J Forensic Sci, March 2009, Vol. 54, No. 2
doi: 10.1111/j.1556-4029.2008.00947.x
Available online at: www.blackwell-synergy.com

Stefano Benazzi,[1] Ph.D.; Claudia Maestri,[2] B.Sc.; Simona Parisini,[2] B.Sc.; Francesco Vecchi,[3] Prof.; and Giorgio Gruppioni,[2] Prof.

Sex Assessment from the Sacral Base by Means of Image Processing

ABSTRACT: To help improve sex assessment from skeletal remains, the present study considers the diagnostic value of the sacral base (basis osseus sacri) based on its planar image and related metric data. For this purpose, 114 adult sacra of known sex and age from two early 20th century Italian populations were examined, the first from Bologna, northern Italy (*n* = 76), and the second from Sassari, Sardinia (*n* = 38). Digital photos of the sacral base were taken with each bone in a standardized orientation. Technical drawing software was used to trace its profile and to measure related dimensions (area, perimeter, and breadth of S1 and total breadth of the sacrum). The measurements were subjected to discriminant and classification function analyses. The sex prediction success of 93.2% for the Bolognese sample, 81.6% for the Sassarese sample, and 88.3% for the pooled sample indicates that the first sacral vertebra is a good character for sex determination.

KEYWORDS: forensic science, forensic anthropology, sex assessment, sacrum, image analysis, discriminant analysis, human skeleton remains

Identification of sex from skeletal remains is one of the most important areas of information in bioarcheological and paleodemographic research (1–4) and in forensic anthropology (5–8). Procedures are usually based on visual analysis of sexually dimorphic cranial and pelvic traits. However, the visual approach could have serious limitations, consisting mainly in the high degree of subjectivity in the evaluation of these morphological traits, many of which have continuous variation (e.g., some pelvic features: great sciatic notch, S-form of the iliac crest, shape and sharpness of the rim of the obturator foramen, shape of the pelvic inlet) and thus not clearly referable to a male or female pattern when an intermediate aspect is observed.

New methods based on discriminant function analysis and mathematical models of sexually dimorphic bone traits have recently been proposed to obviate this limitation (9–12). Several studies have demonstrated the high discriminant power of numerous bone traits in the pelvic area; some considered the whole pelvis (13–15), others the os coxae (16) and sacrum independently (17–22). Flander (20) showed that the dimensions of the first sacral vertebra (anterior straight breadth of sacrum at the level of S1; transverse and antero-posterior diameter taken outside and inside the epiphyseal ring) are the most significant sacral traits for sex assessment. The most significant indices obtained by the combination of these measures were those based on the diameters of S1 and their ratio with the straight breadth of sacrum, which included the sacral alae.

The present study proposes a new method of sex assessment based on digital image processing of the sacral base (the broad and expanded upper face of the sacrum, with the upper surface of the body of the first sacral vertebra [S1] in the middle). The method, employing digital photographs associated with discriminant function analysis of derived variables, reduces the observer's subjective evaluations in the determination of sex. Two Italian populations were examined to test the reliability of the new system. In this way, it was possible to evaluate the potential uses of the new method for sex discrimination in different conditions. In fact, new methodologies are usually standardized on a single population, without knowledge of the results when applied to other populations. In our study, specific discriminant functions were obtained for two different populations, considered separately and pooled into a single population.

Materials

Two samples of well-preserved sacra from the Frassetto skeletal collection housed in the Museum of Anthropology, University of Bologna (Italy), were examined. The age at death (from 19 to 70 years old), sex, and provenience of these individuals were well documented by the cemetery archives.

The two samples refer to different Italian populations and represent individuals who died at the beginning of the 20th century: the first consisted of 76 sacra of Bolognese individuals (BO), 37 males and 39 females, coming from Bologna (northern Italy); the second consisted of 38 sacra of Sassarese individuals (SS), 20 males and 18 females, coming from Sassari (Sardinia). These two populations were chosen because of their morphological and morphometric differences: the individuals in the island sample (SS) were generally smaller than the Bolognese individuals. In total, 114 sacra were examined.

Methods

Each bone was placed on a sandy support and orientated according to a standard criterion (23): three bony landmarks were identified (the point on the promontory situated in the midsagittal plane and the two most laterally projecting points on the upper face of the body of S1); by means of a spirit level, the three points were set on a horizontal plane corresponding to a reference Cartesian

---

[1] Department of Palaeoanthropology and Messel Research, Senckenberg Research Institute, Frankfurt am Main 60325, Germany.

[2] Department of History and Methods for the Conservation of Cultural Heritage, University of Bologna, 48100 Ravenna, Italy.

[3] Department of Animal and Human Biology, University of Rome "La Sapienza," 00185 Roma, Italy.

Received 4 Mar. 2008; and in revised form 18 April 2008; accepted 20 April 2008.

plane whose y-axis was perpendicular to the straight line passing through the two lateral points. The lengths of both Cartesian axes were conventionally established as 13 cm (Fig. 1).

A stand-mounted Olympus c 4000 digital camera (4.0 megapixels) with an Olympus AF ZOOM 6.5–19.5 mm 1:2.8 lens and optical axis orthogonal to the reference metric plane was used to take the photos. The camera's LCD monitor was used to compose the photos and control for camera parallax. Without using the zoom, we set the digital camera at a fixed distance (300 mm) so that the reference system was included in the LCD monitor. As all photos had the same orientation criterion and reference system, we used technical drawing software (AutoCAD LT 2.0) to create a grid of analogous dimensions; each photo was transferred into AutoCAD and re-sized by matching the two opposite points of the reference system in the photo with the two homologous points of the grid created in AutoCAD.

For each photo superimposed on the grid, we traced the original profile of the sacral base without considering deviations due to osteophytic processes. The latter phase was carried out with the poly-line function of the software. The trace followed the full extent of the rim of the sacral base and provided a closed profile (Fig. 2). The following metric data were collected:

- Maximum transverse diameter (m.t.d.) of S1: distance between the two most laterally projecting points on the body of S1 measured perpendicular to the midsagittal plane (24);
- Maximum superior breadth (m.s.b.) of sacrum: maximum transverse distance between the most lateral parts of the sacral alae measured perpendicular to the midsagittal plane;
- Area of the upper face of the body of the first sacral vertebra (S1 area);
- Perimeter of the body of the first sacral vertebra (S1 perimeter).

To determine the accuracy of the measurements taken on the photos of 10 sacra (in CAD), we compared the values of m.t.d. and m.s.b. with those taken on the original specimens using a 200 mm Mitutoyo Digimatic Absolute caliper (Mitutoyo Corporation, Aurora, IL). There were no significant differences between the results of the two measurement techniques (Table 1). To evaluate inter- or intra-observer error, two operators digitized the vertebral profile five times on each of five sacra at different times. There were no significant differences in the values of the four variables (Table 2).

The data were analyzed by discriminant analysis using SPSS version 11.5 for Microsoft Windows (SPSS Inc., Chicago, IL). Cross-validation analysis was carried out to verify the results. This analysis repeatedly divides the sample into three subsamples and constructs specific models based on them: each model is constructed from two subsamples and is then used to classify the cases of the subsample not used to generate the model. In this way, a single final model is constructed whose estimation of the "classification error" is given by the mean value of the individual results obtained from the various models. The data were initially considered separately as two different populations and then pooled to determine the discriminant power of the metric data in both intra- and inter-population contexts.

To assess the utility of the method applied to sacra from archeological excavations, we used the discriminant equation with three variables (S1 area, S1 perimeter, and m.t.d.) obtained by pooling the Bolognese and Sassarese samples (BO + SS) to determine the sex of 12 individuals from an early medieval necropolis in northern Italy (Casalmoro near Mantua) (VI–VII century AD) whose sex had been determined from the sexual characters of the skull and pelvis (1,2). The previously described procedures were used to measure the osteometric variables of the sacrum. In some cases, it

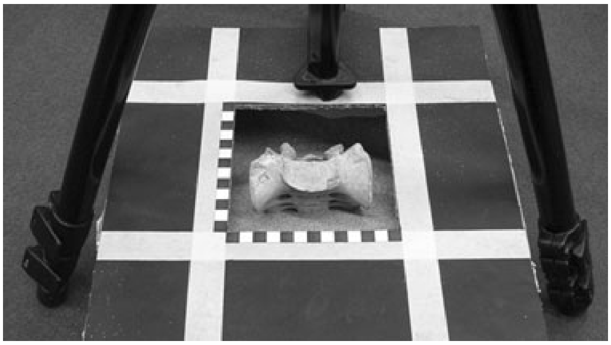

FIG. 1—*Reference system in which the sacrum is positioned. The upper face of the body of S1 is parallel to the reference Cartesian plane.*

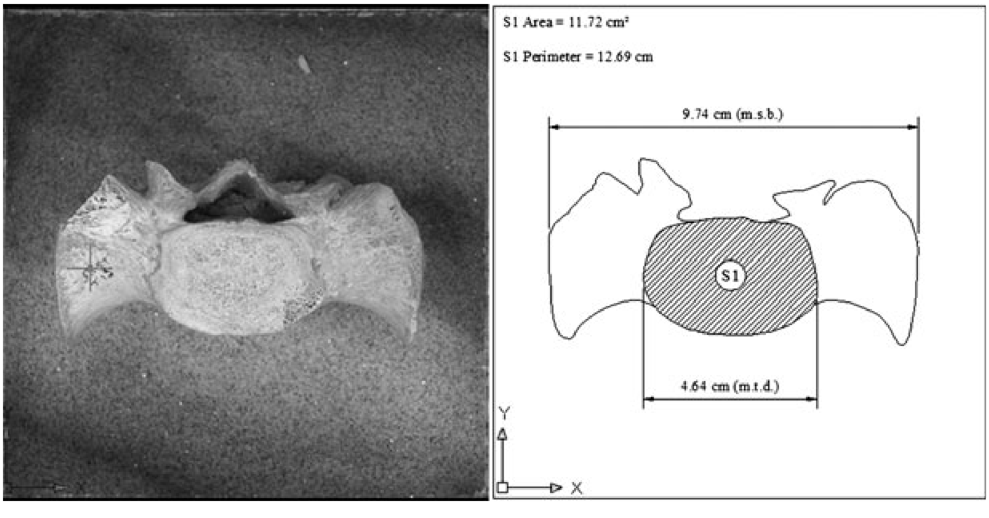

FIG. 2—*Example of the profile of the sacral base, with the four variables (S1 area, S1 perimeter, m.t.d., m.s.b.).*

TABLE 1—*Independent-sample test to evaluate the difference between the values of maximum transverse diameter (m.t.d.) and maximum superior breadth (m.s.b.) measured with the caliper and with CAD.*

Variable	Method	*n*	Mean*	SD*	*t*	Significance
m.t.d.	Caliper	10	4.599	0.412	0.065	0.949
	CAD	10	4.587	0.417		
m.s.b.	Caliper	10	11.262	0.789	0.152	0.881
	CAD	10	11.208	0.803		

*Measurements in centimeters.

TABLE 2—*Test to evaluate intra- or inter-observer error.*

			Observer 1		Observer 2		Inter-observer Error	
Sample	*n**	Variable	Mean	SD	Mean	SD	*t*	Significance†
1	5	S1 area	9.540	0.053	9.520	0.007	0.830	0.430
	5	S1 perimeter	11.392	0.036	11.390	0.016	0.115	0.912
	5	m.t.d.	3.990	0.022	3.992	0.016	−0.161	0.876
2	5	S1 area	11.746	0.029	11.752	0.033	−0.308	0.766
	5	S1 perimeter	12.704	0.017	12.732	0.029	−1.888	0.096
	5	m.t.d.	4.644	0.022	4.660	0.012	−1.425	0.192
3	5	S1 area	10.534	0.067	10.484	0.054	1.303	0.229
	5	S1 perimeter	11.920	0.037	11.898	0.030	1.021	0.337
	5	m.t.d.	4.350	0.035	4.316	0.011	2.047	0.075
4	5	S1 area	10.932	0.070	10.902	0.016	0.936	0.377
	5	S1 perimeter	12.466	0.049	12.434	0.011	1.414	0.195
	5	m.t.d.	4.336	0.023	4.360	0.012	−2.058	0.074
5	5	S1 area	11.610	0.033	11.612	0.025	−0.108	0.917
	5	S1 perimeter	12.618	0.027	12.624	0.018	−0.414	0.690
	5	m.t.d.	4.558	0.018	4.552	0.008	0.679	0.516

*Number of profiles.
†Independent-samples *t*-test (two-tailed).

was necessary to virtually reconstruct part of the profile of the body of S1 (by interpolation), although this was limited to less than a quarter of its perimeter (Fig. 3).

Results

Table 3 presents the means and corresponding standard deviations of the sacral base variables (area, perimeter, m.t.d. of S1, and m.s.b. of sacrum) used in the discriminant function analysis for sex prediction. The data are related to the Bolognese (BO) and Sassarese (SS) samples and also to the pooled sample.

To test the relative contribution of each independent variable, we calculated Wilks' lambda and its related F value (Table 4). The data differ significantly between the sexes for each sacral base variable. Thus, each variable has a high sex-discriminant value, even though the most significant ones are area and perimeter of S1; their Wilks' lambda scores are nearly the same in both single-population samples and in the pooled one. Canonical correlation analysis was then performed to establish the relationship between the sets (male and female) of variables (Table 5). The eigenvalue of the function is higher for the Bolognese sample (2.27) than for the Sassarese one (0.95), showing that the discriminant function classifies the dependent variables of the first group more correctly than those of the second one. The Wilks' lambda score, obtained from a multivariate significance test, offers additional evidence.

Fisher's linear discriminant function was used to determine the efficiency of the discriminant function (Table 6). Comparison of the known data for the sacral base samples with the data predicted by the discriminant function showed variable sex prediction success. Sex was correctly assigned in 93.2% of cases for the Bolognese sample using a discriminant function analysis of all four variables, although this value decreased slightly after the cross-validation analysis (90.4%) (Table 7). When we used a discriminant function analysis of the three variables related to S1 (area, perimeter, m.t.d.), the percentage decreased only slightly (92.1%) and the result of the cross-validation analysis remained virtually the same (90.8%); moreover, the percentage did not change when only the perimeter and m.t.d. were used. Area of S1 was the best single discriminator, with an accuracy of 86.9%, followed by perimeter (85.7%) and m.t.d. (81.5%).

In the Sassarese sample, the sex prediction success was 81.6% with a discriminant function analysis of four variables, although the percentage of correct classification was lower after the cross-validation analysis (73.7%). The percentage increased (84.2%) when m.s.b. of the sacrum was omitted from the discriminant function, an improvement shown also by the cross-validation analysis (76.3%) (Table 8).

When the two samples were pooled (BO + SS), the discriminant function analysis based on four variables showed a sex prediction success of 88.3%; the percentage decreased only slightly after the

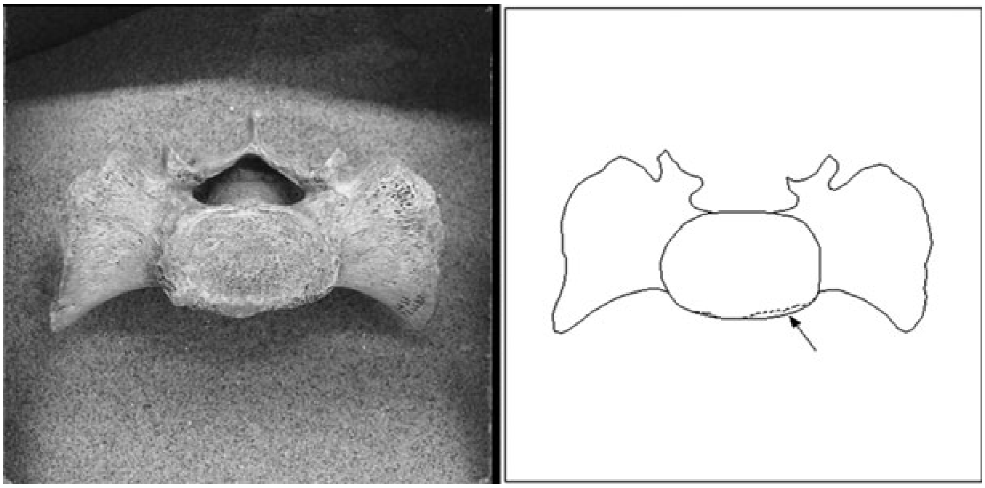

FIG. 3—*Left: sacrum with osteophytic processes and partial destruction of S1 in the left anterior portion. Right: digital reconstruction of the missing part (see arrow).*

TABLE 3—*Measurements of the sacrum (BO, SS, BO + SS)—univariate statistics.**

	Males (BO)			Females (BO)			Males (SS)			Females (SS)			Males (BO + SS)			Females (BO + SS)		
Variable	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
S1 area	35	14.09	1.52	38	10.35	1.42	20	12.14	1.64	18	9.95	1.07	55	13.38	1.82	56	10.22	1.32
S1 perimeter	35	13.92	0.75	38	11.88	0.89	20	13.11	0.95	18	11.76	0.72	55	13.63	0.91	56	11.84	0.83
m.t.d.	35	5.07	0.33	38	4.41	0.39	20	4.86	0.40	18	4.34	0.37	55	5.00	0.37	56	4.39	0.38
m.s.b.	35	11.51	0.53	38	11.44	0.56	20	10.74	0.63	18	10.79	0.54	55	11.23	0.68	56	11.23	0.63

*All dimensions in centimeters.

TABLE 4—*Stepwise discriminant function analysis (BO, SS, BO + SS).*

	BO					SS					BO + SS				
Variable	Wilks' Lambda	F Ratio	d.f. 1	d.f. 2	Significance	Wilks' Lambda	F Ratio	d.f. 1	d.f. 2	Significance	Wilks' Lambda	F Ratio	d.f. 1	d.f. 2	Significance
S1 area	0.38	117.65	1	71	0.000	0.61	23.05	1	36	0.000	0.50	109.62	1	109	<0.001
S1 perimeter	0.39	111.13	1	71	0.000	0.60	24.10	1	36	0.000	0.48	116.16	1	109	<0.001
m.t.d.	0.54	60.81	1	71	0.000	0.68	17.01	1	36	0.000	0.60	72.54	1	109	<0.001
m.s.b.	1.00	0.31	1	71	0.578	1.00	0.06	1	36	0.806	1.00	0.00	1	109	0.995

TABLE 5—*Canonical discriminant function (BO, SS, BO + SS).*

Group	Discriminant Function No.	Eigenvalue	% of Variance	Canonical Correlation	Wilks' Lambda	Chi-squared	d.f.	Significance
BO	1	2.27	100	0.83	0.31	81.75	4	<0.001
SS	1	0.95	100	0.70	0.51	22.76	4	<0.001
BO + SS	1	1.60	100	0.78	0.39	102.02	4	<0.001

TABLE 6—*Fisher's linear discriminant functions.*

	BO		SS		BO + SS	
Variable	Males	Females	Males	Females	Males	Females
Classification function coefficients—four variables						
S1 area	−64.68	−65.42	−149.44	−149.39	−77.00	−76.90
S1 perimeter	147.32	141.12	384.72	381.01	186.40	180.46
m.t.d.	−58.27	−48.65	−340.51	−337.84	−111.24	−104.64
m.s.b.	29.17	31.37	51.72	53.52	28.80	30.94
Constant	−590.69	−572.62	−1066.17	−1052.22	−639.54	−620.21
Classification function coefficients—three variables						
S1 area	−67.80	−68.41	−122.22	−121.23	−70.91	−70.21
S1 perimeter	169.22	164.04	323.46	317.63	188.58	182.48
m.t.d.	−78.39	−70.44	−257.79	−252.24	−115.96	−109.70
Constant	−502.47	−466.07	−753.09	−716.99	−521.70	−481.65

TABLE 7—*Classification results—BO (four variables).*

			Predicted Group Membership		
		Group	Males	Females	Total
Original	Count	Males	32	3	35
		Females	2	36	38
	%	Males	91.43	8.57	100
		Females	5.26	94.74	100
Cross-validated	Count	Males	31	4	35
		Females	3	35	38
	%	Males	88.57	11.43	100
		Females	7.89	92.11	100

93.20% of original grouped cases correctly classified.
90.40% of cross-validated grouped cases correctly classified.

TABLE 8—*Classification results—SS (three variables).*

			Predicted Group Membership		
		Group	Males	Females	Total
Original	Count	Males	15	5	20
		Females	1	17	18
	%	Males	75	25	100
		Females	5.56	94.44	100
Cross-validated	Count	Males	14	6	20
		Females	3	15	18
	%	Males	70	30	100
		Females	16.67	83.33	100

84.20% of original grouped cases correctly classified.
76.30% of cross-validated grouped cases correctly classified.

TABLE 9—*Classification results—BO + SS (four variables).*

			Predicted Group Membership		
		Group	Males	Females	Total
Original	Count	Males	48	7	55
		Females	6	50	56
	%	Males	87.27	12.73	100
		Females	10.71	89.29	100
Cross-validated	Count	Males	47	8	55
		Females	7	49	56
	%	Males	85.45	14.55	100
		Females	12.50	87.50	100

88.30% of original grouped cases correctly classified.
86.50% of cross-validated grouped cases correctly classified.

cross-validation analysis (86.5%) (Table 9). The final results did not change substantially when m.s.b. was excluded from the analysis, i.e., when only the three variables on the upper face of the body of S1 were used (86.0% correct classification; 85.1% after the cross-validation analysis). Finally, it should be mentioned that the data were also analyzed after square root transformation (i.e., area was considered as a quadratic dimension), but this procedure did not significantly alter the results.

The proposed method was then tested in the sex assessment of 12 skeletons from the early medieval necropolis of Casalmoro (Mantua—northern Italy). As some of the sacra were damaged and thus often lacked part of the alae, we used the three-variable equation obtained from the pooled sample (BO + SS) (see Table 6). The resulting sex diagnoses were compared with the diagnoses made by the traditional method (Table 10). In 10 of the 12 cases (83.3%), the discriminant function yielded the same results as the traditional methods.

Discussion and Conclusion

Several authors have demonstrated the diagnostic value of the sacrum (morphological and metric data) for sex determination from skeletal remains. Flander (20) analyzed samples belonging to two American populations, one of blacks and the other of whites, recording six measurements of the sacrum and using them as variables for discriminant function analysis. The transverse diameter of S1 showed remarkable discriminant power and the accuracy of sex assessment was high (91% for blacks and 84% for whites). Unfortunately, however, this study was limited to measurements of complete sacra, which are rare in archeological contexts.

TABLE 10—*Comparison of the sex assessment results obtained with the traditional method and with the discriminant function analysis in a medieval sample from the Casalmoro necropolis (Mantua—northern Italy).*

						Discriminant Function*		
Sample	Sex[†]	Age	S1 area	S1 perimeter	m.t.d.	Males	Females	Sex[‡]
T2	F	36	10.73	12.05	4.37	487.545	488.701	F
T7	F	33	9.56	11.29	4.13	450.554	454.281	F
T27	F	46	11.34	12.30	4.36	488.129	488.381	F
T29	F	37	10.18	11.77	4.43	462.320	465.431	F
T3	M	40	10.70	11.91	4.25	472.721	474.215	F
T4	M	39	13.54	13.80	5.13	525.708	523.170	M
T13	M	56	12.13	12.76	4.62	488.707	488.334	M
T26	M	23	10.06	11.69	4.20	482.414	484.489	F
T43	M	20	13.47	13.70	5.05	521.090	518.612	M
T45	M	49	13.43	13.73	5.31	499.435	498.373	M
T52	M	51	12.33	12.97	4.71	503.691	502.739	M
T53	M	21	13.21	13.79	5.27	530.988	529.156	M

*Fisher's linear discriminant function = BO + SS (three variables).

[†] Results obtained with the traditional anthropological method based on sexual traits of the skull and pelvis.

[‡] Results obtained with Fisher's linear discriminant function.

In our study, we considered four variables of the sacral base, but only the three related to S1 (area, perimeter, and m.t.d. of S1) showed high sex discrimination potential; m.s.b. of sacrum was not very useful for sex prediction. A discriminant function analysis of the three variables of S1 yielded a prediction accuracy of 92.1% for the Bolognese sample and 84.2% for the Sassarese sample. These percentages are comparable to those of Flander (20), but the main difference is that a complete sacrum is not necessary with our method and accurate sex determination can be achieved with only S1. Our study also illustrates the utility of image processing in sex-determination studies, as it allows precise, quantitative measurements of sexually dimorphic bone traits (e.g., area and perimeter of S1).

The high accuracy of sex assessment (88.3%) in the pooled sample suggests that discriminant analysis of these sacral base traits is a valid method to estimate the sex of skeletal remains from a range of populations. The discriminant power of Fisher's equation with three variables obtained from the pooled sample of sacra (BO + SS) is confirmed by the satisfactory results of its application to sacra from archeological excavations. In 83.3% of the cases, it yielded the same results as the traditional sex assessment method. However, the proposed method is not meant to replace the traditional anthropological procedures based on the sexual traits of the skull and pelvis; instead, it is a useful tool when those parts of the skeleton are missing but the sacrum is present (even if incomplete).

Acknowledgment

This work was supported by EU Marie Curie Training Network MRTN-CT-2005-019564 EVAN.

References

1. Acsàdi G, Nemeskéri J. History of human life span and mortality. Budapest: Akadémiai Kiadò, 1970.
2. Ferenbach D, Schwidetzky I, Stloukal M. Recommendations for age and sex diagnosis of skeletons. J Hum Evol 1980;9:517–50.
3. Greene DL, Van Gerven DP, Armelagos GJ. Life and death in ancient populations: bones of contention in paleodemography. J Hum Evol 1986;1:193–207.
4. Buikstra JE, Ubelaker DH. Standards for data collection from human skeletal remains. Research series, no. 44. Fayetteville: Arkansas Archaeological Survey Press, 1994.
5. Krogman WM, Işcan MY. The human skeleton in forensic medicine. Springfield: Charles C. Thomas Publisher, 1986.
6. Işcan MY, Kennedy KAR. Reconstruction of life from the skeleton. New York: Alan R. Liss, 1989.
7. France DL. Observational and metric analysis of sex in the skeleton. In: Reichs KJ, editor. Forensic osteology. Advances in the identification of human remains. Springfield: CC Thomas Publisher Ltd, 1998;163–86.
8. Cox M, Mays S. Human osteology in archaeology and forensic science. London: Greenwich Medical Media Ltd, 2000.
9. Gonzalez-Reimers E, Velasco-Vazquez J, Arnay de la Rosa M, Santolaria Fernandez F. Sex determination by discriminant function analysis of the right tibia in the prehispanic population of the Canary Islands. Forensic Sci Int 2000;108:165–72.
10. Mall G, Graw M, Gehring KD, Hubig M. Determination of sex from femora. Forensic Sci Int 2000;113:315–21.
11. Murphy AMC. Articular surfaces of the pectoral girdle: sex assessment of prehistoric New Zealand Polynesian skeletal remains. Forensic Sci Int 2002;125:134–6.
12. Kemkes-Grottenthaler A. Sex determination by discriminant analysis: an evaluation of the reliability of patella measurements. Forensic Sci Int 2005;147:129–33.

13. Iordanidis P. Détérmination du sexe par les os du squelette (os coxal et sacrum). Ann Med Leg 1961;41:280–91.
14. Rogers T, Saunders S. Accuracy of sex determination using morphological traits of the human pelvis. J Forensic Sci 1994;39:1047–56.
15. Bruzek J. A method for visual determination of sex using the human hip bone. Am J Phys Anthropol 2002;117:157–68.
16. Genovés S. L'estimation des différences sexuelles dans l'os coxal; différences métrique et différences morphologiques. Bull Mém Soc Anthropol Paris 1959;10:3–95.
17. Trotter M. The sacrum and sex. Am J Phys Anthropol 1926;9:445–50.
18. Fawcett E. The sexing of the human sacrum. J Anat 1938;72:633–44.
19. Stradalova V. Sex differences and sex determination on the sacrum. Anthropologie 1975;13:237–44.
20. Flander LB. Univariate and multivariate methods for sexing the sacrum. Am J Phys Anthropol 1978;49:103–10.
21. Kimura K. A base-wing index for sexing the sacrum. J Anthropol Soc Nippon 1982;90(Suppl.):153–62.
22. Moore-Jansen PH, Plochocki JH. Morphometric variation and sex determination in the human sacrum. Am J Phys Anthropol 1999;28(Suppl.):205–6.
23. Testa-Bappenheim I. Sull'osso sacro appartenente ai resti umani fossili già rinvenuti S. Teodoro (Messina), studiato con metodo perigrafico. Riv Antrop 1962;49:177–92.
24. Moore-Jansen PH, Ousely SD, Janz RL. Data collection procedures for forensic skeletal material, 3rd ed. Knoxville (Tennessee): University of Tennessee Forensic Anthropology Series, 1994.

Additional information and reprint requests:
Stefano Benazzi, Ph.D.
Department of Palaeoanthropology and Messel Research
Senckenberg Research Institute
Senckenberganlage 25
Frankfurt am Main 60325
Germany
E-mail: sbenazzi@senckenberg.de