Sex determination by discriminant analysis of clavicular measurements

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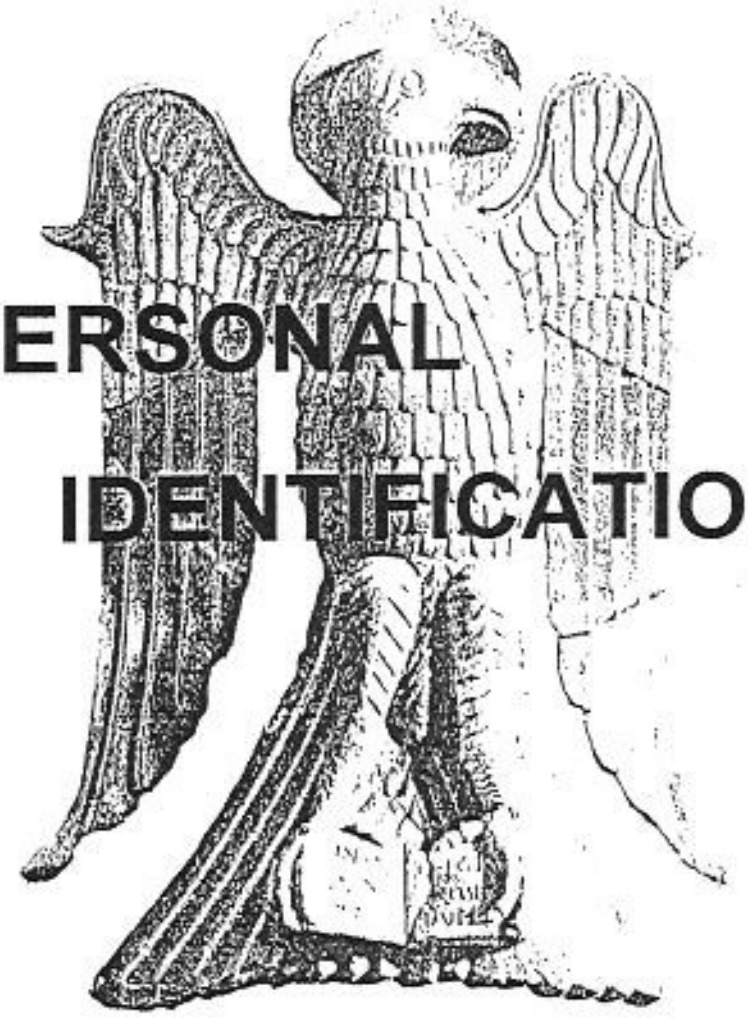

PERSONAL IDENTIFICATION

PROCEEDINGS

SEX DETERMINATION BY DISCRIMINANT ANALYSIS OF CLAVICULAR MEASUREMENTS.

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Key words: *Skeletal sex determination, discriminant functions, clavicular measurements.*

Summary

Measurements of six clavicular parameters (body length, circumference, breadth of proximal end, breadth of distal end, robustness, product index), obtained from a known contemporary Apulian skeletal population were taken to study sex determination by discriminant analysis.

In the multivariate discriminant analysis ten functions show a percentage of sex misclassification of 10% and three of these were obtained using just two parameters. Anyway the best multivariate function was obtained using two measurements (maximum length, midclavicular circumference) takeable directly from the clavicle.

Formulae for sex determination even from fractured clavicle are reported.

Sex determination is the first step in personal identification procedures from skeletal remains (1).

It may be obtained studying morphological parameters or performing quantitative analysis of selected skeletal measurements.

In the first case unfractured skeletal remains and examiner's specific experience are required. Anyway the final judgement will

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be marked by subjective evaluation.

The quantitative analysis is more objective and it can be performed even on fragmented skeletal remains.

This study is part of a research program to sex determination from skeletal remains performed at the Institute of Legal Medicine of the University of Bari (2-8).

In the forensic anthropology literature there are few studies that allow to obtain sex indication from clavicular parameters (9, 10), then we have applied discriminant analysis on clavicular measurements obtained from a skeletal collection of contemporary Southern Italian population with sex, age and time of death known.

Materials and methods

Eighty clavicular samples (40 male, 40 female) of skeletons, collected at the Legal Medicine Institute of University of Bari from a contemporary Apulian population with period of death around 1960 and age ranges from 26 to 78 years, were analyzed.

Four measurements were taken from clavicula on the Martin and Saller indications (11).

The parameters considered were then following (Martin's numerations is reported in parenthesis):

maximum length	[1]
midclavicular circumference	[6]
breadth on proximal side	[7]
breadth on distal side	[8].

The measurements were taken by two examiners in different time. Length measurements were obtained using an osteometric board accurate to 0.5 mm. The circumference was measured using a flexible tape accurate to within 0.5 mm; breadths were measured using a calibre accurate to within 0.05 mm.

Product index (the product of clavicular length for clavicular circumference) and *clavicular robustness* (circumference multiplied by 100 and divided for the value of the length) were also calculated for each clavicle as suggested by McCornick and coll. (12).

For descriptive, statistical and discriminant analysis, we translated and modified the Davies program n. 1 and 29 (13) originally written in Fortran IV. The computer required for our purpose was a Ms-Basic microcomputer with an "Intel 80386" microprocessor.

Statistical analysis of each parameter including mean, standard deviation, standard error, variance, coefficient of variability was conducted. Distance of population (d/s) was also determined from the ratio of the mean difference and the mean standard deviation (14) to demonstrate the overlap between male and female samples. The formula used was the following:

$$d/s = (X_M - X_F) / \sqrt{(n_M s^2_M + n_F s^2_F) / (n_M + n_F)}$$

(X_M-X_F= means; n_M, n_F= examined sample;s^2_M ,s^2_F= variance in two samples).

Univariate discriminant analysis was then performed to indicate the attitude of each measurements to sex discrimination [Z = ax; Z= output value of sex discrimination, a= bone measurement considered].

Next, the multivariate discriminant analysis was performed applying the Fisher formula [$Z = a_1x_1 + a_2x_2 + ... a_nx_n$; Z= output value of sex determination, a_{1-n}= bone measurements, x_{1-n}= discriminant coefficients].

The functions were then automatically tested on the same skeleton sample. For each function the percentage of sex misclassification was so obtained.

Then the functions were listed in order to obtain the highest sex discriminant degree using the less number of variables. The computer output was the list of the best fifty functions so obtained.

The first twelve functions are reported in tab. 3.

For each function, coefficients of discrimination, T^2, F value, male and female centroids, section point, and the percentage of

correct classification are reported. All the functions reported for the univariate and multivariate analysis must be considered significative; for those the value of DET (inverse of covariance matrix) was always 0.0001.

Results

The results of descriptive statistical analysis are reported in Tab. 1.

Tab. 2 shows the results of the univariate discriminant analysis.

In Tab. 3 the best results of the multivariate discriminant analysis are reported.

	MALE			FEMALE			
	Mean	Var.	SD	Mean	Var.	SD	Distance
Maximum length	14.74	0.75	0.87	13.32	0.55	0.74	1.76
Midclavicular circumference	4.07	0.11	0.33	3.49	0.08	0.29	1.86
Breadth on priximal side	2.63	0.008	0.28	2.37	0.06	0.25	0.99
Breadth on distal side	2.55	0.19	0.43	2.11	0.11	0.32	1.16
Robustness	27.68	7.44	2.73	26.62	4.04	2.01	0.61
Product index	59.85	41.81	6.47	46.61	30.51	5.52	2.20

Tab 1. Descriptive statistical analysis and distance of the population for each parameter

Maximum length	2.19					
Midclavicular circumference	-	5.95				
Breadth on priximal side	-	-	3.74			
Breadth on distal side	-	-	-	3.02		
Robustness	-	-	-	-	0.25	
Product index	-	-	-	-	-	0.36
Section point	30.75	22.54	9.36	7.03	6.87	19.49
Percentage of misclassification	18.75	17.50	28.75	28.75	32.50	11.25

Tab 2. Univariate discriminant analysis

Function n. ---------->	1	2	3	4	5	6	7	8	9	10	11	12
Parameters used -------->	5	4	3	3	3	5	3	2	2	2	2	2
Maximum length	5.49	6.65	2.96	--	5.49	2.92	2.96	--	3.09	1.74	--	--
Midclavicular circumference	--	- 6.11	9.32	15.12	--	9.36	9.32	11.06	--	4 90	5.54	5 52
Breadth on proximal side	1.14	--	--	--	--	1.19	--	--	--	--	2.46	--
Breadth on distal side	1.69	--	--	--	--	1.66	--	--	--	--	--	2.33
Robustness	1.33	2.04	--	- 1.14	1.3 1	--	--	- 0.86	0.70	--	--	--
Product index	- 0.35	- 0.25	- 0.31	- 0.14	- 0.31	- 0.34	- 0.31	--	--	--	--	--
T2	123.27	111.69	108.82	103.63	111.29	120.61	108.82	103.16	108.51	106.58	77.32	84.69
F	23.39	26.85	35.34	33.65	36.14	22.88	35.34	50.91	53.53	52 61	38.16	41 80
Degree of freedom	5-74	4-75	3-76	3-76	3-76	5-74	3-76	2-77	2-77	2-77	2-77	2-77
Centroid male	104.17	114.88	62.81	21.26	98.65	67.82	62.81	21.29	65.09	45.77	29.10	28 44
Centroid female	98.00	109.29	57.36	16.08	93.08	61.79	57.36	16.13	59.66	40.44	25.24	24.21
Section point	101.08	112.09	60.08	18.67	95.86	64.81	60.08	18.71	62.38	43 11	27.17	26.32
Misclassification	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	15%	16%

Tab. 3 - **Multivariate discriminant analysis.**

Discussion and conclusions

The descriptive statistical analysis (tab.1) reveals that product index, midclavicular circumference and maximum length were the parameters with the high attitude of sex discrimination; the distance of population for these parameters ranged from 2.20 to 1.76.

In the univariate discriminant analysis (tab.2), where the discrimination ability of each parameters is valuable, only the product index revealed an acceptable sex misclassification rate (11.25%). The functions obtained using the other measurements revealed percentage of misclassification too high to be currently used.

The first ten functions obtained by discriminant multivariate analysis (reported in tab.3) revealed a percentage of misclassification of 10%. Of these three functions was obtained using only two parameters (funct. n. 8,9,10). Anyway the best function obtained should be considered the function n.10 where 10% of misclassification is obtained just using two measurements directly takeable from the clavicle. Practically, it is necessary to take only *maximum length* and *midclavicular circumference* and to use function n. 10 to have a correct sex classification of 90%.

In tab.3 are also reported the functions prepared for fractured clavicles (funct. n.11 and 12) the midclavicular circumference is related respectivly with the breadth of proximal side (function n.11) and with the breadth of distal side (function n.12). These two functions are really useful where the only opportunity to obtain a sex determination by bones is just using a fractured clavicle. In these case the percentage of correct sex classification is a little bit lower (85% for funct. n. 11, 84% for funct. n. 12) but however acceptable.

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