Trudell M.B.,[1] *Ph.D.*

Anterior Femoral Curvature Revisited: Race Assessment from the Femur

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ABSTRACT: The increasing need for accurate race assessment from postcranial skeletal remains has emphasized the lack of simple, replicable methods by which to accomplish the task. Several techniques have been proposed, but without adequate results. Anterior femoral curvature was first suggested and researched by T. Dale Stewart in 1962 (6). The technique used in that study was subjective at best. He provided no substantial discrimination between whites or blacks. Two later studies only reused Stewart's technique and/or data. This study was assumed to address these issues and provide an improved technique.

Skeletal collections at the Smithsonian, as well as the forensic collections at the University of Florida and the University of Tennessee, provided the specimens for this study. The historical collection of the First African Baptist Church of Philadelphia, PA, and the modern forensic collection at Louisiana State University provided the test samples. Only black and white individuals were used, and those were selected based on previous soft tissue or positive identification. Thirteen measurements were taken, including six newly developed measures. Age, race, and sex were also documented.

Discriminant analysis was used to develop functions for race assessment. After analyzing the data through SPSS[x] using Discriminant, the variables selected provided an accuracy of 88.15% using the right femur and 86.10% with the left femur. Age was divided into two groups: under 30 and over 30. Most skeletons can be easily aged into these categories.

KEYWORDS: forensic science, forensic anthropology, William R. Maples, physical anthropology, race assessment

While the use of the cranium has long been observed and accepted as a valid method of determining race, the use of the postcranial skeleton for that task has been documented only in a limited number of studies (1–4). The utility of the pelvis and limbs was researched, but no simple, single method for assessment was proposed. Most emphasize the need for a combination of bones in the accurate analysis of ancestry. Nonmetric analysis of race from the femur is not the best method, but it has been utilized often (5). Visual inspection can give some indication of the possible race, although no degree of accuracy has been determined.

The use of the femur, and in particular the anterior femoral curvature, has been suggested in three projects (6–8). While the differences between groups were noted by each of the authors, no adequate study has confirmed the use of this trait in the classification of individuals into racial categories.

[1] Adjunct professor, Department of Criminal Justice, University of Southern Mississippi, Gulf Coast, Long Beach, MS.

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This research was undertaken to provide a more accurate technique of determining ancestry from the morphology of the femur. An update on the procedure established by Stewart in 1962, and used in both of the other studies of anterior femoral curvature, is utilized. The methods of accumulation of the data and its analysis are also presented. The goal of this project is to determine the acceptability of anterior femoral curvature as a race assessor and, if useful, to provide a replicable and easy method of classification.

Previous Studies

Interest in racial differences in humans reached a high point in the early part of the twentieth century (9–14). Numerous studies were done during that period that centered on the variations between whites and blacks. Each focused on a particular bone or area of the body. Some attempted to show the "evolutionary advancement" of the whites. None were adequate for individual race assessment.

Studies of racial affinity, except those involving the cranium, were largely ignored in the latter half of the century. Resurgence came about in the 1970's, and several analyses that centered on the infracranial bones were undertaken (1–4,15). Again, no exceptional method of assessing race was found.

T. Dale Stewart did the first study of anterior femoral curvature for race assessment in 1962 (6). His reason for pursuing this method of race determination stemmed from the following:

> For a long time now I have been aided in skeletal identification by a rule regarding long bones which I learned from the late Ales Hrdlicka during the many years of my apprenticeship under him. I recall that when together we examined bones of unknown individuals he would call attention to the amount of curvature or bowing (or conversely to the relative straightness) of the long bones and comment to the effect that skeletons of Negroes are always to be distinguished from those of other races by the straightness of their long bones. (Italics in original) (p. 1).

Stewart admitted he was never certain of the method's limitations. Therefore, he set out to study the phenomenon.

A sample of 35 right femurs was taken from the skeletal collection of the Smithsonian, representing each of three racial groups. The blacks and whites of the sample died between 1895 and 1910, while the Dakota Indians died between 1725 and 1825. The blacks appeared to be without white admixture.

Each femur was placed flat on a table, anterior side up, resting on its condyles and quadratus tubercle. A wooden wedge was inserted under the proximal end until the bone was horizontal and level, with the proximal and distal concavities at the same height. The height from the table was measured at the leveling points, the greatest concavity (anterior femoral curvature), the highest point of the cervical tubercle at the greater trochanter, and the highest point of the head. The first two measurements gave anterior femoral curvature, and the latter two gave torsion. Condylar length was used in ratios with the previous two heights. The distance from the most proximal point of the greater trochanter to the point of the greatest curvature was also measured. The ratio of the two lengths was also used.

Stewart concluded the longest femurs were from the blacks, and the Indians had the greatest curvature, both visually and relative to length. However, only the differences between blacks and Indians were statistically significant. Torsion and curvature appeared related, but the connection may have only been in the fact that both were great in the Indians (6).

In 1965, Walensky furthered Stewart's work when he increased the sample size. In addition, he examined previously unstudied groups, as well as sex and side differences in the amount and position of femoral curvature. A total of 874 femurs, including white, Indian, Eskimo, a heterogeneous group of blacks, and a "pure" group of blacks, made up the sample. The racial differences were more apparent than those of side or sex. The pure black sample had the longest femurs, which were least bowed. The mixed black group was between the first and the whites, which were only slightly more curved. The Indians had the most bowing with the most distally located point of maximum curvature. The Eskimos were more closely associated with the Indians (7).

Gilbert's study in 1976 only increased the information available on the Native American populations. He used the data from Stewart's research for the sample of whites and blacks, with the exception of thirty ectomorphic (over 74 inches in height weighing less than 150 pounds) and ten endomorphic (over 200 pounds but less than 60 inches tall) whites and blacks. His goal was to answer some of the questions of causes of anterior femoral curvature that the previous studies had put forth. The sample included mostly males and only right femurs when available (8).

None of these studies give satisfactory answers to the question of why femoral curvature exists. In addition, the utility of this trait as a classificatory tool has yet to be determined. Although forensic and physical anthropologists have long discussed the differences, any test to prove the differences has not been developed.

Methods and Materials

Analysis of the femur requires very little in the way of specialized materials. The specimens for this research came from modern skeletal populations throughout the country. The tools used were almost all readily available in the forensic laboratory. The need to have a simple, replicable, reliable method of assessing race from postcranial remains was a guiding factor in this investigation.

This research was undertaken to broaden the scope of Stewart's work. The distinction between whites and blacks was addressed, because that is where the greatest deficiency lies in current methods. Stewart recognized that his undertaking only further separated Native American bones from those of whites or blacks, but provided little or no substantial discrimination between the latter groups.

The reason for developing a new method of measuring the femur was to reduce the subjectivity of Stewart's technique. Stewart used "eyeballing" as the standard for determining the femur was at the leveling point. The femur was placed on a table, and a wooden wedge was placed under the proximal end of the bone, "so as to raise the deepest point (bottom) of the anterior concavity at the proximal end of the shaft to the same level as the bottom of the anterior concavity at the distal end" (6). With some femora, this level is not exact, nor is it easy to determine.

The data for this study were gathered from several collections. Existing as donated and unidentified remains, some of the skeletal material was located in the forensic laboratories at the University of Florida and the University of Tennessee. The University of Florida collection at the C.A. Pound Human Identification Laboratory consisted of strictly forensic specimens. A total of 36 individuals were used, with only 18 being in the final analysis. The sample at the University of Tennessee Department of Anthropology was from both forensic cases and donated bodies at the Bass Anthropological Research Facility. A total of 50 individuals were selected from this contribution.

The majority of the sample specimens derive from two different collections at the Smithsonian Institution. The Terry collection consisted of dissecting-room cadavers of known age at death, race, and sex. The Huntington collection consisted of immigrant and American populations of known ancestry or country of origin, age at death, and sex. The research sample included only those individuals who were positively identified, or whose race was determined by soft tissue or hair samples present when the remains were collected. If the race was determined solely on the basis of skeletal analysis, the specimen was rejected. Any specimen with a pathological deformity affecting the lower limb was rejected as well. An even breakdown according to sex and race was attempted, though black females were underutilized in all collections.

The material for the test sample came from two very different collections. Femora were selected from the historical collection of the First African Baptist Church of Philadelphia. This population consisted of several skeletons of free blacks interred between 1810 and 1842. The average age was mid-thirties for both males and females. The forensic laboratory at the Louisiana State University Department of Geography and Anthropology provided modern specimens from forensic cases.

The measurement sheet used to record findings included right and left femurs if both were available (Fig. 1). Each individual's age and sex were recorded for inclusion in the calculations. Initially the ages were grouped according to decade from 1, which was under 20, to 7, or 70 and over. When the discriminant function analysis was begun, the ages were indexed as AGE1 for under 30, AGE2 for 30–59, and AGE3 for those 60 and over.

The new method for measuring anterior femoral curvature differs significantly from the previously established technique. Most notably, the curvature is determined with the anterior surface of the femur facing the table. All standard measurements were made according to the descriptions in Olivier (16). Additionally, new distances are included.

The standard measurements of the femur made on the osteometric board included the maximum length (MAX), the oblique length (OBL), and the bicondylar breadth (BICON). After the maximum length was obtained, the length of the femur was divided into three equal portions: one-quarter length (R1), one-half length (R2), and three-quarter length (R3), and points were marked.

Diameter measurements were made from the anterior and lateral surfaces at the subtrochanteric level and the midshaft. The transverse diameter was determined at each point with the calipers perpendicular to the table (TRMID, TRSUB). By turning the femur until the condyles were exactly perpendicular to the table, the sagittal, or anterior-posterior, diameter was made (APMID, APSUB).

Next, the femur was placed on two blocks, with the anterior side of the bone facing the table. The dimensions of the blocks, which were cut from a solid piece of aluminum, were exactly 50 mm by 50 mm by 100 mm (Fig. 2). The measurements were collected using a metric dial caliper, in tenths of millimeters. Correct positioning of the femur was accomplished by ensuring that the head and greater trochanter rested completely on one block. At the other end, the lateral condyle also contacted the block, while the medial condyle was suspended (Fig. 3). The distance from the surface of the block to the most superior point of the medial patellar joint surface composed the distal measure (BDIS) (Fig. 4). The distal condyles were then laid flat on the block, suspending the greater trochanter of the femur (Fig. 5). The distance from the cervical tubercle at the intertrochanteric line to the block was the proximal

FEMORAL MEASUREMENT SHEET

SEX: 1-M; 2-F AGE: Under 30-1; Over 30-0

MEASUREMENTS (IN MM)	RIGHT	LEFT
MAXIMUM LENGTH	RMAX	LMAX
OBLIQUE LENGTH (IN POSITION)	ROBL	LOBL
BICONDYLAR BREADTH	RBICON	LBICON
AP DIAMETER AT MIDSHAFT	RAPMID	LAPMID
TRANSVERSE DIAMETER AT MIDSHAFT	RTRMID	LTRMID
SUBTROCHANTERIC TRANSVERSE	RTRSUB	LTRSUB
DISTANCE FROM TABLE (R1)	RR1	LR1
DISTANCE FROM TABLE (R2)	RR2	LR2
DISTANCE FROM TABLE (R3)	RR3	LR3
DISTANCE FROM TABLE (PROXIMAL)	RPROX	LPROX
DISTANCE FROM BLOCK (DISTAL)	RBDIS	LBDIS
DISTANCE FROM BLOCK (PROXIMAL)	RBPROX	LBPROX

FIG. 1—*The sheet was used to record measurements as they were taken. The variable designations were added for the statistical analysis.*

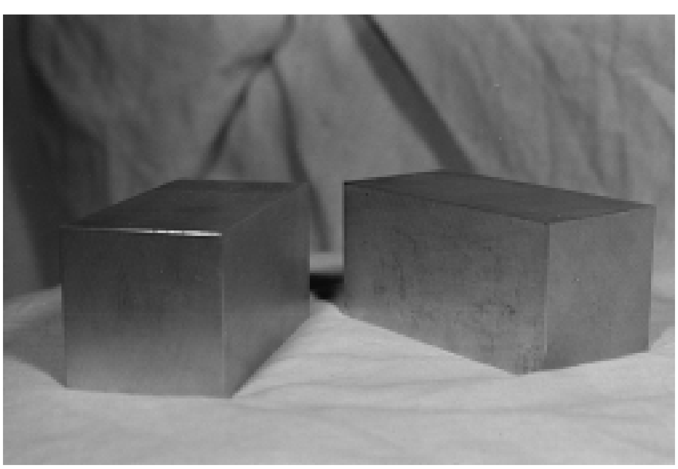

FIG. 2—*The blocks were cut from solid aluminum to precisely 50 mm × 50 mm × 100 mm. The heights of the blocks were subtracted to obtain actual measures.*

FIG. 3—*The femur lies on the blocks with the head and greater trochanter flat on the surface, and the medial condyle suspended.*

FIG. 4—*The distal measure (BDIS) is from the medial patellar surface to the block.*

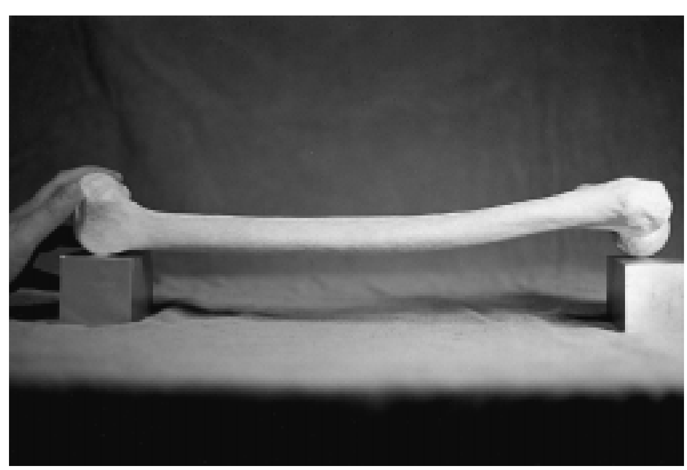

FIG. 5—*The femur is repositioned for the proximal measure by holding the distal condyles flat on the block, suspending the greater trochanter.*

measure (BPROX) (Fig. 6). By subtracting the distal measurement from the proximal measurement, the amount of variance in the torsion of the femur was determined (TORS).

Anterior femoral curvature, the measurement most important to this study, was measured at four points. The distance from the table to each of the three previously determined points yielded the curvature (Figs. 7–9). In addition, the distance from the cervical tubercle to the table was used to further illustrate the amount of curvature (PROX) (Fig. 10).

After finishing all block-to-table measurements, the heights of the blocks were subtracted to obtain real distances. This was done to allow others to use any size blocks with the technique to determine anterior femoral curvature. Provided a researcher has exact measures of the blocks used, the results should not vary.

From the above measurements, anterior femoral curvature, along with any other racially influenced factors, could be established. Statistical analyses were performed and the relationships of the characteristics one to another were created. The mainframe computer at the University of Southern Mississippi provided the SPSSx program, from which all statistical functions were calculated. The Discriminant command was used, with the RAO subcommand cre-

FIG. 6—*The proximal measurement (BPROX) is taken from the cervical tubercle to the block.*

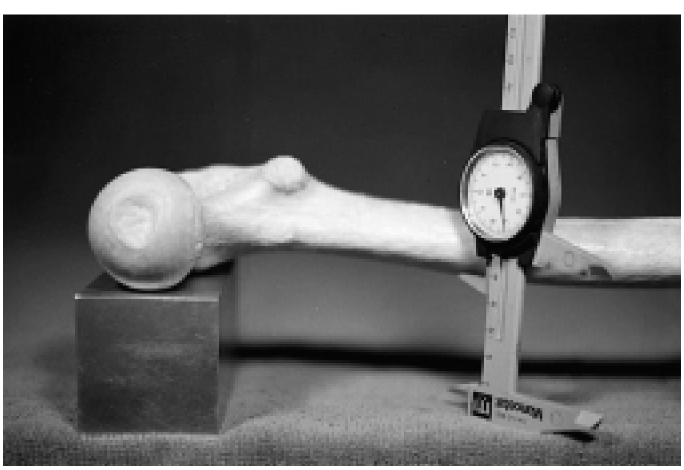

FIG. 7—*The first measurement of anterior femoral curvature (R1) is taken at one quarter of the total length.*

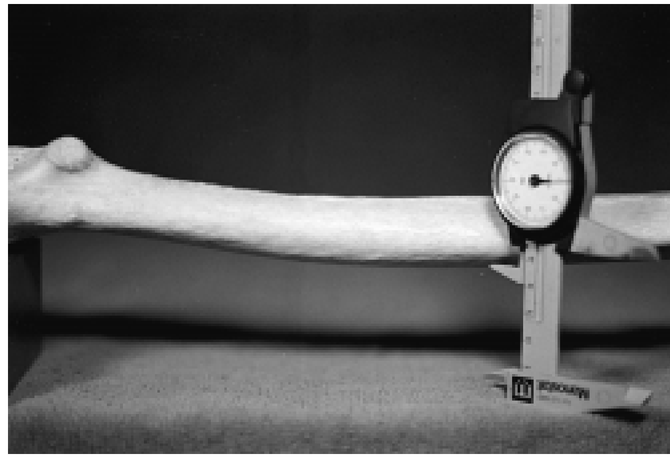

FIG. 8—*The second measurement (R2) is at one-half of the total femoral length.*

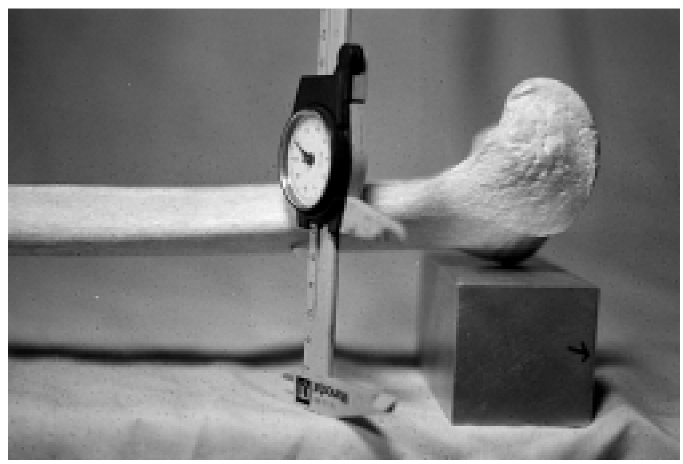

FIG. 9—*Three-quarters of the length of the femur is the third measure (R3).*

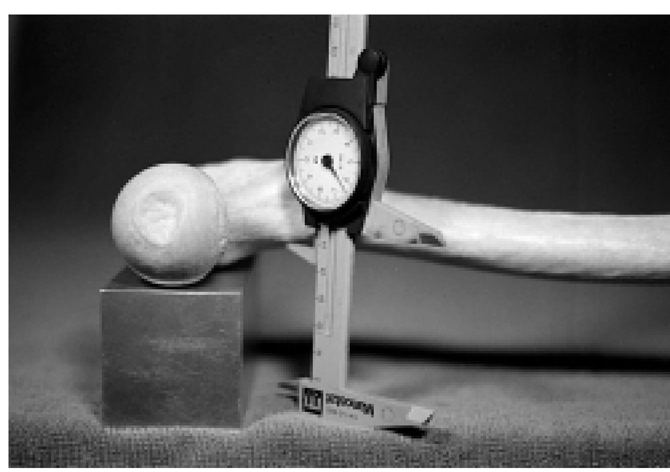

FIG. 10—*The proximal measurement (PROX) is from the most anteriorly projecting point on the intertrochanteric line to the table.*

ating the stepwise analysis. The variables were selected to minimize RAO's V, with a minimum tolerance of .001 for inclusion. The analyses of both femurs took sixteen steps to derive the coefficients needed to accurately classify the groups.

Results

The ultimate goal of this study was to provide a new, easily utilized technique to better identify skeletal remains by forensic anthropologists. A formula for which a single specimen can be accurately placed in a racial category was devised. The technique to obtain the measures is simple and does not require specialized and expensive tools. Most well equipped laboratories or practitioners already own the necessary implements. The success of finding racial factors in the measurements of the femur was good. By using the unstandardized canonical discriminant function coefficients, race can be determined with an accuracy of 88.15% on the right femur, and an 86.10% accuracy rate using the left femur. While the differences overlap between the groups, and within the groups, race determination with femoral measurements is attainable.

The statistics represented both previously noted variations and newly derived calculations of the differences between the femurs of blacks and whites (Table 1). The maximum and oblique lengths, as historically noted, were greater in blacks than whites. White femora, though shorter, have been described as being more robust than black femora. The bicondylar breadth was larger in whites. However, the subtrochanteric and midline diameter measures, which yielded the overall dimensions including the pilastry and cross-sectional shape, were not significantly different between the groups.

TABLE 1—*Group statistics.*

	Mean			Standard Deviation		
Variables	White	Black	Total	White	Black	Total
RMAX	445.49	460.04	452.03	29.78	31.50	31.36
ROBL	441.55	455.18	447.67	29.61	31.94	31.37
RBICON	79.42	78.67	79.09	6.65	6.18	6.44
RAPMID	27.89	28.17	28.02	2.95	2.78	2.87
RTRMID	25.94	25.76	25.86	2.85	2.68	2.77
RAPSUB	28.84	28.92	28.88	3.08	2.57	2.86
RTRSUB	30.88	30.69	30.79	2.97	2.68	2.84
RR1	−0.39	0.77	0.13	3.02	2.82	2.99
RR2	−5.88	−3.53	−4.82	3.77	3.67	3.90
RR3	0.33	3.68	1.84	3.39	3.55	3.84
RPROX	4.85	5.47	5.13	2.14	2.19	2.19
RBDIS	14.60	18.22	16.23	4.67	4.84	5.07
RBPROX	18.52	21.41	19.82	6.26	6.59	6.56
RTORS	3.91	3.19	3.59	2.62	3.15	2.89
LMAX	445.80	460.99	452.62	29.49	31.41	31.25
LOBL	442.46	456.79	448.90	29.41	31.40	31.10
LBICON	79.04	78.17	78.65	6.53	6.20	6.39
LAPMID	27.57	27.71	27.63	2.80	2.65	2.73
LTRMID	26.18	26.05	26.12	3.02	2.71	2.88
LAPSUB	29.05	29.36	29.19	3.27	2.87	3.09
LTRSUB	30.79	30.71	30.75	2.94	2.78	2.86
LR1	−0.12	1.18	0.46	2.99	2.73	2.94
LR2	−5.73	−3.18	−4.59	3.67	3.77	3.92
LR3	0.07	3.08	1.42	3.39	3.38	3.69
LPROX	4.95	5.70	5.29	1.95	2.02	2.01
LBDIS	14.66	17.86	16.10	4.74	5.32	5.25
LBPROX	18.68	21.03	19.74	6.51	7.10	6.87
LTORS	4.02	3.17	3.64	3.04	3.03	3.06

Anterior femoral curvature is justified as a racially distinguishing characteristic. The measurements indicating anterior femoral curvature showed striking differences between the groups. The overall trend is evident in the differences between the group means for the variables directly related to curvature. The distance-to-table variables (R1, R2, R3, and PROX) demonstrate group means that deviate from the sample mean by a minimum of 4. Blacks are consistently above the mean, and whites are below the mean. The group proximal means were closer to the total means, with less of a difference between (Fig. 11).

The measurements from the bone to the block also indicated some variation between blacks and whites. The differences between the means were near three for both the distal and proximal measures on both femurs. In addition, the groups were equally distant from the total variable means. While whites had lower means for both block variables, the mean for the torsion variable was greater for whites than for blacks. This would indicate that there is less torsion for blacks than whites.

The variables alone provided significant indications of the racial differences in the femur. However, the discriminant function analysis was able to provide simple measurements applied to a formula to classify a single bone. All variables except the subtrochanteric antero-posterior diameter (APSUB) and the calculated torsion measurement (TORS) were used. Apparently, the proximal and distal distance-to-block measures were adequate to describe the variation of the torsion of the femur. The maximum variability between the races can only be determined from the entire femur rather than a few select indicators.

The age variable chosen by the program was AGE1, or under 30. All individuals over the age of 30 were assigned a zero, while those under that age received a one. Those numbers were multiplied to the coefficient to include in the formula. Males are assigned a one for the SEX variable, and females are given a two.

Classification was achieved by assigning scores for each case. The discriminant scores were calculated with the variables and the unstandardized canonical coefficients. Each femur was treated as a separate case. While using both femurs would be useful in verifying the results, it is not necessary to have both. The following is the basic formula to be used with those coefficients for the right and left femora.

$$(\text{VAR1*coefficient}) + (\text{VAR2*coefficient}) + \ldots.$$

$$(\text{VAR14*coefficient}) + \text{Constant} = \text{Discriminant Score}$$

The black scores were calculated as positive, while whites were negative. The dividing point between the groups was .10. Those above the point (positive) were classified as black, while those below that point (negative) were classed as white (Figs. 12, 13). Only 39 of 329 cases were misclassified using the formula for the right femur. The left femur formula was not as accurate. Forty-six of 331 were incorrectly classified. Blacks were more often misclassified than whites. Of those incorrectly grouped, none fell into any pattern with regard to the variables, including age or sex.

The data were tested with the skeletal collections at the Louisiana State University Department of Geography and Anthropology Forensic Laboratory and the First African Baptist Church of Philadelphia. The results were noteworthy: 75% accurate. This is slightly lower than the results from the study, which is as anticipated. All of the cases from the First African Baptist Church were classified correctly, while the only misclassifications in the LSU data were whites, which is contrary to the sample analysis.

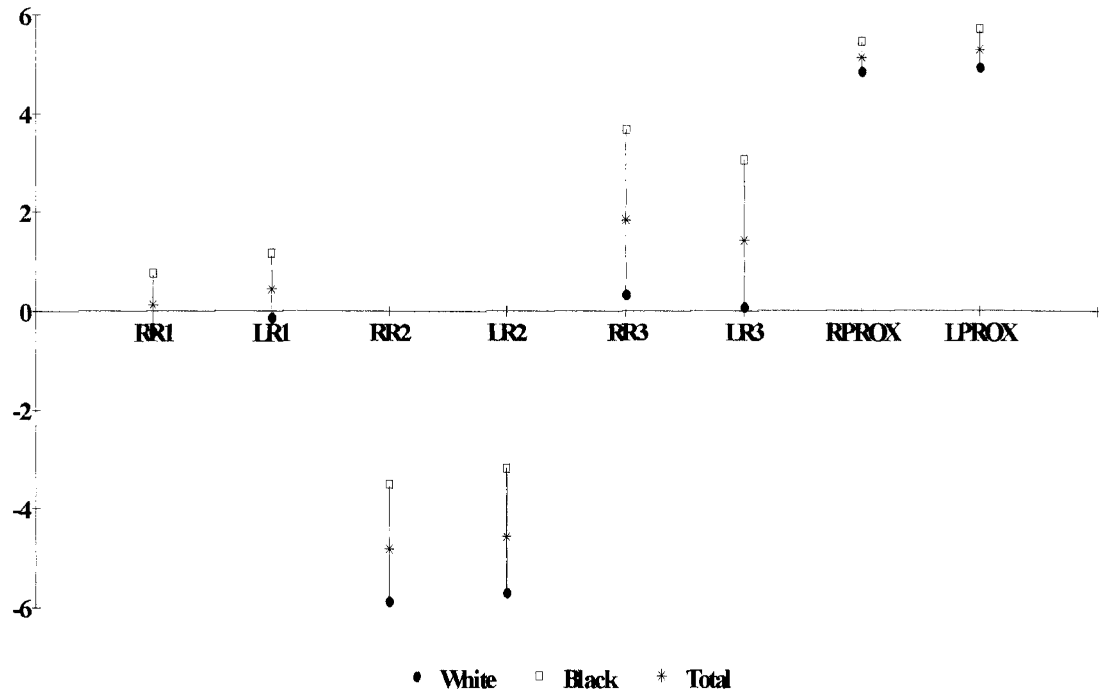

FIG. 11—*The variables of anterior femoral curvature by group.*

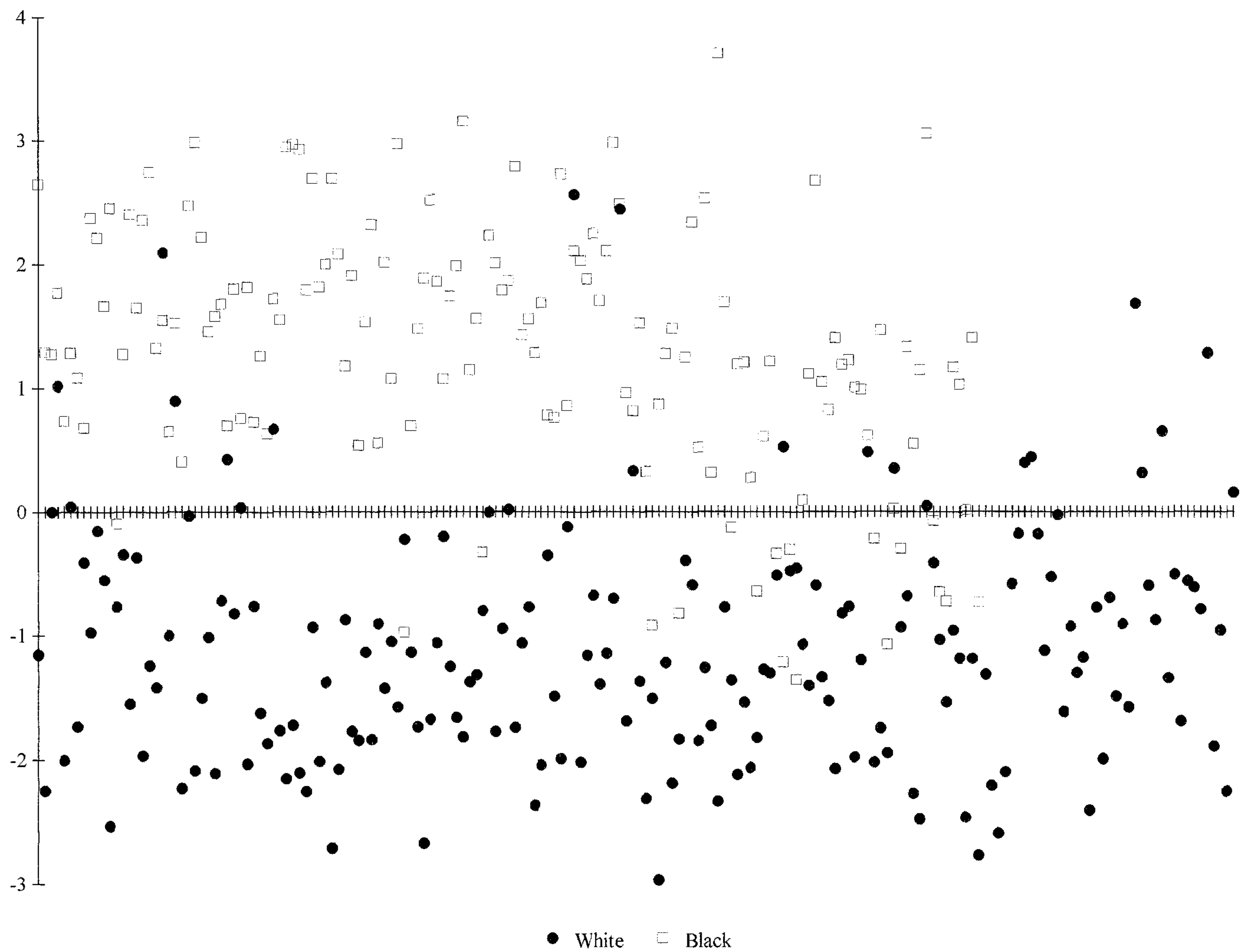

FIG. 12—*Histogram of the discriminant scores for the right femur.*

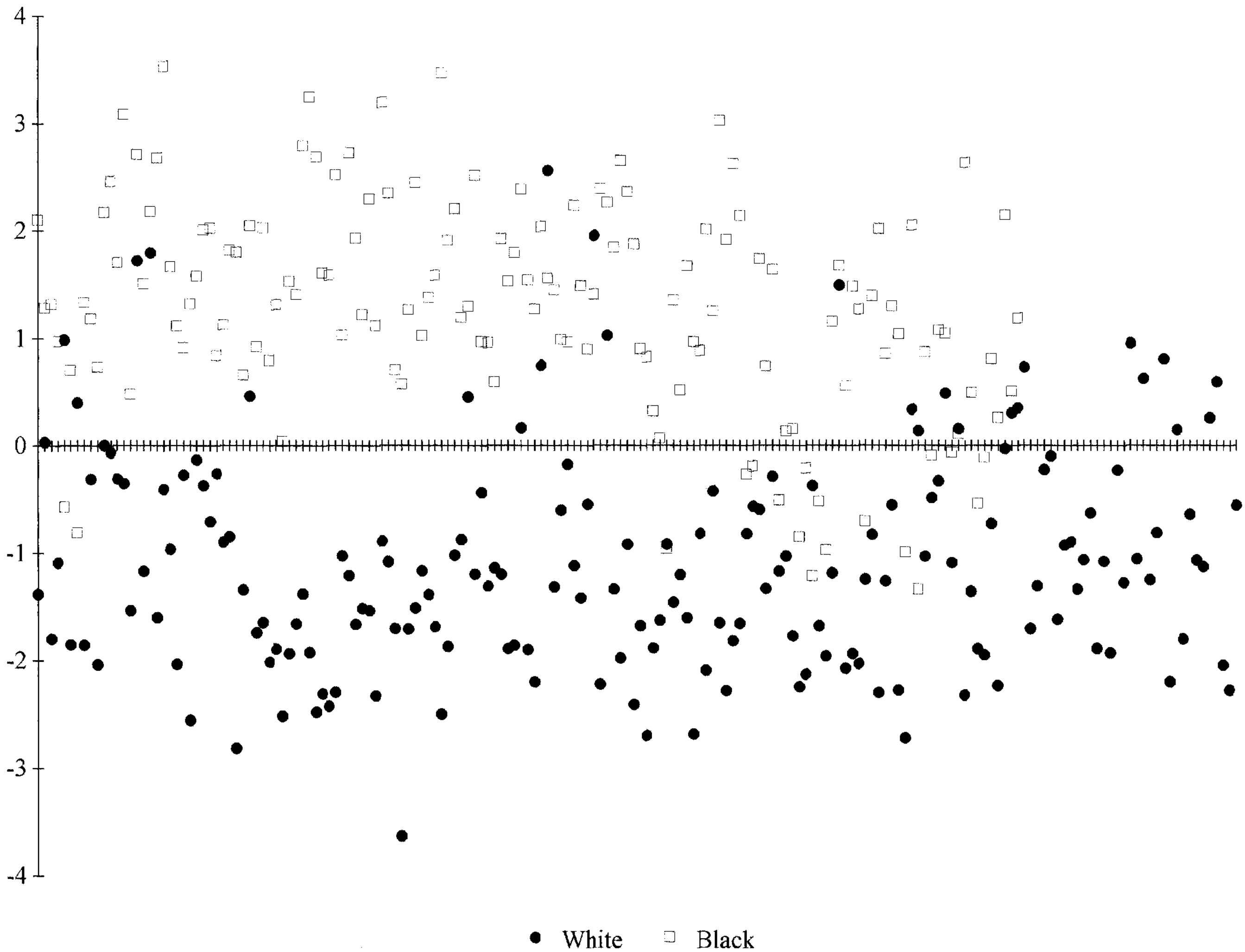

FIG. 13—*Histogram of the discriminant scores for the left femur.*

Discussion

The investigator can now easily determine race from postcranial remains with reasonable accuracy. The materials necessary are readily available, and include blocks and metric dial calipers. When using this method, however, a few simple procedures must be remembered.

The age and sex of the remains must be decided prior to determining the race. Provided more elements than the femur are available this task should be simple. Even if only a femur is available, many methods exist to easily determine these data. Age has to be determined to over or under 30 years, an easy task even for a novice. The age variable is assigned a one for under 30 and a zero for over 30. Males are assigned a one for the sex variable, while females receive a two. These numbers are calculated into the formula.

Anything can be used for the blocks, such as wood, brick, or books. The only criteria are that both blocks be equal in size, and they be a minimum of 20 mm high. Simply measure the blocks prior to proceeding, and subtract that measurement from the scores of the variables.

After completing the measurements as prescribed, the variables should be used in the discriminant function formula. Race is then decided based on the discriminant score. Again, if the score is over .10, the remains are most likely black; under .10, white. If the score is close, non-metric analysis is useful for corroboration.

One prevailing problem is that the femur must be mostly complete to utilize this formula. Bones missing just medial or lateral epicondyles or condyles, or portions of the trochanters, are useable. However, those missing parts that would interfere with obtaining measures should be rejected. Future studies should rectify this deficiency. This study fills a current gap in forensic identification that can only be improved in time.

Forensic anthropologists are called upon to provide a description of skeletal remains in order to make an identification of the person. Part of a person's profile is race. The categories for race used by the forensic anthropologist must reflect those in use by society whenever possible. The ongoing argument among anthropologists regarding race as an improper classification cannot cloud the issue when dealing in the realm of forensics. Therefore, reasonable methods of determining race by whatever bones are available must be accessible.

Analysis of the cranium is an accepted method of determining race. However, use of the postcranial skeleton for that task has been documented only in a few studies, with no simple, single method for assessment proposed. Most studies call for the use of several bones in the accurate analysis of ancestry. The femur, and in particular anterior femoral curvature, described the differences between groups, but no adequate method of utilizing this trait in the classification of individuals into racial categories was provided.

Based on Stewart's work in 1962, this project determined the practicality of anterior femoral curvature as a race assessor and furnished an easy and reproducible classification technique. The methods for the new technique do not require specialized materials; the instruments used are all readily available in any forensic laboratory. The formula developed was simple to use and accurate. This is a vast improvement over previous techniques of postcranial race assessment.

The femur proved to be useful for determining race. The unstandardized canonical discriminant function coefficients were multiplied to the variable measurements and added together to determine a score. This score was used to place the individual into a race category. The accuracy rate was 88.15% on the right femur, and 86.10% using the left femur. An overlap of variation was seen between the groups, and even within the groups, but overall race determination with femoral measurements is achievable.

Acknowledgment

The person I need to thank the most is Dr. William R. Maples, my mentor and advisor. He provided me with the opportunity to obtain a superior education. Dr. Maples often tolerated me, but always taught me. It is because of him that I can call myself a Forensic Anthropologist. I miss him terribly.

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Additional information and reprint requests:
Mary B. Trudell, Ph.D.
118 Engman Avenue
Bay St. Louis, MS 39520

ERRATUM

In the Maples Symposium paper, Trudell MB. Anterior femoral curvature revisited: race assessment from the femur. J Forensic Sci 1999;44(4):700–707. Table 2 was inadvertently omitted and is printed below. In addition, it should also be noted that the author's name has changed to Mary E. Ballard. For further information, please contact the author at the following address: Dr. Mary E. Ballard, Assistant Professor, Northeastern State University, Dept of Criminal Justice and Legal Studies, Seminary Hall 315, Tahlequah, OK 74464. The journal regrets any errors. Future citations of the above captioned paper should read: Ballard ME. Anterior femoral curvature revisited: race assessment from the femur. [Published erratum appears in J Forensic Sci 1999; Sept: 44(5)] J Forensic Sci 1999 Jul:44(4):700–707.

TABLE 2—*Discriminant function canonical coefficients.*

	Right Femur		Left Femur	
	Variable	Coefficient	Variable	Coefficient
Maximum length	(RMAX)	.05616	(LMAX)	.11350
Oblique length	(ROBL)	−.05128	(LOBL)	−.10512
Bicondylar breadth	(RBICON)	−.17654	(LBICON)	−.19943
Antero-posterior diameter—Midshaft	(RAPMID)	.12429	(LAPMID)	.13742
Transverse diameter—Midshaft	(RTRMID)	.09677	(LTRMID)	.08134
Subtrochanteric transverse diameter	(RTRSUB)	.09223	(LTRSUB)	.11450
¼ Shaft distance from table	(RR1)	.05108	(LR1)	−.10236
½ Shaft distance from table	(RR2)	−.04478	(LR2)	.10988
¾ Shaft distance from table	(RR3)	.15911	(LR3)	.05371
Proximal distance from table	(RPROX)	.06122	(LPROX)	.19554
Distal distance from block	(RBDIS)	.19848	(LBDIS)	.16902
Proximal distance from block	(RBPROX)	−.11947	(LBPROX)	.19554
Sex (Sex)		−.62248		−.84729
Age (Age1)		2.04084		2.03726
Constant		.98848		1.02720