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V. Alunni-Perret,[1] *M.D.; P. Staccini,*[2] *M.D.; and G. Quatrehomme,*[1] *M.D., Ph.D.*

Reexamination of a Measurement for Sexual Determination Using the Supero-Inferior Femoral Neck Diameter in a Modern European Population

ABSTRACT: The present study reexamines the accuracy of the supero-inferior femoral neck diameter for the determination of sex using a modern sample of French individuals. In 1998, Seidemann et al. used this univariate method for sex determination with the Hamann-Todd collection. Stojanowski and Seidemann in 1999 tested previous results on a modern sample taken from the University of New Mexico and concluded that the Caucasian male samples exhibited no significant differences between individuals born before and after 1900, but the Caucasian female subgroup did exhibit differences with an increase of the SID in the modern sample. The current study compares the previous results of the supero-inferior femoral neck diameter with a modern sample of elderly French individuals born after 1910. Both sides of the femur were measured. No statistical difference was found between the right and left side ($p = 0.31$). The results showed a significant difference between the pre-1900 and the modern sample, with an increase in femoral neck diameter in modern populations. The comparison of the SID values between the two modern samples (Mexico and Nice) showed no significant differences in the femoral neck diameter in the two male subgroups ($p = 0.05$), but the measurements of the SID in the female subgroup did exhibit significant differences with an increase of the neck femoral diameter ($p < 0.01$) in the modern French population. These results demonstrate an increase in the neck femoral morphology in the elderly European French females samples.

KEYWORDS: forensic science, forensic anthropology, discriminant function analysis, femur, sexual dimorphism

Determination of sex from the skeleton is a basic aim of forensic analysis. The determination of sex from the femur has been the subject of many studies, including those of Işcan and Miller-Shaivitz (1), Işcan and Shihai (2), Holliday and Falsetti (3), Taylor and DiBennardo (4), Asala (5), both on well-preserved bones and poorly preserved skeletal remains (6). Measurements at the midpoint of the shaft (7), the femoral head diameter, and the femoral distal breadth are usually taken for the determination of sex from the femur (8), and multivariate and univariate analyses are performed (9,3,10). Seidemann et al. (11) used a univariate method for sex determination based upon the minimum supero-inferior femoral neck diameter (SID) from the Hamann-Todd collection. Stojanoswski and Seidemann (12) tested previous results computed from the Hamann-Todd skeletal sample on a modern sample of documented age and sex taken from the University of New Mexico. The authors concluded in the second paper that, with regard to the SID measurements, the Caucasian male sub-samples exhibited no significant differences between individuals born before and after 1900, but the Caucasian female subgroup did exhibit differences with an increase of the SID in the modern samples.

The aim of this study was to compare the results of the supero-inferior femoral neck diameter between the Hamann-Todd skeletal collection and a modern femur collection of French adults born after 1910 and having died in 1998, 1999, and 2000. Then we compared our results with the Stojanowski and Seidemann's results (12) (both samples issued from a modern population) and revealed a new discriminant function for this European modern population. Furthermore, both sides of the femora were measured in order to assess if a significant difference could be recorded in our sample.

Material and Statistical Analysis

A total of 70 pairs of adult femora (35 white males (50%), 35 white females (50%)) of European White (French people) were used for this study. In order to overcome ethical issues, these bones were collected from people who had given their bodies to the University of Medicine of Nice (UMN) via a specific law in France called "don du corps" (i.e., "to donate one's body to research"). The age and sex of all the specimens were documented. All of the individuals examined in this collection were born after 1910 and had died between 1998 and 2000 and all were Caucasian. We excluded bones with femoral prostheses.

The measurements were taken with a digital sliding caliper zeroed between each measurement. The measurement was taken at the minimum diameter of the femoral neck in a supero-inferior direction across the narrowest part of the femoral neck (Fig. 1). We defined the protocol as follows: For each individual, the femoral SID was measured on both left and right femora in order to assess if a statistical significant difference between the two sides could be recorded. The Student paired-test was used to compare the right and the left sides. In order to minimize measurement error, we completed three measurements for each specimen for each side. The analysis of variance for repeated measurements was performed to check any absence of statistical difference between the three values that we obtained for each side. Finally, we computed the mean of the three values and used it to characterize a bone. For each side,

[1] Laboratoire de médecine Légale et Anthropologie medico-légale, 28 avenue de Valombrose, 06107 Nice Cedex 2, France.
[2] Département de Biostatistique, Informatique Médicale et Technologies de Communication—Faculté de Médecine de Nice, 28 avenue de Valombrose, 06 107 Nice Cedex 2, France.

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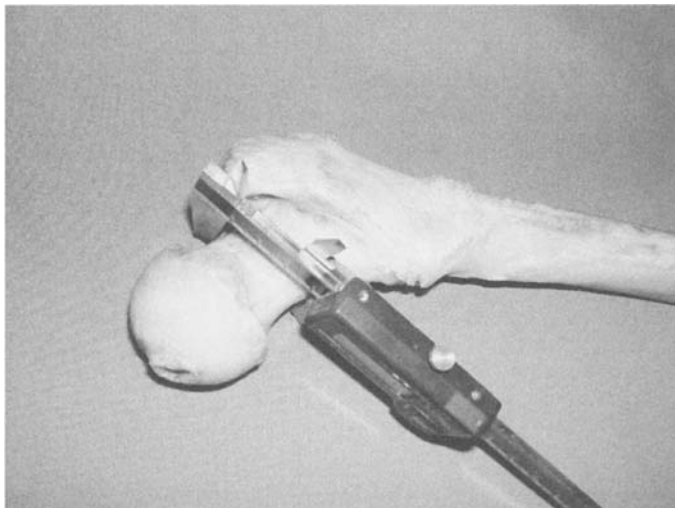

FIG. 1—*Measurement of the SID with a digital caliper*.

the mean values of the bones were tested for normality by the Shapiro-Wilk test. In order to evaluate the accuracy of previous discriminant functions in the current French population, all of the 70 individuals of the French sample were evaluated using the two previously Caucasian-defined functions (11,12). A logistic regression was then used to establish a modern European discriminant formula to classify males and females. We coded the variable "sex" as follows: 1 for male and 0 for female. The Type I error risk was fixed at 0.05.

Results

The characteristics of the sex repartition and the age mean value of the population are detailed in Table 1. The analysis of variance for repeated measurements checks the absence of difference for the three measurements. The Shapiro-Wilk test could not reject the hypothesis of normality of the distribution of the mean values computed with the three initial measures. No statistical difference was found between the right and left side for the mean values computed from the three measurements (Table 2).

Descriptive data of the measurements of the minimum supero-inferior femoral neck diameter (SID) for the University of Medicine of Nice are presented in Table 3, with a mean value of 35.09 for males and 30.85 for females. Table 4 shows the comparison of the data of the University of Medicine of Nice, the data of the previous results of the Hamann-Todd collection, and the data of New Mexico's documented collection, with an increase of the neck diameter in the French sample. We first tested SID for differences between the Hamann-Todd collection and the University of Medicine of Nice's sample (Table 5) and next between the University of New Mexico's collection and the French sample (Table 6). The results of the measurements of the modern European population exhibit significant difference at $p < 0.01$ level with the pre-1900 sample. The modern group taken from New Mexico's documented collection exhibits no significant difference with the European male subgroup, but the Nice female group showed an increase in the mean neck diameter.

We redefined the discriminant functions for the modern French individuals by using Nice's sample data to generate a new model. According to the logistic regression with the breakpoint set equal to zero, scores above zero indicate a male and scores below zero in-

TABLE 1—*Sex repartition and age mean value (SD = standard deviation: M = male, F = female).*

Sex	N	%	Age Mean	SD
M	35	50	83	10
F	35	50	87	7

TABLE 2—*Statistical analysis of right and left measurements.*

	Left	Right	*p*
Mean	33.17	32.97	0.31
SD	3.17	3.20	
Median	33	33	
Min	26	27	
Max	41	41	

TABLE 3—*Femoral neck diameter in the University of Medicine of Nice's sample.*

	Nice's Collection				
Group	Mean	SD	Median	Min	Max
Caucasian males	35.09	2.49	35.40	29.50	41
Caucasian females	30.85	2.20	30.70	26.30	36.20

TABLE 4—*Femoral neck diameter in the University of Medicine of Nice sample. In Hamann-Todd (HT) sample and in the New Mexico's documented collection.*

	Hamann-Todd		Mexico		Nice	
Group	Mean	SD	Mean	SD	Mean	SD
Caucasian males	33.53	2.20	33.91	2.90	35.09	2.49
Caucasian females	27.86	1.70	28.92	1.90	30.85	2.20

TABLE 5—*Evaluation of differences in the femoral neck diameter between the Hamann-Todd sample (HT) and the University of Medicine of Nice's sample.*

		Hamann-Todd			Nice		
Sex	N	Mean	SD	*N*	Mean	SD	*p*
Caucasian males	50	33.53	2.20	35	35.09	2.49	<0.01
Caucasian females	50	27.86	1.70	35	30.85	2.20	<0.01

TABLE 6—*Evaluation of differences in the femoral neck diameter between the New Mexico's Documented Collection and the University of Medicine of Nice's sample.*

		Mexico			Nice		
Sex	N	Mean	SD	*N*	Mean	SD	*p*
Caucasian males	62	33.91	2.90	35	35.09	2.49	=0.05
Caucasian females	32	28.92	1.90	35	30.85	2.20	<0.01

dicate a female. The French Caucasian discriminant function for modern individuals is as follows:

$$\text{Sex} = 0.505 \cdot \text{SID} - 17.136$$

According to this equation, 90.1% of patients are sexed correctly.

The accuracy of the previous discriminant functions generated from the Hamann-Todd sample and from Mexico's collection was evaluated on the modern French sample. The Caucasian specific function was utilized:

$$\text{Sex} = 0.496 \cdot \text{SID} - 15.163 \text{ (Hamann-Todd's sample)}$$

and

$$\text{Sex} = 0.387 \cdot \text{SID} - 12.462 \text{ (Mexico's sample)}$$

Results show that 77.1% of the sample was correctly classified using the Mexico Caucasian specific function, and 71.4% was correctly classified using the Hamann-Todd Caucasian specific function.

Discussion

We re-examined the method using the minimum supero-inferior diameter of the femoral neck for determining sex on our French sample (individuals born after 1910 and having died between 1998 and 2000). Each specimen was measured three times, and the average of the three measurements was recorded. The analysis of variance for repeated measures was performed to check the absence of difference, and *p* values were found to be not significant either for right and left side (respectively, $p = 0.47$ and $p = 0.12$). We measured the two femoral sides. Usually, in anthropology, the left side is measured (8,12), substituting the right side when the left side is unavailable. The comparison right-left was achieved because specific comparisons of both sides are rarely studied in the literature. In our sample, no statistical differences were found between right and left side ($p = 0.30$), but, for some authors, there is a little asymmetry in the human lower limb (13).

The osteometric assessment of femoral sexual dimorphism in the modern French population using the supero-inferior neck diameter was studied in order to develop a specific discriminant function standard. Stojanowski and Seidemann (12) have previously observed differences in Caucasian femoral morphology between females pre-1900 (Hamann-Todd Collection) and a modern female sample (Mexico's sample) with tests demonstrating an increase in the mean neck diameter in the modern female sample (in this paper, the Caucasian males do not exhibit significant differences in both populations). Stojanowski and Seidemann (12) generated a new discriminant function resulting from an increase of sample means.

Our current results showed significant differences between the Nice sample and HT sample, with an increase in femoral neck diameter in both sexes in the modern French population. Sexual dimorphism is expressed differently according to whether the population is contemporary or more ancient. Lavelle (14) showed a progression in femoral dimensions from the Bronze Age to present day. Some aspects of sexual dimorphism can equally be attributed to labor, to various ways of subsistence, and to the lifestyle changes (15). This can explain a significant difference in femoral neck diameter between the pre-1900 and modern samples. We tested for significant differences between the Hamann-Todd sample, Mexico's sample, and the sample of the University of Medicine of Nice. Using the previous discriminant functions generated from the HT and Mexico's collections, more than 25% of individuals were incorrectly classified, indicating a significant decrease in correct sex assessment. The use of discriminant functions taken from a sample consisting of individuals born before this century may produce errors for its application on actual forensic cases, and the functions derived from these populations can create differences on osteometric assessments. The same methodology cannot be applied from an archaeological population to a contemporary one.

The comparison of the SID values between the modern sample of Mexico and the modern sample of Nice showed an interesting feature. There was no significant difference in the femoral neck diameter in the two male subgroups ($p = 0.05$), but the measurements of the SID in the female subgroup did exhibit significant differences with an increase of the neck femoral diameter ($p < 0.01$) in the French modern population. These results show an increase in the neck femoral morphology in the elderly European French females. Some hypotheses can be examined, like population type (French and contemporary individuals) or age at death. The two samples (Mexico's and Nice's samples) consisted of modern individuals. Moreover, the French specimens were of an elderly population (more than 80 years old at time of death). In this population, the femoral neck at the point of the measurements did not show evidence of pathology that could affect the accuracy of the measurement (the five specimens who exhibited pathological conditions, arthritis, neck fractures, or ossification were excluded from this analysis). Stojanowski and Seidemann (12) stated with the Hamann-Todd collection that the SID measurement remains stable with regard to aging. In the Beck et al. paper (16) femoral neck bone mineral density values show the familiar age-related decline in both sexes, more rapid in the female. In males, there is a lack of apparent age change in the femoral neck cross-sectional moment of inertia at the narrowest section, suggesting a compensatory increase in bone girth in that sex. Females present a different pattern, because there is no change in femoral neck width. In 2000, Beck et al. (17) assessed a linear expansion in subperiosteal diameter in both sexes and in both regions, which tends to mechanically offset net loss of medullary bone mass. In our current paper, only females exhibit differences with an involvement of the SID.

With regard to population types, postcranial features differ significantly between widespread geographical groups of modern humans (3). Studies have demonstrated that populations differ from each other in size and proportions and that these differences can affect the metric assessment of sex (2,8). With regard to the femora of the Chinese population, some reports state that distal epiphyseal breadth is the most dimorphic part (2), while, with regard to the American population, the most dimorphic part could be the head diameter (5), and, with the Scottish Short Cis population (18), maximum anteroposterior diameter of the femoral shaft could be used as a sex discriminator. Trancho et al. (19) have presented specific functions for the Spanish population. Differences in femoral morphology between Caucasian and African-American have been observed previously (11). Moreover, there is a significant increase in mean neck-shaft angles across populations (20). So we think that population differences are important enough to need specific group standards, with Caucasian subgroups having specific standards.

The analytical procedure shows the method to have a high level of accuracy, especially with contemporary populations. The femoral male dimensions usually exceed the female dimensions (1). From the Nice sample, we defined a new discriminant function with 90% of individuals sexed correctly. This represents a high level of accuracy for discriminant function using one measurement. This is essentially comparable to the results reported in the Seidemann and Stojanowski paper (11) (92% accuracy) and better than

the Stojanoswki and Seidemann accuracy (12) (84% for Caucasian function) with a different geographical population. In that paper, the authors state that the increase in female neck morphology in recent years had decreased the distance between the male and female distribution, resulting in a reduction in the accuracy of the technique. In the Nice sample, there is an increase in both male and female neck morphology with a high rate of correct classification.

Conclusions

There are significant differences in the SID between individuals born before and after 1900. The results were not the same as those of another modern sample, taken from a population of New Mexico (12). The accuracy of prediction with a new discriminant function applied to a modern population is the same as in the Seidemann and Stojanowski paper (11) (using a pre-1900 collection) with consequently interesting applicability of the method to modern forensic cases. We have established standards to determine sex from the femur using a new sample of contemporary French individuals. The accuracy of the discriminant function reported above is 90%. From a practical standpoint the results of this study should be applicable only to specimens with similar biological and environmental background.

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Additional information and reprint requests:
V. Alunni-Perret, M.D.
Laboratoire de médecine
Légale et Anthropologie medico-légale, 28
Avenue de Valombrose
06107 Nice Cedex 2
France
E-mail: alunni—perret.v@chu-nice.fr