TECHNICAL NOTE

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A Reevaluation of the Sex Prediction Accuracy of the Minimum Supero-Inferior Femoral Neck Diameter for Modern Individuals

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ABSTRACT: The results of an independent test of the minimum supero-inferior femoral neck diameter as a sex predictor are presented. Seidemann et al. (1) generated discriminant functions for Caucasians, African-Americans, and a combined race sample from the Hamann-Todd skeletal collection. Jackknifed classification matrices and the use of independent, random validation samples indicated a sex prediction accuracy in the 90% range. This, combined with a high rate of preservation, makes the femoral neck a significant measure for forensic applications. However, the method has not been evaluated on a truly modern sample.

Data were collected for 94 males and 49 females from the Documented Collection at the University of New Mexico. The sample consists of 94 Caucasians, 33 African Americans, three modern Native Americans, two Hispanics, and 11 individuals of unknown ancestry. All individuals were born after the turn of the century. We evaluate the accuracy of the discriminant functions generated from the Hamann-Todd control sample. For Caucasians, 83% were correctly classified, for African Americans 97% were correctly classified and for the combined race function 85% were correctly classified. This decrease in accuracy is the result of the increase in African American male and all female sample means. This effectively decreases the separation between males and females for the femoral neck diameter. We generate new discriminant functions from the modern data and jackknife the classification matrices. The Caucasian function was 84% accurate, the African-American function was 82% accurate and the combined sample function was 85% accurate. The femoral neck may provide a useful alternative to multivariate techniques for individuals who are poorly preserved.

KEYWORDS: forensic science, forensic anthropology, physical anthropology, sex determination, femur, secular trend

The attribution of skeletal sex is one of the most basic and essential goals of forensic analysis. To this end, much research has been performed resulting in the identification of both metric and non-metric indicators. While the cranium and pelvis are the preferred methods for sex determination (e.g., Buikstra and Ubelaker (2)), these regions are often absent and secondary postcranial methods must be employed. Multivariate analyses are preferred but are again compromised by incomplete preservation. Continued research on univariate methods is important, assuming the landmark being analyzed is fairly resilient to taphonomic deterioration.

Seidemann et al. (1) introduced a univariate method for sex determination based upon the minimum supero-inferior femoral neck diameter (SID). Using the Hamann-Todd skeletal sample, the authors generated three linear discriminant functions, one for Caucasians, one for African-Americans, and a combined race function. The accuracy of the functions was evaluated using jackknifed classification matrices and cross-validation with random holdout samples. Correct sex prediction was in the 90% or above range. The femoral neck also displayed little evidence of changes with age and a high rate of preservation making the technique useful in fragmentary forensic contexts. However, the use of a sample composed of individuals born before the turn of the century may present problems for direct application on modern forensic cases (3). We test the previously defined functions on a modern sample of documented age, sex, and biological affinity.

Materials

The study sample is derived from the University of New Mexico's Documented Collection which contains the remains of approximately 200 individuals of known sex, age, and race. All individuals used in this study were born after 1900 and are of documented sex. The sample contains 143 individuals which can be subdivided as follows: 62 Caucasian males, 32 Caucasian females, 20 African-American males, 13 African-American females, three Native American males, two Hispanic females, nine males of unknown ancestry, and two females of unknown ancestry. In this paper Caucasian refers to Americans of European descent. The entire collection was utilized excluding only those individuals whose growth was incomplete, who exhibited pathological conditions which affected neck morphology, or who exhibited deterioration of the neck area.

Methods

All measurements were taken with a pair of digital sliding calipers and recorded to the nearest hundredth of a millimeter. The calipers were zeroed between measurements to ensure accuracy. The left side was measured substituting the right when the left was

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unavailable. A diagram of the exact measurement can be found in the original report (1), however, the measurement is easy to locate and measure. The measurement is taken at the minimum diameter of the femoral neck in a supero-inferior direction. The calipers should be held roughly parallel to the femoral diaphysis.

We evaluated differences in the femoral neck measurement using standard parametric t-tests. We tested for significant differences between the Hamann-Todd and UNM Documented collections and between males and females for the UNM sample only. We used the Satterthwaite approximation to calculate the degrees of freedom to avoid problems with unequal sample variances.

All 143 individuals in the UNM sample were evaluated using the discriminant functions previously defined (1). Classification matrices were generated to summarize the accuracy of the previous models. We then utilized the UNM data to generate three new discriminant functions based solely on the modern data. Two population specific functions, Caucasian and African American, and one combined population function were generated using a linear discriminant analysis with the sectioning point set equal to zero. Normal and jackknifed classification matrices were generated to evaluate the accuracy of the functions derived from the modern data. All statistical calculations were performed using the Systat for Windows version 7.0 statistical package.

Results

We first tested for significant differences in the femoral neck diameter between the pre-1900 and modern samples. We present the population specific and combined population means and standard deviations and the appropriate test statistics in Table 1. The Caucasian male and the combined population male sample exhibit no significant differences between the pre-1900 and modern groups. However, both females groups and the African American male sample do exhibit statistically significant differences. Without exception, all significant tests involved an increase in the mean neck diameter in the modern sample. This indicates that the functions previously defined (1) may not be appropriate for modern individuals.

We present the descriptive statistics and the test statistics for the UNM Documented sample in Table 2. All test statistics were computed using the Satterthwaite approximation since the assumption of equal sample variances seems to be untrue for the three subsamples. The male samples were consistently more variable than the female samples. The Caucasian, African-American, and combined population samples exhibit significant male/female differences at the $p = 0.0001$ level. Despite the consistent increases when compared to pre-1900 individuals, the femoral neck still exhibits considerable sexual dimorphism. The difference in means for the respective time periods does, however, exhibit an overall decrease which may indicate a decrease in sex prediction accuracy.

The accuracy of the discriminant functions generated from the Hamann-Todd sample was evaluated on the modern UNM sample. The results are presented in Table 3. For the Caucasian sample, the Caucasian specific function (1) was utilized (Sex=.578*SID-17.141). Sixteen of 94 individuals were incorrectly classified resulting in a sex prediction accuracy of 83%. For the African American sample, the African-American function (1) was utilized (Sex=.496*SID-15.163). One of 33 individuals was incorrectly classified resulting in a sex prediction accuracy of 97%. The entire UNM Documented sample (n=143) was evaluated using the combined race function (1) (Sex=.510*SID-15.356). Twenty-one of 143 individuals were incorrectly classified resulting in a sex prediction accuracy of 85%.

We redefined the discriminant functions for modern individuals by using the UNM data to generate new models. We used a linear discriminant analysis with the sectioning point set equal to zero. Scores above zero are considered male, scores below zero are considered female. The Caucasian specific function is:

Equation 1: Sex = 0.387*SID-12.462

The normal and jackknifed classification matrices for Caucasians are presented in Table 4. Both matrices produce identical results

TABLE 1—*Evaluation of femoral neck differences between the Hamann-Todd and UNM Documented collections.*

	Hamann-Todd		UNM				
Group	Mean	sd	Mean	sd	df	*t*	*p*
Caucasian M	33.53	2.2	33.91	2.9	86.1	.127	.849
Caucasian F	27.86	1.7	28.92	1.9	58.5	−2.537	.014
Afr.-Am. M	31.93	1.7	34.36	2.8	24.9	−3.61	.001
Afr.-Am. F	27.31	1.7	29.19	1.6	19.4	−3.83	.001
Total M	32.72	2.1	33.85*	2.9*	130.3	−1.592	.114
Total F	27.58	1.7	28.84*	2.2*	76.5	−3.572	.001

* Includes two Hispanics, three Native Americans, and 11 individuals of unknown ancestry.

TABLE 2—*Evaluation of sexual dimorphism in UNM Documented sample.*

	Male		Female				
Race	Mean(n)	sd	Mean(n)	sd	df	*t*	*p*
Caucasian	33.91(62)	2.88	28.92(32)	1.96	86.5	6.084	.0001
African-Am.	34.36(20)	2.82	29.19(13)	1.56	30.4	6.772	.0001
Total	33.85(94)	2.87	28.84(49)	2.17	140.4	8.407	.0001

TABLE 3—*Classification matrices for UNM Documented sample.*

		Caucasian Estimated Male	Female	% Correct
Actual	Male	58	12	83
	Female	4	20	83
				83%
		African American Estimated Male	Female	% Correct
Actual	Male	20	1	95
	Female	0	12	100
				97%
		Combined Race Estimated Male	Female	% Correct
Actual	Male	85	12	88
	Female	9	37	80
				85%

TABLE 4—*Classification matrices for UNM Caucasian sample.*

		Normal Matrix Estimated Male	Female	% Correct
Actual	Male	50	12	80
	Female	3	29	91
	Total	53	41	84
		Jackknifed Matrix Estimated Male	Female	% Correct
Actual	Male	50	12	80
	Female	3	29	91
	Total	53	41	84

TABLE 5—*Classification matrices for UNM African American sample.*

		Normal Matrix Estimated Male	Female	% Correct
Actual	Male	16	4	80
	Female	1	12	92
	Total	17	16	85
		Jackknifed Matrix Estimated Male	Female	% Correct
Actual	Male	15	5	75
	Female	1	12	92
	Total	16	17	82

TABLE 6—*Classification matrices for UNM total sample.*

		Normal Matrix Estimated Male	Female	% Correct
Actual	Male	78	16	83
	Female	5	44	90
	Total	83	60	85
		Jackknifed Matrix Estimated Male	Female	% Correct
Actual	Male	78	16	83
	Female	5	44	85
	Total	83	60	85

results based on a sample of individuals born prior to the turn of the century indicated a high rate of correct classification. However, secular increases in female neck morphology in recent years have effectively decreased the distance between the male and female distributions resulting in a decrease in overall accuracy of the technique. Jackknifed classification matrices for both the Hamann-Todd and UNM Documented samples indicated consistent decreases in correct sex estimation (Caucasians from 92 to 84%, African-Americans from 87 to 82%, and the combined race sample from 90 to 82%). Cross validation of the newly generated discriminant functions was not possible due to a lack of known sex females in the study sample. Similar problems have been reported elsewhere (4).

Despite the slight decrease in observed classification accuracy, we feel that this univariate measure is significant due to its high rate of preservation (1). This coupled with the apparent lack of age dependence makes this technique more appropriate than some widely applied landmarks that demonstrate age related changes (5). Of course a complete skeleton will yield more accurate indicators, however, incomplete and poorly preserved remains may require the application of more resilient univariate methods.

with 84% of the sample being correctly classified. The African American function is:

$$\text{Equation 2: Sex} = 0.415*\text{SID} - 13.422$$

The jackknifed classification matrix (Table 5) indicates that 82% of the sample was correctly classified. The combined race function is:

$$\text{Equation 3: Sex} = 0.379*\text{SID} - 12.174$$

Both the normal and jackknifed classification matrices produced identical results with 85% of the total sample being correctly classified (Table 6).

Discussion and Summary

In this paper we have evaluated the sex prediction accuracy of the minimum supero-inferior femoral neck diameter. Previous re-

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