A Method for Visual Determination of Sex, Using the Human Hip Bone

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KEY WORDS human pelvis; sex determination; morphological traits; method

ABSTRACT A new visual method for the determination of sex using the human hip bone (os coxae) is proposed, based on a revision of several previous approaches which scored isolated characters of this bone. The efficacy of the methodology is tested on a sample of 402 adults of known sex and age of French and Portuguese origins. With the simultaneous use of five characters of the hip bone, it is possible to provide a correct sexual diagnosis in 95% of all cases, with an error of 2% and an inability to identify sex in only 3%. The advantage of this new method is a reduction in observer subjectivity, since the evaluation procedure cannot involve any anticipation of the result. In addition, this method of sex determination increases the probability of a correct diagnosis with isolated fragments of the hip bone, provided that a combination of elements of one character is found to be typically male or female. Am J Phys Anthropol 117:157–168, 2002.
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Correct sex identification of the human skeleton is important in bioarcheological and forensic practice. Current opinion regards the hip bone (os coxae) as providing the highest accuracy levels for sex determination. However, "simple" observations of the hip bone without any scoring of related traits should not be normally considered proper, despite the fact that the results may be surprisingly accurate. Only those procedures which define a precise and unambiguous methodology leading to an accurate diagnosis of sex should be employed.

Three techniques for the visual evaluation of traits of the hip bone are: 1) the method of Phenice (1969), which uses three traits on the pubis, 2) the method of Iscan and Derrick (1984) using the posterior pelvis, and 3) the method of Ferembach et al. (1980) of sexing the entire pelvis through an evaluation of eleven traits. However, even if it is generally accepted that these methods provide satisfactory accuracy, only a few studies have tested their reliability in known-sex samples and, surprisingly, the results are often ignored.

The results from the method of Phenice (1969) have been inconsistent, as accuracy levels range from 59% (MacLaughlin and Bruce, 1990) to 96% (Schone, quoted in Sutherland and Suchey, 1991). Such inconsistency is due to the fact that sexual dimorphism of the whole hip bone should be considered, and observations should not be restricted to the pubis (Novotný, 1986; Bruzek, 1992). Following Lovell (1989), MacLaughlin and Bruce (1990), and Bruzek (1991), the reliability of the method of Phenice (1969) is probably ca. 80%. Furthermore, pubic preservation rarely exceeds 30% in archaeological samples (Waldron, 1987).

The method proposed by Iscan and Derrick (1984) provides an accuracy level of 90% (Iscan and Dunlap, 1983), but it cannot be regarded as equivalent to the results found with methods using the entire hip bone. The accuracy of the method of Ferembach et al. (1980) has not been studied. Bruzek and Ferembach (1992) found 93% correct sex assignment, using a set of eight variables of the hip bone. However, this method necessitates highly trained observers with experience in morphological variability, because it is based on an ordinal scale of evaluation.

When (Novotný, 1981, 1988) studied the discrimination power of 14 sexually dimorphic traits of the hip bone frequently used in sex determination, he replaced a descriptive or ordinal evaluation of characters (e.g., small, wide, shallow) with binary scoring (yes or no) along an intermediate category morphology. He then selected the characters with the highest diagnostic value, reducing the analysis to three complex variables: the preauricular surface, the sciatic notch, and the inferior aspect of the hip bone. These characters reduce misclassification (Bruzek, 1991). In addition, Rogers and Saunders (1994) tested accuracy and reliability in a set of 17 individual traits on a small sample of identified pelves. Accuracy varied from 6.1–94.1% for each individual pelvic trait, and the greatest accuracy was obtained by combining the scoring of three traits.

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The level of intraobserver error for all pelvic traits in combination was 11.3%.

In these techniques and evaluations of them, the frequently cited drawbacks of visual techniques for determining the sex of an individual are: 1) the high degree of observer subjectivity, 2) a lack of consistency in the evaluation of traits, and 3) a strong dependence on the results of previous experiences of the observer. Nonetheless, there is an advantage in visual techniques, which emanate from their rapidity of use as well as their ability to be used when damage does not allow complete set if measurements.

To address these problems, this study proposes a method for the visual allocation of sex from the hip bone, emphasizing four aspects insufficiently considered in previous studies. First, there is a reduction of observer subjectivity during the evaluation of selected traits by using only three possibile scores (present, indeterminate, absent), contrary to ordinal scoring in which it is always difficult to make a decision between two neighboring categories. Second, the method eliminates confusion between traits (e.g., the preauricular and paraglenoid grooves, which represent separate elements; Kurihara et al., 1996). Third, when necessary for complex characters, it uses a rigorous evaluation of three relatively independent characters reflecting the sex of the individual. When at least two of these elements lead in the same direction, it is possible to decide whether a determination is possible. A reliable male or female diagnosis is considered possible when at least two variables are concordant. This approach is the opposite to one attempting to score a primary sexual characteristic, thereby anticipating the presence or absence of its secondary manifestations. And fourth, this method can be applied to damaged or incomplete hip bones.

MATERIALS

This study is based on an examination of 402 specimens of adult individuals of known sex from two European collections (Paris, France: 98 males and 64 females; Coimbra, Porugal: 106 males and 134 females). The French collection dates to the first half of the twentieth century (Carre, 1978; Olivier, 1972); the Portuguese collection includes people born between 1820–1920, for which a number of sociological, medical, and anthropological data are also available (Bocquet et al., 1978).

METHODS

Five characters of the hip bone were used. They are: 1) aspects of the preauricular surface (Novotný, 1981), 2) aspects of the greater sciatic notch (Novotný, 1981), 3) the form of the composite arch (Genovés, 1959), 4) the morphology of the inferior pelvis (margo inferior ossis coxae; Novotný, 1981), and 5) ischiopubic proportions.

These characters were chosen to reflect the functional morphology of two very distinct areas of the pelvis: the sacroiliac complex and the ischiopubic complex. The first three characters are sex-specific adaptations of the sacroiliac complex to bipedal locomotion. Expression of sexual dimorphism in the sacroiliac complex is visible during the fetal period (Boucher, 1955; Fazekas and Kosa, 1978; Holcomb and Konigsberg, 1995). The fourth and fifth characters (the ischiopubic complex) reflect the adaptation of the female pelvic canal to the requirements of reproduction. In addition, this region reflects differences in the anatomy of the external genitalia in both sexes. Manifestations of sexual dimorphism in the ischiopubic complex do not begin until puberty (Coleman, 1969).

General procedure

Table 1 presents a formula for sex diagnosis and the principles of evaluation. The first column lists the five characters used. Sexing can be divided into three steps: 1) scoring of the traits; 2) evaluation of the form of the character; and 3) sexual diagnosis based on the five characters (last column).

Each character is defined either by one condition (simple: third and fifth characters) or three conditions (complex: first, second, and fourth characters). The observer determines whether each character is male or female or indeterminate. For the simple characters, this score corresponds directly to the sexual form of character, designated by symbols "F" for female form, "0" for intermediate form, or "M" for male form. The sexual form of complex characters results from the combination of the three separate subcharacters. When at least two answers indicate either "male" or "female," these are used as a basis to determine sexual morphology. A majority of "F" or "M" sexual forms indicates female and male sex, respectively. If equal amounts of the sexual forms are present, sex is considered as indeterminate. We should underscore that all the figures given in this text are provided for strictly illustrative purpose and do not correspond at all to practical diagnostic tools.

Preauricular surface

On the preauricular surface, three morphological structures may occur independently of each other, all of which are sexually dimorphic (Fig. 1). The first structure was originally described by Löhr (1894) as the "paraglenoid groove" and is characterized by a depression or groove along the antero-inferior edge of the auricular surface. The arc of the groove is open, or makes up less than half the circumference of a circle (Hoshi, 1961). The depression is a result of ligaments exerting tension on the sacroiliac joint capsule (Weisl, 1954). This groove is related to general skeletal robusticity and thus is more frequent in males (Lazorthes and Lhés, 1939).

The second structure is the preauricular groove (Zaajer, 1866), a closed depression in the bone in the form of one or several pits (Hoshi, 1961), each with a closed circumference (arc is greater than half of a

TABLE 1. Sexing method based on five characters of the hip bone

Characters	Scoring of sexualization		Sexual form evaluation	Sex diagnosis
	One condition	One response		
Preauricular surface	First condition: development of negative relief on preauricular surface	f, deep depression well-delimited (pits) i, intermediate form m, relief smooth or very slightly negative relief	$\Sigma f > \Sigma m \Rightarrow F$	Female: $\Sigma F > \Sigma M$
	Second condition: aspect of grooves or pitting	f, pits or groove with closed circumference i, intermediate form m, depression with open circumference	$\Sigma f = \Sigma m \Rightarrow 0$	
	Third condition: development of positive relief on preauricular surface	f, lack of tubercle i, intermediate form m, turbercle present or clear protuberance	$\Sigma i < \Sigma m > \Sigma f \Rightarrow M$	
Great sciatic notch	First condition: proportion of length of sciatic notch chords	f, posterior chord segment (AC) longer than or equal to anterior chord (CB) i, intermediate form m, posterior chord (AC) shorter than anterior chord (CB)	$\Sigma i < \Sigma f > \Sigma m \Rightarrow F$	
	Second condition: form of contour notch chords	f, symmetry relative to depth in basal portion of sciatic notch i, intermediate form m, asymmetry relative to depth of sciatic notch	$\Sigma f = \Sigma m \Rightarrow 0$	Male: $\Sigma F < \Sigma M$
	Third condition: contour of posterior notch chord relative to line from point A to sciatic notch breadth	f, outline (contour) of posterior chord doesn't cross perpendicular line i, intermediate form m, contour of posterior chord crosses perpendicular line	$\Sigma i < \Sigma m > \Sigma f \Rightarrow M$	
Composite arch	One condition: relation between outline of sciatic notch and outline of auricular surface	Double curve Intermediate form Single curve	F 0 M	
Inferior pelvis	First condition: characterization of margo inferior ossis coxae	f, external eversion i, intermediate form m, direct course of medial part	$\Sigma i < \Sigma f > \Sigma m \Rightarrow F$	
	Second condition: absence or presence of the phallic ridge	f, lack of the phallic ridge or presence of only little mound i, intermediate form m, clear presence of the phallic ridge	$\Sigma f = \Sigma m \Rightarrow 0$	Indeterminate: $\Sigma F = \Sigma M$
	Third condition: ischio-pubic ramus aspect	f, gracile aspect i, intermediate form m, robust aspect	$\Sigma i < \Sigma m > \Sigma f \Rightarrow M$	
Ischiopubic proportion	One condition: relation between pubis and ischium lengths	Pubis longer than ischium Intermediate form Ischium longer than pubis	F 0 M	

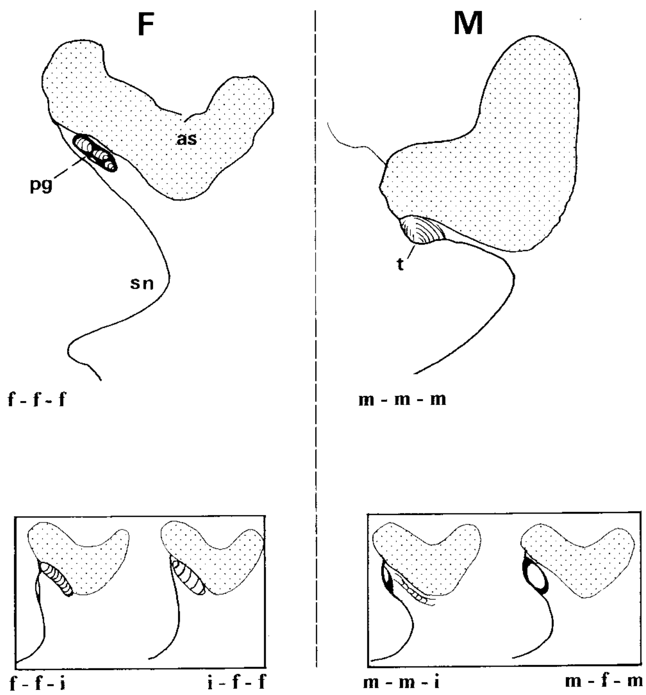

Fig. 1. Preauricular surface. as, auricular surface; sn, sciatic notch; t, piriform tuubercle; pg, preauricular groove; f, female condition; m, male condition. F: Specific female shape (f-f-f), showing the deep depression, with closed circumference (true preauricular groove), associated with lack of tubercle. M: Typical male form (m-m-m), showing the relief as smooth or very slight, with open border, associated with presence of tubercle. Two examples of other female forms: f-f-i, deep depression, pits or groove with closed border, with intermediate aspects of positive relief; i-f-f, little depression with closed border, associated with lack of tubercle. Two examples of other male forms: m-m-i, little groove opened laterally, with intermediate aspect of positive relief (paraglenoid groove); m-f-m, smooth relief with closed circumference and very prominent tubercle.

circle) along the anteroinferior edge of the auricular surface. According to Houghton (1974), this formation results from obstetrical trauma during the course of delivery. This trait, in its most typical form, would allow for differentiation between two groups, nulliparous women plus males vs. females who have given birth (Ullrich, 1975). It is possible, however, that for parous females, the flexibility of the pelvis and the relationship between their pelvic dimensions and the size of the foetus at parturition do not always produce this obstetrical trauma during delivery; therefore, some parous females do not present a preauricular sulcus.

The third structure in this region is the highly variable, so-called piriform tubercle (*tuberculum musculi piriformis*). The presence of this feature is likely associated with high levels of muscular activity, and it occurs more frequently in males than in females (Genovés, 1959).

For sexual assessment, evaluation of all three structures is necessary. Three steps are required to determine the sexual morphology of the preauricular surface (Novotný, 1981). The first is to determine the presence or absence of negative relief (pits). The second step evaluates the outline border of the pit or the groove; if an absence of negative relief is observed in the first step, then the score is "m" in the second step as well. In case of negative relief, if the outline border of this depression is closed, one scores "f." Forms of the depression with open borders are classified as "m." The third step evaluates the presence and relief of the piriform tubercle. Only an f-f-f combination determines a true preauricular groove and a reliable female sex diagnosis. Other combinations yield the theoretically highest risks of misclassifications.

Greater sciatic notch

The sexual characteristics of the sciatic notch are exceedingly difficult to use. Not only is the observer influenced by the size of the pelvis (which undoubtedly affects the morphological shape of the sciatic notch), but by the development of marginal structures (e.g., ischial spine, piriform tubercle) which exhibit high levels of sexual dimorphism. Direct evaluation of notch shape is thus subjective. Furthermore, a number of authors (Lazorthes and Lhés, 1939; Glanville, 1967; Singh and Potturi, 1978; Novotný, 1981) demonstrated that the degree of sexual dimorphism is most distinct along the posterior chord of the sciatic notch.

In order to achieve a more objective evaluation of the notch shape, Novotný (1981) proposed the use of a "shadow image" of the contour. This is a modification of the technique employed by Hanna and Washburn (1953), whereby a contour of the sciatic notch is obtained by the exposure of photosensitive paper onto which the hip bone is placed, with the laterodorsal iliac surface on the paper. After exposure, a contour is drawn by marking points corresponding to the scheme outlined in Figure 2. The line of the notch width (A–B) is defined from the base of the ischial spine (point B, frequently broken off but its base preserved) to the top of the piriform tubercle (point A). In case of its absence, the line should be drawn to the posterior inferior iliac spine (point A′). A perpendicular line (the depth) is then drawn from the deepest point of the notch to the notch width, separating it (at point C) into two chords, posterior and anterior.

The three aspects can then be evaluated. The first evaluates visually the proportions between the two segments (A–C and C–B) of the A–B chord. The second trait evaluates the symmetry (female element "f") or asymmetry (male element "m") of the notch base according to the depth line. The third aspect follows the course of the contour above the posterior chord, using a line parallel with the depth line extended through point A of the sciatic notch width.

Composite arch

The trait proposed by Genovés (1959) evaluates the course of the contour of the anterior arm of the

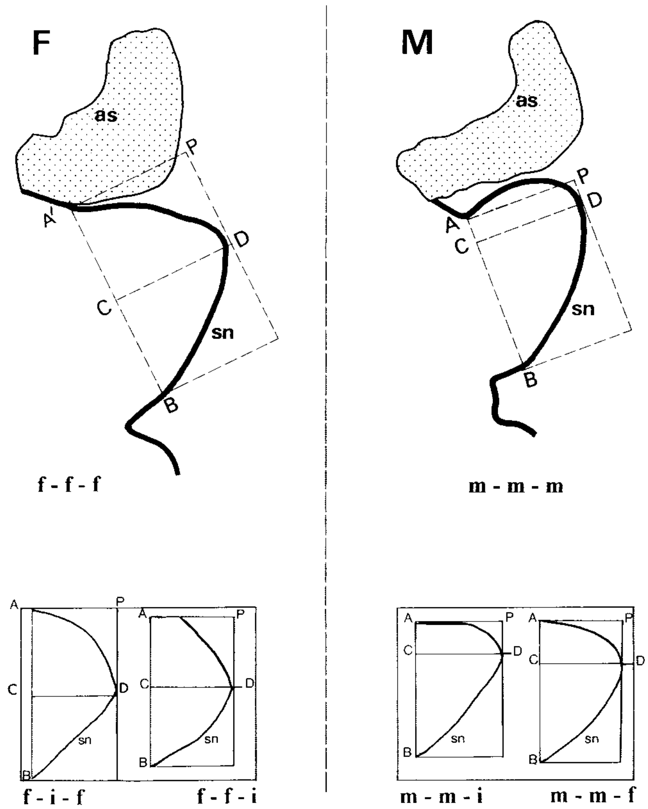

Fig. 2. Greater sciatic notch. as, auricular surface; sn, sciatic notch; A, top of piriform tubercle, in the case of its absence; A′, top of posterior inferior iliac spine; AB and A′B, sciatic notch breadth; CD, sciatic notch depth; AC and A′C, posterior chord of sciatic notch breadth; CB, anterior chord of sciatic notch breadth; AP (A′P), perpendicular at point A (A′) to the line formed by the sciatic notch breadth. F: Extreme female form (f-f-f), showing posterior chord segment AC (or A′C) longer (or close to equality) than the anterior chord CB, symmetry of notch contour associated with no crossing of the line A–P (A′–P) with the contour of the posterior chord. M: Extreme male form (m-m-m), showing the posterior chord segment AC (A′C) shorter than the anterior chord CB, asymmetry of the outline chords associated with the crossing the line A-P (A′P) with the contour of the posterior chord. Two examples of other female forms: f-i-f, posterior chord segment AC equal the anterior chord CB, associated with intermediate pattern of the outline chords relative to the deep of the notch, and outline of the posterior chord does not cross the perpendicular line AP. f-f-i, posterior chord segment AC equal to anterior chord CB, presence of relative symmetry of outline chords to the deep of notch and the line AP tangent to the outline of the posterior chord. Two examples of other male forms: m-m-i, posterior chord segment AC shorter than anterior chord CB, associated with asymmetry of outline chords and line AP tangent to the outline of the posterior chord; m-m-f, posterior chord segment AC shorter than anterior chord CB, associated with asymmetry of outline chords; finally, outline of posterior chord doe not cross perpendicular line AP.

auricular surface and the contour of the anterior chord of the sciatic notch (Fig. 3).

In females, both contours are sections of two distinct circles with different radii: the composite arch is present. Among males, both contours are a part of one circle: the composite arch is absent.

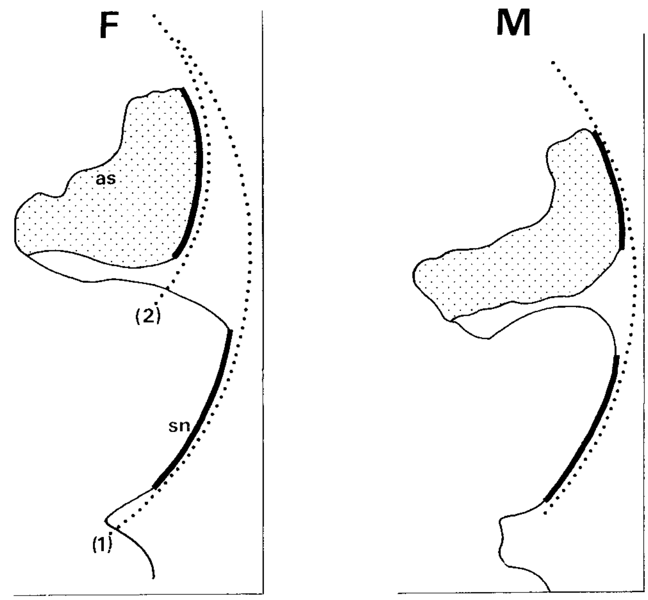

Fig. 3. Composite arch. Outline of anterior sciatic notch chord (2), relative to outline of anterior segment of auricular surface (1). as, auricular surface; sn, sciatic notch. M: Absence of composite arch (single curve, $1 = 2$). F: Presence of composite arch (double curve, $1 \neq 2$).

Inferior pelvis (inferior margin of the os coxae)

Sexual dimorphism of the ischiopubic ramus, the caudal region of the hip bone that results from the junction between ischium and pubis, is concentrated on its lateral margin (Fig. 4). In the pelvis, both the left and right ischiopubic rami form strongly sexually differentiated subpubic angles: a closed angle (angulus pelvis) in males, and an obtuse angle (arcus pelvis) in females. Sexual differences of the ischiopubic ramus are related to the shape of the pelvic outlet and to the anatomy of the urogenital tract. The angle of the pelvis, however, cannot be evaluated directly on the hip bone.

Following Novotný (1981), this region can be sexed by a simultaneous evaluation of three conditions. The first concerns the external eversion of the inferior border. The second consists of a morphological analysis of the middle part of the ischiopubic ramus, which is frequently broad in males and has a laterally directed swelling known as the crista phallica (phallic crest). In certain female specimens, a narrowing occurs in the middle part of the ramus, which is quite similar to males who display the presence of the phallic ridge (Poulhes, 1948; Genovés, 1959). When the phallic ridge is not separate, then the course of the inferior pelvic aspect (inferior margin of the os coxae) may seem to be identical in both sexes (Francis, 1952; Smout and Jacoby, 1948). The third condition refines the two preceding ones evaluating the gracility (f) or robusticity (m) of the inferior pelvic aspect. It is recognized that the scoring of this character is subjective. It depends on the experience of the investigator and on the nature of the population studied. For these

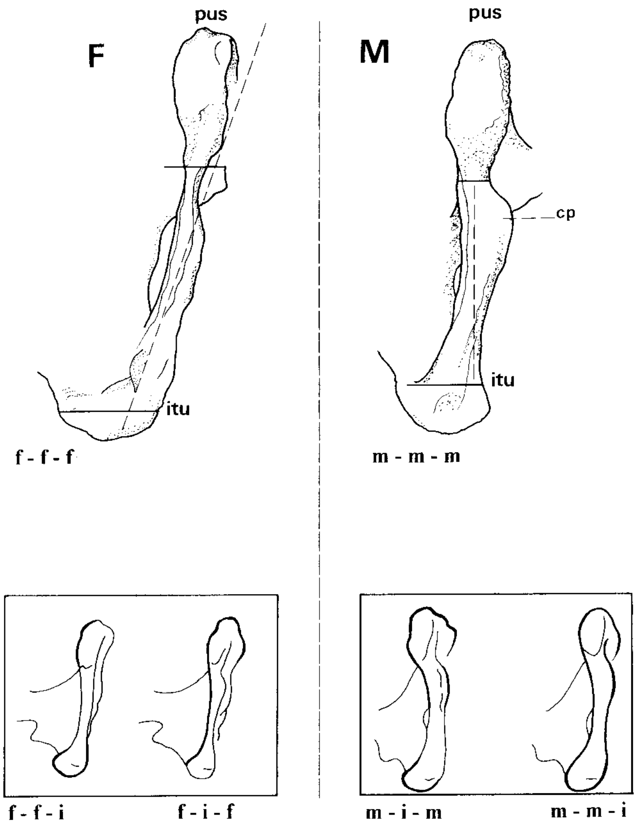

Fig. 4. Inferior pelvis. pus, pubic symphysis; itu, ischial tuberosity; cp, phallic ridge. Horizontal lines limit the middle part of the ischiopubic ramus. Broken line represents major axis of this structure. F: Typical female form (f-f-f), showing external eversion of ischiopubic ramus and absence of the phallic ridge, associated with gracility of the bones. M: Typical male form (m-m-m), showing direct course of medial part of ischiopubic ramus and presence of phallic ridge, associated with robustness of the bones. Two examples of other female forms: f-f-i, external eversion of ischiopubic ramus and absence of phallic ridge, associated with intermediate aspect of ischiopubic ramus; f-i-f, external eversion of ischiopubic ramus and doubt about absence of crista phallica, associated with gracility of the bones. Two examples of other male forms: m-i-m, direct course of medial part of ischiopubic ramus and doubt about presence of phallic ridge, associated with robustness of bones; m-m-i, direct course of medial part of ischiopubic ramus and presence of phallic ridge, associated with intermediate aspect of ramus morphology.

reasons, in many cases, the intermediate category is selected. The sexual form of the character is given by a combination of the results of the three steps, according to Table 1.

Ischiopubic proportions

The sexual differences of the ischiopubic proportions reflect the adaptation of the female pelvis to parturition, and result in the remodeling of the female bone pelvis during puberty. These changes can be observed in the proportions of the length of the pubis and ischium (Fig. 5).

In women, the pubic length/ischium length ratio is higher than in men. Practically, this ratio is assessed by a visual inspection only and corresponds to the ischiopubic index (Schultz, 1930; Washburn, 1948).

RESULTS

The reference samples were scored blind, without knowledge of actual sex. The level of accuracy corresponds to the percentage of correct sex identification. The level of error corresponds to the percentage of individuals whose sex was incorrectly identified without taking into account specimens recorded as “indeterminate.”

Preauricular surface

The results of the evaluation of the preauricular surface are shown in Table 2. The female morphology of the preauricular surface occurred in 76% of French and 70% of Portuguese females. In three male specimens, the feminine morphology of this character was observed, in conjunction with the presence of the piriform tubercle, resulting in the combination (f-f-m). Similar results were obtained by Novotný (1981) in females of a Czech-German sample (71% of females displayed the female morphology of the character). These results also correspond to the frequency of 71% for a “GP-type” named by Houghton (1974), and 70% for the “cavity type” of pits by Hoshi (1961). These results cannot be compared with those of other authors, who considered any depression as the preauricular groove and did not differentiate it from the paraglenoid groove. In the two groups studied here, the f-f-f combination (true preauricular groove) was observed in 23% of females from Paris and 28% of females from Coimbra. Novotný (1981) reported the presence of this combination in 31% of women. The combination attributed to male morphology is shared with nulliparous women. This combination alone, therefore, cannot result in an accurate diagnosis of sex when fragments of hip bone are examined.

Recently, Schemmer et al. (1995) refuted the conclusions of Spring et al. (1989) and Cox and Scott (1992) about the lack of a relationship between the preauricular groove and parity. These authors documented a deep groove in the preauricular region due to past pregnancy. These authors nonetheless conceded that genetic and behavioral factors contribute to variability in the expression of the deep groove.

Greater sciatic notch

The results of the shape of the greater sciatic notch are shown in Table 2. In the sample from Paris, the female shape of the notch was observed in 67% of the women, and in the Coimbra sample, it was found in 70% of the women. The male condition of the character occurred in 67% of French men and 80% of Portuguese men. Previous studies using this methodology reported 58% of women and 85% of men with the correctly corresponding sexual form of the notch (Novotný, 1981). Misclassifications oc-

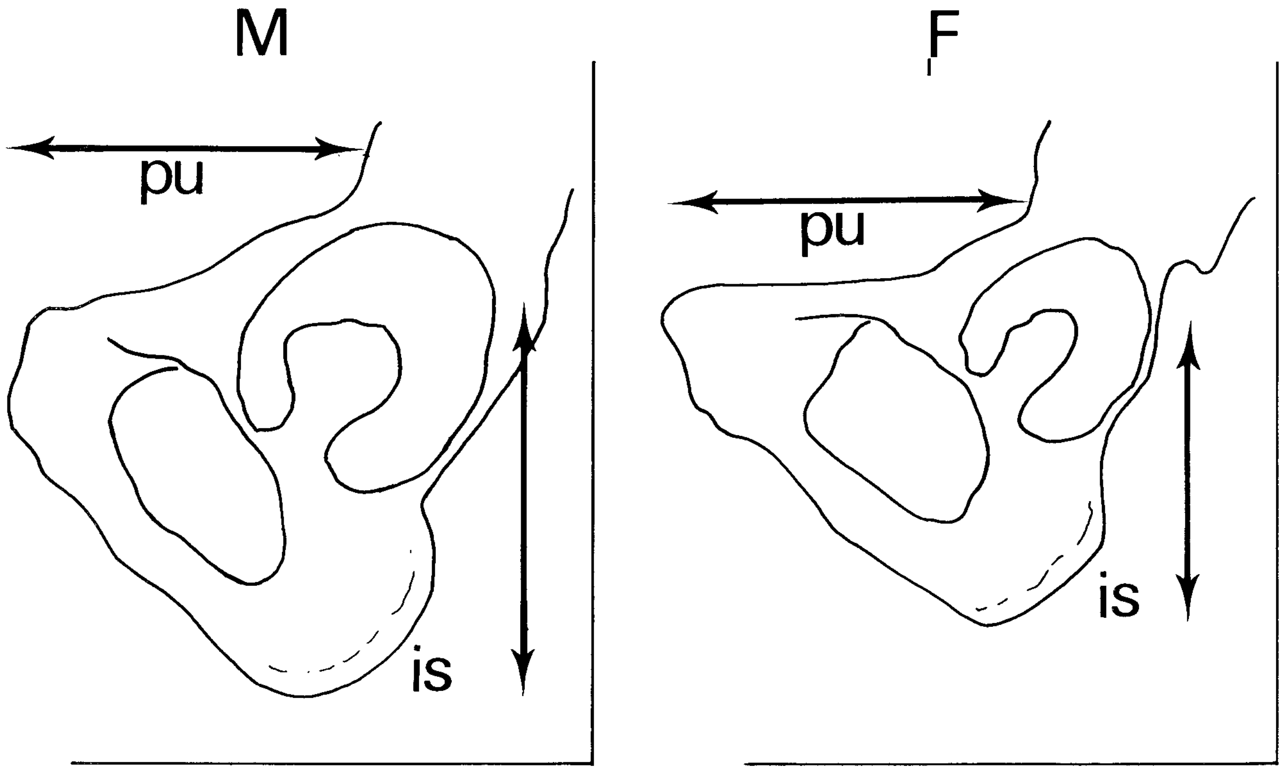

Fig. 5. Ischiopubic proportions. Proportions of length of pubis (pu) and ischium (is). M: Male morphology (pu < is). F: Female morphology (pu > is).

curred in 8% of the men and in 21% of the women of the French group, but in only 6% of men and 16% of women of the Portuguese collection. Novotný (1981) reported only 1% of males with the feminine form of the notch, and 10% of females with the masculine form of the notch. When the two samples are grouped, the typical female combination (f-f-f) was present in only one male, while the typical male combination (m-m-m) was observed in less than 5% of women from Paris and less than 7% of women from Coimbra. Novotný (1981) did not find this combination in women. The precision of sex determination using this set of traits to describe the shape of the sciatic notch directly corresponds to an estimation of the discrimination power of this character, which varies by around 70%, as found by Washburn (1948), Genovés (1959), Novotný (1981), and Bruzek and Ferembach (1992).

Composite arch

The concordance of the observations with known sex (Table 2) were found in 67% of males and 92% of females of the French series. In the Portuguese sample, observation of the male pattern was in agreement with the known sex of 78% of males, while female morphology was observed in 87% of the females. Genovés (1959) demonstrated concordance with known sex in 80% of males and 87% of females in an English population. In contrast to this, Novotný (1981) observed a single circle in 67% of males and a double circle in only 56% of females in the Czech sample.

It would appear difficult to attribute the observed differences in the composite arch solely to pelvic sexual dimorphism. Interpopulational differences suggest that it is unlikely that all pelvic differences would be attributed to differences between sexes. The concordance of the determined and actual sex of the specimens studied in this series approaches 80%. This success rate falls within those obtained by Genovés (1959) (83%) and Novotný (1981) (61%). The occurrence of erroneously attributed sex (12%) appears high in comparison to that of Genovés (1959) (6%) and Novotný (1981) (8%). The percentage of specimens with indeterminate sex (7%) closely approximates that of Genovés (1959) (11%), while Novotný (1981) noted a much greater percentage of indeterminate cases (31%).

This trait confers greater accuracy and precision when sexing a female pelvis, as indicated by the higher proportion of correctly sexed females. But it is important to note that the use of the composite arch in sexing individual specimens has its greatest potential in association with other features of the pelvis, rather than as an independent indicator.

Inferior pelvis

Table 3 shows the frequency of male, female, and indeterminate morphology of the inferior border of the ischiopubic ramus. Male morphology was found

TABLE 2. Frequencies of scoring and sexual form distribution in three traits of sacroiliac complex of hip bone[1]

Sexual form of traits	Preauricular surface aspects								Sciatic notch aspects								Composite arch							
	Paris sample				Coimbra sample				Paris sample				Coimbra sample				Paris sample				Coimbra sample			
	Males		Females		Males		Females		Males		Females		Males		Females		Males		Females		Males		Females	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
f-f-f			15	23.5			38	28.4	1	1.1	25	39.0	5	4.6	44	32.8								
f-f-i			8	12.5			11	8.3																
f-i-f			1	1.6			2	1.5	3	3.1	11	17.2	1	0.9	28	20.5								
i-f-f			2	3.2			4	3.3	2	2.0	5	7.7	1	0.9	6	4.5								
f-f-m			23	35.4	3	2.8	38	28.4			1	1.6												
f-m-f															6	4.5								
m-f-f									2	2.0	1	1.6			9	6.7								
F	0	0.0	49	76.2	3	2.8	93	69.9	8	8.2	43	67.1	7	6.4	93	69.4	21	21.4	59	92.2	10	9.5	116	86.6
f-m-i																								
f-i-m					1	0.9	1	0.7																
i-f-m			2	3.2	1	0.9	4	3.0																
f-i-i			1	1.6					1	1.1														
i-f-i			2	3.2			1	0.7																
i-i-f			1	1.6	1	0.9	7	5.2	3	3.1	2	3.2	1	0.9	4	3.3								
i-i-i	3	3.1	1	1.6	2	1.8	2	1.5																
i-i-m	3	3.1	4	6.3	3	2.8	6	4.5																
i-m-i	1	1.1																						
m-i-i					1	0.9			4	4.0			2	1.8	3	2.8								
i-m-f	1	1.1							2	2.0	1	1.6												
m-i-f			1	1.6					14	14.3	4	6.5	10	9.6	8	6.6								
m-f-i													1	0.9	4	3.3								
0	8	8.4	12	19.1	9	8.2	21	15.6	24	24.5	7	11.3	14	13.2	19	15.0	11	11.2	1	1.6	13	12.2	3	2.2
f-m-m	3	3.1																						
m-f-m																								
m-m-f	3	3.1			5	4.8	9	6.7	20	20.3	8	12.4	18	17.1	5	3.7								
i-m-m	20	20.3			9	8.6																		
m-i-m	4	4.0			5	4.7	1	0.7	1	1.1			2	1.8	1	0.7								
m-m-i	12	12.1			13	12.4	1	0.7	20	20.3	3	4.6	24	22.7	6	4.5								
m-m-m	48	49.0	3	4.7	62	58.5	9	6.7	25	25.6	3	4.6	41	38.8	9	6.7								
M	90	99.6	3	4.7	94	89	20	14.8	66	67.3	14	21.6	85	80.4	21	15.6	66	67.3	4	6.2	83	78.3	15	11.2

[1] f, female; i, intermediate; b, male. Sexual forms: F, female; 0, intermediate; M, male.

TABLE 3. Frequencies of scoring of elements and sexual form distribution in two traits of ischiopubic complex of hip bone[1]

Sexual form of traits	Inferior pelvic aspects								Ischiopubic proportion aspects							
	Paris sample				Coimbra sample				Paris sample				Coimbra sample			
	Males		Females		Males		Females		Males		Females		Males		Females	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
f-f-f			30	47.6	2	1.9	68	51.1								
f-f-i			10	15.9	1	1.0	9	6.8								
f-i-f							6	4.5								
i-f-f			9	14.3	2	1.9	28	20.9								
f-f-m																
f-m-f																
m-f-f	2	2.1			7	6.6	2	1.5								
F	2	2.1	49	77.8	12	11.4	113	84.8	0	0.0	53	87.0	8	7.8	102	77.9
f-m-i							3	2.2								
f-i-m			2	3.2	6	5.9										
i-f-m																
f-i-i	2	2.1	7	11.1	7	6.6	7	5.3								
i-f-i					1	1.0	1	0.8								
i-i-f			1	1.5												
i-i-i	1	1.1			1	1.0	1	0.8								
i-i-m	1	1.1	2	3.2			1	0.8								
i-m-i	4	4.3			1	1.0										
m-i-i	16	17.3			13	12.7										
i-m-f					4	3.9										
m-i-f					6	5.9										
m-f-i	2	2.1														
0	26	28.0	12	19.0	39	38.0	13	9.9	27	29.0	8	13.0	22	21.3	23	17.2
f-m-m																
m-f-m																
m-m-f																
i-m-m	4	4.3			8	7.8	1	0.8								
m-i-m	18	19.4	2	3.2	20	19.5	5	3.7								
m-m-i	10	10.7			8	7.8										
m-m-m	33	35.5			16	15.5	1	0.8								
M	65	69.9	2	3.2	52	50.6	7	5.3	66	71.0	0	0.0	73	70.4	4	4.6

[1] f, female; i, intermediate; b, male. Sexual forms: F, female; 0, intermediate; M, male.

to occur in 70% of males from Paris and in 51% of males from Coimbra. The female form was observed in 78% of French females and 85% of Portuguese females. Incorrect allocations were more frequent in Portuguese males (11%) than in French males (2%). The frequency of correctly diagnosed male and female morphology in the Czech-German series of Novotný (1981) falls between values for the French and Portuguese series. Furthermore, the male form was found in 3% of French and 5% of Portuguese women. The typical female form of this character, denoted by the combination (f-f-f), accurately determined 36–51% of the female individuals examined and was found in only two male specimens from the Portuguese series. Similarly, the typical male combination (m-m-m) accurately determined 15–36% of the men and was observed only in one female hip bone. In the sample of Novotný (1981), forms typical for one sex did not occur in individuals of the other sex. This character, therefore, makes it possible to allocate sex with an error which does not exceed 12%. The presence of a typical sexual form for this trait provides a high probability of correctly estimating the sex of bone fragments. But the subjectivity of the character evaluation, suggested by as many as 38% of cases of the intermediate form in certain groups, is high.

Ischiopubic proportions

Employing a visual evaluation of the ischiopubic proportion aspects (Table 3), it is possible to correctly estimate sex in 71% of French and Portuguese males. Among females, the pubis is relatively longer in 87% of cases in the French series, but only in 78% of cases in the Coimbra sample. A high frequency of the intermediate morphology is observed (one third of all specimens), but the margin of error (the wrong sexual attribution) is very small. In the Portuguese sample, misclassification was encountered in only 8% of males and in 5% of females. In the Paris sample, no false classifications occurred. The high reliability of this trait is attributed to the introduction of the category "intermediate morphology," which reduces subjectivity. This character is suitable as a preliminary indicator of the sex and, together with the other characters, contributes to an accurate evaluation of sexual dimorphism of the hip bone overall.

Sacroiliac pelvic complex

The combination of the first three characters (preauricular surface aspects, sciatic notch aspects, and morphology of the composite arch) correctly determines sex in 91% of individuals (Table 4A). The

TABLE 4. Results of sexual diagnoses[1]

		Sacroiliac complex sex assessment					
		Correct		Undete.		Errors	
Series A		n	%	n	%	n	%
Paris, males	n = 98	89	91.8	4	3.1	5	5.1
Paris, females	n = 64	58	90.6	3	4.7	3	4.7
Paris, males and females	n = 162	147	90.7	7	4.3	8	5.0
Coimbra, males	n = 106	101	95.5	3	2.8	2	1.7
Coimbra, females	n = 134	117	87.3	8	6.0	9	6.7
Coimbra, males and females	n = 240	218	91.0	11	4.5	11	4.5
Paris and Coimbra, males	n = 204	190	93.0	7	3.5	7	3.5
Paris and Coimbra, females	n = 198	175	88.4	11	5.6	12	6.0
Paris and Coimbra, males and females	n = 402	365	90.8	18	4.5	19	4.7

		Ischiopubic pelvic complex sex assessment					
		Correct		Undete.		Errors	
Series B		n	%	n	%	n	%
Paris, males	n = 93	84	90.8	9	9.2	0	0.0
Paris, females	n = 61	59	96.7	0	0.0	2	3.3
Paris, males and females	n = 154	143	92.8	9	5.8	2	1.4
Coimbra, males	n = 104	73	70.2	20	19.2	11	10.6
Coimbra, females	n = 129	118	91.4	6	4.7	5	3.9
Coimbra, males and females	n = 233	191	82.0	26	11.6	16	6.4
Paris and Coimbra, males	n = 197	157	79.7	29	14.7	11	5.6
Paris and Coimbra, females	n = 190	177	93.2	6	3.2	7	3.6
Paris and Coimbra, males and females	n = 387	334	86.3	35	9.0	18	4.7

		Entire hip bone sex assessment					
		Correct		Undete.		Errors	
Series C		n	%	n	%	n	%
Paris, males	n = 93	90	96.8	2	2.1	1	1.1
Paris, females	n = 63	60	95.2	1	1.6	2	3.2
Paris, males and females	n = 156	150	96.2	3	1.9	3	1.9
Coimbra, males	n = 103	97	94.2	5	4.8	1	1.0
Coimbra, females	n = 133	123	92.6	5	3.7	5	3.7
Coimbra, males and females	n = 236	220	93.3	10	4.2	6	2.5
Paris and Coimbra, males	n = 196	187	95.4	7	3.6	2	1.0
Paris and Coimbra, females	n = 196	183	93.3	6	3.1	7	3.6
Paris and Coimbra, males and females	n = 392	370	94.4	13	3.3	9	2.3

[1] A, sacroiliac pelvic complex (combination of three characters). B, ischiopubic pelvis complex (combination of two characters). C, pelvic bone as a whole (combination of the five characters of two pelvic complexes). Correct, concordance with sex of specimens. Undete., undeterminable, equality of forms "F" and "M." Errors, discordance of sexual diagnosis regarding known sex of specimens.

lowest success was encountered in Portuguese females (87%), in spite of the fact that the success in determining sex using all three characters is higher than using each variable separately. On the other hand, the highest percentage of correctly determined sex was achieved in Portuguese males (95%). The error of sexual diagnosis oscillates between 2–7% of cases in both groups. It is higher in females than in men, but in the whole collection (pooled groups) achieves a value of less than 5%. The percentage of intermediate cases varies between 3–6% in individual groups, and when the two groups are pooled it does not exceed 5%.

Ischiopubic pelvic complex

The combination of the last two traits (morphology of the inferior pelvic aspects, and the ischiopubic proportion aspects) permits proper assessment of sex in 86% of all specimens studied (Table 4B). However, the success in individual groups varied from 70% (males, Coimbra) to 97% (females, Paris). No errors in sexual diagnosis were encountered in French men. The largest error occurred with Portuguese men (11%). In the pooled sample, the total error ws lower than 5%. The highest frequency of indeterminate cases was in men (9%, Paris; 19%, Coimbra). The overall occurrence of errors for women did not exceed 5%.

Sexual diagnosis of entire hip bone

With the combination of all five traits (Table 4C), the results become very homogeneous. When the two series were considered separately, a correct diagnosis was achieved in 93–98% of all cases. The largest margin of error was seen in groups of females, yet the difference between females and males was only 2%. For both samples, the frequency of correctly diagnosed cases was 95%. The error of determining the sex did not exceed 4% in any subgroup, and for the sample as a whole was only 2%. The percentage of indeterminate cases did not exceed a level of 5% for the separate samples, and was only 3% when the two series were pooled.

Sexual assessment using fragmentary hip bones

The contribution of each trait towards a correct sex diagnosis differs considerably (Tables 2 and 3). With respect to simple traits such as the composite arch or ischiopubic proportion, the level of success varies between 60–80%. Error for these traits becomes very important, and reduces the accuracy of the diagnosis.

With the more complex traits (preauricular surface, greater sciatic notch, and inferior pelvic), the subscores (i.e., the combination of the three conditions) which are included in the complex trait may be of significance and may lead to a reliable sexual diagnosis. This is the case with the morphology of the preauricular surface, whereby the diagnosis of a true preauricular groove (f-f-f) may lead to a correct diagnosis of the female sex. Some of the other possible combinations which describe the variety of preauricular groove, such as f-f-i, f-i-f, or i-f-f, have only been found in females; for this character, then, the above combinations may be absolute indicators of female specimens. The subscore (f-f-m) preauricular groove with presence of a piriform tubercle is rare in males. However, three males manifest this triplet, which can be explained by a false praeauricular groove diagnosis in association with a very deep paraglenoidal groove with a strongly developed piriform tubercle. Theoretically, it is possible that a strong injury comparable to obstetric trauma could cause the rupture of the anterior sacroiliac ligament in a few males or nulliparous females. Furthermore, the absence of any grooves or the presence of the paraglenoid groove (m-m-m or m-m-i and f-m-m) does not assist in the diagnosis, for its existence is common in both sexes.

With respect to the form of the sciatic notch, it is only those subscores which resemble the unique morphology which actually contribute to a correct sex diagnosis. The observation of the typical female morphology (f-f-f) guarantees a 92% chance of the correct sex allocation, while for the typical male morphology (m-m-m) only 85% of the cases with this combination of scores were accurately diagnosed.

The presence of the typical female morphology of the inferior pelvic aspects (f-f-f) correctly determined 98% of all specimens with this combination of scores; the typical male morphology (m-m-m) also correctly determined 98%. The other subscores have reduced reliability for the diagnosis of fragments.

DISCUSSION

With respect to the accuracy of sex determination in men and women, Meindl et al. (1985) considered that the female skeleton is seldomly incorrectly diagnosed. This is apparently due to less variability in female pelvic size, since women are under strong selective pressures related to adaptations in locomotion as well as reproduction. Reduced variability in pelvic size of women has not, however, been statistically confirmed (Tague, 1989). However, Pachner (1937) demonstrated that the greater pelvis is more variable in men than in women. Inversely, the lesser pelvis is more variable in women. Therefore, this variability has nothing to do with different levels of accuracy in determining the sex of males and females. When one sex is more frequently identified than the other, it should be considered a manifestation of an insufficiency in the method used, rather than a consequence of various biological characteristics of the material under study.

It is difficult to admit that sexual traits of the skeleton could be more clearly expressed in one sex than the other. The total degree of sexual dimorphism of the hip bone is a function of the interaction of the partial dimorphism of the two main regions of the pelvis. Thus, according to the concept of functional integration, lower levels of sexual dimorphism in one morpho-functional pelvic *complex* (i.e., openness vs. closure of the greater sciatic notch) can be functionally compensated by higher levels of dimorphism in the other morpho-functional pelvic complex (i.e., ischiopubic proportions). The intersegment size relationships are sex- and population-specific. This can be seen in the reduction of the frequency of misdiagnosed specimens between subgroups, from isolated characters through isolated complex or functional divisions (sacroiliac pelvic complex and ischiopubic pelvic complex) to the hip bone as a whole. The inconsistency of the success of the method of Phenice (1969) demonstrated by Lovell (1989), MacLaughlin and Bruce (1990), and Bruzek (1991) can be considered in the same manner using different population samples, since the dimorphism of the pubis does not reflect the total dimorphism of the hip bone.

CONCLUSIONS

These results demonstrate that the method outlined above yields an accuracy rate close to 98% using the whole hip bone, while the misclassification rate is 2%. Three percent of the sample was classified as indeterminate. The advantage of the method proposed is the potential of sexing with high accuracy, even with fragmentary hip bones, when establishing the specific male (m-m-m) or specific female (f-f-f) combination for complex characters. The binary scoring method of Novotný (1981) for sex evaluation compares favorably with other methods which use criteria such as "smaller than" or "larger than." Binary scoring rather than subjective assignment allows for the systematic accomodation of more of the inherent variation seen in pelvic morphology.

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