

Sulcus Nervi Dorsalis Penis/Clitoridis: its Reliability as a Character for Sex Determination of Isolated Human Pubic Bones

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Abstract: This study describes a distinct groove on the caudal and ventral surfaces of the pubic bone termed the “sulcus nervi dorsalis penis/clitoridis” and assesses its usefulness as a character for sex determination of isolated pubic bones. Analysis of 168 male and 118 female pubic bones showed that the presence of a sulcus was a non-random event. A sulcus was present in 72% of male pubic bones and 83% of female pubic bones examined (Czech population). Seven characters (including three of the sulcus) were measured in a sample of an 86 isolated pelvises grouped according to the gender. A step-wise discriminant function analysis was performed on this dataset to assess whether a combination of these characters could be used for gender identification of isolated pubic bones. A bivariate plot using Mahalanobis distances showed distinct differences in male and female pubic bones. The width of the sulcus and the craniocaudal length of the pubic symphysis significantly described most of the variations observed between male and female pelvises. A *post hoc* analysis of the reliability of the technique showed that stepwise discriminant function correctly identified 83% of male and 86% of female known-sex pelvises. Thus discriminant function analysis of the sulcus and pubic bones can reliably be used to determine sex in human osseal remnants.

Introduction

Analysis of mineralized tissues is a cornerstone of anthropology and forensics. In this context, the pelvis is generally accepted as the region of skeleton that best allows determination of sex [1]. The rate of accuracy of sex determination using the entire pelvis is reported to range between 88–97% [1, 2, 3]. However, the entire pelvis may not always be preserved for analysis of skeletal remains; consequently, several studies have focused on the pubic bone for gender determination [4, 5, 6].

The most frequently used visual method for sexing the adult pubis is an analysis of the ventral arc, subpubic concavity and medial aspect of ischiopubic ramus [4]. The accuracy of sex determination by this technique is estimated to range between 59–96% [4, 5, 7, 8, 9] or greater when used in combination with other methods [10]. However, one criticism of this technique and of other techniques using the pelvis for determining sex is the lack of testing of the reliability of the technique in known-sex samples [10].

Our laboratory previously undertook tracing the course of the dorsal nerve of penis/clitoris in cadavers as an exercise to prevent its damage during surgery [11]. During the course of these dissections, we observed that a segment of the nerve occupied a distinct groove on the pubis, which we termed the “sulcus nervi dorsalis penis/clitoridis” [11]. Sulcus nervi dorsalis penis accommodates the dorsal nerve of the penis whereas the dorsal nerve and artery of clitoris runs in sulcus nervi dorsalis clitoridis [11]. Based on this observation, we performed a systematic quantitative analysis of this sulcus and other features of the pubic bone in order to determine whether this groove: (1) is present in most pubic bones; (2) is sexually

dimorphic; and (3) could be reliably used in conjunction with other features of the pubis for sex determination in humans. The preliminary data of this study have been published in an abstract form [12].

Materials and Methods

Distribution of skeletal specimens into groups

A sample of 168 male and 118 female pelves (Czech population) from the collection at the Institute of Anatomy, Prague was examined. Specimens were grouped qualitatively into one of three classes based on the presence or absence, and the size of the sulcus (Table 1) [11]. Whether the presence of sulcus was a random in male and female pelves was analyzed by chi-square analyses of the distributions into the three classes (Table 2). The distributions in both males and females were found to be non-random; hence further analyses of the sulci in Classes I and II were performed. Features of pubic bones and sulci were compared between Classes I and II for males and females. No significant differences were found between classes I and II for either sex (Table 3), hence data were pooled for subsequent analyses.

Analysis of sulcus nervi dorsalis penis/clitoridis from skeletal specimens

Seven parameters of the pubis, including three of the sulcus, were measured for each pubic bone: the craniocaudal length of the pubic symphysis (LoSy), mediolateral width of the pubic symphysis (WoSy), distance between the pubic tubercle and acetabulum (PT-A), distance between the pubic tubercle and ischial tuberosity (PT-IT) [13, 14] the craniocaudal length of sulcus nervi dorsalis penis/clitoridis on anterior surface of pubis (LoSu), the maximum mediolateral width of sulcus nervi dorsalis penis/clitoridis on anterior surface of pubis (WoSu), and the length of the sulcus nervi dorsalis penis/clitoridis on inferior pubic ramus (LoSu-r). Morphometric measurements were performed on isolated pubic bones from 29 females (24 Class I and 5 Class II) and 57 males (33 Class I and 24 Class II).

Statistical analysis

Cases, grouped by sex, were put into a matrix with each case as a row and the seven measurements of the pubis/sulcus as columns. Sex was designated as the

Table 1 – Criteria for the classification of sulcus nervi dorsalis penis/clitoridis (SNDP/SNDC)

Class	I	II	III
SNDP/SNDC	present	present	absent
Constitution	complete	incomplete	absent
Length	> 1/3 of pubis	< 1/3 of pubis	NA
Depth	1.5 mm and more	0.2–1.5 mm	NA

NA – not applicable.

dependent variable; pubic bones from females were assigned a value of 1 and those from males were coded as a 2. Data were analyzed by a stepwise discriminant function analysis (SDFA) with the criterion for inclusion set at 0.15 (Systat program). SDFA was selected to analyze the data matrix because: (1) independent variables are analyzed simultaneous and the ones that contribute most to differentiating between males and females are included and those that do not contribute significantly are excluded; and (2) for each case, the analysis calculates a post hoc probability of being from a male or a female. This probability can be compared to gender of the individual from which the pubic bones was isolated to give an index of the reliability of the technique; and the model is predictive and can be applied to isolated pubic bones of unknown gender to calculate the probability of originating from a female or male.

Results

Incidence of sulci in pubic bones

The distribution of sulci into Classes I, II and III deviated significantly from an equiprobable distribution ($p < 0.001$) for both males and females. Sulci nervi dorsalis penis/clitoridis were present in approximately 72% of male and 83% of female pubic bones (Table 2). Females tended to have better developed sulci than males. The differences in male/female distributions of sulci into the three classes (present/well-developed, present, and absent) approached statistical significance ($\chi^2 = 5.8, p = 0.055$).

Sulcus nervi dorsalis penis

Sulcus nervi dorsalis penis was visible on the inferior ramus of pubis for a mean distance of 15.8 (± 3.8) mm from the inferior border of pubis (Table 3 and 4). Sulci continued on the inferior border of pubis and curved to the anterior surface of body of pubis for a mean distance of 21.3 (± 5.3) mm. Sulci coursed cranially and parallel to the pubic symphysis. Mean length of the sulcus was 55% of the total craniocaudal length of the anterior surface of pubic symphysis. The cranial end of the sulcus marked the site of anterior curving of the nerve to the penile

Table 2 – Classification of pubic bones based on the presence (Classes I and II) or absence (Class III) of a sulcus nervi dorsalis penis/clitoridis. Note that most male and female pubic bones exhibited a sulcus

	(N) Males	(%) Males	(N) Females	(%) Females	(N) Total	(%) Total
Class I	81	48.2	72	61.0	153	53.5
Class II	40	23.8	26	22.0	66	23.1
Class III	47	28.0	20	17.0	67	23.4
Total	168	100.0	118	100.0	286	100.0

dorsum. No significant differences were noted between male pubic bones classified as Class I or II (Table 3).

Sulcus nervi dorsalis clitoridis

The sulcus nervi dorsalis clitoridis followed a similar course as the sulcus nervi dorsalis penis in males. Its mean length on inferior ramus of pubis was 0.8 mm longer than in males. The sulcus nervi dorsalis clitoridis on inferior ramus of pubis was thinner than the corresponding groove in males. However, mean mediolateral diameter of sulcus nervi dorsalis clitoridis on the anterior surface of body of pubis is 2.4 mm or 32% wider than the groove in males due to accompaniment of the nerve by the dorsal artery of clitoris. The length of the sulcus expressed as a percent of the length of pubic symphysis (57%) was equivalent to that observed in

Table 3 – Measurements (mm) of pubis and sulcus nervi dorsalis penis/clitoridis

Sex Class	Males		Females	
	I	II	I	II
LoSy	38.8 ± 4.3	37.8 ± 4.5	34.6 ± 3.4	35.3 ± 7.4
WoSy	14.1 ± 2.3	14.7 ± 2.3	12.2 ± 2.1	12.6 ± 3.5
PT-A	69.1 ± 6.4	69.5 ± 4.6	72.4 ± 4.5	73.1 ± 3.6
PT-IT	120.4 ± 6.6	119.5 ± 6.0	119.4 ± 5.4	121.4 ± 4.7
LoSu	22.4 ± 5.9	19.8 ± 3.8	20.3 ± 4.6	17.7 ± 3.4
WoSu	5.2 ± 1.4	4.8 ± 1.4	7.5 ± 1.6	7.1 ± 1.2
LoSu-r	16.1 ± 3.8	15.4 ± 3.7	17.0 ± 3.0	15.2 ± 3.0
Sample size (N)	81	40	72	26

LoSy – craniocaudal length of symphysis. WoSy – mediolateral width of symphysis. PT-A – minimal distance between pubic tubercle and border of acetabulum. PT-IT – distance between pubic tubercle and ischial tuberosity. LoSu – craniocaudal length of sulcus nervi dorsalis penis/clitoridis on anterior surface of pubis. WoSu – maximal mediolateral width of sulcus NDP/NDC on anterior surface of pubis. LoSu-r – length of sulcus nervi dorsalis penis/clitoridis on inferior pubic ramus. No significant differences were noted between classes within males or females, hence classes were pooled within males and females for subsequent analyses.

Table 4 – Comparison of male and female pubis and sulcus nervi dorsalis penis/clitoridis. Classes I and II were pooled for both males and females

	Male I and II	Female I and II	Mean Difference
LoSy	38.4 ± 4.3	34.8 ± 4.3	3.6***
WoSy	14.4 ± 2.4	12.2 ± 2.4	2.2***
PT-A	69.2 ± 5.7	72.5 ± 4.3	-3.3**
PT-IT	120.0 ± 6.4	119.8 ± 5.4	0.2
LoSu	21.3 ± 5.3	19.8 ± 4.5	1.5
WoSu	5.0 ± 1.4	7.4 ± 1.5	-2.4***
LoSu-r	15.8 ± 3.8	16.9 ± 3.0	-1.1
Pubic bones (N)	121	98	

Abbreviations are the same as those shown in Table 3. *, **, and *** denote a significant difference between males and females at $p > 0.05$, 0.01 and 0.001 respectively.

males. No significant differences were noted between female pubic bones classified as Class I or II (Table 3).

Morphometric analysis of the sulcus nervi dorsalis penis/clitoridis

Four features of pubic bones and sulci significantly differed between females and males (Table 4). However, simultaneous analysis of the seven parameters by stepwise regression showed that two variables, WoSu and LoSy, significantly explained the variation observed between the two populations (Wilk's W = 0.53, approx. F = 34.8, df = 2.83; p < 0.001). Discriminant function analysis of the seven pubic bone variables plotted as a bivariate scatter gram revealed distinct male and female populations with minimal overlap (Fig. 1).

The equation generated that predicted gender (female=1, male=2) was:
 $-209.6 - 0.77 \text{ LoSy} + 1.54 \text{ WoSu} + 0.93 \text{ PT-A} + 3.19 \text{ PT-IT} - 0.53 \text{ LoSu} - 1.66 \text{ WoSu} - 0.12 \text{ LoSu-r}$

Eighty-eight (88) percent of male and 83% of female pubic bones were classified correctly according to discriminant function analysis of the seven pubic and sulci parameters (Table 5). Hence the seven parameters, and particularly maximal mediolateral width of the sulcus (WoSu) and craniocaudal length of the pubic symphysis (LoSy), provided a reliable means of differentiating male and female pubic bones.

Discussion

Sulcus nervi dorsalis penis/clitoridis as a marker of sex differentiation

Our data indicate the sulcus nervi dorsalis penis/clitoridis can be used for sex determination of isolated pubis. The discussion about anatomical relations of sulcus and clinical situations demanding its precise knowledge has been done previously [11] .

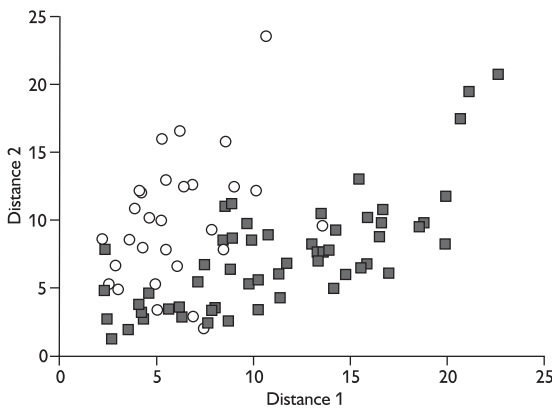


Figure 1 – Bivariate scattergram of discriminant function analyses of features of pubic bones and sulci nervi dorsalis penis/clitoridis. Open circles denote females and filled boxes denote males. Note that two distinct populations (females and males) are readily discernible based on features of pubic bones and sulci.

The pubic bone is often preserved in skeletal remnants or can be easily removed from mutilated or burned bodies during the forensic dissection [5]. In mature human skeletal remains, the dorsal pits of pubic bone and the pubic tubercle can be used as a parity indicators [15], the symphyseal surface of the pubis can be used for the estimation of the age at death [16, 17, 18, 19, 20].

However, the most frequent situation in forensic medicine demanding the use of pubic bone is the estimation of sex of body remnants [5, 6]. Today, the most frequent method of sex determination of isolated pubic bones is the Phenice's method [4]. This method includes analysis of the ventral arc, subpubic concavity and medial aspect of ischiopubic ramus. The accuracy according to the Phenice's method was stated between 83–96% [4, 5, 7, 8, 9]. Our analysis of sulcus revealed a 88% accuracy in males vs. a 83% in females. Thus, the results obtained by these two methods are comparable.

Lateral border of sulcus nervi dorsalis penis/clitoridis is Phenice's vertical ridge/ventral arc

On the anterior surface of pubis, Phenice described the ventral arc in female as “a slightly elevated ridge of bone that extends from the pubic crest and arcs inferiorly across the ventral surface to the lateral extension of the subpubic concavity where it blends with the medial border of the ischiopubic ramus” [4]. We assume that this feature, often used in sexing of the isolated pubis corresponds to the lateral border of the sulcus nervi dorsalis clitoridis [1, 5]. Similarly, “ventral ridge” in male, described by Phenice as “similar ridge, but this should never be confused with the ventral arc if proper observation is carried out... 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 to 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 ischiopubic ramus parallel to its medial border.” corresponds to the lateral border of the sulcus nervi dorsalis penis [4]. Moreover, Phenice stated, that on the ischio-pubic ramus, there is a “sharp ridge” in females, although it is “flat” in males

Table 5 – Success rate of sex identification of pubic bone using measurements of the pubis and sulcus nervi dorsalis penis/clitoridis. Classes I and II were pooled for both males and females prior to analysis

		Classified As		% Correct
		Female	Male	
Sex	Female (N=29)	24	5	83
	Male (N=57)	7	50	88
	Total (N=86)			86

[4]. We assume that this “sharp ridge” is the ventrolateral border of the sulcus nervi dorsalis penis/clitoridis.

Morphological characteristics of ventral arc/vertical ridge are probably determined by different widths of the sulcus nervi dorsalis penis/clitoridis and the shape of the subpubic concavity as a consequence of different developmental bases of pubis in males and females. Wider sulcus nervi dorsalis clitoridis compared to the sulcus nervi dorsalis penis is a result of the presence of nerve and artery in the sulcus nervi dorsalis clitoridis (Figures 2A, C) and only the nerve in sulcus nervi dorsalis penis as shown in Figures 2B and 2D.

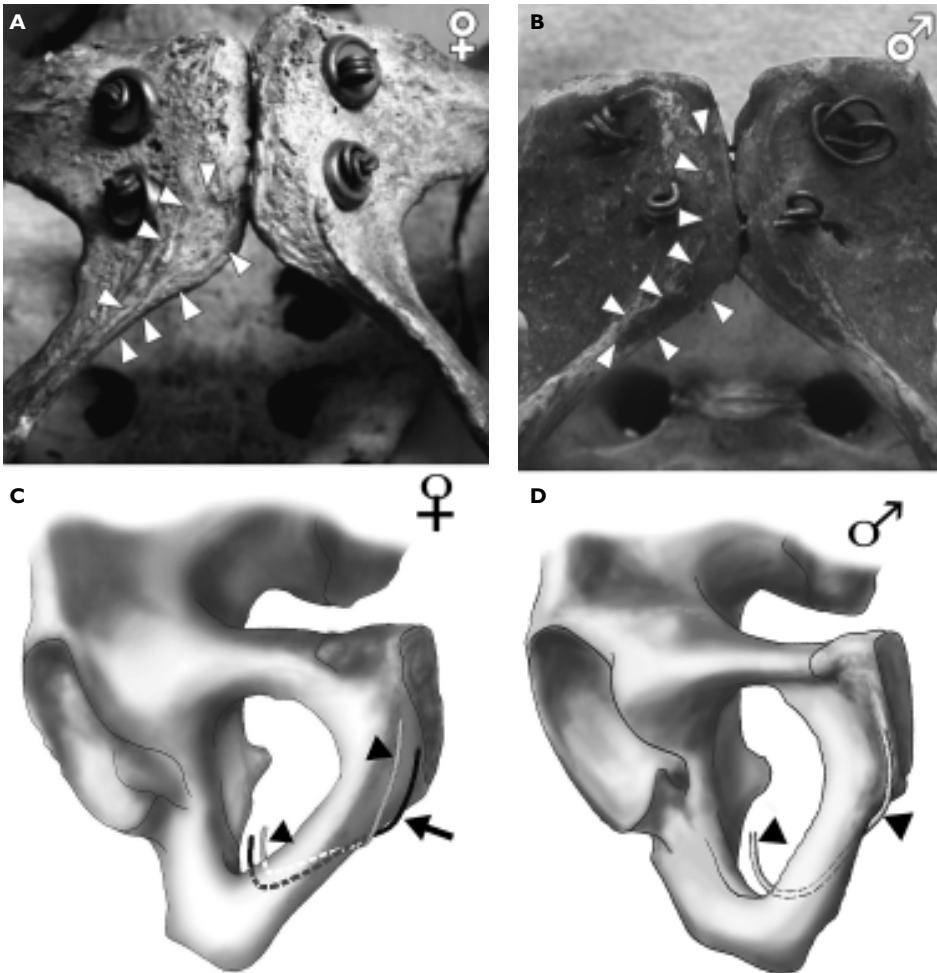


Figure 2 – Sulcus nervi dorsalis penis/clitoridis on a pubic bone. A. Sulcus nervi dorsalis clitoridis (arrowheads) from ventrocaudal view. B. Sulcus nervi dorsalis penis (arrowheads) from ventrocaudal view. C. Scheme of the dorsal nerve of clitoris (arrowheads) and dorsal artery of clitoris (arrows) running in the sulcus nervi dorsalis clitoridis. D. Scheme of the dorsal nerve of penis (arrowheads) running in the sulcus nervi dorsalis penis.

Study of Budinoff and Tague hypothesize that ventral arc morphology coincides with the elongation of pubis in females and more “lateral placement” of ventral arc in females [21]. They define “lateral placement” as a minimum distance between the ventral arc/vertical ridge and the inferior border of the symphyseal face of the pubis” [21]. Our study supports these findings and concludes that different shape of the subpubic concavity and different “lateral placement” of the ventral arc/vertical ridge result in different morphological characteristics of the sulcus in males and females.

Commentaries on the anatomical basis of the ventral arc have been few. Phenice, as well as his followers, focused on antropological and forensic aspects of the ventral arc and the vertical ridge and did no anatomical study [1, 4, 5]. Several speculations and partial descriptions have been made as reviewed in Introduction of paper by Budinoff and Tague [21]. In fact, only two studies systematically analyzed developmental and anatomical relations of the ventral arc/vertical ridge. Budinoff and Tague studied this problem extensively and found that the ventral arc/vertical ridge is an insertion site of tendons of the adductor brevis and the gracilis and fibers of the ventral pubic ligament [21], Anderson revealed developmental basis of these attachments [22]. These results are indirectly supported by study of Sutherland and Suchey [5], who found that precursor of the ventral arc appears in about 20 years of age and the definite modal ventral arc appears in about 23 years of age. Thus, in female, the definite modal ventral arc and its lateral placement present a consequences of changes of the site of osseous attachment of the adductor brevis and the gracilis during the hormone-dependent pubic elongation in puberty [21, 22], while in male, the presence of the vertical ridge is probably associated with an entesopathic changes [21, 22]. We found no description of relationship of the pubic bone and the dorsal nerve of penis and the dorsal nerve and artery of clitoris in terms of groove in literature. Thus, we systematically analyzed these relations and termed the groove “sulcus nervi dorsalis penis/clitoridis”.

Conclusions

We have identified and systematically analyzed a groove on the pubis which we previously termed the “sulcus nervi dorsalis penis/clitoridis” [11, 12]. This groove accommodates the dorsal nerve of penis in males and the dorsal nerve and artery of clitoris in females. Moreover, this sulcus is sexually dimorphic and can be used for sex determination of isolated pubic bones.

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