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Quantitative dermatoglyphics in males and females of five Sardinian linguistic groups

Discriminant analysis of 23 digital and 15 palmar quantitative dermatoglyphic variables of 1364 Sardinians, 689 males and 675 females, were performed to identify biological relationships among five Sardinian linguistic groups of both sexes. By ANOVA 17 of the 23 digital variables and 4 of the 15 palmar variables were significantly different among males and females of the Sardinian linguistic groups. By MANOVA the results indicate high intergroup heterogeneity also within each sex. By stepwise discriminant analysis with $p \leq 0.01$ as F-to-enter and $p \leq 0.05$ as F-to-remove, only 4 of the 38 digital and palmar variables were in the model (URC R5, RRC L5, RRC R5, URC R4). The pattern of interpopulation biological relationships shows a clearly distinct position of the Gallurian group (both males and females) which speaks an Italian dialect. The properly Sardinian linguistic groups (Campidanian and Logudorian), the Sassarian group (which speaks an Italian dialect) and the Alghero group (which speaks Catalan) were close to one another. This pattern agrees more with the ethno-historical background than with the linguistic one.

Keywords: quantitative digital,
quantitative palmar, dermatoglyphics,
linguistic groups, Sardinia

Introduction

Dermatoglyphics are considered a good tool for the reconstruction of relationships among populations since these phenetic markers are conservative with respect to environmental influences and stochastic processes of evolution (Froehlich and Giles, 1981; Milièia, 1990; Demarchi et al., 1997).

The temporal stability of dermatoglyphic traits has been proved by studies on Jewish populations that have demonstrated the persistence of genetic affinities among populations with the same biological origin even though they have been spatially separated for two thousand years (Sachs and Bat-Miriam, 1957; Micle and Kobylansky, 1985; Bat-Miriam Katznelson et al., 1987).

Recent studies using discriminant analysis of quantitative digital dermatoglyphic traits have demonstrated that digital dermatoglyphics are useful in the assessment of ethno-historical relationships among endogamous populations of Andhra Pradesh (both sexes) (Reddy & Reddy, 1992) and among Sardinian linguistic groups (females) (Sanna et al., 2000).

In this study, we use stepwise discriminant analysis of 23 quantitative finger and 15 quantitative palmar traits in both males and females to examine the biological relationships among five Sardinian linguistic groups.

Materials and methods

The sample consists of the finger and palmar prints of 1364 unrelated and apparently healthy Sardinians, 689 males and 675 females, attending lower and upper secondary schools in 16 Sardinian villages. The prints were collected from 1985 to 2000 using the ink method and were analyzed according to Cummins and Midlo (1961) and Holt (1968).

The 23 quantitative digital dermatoglyphic traits are the radial and ulnar ridge counts on each of the 10 fingers, the total finger ridge count (TFRC), the absolute finger ridge count (AFRC) and the pattern intensity (PI). The 15 quantitative palmar dermatoglyphic traits are the main line index (MLI), and for each side, the average of the main line terminations A, B, C and D (MA, MB, MC and MD), the a-b and A-d counts, the atd angle value.

Since the prints were analyzed by only one of the Authors (G. Floris), there are no problems with interobserver variations.

Data storage was supervised by one of the Authors (E. Usai).

The names of the Sardinian linguistic groups considered in this study and their sample sizes are given in Table 1. They are based on the linguistic hypothesis and current geographic diffusion of linguistic groups in Sardinia proposed by Blasco Ferrer (1986, 1994). Information about the historical-linguistic background of the Sardinian linguistic groups considered in this study can be found in previous papers (Sanna, 1985, 1986; Sanna & Floris, 1995; Sanna et al., 1998; Sanna et al., 2000, 2001).

Table 1. Sardinian linguistic groups studied and sample sizes.

	Linguistic groups	M	F
1	Campidanian	387	379
2	Logudorian	89	87
3	Sassarian	119	129
4	Gallurian	25	35
5	Alghero	69	45
	TOTAL	689	675

Statistical procedures

One-way analysis of variance (ANOVA) was applied to assess whether there is significant heterogeneity among the linguistic groups for each of the quantitative finger traits considered.

Multivariate analysis of variance (MANOVA) was performed to evaluate if there is significant heterogeneity among males and among females of the five linguistic groups.

The relationships among the Sardinian linguistic groups were analyzed by stepwise discriminant analysis. To optimize a linear discriminant analysis, it is necessary that each variable be normally distributed in each group and that the population covariance matrices be equal. These assumptions are not met since our data for several variables are not normally distributed (not necessarily in the same groups). However, the discriminant analysis was used to graphically represent the biological relationships among populations with different historical-linguistic backgrounds, corresponding to the first phase of the discriminant analysis. In this phase, the dimensions of variation are reduced while the group differences are maximized, and heterogeneity and non-normality are not critical. These theoretical requirements are only crucial for significance testing and the attribution of specimens to predefined groups (Froehlich & Giles, 1981; Demarchi et al., 1997). Analysis of variance techniques are robust procedures that work reasonably well even when the assumptions of equal variances and normal distribution are not exactly met (Campbell, 1989; Demarchi et al., 1997).

Results and discussion

In Table 2 and Table 3 are presented the means and standard deviations of the 23 digital and 15 palmar quantitative variables respectively, along with ANOVA F-values for heterogeneity among males and females of the linguistic groups for each dermatoglyphic trait.

Multivariate analysis of variance (MANOVA) was used to test whether the linguistic groups could be distinguished on the basis of the 38 dermatoglyphic traits (Table 4). The Wilks' lambda values and the associated F-values indicate that the linguistic groups are significantly distinguished within each sex.

Table 5 reports the stepwise selection of variables. The number of variables selected in a stepwise discriminant analysis can depend on the F-value fixed as the condition to enter or to remove the variables in the equation (Afifi and Clark, 1984; Reddy and Reddy, 1992; Sanna et al., 2000). In this study with $p \leq 0.01$ for F-to-enter and $p \leq 0.05$ for F-to-remove, only 4 digital traits of the 38 digital and palmar variables are in the equation (URC R5, RRC L5, RRC R5, URC R4).

Table 6 reports the eigenvalues and summary statistics of the stepwise discriminant analysis. Wilks' lambda (0.7151) shows high intergroup heterogeneity: approx. $F=13.285$ (d.f.=36; 5109; $p<0.0001$), requiring two of the canonical variates to account for significant intergroup variation. In fact, the first function explains 86.37% and the second function 11.99% of the total dispersion.

Examination of standardized discriminant coefficients suggests that RRC L5, URC R5 and RRC R5 have the maximum influence on the first discriminant function, whereas the variables with the highest loadings for the second function are URC R4 and URC R5 (Tab. 7).

Figure 1 shows the centroids of the Sardinian linguistic groups derived from the stepwise discriminant analysis of the 23 finger and 15 palmar dermatoglyphic traits.

The first canonical variate clearly differentiates the Gallurian linguistic group (both males and females) from the other groups, reflecting the relationship expected from both the historical and linguistic perspectives. It should be noted that this group (NE Sardinia) speaks an Italian dialect which is distinct from, but close to, Sassarian (NW Sardinia). It originated mainly from Corsican immigration to the Gallura region starting from the XVII century, when the area was almost totally uninhabited (Le Lannou, 1941; Sanna, 1980; Sanna & Melis, 1998). Therefore, being a population that settled in Sardinia quite recently with respect to the others, the Gallurian group occupies a position distant from the other linguistic groups.

Table 2. Means and standard deviations of digital variables in five Sardinian linguistic groups (males and females) and F-value for inter-group heterogeneity.

Variables	Campidanian				Logudorian				Sassarian				Gallurian				Alghero				F-value (9; 1354)
	M	SD	M	SD	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	
RRC L1	16.80	3.99	15.07	6.10	16.72	6.48	15.38	5.92	16.72	5.88	15.10	6.15	15.32	7.06	15.83	6.12	16.56	7.39	13.33	6.46	3.354 ^a
RRC R2	8.25	6.75	8.01	6.34	9.56	6.83	7.86	6.19	8.34	6.19	8.35	6.44	8.24	7.35	11.26	5.81	8.45	7.21	7.78	6.49	1.323
RRC L2	7.99	6.46	6.94	6.40	9.52	6.50	7.85	6.47	7.65	6.39	7.03	6.15	9.36	6.37	7.26	6.27	7.88	6.83	6.93	6.04	1.869
RRC R3	11.73	5.48	10.32	5.44	12.09	5.16	11.14	5.45	11.38	5.37	10.64	5.61	11.24	5.63	11.89	5.38	12.05	5.33	10.15	4.97	2.368 ^a
RRC L3	11.72	5.91	9.88	6.32	12.42	5.68	10.99	5.70	11.10	6.24	10.38	6.15	11.84	5.71	11.57	6.03	11.55	6.26	9.62	5.39	3.132 ^a
RRC R1	19.27	5.65	17.32	5.93	19.58	5.24	17.67	6.02	19.35	5.64	17.79	5.50	18.56	7.09	17.00	6.86	19.95	7.04	16.44	6.90	4.711 ^a
RRC R4	14.70	5.83	14.09	5.97	14.92	5.62	13.59	5.41	13.79	5.67	14.38	5.33	14.80	5.16	14.29	6.40	16.17	5.59	12.78	6.21	1.801
RRC L4	14.80	5.70	13.55	6.22	15.38	5.40	13.76	6.75	14.37	5.75	14.18	5.94	13.44	4.14	11.00	4.89	16.27	5.26	12.98	5.21	3.817 ^a
RRC R5	13.03	5.31	12.07	5.15	13.80	4.70	12.20	5.06	12.65	5.09	11.42	5.43	12.88	4.38	11.97	4.92	14.03	4.72	11.16	5.48	3.156 ^a
RRC L5	12.95	5.08	11.73	5.23	14.19	4.10	12.37	5.17	12.96	5.04	11.68	5.33	8.84	8.25	6.46	7.01	14.04	4.35	11.18	5.12	10.197 ^a
URC R1	7.43	8.19	6.38	7.25	7.80	8.23	6.10	7.15	6.72	7.64	5.84	7.43	8.64	7.17	6.80	8.06	9.59	9.12	3.71	6.29	2.856 ^b
URC L1	5.83	7.67	5.90	7.17	6.98	7.72	5.06	7.05	5.08	7.14	5.67	7.51	4.68	6.34	9.14	8.04	7.94	7.81	3.98	6.69	2.254 ^a
URC R2	7.34	7.74	6.45	7.54	7.95	7.68	4.62	7.23	7.94	7.97	5.95	7.58	3.40	6.36	1.71	4.44	7.77	7.98	4.89	7.05	4.477 ^a
URC L2	6.32	7.52	6.72	7.41	6.92	7.99	5.16	6.71	7.23	7.86	6.81	7.76	3.00	5.96	3.11	5.37	7.59	8.02	5.28	6.98	2.246 ^a
URC R3	2.52	5.48	1.68	4.84	3.11	5.88	1.39	4.62	2.88	5.78	1.27	4.04	6.32	6.52	3.60	5.28	3.62	6.49	0.64	2.74	4.848 ^a
URC L3	2.44	5.39	2.44	5.25	3.34	6.26	2.00	5.39	2.63	5.59	2.26	5.41	3.76	5.34	4.54	5.49	2.95	6.35	1.89	4.32	1.146
URC R4	5.77	6.49	3.93	5.62	7.04	6.78	3.45	5.39	5.57	6.16	3.75	6.17	2.68	4.76	0.69	2.39	6.60	7.52	2.85	5.39	7.632 ^a
URC L4	4.92	6.69	4.11	5.86	4.99	6.15	3.74	5.40	3.66	5.47	4.12	6.25	1.00	2.86	0.97	3.09	6.00	7.46	2.40	4.44	3.940 ^a
URC R5	1.84	3.99	0.86	2.76	2.47	4.36	0.71	2.51	1.53	3.51	1.22	3.16	6.96	7.69	7.34	6.89	2.16	4.55	0.62	2.29	18.662 ^a
URC L5	1.69	4.07	1.08	3.21	2.25	4.19	1.36	3.26	1.03	2.99	1.40	3.54	1.00	2.86	0.97	3.09	1.20	3.54	1.09	3.21	1.457
TEFC	137.78	47.24	126.17	47.55	146.01	43.07	128.34	43.99	134.92	46.21	128.19	45.42	136.68	47.50	132.91	47.10	142.58	45.27	115.75	47.26	3.433 ^a
AFRC	174.04	84.35	155.08	80.57	174.38	102.26	140.02	86.67	170.23	74.90	159.23	77.95	178.72	82.37	169.63	72.71	188.22	83.23	133.91	70.28	3.481 ^a
PI	12.96	3.46	12.29	3.64	13.52	3.72	12.22	2.99	13.07	3.24	12.20	3.35	13.36	3.33	12.60	3.75	13.20	3.47	11.49	3.37	2.855 ^b

a = $p < 0.05$; b = $p < 0.01$; c = $p < 0.001$

Table 3. Means and standard deviations of palmar variables in five Sardinian linguistic groups (males and females) and F-value for intergroup heterogeneity.

<i>Variables</i>	Campidanian		Logudorian		Sassarian		Males		Females		Males		Females	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
MD R	9.39	1.31	9.34	1.26	16.04	7.17	9.45	1.30	99.75	1.19	9.22			
MB R	6.31	1.36	6.12	1.26	13.04	6.61	6.21	1.10	6.45	1.09	6.00			
MC R	7.50	2.04	7.47	2.09	7.55	6.46	7.51	2.13	7.51	2.49	7.19			
MA R	4.18	1.00	4.20	0.96	6.64	6.07	4.15	0.96	4.28	0.96	4.04			
MD L	9.05	1.23	8.97	1.30	9.81	5.15	9.07	1.38	9.25	1.13	8.88			
MB L	5.86	1.18	5.78	1.03	9.21	5.62	5.68	0.96	5.91	0.95	5.64			
MC L	7.07	2.00	6.80	2.19	12.51	6.35	6.75	2.24	7.13	2.20	6.67			
MA L	3.40	1.11	3.59	1.13	12.51	6.35	3.43	1.14	3.55	1.09	3.31			
MLI	16.00	3.61	16.11	3.45	10.85	5.62	16.09	3.70	16.82	3.31	15.46			
a-b R	41.16	5.26	40.56	5.27	10.85	5.62	40.57	5.79	40.31	5.40	41.34			
a-b L	42.13	5.50	41.83	5.49	3.55	6.21	42.03	5.10	41.02	4.68	42.91			
A-d R	44.57	28.75	40.78	11.70	3.81	6.59	40.11	11.89	41.54	11.88	44.08			
A-d L	53.48	11.42	48.62	11.91	4.68	6.97	50.47	13.35	50.52	12.29	53.75			
Atd R	45.52	8.40	45.85	8.46	5.21	6.88	48.11	9.41	45.60	9.68	46.03			
Atd L	44.90	8.46	46.21	9.00	0.62	2.68	48.45	9.93	44.93	8.81	47.08			

Gallurian				Alghero				F-value		
Males		Females		Males		Females		SD		(9; 1354)
SD	M	SD	M	SD	M	SD	M	SD	M	
1.28	9.32	1.31	9.57	1.40	9.64	1.24	9.78	1.18		2.492 ^b
1.08	6.20	1.04	6.34	1.06	6.29	1.05	6.47	1.12		1.933 ^a
2.33	6.56	3.18	7.77	1.94	7.52	2.41	7.98	1.81		1.080
1.02	4.20	1.08	4.40	0.88	4.23	1.03	4.02	1.01		0.875
1.34	9.00	1.22	9.14	1.44	9.30	1.11	9.27	1.17		1.282
0.95	5.76	1.09	5.97	0.95	5.79	0.99	5.84	0.90		0.929
2.36	6.64	2.45	7.29	1.90	6.65	2.91	7.78	1.43		1.884
1.16	3.52	1.08	3.63	1.17	3.51	1.23	3.31	1.20		1.318
3.77	16.04	3.65	16.74	3.83	16.68	3.55	16.38	3.53		1.510
5.82	42.92	6.54	41.11	3.49	40.22	5.87	42.04	5.42		1.295
5.97	41.84	6.07	41.91	4.57	41.96	5.89	42.12	4.50		0.930
13.63	42.92	11.32	39.54	10.38	41.75	13.88	45.00	10.86		1.498
13.00	52.84	10.09	45.43	13.21	52.00	15.26	52.62	14.36		5.140 ^c
8.38	45.40	9.64	47.83	10.62	47.47	9.86	49.11	11.32		1.660
8.97	44.68	9.29	48.33	11.96	49.01	12.79	48.11	11.67		2.814 ^b

a = $p < 0.05$; b = $p < 0.01$; c = $p < 0.001$

Table 4. Results of the multivariate analysis of variance (MANOVA) of 38 dermatoglyphic variables, for males vs males and females vs females, and sexes combined.

Sample	Wilks' λ	F-approx.	p
Males	0.56385	2.6568	0.000
Females	0.38897	4.4911	0.000
Males and females	0.41776	3.6042	0.000

Table 5. Stepwise selection of 38 dermatoglyphic variables with $p \leq 0.01$ for F-to enter and $p \leq 0.05$ for F- to remove.

Variables	Wilks' Lambda	F-remove (9;1363)	p
URC R5	0.862	31.006	0.000
RRC L5	0.803	18.696	0.000
RRC R5	0.762	9.845	0.000
URC R4	0.761	9.650	0.000

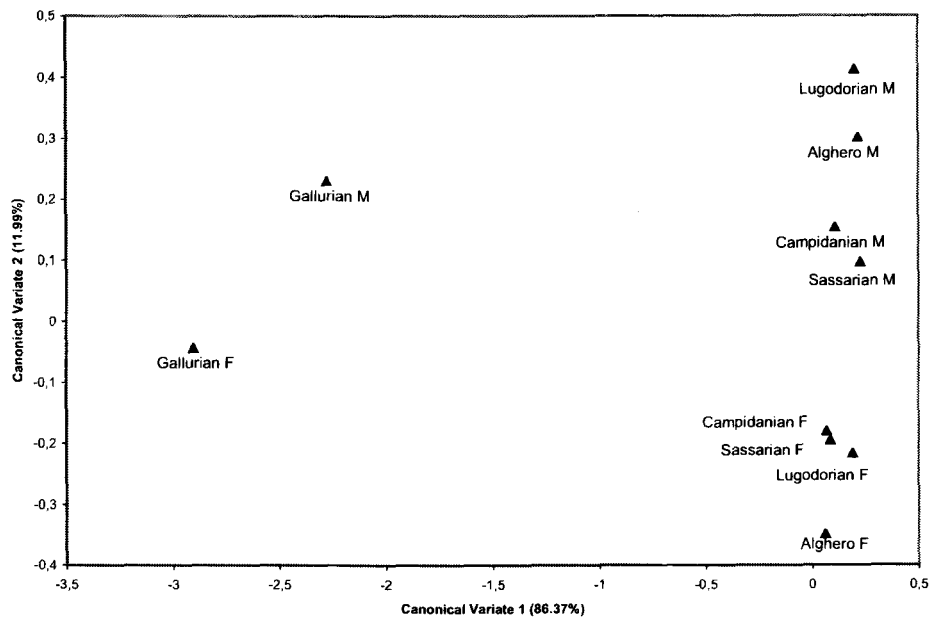
Table 6. Eigenvalues and summary statistics for the first three discriminant functions obtained by stepwise procedure.

Function	Eigenvalues	Percentage of Variance	Canonical Correlation	Function Removed	Wilks' Lambda	X ²	df	p
1	0.329	86.37	0.498	0	0.715	458.702	36	0.000
2	0.046	11.99	0.209	1	0.950	69.621	24	0.000
3	0.004	1.07	0.064	2	0.994	8.515	14	0.861

Table 7. Standardized coefficients for canonical variables.

Variables	Root 1	Root 2
URC R5	-0.926	0.418
RRC L5	1.074	0.294
RRC R5	-0.791	0.052
URC R4	0.539	0.525

Figure 1. Centroids of Sardinian linguistics groups derived from stepwise discriminant analysis of 23 quantitative digital dermatoglyphic traits and 15 quantitative palmar variables



The properly Sardinian linguistic groups (Campidanian and Logudorian), the Sassarian and the Alghero groups occupy positions close to one another.

These findings appear to be partially contradictory from a linguistic point of view, although the historical perspective strongly supports them. In fact, the Sassarian group speaks an Italian dialect believed to be the result of a fusion between a Sardo-Logudorian basis and Italian elements of Pisan and Genoese origin (Sanna, 1976, 1980). This dialect developed as a "lingua franca" during the Middle Ages (XII-XIV centuries) due to linguistic contact between Sardinian and Italian languages (Viridis, 1978).

Besides, the Alghero linguistic group is near to the Campidanian, Logudorian and Sassarian linguistic groups. Again, this is contradictory from a strictly linguistic point of view but not from a historical-demographic and biological perspective. In fact, the Catalan linguistic group of Alghero, is the result of expulsion of the autochthonous element and its substitution with individuals coming from Catalonia in 1354, following a decree by Peter IV of Aragon. This measure was taken to punish the autochthonous inhabitants of Alghero for their participation in an insurrection in 1353 against the Aragonese-Catalan invasion. However, it is to be noted that according to Budruni (1990), in the second half of the XVII century the population of Alghero was 70% Sardinians, 20% Italians (especially Ligurians) and only 7% of Catalan origin (the remaining 3% were not specified). Furthermore, studies using dermatoglyphic distances (Floris and Sanna, 1993) and genetic polymorphisms (Moral et al., 1994) have shown that the current Alghero population is biologically much closer to Sardinians than to Catalans.

The second canonical variate differentiates sexes. The separation of males and females along the second axis by discriminant analysis applied to digital variables was reported by Reddy and Reddy (1992) in several Indian castes of Andhra Pradesh and by Demarchi et al. (1997) in South American native populations.

In conclusion, stepwise discriminant analysis of 23 quantitative finger and 15 quantitative palmar traits, with $p \leq 0.01$ as F-to-enter and $p \leq 0.05$ as F-to-remove, shows only 4 digital variables in the model: URC R5, RRC L5, RRC R5, URC R4. It produces a separation of the sexes and a picture of the biological relationships among Sardinian linguistic groups compatible with their ethno-historical backgrounds. The results obtained support the hypothesis that radial and ulnar digital counts are more informative to identify the biological relationships among Sardinian linguistic groups than summary variables as TFRC, AFRC, PI, MLI and quantitative palmar variables.

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Received: October 10, 2004

Accepted: December 20, 2004