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Sexing North American Eskimo and Indian Innominate Bones with the Acetabulum/Pubis Index

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ABSTRACT: The acetabulum/pubis index was tested on American Eskimo and Indian samples of innominate bones to which sex had been assigned by visual inspection. The index alone sexed 91 and 89% of the Eskimo and Indian samples, respectively. Subsequent sorting of misclassified specimens with femur head diameter resulted in 96 and 99% rates of classification. The index and a measurement of ischial height were used in a discriminant function model which correctly identified the sex of 93% of the Eskimo and 92% of the Indian bones. Using femur head diameter to sort those specimens which were misclassified by their discriminant function score yielded classification rates of 96 and 98%. These results are compared to a range of 92 to 100% obtained with the index in earlier studies of American black and white pelvic bone samples.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, acetabulum/pubis index

The acetabulum/pubis index is derived from innominate bone measurements which we defined in earlier reports of studies aimed at identifying sex in randomly selected samples of adult American black and white skeletal populations [*1,2*]. In those samples, the index proved to be an efficient predictor of sex when used in discriminant function analyses in combination with a measurement of ischial height and when used alone with specific sample sectioning points.

According to Brues [*3*], sex differences in the pelvis are less marked in blacks than in whites, and our data supported this. Despite these findings, with our method we were able to predict sex with up to 100% accuracy in both races. Also, Brues' observation suggested to us that the variables we used might detect racial differences. We tested our data and correctly identified the race of 79% of our mixed sample of black (100) and white (100) skeletons. When variability was reduced by considering the subsamples of known sex, 85% were correctly identified [*4*].

To test the efficacy of our method further, we collected data from samples of North American Eskimo and Indian innominate bones and femora. This paper reports our findings regarding the use of the acetabulum/pubis index, alone and in combination with other variables, for determining sex in these two additional skeletal populations. The results of our

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efforts to predict race, and race and sex simultaneously, for all four populations that we have now studied, will be presented in a future paper.

Materials and Methods

Our samples were composed of 75 (38 male, 37 female) Eskimo and 96 (58 male, 38 female) American Indian left innominate bones and matching femora in the Smithsonian Institution collections. The criteria for selection were intact reference points for measuring and the absence of deforming pathology. The Eskimo specimens were from the Nunivak, Kodiak, and St. Lawrence Islands. The Indian specimens were from the Mobridge and nearby sites in South Dakota. Sex had been assigned to all by visual inspection. All measurements were made and recorded by a single observer (Schulter-Ellis). After a lapse of approximately 2 months, a sample of specimens was randomly selected from each site for remeasuring. Differences in values obtained between the two measuring sessions did not exceed 2 mm in any instance.

The following three pelvic measurements were taken to the nearest millimetre and are illustrated in Fig. 1: (1) length, parallel to the pubic axis, from the superiormost aspect of the pubic symphysis to the nearest rim of the acetabulum (PS-A); (2) diameter of the acetab-

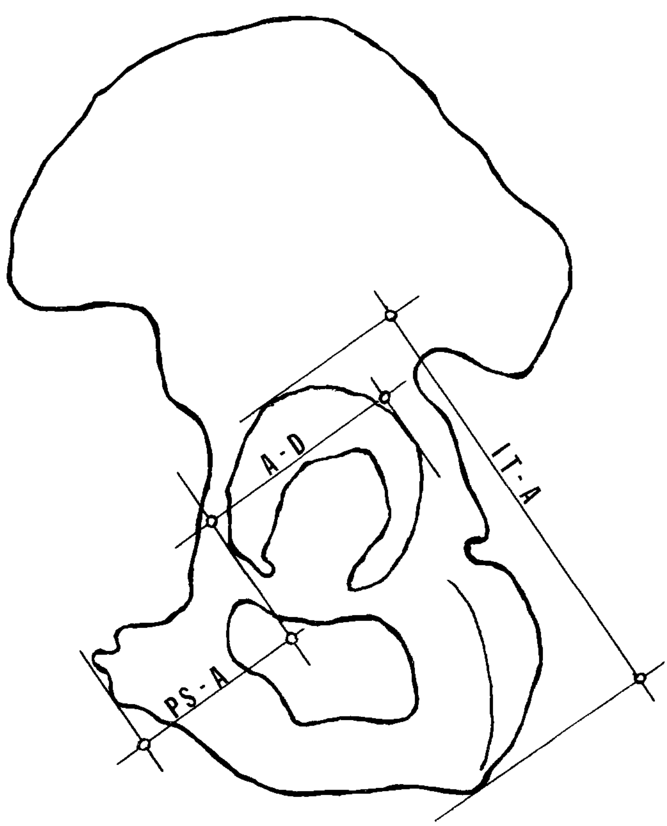

FIG. 1—*Left pelvic bone illustrating: length, parallel to the pubic axis, from the* (1) *superiormost point of the pubic symphysis to the nearest rim of the acetabulum* (PS-A); (2) *the diameter of the acetabulum* (AD); *and* (3) *a length from the anterior aspect of the ischial tuberosity to the opposite rim of the acetabulum* (IT-A).

ulum (AD) representing a parallel extension of measurement (1); and (3) the distance from the anterior aspect of the ischial tuberosity to the farthest point on the opposite rim of the acetabulum (IT-A) which we refer to as "ischium-acetabulum height." Note that this measurement, taken in this manner, does not require the location of reference points that are difficult to find, nor does it require any special spacial orientation of the pelvic bone. Greatest femoral length (Flg) and maximum femur head diameter (FHD) were also measured. We used the latter in our previous studies for sorting specimens with overlapping discriminant scores because it had been found by us and other investigators [5,6] to be a reliable indicator of sex. The acetabulum/pubis (A/P) index was calculated as acetabulum diameter/pubic length (AD/PS-A).

Statistical Analysis

Since neither the Eskimo nor Indian bones came from a single archeological site, descriptive statistics, tests of assumptions, and tests of equality of means were performed by sex for each site. No significant site differences were found for male, female, or total samples. After determining that the means for males and females differed significantly in both the Eskimos and Indians, the five measurements and the A/P index were used as independent variables in stepwise discriminant analyses. Because of redundancies among some of the measures and also because we wanted to provide for a more parsimonious description, subsets of variables were selected for constructing additional models. In each of these, the index was included since it was the most important contributor in the first, six-variable model. That is, the index was used in combination with all groups of four, three, two, and one of the other variables. When not included in a model, FHD was used for subsequent sorting of those pelves that had overlapping discriminant scores. Finally, the specimens were sexed using A/P index values, alone, and subsequent sorting of those in the overlap area by femur head diameter. Because of the limited number of specimens with intact reference points from each site, cross validation of our discriminant function (that is, testing by using specimens that were not a part of our study sample) was not possible.

Results and Discussion

The basic descriptive statistics for each variable, including the calculated A/P index, for both the Eskimo and Indian samples are given in Table 1. The use of all five measurements with the index in a discriminant function model to detect sex differences showed only the index and IT-A to be of importance for the Eskimos. The F-to-enter values for all other variables were not significant, and no other variable contributed to the separation of the sexes. When used in a two-variable analysis of the Indian data, the index and IT-A formed one of the three best fitting models among which there were no significant differences in correct classification; however, this model did yield the smallest residuals. Neither acetabulum diameter nor femur length provided any important contribution.

Canonical discriminant function coefficients for the index and IT-A are listed in Table 2 in order of stepwise entry. For both Eskimos and Indians, the standardized coefficients show the index to be the more important detector of sex and the variable which is more highly correlated with the discriminating function.

Histograms of the discriminant scores for both sample populations are provided in Fig. 2. The scores are based on the functions

$$Y = 16.84(\text{AD/PS-A}) + 0.137(\text{IT-A}) - 26.411$$
for the Eskimos and
$$Y = 17.265(\text{AD/PS-A}) + 0.144(\text{IT-A}) - 27.194$$
for the Indians.

TABLE 1—*Basic descriptive statistics.*[a,b,c]

Sample Population	Variable	Sex	No.	Mean	Standard Deviation	Maximum	Minimum
Eskimo	A/P Index	M	38	0.768	0.050	0.869	0.676
		F	37	0.650	0.038	0.746	0.597
	IT-A	M	38	109.605	4.487	116.0	97.0
		F	37	100.270	4.032	113.0	93.0
	FHD	M	38	46.763	2.085	50.0	42.0
		F	37	42.459	2.022	48.0	39.0
	AD	M	38	52.632	2.645	57.0	48.0
		F	37	47.649	2.137	53.0	45.0
	PS-A	M	38	68.684	4.375	78.0	58.0
		F	37	73.486	4.121	84.0	67.0
Indian	A/P Index	M	58	0.711	0.050	0.844	0.610
		F	38	0.622	0.034	0.716	0.563
	IT-A	M	58	111.500	3.935	121.0	100.0
		F		103.053	5.812	113.0	77.0
	FHD	M	58	47.190	1.995	54.0	43.0
		F	38	42.763	2.136	50.0	39.0
	AD	M	58	51.397	2.271	56.0	46.0
		F	38	47.368	2.295	54.0	43.0
	PS-A	M	58	72.552	4.762	82.0	61.0
		F	38	76.316	4.088	83.0	67.0

[a] All *F*-tests for variance were not significant.
[b] Two-tail tests on means of each variable were significant at the 0.001 level.
[c] All measures are in millimetres.

TABLE 2—*Canonical discriminant function coefficients.*

Sample Population	Variable	Unstandardized Weights	Standardized Weights	Correlations of Variables with Discriminant Function
Eskimo[a]	A/P Index	16.841	0.750	0.81
	IT-A	0.138	0.587	0.67
Indian[b]	A/P Index	17.265	0.765	0.73
	IT-A	0.144	0.683	0.64

[a]Constant is 26.411.
[b]Constant is 27.194.

Eskimos—Since the sample size contained an approximately equal number of males and females, zero was the discriminating score, and with it, only two males and three females were misclassified. One male and one female sorted with femur head diameter (45 mm or greater representing males), giving a predictive rate of 96% for this method. However, because of their overlapping scores, eight males and three females would be considered doubtful if sex were unknown or unassigned. Five of those eleven were identified by FHD, and 92% of the sample was, thereby, correctly assigned. Four males and two females remained misclassified.

As in our earlier studies of blacks and whites, we examined the A/P ratio as a sole predictor (because both variables used in the discriminant analysis included a measurement of the acetabulum). With a sample specific separating value of 0.71, it correctly sexed 91% of our specimens (Fig. 3). Of the seven (three females, four males) improperly assigned individuals, three (two females, one male) failed to sort by FHD. Therefore, the index with FHD provided 96% predictability in our Eskimo sample. However, as can be seen in Fig. 3, there were twenty-three specimens in the overlap area. Sorting of all of those by FHD resulted in an overall classification rate of 91%, with four females and three males remaining improperly assigned.

Indians—Owing to an unequal number of males and females in the Indian sample, the cut point for the discriminant scores in the two variable analysis of the Indian data was determined statistically to be −0.3. Ninety-two percent of the sample was correctly assigned using that cut-off value—three females and five males were misclassified (Fig. 2). Six of those were identified by FHD (45 mm or greater representing males), yielding a 98% correct prediction. However, because of one "super" female and a very gracile male, twenty-four specimens had overlapping scores, five of which (four females, one male) failed to sort with femur head diameter. The overall rate of correct classification was thereby reduced to 95%.

With a separating value of 0.66, the index as the sole predictor identified 89% of the sample. The sex of ten of the eleven improperly assigned pelves was identified by FHD, yielding a 99% rate of prediction. Only the "super" female, whose femur head diameter was 50 mm, remained incorrectly assigned. Because of one female with an index value of 0.72 and one male with a value of 0.61, the overlap area included 63 specimens, seven of which were not identified by FHD. Without the two extreme cases, five of those seven specimens (two males and three females) would not have been in the overlap area. The males' values were 0.70 and 0.71; the females' were 0.61, 0.62, and 0.63. Since certainty is a function of the distance and direction of the individual value from that of the group, these cases would have been sexed with a considerable degree of confidence by the index alone (Fig. 3). Therefore, it is reasonable to conclude that the overall rate of classification achieved with the index and subsequent sorting of specimens by their femur head diameter was 98%.

Just as with Schultz' ischium pubis index [7], absolute size bears no relation to the acetab-

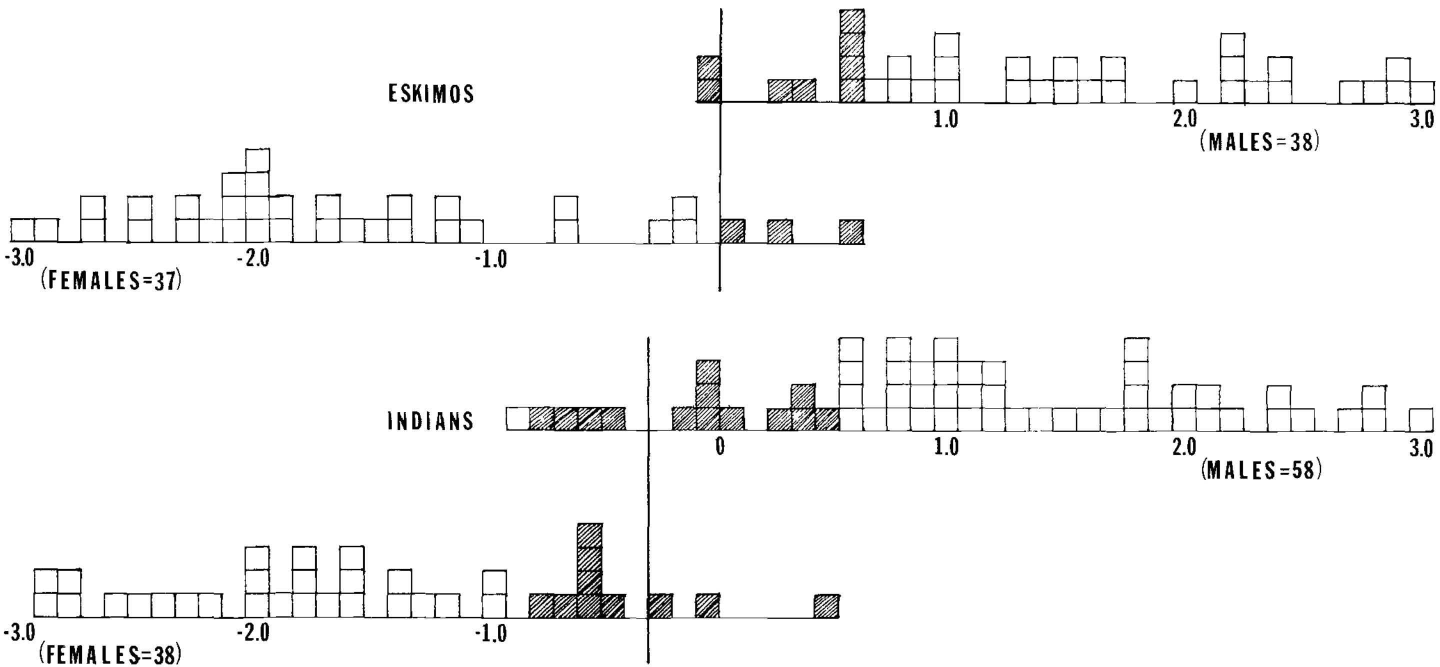

FIG. 2—*Histograms giving the discriminant score distribution by sex for 75 Eskimo and 96 Indian left pelvic bones. The shaded areas include 11 Eskimo and 23 Indian specimen with overlapping scores. Three Eskimo males with scores greater than 3.0; plus two Eskimo and two Indian females with scores less than −3.0 are not illustrated.*

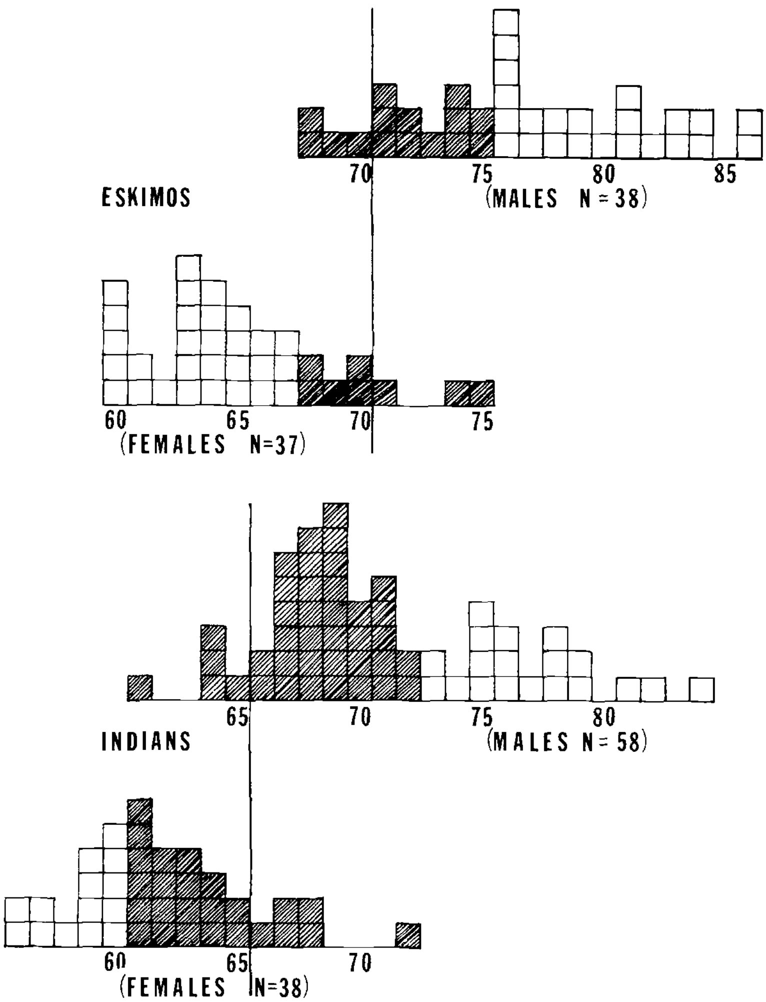

FIG. 3—*Histograms giving the acetabulum/pubis index distribution by sex for 75 Eskimo and 96 Indian pelves. The shaded (overlap) areas include 23 Eskimo pelves with index values between 0.68 and 0.75, and 63 Indian specimens with index values between 0.61 and 0.72. Note that the large number of Indian specimens with overlapping values is owed to 1 gracile male (0.61) and 1 super female (0.72). Otherwise the overlapping scores would be 0.64 to 0.68.*

ulum/pubis index. Construction of our index was based on Last's observation [*8*] that the length of the pubic bone is greater than the diameter of the acetabulum in the female and equal to or less than it is in the male. Our decision to use the measurement of ischium height and femur head diameter in combination with the index was based upon Washburn's statement [*9*]:

> since sex difference in the size of the ischium is pronounced, small ischia will tend to be female. Also, the greater size of the femoral heads (and hence acetabulae) in the males may be unrelated to the other characters. Size of ischia and acetabulae will afford additional evidence of sex in doubtful cases.

Human variation among both individuals and populations is well recognized as a complicating factor in efforts to identify sex from the skeleton. Washburn [9] acknowledged this when he stated that the ischium/pubis (I/P) index would sex 90% of skeletons if they belonged to one major racial group. Kelly's [10] sciatic notch/acetabular index appeared to overcome the problem. He used it on samples of American white, black, and Indian skeletons and concluded that it would sex 90% of adult skeletons regardless of their ethnic origins and without allowances for group variations. However, MacLaughlin and Bruce [11] used Kelly's method with disappointing results in a study of two European skeletal collections when no allowances were made for group variations.

The results in percentages of correctly assigned sex that we obtained with the A/P index (1) combined with a measurement of ischial height to construct two-variable discriminant function models and (2) alone are summarized in Tables 3 and 4, for four human populations representing the three major races. Also given are the results obtained from sorting misclassified and doubtful specimens by FHD for which 45 mm or greater identified both Eskimo and Indian males. Group-specific separating values were used for each population. It follows that our method is valid when applied to a sample of known ethnicity. The rate of correct classification was above 90% for all samples with all methods that we used, except one; that is, the A/P index, without subsequent sorting by FHD, classified only 89% of the Indian sample. Recall that sex was assigned by visual inspection in the field of the specimens in our Indian and Eskimo samples. Such assignment is generally considered to be about 80 to 90% correct. Therefore, our error rate is not necessarily a true error rate. Rather, it is the rate of disagreement with the field designation of sex.

The same caviats apply to the results that we have reported here as to any others obtained with discriminant function analyses or the use of measurements of skeletal variables, alone. Examples of problematic factors about which one should be aware are (1) how well the sample represents its racial group owing to different environmental and socio-economic factors [12], (2) the possible effects of secular changes that are known to have occurred [13], and (3) how the measured variables might be affected by indiscrete morphological traits that vary among races or subpopulations. Compared to each of our other samples of the latter example, the Indian pelves seemed to have more pronounced iliopectineal eminences, and the acetabular notch seemed to be more medially positioned. If these subjective observations are valid, our measurements of pubic length and acetabular diameter in the Indians could have been affected in such a way that the index would have a lower separating value and predictive efficiency for the Indian than for either of the other three skeletal collections that we have studied. The Indian sample also contained the largest number of specimens with overlapping scores.

Finally, femur head diameter separated our black and white doubtful cases [1,2] better than either the Eskimo or Indian ones. This is easily explained by the fact that our data reveal greater sex differences in the size of the femoral head in our black and white than in our Eskimo and Indian samples. These considerations not withstanding, our studies indicate strongly that the index is an efficient predictor of sex and it has the advantage of being constructed of measurements obtained from reference points that are easily identified.

Summary

1(a) A discriminant function analysis of three pelvic bone variables (two of which were used for calculating an acetabulum/pubis index) correctly identified 93 and 92%, respectively, of randomly selected Eskimo and Indian innominate bones in the Smithsonian Institution's skeletal collections. This compares to 96% of black and 98% of white Terry Collection pelves that we studied earlier.

TABLE 3—*Comparison of results of using a discriminant function analysis of the acetabulum/pubis index and ischial height to classify North American black, white, Eskimo, and Indian pelves regarding sex. Group specific separating values were used for each population sample.*

			Classified		Misclassified			Overlap Area		
Sample	Sex	No.	No.	Total Sample, %	No.	FHD Sorted	Total Sample Classified, %	No.	FHD Sorted	Total Sample Classified, %
Black	M	50	49	96	1	1	100	9	6	97
	F	50	47		3	3		5	5	
White	M	50	49	98	1	1	99	2	2	97
	F	50	49		1	0		3	0	
Eskimo	M	38	36	93	2	1	96	8	4	92
	F	37	34		3	1		3	1	
Indian	M	58	53	92	5	4	98	14	13	95
	F	38	35		3	2		10	6	

TABLE 4—*Comparison of results of using acetabulum/pubis index values to classify North American black, white, Eskimo and Indian pelves regarding sex.*

				Classified		Misclassified			Overlap Area		
Sample	Group Separating Value	Sex	No.	No.	Total Sample, %	No.	FHD Sorted	Total Sample Classified, %	No.	FHD Sorted	Total Sample Classified, %
Black	>0.74	M	50	46	92	4	4	100	39	35	96
	<0.73	F	50	46		4	4		16	16	
White	>0.71	M	50	45	95	5	5	100	5	5	97
	<0.70	F	50	50		0	...		11	8	
Eskimo	>0.71	M	38	34	91	4	3	96	15	12	91
	<0.70	F	37	34		3	1		8	4	
Indian	>0.66	M	58	53	89	5	5	99	39	37	93
	<0.65	F	38	32		6	5		24	19	

(b) Subsequent sorting of doubtful specimens by FHD (45 mm or greater representing males) yielded an overall classification rate of 92% of the Eskimos and 95% of the Indians. By comparison, we correctly determined the sex of 97% of both our Terry Collection black and white samples.

2(a) With index values of 0.71 or greater identifying Eskimo males and 0.66 or greater identifying Indian males, the acetabulum/pubis index alone correctly assigned 91% of the Eskimo and 89% of the Indian pelves. By comparison, it classified 92 and 95% of our black and white samples, respectively.

(b) Sorting of specimens with overlapping index values by FHD gave an overall correct identification rate of 91% of the Eskimos and 93% of the Indians. This compares with 96 and 97% correct classification obtained by this procedure for the black and white samples, respectively.

We have used the acetabulum/pubis index alone and in combination with other variables to sex four samples of innominate bones from skeletal collections of the three recognized human races. The procedures which we followed have yielded classification rates in excess of 90% in all instances except one; that is, the A/P index, without subsequent sorting by FHD, classified only 89% of the Indian sample. Based on subjective observations, it appears that both the Eskimo, and especially, the Indian bones, have more prominent iliopectineal eminences and more medially directed acetabular notches than the black and white bones that we studied. Also, our empirical data reveal greater sex differences in femoral head size in our black and white than in our Eskimo and Indian samples. These morphological differences might account for the higher classification rates that we have obtained for our white and black population samples than for our Eskimo and Indian samples.

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References

[1] Schulter-Ellis, F. P., Schmidt, D. J., Hayek, L-A. C., and Craig, J., "Determination of Sex with a Discriminant Analysis of New Pubic Bone Measurements: Part I," *Journal of Forensic Sciences*, Vol. 28, No. 1, Jan. 1983, pp. 169-180.

[2] Schulter-Ellis, F. P., Hayek, L-A. C., and Schmidt, D. J., "Determination of Sex with a Discriminant Analysis of New Pelvic Bone Measurements: Part II," *Journal of Forensic Sciences*, Vol. 30, No. 1, Jan. 1985, pp. 178-185.

[3] Brues, A. M., "Identification of Skeletal Remains," *The Journal of Criminal Law, Criminology and Police Science*, Vol. 48, No. 5, Jan./Feb. 1958, pp. 551-563.

[4] Schulter-Ellis, F. P. and Hayek, L-A. C., "Predicting Race and Sex with an Acetabulum/Pubis Index," *Collegium Antropologicum*, Vol. 8, No. 2, Dec. 1984, pp. 155-162.

[5] Thieme, F. P., "Sex in Negro Skeletons," *Journal of Forensic Medicine*, Vol. 4, No. 2, April/June 1957, pp. 72-81.

[6] Richman, E. A., Michel, M. E., Schulter-Ellis, F. P., and Corruccini, R. S., "Determination of Sex by Discriminant Function Analysis of Postcranial Skeletal Measurements," *Journal of Forensic Sciences*, Vol. 24, No. 1, Jan. 1979, pp. 159-167.

[7] Schultz, A. H., "The Skeleton of the Trunk and Limbs of Higher Primates," *Human Biology*, Vol. 2, No. 3, Sept. 1930, pp. 303-438.

[8] Last, R. J., *Anatomy: Regional and Applied*, 4th ed., Churchill, London, 1966, p. 289.

[9] Washburn, S. L., "Sex Differences in the Pubic Bone," *American Journal of Physical Anthropology*, Vol. 6, No. 2, June 1948, pp. 199-207.

[10] Kelley, M. A., "Sex Determination with Fragmented Skeletal Remains," *Journal of Forensic Sciences*, Vol. 24, No. 1, Jan. 1979, pp. 154-158.

[11] MacLaughlin, S. M. and Bruce, M. F., "The Sciatic Notch/Acetabular Index as a Discriminator of Sex in European Skeletal Remains," *Journal of Forensic Sciences*, Vol. 31, No. 4, Oct. 1986, pp. 1380-1390.

[12] Iscan, M. Y., "Assessment of Race from the Pelvis," *American Journal of Physical Anthropology,* Vol. 62, No. 2, Oct. 1983, pp. 205-208.
[13] Angel, J. L., "Colonial to Modern Skeletal Change in the U.S.A.," *American Journal of Physical Anthropology,* Vol. 45, No. 3(2), Nov. 1976, pp. 723-735.

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