J Forensic Sci, November 2003, Vol. 48, No. 6
Paper ID JFS2003027_486
Available online at: www.astm.org

TECHNICAL NOTE

J. Josh Snodgrass,[1] M.A. and Alison Galloway,[2] Ph.D.

Utility of Dorsal Pits and Pubic Tubercle Height in Parity Assessment*

ABSTRACT: Parity indicators in human skeletal material are highly desirable yet elusive. In this study, the relationships of dorsal pits and pubic tubercle elongation to parity are investigated in a sample of 148 modern female sets of pubic bones with associated birth information. The elongation of the pubic tubercle shows no significant correlation with number of births, but instead is associated with the distance this feature is from the pubic symphysis ($p < 0.01$) and the size of the arcuate angle ($p < 0.05$). Dorsal pits show a strong association with increasing numbers of births ($p < 0.01$), especially in younger women. However, in women over 50 years old, dorsal pitting is correlated with BMI ($p < 0.05$) and is not significantly correlated with number of births. While this study lends support to the correlation of dorsal pitting and parity, it currently does not reach the level of accuracy needed for forensic applications at the level of the individual.

KEYWORDS: forensic science, forensic anthropology, parity, dorsal pitting, pubic tubercle, body mass index (BMI)

Despite considerable research, accurate parity determination from human skeletal remains continues to elude forensic anthropologists. Skeletal changes on the dorsal aspect of the pubis and in the auricular surface region have been linked to pregnancy and parturition through studies of human skeletal remains from archaeological sites. In particular, pubic bones have been the subject of intense research for indicators of childbirth. Pitting on its dorsal surface (1–3) and the height of the associated pubic tubercle (4,5) have been proposed as markers indicating parity. Unfortunately, the results of these studies are often conflicting (see review in Ref 6).

The reliability of dorsal pitting as an indicator of parity is uncertain, as studies with documented skeletal series have produced contradictory results (7–10). Even some males possess dorsal pits, which calls into question the causal factor involved in producing the scars. Some studies have achieved positive results through the use of remains with documented histories of parity. For instance, Suchey and colleagues (11) found a correlation, though weak, between pitting and full-term pregnancies.

The height of the pubic tubercle has been proposed as an indicator of parity (4,5), but has yielded mixed results. The most promising study to date used the Spitalfields skeletal series, dating from 1729 to 1859, for which parturition information could be reconstructed from historical records. In this study, Cox and Scott (5) found a correlation between pubic tubercle height and parity status. The study assessed the degree of extension of the pubic tubercle using a four-stage classification system, after Bergfelder and Herrmann (4). While most parous females (87%) had an extended pubic tubercle, some nulliparous females (33%) also had extended tubercles.

Forensic anthropologists have a vested interest in discovering markers indicative of parity, as they may be helpful in forming a description of an individual. This, combined with the conflicting results of previous studies, led us to examine the utility of dorsal pitting and pubic tubercle height in parity assessment using a large sample of pubic bone pairs with associated information on number of births.

Methods

The sample consisted of 148 sets of pubic bones randomly selected from an extensive sample of 486 females previously described (11). This sample was collected at autopsy at the Los Angeles County Department of the Coroner in the late 1970s and includes information on height, weight, age, and reported number of births. Body mass index (BMI) was calculated as the weight in kilograms divided by the square of height in meters. The sample was entirely female and the age range from 17 to 99 years, with a mean age of 44.7 years.

Approximately one third of the women ($n = 49$) in the study had no reported births, while one third had one or two children ($n = 50$), and one third had three or more children ($n = 48$). Parity history and age at death was missing for one individual. The number of reported births ranged from zero to 17, with a mean of 2.1 births.

[1] Department of Anthropology, Northwestern University, 1810 Hinman Avenue, Evanston, IL.
[2] Department of Anthropology, Social Sciences One Faculty Services, University of California, Santa Cruz, 1156 High Street, Santa Cruz, CA.
* A version of this paper was presented at the 50th annual meeting of the American Academy of Forensic Sciences in San Francisco, California, in February 1998. Financial support for the project was provided by the University of California, Santa Cruz Division of Social Sciences, in a grant to A. Galloway.
Received 31 Jan. 2003; and in revised form 17 May 2003; accepted 10 July 2003; published 25 Sept. 2003.

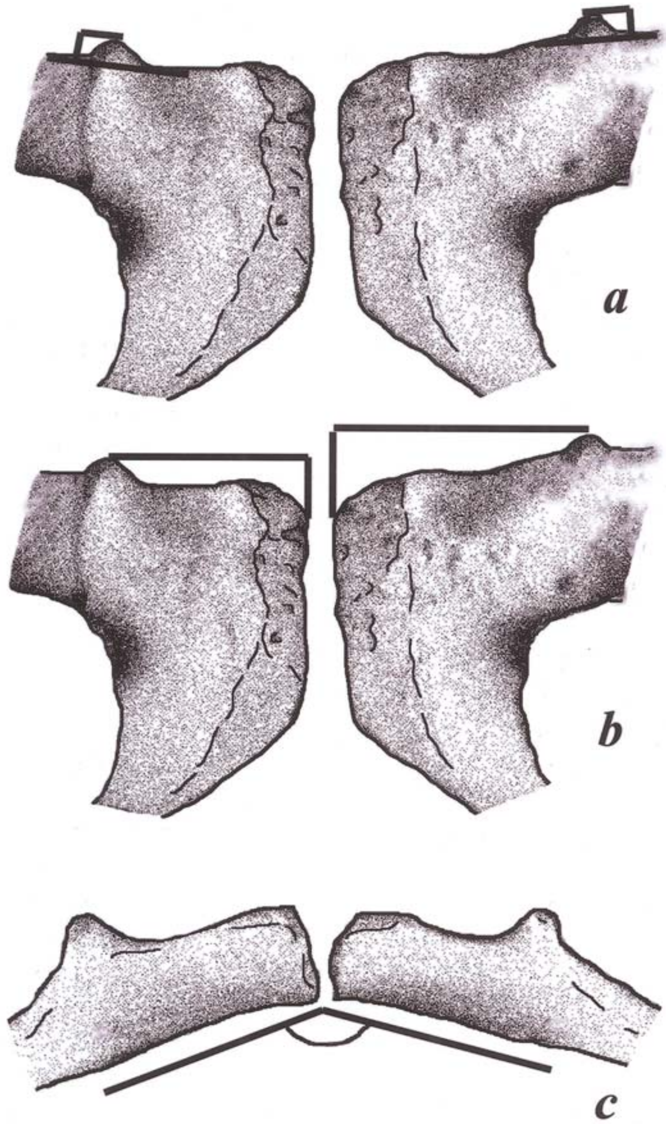

FIG. 1—*Illustrations of the pubic symphysis indicating:* (a) *the height of the pubic tubercle (on the ventral aspect);* (b) *the distance from the symphysis to the pubic tubercle (on the superior aspect); and* (c) *the arcuate angle*.

Individuals were classified into parity groups according to number of reported births: 0 births, 1–2 births, 3–4 births, and over 5 births.

We assigned study numbers to all bones and made all measurements and observations prior to the matching of the biological profile information to the case. Height of the pubic tubercle was measured directly from the bone, while the other measurements in this study were taken from photographs. Four standardized photographs of each specimen were taken at a set distance, producing ventral, dorsal, symphyseal, and superior views. All photographs, with the exception of those of symphyseal surfaces, were taken with the pubic bones aligned so that the symphyseal surfaces were parallel. All photographs were digitized, and two additional measurements were obtained using UTHSCSA ImageTool (12).

The measurements used in this study include:

1. Pubic tubercle height—measured with sliding calipers (to the nearest 0.01 mm) and defined as the maximum height that the tubercle protruded from the bone (5) (Fig. 1*a*).
2. Tubercle distance—distance (measured to the nearest mm) of the pubic tubercle at its most anterior point to the anteriormost margin of the symphyseal surface (Fig. 1*b*).
3. Arcuate angle—angle (measured to the nearest 0.5°) formed by the continuation of the arcuate line to the pubic tubercle (Fig. 1*c*).

Additionally, we assessed the degree of dorsal pitting according to the classification system of Ullrich (3). Pits were classified into Stages 0 (absent) through 4 (severe) independently by each of the authors; however, no significant interobserver differences existed and only one individual was classified in a different stage.

Statistics were performed using SPSS Version 8.0. T-tests were used to distinguish between parity and pitting groups. Pearson's correlations were used to assess the significance of correlations between variables. Additionally, stepwise multiple regression analysis and factorial ANOVA were used to assess the relationship of number of births, age, and body size (i.e., height, weight, and BMI) to pitting groups.

Results

Descriptive statistics for this sample are presented in Table 1. Age ranges from 17 to 99 years. Considerable variation is seen in the weight of the women, and the standard deviation in the arcuate angle also is relatively large.

Analysis of the correlations shows that age correlates with none of the pubic measurements, although it is negatively correlated with height ($p < 0.01$) (Table 2). As expected, height and weight are positively correlated ($p < 0.01$); however, weight does not appear to systematically differ with age, although it is significantly correlated with body mass index (BMI, an index of weight for height) ($p < 0.01$). Height positively correlates with right tubercle distance ($p < 0.05$), and there is a similar, though nonsignificant, tendency that exists for the left tubercle distance. Taller women have longer distances between the symphysis and the tubercle ($p < 0.05$). The arcuate angle is negatively correlated with tubercle distance ($p < 0.01$), showing that longer pubic bones tend to be associated with a more acute articulation between the symphyses.

Tubercle height (for both right and left) is not significantly correlated with number of reported births. Lack of correlation is consistent if examined in women 50 years of age or younger and in women aged over 50 years. Tubercle height is negatively correlated with arcuate angle ($p < 0.05$), showing that women in whom the angle is more acute tend to have larger tubercles. Tubercle height is positively correlated with distance from the symphyseal face ($p < 0.01$). Women in whom the pubic tubercle is more laterally placed tend to have longer pubic tubercles ($p < 0.01$). Not surprisingly, the right and left tubercle heights correlate to each other ($p < 0.01$).

Means by dorsal pitting group are presented in Table 3. Degree of dorsal pitting is strongly related to the number of births ($p < 0.01$) and also to age ($p < 0.01$). However, if the analysis is confined to women over age fifty ($n = 59$), the number of births is not significantly correlated to dorsal pitting. When assessed using t-tests, no significant differences in degree of pitting are seen between parity groups, even between women with no births and those with five or more births. BMI is significantly (positively) correlated with degree of pitting in women over 50 years old ($p < 0.05$). In women 50 years old or younger ($n = 88$), dorsal pitting is strongly correlated with number of reported births ($p < 0.01$), while BMI is not significantly correlated with dorsal pitting.

TABLE 1—*Descriptive statistics for measurements.*

	N	Mean (SD)	Minimum	Maximum
Age	147	44.7 (21.1)	17 years	99 years
Height (cm)	142	163.8 (7.7)	132.1 cm	190.5 cm
Weight (kg)	139	62.2 (16.6)	36.3 kg	142.4 kg
Body mass index (BMI)	139	23.1 (5.5)	12.8	43.8
Number of births	147	2.1 (2.6)	0	17
Right tubercle height	144	2.3 (1.5)	0 mm	6.7 mm
Left tubercle height	143	2.4 (1.4)	0 mm	6.9 mm
Right tubercle distance	142	24.4 (4.5)	10 mm	34 mm
Left tubercle distance	139	24.6 (4.4)	11 mm	34 mm
Arcuate angle	123	92.3 (12.2)	64°	132.5°

TABLE 2—*Correlation matrix.*

	Age	Height	Weight	R Tubercle Height	L Tubercle Height	R Tubercle Distance	L Tubercle Distance	Arcuate Angle
Age	1	−0.318**	ns	Ns	Ns	ns	ns	ns
Height		1	0.366**	Ns	Ns	.169*	ns	ns
Weight			1	Ns	Ns	ns	ns	ns
R tubercle height				1	0.659**	0.411**	0.306**	−0.198*
L tubercle height					1	0.293**	0.241**	−0.186*
R tubercle distance						1	0.833**	−0.394**
L tubercle distance							1	−0.277**
Arcuate angle								1

TABLE 3—*Means (SD) by dorsal pitting groups (classified according to Ullrich [3]).*

Dorsal Pitting	*N*	Age	Height	Weight	BMI	Births	R Tubercle Height	L Tubercle Height	R Tubercle Distance	L Tubercle Distance	Arcuate Angle
0	62	40.7 (22.2)	164.9 (7.8)	59.4 (11.0)	21.9 (3.8)	1.4 (1.8)	2.2 (1.5)	2.4 (1.5)	24.1 (4.0)	24.8 (3.7)	93.2 (12.0)
1	35	40.0 (16.1)	164.9 (7.4)	63.7 (19.2)	23.4 (6.4)	1.9 (1.9)	2.5 (1.5)	2.2 (1.2)	25.1 (5.2)	25.1 (4.8)	93.8 (10.7)
2	26	49.9 (21.8)	162.4 (5.3)	64.4 (15.1)	24.4 (5.4)	2.0 (1.7)	2.3 (1.8)	2.5 (1.7)	25.0 (4.0)	25.0 (4.9)	90.4 (11.9)
3	14	53.4 (18.6)	163.0 (7.2)	66.3 (20.0)	24.6 (5.9)	3.6 (3.6)	2.5 (1.1)	2.7 (1.0)	24.1 (3.0)	22.7 (3.5)	85.7 (12.6)
4	10	60.7 (19.6)	158.1 (11.0)	62.7 (29.8)	24.5 (9.2)	5.6 (5.0)	1.9 (1.5)	2.1 (1.4)	23.2 (7.3)	22.6 (6.2)	96.6 (16.0)

In stepwise multiple regression analysis of number of births, age, and BMI to pitting group (dependent variable), the combination of number of births ($p < 0.001$; $\beta = 0.337$) and age ($p < 0.05$; $\beta = 0.192$) is the best predictor of pitting stage ($r^2 = 0.184$). When the relationship of parity group (fixed factor), age (covariate), and BMI (covariate) to pitting group (dependent variable) is assessed using factorial ANOVA, parity group ($p < 0.01$; $F = 5.352$), age ($p = 0.01$; $F = 6.753$), and BMI ($p < 0.05$; $F = 4.477$) are significant in the dorsal pitting stage ($r^2 = 0.207$). Parity group is a significant predictor of dorsal pitting stage even when controlled for the effects of age and BMI.

In the subset of women age 50 or younger, when the relationship of the parity group (fixed factor), age (covariate), and BMI (covariate) to pitting group (dependent variable) is assessed using factorial ANOVA, only the parity group is significant ($p < 0.001$; $F = 10.483$; $r^2 = 0.351$). In stepwise multiple regression analysis of number of births, age, and BMI to pitting group (dependent variable) for the subset of women age 50 or younger, only the number of births is significant in predicting the degree of dorsal pitting ($p < 0.001$; $\beta = 0.532$; $r^2 = 0.283$).

In the subset of women over 50 years of age, when the relationship of number of births, age, and BMI to pitting group (dependent variable) is assessed using stepwise multiple regression analysis, only BMI is significant (and the direction of influence is positive) in predicting degree of dorsal pitting ($p < 0.05$; $\beta = 0.339$; $r^2 = 0.115$).

Pitting is negatively correlated with height ($p < 0.05$); shorter women have more pronounced pitting. However, in multivariate models, height does not add significant predictive power. When analyses are confined to women age 50 or younger ($n = 88$), the relationship of pitting and height is not statistically significant. Pitting also may be affected by pubic shape; those with the most severe pitting tend to have somewhat shorter pubic bones and obtuse arcuate angles, although in multivariate models these variables do not explain more of the variation.

When the sample is examined by the number of births, those women with more reported births tend to be older and slightly heavier (Table 4). Tubercle height, tubercle distance, and arcuate angle do not seem to affect or reflect birth rates.

Discussion

This study fails to support the relationship between pubic tubercle height and number of births, as previously suggested by Cox and Scott (5). Instead, pubic tubercle height appears to reflect other factors, including distance of the tubercle from the symphyseal face and the acuteness of the arcuate angle. This suggests that women in whom the arcuate angle is obtuse but who have long pubic bones are more prone to enhancement of the tubercle. In the parity ranges observed in most contemporary forensic populations, tubercle height does not provide a reliable assessment of parity. Consequently, tubercle height should not be used to assess parity information.

As reported previously (11), dorsal pits were found to be associated with a greater number of reported births. Age also appears to be an important factor in the development of pitting. However, when age and number of births are considered together, number of births is the strongest predictor of dorsal pitting stage. This approach, however, masks considerable variation within the sample. Dorsal pitting in individuals over the age of 50 is most closely related to BMI, while number of reported births is not significantly correlated with dorsal pitting. In this group of older individuals, ten individuals have dorsal pitting, yet have no reported births. In contrast, in women under 50 years old, dorsal pitting is strongly correlated to the number of reported births. However, 13 individuals in this group have no reported births, yet show dorsal pitting (though most of the pitting is concentrated in the lower stages). Changes to the pubic region are likely the result of the interplay of multiple factors and are not solely the result of parity. This study suggests that age and body size play an important role in the development of dorsal pits, with older individuals (>50 years old) with higher BMIs tending to develop more pitting. Even within the reproductive event, there are probably a number of factors that affect pit formation, including levels of relaxin production, interval since last pregnancy, infant sizes, obstetric practices, body shape, weight gain, and activity levels during pregnancy. Andersen (10) suggests that so-called parity indicators are the result of pelvic instability, which is more common in females than males. Since females have wider hips than males, but smaller articular surfaces at both the pubic symphysis and auricular surfaces, their pelves should be more prone to movement throughout their adult lives. Age-related changes in the development of pitting may be the result of changes in hormonal levels that occur at the end of childbearing years, which may affect pelvic stability directly or through bone loss in the immediate structural environment of the pubic joint.

Since the present study was confined to the extracted pubic symphysis itself, greater pelvic dimensions could not be assessed. Previous studies have indicated that in females certain measures of pelvic size, such as the diameter of the pelvic inlet, are positively correlated with stature, although the overall strength of the relationships is low (13,14). However, although some measures of female pelvic size do increase with stature, other measures of pelvic size are not significantly correlated with stature (15,16). Other studies indicate that female pelvic dimensions are significantly correlated with several other measures of body size, namely body weight, femoral head diameter, and biacromial diameter (16–18). A recent study by Tague (19) concludes that clavicular length (an indicator of torsal breadth) and femoral head diameter (a proxy for body weight) are more broadly linked to pelvic size than femoral length (an indicator of stature). These results combined with the results of the present study suggest that differences in shape may oc-

TABLE 4—*Means (SD) by parity groups.*

Birth Group	*N*	Age	Height	Weight	BMI	R Tubercle Height	L Tubercle Height	R Tubercle Distance	L Tubercle Distance	Arcuate Angle
0 births	49	38.2 (21.1)	165.3 (6.3)	61.1 (10.3)	22.4 (3.8)	1.9 (1.5)	2.3 (1.6)	23.6 (4.2)	24.0 (4.4)	91.3 (12.2)
1–2 births	50	43.2 (19.7)	164.2 (8.7)	59.6 (13.6)	22.1 (4.6)	2.7 (1.5)	2.5 (1.5)	24.9 (3.7)	25.2 (3.5)	93.5 (11.1)
3–4 births	28	52.0 (22.7)	161.3 (8.0)	69.7 (25.3)	25.7 (7.6)	2.1 (1.6)	2.1 (1.3)	25.9 (3.9)	25.5 (3.9)	92.5 (9.6)
5+ births	20	54.4 (16.1)	163.0 (7.1)	62.7 (18.9)	23.5 (6.5)	2.5 (1.4)	2.5 (1.1)	23.3 (6.8)	23.3 (6.9)	91.8 (17.0)

cur, but that increases in linear growth of the limbs and overall stature may not directly translate into increased pelvic diameter.

In the matter of dorsal pits, the placement of the soft tissue associated with the pits and pressure from surrounding structures may be a critical factor. Future studies are needed to understand the interplay of variables involved in the formation of dorsal pits. While this study lends support to the correlation of dorsal pitting and parity, especially in younger women, it currently does not reach the level of accuracy needed for forensic applications at the level of the individual.

Acknowledgments

We thank William Leonard and Lauren Rockhold Zephro for comments on the paper. In addition, we thank the Los Angeles County Coroner's Office for providing access to the pubic bone collection.

References

1. Stewart TD. Distortion of the pubic symphyseal surface in females and its effect on age determination. Am J Phys Anthropol 1957;15(1):9–18.
2. Stewart TD. Identification of the scars of parturition in the skeletal remains of females. In: Stewart TD, editor. Personal identification in mass disasters. Washington, DC: Smithsonian Press, 1970;127–35.
3. Ullrich H. Estimation of fertility by means of pregnancy and childbirth alterations at the pubis, the ilium, and the sacrum. Ossa 1975;2:23–39.
4. Bergfelder T, Herrmann B. Estimating fertility on the basis of birth traumatic changes in the pubic bone. J Hum Evol 1980;9:611–3.
5. Cox M, Scott A. Evaluation of the obstetric significance of some pelvic characters in an 18th century British sample of known parity status. Am J Phys Anthropol 1992;89:431–40.
6. Galloway A. Determination of parity from the maternal skeleton: an appraisal. Riv di Anthropol (Roma) 1995;73:83–98.
7. Gilbert BM, McKern TW. A method for aging the female os pubis. Am J Phys Anthropol 1973;38:31–8.
8. Holt CA. A re-examination of parturition scars on the human female pelvis. Am J Phys Anthropol 1978;49:91–4.
9. Kelley MA. Parturition and pelvic changes. Am J Phys Anthropol 1979;51:541–6.
10. Andersen BC. Parturition scarring as a consequence of flexible pelvic architecture [dissertation]. Burnaby: Simon Fraser University, 1986.
11. Suchey JM, Wiseley D, Green RF, Noguchi TT. Analysis of dorsal pitting in the os pubis in an extensive sample of modern American females. Am J Phys Anthropol 1979;51:517–40.
12. Wilcox D, Dove B, McDavid D, Greer D. UTHSCSA ImageTool for Windows, Version 1.27. San Antonio: University of Texas Health Science Center in San Antonio, 1997.
13. Holland EL, Cran GW, Elwood JH, Pinkerton JHM, Thompson W. Associations between pelvic anatomy, height and year of birth of men and women in Belfast. Ann Hum Biol 1982;9:113–20.
14. Adadevoh SWK, Hobbs C, Elkins TE. The relation of the true conjugate to maternal height and obstetric performance in Ghanaians. Int J Gynaecol Obstet 1989;28:243–51.
15. Moerman ML. A longitudinal study of growth in relation to body size and sexual dimorphism in the human pelvis [dissertation]. Ann Arbor: University of Michigan, 1981.
16. Walrath DE, Glantz MM. Sexual dimorphism in the pelvic midplane and its relationship to Neandertal reproductive patterns. Am J Phys Anthropol 1996;100:89–100.
17. Ince JGH, Young M. The bony pelvis and its influence on labour: a radiological and clinical study of 500 women. J Obstet Gynaecol Br Emp 1940;47:130–90.
18. Rosenberg KR. The functional significance of Neanderthal pubic length. Curr Anthropol 1988;29:595–617.
19. Tague R. Do big females have big pelves? Am J Phys Anthropol 2000;112:377–93.

Additional information and reprint requests:
J. Josh Snodgrass
Department of Anthropology
1810 Hinman Avenue
Northwestern University
Evanston, IL 60208
E-mail: j-snodgrass@northwestern.edu