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The Sciatic Notch/Acetabular Index as a Discriminator of Sex in European Skeletal Remains

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ABSTRACT: The sciatic notch/acetabular index and its rule of thumb application was tested on two European skeletal series of documented sex. The results showed poor consistency between documented and estimated sex. Of the two variables comprising the index, it appeared that sciatic notch width was a particularly poor discriminator of sex. It is suggested that this may be due to differences in the relationship between sciatic notch form and body size in different ethnic groups.

KEYWORDS: physical anthropology, musculoskeletal system, human identification

One of the first steps in the analysis and description of human skeletal remains is the determination of the sex of the individual represented. This is true whether the primary purpose of the analysis is forensic science identification or anthropological/archaeological investigation.

Virtually every element of the adult human skeleton has been shown to exhibit some degree of sexual dimorphism [*1-8*]. However, the pelvis, or more precisely, the innominate, is generally regarded as the most reliable skeletal indicator of sex [*9-11*]. These standard forensic science texts state that, with some experience, an investigator can expect to achieve an accuracy of sex prediction in the region of 90 to 95% using the innominate alone.

Many earlier studies of sex differences in the innominate were purely morphological in orientation [*12-15*], but there are problems associated with this form of approach. In particular, it is essentially subjective in nature, and relies heavily on the experience of the observer. There has been therefore an increasing trend towards a more objective quantitative approach to the determination of sex from skeletal remains [*1-5,7-8,16-18*].

In the case of the innominate, several methods based on the derivation of indices or ratios have been proposed [*16,19-23*].[2] Most of these indices incorporate (1) a parameter which provides an estimate of body size which would be expected to have a larger value in males than in females, and (2) a parameter which is considered to be an indicator of "femaleness," the value of which would be expected to be relatively, and often absolutely, greater in females. Of these indices, only that tested by Washburn [*19*], and Hanna and Washburn [*24*],

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based on the ischio-pubic index of Schultz [25], has been much cited in the literature. Problems in its application, particularly in relation to the difficulty in defining the relevant osteometric landmarks, have been well documented [2,23,26]. Apart from these criticisms, a major limitation to its general applicability is that noted by Washburn himself [19].

> The ischium-pubis index alone will sex over 90% of skeletons, *provided that they belong to one major racial group.*

This is a problem with most quantitative methods. However, Kelley [26] proposed the use of an index, the sciatic notch/acetabular index, which appeared to overcome this limitation. He concluded not only that the use of this index should correctly sex at least 90% of adult skeletal remains, but also that no major allowances are necessary to determine sex, even when applied to biologically distinct groups. Indeed, Kelley suggested a useful "rule of thumb" approach whereby innominates with an index value of more than 88 are classified as female, and those 86 or less as male. In addition, this method has the advantage that it can be applied to fragmentary as well as to intact innominates.

Kelley's sample consisted of three different ethnic groups, American whites and American blacks from the Hamman Todd collection, and American Indians from an archaeological collection. To date, this method has not been tested on European skeletal series. The purpose of this study was to test the discriminatory capacity of Kelley's sciatic notch/acetabular index on human skeletons of European origin.

Materials and Methods

Two European skeletal collections of documented sex and age were available for study.

The English collection is housed in the crypts of St. Brides Church in the City of London. The church was extensively damaged during World War II and, in the course of restoration, some 700 human skeletons were exhumed. Of these, some 250 had been inhumed in lead coffins bearing inscriptions relating to name, sex, and age. However, documentation can be regarded as secure for only some 160 individuals. After exclusion of nonadult material and of bones showing gross evidence of pathological conditions, a sample of innominates representing 131 adult individuals was available. Of these, 71 were documented as male and 60 as female, with dates of birth ranging from 1676 to 1827.

The second collection is housed in the Department of Anatomy and Embryology at the University of Leiden in The Netherlands. This documented series was derived from dissecting room cadavers. Again, only adult specimens in whom the innominates showed no gross evidence of pathology were included in the study. The Dutch sample numbered 140 individuals of whom 74 were documented as male and 66 as female. The dates of birth for this sample ranged from 1860 to 1930.

The collections will be referred to hereafter as "English" and "Dutch," respectively.

Sciatic notch width and vertical acetabular diameter, as defined by Kelley [26] were recorded using dial calipers. The sciatic notch/acetabular index was then derived for each individual. In addition, sex was assigned according to the morphological configuration of the sciatic notch and of the pubic bone [9-11].

Both quantitative and qualitative procedures were completed without prior knowledge of the documented sex of each individual. Further, in each case the quantitative analysis preceded the qualitative analysis.

Results

Table 1 shows the accuracy of sex prediction achieved using Kelley's rule of thumb approach on the two European skeletal samples. For the combined sexes this proved to be a moderately good predictor, the sex of 73 to 75% of the individuals being correctly assigned.

TABLE 1—*Accuracy of sex prediction (%) based on Kelley's "rule of thumb" approach* [26].[a]

	n	% Accuracy
	ENGLISH	
Combined sexes	131	73.3
Males	71	95.8
Females	60	46.7
	DUTCH	
Combined sexes	140	75.0
Males	74	90.5
Females	66	57.6

[a]Index values ≥ 88 = female
≤ 86 = male.

However, when the sex specific prediction was examined this method proved to be much more efficient in discriminating correctly the males in each sample (>90%) than it was in discriminating correctly the females in each sample (<60%).

From Table 2 it can be seen that mean sciatic notch width was significantly greater in females than in males ($p < 0.001$) in both the English and the Dutch samples. Both samples showed a considerable overlap between the sexes in the range of values of sciatic notch width. In each group the males showed a higher coefficient of variation (CV) than did the females. (English males CV = 11.47, English females CV = 10.88; Dutch males CV = 13.71, Dutch females CV = 10.60.)

The mean male vertical acetabular diameter was significantly larger than the mean female vertical acetabular diameter ($p < 0.001$) in each sample. There was a considerable overlap between the sexes in the range of acetabular dimensions in both groups. The females of the two samples were marginally more variable than the males (English males CV = 5.64, English females CV = 5.66; Dutch males CV = 5.78, Dutch females CV = 6.96).

The values for the coefficient of variation for the sciatic notch width were almost twice those for the vertical acetabular diameter (sciatic notch CV = 10.60 to 13.71: vertical acetabular diameter CV = 5.64 to 6.96).

The females showed significantly larger mean values for Kelley's index than did the males ($p < 0.001$) in each group. The overlap in the range of values for the index between the sexes was again considerable, while the coefficients of variation were high but similar for both sexes in each group (English males CV = 11.36, English females CV = 12.04; Dutch males CV = 13.50, Dutch females CV = 13.30).

Table 3 shows that mean sciatic notch width was significantly greater in Dutch males than in English males ($p < 0.001$) and also significantly greater in Dutch females than in English females ($p < 0.001$). The Dutch males also had significantly larger mean acetabular dimensions than the English males ($p < 0.001$) and Dutch females had significantly larger values than the English females ($p < 0.001$). The values for Kelley's index showed no significant difference between English and Dutch males or between English and Dutch females.

In view of the disappointingly low accuracy of sex prediction achieved using Kelley's rule of thumb approach, it was decided to substitute the values proposed by Kelley with values derived specifically from each group in this study, that is, to derive group specific sectioning values. This was done following the method described by Black [7], DiBennardo and Taylor [*17*], and MacLaughlin and Bruce [*18*], where the group specific sectioning point is defined as the midpoint between the male and the female mean values.

Table 4 shows these sectioning point values derived for Kelley's index for the sciatic notch width and for the vertical acetabular diameter in the English and in the Dutch samples. For

TABLE 2—*Pertinent data for the English and Dutch skeletal samples.*

		Sciatic Notch Width, mm				Vertical Acetabular Diameter, mm				Kelley's Index			
	n	$\bar{X}$	Range	SD[a]	CV[b]	$\bar{X}$	Range	SD	CV	$\bar{X}$	Range	SD	CV
						ENGLISH							
Males	71	38.52[c]	27.4-49.9	4.42	11.47	54.06[c]	48.2-61.3	3.05	5.64	71.36[c]	52.2-88.5	8.11	11.36
Females	60	42.0	31.8-53.7	4.57	10.88	48.58	42.4-54.7	2.75	5.66	86.76	62.4-108.9	10.45	12.04
						DUTCH							
Males	74	41.93[c]	28.6-58.6	5.75	13.71	57.08[c]	51.7-64.5	3.30	5.78	73.56[c]	47.6-93.0	9.92	13.50
Females	66	45.88	36.5-61.1	4.88	10.60	51.52	39.0-62.2	3.59	6.96	89.54	68.3-121.4	11.93	13.30

[a]Standard deviation.
[b]Coefficient of variation.
[c]$p < 0.001$.

TABLE 3—*English and Dutch samples compared.*

	n	Sciatic Notch Width, mm	Vertical Acetabular Diameter, mm	Kelley's Index
		$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$
English males	71	38.52 ± 4.42[a]	54.06 ± 3.05[a]	71.36 ± 8.11
Dutch males	60	41.93 ± 5.75	57.08 ± 3.30	73.56 ± 9.92
English females	74	42.0 ± 4.75[a]	48.58 ± 2.75[a]	86.76 ± 10.45
Dutch females	66	45.88 ± 4.88	51.52 ± 3.59	89.54 ± 11.93

[a] $p < 0.001$.

TABLE 4—*Sectioning points[a] for the English and Dutch samples.*

	Kelley's Index	Sciatic Notch Width, mm	Vertical Acetabular Diameter, mm
English	79.1	40.3	51.3
Dutch	81.5	43.9	54.3

[a] Sectioning point $= \frac{\text{male mean} + \text{female mean}}{2}$

each variable, the Dutch sectioning point values were higher than the corresponding values in the English sample.

Table 5 shows the accuracy of sex prediction expressed as a percentage for each variable using these group specific sectioning points.

Kelley's index, using the appropriate sectioning point, proved to be a better predictor of sex in the English sample (male 82%, female 77%) than in the Dutch sample (male 77%, female 76%). This was true whether the combined sex prediction or the sex specific prediction rate was compared. In both the English and the Dutch samples, the index was somewhat more efficient at correctly assigning sex in the male samples than in the females.

The pattern was similar for the sciatic notch width.

Using vertical acetabular diameter, the prediction accuracy was greater for the English than for the Dutch sample when the sexes were combined. However, in this case, the prediction was better for the Dutch females (85%) than for the Dutch males (74%) or for the English females (82%).

Table 6 shows the levels of accuracy of sex prediction achieved using the morphological approach. The conformation of the sciatic notch was particularly useful in identifying English females (92%) and Dutch males (92%), less so in identifying English males (79%), and poor in identifying Dutch females (65%).

The pubic bone proved to be the most efficient morphological discriminator in each group, whether by combined sex prediction or sex specific prediction. As with the sciatic notch, the Dutch females again showed the lowest percentage accuracy (81%) in sex prediction.

Table 7 shows the indices of sexual dimorphism (male mean/female mean) calculated for each of the European samples, and also derived from Kelley's data for his American white and American black groups [26]. The American Indian sample was excluded from comparison as the sex of these skeletons was estimated rather than documented.

TABLE 5—*Accuracy of sex prediction (%) from the English and Dutch innominates based on sample specific sectioning points.*

	n	Kelley's Index	Sciatic Notch Width, mm	Vertical Acetabular Diameter, mm
		ENGLISH		
Combined sexes	131	79.4	71.7	84.0
Males	71	81.7	71.8	85.9
Females	60	76.7	71.7	81.7
		DUTCH		
Combined sexes	140	76.4	62.8	79.3
Males	74	77.0	64.9	74.3
Females	66	75.7	60.0	84.8

TABLE 6—*Accuracy of sex prediction (%) from sciatic notch and pubic morphology.*

	n	Sciatic Notch	PUBIC BONE
	ENGLISH		
Combined sexes	131	84.7	96.2
Males	71	78.9	94.4
Females	60	91.7	98.3
	DUTCH		
Combined sexes	140	79.3	89.0
Males	74	91.9	95.9
Females	66	65.1	81.0

TABLE 7—*Sexual dimorphism*[a] *in the European samples compared with Kelley's* [26] *American samples.*

	Sciatic Notch Width, mm	Vertical Acetabular Diameter, mm	Kelley's Index
English	0.91	1.11	0.82
Dutch	0.91	1.11	0.82
Kelley [26]			
White	0.92	1.16	0.79
Black	0.87	1.14	0.76

[a] $\frac{\text{Male } \bar{X}}{\text{Female } \bar{X}}$

For the sciatic notch width each of the European groups showed similar levels of sexual dimorphism. These values (0.91) are close to Kelley's white sample (0.92), but significantly lower in terms of sexual dimorphism than Kelley's black sample (0.87, $p < 0.05$) using Relethford's technique for comparing levels of sexual dimorphism between groups [*27*]. Both European groups showed similar levels of sexual dimorphism for vertical acetabular diameter (1.11). This is significantly lower than the level for both Kelley's black sample (1.14, $p < 0.05$) and for his white sample (1.16, $p < 0.001$). The European samples showed similar levels of sexual dimorphism for Kelley's index (0.82) and were significantly less dimorphic than either Kelley's white (0.79, $p < 0.05$) or black (0.76, $p < 0.001$) samples.

Overall, American samples showed significantly more sexual dimorphism in vertical acetabular diameter (males being some 14 to 16% larger than females) compared with European males (some 11% larger than European females). In sciatic notch width the American blacks showed more sexual dimorphism (males 13% less than females) than the European material (males 9% less than females) or the American white sample (males 8% less than females). For Kelley's index the American blacks were the most sexually dimorphic (black male values being 24% smaller than black female values) compared with the American whites (male values 21% less than female values) or the European samples (male values 18% less than the female values).

Discussion

It is generally recognized that of all the elements of the human skeleton, the innominate offers the best prospect for the correct identification of the sex of an individual. Unfortunately, the very features of the innominate that exhibit the highest levels of sexual dimorphism are frequently found to be damaged or missing in exhumed material. The highly dimorphic pubic element of the innominate is especially vulnerable to postmortem damage and decay as it is covered by only a thin fragile shell of cortical bone.

The identification of sex from the human skeleton is further complicated by the considerable morphological and metric variation which exists between and within human populations. Criteria for the identification of sex established on one ethnic group are unlikely to be applicable to another group of different ethnic origin. Similarly, criteria appropriate to present populations may not be appropriate for past populations and vice versa.

Further, it is important that criteria used for sex discrimination should be unequivocal and hence as free as possible from subjective bias.

Kelley's sciatic notch/acetabular index appeared to offer a means whereby these particular problems could be largely overcome because (1) only the more durable parts of the innominate are required to be intact for construction of the index, (2) it was applied to both recent and historic populations of differing ethnic origins with high levels of accurate sex prediction, and (3) it is a metric, and hence, likely to be a more objective method.

However, a further qualification for any osteometric technique is that the landmarks from which the relevant dimensions are determined must be clearly defined. This is a major criticism of several other indices, notably the ischio-pubic index devised by Schultz [*25*] and described by Washburn [*19*] where the confluent point within the acetabulum (from which both dimensions of the index are determined) is not readily discernible in the adult innominate.

Some similar difficulties were encountered by the authors in determining each of the dimensions comprising Kelley's sciatic notch/acetabular index.

The sciatic notch width was defined by Kelley as "the distance from the base of the ischial spine—that is where it usually breaks off—to the tip of the pyramidal projection on the posterior border of the ilium."

In the European innominates under investigation, the base of the ischial spine was found to be neither a well-defined point nor a well-defined zone (Fig. 1*a*). Further, the pyramidal projection was found to be variable in its form, ranging from virtual absence to a substantial projection which markedly impinged into the space separating the posterior ilium from the ischium (Fig. 1*b*). It is reported that several fibers of the piriformis muscle are attached to this process [*28*]. Thus, its variable development may be related to the size of the piriformis muscle or to the age of the individual concerned or both. Ossification into the connective

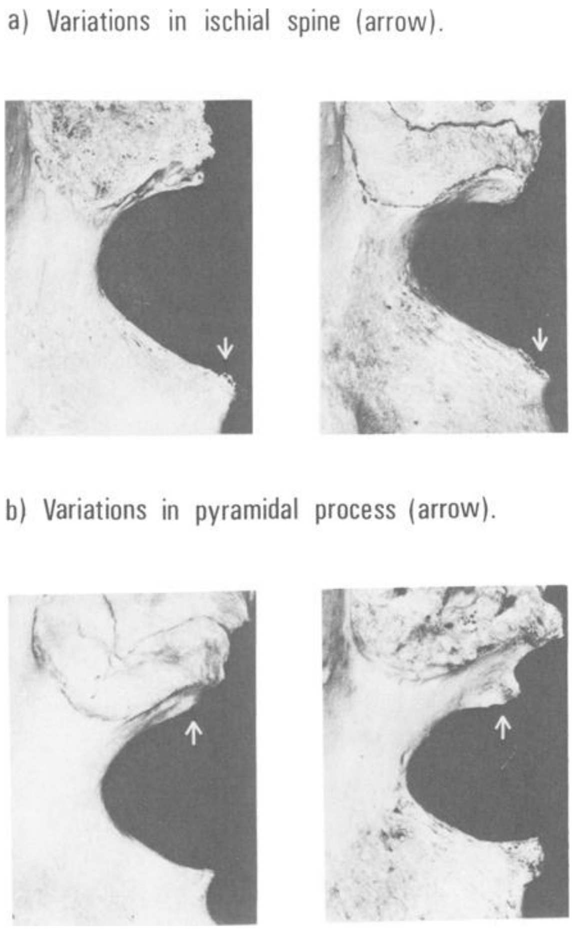

FIG. 1—*Difficulties in the determination of the relevant osteometric landmarks.*

tissue of muscle is a well-documented feature of increasing age. Decreased width of the sciatic notch may therefore be related to increasing age. Although the level of association was not statistically significant it was noted that a negative correlation existed between sciatic notch width and age for both English males and females and for Dutch males. Unfortunately, neither the mean ages of Kelley's samples nor the individual data were available for comparison.

The second variate in Kelley's index, vertical acetabular diameter, also presented some difficulties in definition. To determine the vertical acetabular diameter the innominate should first be orientated in the anatomical position. This is difficult to achieve unless the pubic tubercle and the anterior superior iliac spine are intact.

Thus, for the two European skeletal series some difficulty was experienced in obtaining reliable measurements of each component of the sciatic notch/acetabular index.

The discriminatory capacity of the index using the rule of thumb approach was disappointingly low for both the English and the Dutch samples. At best only 75% consistency between documented sex and predicted sex from the index values was recorded. When sex specific consistencies were examined it could be seen that while the index was in fact an efficient discriminator of male pelves, it proved little better than chance at correctly discriminating female pelves.

Thus, it appears that the general applicability of Kelley's rule of thumb approach for the sciatic notch/acetabular index does not extend to these two European series at least.

It was considered worthwhile to examine whether the discriminatory capacity of the index could be improved by determining group specific sectioning points. Both the English (79.1) and the Dutch (81.5) sectioning points were considerably lower than Kelley's rule of thumb values (males <86, females >88). Many of the European females were therefore being misclassified as male by the use of Kelley's values (Fig. 2).

When the consistency between "index predicted" sex based on group specific values and documented sex was compared, it could be seen that considerably more females were then correctly identified. However, the overall (combined male and female) prediction showed only slight improvement over the values obtained from the rule of thumb approach. That is, the index was now equally effective at discriminating male and female pelves, but the level of accuracy of prediction was still disappointingly low.

The discriminatory capacity of each of the component variables of the index was then investigated.

A wide and hence large sciatic notch width value is associated with a larger pelvic cavity

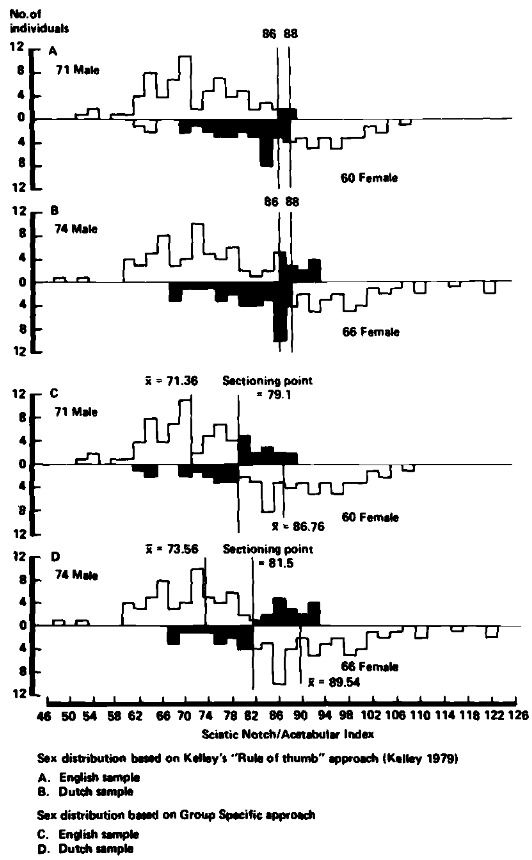

FIG. 2—*Frequency diagrams for the English and Dutch skeletal collections.*

and is thus a female attribute, and similarly a large acetabular value is associated with a larger body size and is thus a male attribute.

Sciatic notch width alone proved to be a poor sex discriminator. The coefficient of variation was almost twice as high for the sciatic notch width as for the vertical acetabular diameter in both European and also in both Kelley's documented sex series. Vertical acetabular diameter alone proved not only to be a better predictor of sex than sciatic notch width but was also more efficient than the index in both European samples.

Levels of sexual dimorphism were remarkably similar in both European groups for both components of the index, but interestingly, the Europeans were in general less sexually dimorphic than the Americans of Kelley's samples.

Thus the poor discriminatory capacity of the rule of thumb approach to the index may reflect differences in the levels of sexual dimorphism between the American and the European series. However, the disappointing results, even using the group derived specific values, must bring into question the validity of the sciatic notch as an indicator of "femaleness." The difficulty encountered in determining sex from the sciatic notch morphology was particularly marked in Dutch females in whom body size was the largest of the European and American female samples. It may be that the relative proportions of the sciatic notch to overall body size may differ with different body size. Work is in progress to analyze further the relationship of sciatic notch width to overall body size, using nonpelvic indicators of body size in these two European groups.

The best correspondence between documented sex and estimated sex was obtained using pubic morphological criteria [*9-11*]. Work is also in progress to test an index combining pubic dimensions with acetabular dimensions in these two European groups.

Meanwhile, it is suggested that the use of the sciatic notch/acetabular index, and in particular, its rule of thumb approach, be restricted to those groups of the same provenence as those from which it was derived.

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