Sibling Correlations of Skin Pigmentation during Growth

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Abstract The present study is focused on the analysis of skin color correlations in a sample of 1039 siblings aged 4 to 20 years from the province of Biscay (Basque Country, Spain). Measurements were taken at the upper inner arm and forehead by means of an EEL DS29 Digital Unigalvo reflectance spectrophotometer fitted with filters 601, 605, and 609. The reflectance data were internally standardized according to sex and age of the individuals, and the analysis of the degree of similarity between siblings was based on the calculation of intraclass correlation coefficients. All 3 filters gave fairly high and statistically significant correlations regarding forehead skin color (between 0.28 and 0.45) for all types of siblings under consideration. However, with respect to filter 609 the arm reflectance values did not reveal correlation either between brothers (0.01) or between siblings (0.02), even though it did reveal correlation between sisters (0.29). When other filters or type of sibling were considered (also for arm), all coefficients happened to be statistically significant and relatively high (0.35–0.43). This study confirms that the degree of sibling resemblance with regard to skin pigmentation is influenced by growth factors and that the upper inner arm and the forehead skin patterns change with age in the sense that, during and especially after puberty, the coefficients of correlation are higher for arm reflectance than for forehead reflectance; the forehead is a site that is more influenced by environment.

Skin pigmentation is a classic example of a polygenic trait with continuous variation (Cavalli-Sforza and Bodmer 1981). The genetics of normal skin color variation seems to respond to a polygenic model regulated by several major genes. Some researchers have suggested that genetic factors involved in skin color are equal and additive in nature and that the number of genes involved probably ranges from 3 to 6 (Harrison and Owen 1964; Harrison et

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al. 1967; Stern 1970; Harrison 1973). However, the method of constructing models to determine the number of loci in a hybrid population was called into question because it seemed probable that many more loci were involved in the determination of skin pigmentation (Byard 1981; Byard and Lees 1981). In the analysis of intrapopulational variation environmental influences and age and sex factors are not negligible (Leguebe 1986). The quantitative method based on spectrophotometry (Weiner 1951) allowed many anthropological analyses of interpopulational variability, microdifferentiation, sexual dimorphism, ontogeny, socioeconomic variability, assortative mating, and estimation of heritability, even though studies on heritability do not abound (Kalla 1972; Roberts and Khalon 1972; Rigters-Aris 1973; Post and Rao 1977; Clark et al. 1981; Frisancho et al. 1981; Banerjee 1984; Williams-Blangero and Blangero 1992).

Familial resemblance is often used to estimate the heritability of anthropometric traits (Susanne 1975, 1977, 1980). Anthropological studies of familial resemblance in Spain have seldom been undertaken. Nevertheless, recent research on the heritability of body measurements and body composition and on cephalic and facial traits (Sánchez-Andrés 1992, 1995; Sánchez-Andrés and Mesa 1994) were published together with parallel studies carried out among the Basque population (Rebato et al. 1995; Rebato, Rosique et al. 1997; Rebato, Salces et al. 1997; Salces 1995; San Martín 1995). Studies on heritability of skin pigmentation in Spain are not frequent either and have never been published. The anthropological variability of skin pigmentation in the Basque Country, on the other hand, has already been analyzed (Rebato 1987; Rebato et al. 1991; Rebato, Rosique et al. 1993). The present research is focused on the degree of skin pigmentation resemblance during growth among siblings from a sample of Basque individuals from Biscay province; the correlations between siblings and the evolution of such correlations with age are studied.

Materials and Methods

The sample was made up of 1039 siblings (521 boys and 518 girls) from 530 families living in Biscay province (Basque Country, Spain), whose ages range from 4 to 20 years [the exact age was obtained using the method of Weiner and Lourie (1981)]. According to the professional and cultural levels of their parents, we can consider the individuals of our sample as belonging to the middle socioeconomic class. This sample was included in a general study of growth and development among the school-aged population from Biscay province.

The upper inner arm and the forehead were measured with a portable EEL DS29 Digital Unigalvo reflectance spectrophotometer fitted with filters 601, 605, and 609, corresponding to wavelengths of 425, 545, and 685 nm, respectively. The filters can successfully summarize the complete spectral variation of human skin reflectance (Leguebe 1961) and are the most commonly and frequently used in both inter- and intrapopulational studies of variability, particularly on the macrogeographic level [see review by Byard (1981)], and in genetic analyses (Greksa 1992, 1996; Greksa et al. 1991; Williams-Blangero and Blangero 1992), including familial studies (Clark et al. 1981).

Nevertheless, it should be stressed that the reflectance measurements taken with filter 609 (685 nm) provide the most reliable means of determining skin melanin concentration (Kalla 1968), because melanin concentration is not significantly conditioned by changes in blood flow (Lee and Lasker 1959; Harmse 1964; Harrison and Owen 1964) or by external sources of variation (such as ultraviolet radiation) when measurements are taken at unexposed areas such as the upper inner arm (Harrison 1961; Byard 1981; Byard and Lees 1982). On the other hand, reflectance measurements obtained with filter 605 are closely linked to vascular changes, because the absorption band of hemoglobin lies at 545 nm (Edwards et al. 1951). Measurements taken with filter 601 (425 nm) are related to flushing rather than to tanning (Barnicot 1958; Conway and Baker 1972), although the absorption band of melanin is located close to this wavelength (Garn et al. 1956).

Although it has been satisfactorily proved that, unlike other anthropometric traits, interobserver error is negligible in skin reflectance measurements (Lees et al. 1978; Greksa et al. 1991), all measurements were taken by only one of us (E. Rebato) following standard protocols (Weiner and Lourie 1981). Beerens (1980) drew attention to the possibility of making systematic measurement errors because of the position of the measuring head, so we took all feasible precautions when we applied the head to the measured surface. Measurements were taken during the academic year to avoid the summer period of maximum exposure to the sun. The normality of the reflectance data was verified by means of the Kolmogorov-Smirnov test, whereas global variations in pigmentation with age were checked using a (one-way) analysis of variance (ANOVA).

The degree of resemblance among siblings has been expressed by intraclass correlation coefficients (Sokal and Rohlf 1981) on the basis of standard reflectance percentage terms calculated with the formula $z = (x - X)/SD$ according to age and sex, where x is the individual observed value of reflectance, X is the expected mean value of the variable (percentage of reflectance) according to age and sex, and SD is the expected standard deviation.

The expected mean values (X) used to calculate each individual's z score were obtained by fitting raw variables (reflectance percentages) by age to a third-degree polynomial,

$$X = a(\text{age}) + b(\text{age})^2 + c(\text{age})^3, \tag{1}$$

for both sexes separately. Similarly, the expected standard deviations were computed by fitting a second-degree polynomial,

$$SD = a(\text{age}) + b(\text{age})^2, \quad (2)$$

to the standard deviations obtained from the 1-year age group. These fitted curves provide appropriate estimations of the sample's means and standard deviations at specific ages.

The variation of correlations between siblings resulting from age were estimated by establishing 3 age groups: younger than 12 years, between 12 and 15 years, and 15 years and older. We fixed these groups as prepubertal, pubertal, and postpubertal after checking the mean age of menarche of our population (Rebato González Apraiz et al. 1993; Rebato et al. 1994) and the age at peak height velocity (PHV) (Rosique and Rebato 1995). The correlation coefficients were tested 2 by 2 by means of a t_S homogeneity test based on the t test (Sokal and Rohlf 1981).

Results

Variability of Average Reflectometry Values. Table 1 describes statistically the upper inner arm and forehead reflectances measured with the 3 wavelengths in different age and sex groups. The distribution of data can be considered normal (Kolmogorov-Smirnov test, $p \leq 0.05$). Because of the rather small sample size, individuals between 4 and 5 years old were included in the 5-year-old category. Likewise, the category of 18-year-olds included individuals up to age 20 years.

Filters 601 and 605 proved that in both sexes the color of the skin was lighter in the arm than in the forehead. Filter 609 revealed variations dependent on age, with the arm more pigmented than the forehead in 11–13-year-old girls and in 8-year-old and 10–13-year-old boys. In general, the girls' arm and forehead skin was less pigmented than the boys' and possessed higher reflectance average values at almost all ages and filters. With regard to age variability, the arm reflectance measurements taken with filter 609 revealed a tendency to be darker (lower reflectance percentages) in both sexes during the prepubertal period. During the following pubertal and postpubertal periods (girls older than 13 years and boys older than 14 years), the skin tended to become lighter. The general lightening trend of the arm skin at the pubertal-postpubertal period could be extended with the other filters.

The pattern of change with age was dubious so far as the forehead was concerned. All 3 filters revealed a tendency toward darkening in 12–17-year-old boys (interrupted, though, at age 15), whereas reflectance values later increased in 18–20-year-olds. The girls' tendencies were more variable and more pronounced than the boys', showing a tendency to be lighter after 15 years old, mainly with filter 609. Age pigmentation variations were statistically significant for both sexes ($p \leq 0.001$), with the exception of boys' reflectance values measured at the forehead with filter 609 ($p = 0.146$) and with filter 601 for girls ($p < 0.08$).

Sibling Resemblance. Arm and forehead intraclass correlation coefficients for the 3 filters and the 3 types of sibling correlations (brother-brother, sister-sister and sib-sib) appear in Table 2. Between brothers the highest correlation coefficients correspond to the forehead with filter 601 (0.45) and to the arm (0.42) and forehead (0.41) with filter 605, with the lowest coefficient corresponding to the arm with filter 609 (0.01). Between sisters the highest correlation values were observed in the arm with filter 601 (0.43) and the lowest values were observed with filter 609 also in the arm (0.29). Among the whole sibling group the highest correlations were observed in the arm with filter 601 (0.40) and the lowest correlations were found in the arm with filter 609 (0.02). All correlation coefficients were statistically significant ($p \leq 0.001$), with the exception of filter 609 between brothers and between siblings at the arm.

Age Variation of Intraclass Correlations. Table 3 shows intraclass correlations for the whole sibling sample in the 3 age groups: prepubertal (<12 years), pubertal (12–15 years), and postpubertal (≥ 15 years). The calculated forehead coefficients were clearly higher in the prepubertal period (0.47 with filter 601, 0.44 with filter 605, and 0.42 with filter 609) than in the postpubertal period (0.31, 0.23, and 0.24, respectively). On the other hand, the arm coefficients were much lower during the prepubertal period (the value even approached 0 with filter 609) than during the postpubertal period, where filter 601 revealed a value of 0.6, higher than the theoretical value of 0.5 expected between siblings. It was also interesting to observe that, during the prepubertal period, the correlation coefficients were clearly higher with regard to the forehead (0.42–0.47) than to the arm (0.01–0.32). On the contrary, during the postpubertal period, the tendency was reversed and the correlations were lower at the forehead (0.23–0.31) than at the arm (0.41–0.60). In both cases all coefficients were statistically significant.

Figure 1 illustrates the age variation patterns of intraclass coefficients at the forehead and arm with the 3 filters. Statistical differences between correlations in each age group are shown in Table 4. The correlation values of the forehead decreased gradually during growth, with the exception of filter 601, which revealed a small increase after puberty but did not altogether reach prepubertal values again (Figure 1, top). This decrease was significant between the pre- and postpubertal periods with filters 605 and 609 and between the pre- and pubertal periods with filter 601 (Table 4). With the exception of filter 601, which showed a nonsignificant decrease between the prepubertal and pubertal periods, a gradual increase of arm correlation values could be observed to hit the highest values during the postpubertal period (Figure 1, bottom). Between the pre- and postpubertal periods correlations were significantly different (Table 4).

Table 1. Means and Standard Deviations (SD) of the Biscayan Sibling Sample for the Measurements of Skin Reflectance with 3 Filters

		Forehead, Filter 601		*Forehead, Filter 605*		*Forehead, Filter 609*		*Arm, Filter 601*		*Arm, Filter 605*		*Arm, Filter 609*	
Age (Years)	*n*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Boys													
4–5	39	31.64	5.37	38.38	4.68	63.49	5.35	38.77	4.92	43.87	4.12	65.59	3.75
6	25	31.08	6.90	36.92	6.92	62.24	6.24	35.36	7.51	39.80	6.82	62.64	6.18
7	23	31.04	4.45	38.70	4.99	62.70	5.04	35.43	5.09	41.04	4.77	63.61	5.91
8	21	31.86	6.33	38.24	6.08	62.71	5.21	34.90	7.25	38.81	8.43	59.09	7.27
9	52	31.75	6.02	37.56	5.74	62.25	5.94	35.36	6.95	40.92	5.66	62.79	4.97
10	48	30.75	6.26	37.35	4.79	63.04	4.52	32.96	6.98	39.56	4.89	62.50	4.56
11	46	30.96	6.56	36.41	5.86	64.59	5.11	32.35	5.93	36.83	5.73	62.85	5.90
12	57	30.56	6.43	36.33	5.97	63.33	5.41	32.10	6.65	39.03	5.94	62.56	5.33
13	44	27.79	6.10	32.66	5.66	62.59	4.85	31.02	6.82	37.68	5.10	61.32	4.19
14	40	28.05	6.40	31.45	5.58	60.50	6.46	34.20	6.06	39.30	5.43	63.47	4.70
15	38	29.18	4.82	33.74	4.75	63.66	5.65	36.26	7.12	40.39	5.65	64.47	5.62
16	37	27.65	4.78	31.86	5.79	62.78	6.05	35.38	7.21	39.89	6.11	64.78	6.23
17	39	25.61	4.63	29.56	4.43	61.31	5.43	35.72	7.18	41.26	5.86	64.82	4.89
18–20	12	30.50	5.42	34.75	5.43	64.17	6.04	39.75	8.41	42.75	5.94	68.50	5.35

Girls													
4–5	37	32.22	5.92	38.00	5.88	63.19	5.92	38.76	4.96	43.84	4.48	65.54	4.05
6	19	32.42	4.83	38.10	4.48	62.84	5.59	36.63	5.55	41.53	4.74	65.42	3.20
7	13	29.61	5.45	34.31	5.53	56.92	7.19	34.15	5.77	38.23	5.58	60.15	5.32
8	19	33.32	4.67	39.79	4.74	64.21	5.15	38.63	5.44	43.79	4.71	64.84	5.58
9	31	30.00	5.73	37.19	6.60	63.35	4.09	33.64	7.16	40.84	5.59	62.64	4.09
10	45	30.40	5.30	36.40	5.32	61.64	5.66	34.07	6.59	39.31	6.33	61.09	6.19
11	54	30.50	5.60	36.37	4.95	63.78	5.09	32.96	6.15	39.43	4.34	62.46	4.42
12	53	30.40	5.71	35.11	4.41	63.23	5.08	33.47	5.70	39.79	4.93	62.57	3.52
13	48	30.46	5.42	35.77	4.21	64.75	4.52	33.25	6.04	40.56	4.27	64.10	4.28
14	66	29.36	5.31	34.32	5.03	62.62	6.10	35.53	7.03	41.17	5.87	64.73	4.85
15	38	29.63	5.87	34.29	4.82	63.92	5.44	36.76	7.85	42.29	5.78	65.13	5.04
16	52	30.17	5.09	34.08	5.03	64.79	4.83	36.56	8.29	42.11	6.46	65.33	5.76
17	29	32.69	6.70	35.93	6.33	67.72	6.72	40.59	8.07	45.45	7.05	68.38	5.75
18–20	14	31.93	4.20	36.29	5.98	66.64	5.29	43.00	6.42	46.07	4.39	68.86	4.22

Table 2. Intraclass Correlations among Brothers, Sisters, and Sibling Pairs for Reflectance Measurements

Correlation	*Forehead, Filter 601*	*Forehead, Filter 605*	*Forehead, Filter 609*	*Arm, Filter 601*	*Arm, Filter 605*	*Arm, Filter 609*
Brother-brother (n = 272)						
r intraclass	0.45	0.41	0.35	0.40	0.42	0.01
F among groups (d.f. = 134, 137)	2.679[a]	2.376[a]	2.086[a]	2.373[a]	2.471[a]	1.015[b]
Sister-sister (n = 269)						
r intraclass	0.38	0.32	0.37	0.43	0.38	0.29
F among groups (d.f. = 132, 136)	2.264[a]	1.963[a]	2.178[a]	2.499[a]	2.275[a]	1.831[a]
Sib-sib (n = 1037)						
r intraclass	0.35	0.32	0.28	0.400	0.35	0.02
F among groups (d.f. = 507, 529)	2.099[a]	1.964[a]	1.820[a]	2.32[a]	2.089[a]	1.037[b]

a. $p \leq 0.001$.
b. Not significant.

Discussion

Both forehead and arm reflectometry values for each filter showed intrapopulational variation depending on the individual's sex and age. In our population the arm is in general less pigmented than the forehead, a difference often considered a measurement of tanning in children and adults (Rigters-Aris 1973; Weiner and Lourie 1981), even though a small proportion of the difference might be due to innate biological differences between the 2 anatomical sites (Williams-Blangero and Blangero 1991). In terms of sexual dimorphism, girls are less pigmented than boys at both body sites, and the reflectometry values are higher at the same age groups. The conclusions are similar to those mentioned in other studies, generally with females being lighter skinned than males (Harrison et al. 1967; Kalla 1974; Byard 1981; Byard and Lees 1982; Greksa et al. 1991), although other researchers have inferred the opposite conclusion from some groups (Leguebe 1961; Rigters-Aris 1973). Nevertheless, it is difficult to conceive sexual dimorphism in skin color without taking into account age changes, which are responsible for sex differences in skin pigmentation, particularly during adolescence (Kalla and Tiwari 1970; Conway and Baker 1972). This is a specific case of nonexposed parts of the skin, such as the upper inner arm, where pigmentation changes occur at different chronological periods with different intensity or tendency (lighter or darker) in each sex (Kalla 1973).

Table 3. Intraclass Correlations among Siblings According to Age Period

Correlation	*Prepubertal* (*<12 Years*) (n = 308)	*Pubertal* (*12–15 Years*) (n = 82)	*Postpubertal* (*≥15 Years*) (n = 149)
Forehead			
Filter 601			
r intraclass	0.47	0.22	0.31
F among groups	2.785[c]	1.596[d]	1.909[b]
d.f.	151, 156	39, 42	73, 75
Filter 605			
r intraclass	0.44	0.38	0.23
F among groups	2.586[c]	2.293[b]	1.608[a]
d.f.	151, 156	39, 42	73, 75
Filter 609			
r intraclass	0.42	0.28	0.24
F among groups	2.445[c]	1.785[d]	1.634[a]
d.f.	151, 156	39, 42	73, 75
Arm			
Filter 601			
r intraclass	0.32	0.26	0.60
F among groups	1.957[c]	1.712[d]	4.023[c]
d.f.	151, 156	39, 42	73, 75
Filter 605			
r intraclass	0.23	0.42	0.46
F among groups	1.596[b]	2.475[b]	2.715[c]
d.f.	151, 156	39, 42	73, 75
Filter 609			
r intraclass	0.01	0.38	0.41
F among groups	1.026[d]	2.285[b]	2.421[c]
d.f.	151, 156	39, 42	71, 73

a. $p \leq 0.05$.
b. $p \leq 0.01$.
c. $p \leq 0.001$.
d. Not significant.

Age variations in skin pigmentation are often difficult to interpret, because environmental agents exert a remarkable influence, particularly on the forehead. In fact, mesological conditions can overlap variations with age. However, the reflectance percentages resulting from the measurements taken at the upper inner arm minimize these environmental effects. The obtained results at this body site show both sexes' tendency toward darkening before puberty, followed by a general trend toward lightening mainly during the postpubertal period. Several researchers have hypothesized that the increase in melanin pigmentation in unexposed areas during early adolescence is closely related to endocrinological changes during this ontogenic period, which are linked, in particular, to an eventual prepubertal increase of the

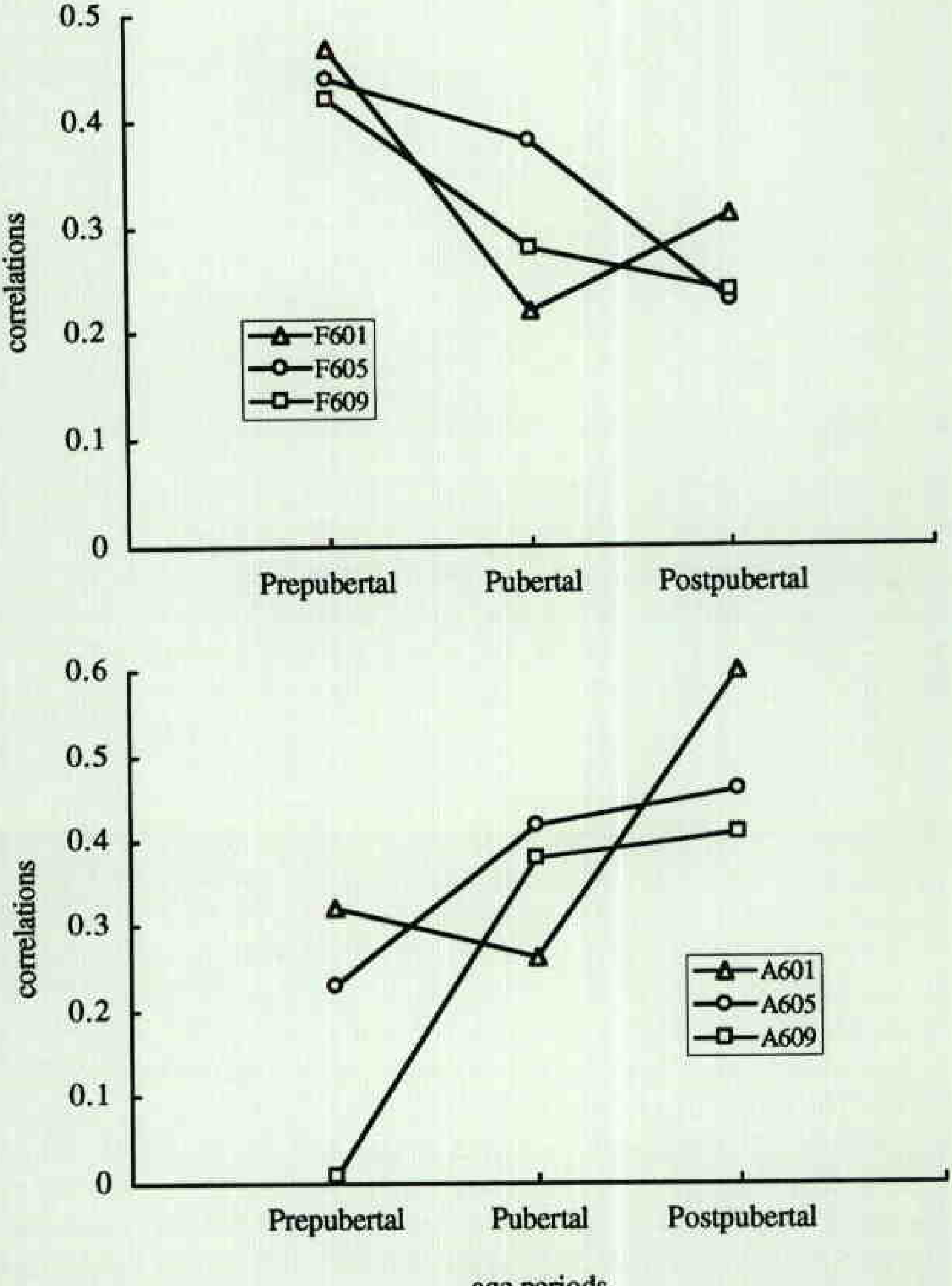

Figure 1. Variations with age of the intraclass correlations for the forehead (top) and the arm (bottom) for the 3 filters 601, 605, and 609 (whole sibling group). F601, F605, and F609 indicate forehead measurements taken with filters 601, 605, and 609, respectively. A601, A605, and A609 indicate arm measurements taken with filters 601, 605, and 609, respectively.

Table 4. Results of the Homogeneity Test (t_S) between Intraclass Correlation Coefficients

Filter	*Prepubertal-Pubertal*	*Prepubertal-Postpubertal*	*Pubertal-Postpubertal*
Forehead			
Filter 601	2.2085[a]	1.8492	0.6637
Filter 605	0.4998	2.3341[b]	1.2300
Filter 609	1.2579	1.9764[a]	0.2871
Arm			
Filter 601	0.5434	3.5871[b]	3.0780[b]
Filter 605	1.6983	2.6421[b]	0.3687
Filter 609	3.1178[b]	4.2459[c]	0.2413

Prepubertal period, <12 years; pubertal period, 12–15 years; postpubertal period, ≥15 years.
a. $p \leq 0.05$.
b. $p \leq 0.01$.
c. $p \leq 0.001$.

melanocyte stimulating hormone (MSH) during prepuberty (Marshall 1960; Kalla 1974). After puberty the production of MSH gradually decreases and melanogenesis decreases accordingly, resulting in lightening of the skin (Kahlon 1976). Nevertheless, these changes related to age have not yet been clearly settled. The tendencies observed in our sample are in accordance with general patterns followed by other similar populations so far as ethnic origin, habits, and ways of life are concerned, such as the sample of US whites studied by Garn et al. (1956), the Spanish sample analyzed by Mesa (1983), and studies on the Basque population by Rebato et al. (1991) and Rebato, Rosique et al. (1993). In these population groups preadolescent darkening followed by gradual lightening of arm pigmentation with age was observed. The age at the beginning of the lightening process fluctuates depending on the sex and population group, because pubertal age varies in different ethnic groups and depends on living conditions.

Unlike the results obtained after measuring the boys' arms, measurements taken at the forehead demonstrated a general tendency toward progressive darkening with age, particularly from the pubertal period. Nevertheless, the results show a tendency toward lighter skin color in the oldest age group (18–20-year-old individuals); this result must be considered with caution because the sample was limited. The darkening of the forehead could be the result of both environmental influence and a stronger blood supply at this site, as shown by reflectance values taken with filters 601 and 605. These results coincide with studies made among males from other populations (Garn et al. 1956; Hulse 1970). Girls, on the other hand, exhibited variations with age only with regard to forehead reflectance values taken with filter 609, with skin lightening occurring during the postpubertal period, as observed in other population groups (Greksa et al. 1991). Finally, both the age patterns and the skin reflectance values of our sibling sample correspond to the wide range of variations reported in other white populations.

So far as intraclass correlations and linked research on skin pigmentation heritability are concerned, studies are scarce and sometimes contradictory, displaying higher correlations at the forehead than at the arm or vice versa. Clark et al.'s (1981) study of European twins found that tanning ability was controlled to a lesser degree by genetic factors than by the natural pigmentation itself. On the contrary, Kalla (1972) and Banerjee (1984) found higher heritability at the body areas exposed to the sun. Therefore the different genetic contribution to pigmentation at exposed or unexposed areas remains unclear. Such contradictory results might be due to age variations in the considered samples or to the different genetic backgrounds and different nature of exposure to the sun of the populations.

Despite some exceptions (Tiwari 1963), there seems to be widespread agreement that skin color heritability is relatively high, based on studies of twins where reflectance heritability (h^2) ranged from 0.72 to 0.83 depending on the wavelength and the skin body site (Clark et al. 1981). Familial studies reflect lower values of h^2: 0.46–0.64 (Frisancho et al. 1981) and 0.57–0.66 (Williams-Blangero and Blangero 1992); Williams-Blangero and Blangero's (1992) study was conducted using multivariate procedures. The correlation coefficients (r) ranged from 0.225 to 0.380 (Rigters-Aris 1973) and from 0.25 to 0.47 (Banerjee 1984). Post and Rao (1977) estimated the overall heritability of the skin color phenotype as 72%, most of it on account of ethnicity. Considering such a high level of heritability, some researchers have made use of skin color to measure the degree of admixture in several populations (Lees and Relethford 1978; Relethford and Lees 1982; Greksa et al. 1991; Greksa 1992, 1996), although microevolutionary studies based on this trait should be considered cautiously (Williams Blangero and Blangero 1992).

The correlations drawn from the analysis of our population were in accordance with the range of variations previously mentioned (0.28–0.45 for the forehead and 0.29–0.43 for the arm), all of them significant with the exception of those taken with filter 609 and arm measurements between brothers and between siblings. We did not observe in our sample a clear rank order of correlation in function of filters or of site, as did Frisancho et al. (1981) and Banerjee (1984) with lower correlations (although significant) for filters of lower wavelength.

The analysis of correlations revealed that higher values resulted from measurements taken at the forehead rather than at the arm, especially with filter 609, which is most directly related to melanin changes eventually related to similar environmental influences shared by the siblings. Because the forehead skin color is highly affected by environmental factors, the environmental influence on familial correlations resulting from similar holiday, weekend, or sporting activities could easily be observed. The correlation coefficients derived from the measurements of the forehead reached similar magnitudes with the 3 filters. Considering the spectral characteristics of filters 601 and 605, mainly related to hemoglobin absorption, the correlations obtained at these wavelengths reflected above all the degree of familial resemblance with regard to vascular response (blood supply) and skin itself (corneum depth) (filter 601).

The reflectance correlations in arm skin measurements observed between brothers and between siblings with filter 609 displayed values close to 0, probably linked to the ontogenic changes of pigmentation at the arm mentioned previously. Such changes, unlike those referred to the forehead, are not minimized by environmental influences. Although sex is a possible influence, age differences between pairs of siblings might have altered the obtained correlations, whereas only correlations between sisters happened to be significant. The influence of X-chromosome-linked genes on arm pigmentation obtained with filter 609 was suggested by Rigters-Aris (1973), although the study made by Frisancho et al. (1981) did not reveal any X-chromosome-linked influence. X-chromosome-linked influence could not be proved in our population sample at any site or with any filter, where we should have observed that $r_{\text{sisters}} > r_{\text{brothers}} > r_{\text{sibs}}$. However, with both filter 609 at the forehead and filter 601 at the arm correlations were high in sisters and in brothers but never reached the values expected for sex linkage (0.75 for sisters and 0.5 for brothers). Other sexual differences could be influenced by environmental factors. For example, if we hypothesized that environmental factors exert a different influence on each sex, we would similarly hypothetize that the same environmental influences would equally affect siblings of the same sex (brothers or sisters) than a brother and a sister in the same sibship, as a function of different lifestyles (i.e., clothing habits or cultural, occupational, and sport activities). Our data do not reflect the influence of sex on the obtained correlation coefficients.

Effects of Age on Intraclass Correlations. The estimates of heritability based on correlation coefficients between relatives imply a standardization of data for sex and age (Rao et al. 1975, 1987; Malina et al. 1986; Sharma 1988; Friedlander et al. 1989; Tiret et al. 1991), allowing one to eliminate growth and sex variations in the anthropometric traits. If standardization eliminates the effects of age on the traits themselves, it does not eliminate age effects on correlation coefficients, because environmental factors affect children differently depending on age and, eventually, sex, as do genetic factors depending on age if gene activity changes. Our results confirmed the effects of age on the reflectance correlation coefficients, with specific variations either at the arm or at the forehead.

The arm correlation coefficients tend to increase between the pre- and the postpubertal periods and to chronologically decrease with regard to the forehead. The low coefficients verified in the arm before the pubertal period could reflect a large pigmentation variability linked to changes related to age.

Indeed, eventual endocrinological alterations, such as an increase in MSH, producing the darkening of this skin area, might happen during the prepubertal period between 4 and 11 years. On the other hand, such pigmentation is less influenced by environmental factors, and the increase of correlation with age can be largely influenced by a large genetic effect during growth and development and by increasing gene expressions that can also be observed in stature and weight measurements (Byard et al. 1983a,b). In short, the pigmentation of the arm seems to be highly dependent on genetic factors after the pubertal period, once the endocrinological changes that cause outstanding variations in skin color cease to exist. The environment shared by siblings is usually more similar during the first stages of the growing period than during puberty and onward, and therefore familial resemblances regarding the forehead are higher during the prepubertal period than in the following pubertal and postpubertal stages. Siblings may progressively become less similar in skin color because of relatively slightly pronounced common environment during their pre-adult and adult lives.

A recent study made on the Basque population (Rebato, Salces et al. 1997) confirmed that the correlation coefficients of body dimensions also fluctuate during growth, with the degree of genetic determination after puberty being higher with regard to bone measurements but not to weight. For skin pigmentation the sibling correlation variations at 2 different body sites, 1 of them exposed and the other usually not influenced by environmental factors, confirmed a higher degree of genetic dependence for pigmentation at the arm and a higher environmental influence on forehead pigmentation correlations from the postpubertal period onward.

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