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SHAPE ANALYSIS OF *INCISURA ISCHIADICA MAJOR* IN SEXING THE HUMAN PELVIS

ABSTRACT: The problem of correctly sexing unknown skeletal material is given by the contradiction between the discrete classification according to genetically determined sex and the continuous transitions of somatic sexual characters of the phenotype. This is true for pelvic bones also, despite the fact that they are the most sexually differentiated bones of the skeleton.

The combination of metric characteristics of the two fundamental subsystems of os coxae *(ischiopubic and sacroiliac) is not only necessary but is also sufficient for a multivariate discriminant analysis which separates completely the two sexes in a recent population.*

The discriminant functions obtained by using the metric characteristics of the individual pelvic segments are less successful, namely in the sacroiliac segment.

To improve this result, keeping in mind the problem of sexing in unknown and partial pelvises, we have analyzed a sample of incisurae *by using, instead of metric data, shape parametrical descriptions of the boundaries through Fourier analysis.*

In this work 97 male and 98 female os coxae *were considered; the material, of known sex, was of Czech and German origin, dated to the last century (about 1880-1980) from the collections of Institutes of Anatomy in Prague and Brno.*

Data acquisition and treatment were performed by means of S.A.M. (Shape Analytical Morphometry) software-system; the system is constituted by an integrated architecture of analytical procedures which allow a complete description of the shape in two-dimensional objects.

The boundaries to be described, dimensionally normalized and standardized for the position, are decomposed by the analysis in series of sine/cosine coefficients (from which amplitude and phase angle are obtained) for a finite number of sinusoidal harmonics; these data are then used in performing multivariate discriminant analysis to set linear functions efficacious in distinguishing the male and female groups.

Having used various combinations of variables, the degree of correct attribution reached 97% of all cases.

The morphological features, more informative in determining the correct sex attribution, are then identified and discussed on the basis of the obtained results.

KEY WORDS: Sex determination – Pelvic bone – Fourier analysis – Incisura ischiadica major

INTRODUCTION

The problem of accurate sex determination on skeletal remains is complicated by the contradiction between the discrete classification according to genetically determined sex and the quasi-continuous variation of somatic sexual characters of the phenotype. While a simple analysis of sex differences, often, shows a certain overlapping of the two sexes, both in their size and shape, a normal human is either a man or a woman. Thus, the problem confronting the osteologist/paleoanthropologist is often how to determine the true sex of specimens with mixed male and female features. This is true for pelvic bones also, despite the fact that they are the most sexually differenciated bones of the skeleton.

Thanks to its expansive development (i.e. multidirectional, multidimensional and multifactorial growth and uneven timing of development) the bony pelvis appears as a complicated, hierarchically integrated system and simultaneously as an intersection point of various factors determining the skeletal sexual dimorphism (locomotion, reproduction, cultural evolution).

The single pelvic bone (*os coxae*) can be divided into two evolutionary, functional and causally relatively independent sub-systems, namely the ischiopubic and sacroiliac segment.

The ischiopubic segment reflects well the phylogenetic adaptation of the female small pelvis to the mechanical conditions of parturition with a relatively large foetus. The ontogenetic development of this segment is controlled by hormones. The sexual difference is caused by the remodelling of the feminine small, i.e. obstetric pelvis into an adequately spatious birth canal first of all by pubis elongation during puberty. The most representative character of the small pelvis is the ratio of the longitudinal dimensions of the pubis and the ischium.

The sacroiliac segment reflects the sexually differentiated process of hominization: adaptation to the verticalization of the bony and bipedal locomotion. Dorsal extension and downward shift of the ilium is advanced further in males than in females where necessarily dimensions of the pelvic cavity have to be preserved. Because of the greater weight in males, the greater sciatic notch is even more expressed with the downward tendency of the ilium. In females, the sciatic notch remains at a lower developmental stage, sometimes forming only a flat arch.

This greater sciatic notch (*incisura ischiadica major*) as a whole is the most representative character of the sacroiliac segment. The sexually dimorphic shape of the notch is inborn and seems to be under direct genetic control, but the degree of its expression is influenced by local factors.

The combination of the representative characters of the two basic sub-systems is not only necessary but is also sufficient for a multivariate discriminant analysis which separates completely the two sexes in a recent population.

The discriminant functions obtained by using the individual pelvic segments are less successful, namely in the sacroiliac segment. From these presented examples of discriminant functions based on the dimensions of sciatic notch only, the zone of overlapping of the discriminant scores of both sexes regarding the 35% of the studied data cases is apparent (Novotný 1980, 1984).

In some females the pubic bone is markedly elongated while the sciatic notch shows excessive narrowing. The reduction of the sacroiliac segment is compensated for by extension of the ischiopubic segment. According to the principle of equifinality any of the main pelvic sub-systems appears to be capable of compensating for the possible deficiency of the opposite sub-system in order to preserve the basic function of the system of a higher order, i.e. spaciousness of the birth canal in the present case (Novotný, Vančata 1985).

In these cases metric analysis fails completely.

Because of this kind of problem in determining sex Novotný (1980) focused attention on studying only the shape of the *incisura*. In order to derive the shape types characteristic of one sex only, regardless of absolute size and concrete variability, a special type of logical analysis of an idealized shape was used. The idealized shape was derived and scored from those characteristics of the *incisura* profile that did not contradict each other: in males the *incisura ischiadica major* in contrast with the opposite sex is always narrower, deeper, more closed and the shorter superior arm has recurvate course; in females the *incisura* on the contrary is wider, shallower, more open and its equally long arms diverge symmetrically forming a parabolic arch. The key sex difference for the sciatic notch is its superior arm behaviour. The shape variability based on the scoring of form according the "ideal shape analysis" principles is great, given that only 70 % of correct sex attribution is obtained (Novotný 1980).

To improve this result, keeping in mind the problem of sexing in unknown and partial pelvises, we started to study the same samples of *incisurae*, on which the dimensional analysis and the "ideal shape analysis" had been carried out, using shape parametrical descriptions based on the logic of the S.A.M. (Shape Analytical Morphometry) software system (Pesce Delfino, Ricco 1983).

For a pilot study a reduced sample of pelvic bones were selected covering the full range of variability of the *incisura* according to Novotný's "ideal shape analysis". Encouraging preliminary results (Novotný *et al.* 1993) suggested an extension of the analysis to a larger sample.

MATERIALS AND METHODS

In this work 97 male and 98 female *os coxae* were studied. The material, of known sex, was of Czech and German origin, dated to the last century (about 1880-1980) from the collections of Anatomical Institutes in Prague and Brno.

The acquisition and the analytical data processing was performed by using S.A.M. system. The system is constituted by an integrated architecture of analytical procedures which allow a complete description of the shape in two-dimensional objects. For this work, mainly the section dedicated to the description of open curves using the trigonometric interpolation according to Fourier polynomial was used (Pesce Delfino *et al.* 1990, 1991, 1997).

The Fourier harmonic analysis, based on the trigonometric polynomial, involves the use, as the dependent variable, of a series of distance values, the

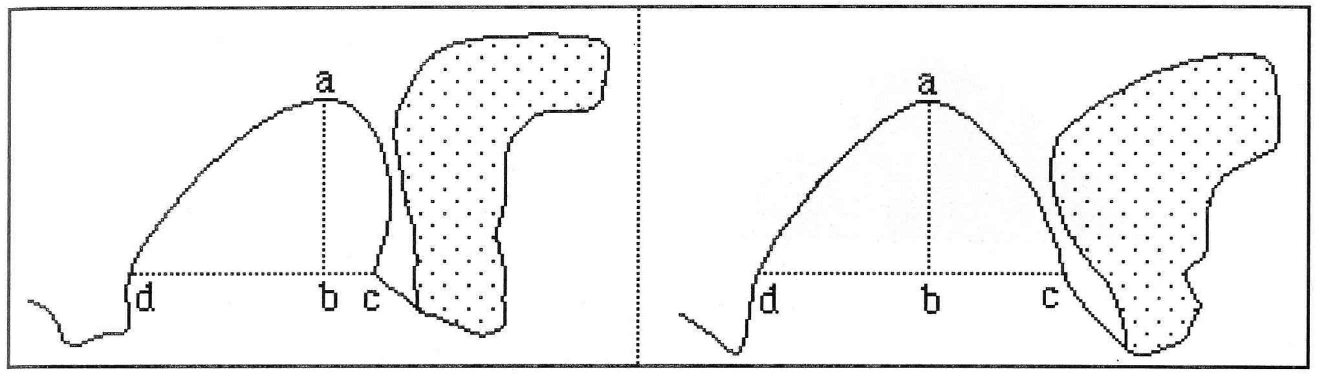

FIGURE 1. A male and a female *incisura* sample; the points used for the positioning (c and d) and the segment adopted for dimensional normalization (a – b) are reported. The examined traits were the latero-superior (a – c) and the latero-inferior (a – d) rami.

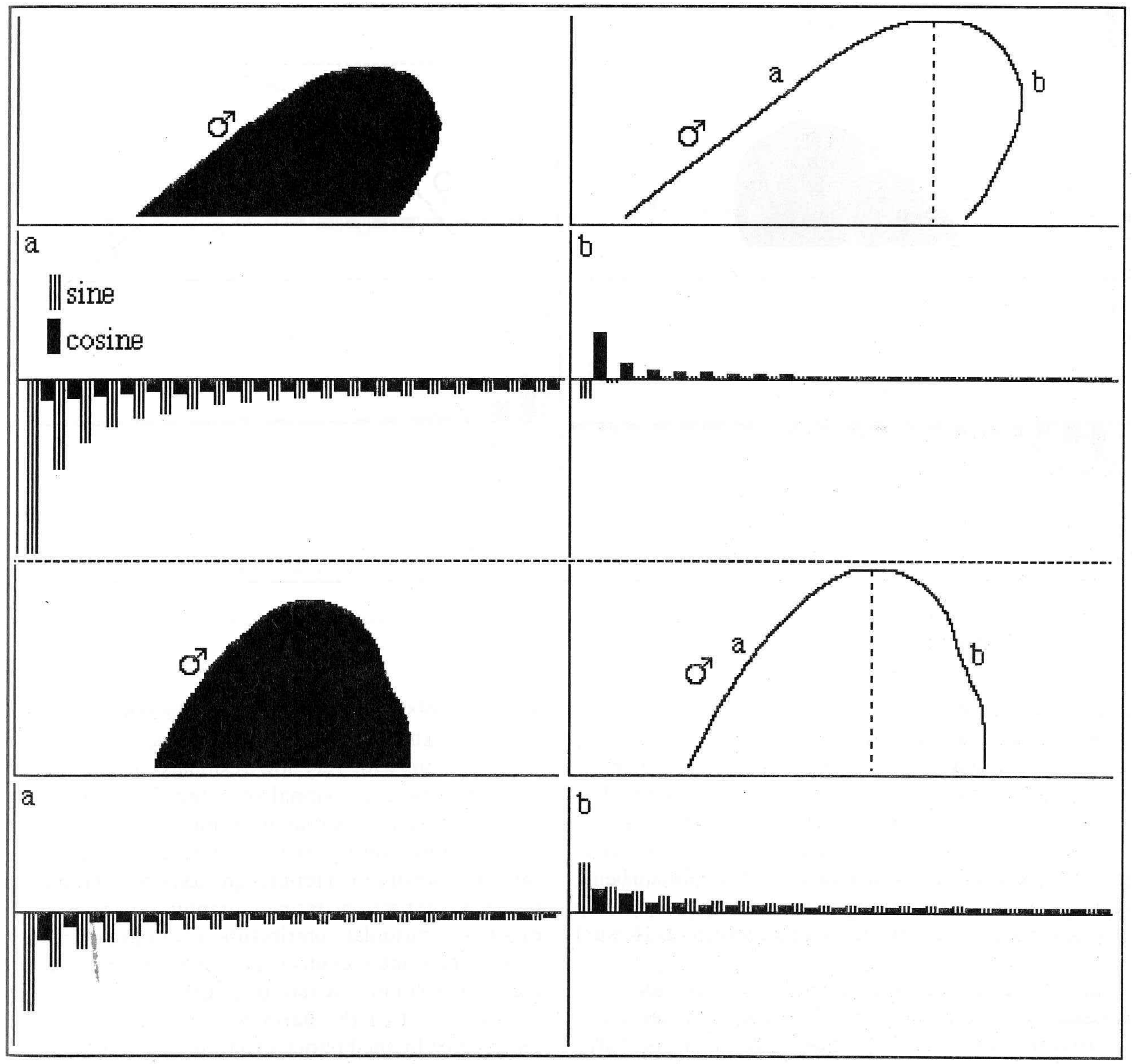

FIGURE 2. Case of clearly male morphology (above) and case of female-like male morphology before and after dimensional normalization; Fourier spectra obtained for: a) latero-inferior ramus, b) latero-superior ramus.

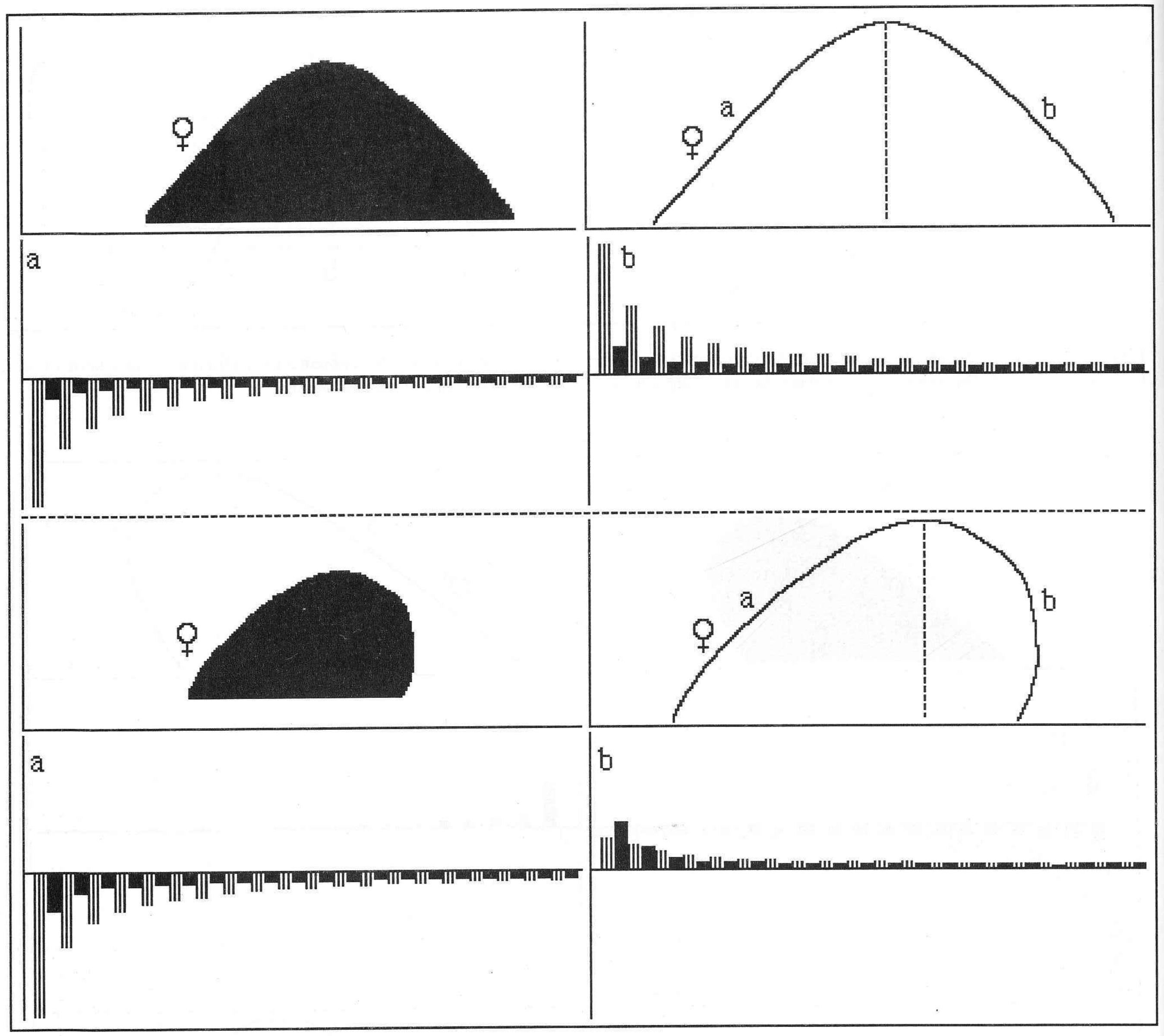

FIGURE 3. Case of clearly female morphology (above) and case of male-like female morphology before and after dimensional normalization; Fourier spectra obtained for: a) latero-inferior ramus, b) latero-superior ramus.

independent variable being the progressive sum of the adopted equiangular steps over the interval 0–2 π.

The result is Fourier sine/cosine coefficients for a number of sinusoidal harmonic contributors not exceeding half of the number of points which constitute the series. By the coefficients the amplitude and phase values of the single contributing harmonics are then calculated, amplitude being related to absolute size of coefficients and phase coming from sign and size ratio of sine/cosine coefficients (Lestrel 1997).

The coefficients of these harmonics are calculated in increasing order corresponding to the period of the sinusoidal contributors, so they are orthogonal or statistically independent of one another (Davis 1986).

According to many authors (Lestrel 1974, 1997, Jacobshagen 1982, Johnson *et al.* 1986, O'Higgins, Williams 1987, Diaz *et al.* 1990, Masashi *et al.* 1992) this is an extremely powerful procedure which can give a description, with very low residuals, of any irregular periodic one-dimensional oriented data series. It is possible to make a partial or overall resynthesis, simply by algebraic adding of the contributing harmonics; further, when different profiles are described, it is possible to make comparisons through graphic superimpositions of single sinusoidal contributors or of partial additions of subsets of these contributors establishing in this way their contribution in determining the studied shape.

The result of the harmonic analysis is typically represented by the Fourier spectrum: a bar graph where, for all the harmonic contributors disposed in a rising order from left to right, the sine and cosine coefficients with positive values (up) and negative values (down) are reported.

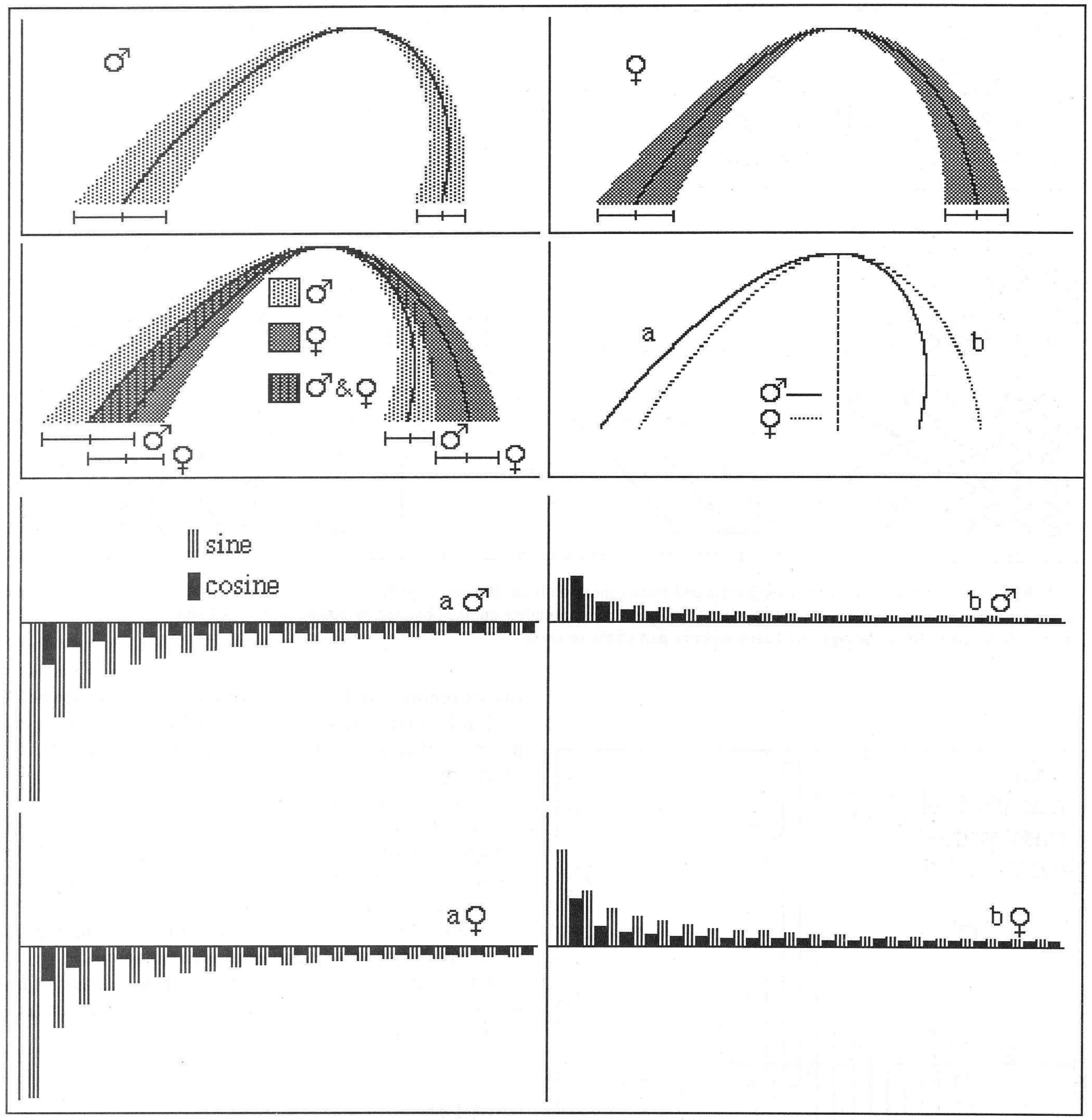

FIGURE 4. Mean outlines for the male (N = 97) and female (N = 98) groups, and Fourier spectra for: a) latero-inferior ramus; b) latero-superior ramus.

In the present study for each *os coxae* the silhouette of the *incisura ischiadica* was first obtained by optical projection and by illuminating the *incisura* by an extended and sufficiently distant light source *(Figures 3, 4)*; then the *incisura* was considered along the line drawn between the *spina ischiadica* and the *spina iliaca posterior inferior* till the point where the latero-superior segment of the *incisura* meets the extremity of the *facies auricularis* (points d, c in *Figure 1*). The above reference points were placed in a system of orthogonal cartesian axis on the same ordinate value; the profiles were dimensionally normalized with an optical scaling attributing the same value of depth to every one (segments a–b in *Figure 1*) so as to reduce size influences.

In each profile the latero-superior and the latero-inferior parts (a–c and a–d traits in *Figure 1*) were examined in an independent way.

For each *incisura* two separate series of 90 equispaced *abscissa* values were serially acquired starting from the deepest point of the *incisura* (point a in *Figure 1*) up to the

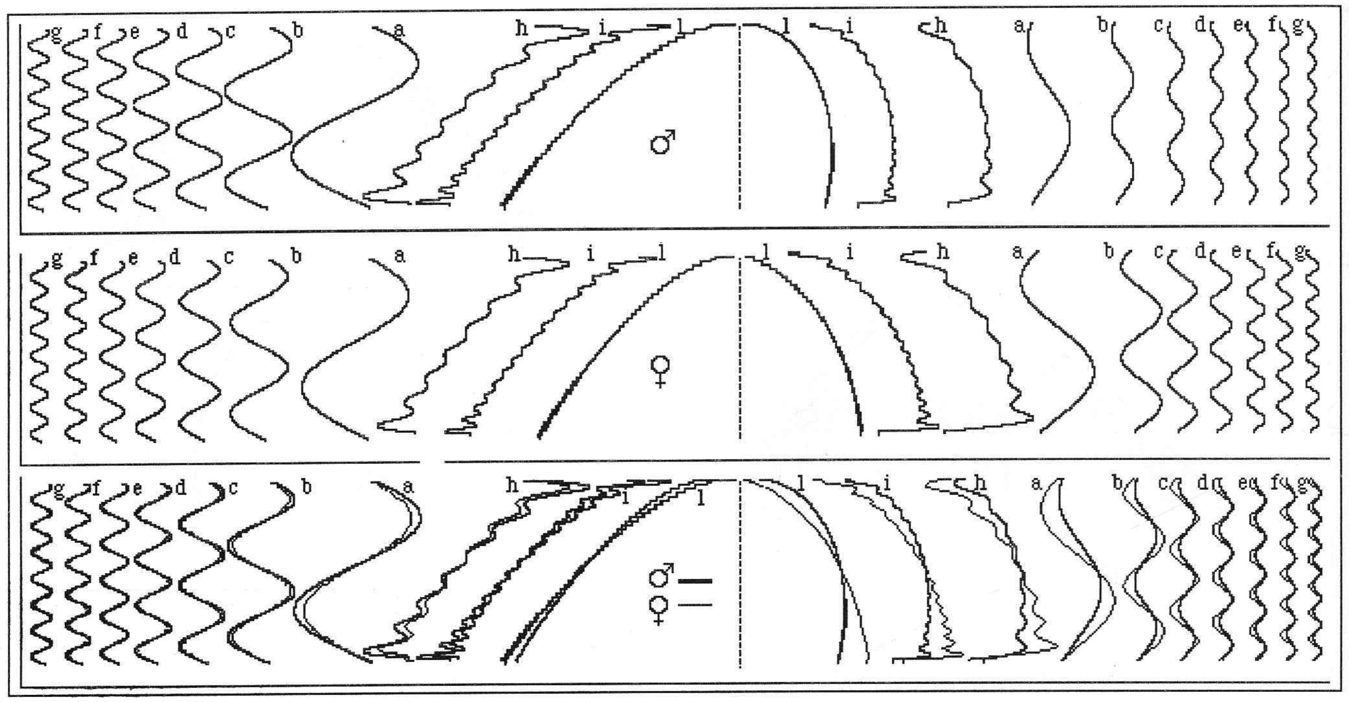

FIGURE 5. Male, female and superimposed male and female mean outlines. Harmonic synthesis of the first seven (a–g) sinusoidal components; sum of the first 7 (h) harmonics; sum of the first 15 (i) harmonics; complete outline obtained by adding all the 44 harmonics (l); on the left the latero-inferior part and on the right the latero-superior part of the *incisura*.

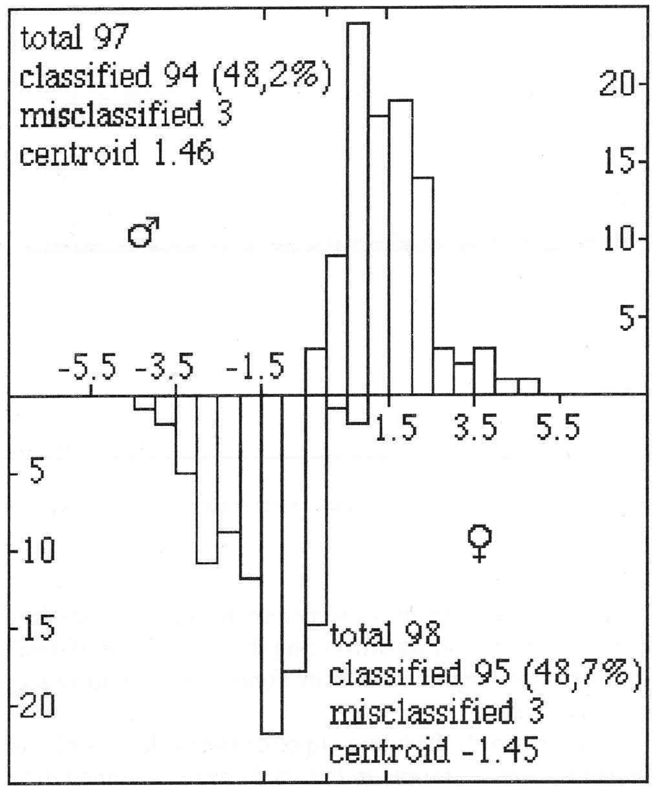

FIGURE 6. Distribution of discriminant scores obtained by using the following variables: phases 1, 2, 5, 8, 9, 10, 11, 12, 13, 14, 15, roughness factor (latero-superior ramus); amplitude sum and roughness factor (latero-inferior ramus). Error = 3%. F = 27.5; d.f. = 14, 180; P < 0.0005.

two extremities of the *incisura* (points c and d in *Figure 1*).

Each series was interpolated by a trigonometric polynomial up to the 44th harmonic defining its coefficient spectrum.

From the coefficient couples sine/cosine defining every sinusoidal component, amplitude and phase values were obtained; in addition the total amplitude sum of all 44 sinusoidal components and the integral of the spectrum (Roughness Factor) were calculated.

The spectra of the mean profiles for the male and the female groups respectively, were also obtained.

Fourier parameters obtained from the description of the *incisura* were used as variables to perform multivariate discriminant analysis (Wilkinson 1989).

RESULTS

In *Figure 2* the original silhouette of an *incisura* of a clearly male kind and a female-like male one, the profile of the inferior and the superior segments of the *incisurae* after dimensional normalization and the relative Fourier spectra are represented.

In *Figure 3* an *incisura* clearly female and a male-like female one, the profile of the inferior and the superior segments of the *incisura* after dimensional normalization and the relative Fourier spectra are represented.

In *Figure 4*, the mean outlines for the male and for the female *incisura* and the corresponding Fourier spectra showing the mean values of the coefficients for both the *incisura* traits are reported.

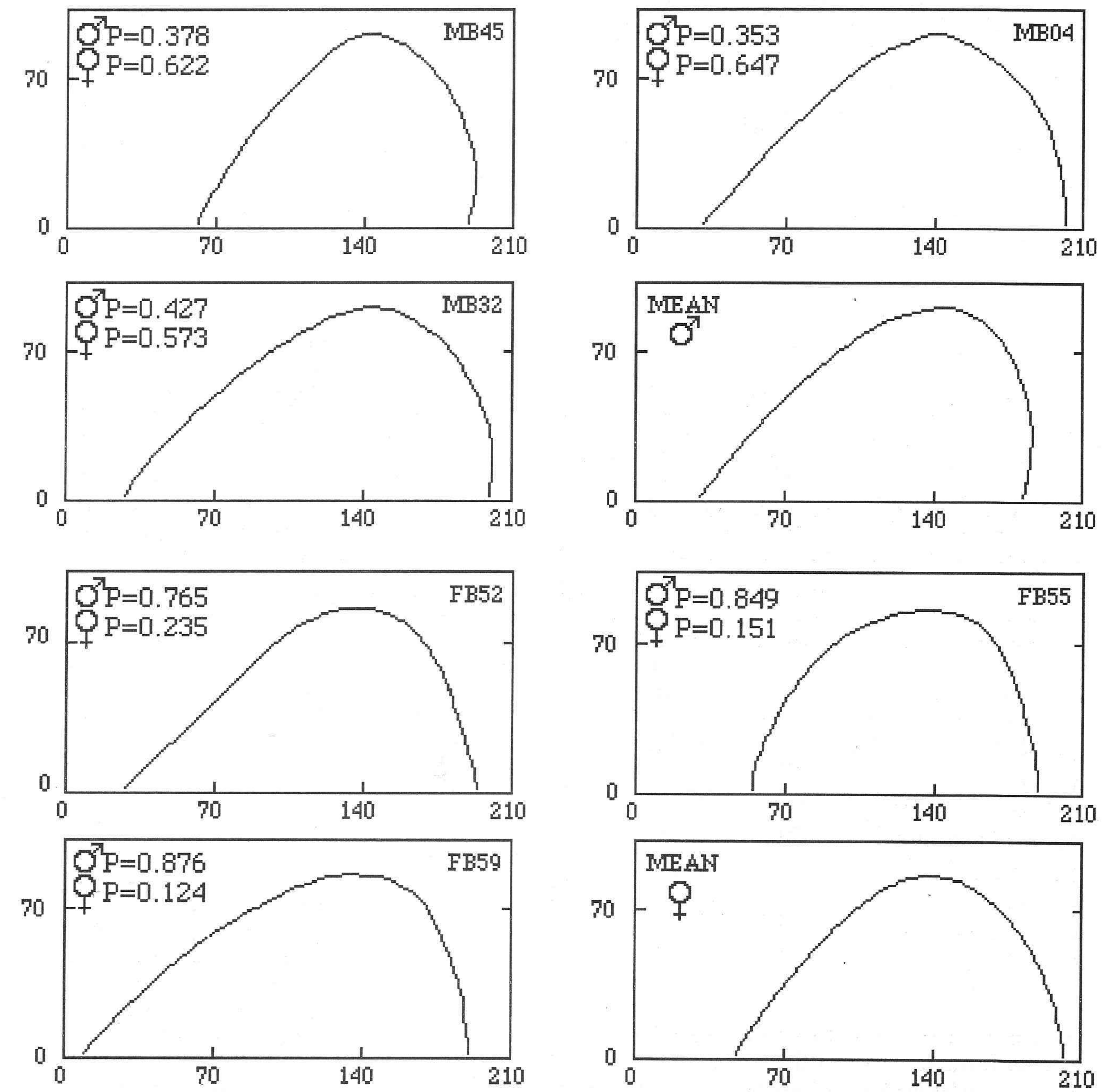

FIGURE 7. Misclassified cases (3 from the male group and 3 from the female group); for each *incisura* the probability of group membership are reported; the male and female mean profiles are also reported for comparison.

Figure 5 shows the graphic synthesis of some harmonics and of their partial and total sums: main sexual differences can be clearly observed in the superior part of the *incisura* as has already been observed in an empirical way from the logic analysis of the shape. We can also observe that the curve obtained by adding the first 15 harmonics (*Figure 5i*) already shows the basic architectural morphology of the profiles; in fact, this strongly reduced subset of harmonics contains more than 80% of the total amplitudes and so the greater part of available morphogenetic (in the analytic sense) information. Considering this, amplitude and phase values of only these sinusoids were used to perform the multivariate discriminant analysis. The information contained in the remaining harmonics is related to the fine and local smoothing of the profiles; however, none of the components of a higher order than the 15th show an amplitude higher than 1% in respect to the total amplitude sum of all 44 extracted harmonics.

In *Table 1* the mean amplitude and phase values are reported for both groups.

The main differences in amplitudes and phases, as expected, are shown by the superior arm of the *incisura*; the maximum values of the total sum amplitude were obtained for the male latero-inferior ramus; whereas for

TABLE 1. Fourier data obtained by describing the greater sciatic notch of the treated sample. Amplitudes of the first 15 harmonics (A01 – A15); Phases of the first 15 harmonics (P01 – P15); Amplitude Sum of all 44 harmonics (SUM); Roughness Factor (RF) (integral of the spectrum).

	MALES (N = 97)				FEMALES (N = 98)			
	RAMUS				RAMUS			
	INFERIOR		SUPERIOR		INFERIOR		SUPERIOR	
VAR.	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
A01	31006	6768	10989	2307	26311	5603	17924	4273
A02	16424	3350	5533	1508	13940	2864	9714	2176
A03	11335	2239	3851	1142	9610	1955	6743	1524
A04	8731	1681	3018	859	7389	1492	5221	1180
A05	7139	1344	2484	710	6019	1211	4273	956
A06	6076	1142	2132	600	5110	1010	3639	808
A07	5283	1007	1867	529	4429	867	3190	696
A08	4712	875	1656	468	3938	762	2828	611
A09	4244	791	1504	418	3545	673	2569	556
A10	3874	698	1380	384	3226	604	2349	496
A11	3561	653	1277	346	2976	556	2165	456
A12	3306	603	1189	333	2763	520	2004	434
A13	3086	566	1108	309	2577	464	1875	406
A14	2905	546	1049	292	2415	439	1755	374
A15	2735	521	992	274	2271	411	1667	358
P01	15.340	5.218	231.258	20.553	14.694	5.532	209.143	8.861
P02	15.258	3.383	219.876	17.363	14.694	3.081	202.612	4.944
P03	16.371	3.219	214.763	14.769	15.714	2.585	201.388	3.637
P04	17.608	2.808	212.701	12.503	17.061	2.191	202.041	3.312
P05	19.175	2.513	211.423	10.893	18.735	2.340	202.816	2.996
P06	20.660	2.286	210.928	9.653	20.041	2.110	204.000	2.929
P07	22.433	2.487	211.588	8.935	21.388	2.232	205.143	2.755
P08	23.918	2.308	211.794	7.882	23.510	2.316	206.653	2.629
P09	25.031	2.182	211.959	6.892	24.857	2.243	207.306	2.505
P10	26.763	2.335	212.619	5.954	26.531	2.253	208.612	2.715
P11	28.495	1.937	213.691	6.294	28.000	2.368	209.755	2.698
P12	29.691	2.297	213.649	5.530	29.633	2.286	211.714	2.585
P13	31.464	2.131	215.175	5.566	31.061	2.283	213.061	2.406
P14	32.577	2.309	215.876	4.414	32.122	1.944	213.878	2.645
P15	33.773	2.079	217.649	4.537	34.000	2.315	214.653	2.364
SUM	161574	31265	56439	14346	135907	26396	96264	21108
RF	29.490	6.052	10.367	2.271	24.867	5.247	17.307	3.907

the latero-superior ramus the maximum amplitude values for the female group were found.

These differences can be easily seen in the harmonic synthesis reported in *Figure 5*. Considering the superimposed fundamental harmonics (a in the figure) of both groups we can note how they differ in size (related to amplitude mainly) and position of the sinusoidal camber (related to phase). The region of maximum convexity, in the female group, is not only more expressed but is placed in the lower part of the profile in respect to the male group.

This corresponds to the shape differences as classically described for the latero-superior arm of the *incisura*: longer, symmetrically diverging from the latero-inferior ramus and without recursive trend in the females; shorter, asymmetrically diverging from the latero-inferior ramus and characterized by a recursive trend in the males.

Multivariate discriminant analysis results confirm that the main sexually differentiated shape characters of the sciatic notch are due to the superior arm: by using 13 amplitude values and 15 phase values obtained from the latero-inferior ramus, 79% of cases were correctly classified, whereas using 10 amplitude values and 11 phase values obtained from the latero-superior ramus, 95% of correct attribution was reached *(Table 2)*.

The best results were obtained using amplitude and phase Fourier parameters from both the latero-superior ramus and the latero-inferior ramus. By utilizing a linear combination of 14 parameters the correct attribution was obtained for 191 data cases on 197 (97% of cases were correctly attributed); 3 cases for the male group and 3 cases for the female group were misclassified *(Figure 6)*. The used parameters are as follows: – from latero-superior ramus: phases 1, 2, 5, 8, 9, 10, 11, 12, 13, 14, 15 and Roughness Factor; – from latero-inferior ramus: Amplitude total Sum and Roughness Factor. The F test perfomed on the 14 selected variables, gives value of 27.5 (14.180 d.f.; P < 0.005) that means that the selected variables are effective in separating the two groups; additional tests (Wilk's lambda, Hotelling-Lawley trace) give results in agreement with F test.

TABLE 2. Multivariate discriminant analysis. Results obtained by using Fourier data in finding the linear combination of variables able to best separate the male and female groups of *incisurae*. The analysis was performed on the latero-inferior ramus and on the latero-superior ramus separately and on both rami together. In the last column the results obtained applying the "leaving one out method" are reported.

Rami	Data cases		Classified	Misclassified	Classified %	Class.% – l.o.out
latero-inferior	males	(97)	75	22	77.319	72.164
	females	(98)	79	19	80.612	78.571
	total	(195)	154	41	78.965	75.367
latero-superior	males	(97)	93	4	95.876	89.690
	females	(98)	92	6	93.877	87.755
	total	(195)	185	10	94.876	88.722
latero-inferior	males	(97)	94	3	96.907	96.907
&	females	(98)	95	3	96.939	91.836
latero-superior	total	(195)	189	6	96.923	94.371

The sample is large enough to accept, eventually, reduction in efficiency of tests of significance and accuracy of probability group membership due to deviation from multivariate normal distribution; considering that due to inequality of covariance matrices canonical discriminant functions may not provide maximum separation among groups and the probability of group membership will be distorted, the "leaving one out" method was applied in order to obtain an almost unbiased estimate of the expected actual error rate (Lachenbruch 1975). The percentage of misclassified data cases obtained by applying the "leaving one out" method is shown in *Table 2.*

The unstandardized coefficients of the obtained linear discriminant functions to be used in sexing unknown pelvises, for separate *incisura* arms and for both rami together, are reported in *Table 3.*

CONCLUSIONS

If comparing the approaches used to evaluate the sex differences of the sacro-iliac segment on the basis of the *incisura ischiadica major*, we have to remember that the best discriminant function obtained by the dimensional parameters correctly classified only 65% of cases; so that the results obtained by using Fourier analysis represent a considerable improvement.

Considering the above reported results one can ask: how can an *incisura* that resulted male from the metrical point of view and with an experienced naked eye, be correctly attributed to the female group using analytical parameters, whereas an *incisura* that resulted female from the metrical point of view and with the naked eye, was correctly attributed to the male group using shape analysis? This could suggest that some shape variations which sometimes escape observation and metrical measurements, can be described, in our case, by variation of Fourier amplitude and phase patterns.

A possible answer to the question could be given by observing the outgroup data cases reported in *Figure 7*. They are not simply morphologically extreme cases as those reported in *Figures 2* and *3* (the female-like males and male-like females were attributed to the proper group) but are cases morphologically characterized by modified basic architecture.

This poses the problem of ascertaining basic or invariant morphological features that can help the diagnosis: for example, beside the already known features described by the "ideal shape analysis", another one regarding the latero-superior ramus may be described; more precisely this is related to the placement of maximum convexity of the ramus: the maximum convexity position placed rather high in the profile drives the description in a masculine sense; if the maximum convexity point is placed at the end of the profile the ramus is analytically defined in a feminine sense.

In fact the outgroup data cases MB45 and MB32 reported in *Figure 7*, although their superior arm show recursive trends (a feature commonly accepted as male), are however characterized by having the maximum convexity of the profile placed rather low, and the same can be said for the MB04 case; this corresponds to a mutual phase arrangement and to an increasing amplitude value characterizing them in a feminine sense.

In FB52, FB59 and FB55 data cases, the upper part of the latero-superior ramus appears to be rather swollen and so these data cases are characterized, by amplitude and phase values, in the male sense.

The recursivity of the latero-superior ramus, therefore, in true male morphology, must be accompanied by the allocation of the maximum convexity point in the upper part of the ramus, on the contrary misclassifications can occur.

TABLE 3. Unstandardized discriminant functions coefficients. The used variables are as follows: Amplitudes of the first 15 harmonics (A01–A15); Phases of the first 15 harmonics (P01–P15); Amplitude Sum of all 44 harmonics (SUMS & SUMI for latero-superior and latero-inferior arms respectively); Roughness Factor (RFS & RFI for the latero-superior and the latero-inferior arms respectively). The F value and D^2 for each equation are also reported.

VAR.	RAMUS INFERIOR	RAMUS SUPERIOR	BOTH RAMI
A01	0.000122	–0.000172	–
A02		–0.001972	–
A03	–0.001969	0.001400	–
A04	–0.000501	–	–
A05	–0.000411	–	–
A06	–	–	–
A07	–0.002332	0.003769	–
A08	0.001435	–0.004644	–
A09	0.000111	–	–
A10	0.002238	–0.005608	–
A11	0.002238	–0.012369	–
A12	–0.001864	0.014588	–
A13	0.001314	0.002323	–
A14	0.003088	–	–
A15	0.001006	0.004232	–
P01	0.114698	–	–0.031320
P02	0.048456	0.172249	0.234192
P03	–0.114908	–	–
P04	–0.020800	0.212745	–
P05	0.010248	–0.256367	–0.235557
P06	–0.076908	–0.151437	–
P07	0.343082	0.116968	–
P08	–0.093008	–0.288943	–0.382640
P09	–0.288914	0.100435	0.064594
P10	–0.110518	–	0.042375
P11	0.056331	0.125462	0.198960
P12	–0.160149	–0.324942	–0.315890
P13	0.228302	–0.143775	0.009618
P14	0.142970	–	0.012869
P15	–0.164515	0.285321	0.382754
SUMS	–	–	–
SUMI	–	–	0.000372
RFS	–	–	–0.840965
RFI	–	–	–1.782686
CONST.	–5.034165	41.047464	6.167500
	F = 3.501 df = 28.166	F = 16.368 df = 21. 173	F = 27.583 df = 14.180
	D^2 = 2.3	D^2 = 7.9	D^2 = 8.5

REFERENCES

DAVIS C. J., 1986: *Statistics and data analysis in Geology*. J. Wiley & Sons, New York.

DIAZ G., QUACCI D., DELL'ORBO C., 1990: Recognition of surface modulation by elliptic Fourier analysis. *Comp. Meth. Prog. Biomed. Elsev*. 31:57–62.

JACOBSHAGEN B., 1982: Variations in size and shape of the orbital contour. A comparison between man and the greater apes using Fourier Analysis. In: J. Jelínek (Ed.): *Man and his origins.* Anthropos 21: 113.

JOHNSON D. R., O'HIGGINS P., MCANDREW T. J., ADAMS L. M., FLINN R. M., 1986: Measurement of Biological shape: a general method applied to mouse vertebrae. *J. Embryol. Exp. Morph.* 90: 363–377.

LACHENBRUCH P. A., 1975: *Discriminant Analysis*. Hafner, New York.

LESTREL P. E., 1974: Some problems in the assessment of morphological size and shape differences. *Yearbook of physical anthropology.* Wistar Institute. Philadelphia. 18: 140–162.

LESTREL P., 1997: Introduction and Overview of Fourier Descriptors. In: P. E. Lestrel (Ed.): *Fourier Descriptors and their Applications in Biology.* Cambridge Univ. Press.

MASASHI I., TERUTAKA I., YOSHITAKA F., KICHIRO O., 1992: Sex determination by discriminant function analysis of lateral cranial form. *Forensic Science International.* 57: 109–117.

NOVOTNÝ V., 1980: *Pohlavní rozdíly a pohlavní diagnóza pánevní kosti* (Sex differences and sex diagnosis of the pelvic bone). CSc. Thesis, J. E. Purkyně University, Brno.

NOVOTNÝ V., 1984: Factorenanalyse der Geschelechtsmerkmale am Becken des Menschen für die Geschlechtsbestimmung und Erforschung des Geschlechtsdimorphismus des Skelettes. Ber. Int. Tagung "Anthroposociogenese", Weimar.

NOVOTNÝ V., VANČATA V., 1985: Systems aspect of the sexual dimorphism in Human Lower Limb. In: J. Mlíkovský, V. J. A. Novák (Eds.): *Evolution and Morphogenesis*. Pp. 611–622. Academia, Praha.

NOVOTNÝ V., VACCA E., VANČATA V., PESCE DELFINO V., 1993: Differenze sessuali rilevabili sulla incisura ischiadica major del bacino dell'uomo: confronto tra analisi metrica e analisi della forma. *Antrop. Cont.* 16, 1–4: 229–237.

O'HIGGINS P., WILLIAMS W., 1987: An investigation into the use of Fourier coefficients in characterizing cranial shape in primates. *J. Zool. Lond.* 211: 409–430.

PESCE DELFINO V., RICCO R., 1983: Remarks on analytic morphometry in biology: Procedure and software illustration. *Acta Stereol.* 2: 458–468.

PESCE DELFINO V., POTENTE F., VACCA E., LETTINI T., RAGONE P., RICCO R., 1990: Shape Evaluation in Medical Image Analysis. *European Microscopy and Analysis:* 21–24.

PESCE DELFINO V., VACCA E., POTENTE F., LETTINI T., RAGONE P., 1991: Morfometria analitica del cranio neandertaliano del monte Circeo (Circeo 1). In: L. Pigorini (Ed.): *Il Cranio Neandertaliano Circeo 1. Studi e Documenti.* Pp. 197– 251. Museo Nazionale Preistorico ed Etnografico. Roma.

PESCE DELFINO V., LETTINI T., VACCA E., 1997: Heuristic Adequacy of Fourier Descriptors: Methodologic aspect and applications in Morphology. In: P. E. Lestrel (Ed.): *Fourier Descriptors and their Applications in Biology*. Cambridge Univ. Press.

WILKINSON L., 1989: *SYSTAT: The System for Statistics.* Evanston, IL: SYSTAT, Inc.

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