

Leslie D. Sutherland,¹ B.A., R.N. and
Judy Myers Suchey,² Ph.D.

Use of the Ventral Arc in Pubic Sex Determination

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ABSTRACT: A sample of 1284 well-documented pubic bones was studied for sex determination methods. This sample included many adolescents and could be used to expand Phenice's 1969 study, which was largely based on mature adults. In the present study, focus was placed on the ventral arc which, when used alone, provided 96% accuracy in sex determination. This paper stresses the development of the ventral arc in the adolescent: a precursor condition is defined, which first appears at age 14 and becomes the most frequent condition at age 20. In mature adults, 4% show conditions that are misleading and likely to lead to sex determination errors. Practical applications of this method are discussed in relation to the forensic science setting, including three cases. A set of casts was developed to increase the reliability of the method, and these casts were then tested in interobserver error studies.

KEYWORDS: physical anthropology, musculoskeletal system, human identification, sex determination, postmortem examination, human remains, pubic bones, ventral arc

Correct diagnosis of sex is crucial to the analysis of unidentified human remains. This may be a problem not only in skeletal cases but also in remains that are decomposed, mummified, or fragmented. There is general agreement in the literature that the pelvis offers the most definitive traits; a variety of metric and nonmetric methods have been presented, but no one has focused on the most accurate technique for use in the forensic science setting. This study is focused on traits of the os pubis (Fig. 1), for two reasons. First, an extensive sample ($n = 1284$) of well-documented pubic bones was available for study. Second, this portion of the skeleton is often preserved and can easily be removed from mutilated and burned bodies. Thus, sex determination techniques utilizing this region are applicable to a majority of unidentified forensic science cases.

Historically, Phenice's 1969 work [1] on sex determination should be noted. He was the first to analyze systematically a large sample ($n = 275$) of documented skeletal remains using visual assessment of pubic traits. In his study of the Terry Collection of American Whites and Blacks he described three traits: the ridge on the medial aspect of the ischiopubic ramus, the lateral recurve, and the ventral arc. By identifying whether these traits were present or absent, he achieved an accuracy rate of 96% for sex determination.

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¹Medical services manager, FHP, Inc., Fountain Valley, CA.

²Professor of anthropology, California State University, Fullerton, CA, and forensic anthropologist, Office of the Chief Medical Examiner-Coroner, County of Los Angeles, CA.

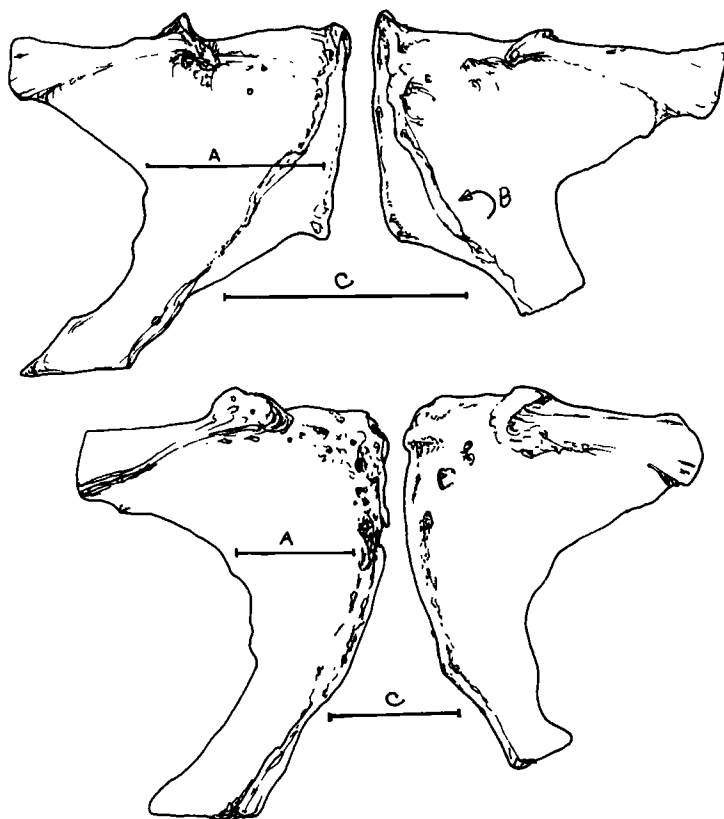


FIG. 1—The ventral view of the classic female (top) os pubis compared with the classic male (bottom) to illustrate typical sexual dimorphism in the mature adult. The female has a wider pubic body than the male (A). The female has a well-defined ventral arc (B), whereas the male does not. The female has a wide subpubic concavity (C), whereas the male exhibits a narrow angle.

An even higher accuracy rate (98.6%) was achieved by Rosenberg [2] in her analysis of another subset ($n = 140$) of the same collection. Schon [3], who tested the Phenice method on the Grant dissection room collection in Toronto, Canada, achieved a 96% accuracy rate but differed in the assessment of the usefulness of the three traits. Whereas Phenice had found the ventral arc to be the most objective and reliable, Schon ranked that trait the lowest. MacLaughlin and Bruce³ tested the method on 225 documented European skeletons, some of cemetery origin and others from dissection rooms; they found the ventral arc to be a poor discriminator of sex. Lovell [4] also tested the technique and found the ventral arc unreliable when used alone. More comparative work is needed on a variety of samples, with attention given to interobserver and intraobserver error testing, before final conclusions can be made.

Materials and Methods

The pubic bone sample reported here originates from cases autopsied at the Office of the Chief Medical Examiner-Coroner, County of Los Angeles. The sample is multiracial

³MacLaughlin, S. M. and Bruce, M. F., personal communication, 1988.

and contains individuals 11 to 99 years old. The age, race, and birth place of the decedents were verified by death certificates or birth certificates or both. For females, data on the number and spacing of children were obtained from relatives, close friends, or persons responsible for the disposition of the remains. Of this sample of 1284, 93% of the specimens were removed by Suchey and 7% were removed by autopsy technicians using standard collection and case numbering methods. Because of the need for accuracy in documentation, a double-checking system was set up to ensure correct identification. The pubic bones were removed using a Stryker saw during or immediately after the autopsy. Suchey took full responsibility for the cleaning and labeling of the specimens.

The sample was examined independently by both Sutherland and Suchey, both analyzing each bone for the presence or absence of Phenice's three traits. The results presented in this paper consist of Suchey's analysis of the collection. The bones were examined "blind" to information on individual case histories. The original numbers were converted to a new order, using tape, in order to mask the original sequencing.

Initial study of the sample showed that the lateral recurve could not be analyzed in this collection because many of the specimens had the ischiopubic ramus cut near the lower symphyseal end. In this study, the presence or absence of the ridge on the ischiopubic ramus was found to be unreliable. Only 70% of the sample could be correctly sexed with this trait alone. Therefore, the study narrowed to an in-depth analysis of the ventral arc. Using Phenice's definition (Ref 1, p. 298),

a slightly elevated ridge of bone which extends from the pubic crest and arcs inferiorly across the ventral surface to the lateral most extension of the subpubic concavity where it blends with the medial border of the ischio-pubic ramus,

the entire sample was analyzed. This trait alone provided sex determination with 96% accuracy. Certain bones in the female sample which were incorrectly sexed were noted to be either young adolescents or possibly pathological. Mature females lacking the arc (Fig. 2) were rare (4%). The present study, with its large number of adolescents, is an expansion of the Phenice study, which was based on mature adults. In this paper, stress is placed on the development of the ventral arc in the adolescent in order to increase the utility of pubic sex determination in forensic science applications. In California, a large number of unidentified remains are adolescents or persons in their 20s, and for this reason the timing and development of the ventral arc demand special attention. In addition, applications of the use of the ventral arc in three forensic science cases are discussed, along with interobserver testing for pubic sex determination methods.



FIG. 2.—Mature female (ventral view) lacking the ventral arc (4% frequency).

Results

The ventral arc does not usually appear in its easily recognizable form until the mid-20s. Figure 3 shows a young adolescent female pubic bone prior to the development of the ventral arc. A precursor arc was identified during examination. The precursor arc, defined in this study as a faint line which is found on the ventral surface, takes the same course as the ventral arc defined by Phenice and is illustrated in Fig. 4. The precursor condition occurs as the lower extremity fills in with fine dense bone before the symphyseal rim becomes fully defined. The authors suggest that Phenice's original definition of the ventral arc be modified to specify that the ridge must be palpable. Using the modified Phenice definition for the ventral arc and the new definition for the precursor condition, we classified the 248 female pubic bones (aged 30 or under) into one of three categories: absence of the arc, a precursor arc, or presence of the arc. Table 1 presents these results according to the age of the female. The ventral arc is absent in the youngest individuals in the sample, usually in females under 21 years. The precursor arc first appears at age 14 in the sample, and at age 20 it becomes the most frequent condition. The ventral arc is the most frequent condition by age 23. There is some overlap, however, and in some cases there is an arc in young females (age 16), though this is not the dominant trend. The ventral arc of females in their 20s usually resembles that shown in Fig. 5; the arc is clearly defined yet does not show as heavy a ridge as that seen in older females.

Classification of adult females in terms of the presence or absence of the ventral arc is important in light of Lovell's recent suggestion that degenerative bony changes in older females may make the ventral arc less useful as a sex discriminator [4]. The Los Angeles sample provides 399 mature females aged 30 to 99; these data are presented in Table 2.

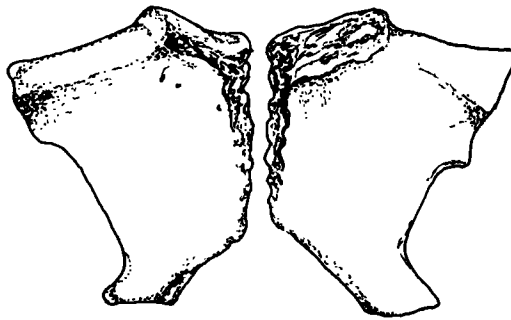


FIG. 3—Young adolescent female (ventral view) prior to the development of the ventral arc.

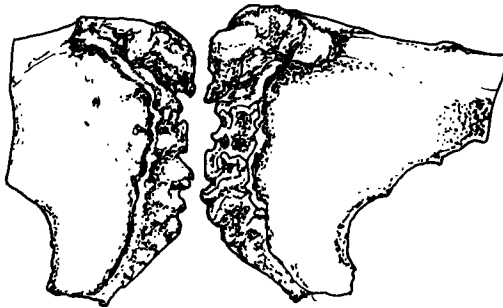
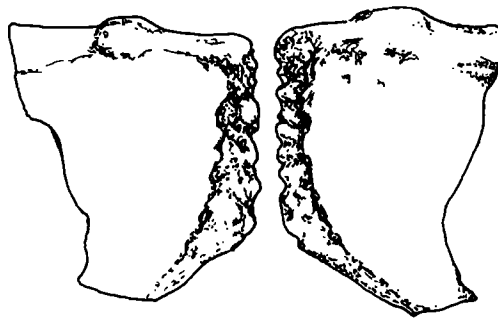


FIG. 4—Young adolescent female (ventral view) showing the precursor arc.

TABLE 1—*Distribution of the ventral arc in females 11 to 30 years old, by number of cases.*

Age, years	<i>n</i>	Absence of Arc	Precursor Arc	Presence of Arc
11	1	1	0	0
12	0
13	2	2	0	0
14	3	2	1	0
15	10	9	1	0
16	5	2	2	1
17	11	5	6	0
18	20	11	9	0
19	14	8	6	0
20	20	5	15	0
21	16	8	6	2
22	20	0	10	10
23	18	0	6	12
24	17	3	1	13
25	11	1	0	10
26	17	1	5	11
27	14	0	0	14
28	22	2	1	19
29	14	1	0	13
30	13	0	1	12

FIG. 5—*Twenty-three-year-old female (ventral view) showing a clearly defined ventral arc which is palpable.*TABLE 2—*Distribution of the ventral arc in females 30 to 99 years old.*

Age	<i>n</i>	Arc Absent, %	Arc Present, %
30-39	97	2	98
40-49	88	2	98
50-59	87	5	95
60-69	47	0	100
70-79	43	7	93
80-89	33	6	94
90-99	4	50	50

The ventral arc is present in frequencies of 93% or greater throughout the 80s. The small sample ($n = 4$) in the 90s prevents conclusions from being drawn. Thus, the ventral arc would appear to be a useful sex discriminator in older as well as younger females.

Often the male shows no ridge in the relevant "arc area." At about age 25, some males show a distinct line which parallels the symphyseal edge (Fig. 6). Phenice previously noted this condition (Ref 1, p. 300):

Either it will extend from the pubic crest or pubic tubercle infero-medially to the inferior margin of the pubic symphysis, or it will extend from the pubic crest inferiorly, parallel to the medial border of the pubis, to a point superior and lateral to the subpubic angle where it too forms an angle and extends for some distance along the ischio-pubic ramus parallel to its medial border.

Phenice declared that this ridge in the male "should never be confused with the ventral arc if proper observation is carried out" [1]. In the Los Angeles sample it was found that 4% of the male sample did exhibit a ridge, which might in fact be confused with the female condition (Fig. 7). Although sex determination errors based on this confusion would be minimal in number, it is important to note for forensic science applications that such cases do exist. In many skeletal samples, such "troublesome cases" are often deleted from the collection or study under the assumption that they must be cataloging or documentation errors. Since great care was taken in the preparation and cataloging of the Los Angeles sample, unusual cases were not deleted.

Practical Applications

The results of this study support Phenice's findings and expand his technique for use with adolescents and young adults. The technique, which utilizes only a small portion of the hipbone, is especially useful in the sex identification of badly decomposed or mutilated remains at autopsy. Cleaning and preparation of specimens are discussed, as well as three relevant forensic science cases analyzed by Suchey. The final question concerns the reliability of the sex determination methods outlined here when used by other researchers. The key pubic bones illustrated in this article (Figs. 1-7) are necessary for learning the method and are available as casts to forensic scientists.⁴

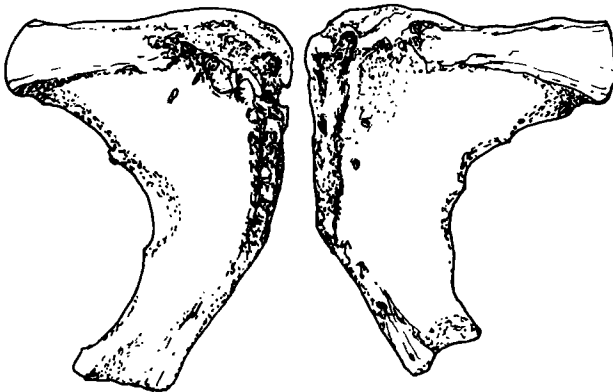


FIG. 6—Male (ventral view) showing a distinct line which parallels the symphyseal edge but lacking a ridge in the "arc area."

⁴For more information, contact Diane L. France. France Casting, 20102 Buckhorn Rd., Bellvue, CO 80512.

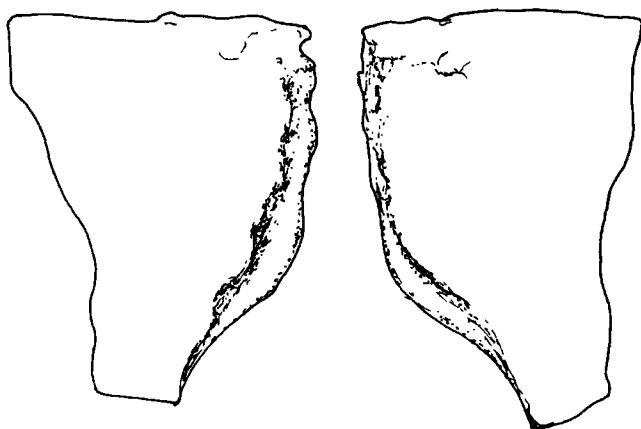


FIG. 7—Male (ventral view) showing a ridge in the “arc area” which might be confused with the female condition (4% frequency).

Preparation of Pubic Bone Specimens of Fleshed Cases

For fleshed remains (whether in a well-preserved, burned, or decomposed state), author Suchy suggests that the pubic bones be removed with a Stryker saw. First, the pelvic cavity should be cleaned of soft tissue and liquid. The entire front part of the bony pelvis should be palpated to locate the superior pubic rami and the ischiopubic rami. These bony structures should then be cleaned free of tissue using a scalpel. Four saw cuts should be made, two on the superior pubic rami and two on the ischiopubic rami (Fig. 8). Note that the entire pubic bone body is being removed, not just the symphyseal region. After the saw cuts are made, the pubic bone portion can be “snapped out.” If the segment does not dislodge easily, one or more of the saw cuts are incomplete and the process should be repeated. Particularly with robust males, a chisel may be necessary after the Stryker saw procedure. This instrument will reduce the number of blades broken in a robust pelvis. Blades can be conserved by the use of direct pressure and care not to twist the saw while it is in operation. After the pubic bones have been removed from the body, an attempt should be made to remove as much of the remaining tissue as possible prior to boiling. If the researcher is knowledgeable about bone morphology, the bones can be cut between the right and left symphyseal borders to facilitate and speed the cleaning process. *Bony specimens removed for this purpose should never be placed in formalin.* The fixation of tissues increases the preparation time of the specimen and may actually result in destruction of key features. Pubic bones can be boiled in a solution of trisodium phosphate (TSP)⁵ and water in a ratio of approximately 250 cc of TSP to 1 gal (3.8 L) of water. The length of the boiling time depends upon several factors: (1) whether the body has been embalmed, (2) the age of the individual at the time of death, (3) the length of the time since death, (4) the strength of the chemicals in the boiling bath, and (5) the temperature of the heat source. Specimens from bodies which have not been embalmed or have only been embalmed a short time will generally clean up easily and the bony features of the specimens can easily be observed. Bodies which have been embalmed for a long period of time may be problematic. The specimens may be difficult to clean and interpret. Caution should be used in cases of this type.

⁵TSP has been changed to a nonphosphate product containing sodium carbonate and sodium sesquicarbonate.

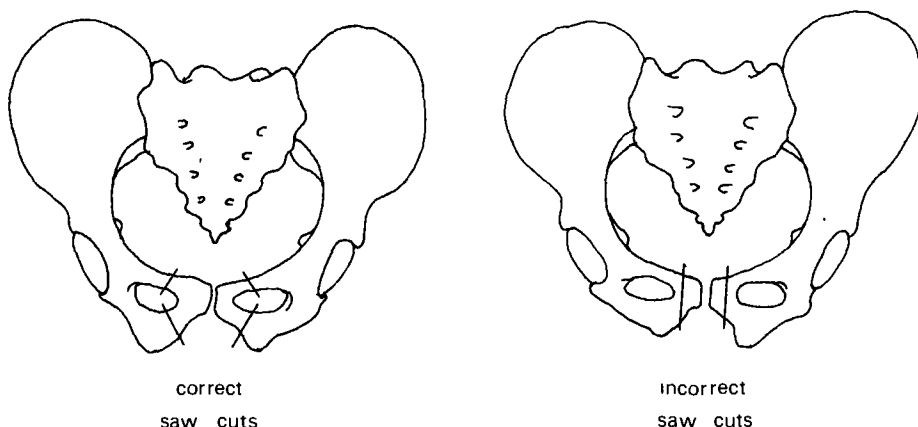


FIG. 8—Diagram of the pelvis, indicating the correct location (left) for the saw cuts in the removal of pubic bone segments.

Case 1

A badly decomposed body was recovered from the sewer system in Los Angeles County in 1986. The body was partially clothed, with the legs bound together with a chain. Since the remains lacked internal pelvic organs or external features which could be used for sex identification, the case was referred for forensic anthropological examination. Figure 9 illustrates the pubic bones from these remains, removed using a Stryker saw. Upon examination, it can be seen that this individual is a male. There is no ventral arc or precursor condition. This sex diagnosis was confirmed after identification.

Case 2

This case consists of a large charred torso removed from the Cerritos air crash disaster in Los Angeles County on September 1986. The remains consisted of portions of the head, trunk, and right arm. The nose and frontal facial features were absent, although some of the teeth of the left mandible were present. Thoracic and abdominal organs were absent. Neither age nor sex was readily apparent, and the remains were among

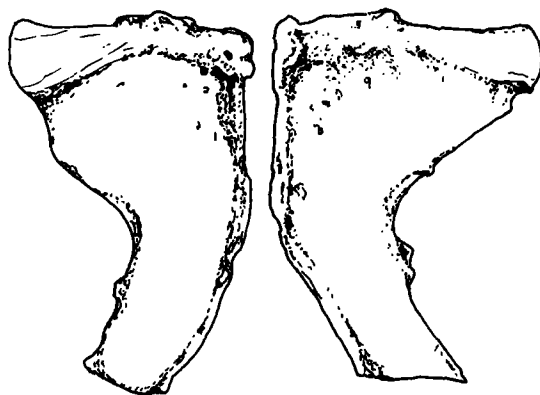


FIG. 9—Case 1—the pubic bone segment is that of an adult male. No ventral arc is present.

those marked for forensic anthropological examination (Fig. 10). Sex was determined to be female from the distinct precursor arc. An upper age limit of 24 could be established from the deep ridges and grooves of the symphyseal surface. This pattern is only seen on individuals (male and female) 24 years of age or less [5]. Following the basic identification of this torso, the identity was established from the few remaining teeth present. This torso was that of female 23 years old.

Case 3

This case consists of skeletonized remains, found December 1987 during construction of a patio, buried in concrete under a beach bungalow in Los Angeles County. Figure 11 illustrates the ventral view of the pubic bone, exhibiting a prominent ventral arc. The skeleton was sexed as female based on this distinctive feature. The identification process was based on evidence of soft tissue morphology remaining in the "concrete tomb." Her face was reconstructed from the impression left in the concrete; it resembled a woman who had lived in the house in the early 1970s. Specific identification was made through fingerprints which remained in the concrete which had been poured on the body when it was buried in the shallow grave. She was a heavyset Caucasian, 31 years old at the time of death.

Development of a "Learning Kit"

The results of this study point to a variety of potential problems inexperienced personnel may face in pubic sex determination. An inexperienced observer may fail to identify the arc when it is in its precursor state as it is in many young females' bones. In some male

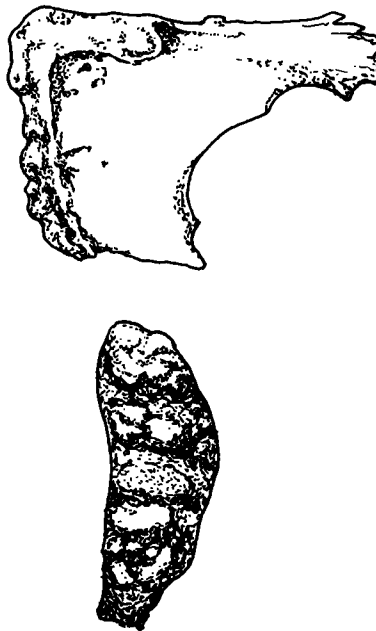


FIG. 10—Case 2—fragmentary left pubic bone from a charred torso in the Cerritos air crash. The top view shows that the ventral arc can be viewed on fragmented pubic bone. The bottom view shows the symphyseal face, providing age data.



FIG. 11—Case 3—ventral aspect of the right pubic bone showing a clearly defined ventral arc, which is present in most mature females.

bones, the parallel ridge may be mistaken for a ventral arc. A kit consisting of nine pubic bone pairs was developed to improve identification accuracy rate.

The traits illustrated by the pubic bone models include Phenice's three traits, emphasizing the ventral arc. In addition, relevant accessory traits are included (the width of the pubic bone body and dorsal pitting). A detailed description of each trait accompanies the kit. Adolescent bones, as well as adult bones demonstrating the hard-to-sex categories, are illustrated by the pubic bone models.

Interobserver Error Studies

An interobserver error study was designed to determine whether the kit was a useful tool and whether the expanded definitions of the traits were helpful in identifying the traits. To compare the accuracy rates of inexperienced and experienced observers, 20 pubic bone pairs were given to 12 forensic dentists (or dental auxiliaries) from Los Angeles and Orange Counties and to 10 "A" students in Suchey's osteology class. The dentists had minimal or no experience in sex determination of pubic bones. The osteology students had received both instructions on Phenice's traits and the pubic sex determination kit during the semester preceding the test. The bone sample used for the test was more difficult than a random sample. Of the 20 bones, 12 were hard-to-sex specimens and 8 were classic examples. The results are presented in Table 3.

The overall results showed that the experienced observers achieved 92.5% accuracy and the inexperienced observers achieved 85.4% accuracy on the complete set of 20 bones. On the classic examples, the experienced observers obtained a 98.7% average accuracy rate and the inexperienced observers an average of 94.8%. Some of the inexperienced observers scored as well as the experienced observers. Though the limited sampling provides only tentative conclusions, the sex determination kit appears to have a positive effect on the accuracy rate of the observers. Also, the expanded definitions of the ventral arc and other traits used for sex determination of the os pubis appear to be beneficial.

Acknowledgments

We wish to thank the entire staff at the Department of Chief Medical Examiner-Coroner, County of Los Angeles, for their support and cooperation in this research. We

TABLE 3—Analysis of responses of participants in sex determination study.

Bone No.	Description of Bone	Number of Inexperienced Observers (out of 12) Missing the Bone	Number of Experienced Observers (out of 10) Missing the Bone
1	Classic female	1	1
2	Male with false arc	3	2
3	Male with false arc	3	1
4	Male with false arc	2	0
5	Male with misleading arc	1	2
6	Male with misleading arc and ridge	6	4
7	Classic female	0	0
8	Classic male	0	0
9	Classic female	1	0
10	Classic male	1	0
11	Male with false arc	2	2
12	Classic male	1	0
13	Classic male, young	1	0
14	Female without arc	1	0
15	Classic female	0	0
16	Female with precursor arc	4	0
17	Young female with faint line	4	0
18	Female with precursor arc	1	0
19	Female with "parallel arc"	2	3
20	Female with precursor arc	1	0

thank the dentists, dental auxiliaries, and anthropology students who participated in the interobserver error study. Acknowledgment is due to James Njavro for his photography of the pubic bones, which were then prepared as line drawings by Deborah Gray. Dr. Diane France's casting of the crucial models has allowed pubic sex determination techniques to be utilized throughout the world. Dr. Robert Tague, Dr. Susan MacLaughlin, and Carol Sanders provided comments on an earlier draft of this manuscript, and their advice is appreciated. The authors take full responsibility for the final format of the article.

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Address requests for reprints or additional information to
 Prof. Judy Myers Suchey
 Department of Anthropology
 California State University
 Fullerton, CA 92634