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PAPER

ANTHROPOLOGY

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Determining Sex of the Posterior Ilium from the Robert J. Terry and William M. Bass Collections

ABSTRACT: Morphological traits of the posterior ilium are commonly used for sex determination in bioarcheological and forensic skeletal analysis. This study was designed to compare the classification correctness of standard scoring systems and measurements of the posterior ilium, including using logistic regression, to develop new formulae to predict sex. Metric measurements and morphological scores for the preauricular sulcus (PS), the elevation of the auricular surface, and the greater sciatic notch width were recorded for 97 males and 101 females of both European and African ancestry from the William M. Bass and Terry Collections. Correct classification of sex was high using individual traits such as the greater sciatic notch score (88.4%), the presence or absence of a PS (78.8%), and the scoring of a present PS as 1, 2, or 3 (100%). Furthermore, an equation combining multiple traits of the posterior ilium had a high classification of 94.9%.

KEYWORDS: forensic science, forensic anthropology, sexual dimorphism, pelvis, logistic regression, classification correctness

Sex determination is important for both forensic and bioarcheological examinations of the human skeleton. The bones of the pelvis, especially those of the anterior os coxa, are the most reliable and accurate indicators of sex though pubic bones are fragile and often damaged, especially in bioarcheological collections (1–9). In these instances, other areas of the os coxa can be used to correctly determine the sex of an individual, such as the greater sciatic notch, elevation of the auricular surface, and the preauricular sulcus (PS).

Forensic anthropology methods often include the greater sciatic notch as an indicator of sex by classifying wide width notches as a female trait while narrow, deep notches are indicative of males (3,6,10–12). The main limitation of this classification system is the subjectivity when using the published descriptions. Other than Reichs's (11) measurement standards of the greater sciatic notch, the definitions of "wide" and "narrow" are rarely explained further than the "thumb rule" (1,3,6,10,12). While Ascádi and Nemeskéri (13) were the first to provide a five-category scoring method for the greater sciatic notch, Buikstra and Ubelaker (14) further refined the five-category classification method that is commonly used today for sex determination of the sciatic notch.

The presence or absence of the PS has also been used as a morphological trait for the purpose of sexing the ilium as the sulcus is present and more pronounced in females than in males; however, some sources describe the PS as being influenced by individual variation rather than sex (1–3,5,6,8–12,14,15). The PS is described as a groove with large, deep, or circular impressions in females and absent or very thin lines in males (2,5,8,10,14,15). More basic distinctions include "rare" in males and "well developed" in females (3).

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The elevation of the auricular surface of the ilium is also often included as a method of sex determination with females expressing a raised surface, while males typically have a nonelevated or depressed surface (5,14,15). However, there are issues using this trait for sex determination because of the difficulty in determining whether to score the surface as raised or nonelevated (5,12). In addition, intra-observer error for this trait has also been reported to be relatively high in a reexamination of the traits of the pelvis in sex determination (5).

We designed a study to reexamine the classification correctness of standard scoring systems and measurements of the posterior ilium used to determine sex including the greater sciatic notch, PS, and the elevation of the auricular surface. The ultimate goal of this research was to provide physical anthropologists with new formulae combining traits and measurements of the posterior ilium to accurately determine sex using logistic regression analysis.

Materials

This sample consisted of 94 individuals from the William M. Bass Donated Skeletal Collection and 104 individuals from the Robert J. Terry Anatomical Collection and included 45 white males, 52 black males, 47 white females, and 54 black females. Individuals were chosen for measurement at random by a researcher (LN). Both study and intra-observer reliability measurements were conducted by the same researcher, and the sex of the individuals recorded was known at the time of measurement. Individuals were excluded from this sample if they displayed pathologies such as extreme osteoarthritis, medical implants such as total hip replacements, or other visible extreme variations in morphology of unknown etiology. Additionally, individuals were excluded if the postmortem damage resulted in the inability to record complete measurements for those individuals.

At the time of data collection, the William M. Bass Donated Skeletal Collection contained 679 individuals, while the Terry Collection consisted of 1728 individuals, mostly of known age, sex, ancestry, cause of death, and antemortem pathology (16). All individuals examined were adults over the age of 20 of European or African ancestry. Similar to other research conducted on sex differences of the pelvis, five age categories of 20–29, 30–39, 40–49, 50–59, and 60+ years of age were used to ensure a wide range of ages in the sample (7) (see Table 1).

Methods

Measurements and morphological classifications of the posterior ilium were recorded for each individual. Morphological scores of the ilium were recorded using Buikstra and Ubelaker's *Standards for data collection from human skeletal remains* (14) and include the elevation of the auricular surface, the presence of a PS, and the width score of the greater sciatic notch (Table 2, Figs 1 and 2). Metric measurements based on Steyn et al. (17) for the left sciatic notch and auricular surface for each individual were recorded and are listed in Table 3. The vertical diameter of the auricular surface was recorded along with the length and width of the greater sciatic notch.

Statistical Analysis

Table 4 provides cross-tabulations of trait scores with sex. Both chi-square statistics and Agresti–Coull (18) confidence intervals were calculated for proportions. Logistic regression was then employed to create classification tables for each measurement to determine accuracy of the current sample. Logistic regression is an extension of multiple regression used when the dependent variable is a categorical dichotomy—in this case, males versus females—and the independent variables are categorical, continuous, or discreet numerical values (19). Logistic regression allows for the allocation of an unknown individual to a set of *a priori* defined groups and generates posterior probabilities of group membership (19). The predictive success of the logistic regression is assessed by examination of the classification table that provides correct and incorrect classifications of the dependent variable (19).

Logistic regression was also used to determine whether it was possible to combine both the Bass and Terry Collections in a single pooled sample. This was done by comparing a model (step 1) with main effects of all predictors plus an indicator variable for collection to a model (step 2) with all main effects plus terms for interactions between collection and each of the predictors. The difference in the −2 log likelihoods between the two models is distributed as chi-squared with 10 degrees of freedom (likelihood ratio test). A significant result would indicate that the estimated prediction equations differ between the two collections and should be estimated separately.

The influence of ancestry on sex determination in this sample was determined using the same method as that for the sample pooling. This was done by comparing a model (step 1) with main effects of all predictors plus an indicator variable for ancestry to a model (step 2) with all main effects plus terms for interactions between ancestry and each of the predictors.

Intra-observer reliability of the recorded measurements was assessed in a subset of 20 individuals (10 from each collection). The reliability subset was randomly selected on the last day of data collection and recorded a second time by the same researcher (LN). Correlation between the two sets of measurements was assessed using Spearman's rank correlation. The morphological and metric measurements of the ilium had p-values that ranged from 0.97 to 1.00.

TABLE 1—*Demographic composition of the sample by age grouping.*

Age Group	White Males	Black Males	White Females	Black Females
20–29	6	11	3	15
30–39	11	10	10	10
40–49	8	11	11	9
50–59	11	10	13	10
60+	9	10	10	10

TABLE 2—*Morphological traits and scoring system.*

Trait	Scoring System
Elevation of auricular surface	0: Nonelevated 1: Raised 2: Midline raised in anteroposterior direction. Ridge does not run along entire surface: score defined in this research only
Presence of a preauricular sulcus (Fig. 1)	0: Absence of a sulcus 1: Sulcus is wide and deep 2: Sulcus is wide but shallow 3: Sulcus is narrow but deep 4: Sulcus is narrow and shallow. Typically only lies along the posterior half of the auricular surface
Width of the sciatic notch (Fig. 2)	1: Widest 2: Wide 3: Intermediate 4: Narrow 5: Narrowest

FIG. 1—*Examples of the four morphological classifications of preauricular sulcus and the absence of a preauricular sulcus.*

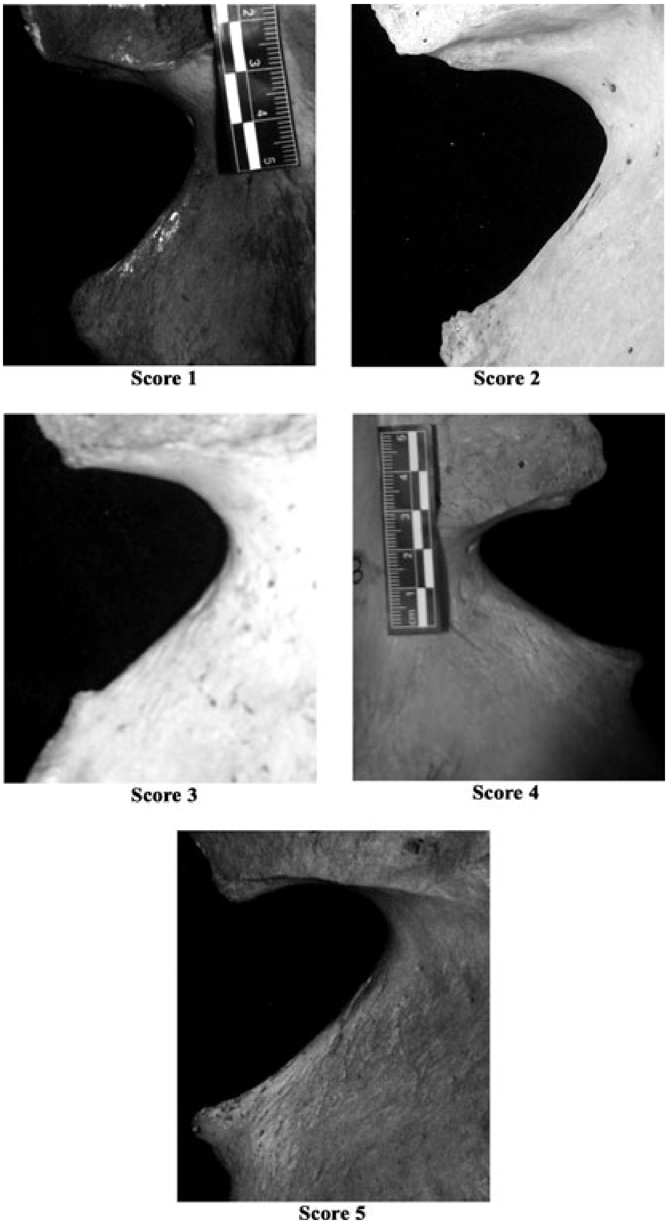

FIG. 2—*Examples of sciatic notch morphological scores.*

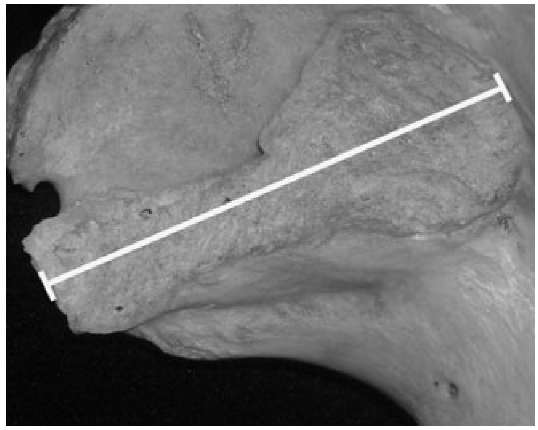

FIG. 3—*Vertical diameter of the auricular surface.*

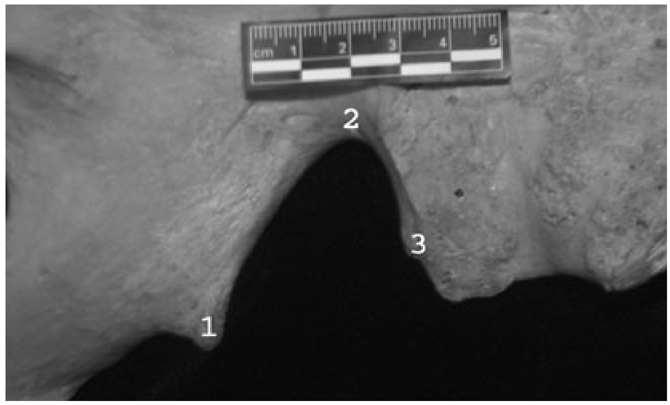

FIG. 4—*Landmarks of the sciatic notch used for the length and width. 1, ischial spine; 2, notch; and 3, auricular surface.*

Results

Morphological Classifications

While 63.4% (95% confidence interval [CI]: 55–73) of the females exhibited a PS, only 5% (95% CI: 2–12) of males exhibited this trait (Table 4). Along with the frequency of individuals exhibiting a sulcus, there was also a significant difference between males and females in the expression of the sulcus scores (χ^2 = 76.2, df = 4, $p < 0.001$; see Table 4). The five male individuals with a PS were only scored as 4, which is the shallowest and least completely formed expression. Twenty-nine percent of the females with a PS were scored as 2, which is a wide but shallow sulcus (Table 4). The difference between males and females in classification of individuals with a sulcus indicates that although some males may express this trait, it is only the least developed expression in comparison with the more distinct morphology of the female sulci. Overall, this trait was useful in correctly classifying 94.8% of males and females, though the rate for females alone was lower at 63.4%. All individuals scored as 1, 2, or 3 were females, while males were exclusively scored as 4 if a sulcus was present. These data indicate that the presence of a prominent PS almost certainly equates to a female pelvis (100% based on this sample).

The majority of females had a raised auricular surface, while males had a nonelevated auricular surface (Table 4). The additional category of those individuals with an auricular surface raised along the midline was found in a higher percentage of males (6.7%, CI: 3–14%) than females (1.9%, CI: 0–7), though the frequency within

TABLE 3—*Metric measurements of the posterior ilium.*

Measurement	Description
Vertical diameter of the auricular surface	Midpoint of the anterosuperior border of the surface to the most posterior point on the surface. This measurement should be perpendicular to the anterior border of the auricular surface. Shown in Fig. 3
Width of the sciatic notch	Ischial spine (point 1) to the most posterior margin of the notch before it angles up the auricular surface (point 3). Landmarks shown in Fig. 4
Length of the sciatic notch	Midpoint of a line drawn between points 1 and 3 to the point of deepest curvature of the notch (point 2). Straight edge was used to hold the line between landmarks 1 and 3, while the midpoint of the line was marked with the points of the calipers. Landmarks shown in Fig. 4

TABLE 4—*Frequency of morphological traits by sex.*

	Males		Females		
Trait	%	*n*	%	*n*	Total *n*
Preauricular sulcus					
Absent	94.8	92	36.6	37	129
Present	5.1	5	63.4	64	69
1	0	0	9.9	10	10
2	0	0	28.7	29	29
3	0	0	4.0	4	4
4	5.1	5	20.8	21	26
Auricular surface relief					
Nonelevated	77.3	75	23.8	24	99
Elevated	15.5	15	74.3	75	90
Raised midline	7.2	7	2.0	2	9
Greater sciatic notch score					
1	0	0	57.4	58	58
2	9.3	9	28.7	29	38
3	22.7	22	9.9	10	32
4	32.0	31	3.9	4	35
5	36.1		0	0	35

both sexes was low. Males were also more likely to be classified correctly based on nonelevation of the auricular surface alone at 84.5% compared with 74.3% for females in this sample.

The mean vertical diameter of the auricular surface was determined to be 59.06 mm with an standard deviation (SD) of 5.27 within the male sample and 54.21 with an SD of 4.78 in the female sample (Table 5). The cut-off value using logistic regression was determined to be 56.89 mm (Table 6). Individuals with measurements above 56.89 mm are classified as male, while those below this value are classified as female.

Prediction Equations

Using the full sample, all iliac variables were included in the logistic regression analysis, and through the process of backward step-wise regression, those that were the least significant were eliminated. Sciatic notch width was included in the final step of the analysis but was eliminated from the final equation as the significance was above 0.05, and this measurement is correlated with the sciatic notch score. The best equation for predicting sex included the sciatic notch score (SNS), vertical diameter (VD), and the presence or absence of a PS. The logistic regression equation output for categorical values was determined with the highest score as the reference.

The final formula for sex determination of the posterior ilium using logistic regression is:

$$P_{\text{female}} = \frac{e^{-5.94+42.05(\text{SNS}=1)+22.95(\text{SNS}=2)+20.75(\text{SNS}=3)+19.08(\text{SNS}=4)-0.22(\text{VD,mm})-3.96(\text{PS}=\text{present})}}{1+e^{-5.94+42.05(\text{SNS}=1)+22.95(\text{SNS}=2)+20.75(\text{SNS}=3)+19.08(\text{SNS}=4)-0.22(\text{VD,mm})-3.96(\text{PS}=\text{present})}}$$

The frequency of morphological scores for the greater sciatic notch for males and females is listed in Table 4. Males, in general, expressed narrower notches than females, and no males in this sample were scored as a 1, which is the widest notch expression. Additionally, no females in this sample were scored as 5, which is the narrowest expression. Thus, this trait proved to be very useful for both males and females in sex determination as 88.4% of the sample was classified correctly based on this trait. In this sample, an observed score of 1 was always female, while a score of 5 was always male; scores in the middle (2, 3, and 4) were less conclusive.

Metric Measurements

The mean ratio of length to width for the greater sciatic notch was larger for males than females, indicating that the length of the male notch was typically longer than the width. The ratio of the length and width of the sciatic notch for males and females was examined to determine trends and cut-off values for males and females. The cut-off value is 0.66 with males falling above this value and females below. The ratios of the sciatic notch proved to be less useful for determining sex than the morphological scores as 76.3% of males and females were classified correctly.

For this formula, the cut-off probability is 0.50 with individuals falling above this value classified as female and those below are classified as male. This formula has a correct classification rate of 94.9%. Moreover, this estimated equation did not differ significantly between the two skeletal collections (likelihood ratio $\chi^2 = 3.9$, df = 6, $p = 0.688$). Likewise, there was no significant modification of the equation by ancestry (likelihood ratio $\chi^2 = 3.0$, df = 6, $p = 0.803$).

One individual (Sample #54) was randomly selected to demonstrate how to use this formula. The values for this individual are the sciatic notch score of 4, vertical diameter of 65 mm, and an absent PS. These values are entered into the logistic regression equation:

$$P_{\text{female}} = \frac{e^{-5.94+19.08-0.22(65)-3.96(0)}}{1+e^{-5.94+19.08-0.22(65)-3.96(0)}}$$

The actual sciatic notch score of the individual is not entered as the X value because the categorical values in the equation are based on the binary code of present or absent for each score. As the logistic regression equation output for categorical values was determined with the highest score as the reference, there is no coefficient for individuals with scores of 5 for the sciatic notch and the

TABLE 5—*Measures of central tendency for metric measurements.*

					95% Confidence Interval for Mean	
Measurement	Sex	*N*	Mean	SD	Lower Bound	Upper Bound
Greater sciatic notch ratio	M	97	0.72	0.09	0.70	0.74
	F	101	0.60	0.09	0.58	0.61
Vertical diameter of the auricular surface	M	97	59.06	5.27	58.00	60.12
	F	101	54.21	4.78	53.26	55.15

TABLE 6—*Cut-off values for metric measurements.*

Measurement	Classification	Range Values
Greater sciatic notch ratio	Male	0.81–0.70
	Indeterminate	0.69–0.63
	Female	0.62–0.51
Vertical diameter of the auricular surface	Male	64.00–59.01 mm
	Indeterminate	59.00–54.00 mm
	Female	53.99–49 mm

equation for those individuals would have a zero for that variable. For the PS, there are only two categories; therefore, there is only one coefficient used, and the X value is based on the presence (1) or absence (0) of the sulcus for the individual.

The probability for this individual is 0.24 that indicates male as it falls below the cutoff of 0.50. After it was determined that this individual was likely male, the demographic information was examined to confirm that Sample #54 is a male.

Discussion

The final model developed in this study included three variables and significant independent predictors: sciatic notch morphological score, presence or absence of a PS, and the vertical diameter of the auricular surface. The metric analysis of the sciatic notch proved to be less useful than the morphological scoring method.

The classification of the greater sciatic notch scores in this study followed the standard anthropological literature in that males generally had narrow sciatic notches, while females typically had wide, shallow notches. Anthropological references for the greater sciatic notch in sex determination often limit their classifications to wide, narrow, and intermediate and exclude definitions for what should be considered wide or narrow (1–3,5,7,14,17). Using the standards provided by Buikstra and Ubelaker (14) for the five-category classification method and combining these with the measurements of Steyn et al. (17), this study sought to determine the classification correctness of the sciatic notch in sex determination. While the findings of this study correlate with Buikstra and Ubelaker (14) in assigning the middle score of 3 as indeterminate, Walker (7) found 2 to be the intermediate or indeterminate category. Interestingly, Walker (7) assigned 7.3% of males a score of 1, which is the widest width category, while the present study did not record a single score of 1 for any males. Additionally, 43% of males in Walker's (7) study were scored as 2, the second widest category, which negatively skewed the average score of males in comparison with the mean for males in the present research which was 3.97. In Walker's (7) method, inexperienced undergraduates along with experienced osteologists were asked to score the sample according to five diagrams of sciatic notches, one example for each score. Even those relatively experienced with human osteology could misuse the scale as the score of 1—the widest and most feminine—appears to also be the largest in the scale. The larger size sciatic notch of males tends to be more similar in size to the score of 1 in the standard rather than the narrower notch score of 5. Those inexperienced with using this standard may have misclassified males as females if they were not aware that width and shape rather than size are the distinguishing features between males and females.

The correct sex classification of the posterior ilium within this sample ranged from 68.7 to 94.9% (Table 7). The greater sciatic notch morphological score and the logistic regression equation both correctly classified sex over 88% of the time (Table 7). Correct classification of sex using individual morphological traits was greater than the metric measurements used individually or in ratios.

TABLE 7—*Classification accuracy for traits of the posterior pelvis.*

Rank	Measurement	% Correct Male	% Correct Female	Total %
1	Logistic regression equation	95.9	94.1	94.9
2	Sciatic notch morphological score	90.7	86.1	88.4
3	Auricular surface relief	84.5	74.3	79.3
4	Preauricular sulcus	94.8	63.4	78.8
5	Sciatic notch metric	74.2	78.2	76.3
6	Vertical diameter of the auricular surface	68.0	69.3	68.7

For all of the morphological traits of the ilium, males were more likely to be classified correctly than females (Table 7).

Correct sex classification for males and females was especially disparate for the presence or absence of a PS. While 94.8% of males were classified correctly based on this trait, only 63.4% of females were classified correctly (Table 7). The disparity between the correct classification for males and females was likely because 95% of males lacked a PS, indicating that the absence of this trait is linked to males. Conversely, only approximately 63% of females exhibited a developed PS which is the typical female expression (Table 4) (1,3,5,14). While 5% of males exhibited a PS, they were all scored as 4, which is the least developed expression. It is possible that when males did express the least developed variation of a sulcus, it was because of specific activities they performed in life and should be considered a para-glenoid groove and not a PS (2). The para-glenoid trait has been described as an open groove that extends along the anteroinferior border of the auricular surface, while the PS is a single or multiple closed depressions along the same border (2,20). Additionally, it is thought that the para-glenoid groove most likely develops from tension exerted on the sacroiliac joint by tendons (20). As this feature is believed to be related to skeletal robusticity rather than gestation, it would likely be found more often in males (2,20). The relationship between parity and a well-developed PS has been well documented in the literature (2,15,21,22). This could be a factor in the high frequency of a well-developed sulcus in the females in this sample, but it is not possible to make inferences about the relationship between the presence of a PS and the stresses of parturition as life and medical histories were not available for the collections used in this study. As 5% of males in this sample did exhibit a slight sulcus, it is likely that the presence of a PS can be due to a variety of pelvic stresses during life.

In the anthropological literature, a raised auricular surface is classified as a trait of the female ilium (1,3,5,15). The expression of a raised surface was found more frequently in females in this sample, though 15% of the males were found to express a raised surface, as well. Correct classification based on this trait was 79.3% which is slightly higher than that for the presence or absence of a PS (Table 7). The presence of a raised auricular surface is more likely to indicate female though the absence of the trait does not necessarily indicate a male individual, which is also similar to the findings for the PS.

In the determination of a biologic profile, it is critical to utilize the most accurate indicators available for sex determination for the skeletal elements. This research based on the William M. Bass and Robert J. Terry Collections has shown the posterior ilium to be reliable in sex determination. Although the sciatic notch ratio only proved to be 76.3% correct, further refinement of the measurements and techniques could lead to higher levels of correct classification. The individual traits of the posterior ilium such as the greater sciatic notch morphological score (88.4%), the presence or absence of a PS (78.8%), and the scoring of a present PS as 1, 2, or 3 (100%) can be fairly useful for sex determination. Furthermore, with correct classification at almost 95%, the logistic regression formula, which included the sciatic notch morphological score, presence or absence of a PS, and the vertical diameter measurement of the auricular surface, has the potential to greatly assist the physical anthropologist as a new method in sex determination. The methods for sex determination examined in the present study are especially useful in forensic and bioarcheological investigations because of the durability of the posterior ilium in comparison with the preservation issues of the anterior os coxa.

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