americans sample are among the most platymeric of all Native American groups. Using a small subsample of the Native American population to represent all groups may grossly distort the forensic utility of femur subtrochanteric shape.

Finally, Adams and Byrd (51) found a significant amount of interobserver variation in subtrochanteric femur measurements regardless of experience level. Their results show that interobserver error in subtrochanteric measurements ranged from 2.38 to 8.52% for the anteroposterior diameter and from 2.79 to 4.33% for the mediolateral diameter. This has obvious consequences for the forensic validity of subtrochanteric shape.

Materials and Methods

Samples

I obtained femoral measurements for mature individuals (complete epiphyseal closure) from five groups: Native Americans ($N = 1659$), Polynesians ($N = 179$), Hispanics ($N = 41$), American Blacks ($N = 320$), and American Whites ($N = 672$). The Native American sample comes from the University of Tennessee/Smithsonian Institution (UT/SI) postcranial database (49), and includes historic and prehistoric samples from the American Great Basin, Great Plains, Southwest, and Texas Gulf Coast (Table 1). The Polynesian sample is drawn from Hawaiian skeletons measured by Dr. Charles Snow (52), and the Hispanic data come from the Forensic Data Base (FDB) (53). The Hispanic individuals are identified as such in the FDB but no specific details regarding ancestry are known. I acquired data for American Blacks and Whites from the Terry Collection housed at the Smithsonian Natural History Museum and the FDB.

TABLE 1—*Native American subsample divisions.*

Class Variable	*N*	Description
Geographical Region		
Eastern Prairie (EP)	58	East of Mississippi River
Gulf Coast (GC)	98	Texas Gulf Coast
Northern Plains (NP)	843	North of Nebraska/South Dakota border
Central Plains (CP)	304	Northern Plains border to Arkansas River
Southern Plains (SP)	119	South of Arkansas River
Southwest (SW)	145	Utah, Colorado, New Mexico, Arizona
Great Basin (GB)	92	Desert basin of Nevada and Utah
Subsistence Strategies		
Agriculturalist (AG)	268	Primarily a farming lifestyle
Plains Horticulturalist (PH)	1068	Combined farming and bison hunting
Hunter-Gatherer (HG)	224	Primarily a hunting-gathering lifestyle
Physical Terrain		
Mountain (MT)	238	Rugged, uneven terrain
Plains (GP)	1266	Flat with rolling hills and rugged areas
Prairie (PR)	58	Gentle rolling hills; gentle gradient
Coast (CT)	103	Low relief; shallow valleys

Measurements

I took four measurements for each adult individual: femur maximum length (FML), vertical head diameter (VHD), and subtrochanteric anteroposterior (APD) and mediolateral (MLD) diameters (54,55). Measurements were recorded to the nearest millimeter, and the left femur was used when available. I calculated the PI to obtain a measure of femur subtrochanteric shape, and used FML and VHD to examine the association between femur size and the PI.

The samples used in this study were measured by multiple observers, but no test of interobserver measurement error could be conducted. Like all compiled datasets, interobserver error has the potential to increase noise in data and to bias results (51). I selected datasets used here partially to reduce interobserver error. With the exception of the Polynesian data collected by Snow (52), the majority of the data were collected by individuals working with and/or trained by Dr. Owsley at the Smithsonian Institution and Dr. Jantz at the University of Tennessee. All Native American data were obtained from the UT/SI database, which was first assembled by Zobeck (54) while working on his dissertation under Jantz. This database has received regular additions by Owsley, Jantz, and their trained coworkers at the Smithsonian Institution and the University of Tennessee (49). Owsley (personal communication) discovered that one osteologist collecting data for the UT/SI database was measuring subtrochanteric diameters incorrectly. Therefore, I removed all femora measured by this osteologist prior to analysis. Likewise, while the FDB receives contributions from forensic scientists throughout the United States, most of the data comes from forensic anthropologists at the Smithsonian or from those trained at the University of Tennessee (53).

TABLE 2—*Descriptive statistics for femur measurements.*[*][†]

		APD			MLD			FML			VHD		
Group	Sex	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
Native American	F	808	23.4	2.3	808	30.6	2.5	698	415.0	20.8	690	41.9	2.4
	M	887	26.3	2.4	887	33.4	2.8	797	449.2	20.7	795	46.7	2.4
Polynesian	F	108	21.3	1.7	108	30.4	2.0	105	411.8	17.8	105	40.9	2.1
	M	71	23.6	1.9	71	33.5	2.7	63	442.4	20.5	70	45.8	2.2
Hispanic	F	7	25.3	2.4	7	29.1	1.7	3	430.7	20.6	5	41.8	3.3
	M	34	27.3	2.4	34	31.0	3.2	31	452.6	24.5	31	46.3	2.4
American Black	F	137	26.2	2.2	137	28.5	2.5	127	441.9	23.8	128	41.8	2.1
	M	183	28.7	2.4	183	31.8	2.6	178	477.6	28.3	180	47.3	2.7
American White	F	265	25.3	2.4	265	28.4	2.2	238	433.6	22.0	235	42.2	2.2
	M	403	28.7	2.5	403	31.9	2.7	358	468.8	25.0	371	48.4	2.7

[*] Anteroposterior Subtrochanteric Diameter (APD), Mediolateral Subtrochanteric Diameter (MLD), Femur Maximum Length (FML), Vertical Head Diameter (VHD).

[†] In millimeters.

Statistical Procedures

I evaluated the influence of sexual dimorphism, within-group variation, and biomechanical stress on subtrochanteric shape using several statistical procedures. First, I calculated summary statistics for each group by sex. Second, I conducted an analysis of variance (ANOVA) procedure for the main effect of sex and population and the interactions of sex and population. ANOVA evaluates if the variation due to group differences is larger than expected by comparing the variation between groups to the error variation (56,57). Group means are likely to be different if the variation between groups is large relative to the error variation. Third, I subdivided the Native American sample into seven geographical regions, three subsistence strategies, and four terrain types (Table 1; see (49) for detailed discussion of geographical locations, subsistence strategies, and terrain types). Summary statistics were calculated for each group and ANOVA was used to evaluate group differences. When comparing more than two groups using ANOVA, it is necessary to use a multiple comparison test to control for type 1 error (incorrectly rejecting the null hypothesis) and gain information on particular population differences. ANOVA only provides information on the overall significance of group differences but not on which groups differ. Therefore, I used Tukey's multiple comparisons tests (56,57). Finally, I used discriminant function analysis with a cross-validation procedure to test how effective subtrochanteric shape is at estimating ancestry. Discriminant function analysis maximizes within-group differences and develops discriminant criteria that classify each observation into one of the five designated populations (56,58). The cross-validation procedure reduces bias by omitting the case being classified from the discriminant function (56).

TABLE 3—*Summary statistics for platymeric index.*

		Platymeric Index[*]						
Group	Sex	*N*	Mean	SD	Range	%P[†]	%E[‡]	%S[¶]
Native American[§]	F	808	76.9	8.8	58–123	85	12	3
	M	887	79.2	10.0	57–126	79	16	5
Polynesian[§]	F	108	70.1	5.0	55–89	99	1	0
	M	71	71.4	5.5	61–93	99	1	0
Hispanic	F	7	86.7	5.7	80–97	50	50	0
	M	34	89.2	13.4	68–123	38	44	18
American Black	F	137	92.7	10.8	74–129	24	53	23
	M	183	90.6	8.5	69–114	35	43	22
American White	F	265	89.5	9.4	68–116	34	48	18
	M	403	90.3	8.9	66–115	29	55	16

[*] Platymeric Index (PI) = APD/MLD $*$ 100.

[†] Percent of platymeric ($PI \leq 84.9$) individuals.

[‡] Percent of eurymeric ($PI = 85–99.9$) individuals.

[¶] Percent of stenomeric ($PI \geq 100$) individuals.

[§] Significantly different ($p \leq 0.05$) from other groups.

TABLE 4—*ANOVA results for the main effects of ancestry and sex.*

	Ancestry		Sex		Ancestry* Sex	
Variable	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
APD[*]	215.7	<0.0001	149.8	<0.0001	2.3	0.0518
MLD[†]	81.9	<0.0001	144.8	<0.0001	2.6	0.0352
FML[‡]	155.5	<0.0001	122.1	<0.0001	0.6	0.6379
VHD[§]	26.2	<0.0001	400.3	<0.0001	8.5	<0.0001
PI[*]	347.3	<0.0001	1.3	0.2616	4.2	0.0021

[*] Native Americans and Polynesians significantly different from all other groups; no significant difference between American Blacks, American Whites, and Hispanics.

[†] No significant difference between Native Americans and Polynesians, but they differ significantly from the other three groups; no significant difference between American Blacks, American Whites, and Hispanics.

[‡] No significant difference between American Whites and Hispanics; all other combinations significant.

[§] Polynesians significantly different from all groups; no significant differences between American Whites and Hispanics, Hispanics and American Blacks, American Blacks and Native Americans; all other combinations significant.

Results

Sexual Dimorphism

Summary statistics for the five groups are presented by sex in Tables 2 and 3. In general, females have significantly smaller femora (shorter length and smaller diameters) and exhibit slightly more platymeria than males, except for American Blacks. In this group, males exhibit a slightly flatter subtrochanteric region than females (Table 3). The main difference between males and females in the proximal femur is size, not shape. Males exhibit significantly larger anteroposterior and mediolateral subtrochanteric diameters, but there is no significant sexual dimorphism in the PI (Table 4).

Within- and Between-Population Variation

Results clearly show that Polynesians and Native Americans are platymeric and have relatively short femora, while American

TABLE 5—*Native American mean PI by geographical region.*

	Sex	Geographical Region*						
		NP	CP	SP	EP	GC	GB	SW
Mean	F	74.3†	79.0	82.2	79.0	78.1	81.1	76.4†
SD		7.3	8.3	11.4	9.1	6.9	9.9	8.8
Mean	M	75.7†	84.0	83.3	79.4	84.5	82.0	79.6
SD		7.9	12.4	8.7	8.2	8.4	9.3	9.7

* See Table 1 for list of abbreviations.

† Statistically significant ($p \leq 0.05$) difference from all other groups. NP and SW females differ from other groups but not from each other.

TABLE 6—*Native American mean PI by subsistence strategy.*

Subsistence	♀ mean	SD	♂ mean	SD
Agriculturalist	76.7	7.6	80.7*	10.3
Plains Horticulturalist	76.1	8.3	76.6*	9.7
Hunter-Gatherer	79.3*	11.0	83.0*	9.5

* Statistically significant ($p \leq 0.05$) difference from all other groups.

TABLE 7—*Native American mean PI by physical terrain.*

Terrain	♀ mean	SD	♂ mean	SD
Mountain	78.1	9.4	80.7	9.6
Plains	76.2	8.5	78.3	10.0
Prairie	76.2	9.1	79.4	8.2
Coast	79.1	8.6	85.2*	9.1

* Statistically significant ($p \leq 0.05$) difference from all other groups.

Blacks and Whites are eurymeric with relatively long femora (Tables 2–4). Hispanics are intermediate in both femur size and shape. Statistically, there are no differences in femoral size (length, APD and MLD) or shape (PI) between American Blacks, American Whites, and Hispanics, but they are all significantly less platymeric than Native American or Polynesians. Polynesians have the shortest and most platymeric femora and differ significantly from all other groups.

Although there are significant population differences in the shape of the proximal femur, all populations exhibit great variation (Table 3). Native American males, for example, range from 57 to 126 in the PI. Likewise, American White males range from 66 to 115. However, whereas only 29% of American White males are platymeric, 79% of Native American males are platymeric.

Effect of Geographic Region, Subsistence Strategy, and Physical Terrain

Within Native Americans there is some geographical variation in the PI (Table 5). Northern Plains males exhibit significant platymeria compared to Native American males from other regions. Among females, the PI is significantly smaller in the Northern Plains and Southwest. No differences were found between Northern Plains and Southwest females. Differences in PI among the other geographical regions are insignificant for both males and females.

Significant differences exist among all three subsistence strategies in males, with Plains Horticulturalists being the most platymeric (Table 6). Among females, there are no significant differences in subtrochanteric shape between Agriculturalists and Plains Horticulturalists, but Hunter-Gatherer females exhibit significantly less platymeria than the other two groups (Table 6).

Examination of the Native American sample by physical terrain showed only trivial differences (Table 7). There were no significant differences in females. Coastal males were significantly more eurymeric than males from other terrains, but this may be due to a correlation of subsistence and geography. The Coastal males are primarily composed of Hunter-Gatherers, which are more eurymeric than other Native American subsistence groups.

Validity of Discriminating Ancestry

Discriminant function analysis was conducted to examine how effectively subtrochanteric size and shape could separate femora by population. The range of individual variation in all populations makes discrimination between the five populations difficult (Table 8). Native Americans, for example, range from extremely platymeric to stenomeric and frequently classify as Polynesian. There are no statistically significant differences in the PI between Hispanics, American Blacks or American Whites for either sex, so separation of these groups is not statistically possible (Table 8).

To test Gill and colleagues' (28,29) claim that subtrochanteric shape can be used to distinguish between platymeric Native Americans and eurymeric American Blacks and Whites, I pooled the American Blacks and Whites and ran a discriminant function analysis with cross-validation first using APD and MLD as variables and then using PI only. As Gill and co-workers (28,29) previously discovered, the results show that femur subtrochanteric shape is moderately useful in distinguishing Native Americans from American Blacks and Whites (Fig. 1). Results show that correct classification of Native American and pooled American Black/White ranged from 72 to 82% using the raw measurements and 73 to 83% using shape (PI) only (Table 9). Since Native American femora were also significantly shorter with a smaller head diameter than the American Blacks and Whites, I calculated discriminant function equations using FML, VHD, and PI. When tested using a cross-validation procedure, the percent of males and females correctly classified as Native American or American Black/White improves to between 78 and 87% (Table 9).

TABLE 8—*Percent correctly classified using APD and MLD as variables.*

	Native American		Polynesian		Hispanic		American Black		American White	
Group	F	M	F	M	F	M	F	M	F	M
Native American	42.5	28.4	42.5	39.9	0.5	13.5	3.1	15.0	11.4	3.2
Polynesian	18.5	19.7	77.7	78.9	0.0	1.4	3.9	0.0	0.0	0.0
Hispanic	33.3	8.8	0.0	17.7	0.0	38.2	33.3	32.4	33.3	2.9
American Black	8.1	11.5	0.0	3.8	0.0	30.1	57.3	41.5	34.9	13.1
American White	15.2	13.9	4.8	4.5	0.0	23.0	37.8	47.9	42.2	10.7

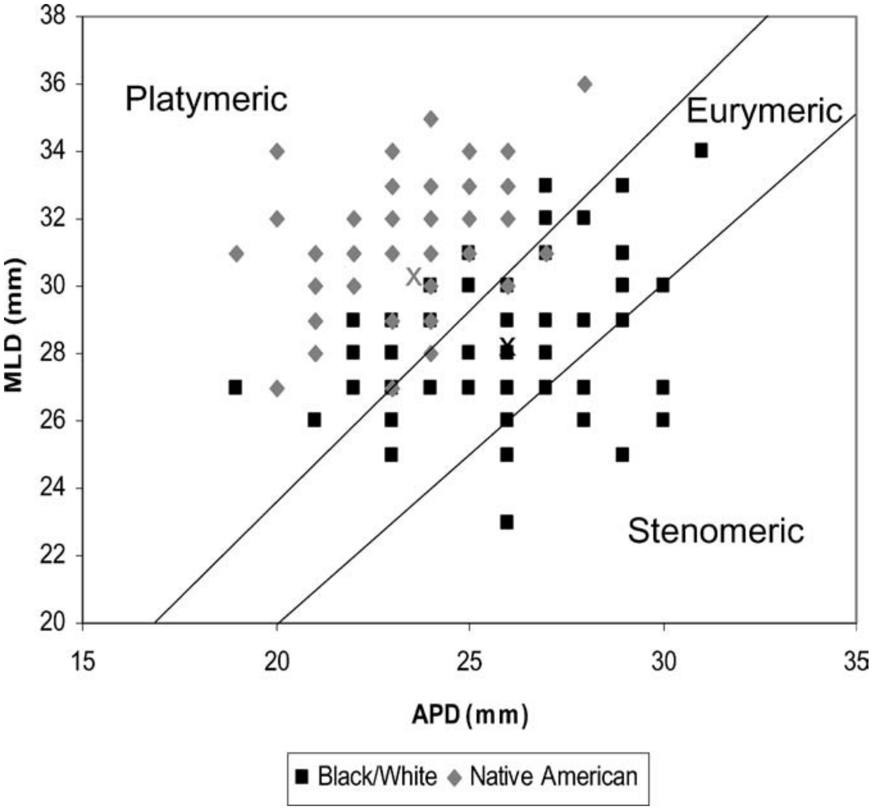

FIG. 1—*Plot of subtrochanteric anteroposterior diameter (APD) against mediolateral diameter (MLD) illustrating the differences between Native Americans and American Blacks and Whites. For illustrative purposes 75 females from each group were randomly selected and plotted. Group means are indicated by X.*

TABLE 9—*Discriminant function classification rates.*

		PI only		APD and MLD		PI, FML, VHD	
Group	Sex	% Correct	% Incorrect	% Correct	% Incorrect	% Correct	% Incorrect
Native American	F	83.4	16.6	81.6	18.4	86.7	13.3
	M	75.1	24.9	71.7	28.3	80.4	19.6
American Black/White	F	72.6	27.4	76.6	23.4	83.1	16.9
	M	75.4	24.6	79.0	21.0	77.7	22.3

Discussion

Difficulties associated with ancestral identification stem from misconceptions regarding the definition of racial categories, population history, gene flow, and the nature of within- and between-group variation. Many physical anthropologists today would agree that race is a social construct and not a biological reality, and it is important to keep in mind that assigning a skeleton to a particular race or ancestral group uses a socially constructed or bureaucratic classification system and not a biological classification scheme (15). As Sauer (4) points out, assignment of human skeletal remains to a particular race does not substantiate the biological concept of race; rather it provides information, based on morphological features of the skeleton, regarding which socially constructed group an individual was assigned to during life.

Since the determination of ancestry from skeletal remains is a critical component of forensic analysis, it is important that anthropologists develop methods using a wide variety of bones and techniques and attendant criteria for determining ancestry. Likewise, it is also important that we continually examine how skeletal plasticity, sexual dimorphism, measurement error, and other factors affect our methods.

Skeletal Plasticity and Population Differences

Differences among populations can be either genetic, environmental, or both. Gill and colleagues (34–36) argue that marked ancestral, and therefore genetic, differences are present in the shape of the proximal femur. Miller (35) found that while there are significant changes with age, femur subtrochanteric shape is established relatively early during growth and development, suggesting that platymeria is controlled more by genetics than by biomechanics or other environmental influences. Work by Ohman and Lovejoy (59) on apes may also support a strong genetic component to femur diaphyseal shape. These authors argue that femur diaphyseal shape, especially at midshaft, is greatly influenced by metaphyseal shape during femoral growth and development and therefore has a strong genetic component (59).

Body build, whether genetically determined or not, may also influence subtrochanteric shape (42). Platymeric Native Americans and Polynesians have relatively short femora, while the eurymeric American Blacks and Whites have long femora. Subtrochanteric shape may be correlated with femur length or body size. Body size can be estimated using pelvic width (43), but these data were not available for the individuals used in this study. Instead, to understand the relationship between body size and femur subtrochanteric shape, I examined the association between the PI and FML and VHD. I found only a slightly positive correlation in females ($r = 0.28$ for FML and $r = 0.07$ for VHD) and almost no correlation in males ($r = 0.04$ for FML and $r = 0.01$ for VHD). Small females have somewhat more platymeric femora than large females, but femur size does not seem to have any influence on male subtrochateric shape.

There is little doubt that subtrochanteric shape has a genetic component, but there is also a significant body of research demonstrating interdependence between long bone architecture and biomechanical stress. Experimental data show that bone reacts to mechanical stress by altering its size, shape, and distribution in such a way that strain on the bone is minimized (60,61). However, Ruff (40) found few same sex differences between hunter-gatherer and agricultural groups in the subtrochanteric region. He argues that changes in lower limb long bone diaphyseal shape associated with mechanical stress appear to be strongest around the knee (from the midshaft of the femur to the midshaft of the tibia) (42). My results, however, suggest that subtrochanteric shape, at least in males, is affected by biomechanics. Among males, activities associated with subsistence strategy appear to have the greatest non-genetic influence on subtrochanteric shape. Males that trek the coastal regions of the United States exhibit less platymeria than males from other physical terrains, but this result may also be an artifact of sampling. The Coastal sample is composed primarily of Hunter-Gatherers, which tend towards eurymeria. My results may contrast with those of Ruff (40) because he used the maximum diameter divided by the minimum diameter to calculate subtrochanteric shape rather than APD divided by MLD. The problem with Ruff's method is that it is impossible to distinguish between platymeric and stenomeric individuals. By using the maximum and minimum diameters, stenomeric individuals would have the same PI as platymeric individuals.

The results of this study demonstrate that both genetics and the environment likely play a role in determining adult subtrochanteric shape. Fortunately environmental influences do not appear to obscure population differences. While there is a significant amount of plasticity in proximal femur size and shape, it is not sufficient to erase the underlying population differences between Native Americans and American Blacks and Whites.

Sexual Dimorphism

Females, with the exception of American Blacks, generally exhibit greater platymeria than males, although this difference is not statistically significant in this study. Ruff (40) argues that greater platymeria in females is associated with sexual dimorphism in pelvic breadth. The wider interacetabular distance of females would result in greater mediolateral bending of the subtrochanteric region, causing greater platymeria (42). This may indeed be the case, but my results show that the primary difference between males and female in the subtrochanteric region is size.

Within- and Between-Population Variation

There is considerable within-group variation in subtrochanteric size and shape. Individual variation in the PI ranges from 55 to 129 with all groups (with the exception of Polynesians) having platymeric, eurymeric, and stenomeric members. This study also confirms that populations from the Northern Plains are among the most platymeric of all Native American groups. This suggests that the sample used by Gill and colleagues is not representative of the larger, more genetically and geographically diverse Native American population. However, even when a sample composed of populations from five geographical regions is used, overall, Native Americans are more platymeric than American Blacks or Whites. This shows that while there is more within-population variation than between-population variation in subtrochanteric shape, the proximal femur is still a good criterion for distinguishing Native American femora from American Blacks and Whites, as suggested by Gill and colleagues (28,29). However, the accuracy of the method may be reduced in some geographical regions. Like Gill and colleagues (28,29), my Native American reference sample is composed largely of very platymeric Great Plains groups.

Clow (37) and Voulgaris (38) observe that Polynesians from Easter Island exhibit greater platymeria than even Native Americans. Thus, Gill (34) called for research to ascertain if the extreme platymeria in Polynesian femora was restricted to Easter Island. My results include a sample of Polynesians from Hawaii and suggest that the trend is not limited to Easter Island. Polynesians are significantly more platymeric than any other group examined, including Northern Plains Native Americans. Interestingly, however, it is nearly impossible to distinguish between these two groups based on proximal femur morphology alone using discriminant function analysis (Table 8).

While the results of this study show that both Polynesians and Native Americans are relatively platymeric compared to American Blacks and Whites, it does not address the question proposed by Gill (34) that all East Asian populations are platymeric. The FDB only has 18 individuals (14 males and 4 females) designated as East Asian. The mean PI for this small sample is 84.1 and 79.7 for males and females, respectively. However, these are insufficient data to determine if there are population differences in subtrochanteric shape based on major geographical areas.

Interobserver Error

One potential problem with using the proximal femur to determine ancestry is that subtrochanteric diameters are among the most error-prone measurements taken on the femur (51). Adams and Byrd (51) found as much as 4.3% interobserver error in MLD and as much as 8.5% interobserver error in APD depending on the experience level of the osteologist. They argue that interobserver error in subtrochanteric measurements results because osteologists are unfamiliar with how far distal to the lesser trochanter the measurement should be taken and how closely anteroposterior and mediolateral orientations must be maintained. I conducted an interobserver error test with a colleague and found approximately 1.3% error in MLD and 4.7% error in APD. The interobserver error in MLD is within the range of most standard measurements, but APD is high.

The sample used in this study was compiled from numerous sources and undoubtedly there is interobserver error. However, every precaution was taken to reduce the error. The greatest problem is likely with the Polynesian data. The extreme platymeria seen in this population may be in part due to differences in measurement technique, as Snow (52) may have used a different description for taking APD and MLD. However, the trend of extreme platymeria in Polynesians has been observed by others as well (37,38), which suggests a pattern-based on reality.

To see how interobserver error might affect the use of the proximal femur as a criterion for distinguishing between Native Americans and American Blacks and Whites, I added 8.5% (the most extreme percentage of error found by Adams and Byrd (51)) to the APD of all Native Americans as a conservative test. The pooled-sex Native American PI mean changed from 78.2 to 84.7. While this is a significant change, Native Americans are still far more platymeric, with 58% of individuals falling below 84.9. This suggests that while interobserver error can add noise to the data, the differences between Native Americans and American Blacks and Whites are not simply the result of interobserver error.

Forensic Utility of the Proximal Femur in Determining Ancestry

Gill and Rhine (29) plot APD and MLD on a graph and locate a sectioning point for ancestry instead of using the PI. The purpose of this is to incorporate both size and shape. However, I found no significant differences in the overall accuracy of discriminating between Native Americans and American Blacks/Whites when using the raw APD and MLD measurements or PI only, but the percent of individuals correctly classified as Native American did increase when FML and VHD were all used in the discriminant function.

Conclusions

My results generally support Gill and colleagues' assertion that femur subtrochanteric shape can be used with moderate success to distinguish Native Americans from American Blacks and Whites. Native Americans are on average more platymeric than American Blacks and Whites. However, subtrochanteric shape appears to be limited to this comparison as Hispanics do not differ significantly from American Blacks and Whites. Even when the method is used only to distinguish between Native Americans and American Blacks and Whites, caution should be taken. Subtrochanteric shape can be influenced by activities associated with subsistence strategy, and there is significant geographical variation among Native Americans. The Native American reference sample used in this study to test the accuracy of separating Native Americans from American Blacks and Whites is largely composed of groups from the Great Plains, which are generally the most platymeric of Native American groups. As a result, the accuracy of distinguishing between these groups may be inflated. I recommended that forensic anthropologists develop a sectioning point for the geographical region in which they work. Also, the anteroposterior subtrochanteric measurement is prone to error, which should be kept in mind. I also recommend using FML, VHD, or some other measure of size to increase the accuracy of correctly distinguishing Native Americans from American Blacks and Whites.

With a few measurements from the femur, we have yet another tool to aid in the determination of ancestry, and therefore the identification of a corpse. Coupled with its efficacy at sex and stature estimation, the femur provides a wealth of information to the forensic anthropologist.

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