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Surnames, geographic altitude, and digital dermatoglyphics in a male population from the province of Jujuy (Argentina)

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ABSTRACT

The possible association between finger dermatoglyphic patterns and altitude and surname distribution was analyzed in a sample of adult males from the province of Jujuy, Argentina. We also investigated the biological affinity of this population with other South American natives and admixed populations. Fingerprints were obtained from 996 healthy men, aged 18–20 years, from the highlands (HL: 2500 m, Puna and Quebrada) and lowlands (LL: Valle and Selvas). Surnames were classified into native/autochthonous (A) or foreign (F), resulting in three surname classes: FF, when both paternal and maternal surnames were of foreign origin; FA,

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when one surname was foreign and the other was native; and AA, when both surnames were native. Frequencies of finger dermatoglyphic patterns – arches (A), radial loops (RL), ulnar loops (UL), and whorls (W) – were determined for each digit in relation to geographic location, altitude, and surname origin, resulting in the following categories: HL-FF, HL-FA, HL-AA, LL-FF, LL-FA, and LL-AA. The statistical analyses showed that UL and RL were more common in individuals of HL origin, whereas *W* and *A* were more frequent in the LL males ($p < 0.05$). Significant associations were observed between finger dermatoglyphic patterns and surname origin when geographic altitude was considered. In the HL group, UL was associated with AA and FA; in the LL group, the presence of A was associated with FF and FA. The distribution of dermatoglyphic patterns shows that the population of Jujuy belongs to the Andean gene pool and that it has undergone differential levels of admixture related to altitude.

Introduction

From genetic, evolutionary, and bioanthropological perspectives, dermatoglyphics have been used extensively to characterize populations, analyze the nature and origin of human variation and population structure, and evaluate the microdifferentiation of populations (Garruto et al., 1987; Jantz, 1987; Meier, 1980; Segura-Wang and Barrantes, 2009; Wertelecki and Plato,1979). Most dermatoglyphic studies of the indigenous and admixed populations of South America were conducted in the 1970s and 1980s (Coope and Roberts, 1971; Garruto et al., 1987; Jantz, 1987). In the 1990s, these studies were interrupted by the development of relatively inexpensive molecular techniques for the direct analysis of DNA polymorphisms, and as a result, dermatoglyphic information of these populations is not as complete as that of other geographic regions of the world.

Numerous multifactorial and gene-related disorders have been associated with the dermatoglyphic characteristics of individuals and populations (Blangero, 1990; Crawford and Duggirala, 1992; Fañanás et al., 1990; Kumbnani, 2007; Loesch, 1983; Rosa et al., 2005; Schaumann and Alter, 1976). Fewer studies have linked these features with climatic and environmental conditions, particularly geographic altitude (Hiernaux and Froment, 1976; Rose, 1985). According to Jantz (1987), Native American populations offer a unique opportunity to evaluate the impact of geographic altitude on the development of dermatoglyphic patterns.

Surnames, like genes, are patrilineally or matrilineally inherited, and they behave as additional genetic markers. Thus, it is reasonable to assume that genetic or partially genetic traits might occur with different frequency in people with surnames of different ethnic, geographic, or cultural origin (Balanovskii et al., 2001). Due to the status of surnames as "quasi-genetic" markers (Balanovskii et al., 2001), their Mendelian transmission; association with different genetic markers (Chakraborty et al., 1989; Dipierri et al., 1998, 1999; Fisher and Vaughan, 1939; Stevenson et al., 1983); and association with multifactorial anthropometric characters, such as male adult height (Bejarano et al., 2009), have been analyzed. Arrieta et al. (1987) used surnames as ethnic indicators to select subjects for dermatoglyphic studies based on the autochthonism of their anthroponyms. However, no study thus far has used surnames to disaggregate populations based on the ethnicity of their surnames, as in the current study.

The aim of this study was to analyze the relationships among variability of finger dermatoglyphic patterns, geographic altitude, and geographic–linguistic surname origin in an adult male population in the province of Jujuy. Concurrently, based on the finger dermatoglyphic pattern frequencies of the population of Jujuy, this study aimed to establish biological affinities with other native and admixed South American populations living in the same Andean environment or in geographically and/or ethnically more remote settings or milieus.

Materials and methods

Fingerprints were collected from 996 healthy men, aged 18–20 years, from the four geographic regions of the province of Jujuy, distributed over an altitudinal gradient as follows: Puna (3500 m asl), Quebrada (2500 m asl), Valles (1200 m asl), and Selvas (500 m asl). In this paper, data from the Puna and Quebrada regions were grouped as highlands (HL), and data from Valles and Selvas were grouped as lowlands (LL).

The individuals in this study were classified into two broad categories according to the linguistic–geographic origin of maternal and paternal surnames: Native American or autochthonous (A) and foreign (F) (*i.e.*, from other parts of the world). This classification was based primarily on empirical knowledge and a literature search. Colonial Charcas, Jujuy, and Tucuman documentation was consulted in the case of indigenous names (Erdman, 1964), in addition to various digital databases available on the Internet. Based on this classification, the individuals were grouped into three subsets: (a) both paternal and maternal surnames of foreign origin (FF), (b) a foreign and a native surname (FA), and (c) both native surnames (AA).

Fingerprints of both hands were obtained by the classical method of impregnating the epidermis with ink and rolling the fingers on paper. Dermatoglyphic patterns were classified according to the number of triradii in arches (A), ulnar loops (UL), radial loops (RL), and whorls (W) (Penrose, 1968).

Statistical analysis

Dermatoglyphic pattern frequencies were calculated for the individual fingers of the right and left hands and for both hands together, according to geographic altitude (HL and LL), linguistic origin of surnames (FF, FA, AA), and geographic altitude/surname, thus establishing six categories for analysis: HL_FF, HL_FA, HL_AA, LL_FF, LL_FA, and LL_AA.

The association between the frequency of dermatoglyphic patterns and different population subsets, defined by geographic altitude, surname origin, and geographic altitude/surname, was analyzed using the Chi-squared test and correspondence analysis (CA).

Biological relationships based on frequencies of dermatoglyphic patterns among the Jujuy population and other South American groups were established by cluster analysis using Ward's method, based on Euclidean distance matrices. For this purpose, two sets of populations were used: (a) individual finger dermatoglyphic frequencies: Pilagá (Demarchi and Marcellino, 1995), Toba (Reichmann, 1978), Chorote (Demarchi and Seisdedos, 1996), Mataco (Salta) (Ocampo et al., 1988), Caingang (Roberts et al., 1971), Cayapó (Peña et al., 1972), Erigbactsa (Janzen et al., 1983), Chiriguano (Giordano, 1981), Cashinahua (Jantz et al., 1969), Quechua (Klayman et al., 1977), Chipaya (Murillo et al., 1977), Mapuche (Rothhammer and Dixon, 1969), Araucano (Giordano, 1975), Pewenche (Rothhammer and Dixon, 1969), Surui (Vieira Filho, 1973), and Jivaro (Sunderland and Ryman, 1968) and (b) pooled finger dermatoglyphic frequencies: Vicos (Ancash, Peru) (Newman, 1974), Macusani, Acllamayo, Ollachea, San Juan de Oro, Nuñoa (Puno, Peru) (Plato et al., 1974), Shipibo, Cocamas (Ucayali, Peru) (Valencia and Arzola, 1981), Mestizos (Lima, Peru) (Valencia et al., 1986), Pamashto, Ondores (Peru) (Klayman et al., 1977), and San Pedro de Casta (Peru) (Ramírez Baca et al., 2001).

Results

Table 1 shows the relative frequencies of finger dermatoglyphic patterns by individual fingers and by hands for previously defined variables and categories. The correspondence analysis revealed a significant association between the altitude and dermatoglyphic patterns (Chi-squared = 31.589, df = 3, $p < 0.001$). The ulnar loops (UL) and radial loops (RL) were more common among highland (HL) individuals, whereas whorls (W) and archers (A) were more frequent among lowland (LL) individuals. No significant association was observed between the frequency of finger dermatoglyphic patterns and linguistic origin of surnames.

When altitude and surname origin were considered together against variation in finger dermatoglyphic patterns (Fig. 1), the CA revealed a highly significant association (Chi-squared = 70.510, df = 15, $p < 0.001$), explaining 97.33% of the inertia in the first two dimensions. The distribution of the patterns

Table 1
Distribution of the sample and percentage frequencies for digital dermatoglyphic patterns by individual fingers and by both hands, according to the variables and categories.

Variables			Altitude		Surnames			Altitude/surnames					
Category			HL	LL	FF	FA	AA	HL_FF	HL_FA	HL_AA	LL_FF	LL_FA	LL_AA
N			231	765	609	314	73	67	122	42	542	192	31
Hands	Fingers	Types of pattern											
	F1	A	3.46	4.84	4.11	6.05	1.37	2.99	4.10	2.38	4.24	7.29	0.00
		RL	2.60	2.09	2.30	1.91	2.74	4.48	1.64	2.38	2.03	2.08	3.23
		UL	38.53	38.30	36.95	40.45	41.10	25.37	44.26	42.86	38.38	38.02	38.71
		W	55.41	54.77	56.65	51.59	54.79	67.16	50.00	52.38	55.35	52.60	58.06
	F2	A	9.09	16.34	15.27	13.69	13.70	1.49	11.48	14.29	16.97	15.10	12.90
		RL	19.48	13.59	14.29	15.92	16.44	23.88	16.39	21.43	13.10	15.63	9.68
		UL	31.60	34.51	33.33	35.35	31.51	25.37	36.89	26.19	34.32	34.38	38.71
		W	39.83	35.56	37.11	35.03	38.36	49.25	35.25	38.10	35.61	34.90	38.71
	F3	A	2.60	6.93	5.75	7.64	0.00	1.49	4.10	0.00	6.27	9.90	0.00
Right hand		RL	0.43	1.31	1.48	0.64	0.00	1.49	0.00	0.00	1.48	1.04	0.00
		UL	68.83	66.41	66.67	66.88	69.86	67.16	70.49	66.67	66.61	64.58	74.19
		W	28.14	25.36	26.11	24.84	30.14	29.85	25.41	33.33	25.65	24.48	25.81
	F4	A	1.30	2.48	1.97	2.87	1.37	0.00	2.46	0.00	2.21	3.13	3.23
		RL	2.60	1.18	1.31	2.23	0.00	2.99	3.28	0.00	1.11	1.56	0.00
		UL	38.10	42.35	40.89	42.99	38.36	25.37	45.08	38.10	42.80	41.67	38.71
		W	58.01	53.99	55.83	51.91	60.27	71.64	49.18	61.90	53.87	53.65	58.06
	F5	A	0.43	3.27	2.96	2.23	1.37	1.49	0.00	0.00	3.14	3.65	3.23
		RL	0.43	1.44	1.31	0.96	1.37	0.00	0.82	0.00	1.48	1.04	3.23
		UL	83.98	79.22	79.47	82.48	78.08	86.57	84.43	78.57	78.60	81.25	77.42
		W	15.15	16.08	16.26	14.33	19.18	11.94	14.75	21.43	16.79	14.06	16.13
	F6	A	3.46	5.36	4.27	6.37	4.11	1.49	4.92	2.38	4.61	7.29	6.45
		RL	4.76	2.35	2.96	2.55	4.11	7.46	2.46	7.14	2.40	2.60	0.00
		UL	45.45	40.92	41.22	41.72	49.32	32.84	50.00	52.38	42.25	36.46	45.16
		W	46.32	51.37	51.56	49.36	42.47	58.21	42.62	38.10	50.74	53.65	48.39
	F7	A	11.69	18.43	17.41	16.24	15.07	5.97	14.75	11.90	18.82	17.19	19.35
		RL	15.15	12.55	12.32	14.97	12.33	16.42	14.75	14.29	11.81	15.10	9.68
		UL	38.10	31.37	32.84	32.48	35.62	31.34	40.16	42.86	33.03	27.60	25.81
		W	35.06	37.65	37.44	36.31	36.99	46.27	30.33	30.95	36.35	40.10	45.16
	F8	A	3.90	6.41	6.08	6.05	2.74	1.49	4.92	4.76	6.64	6.77	0.00
Left hand		RL	0.43	1.57	1.81	0.32	1.37	0.00	0.00	2.38	2.03	0.52	0.00
		UL	71.00	65.88	66.17	68.15	69.86	70.15	72.95	66.67	65.68	65.10	74.19
		W	24.68	26.14	25.94	25.48	26.03	28.36	22.13	26.19	25.65	27.60	25.81
	F9	A	1.73	2.35	1.97	3.18	0.00	0.00	3.28	0.00	2.21	3.13	0.00
		RL	0.87	2.35	2.13	1.91	1.37	1.49	0.82	0.00	2.21	2.60	3.23
		UL	45.89	41.96	43.02	42.99	41.10	49.25	45.08	42.86	42.25	41.67	38.71
		W	51.52	53.33	52.87	51.91	57.53	49.25	50.82	57.14	53.32	52.60	58.06
		A	1.73	3.01	3.12	1.91	2.74	1.49	1.64	2.38	3.32	2.08	3.23
	F10	RL	1.30	1.18	0.82	1.27	4.11	1.49	0.82	2.38	0.74	1.56	6.45
		UL	86.15	78.30	79.47	81.85	78.08	89.55	85.25	83.33	78.23	79.69	70.97
		W	10.82	17.52	16.58	14.97	15.07	7.46	12.30	11.90	17.71	16.67	19.35
		A	3.93	6.94	6.29	6.62	4.24	1.79	5.16	3.80	6.84	7.55	4.83
Both hands		RL	4.80	3.96	4.07	4.27	4.38	5.97	4.09	5.00	3.83	4.37	3.54
		UL	54.76	51.92	52.00	53.53	53.28	50.29	57.45	54.04	52.21	51.04	52.25
		W	36.49	37.17	37.63	35.57	38.02	41.94	33.27	37.14	37.10	37.03	39.54

separated HL from LL along the first dimension. In the HL, UL were more common in individuals with native surnames (AA and FA), whereas RL and W were more common in individuals with foreign surnames (HL_FF). In the LL, the presence of A was associated with individuals with foreign surnames (FF and FA), and RL and W with individuals with native surnames (AA).

A significant association (Chi-squared value = 126.58, df = 95, $p < 0.05$) was found between surname origin according to altitude and digital patterns of individual fingers. This association is shown in the CA plot in Fig. 2, which explains 70% of the total inertia. The first dimension separates LL individuals

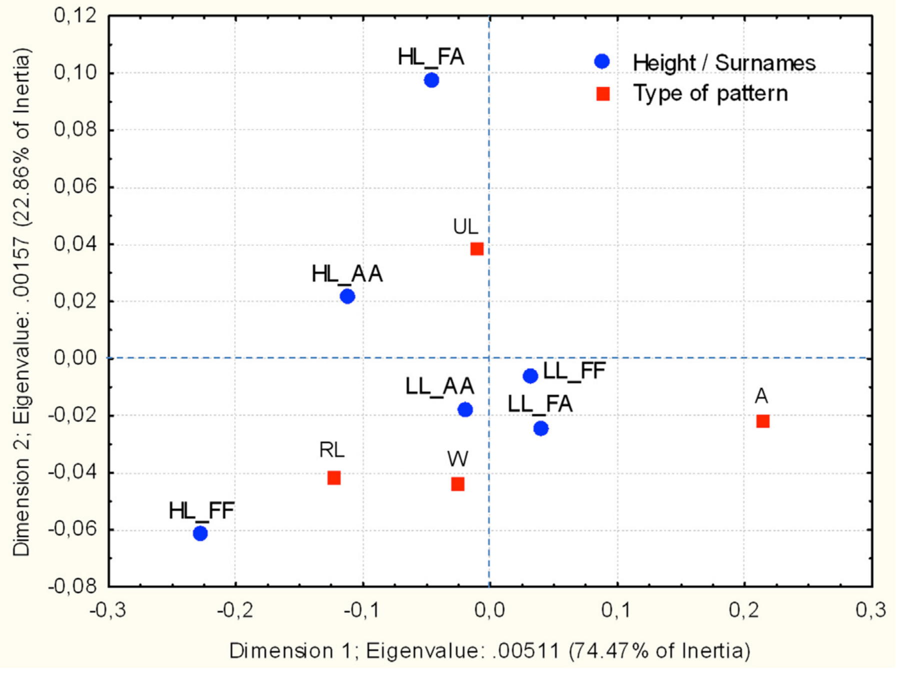

Fig. 1. Analysis of correspondence among geographic altitude, surname origin, and finger dermatoglyphic patterns. Altitude: highlands (HL) and lowlands (LL); surnames: native or autochthonous (A) and foreign (F); type of pattern: arches (A), radial loops (RL), ulnar loops (UL), and whorls (W).

with a foreign surname (FF and FA) from those with AA surnames, and from HL individuals with foreign or indigenous surnames (FF, FA, and AA). The second dimension separates the native surnames (AA) of HL and LL individuals with a predominance of UL from foreign (FF) HL and LL surnames characterized by higher frequencies of A and W. The presence of A was associated with LL individuals who had one or both foreign surnames (FF, FA), and high incidence of W was associated with HL individuals with both foreign surnames (FF). This group also exhibited a predominance of RL.

Fig. 3 presents a cluster analysis based on Euclidean distances that includes samples from other male Native Americans from South America, considering the frequencies of individual dermatoglyphic pattern types. The sample from Jujuy is represented by two separate subsamples (HL and LL). Both samples cluster together with the Mapuche and Araucanian samples, gathered from the southern Andes. These samples are linked first with the Chiriguanos, a group of Amazonian farmers who moved to the western border of the Gran Chaco region in the 15th century, and then with the Pilagá (Giordano, 1981), an ethnic group from the Gran Chaco belonging to the Guaycurú language family. It is relevant to point out the close geographic proximity among the Jujuy populations and the locations where the Chiriguano samples were taken (Yacuy and Carapari River, San Martin Department, and Salta) (Giordano, 1981). Completing this cluster is the Quechua sample, which represents a typical Andean population.

Similar results were found when the total finger dermatoglyphic frequencies by altitude were considered. Here, the LL association with the Mapuche population, and later with the Andean Mestizo population (San Pedro Casta, Peru), was replicated, whereas HL individuals were clearly associated with two Andean Quechua communities of the Peruvian highlands, Vicos (Ancahs) and Ollachea (Puno) (Fig. 4). These two clusters then joined other populations of the Central Andes and the Peruvian Amazon.

Fig. 5 shows that the subset with both maternal and paternal surnames of native origin (HL_AA), again, is associated with the Vicos and Ollachea Andean populations previously described. The subset

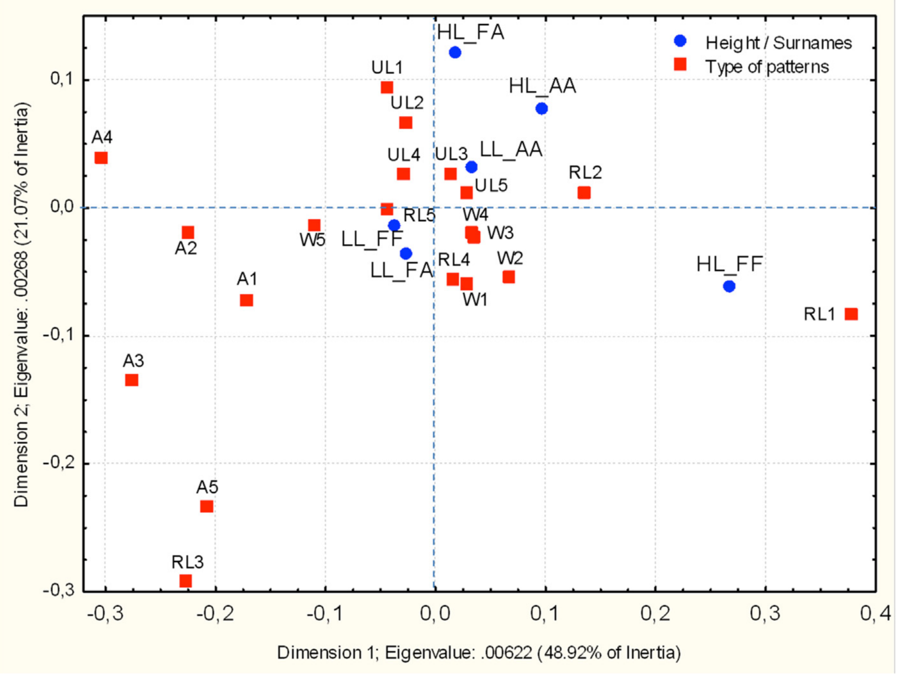

Fig. 2. Analysis of correspondence among geographic altitude, surname origin, and dermatoglyphic patterns on the fingers. Altitude: highlands (HL) and lowlands (LL); surnames: native or autochthonous (A) and foreign (F); type of pattern: arches (A), radial loops (RL), ulnar loops (UL), and whorls (W). Fingers: $i = 1$ to 10.

HL_FF also clusters with another Andean rural community, Nuñoa (Peru), located at 4000 m asl. The subset HL_FA was associated, on one hand, with an Andean Mestizo population and, on the other, with ethnic groups from the Peruvian Amazonia, the Cocamas (Tupi-Guarani language), and the Shipibo (Pano language). However, lowland subsets remained close to each other, joining the Mapuche groups.

Discussion

The results obtained in this study enabled us to characterize the variability of finger dermatoglyphic patterns in the male population of the province of Jujuy, Argentina, and to assess the impact of geographic and ethnic origins on dermatoglyphic pattern variation.

To our knowledge, there are no records in the dermatoglyphics literature about the use of the linguistic origin of surnames to disaggregate populations. Studies are also rather infrequent with respect to the role of geographic altitude in dermatoglyphic variation (Garruto et al., 1987; Jantz et al., 1969; Jantz, 1987; Parham, 1985; Ramírez Baca et al., 2001). Garruto et al. (1987) argued that, compared to other Amerindian populations, South American indigenous groups exhibited a wider range of variability in dermatoglyphic traits. Clear differences in dermatoglyphic traits have also been observed between indigenous Andean and non-Andean groups (Garruto et al., 1987; Klayman et al., 1977; Ramírez Baca et al., 2001). These differences have frequently been attributed to fusion/fission secular processes observed in non-Andean lowland groups. Except for the study by Parham (1985), most studies have interpreted dermatoglyphic differences between Andean and non-Andean populations in terms of genetic drift and/or migration, and not due to geographic altitude and its associated factors, *per se*, especially hypobaric hypoxia. In an analysis of the number of ridges in the distal palms of a Quechua population, Parham (1985) observed altitudinal differences in the form of a radial–ulnar gradient, with the highland Quechua presenting higher a–b and lower c–d counts than the lowland Quechua. The author attributed those differences to the effects of hypoxic stress.

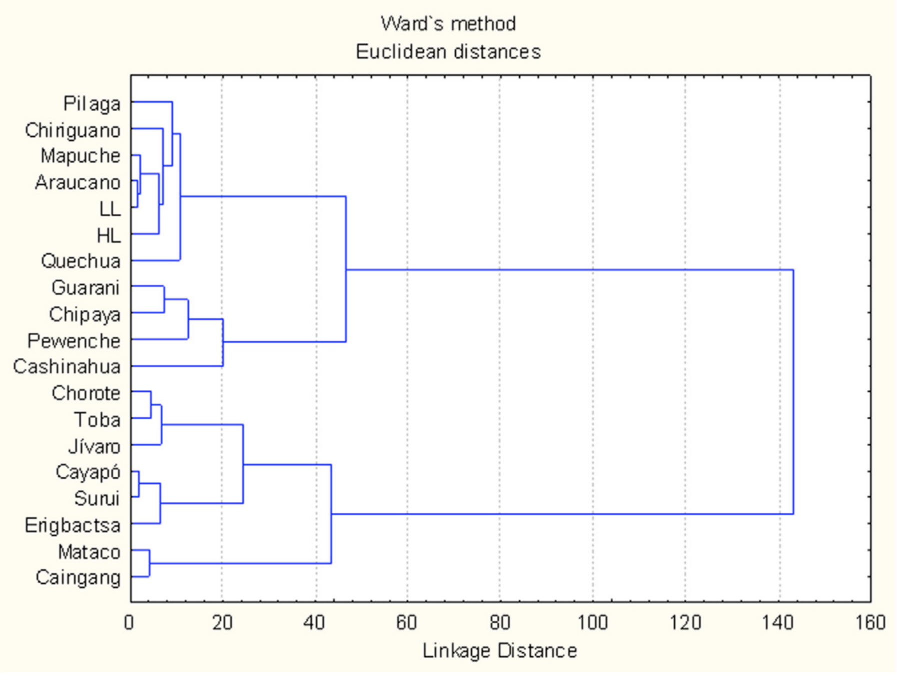

Fig. 3. Cluster analysis based on frequencies of dermatoglyphic patterns on the fingers and altitude. Altitude: highlands (HL) and lowlands (LL).

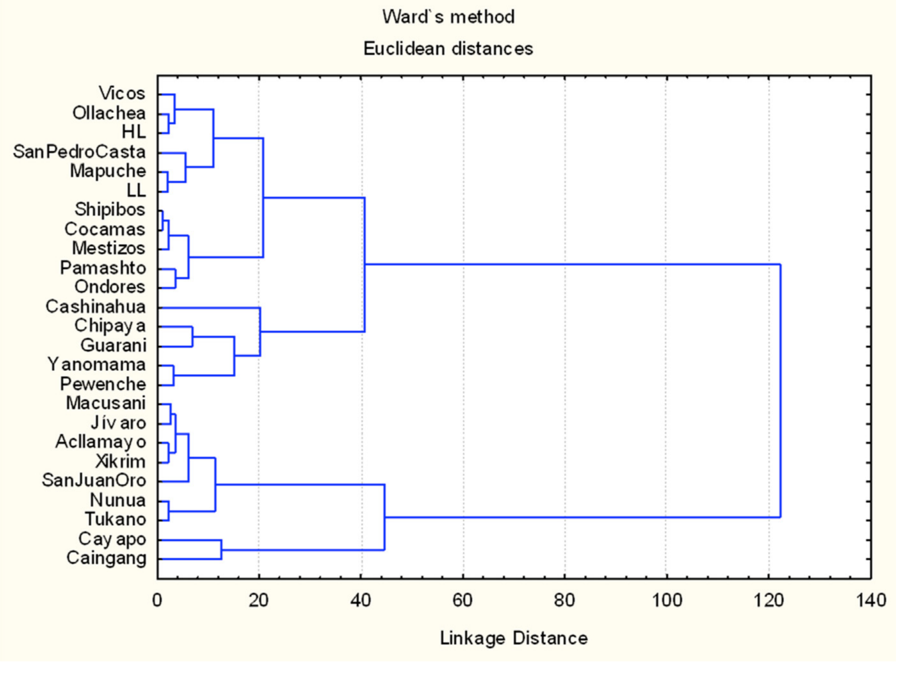

Fig. 4. Cluster analysis of total dermatoglyphic pattern frequencies according to altitude. Altitude: highlands (HL) and lowlands (LL).

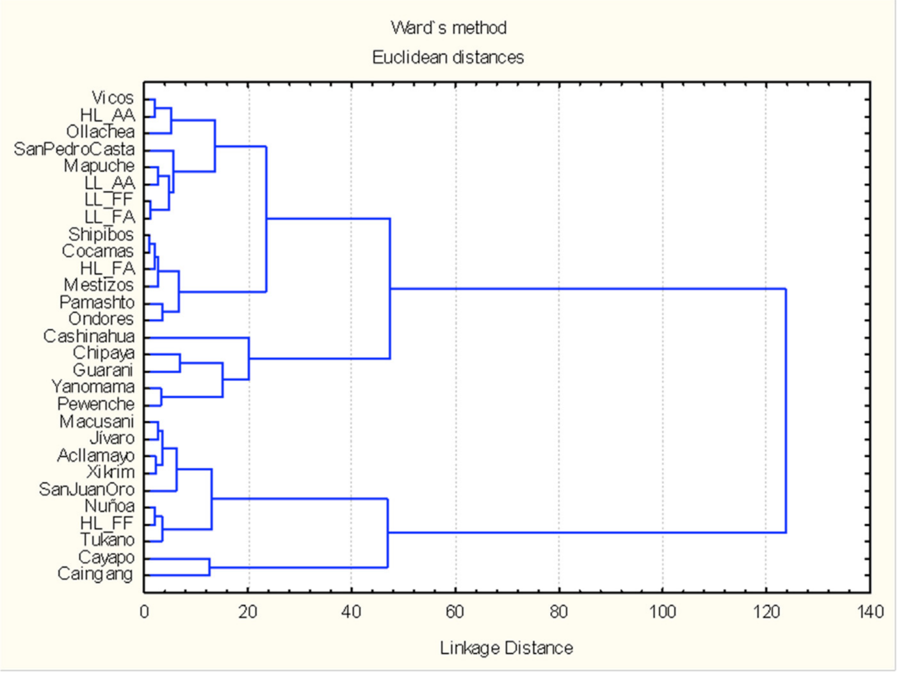

Fig. 5. Cluster analysis of total dermatoglyphic pattern frequencies according to altitude and surname origin. Altitude: highlands (HL) and lowlands (LL); surnames: native or autochthonous (A) and foreign (F).

Limitations in the literature make it difficult to draw comparisons with our results. In addition to a paucity of studies, the studies that do exist are of varying quality and heterogeneity in terms of the geographic or ethno-ecological criteria used to identify the populations (Coope and Roberts, 1971; Garruto et al., 1987; Ramírez Baca et al., 2001). Regardless of geographic altitude and surname origin, the Jujuy populations are characterized by a high frequency of UL (above 50%), followed by W (>30%), with A and RL frequencies below 10% (Table 1). UL and RL were more common in individuals from the HL. In male Andean populations, UL frequencies ranging from 46% in Macusani (Plato et al., 1974) to 61.6% in Chipaya (Murillo et al., 1977) have been reported, whereas RL frequencies ranging between 3.5% in Ondores (Klayman et al., 1977) and 5.3% in Macusani (Plato et al., 1974) have been found. The UL and RL frequencies found in the population of Jujuy fall within these ranges of reference, both for the HL and LL (Table 1). Interestingly, individuals with both paternal and maternal surnames of foreign origin show the lowest frequencies of UL (52%) and RL (4.07%) (Table 1). This trend was also evident in the correspondence analysis, showing that in the highland UL group, most individuals have at least one paternal or maternal Native American surname (FA) (Fig. 1).

Although the frequency of W found in HL individuals (36.49%) was slightly lower than that observed in the LL (37.17%), this value falls within the range of variation reported for Andean populations compared with non-Andean male populations – 32.5% in Ondores (Klayman et al., 1977) and 47.3% in San Pedro Casta (Ramírez Baca et al., 2001). The greatest frequency of W (41.9%) occurred in HL individuals with both maternal and paternal native surnames. The values for A observed in the highland were, on average, 50% lower than those observed in lowland individuals (Table 1); however, both values fell within the range of variation reported for Andean male populations, ranging from 1.8% in San Juan de Oro (Plato et al., 1974) to 11.5% in Ondores (Klayman et al., 1977). The smallest percentage of whorls (4.24%) was noted in individuals with maternal and paternal native surnames. This result is observed in the correspondence analysis, indicating that in the LL, arches are associated more frequently with individuals with at least one name of foreign origin (FA). According to Ramírez Baca et al. (2001), the low percentage of A observed in Peruvian populations is related to their geographic location, with the high-altitude Puno populations (Macusani, Acllamayo, Ollachea, San Juan de Oro, and Nuñoa) having lower A frequencies compared with Amazonian populations (Shipibo, Cocamas, and Cashinahua). These relationships are evident in the dendrogram shown in Fig. 5.

The present-day population of Jujuy is characterized by a significant association between surname origin (native or foreign) and erythrocyte genetic markers (ABO and Rh) (Dipierri et al., 1999; Morales et al., 2003), markers of uniparental inheritance (Dipierri et al., 1998), and multifactorial anthropometric traits, such as height (Bejarano et al., 2009). However, in this study, the Chi-squared test did not show any statistically significant associations between the frequencies of total finger dermatoglyphic patterns and surname origin. However, significant associations were found when the altitude factor and surname origin were considered simultaneously. In addition, the analysis was performed at the individual finger pattern level, indicating that surnames allow disaggregation of populations on the basis of dermatoglyphic frequency (Fig. 5).

Therefore, taking into account geographic altitude and surname origin, the distribution of finger dermatoglyphic patterns in the Jujuy population is characterized by high frequency of UL in HL individuals with native surnames and high frequency of A in LL individuals with foreign surnames (Figs. 1 and 2). Based on these considerations, one could postulate that the ancestral Andean finger dermatoglyphic pattern would most likely be characterized by high frequency of UL and low frequency of A.

Due to the location of the province of Jujuy in the Andean foothills, previous studies have analyzed different genetic markers to assess the influence of altitude on the gene pool of the population. These studies revealed that genetic diversity is geographically structured (Dipierri et al., 2000; Morales et al., 2000). This diversity is conditioned by geographic altitude and characterized by gene flow and differential rates of genetic admixture, where the isolated and less admixed populations, living at higher altitudes, present a predominant Native American contribution, followed, to a much lesser degree, by European and African influences (Demarchi et al., 2000; Dipierri et al., 1998, 1999; Morales et al., 2000; Peña et al., 1972; Tamm et al., 2007; Wang et al., 2008). The distribution of finger dermatoglyphic patterns according to altitude found in this work reveals a differential admixture process experienced by the population at different pre- and post-colonial stages of colonization and settlement. The results also show that although this population shows biological affinity primarily with central Andes populations and secondarily with southern Andean groups and other linguistic groups, it is also genetically and historically related to non-Andean populations, such as Amazonian groups.

The biological affinity between Andean and Amazonian populations based on finger dermatoglyphic patterns is a well-established fact (Ramírez Baca et al., 2001; Demarchi and Marcellino, 1998; Hoff et al., 1981). This relationship suggests gene flow between the Andean highlands populations of Peru and Bolivia with groups from the eastern lowlands (Ortiz and Ventura, 2003). Supporting this evidence, previous research involving the analysis of mitochondrial variation at hypervariable region I (mtDNA HVRI) revealed no significant differences between the Andean and Amazonian populations (Barbieri et al., 2011).

The dermatoglyphic affinities between the population from Jujuy and the Andean populations lead us to conclude that the former is part of the Andean gene pool, and that dermatoglyphic studies, in conjunction with anthroponyms, offer an underexploited and valuable strategy for understanding the evolutionary dynamics of human populations.

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