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Diversity in human hair growth, diameter, colour and shape. An *in vivo* study on young adults from 24 different ethnic groups observed in the five continents

Background: Based on previous findings, from a worldwide study, classified the shapes of human hair into 8 major types, from straight to highly curly. This clearly extended the usual classification of hair into African, Asian or Caucasian types. However, determinations of hair growth parameters and hair density were excluded from such studies. *Objectives:* To measure and compare the hair growth profiles of young adults without alopecia living in the five continents. *Materials & Methods:* 2249 young adults (18-35 years, females and males) without alopecia, originating from 24 various human ethnic groups were included in the study. Total hair density, telogen percentage and growth rate on three different scalp areas were measured, using non-invasive validated techniques. Natural hair colour level, curliness and hair diameter were additionally recorded, when practically possible. *Results:* Diversity in hair growth parameters among the entire cohort was a key finding, with differences linked to scalp area, gender and geographic origin. Statistical approaches depicted African hair as having lower density and a slower growth rate. Asian hair showed a thicker diameter, with faster growth. Caucasian hair showed a high total hair density. *Conclusion:* On the one hand, this inter-continental study of hair growth parameters provides initial valuable base-line data on hair in young adults without alopecia, and on the other hand, further extends our knowledge of this unique human appendage, with some mosaic features, observed worldwide.

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Key words: hair, hair density, hair growth, telogen percentage

There never were in the world two opinions alike, no more than two hairs or two grains; the most universal quality is diversity" (Michel de Montaigne, 1533-1592). With regard to shape, colour, size, transversal section. . .this famous philosopher was probably right: human hair clearly displays large variations and high diversity. When classified according to the degree of curliness, 8 types have previously been defined [1, 2], which largely encompasses the classic sub-division between African, Asian and Caucasian hair. With regard to hair growth, a previous study assessed hair density, telogen percentage and growth rate among these 3 large ethnics [3]. This study was, however, carried out on ethnic groups of rather limited sample size, i.e. a total cohort of 511 individuals aged 18-35 years, among which a significant proportion showed signs of alopecia, requiring separate analysis for these subjects. Hence, hair growth parameters largely overlapped between the three human "sub-groups". This led us to perform a subsequent study, implying a larger cohort, worldwide, strictly dedicated to optimal hair i.e. without any particular sign of hair loss. This paper reports the findings on hair growth patterns that can be observed on three different scalp areas of 2249 young female and male adults (18-35years), from 24 various ethnic origins. With regard to possible seasonal influences upon hair growth [4-6], all studies were conducted during the respective spring periods of both world hemispheres.

Materials and methods

Subjects

A total of 2249 young adult healthy volunteers (18-35 years, 47% male and 53% female), from 24 different ethnic origins living in the five continents, were recruited. Additional to age-class requirement, inclusion criteria were: i) no clinically visible alopecia according to the Ludwig [7] and/or Hamilton-Norwood [8] classification, ii) no grey hair and iii) with all biologic parents and grandparents from the same ethnic origin, irrespective of their actual place of residence, e.g. Chinese living in Paris. Following a full description of the project, all participants signed an informed consent in accordance with internal ethics procedures based upon the guidelines of human experimentation and the Helsinki Declaration of 1975, as revised in 1983. *Table 1* summarizes the

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Table 1. Age (mean ± SD)) and numbers of subjects according to countries and locations.

Studied groups	City	M	W	Age (years)	Available data			
					Hair growth	**Diameter**	**Hair color tones**	**Curliness**
African-American	Chicago (USA)	24	40	29 ± 6	64	30	64	20
Brazilian	Rio of Janeiro (Brazil)	89	95	26 ± 5	184	93	137	57
Caribbean	Paris (France)[1]	43	54	27 ± 5	97	10	63	20
Caucasian-American	New York (USA)	27	28	25 ± 5	55	-	53	12
Caucasian-Australian	Melbourne (Australia)	29	29	26 ± 5	58	-	57	34
Chinese	Beijing (China)	28	33	25 ± 5	249	136	182	116
	Canton (China)	24	30					
	Paris (France)	29	46					
	Shanghai (China)	29	30					
Danish	Copenhagen (Denmark)	34	36	26 ± 3	70	64	70	45
French	Paris (France)	38	48	27 ± 5	86	28	62	31
Indian	Cape Town (South Africa)	18	17	25 ± 5	177	126	169	89
	Mumbai (India)	43	40					
	Paris (France)	28	31					
Japanese	Tokyo (Japan)	27	29	27 ± 6	56	18	41	35
Kanak	Noumea (New Caledonia)	31	33	25 ± 5	64	-	63	34
Korean	Seoul (Korea)	47	49	25 ± 4	96	38	81	27
Latino-American	New York (USA)[2]	30	28	27 ± 5	58	-	56	28
Lebanese	Beirut (Lebanon)	32	24	21 ± 3	56	-	56	28
Mexican	Mexico City (Mexico)	43	49	26 ± 5	92	-	90	58
North-African	Paris (France)[3]	43	42	26 ± 4	85	53	56	36
Peruvian	Lima (Peru)	60	30	26 ± 5	90	-	89	63
Polish	Varsovia (Poland)	25	35	25 ± 4	60	44	60	32
Russian	St Petersburg (Russia)	29	30	26 ± 6	59	-	59	29
Scottish	Glasgow (Scotland)	45	45	22 ± 3	90	13	89	54
South-African	Cape Town (South Africa)	-	30	26 ± 6	114	49	100	32
	Johannesburg (South Africa)	35	49					
Spanish	Valencia (Spain)	23	27	26 ± 5	50	38	48	30
Thai	Bangkok (Thailand)	41	46	25 ± 4	87	73	87	61
Western-African	Paris (France)[4]	71	81	25 ± 5	152	10	90	9
Total		**1065**	**1184**	**26 ± 5**	**2249**	**823**	**1922**	**980**

[1] Martinique/Guadeloupe [2] Porto Rico/Cuba/Dominican Republic [3] Algeria/Morocco/Tunisia [4] Benin/Cameroon/Ivory Coast/Gabon/Guinea/Senegal/Togo

general profiles of the studied groups with regard to cities, average age, size of cohorts and the balance between genders. The very word "populations" can hardly apply here since the number of studied subjects may not perfectly mirror the hair features of millions of inhabitants of a given location or ethnic appurtenance. Hence, the words "ethnic groups" or ethnic cohorts" are used.

Fully aware that ethnicity is quite difficult to define, especially within mixed human peoples, we decided to adopt the state practices when they exist, as in the US, where we studied groups of African-American, Caucasian-American and Latino-American origins. South Africa allowed us to study African and Indian subjects. North African and Western African subjects were studied in Paris, France. In order to increase the number of subjects in these two groups, we gathered subjects from Algeria, Morocco or Tunisia for the first one and subjects from Benin, Cameroon, Ivory Coast, Gabon, Guinea, Senegal and Togo for the second one. In Australia, only a Caucasian Australian ethnic group was studied. Two ethnic groups, Chinese and Indians, were observed in several cities to study the possible environmental effects or living conditions on hair growth parameters.

Hair growth parameters and additional hair characteristics (hair color, hair curliness)

The determination of hair growth parameters of each volunteer was carried out on three distinct scalp areas, vertex, occipital and temporal *(figure 1),* using the non-invasive

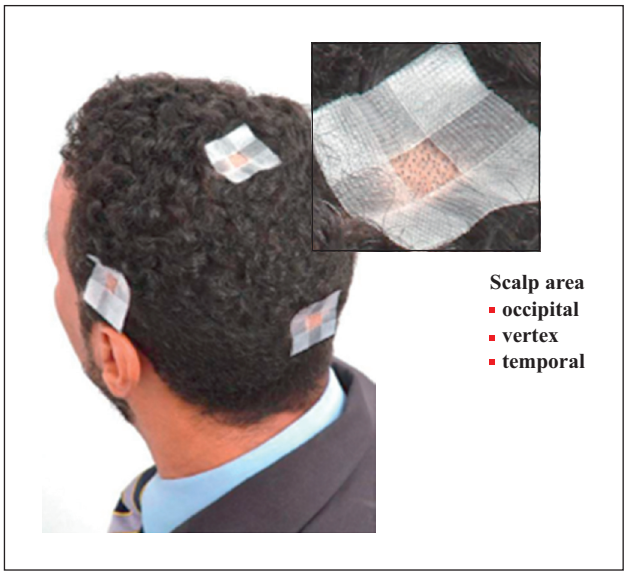


Figure 1. Studied scalp areas localisation.

phototrichogram technique [9-11]. The latter allows four major hair growth parameters to be simultaneously determined: a) telogen density and anagen density, expressed as the number of hairs/cm^2, further leading, by summing up, to b) total hair density in hairs/cm^2, c) T% as the ratio of telogen hair density *versus* total hair density, therefore expressing the percentage of hair in the telogen phase and d) growth rate of individual hairs, expressed as μm per 24 hours [6, 12, 13]. Such growth rates can further be expressed in weeks, months or years, assuming a full linearity with time [14], i.e. a constant growth rate along the anagen phase. These four hair growth parameters were determined in all subjects. When practically possible, hair fibre diameter was measured on 823 subjects (i.e. 37% of the total cohort). Briefly, a lock of hair collected at day zero was cut into multiple two mm pieces and further analysed by the Laser-Scan technique [15], yielding a median hair diameter per subject.

Two additional criteria were determined whenever possible. At first, natural hair colour was assessed on 1922 subjects (85.4% of the total cohort) (*table 3*) from the nape, which is less prone to UV-induced discoloration. Hair colour was matched to a reference scale [16], which is routinely used in our laboratories and comprises a gradient of 10 units, ranging from 1/ black to 10/pale blond. As only very few red hairs were observed, we only took into account the level of darkness of such hair without specifying their natural red shade. Second, matching a given collected hair with the 8 types reference scale (from 1/straight to 8/highly curly) [6, 17] enabled us to confer a degree of hair curliness.

Statistics

Differences in hair growth parameters relating to ethnic and geographic origins, gender and scalp area were processed using variance analysis (ANOVA), a p value with 5% threshold being considered as significant, under the SPSS v17.0 package (IBM, USA). To simultaneously assess all hair growth parameters in the different groups, the analytical

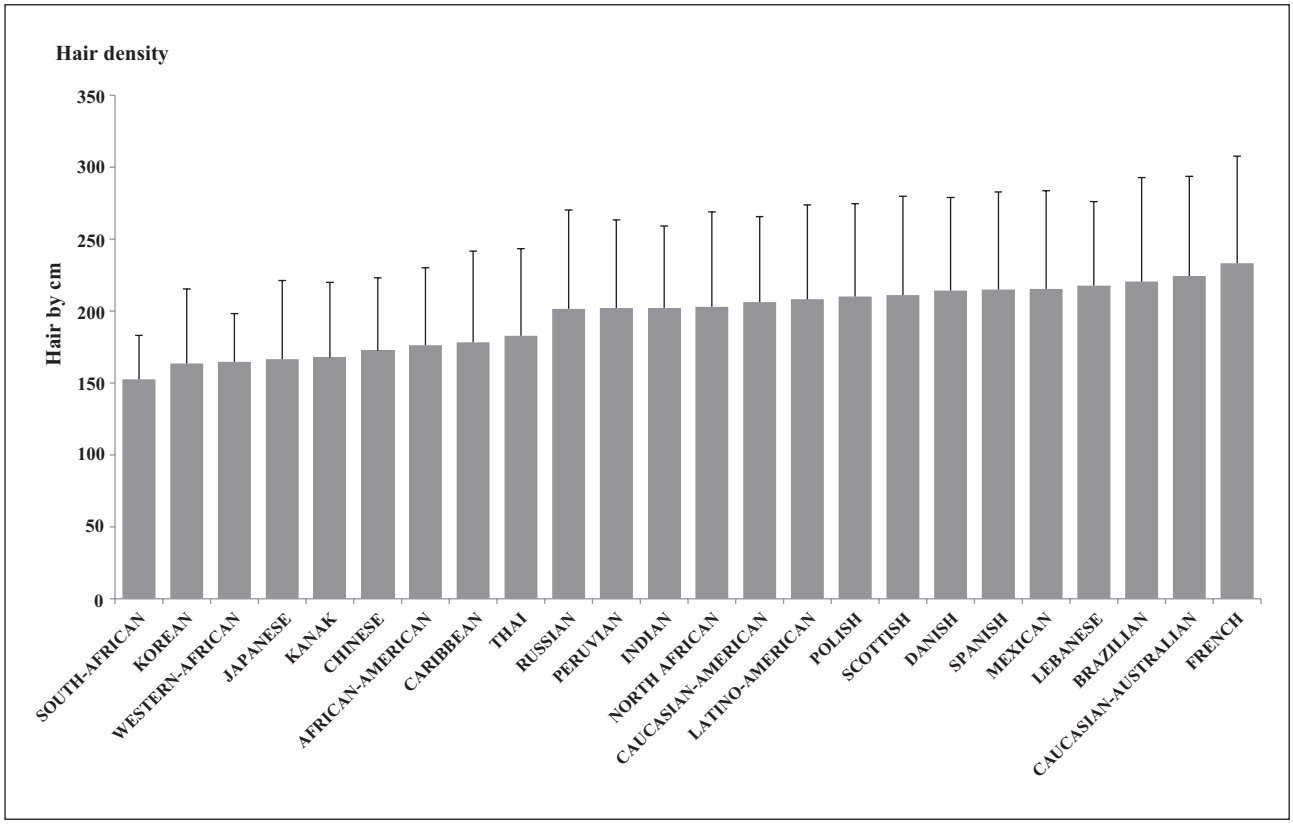


Figure 2. Hair density (N/cm^2, mean ± SD) according to groups.

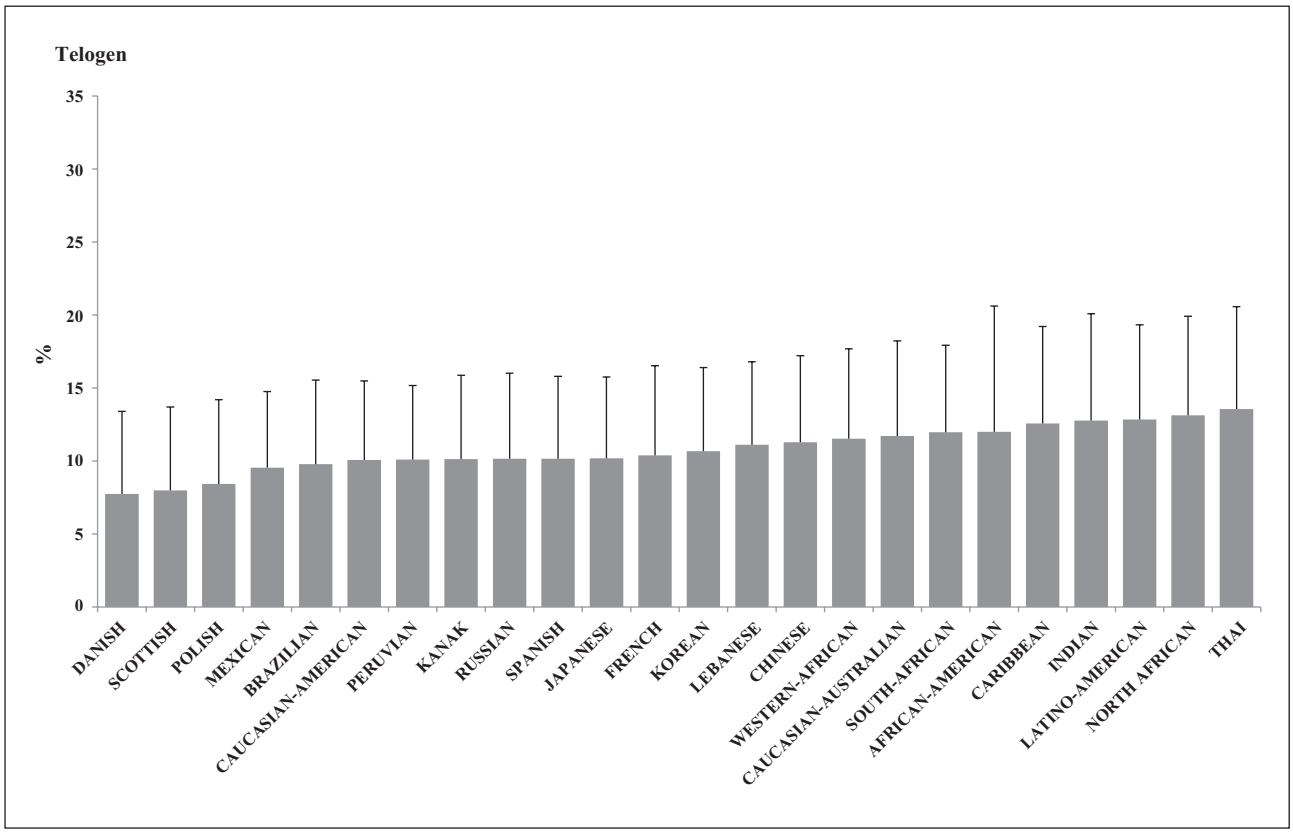


Figure 3. Telogen % (mean ± SD) according to groups.

software SPAD v7.4 (Coheris, France) was used, performing a Principal Component Analysis (PCA), followed by a Hierarchical Ascendant Classification (HAC) for grouping together groups with similar hair parameters. In most cases, values are expressed as average ± S.D (standard deviation).

Results

Hair Growth parameters by gender, scalp area and ethnic/geographic origin

In average, total hair density varies from 153 ± 30 hairs/cm^2 (South-African) to 233 ± 74 hairs/cm^2 (French) ($p<0.001$) (*figure 2*). Total hair density appears significantly lower in men, but only in the vertex area, i.e. by some 19 hairs per cm^2 less than women ($p<0.001$). Comparing the three scalp areas shows a significantly different hair density, of the following gradient: temple<nape<vertex ($p<0.001$), illustrating that, for example, the vertex has about twice as many hairs as the temple ($p<0.001$). These relative differences in hair density between the three areas were observed in every population, in both male and female cohorts.

Globally, T% ranged from 8 ± 6% (Danish) to 14 ± 7% (Thai) (p<0.001) (*figure 3*), a domain of values falling within the normal limits of normal hair renewal [17]. Men show slightly higher T% average values as compared to women (p<0.001) (12.2% *vs* 10.1%). T% appears significantly different on the three scalp areas ($p<0.001$), i.e. for men as women, the highest values are seen at the temple.

The average hair growth rate ranged 272 ± 37 μm/24h (South-African) to 426 ± 39 μm/24h (Korean) ($p<0.001$) *(figure 4)*. Hair growth rate appears significantly lower at the nape in men, by a few 0.1 mm per month ($p<0.001$), as compared to women. Both genders show hairs that grow slightly faster on the vertex, by a few mm per year compared to on the nape and temple ($p<0.001$).

Hair diameter was assessed in 823 volunteers (33% male, 67% women) from 15 countries of Africa, the Americas, Asia and Europe, yielding a range of median diameters from 69 ± 8 μm (French) up to 89 ± 7 μm (Chinese) (p<0.001) *(figure 5)*, reflecting the well-known trend towards increased diameter amongst Asians. No significant difference in hair diameter was observed between the three scalp areas.

As expected, none of the variables, total hair density, %T and diameter seem affected by age [6, 12, 13, 17-19] since the age-range adopted here (18-35y) was limited. However, a gross bi-modal clustering of the global population indicates that hair growth rate slightly decreases (by 0.4 cm/year, p<0.001) above 26y, as compared to below 25y, all scalp areas and gender included. *table 2* summarizes the mean values (± S.D) of hair growth parameters found in the 24 studied populations.

Environmental effects on hair growth parameters

Studying the hair growth parameters of volunteers of similar origin but recruited in different geographical locations

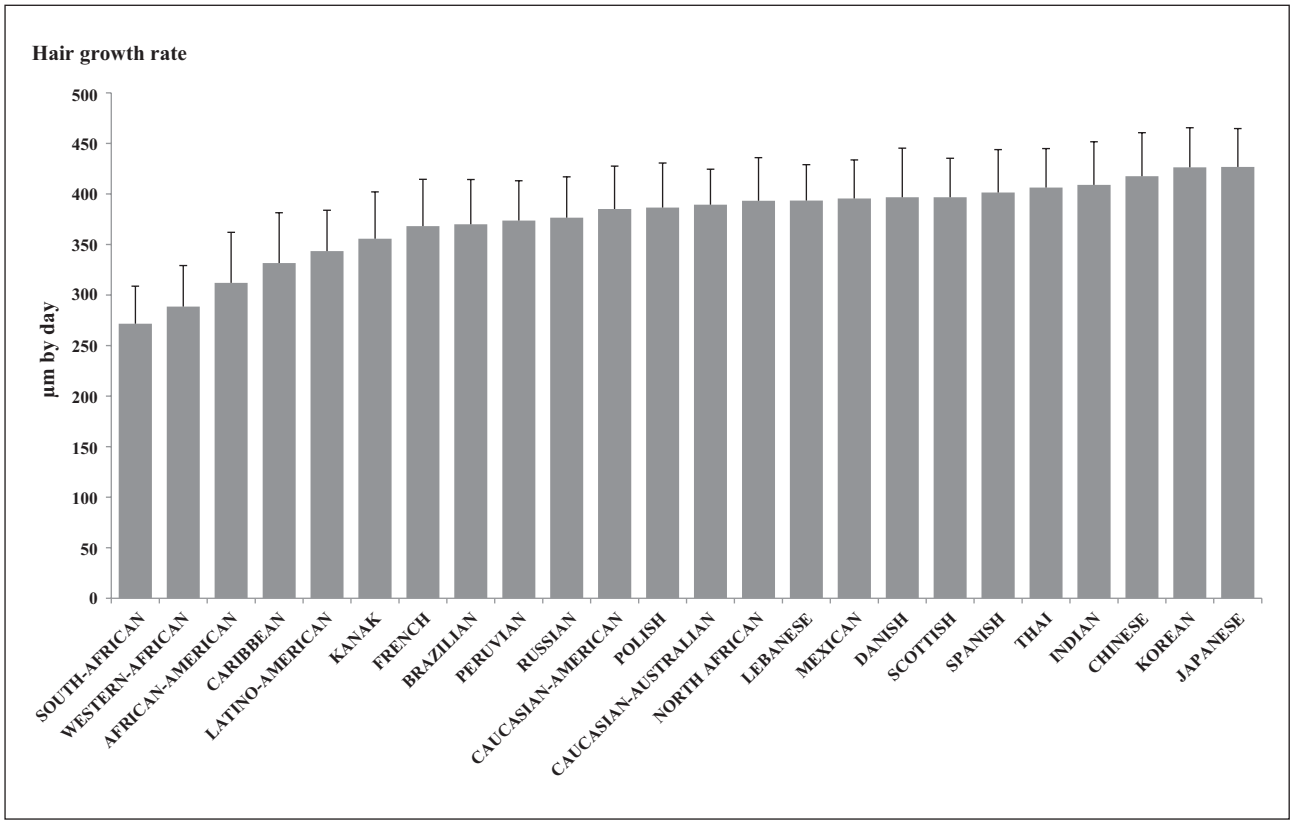


Figure 4. Hair growth rate (µm/day, mean ± SD) according to groups.

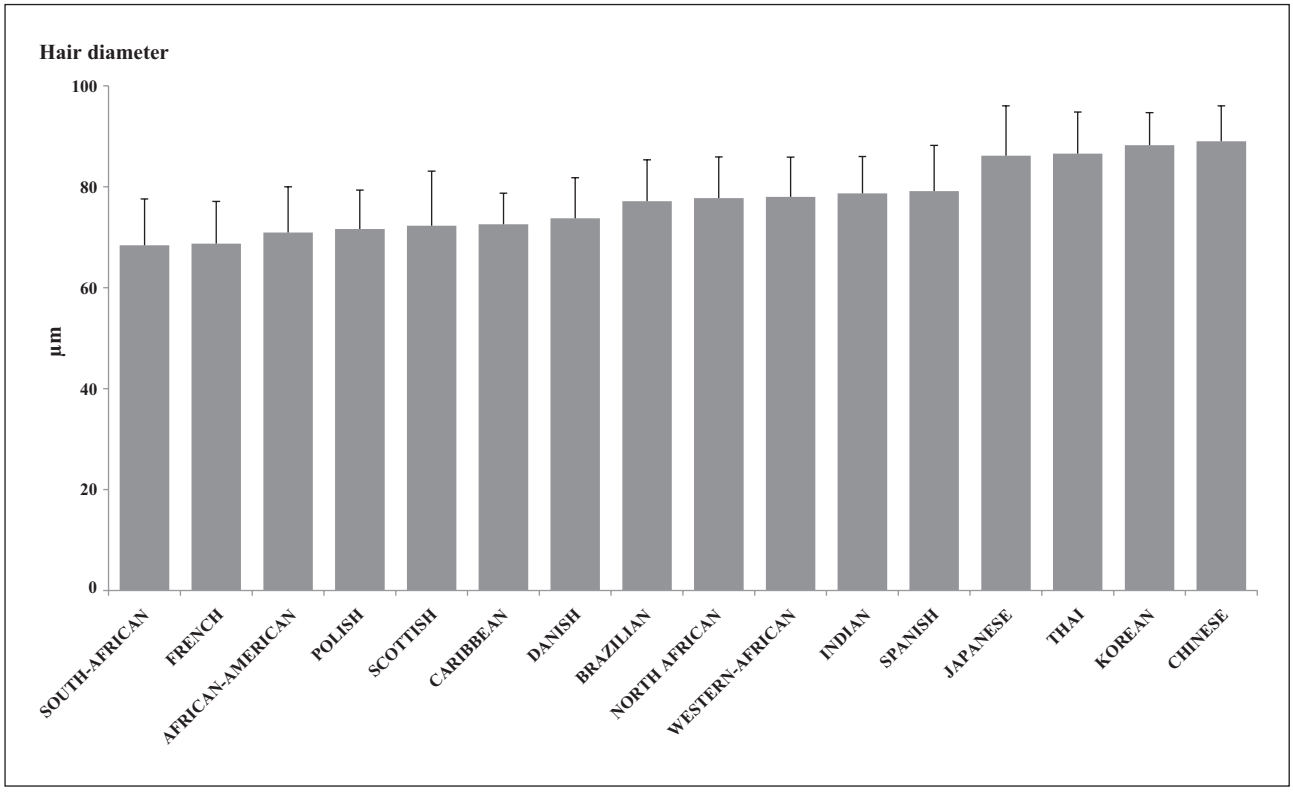


Figure 5. Hair diameter in µm (mean ± SD) according to groups.

Table 2. Hair density, telogen percentage, hair growth rate and hair diameter according to subjects and scalp areas (mean ± SD).

			AFRICAN-AMERICAN	BRAZILIAN	CARIBBEAN	CAUCASIAN-AMERICAN	CAUCASIAN-AUSTRALIAN	CHINESE	DANISH	FRENCH	INDIAN	JAPANESE	KANAK	KOREAN	LATINO-AMERICAN	LEBANESE	MEXICAN	NORTH AFRICAN	PERUVIAN	POLISH	RUSSIAN	SCOTTISH SCOTTISH	SOUTH-AFRICAN	SPANISH	THAI	WESTERN-AFRICAN
Hair density (hair/cm²)	areas combined	**Mean**	**176**	**221**	**178**	**206**	**225**	**172**	**214**	**233**	**202**	**167**	**168**	**164**	**208**	**218**	**215**	**203**	**202**	**210**	**202**	**211**	**153**	**215**	**183**	**165**
		Std dev	*54*	*72*	*63*	*59*	*69*	*51*	*65*	*74*	*57*	*55*	*52*	*52*	*65*	*58*	*68*	*66*	*61*	*65*	*69*	*69*	*30*	*68*	*61*	*34*
	Vertex	**Mean**	**220**	**274**	**237**	**248**	**290**	**219**	**274**	**301**	**242**	**223**	**216**	**213**	**259**	**263**	**281**	**262**	**258**	**271**	**265**	**276**	**188**	**274**	**239**	**198**
		Std dev	*46*	*58*	*55*	*51*	*42*	*36*	*45*	*60*	*46*	*38*	*41*	*34*	*58*	*45*	*52*	*52*	*41*	*47*	*40*	*50*	*43*	*49*	*41*	*44*
	Nape	**Mean**	**180**	**237**	**178**	**224**	**233**	**177**	**223**	**235**	**217**	**171**	**172**	**171**	**217**	**232**	**214**	**212**	**208**	**216**	**215**	**219**	**155**	**226**	**190**	**169**
		Std dev	*39*	*55*	*39*	*43*	*45*	*34*	*38*	*45*	*45*	*28*	*32*	*29*	*48*	*42*	*40*	*39*	*44*	*40*	*43*	*42*	*34*	*43*	*41*	*40*
	Temple	**Mean**	**129**	**151**	**120**	**147**	**151**	**122**	**145**	**163**	**148**	**106**	**116**	**107**	**149**	**159**	**150**	**135**	**140**	**143**	**124**	**140**	**114**	**145**	**119**	**126**
		Std dev	*31*	*37*	*26*	*26*	*30*	*24*	*23*	*38*	*30*	*19*	*20*	*21*	*34*	*28*	*35*	*25*	*25*	*23*	*21*	*25*	*28*	*31*	*22*	*42*
Telogen (%)	areas combined	**Mean**	**12**	**10**	**13**	**10**	**12**	**11**	**8**	**10**	**13**	**10**	**10**	**11**	**13**	**11**	**10**	**13**	**10**	**8**	**10**	**8**	**12**	**10**	**14**	**12**
		Std dev	*9*	*6*	*7*	*5*	*7*	*6*	*6*	*6*	*7*	*6*	*6*	*6*	*6*	*6*	*5*	*7*	*5*	*6*	*6*	*6*	*6*	*6*	*7*	*6*
	Vertex	**Mean**	**9**	**9**	**11**	**11**	**13**	**10**	**8**	**10**	**13**	**10**	**10**	**10**	**12**	**10**	**9**	**13**	**10**	**9**	**10**	**8**	**10**	**10**	**12**	**10**
		Std dev	*5*	*4*	*6*	*6*	*7*	*6*	*6*	*6*	*7*	*5*	*5*	*5*	*6*	*6*	*5*	*7*	*5*	*6*	*7*	*5*	*7*	*5*	*6*	*7*
	Nape	**Mean**	**14**	**9**	**13**	**8**	**10**	**10**	**6**	**9**	**11**	**9**	**8**	**8**	**12**	**10**	**9**	**11**	**9**	**7**	**9**	**6**	**12**	**8**	**13**	**12**
		Std dev	*11*	*5*	*7*	*4*	*6*	*5*	*5*	*5*	*6*	*5*	*5*	*4*	*6*	*5*	*4*	*6*	*4*	*5*	*5*	*4*	*8*	*5*	*6*	*7*
	Temple	**Mean**	**13**	**12**	**14**	**11**	**13**	**13**	**9**	**12**	**15**	**11**	**12**	**13**	**14**	**13**	**11**	**15**	**12**	**9**	**12**	**10**	**14**	**13**	**16**	**13**
		Std dev	*7*	*7*	*7*	*6*	*7*	*6*	*6*	*7*	*8*	*6*	*7*	*6*	*7*	*6*	*6*	*7*	*6*	*6*	*6*	*7*	*7*	*6*	*8*	*9*
Hair growth rate (µm/day)	areas combined	**Mean**	**312**	**370**	**332**	**385**	**389**	**418**	**397**	**368**	**409**	**427**	**356**	**426**	**343**	**394**	**395**	**393**	**374**	**387**	**377**	**397**	**272**	**402**	**406**	**289**
		Std dev	*50*	*44*	*50*	*43*	*35*	*43*	*49*	*46*	*43*	*38*	*46*	*39*	*41*	*36*	*38*	*43*	*39*	*44*	*41*	*39*	*37*	*42*	*39*	*41*
	Vertex	**Mean**	**324**	**383**	**334**	**402**	**399**	**430**	**402**	**375**	**423**	**442**	**370**	**431**	**351**	**426**	**396**	**396**	**392**	**406**	**389**	**391**	**283**	**417**	**413**	**300**
		Std dev	*53*	*50*	*59*	*48*	*41*	*55*	*61*	*61*	*51*	*48*	*59*	*50*	*49*	*46*	*48*	*54*	*49*	*48*	*52*	*56*	*50*	*49*	*44*	*49*
	Nape	**Mean**	**293**	**362**	**321**	**375**	**390**	**418**	**389**	**366**	**397**	**418**	**339**	**432**	**335**	**381**	**403**	**386**	**358**	**373**	**374**	**399**	**259**	**397**	**406**	**276**
		Std dev	*64*	*58*	*63*	*49*	*46*	*55*	*54*	*55*	*59*	*55*	*54*	*51*	*54*	*40*	*54*	*54*	*50*	*67*	*53*	*49*	*43*	*45*	*58*	*49*
	Temple	**Mean**	**318**	**365**	**340**	**379**	**379**	**404**	**399**	**362**	**407**	**420**	**357**	**416**	**345**	**374**	**386**	**399**	**372**	**381**	**366**	**400**	**274**	**391**	**400**	**290**
		Std dev	*53*	*54*	*57*	*49*	*41*	*52*	*54*	*55*	*48*	*48*	*56*	*45*	*46*	*47*	*40*	*51*	*44*	*43*	*45*	*43*	*44*	*48*	*41*	*47*
Hair diameter (µm)	areas combined	**Mean**	**71**	**77**	**73**	-	-	**89**	**74**	**69**	**79**	**86**	-	**88**	-	-	-	**78**	-	**72**	-	**72**	**68**	**79**	**87**	**78**
		Std dev	*9*	*8*	*6*	-	-	*7*	*8*	*8*	*7*	*10*	-	*6*	-	-	-	*8*	-	*8*	-	*11*	*9*	*9*	*8*	*8*
		min	49	58	62	-	-	68	55	54	61	68	-	74	-	-	-	61	-	55	-	55	53	59	64	69
		max	91	104	82	-	-	102	96	86	101	107	-	104	-	-	-	96	-	87	-	95	94	97	102	92

might bring insight about possible external influences such as climate, nutrition, hair-care habits... on hair growth parameters of Chinese and Indians. On the whole, only small differences were observed in groups from same origin living in diverse locations. For example, slightly higher hair growth rates were found in Indians living in France and South-Africa, as compared to those living in Mumbai (+19 μm/24h on average; $p = 0.013$). Chinese volunteers living in Paris showed a lower hair density (14 hair/cm^2 on average; $p = 0.014$) than their counterparts living in mainland China, and Chinese studied in Shanghai showed a slightly lower T% (3% on average; $p<0.001$) [20] than those living in Beijing, Guangzhou (Canton) or Paris. In brief, different living conditions in people of the same origins appear to have a very low influence upon their inherent hair growth parameters. In addition, the young ages of the subjects under study (18-35y) obviously does not allow for a follow-up of external influences with a probable long-term impact, if any.

Hair growth parameters among ethnic groups *vis à vis* natural hair color level and curliness

Hair colour tones were assessed in 1922 of 2249 studied volunteers, the distribution of which is shown in *table 3*. It is noteworthy that the vast majority of subjects (74%) under study showed head hair of darker tones (1 to 4) whereas lighter tones (8 to 10) represent a very small percentage (4%). On the whole, both total hair density and growth rate seem unaffected by tone intensity. However, T% shows a tendency to decrease when hair tones increase above 6 (from 11 ± 5% to 7 ± 4%, $p<0.001$). Similarly, the diameters of hairs with tones > 6 showed significantly lower values than hairs with tones <6, i.e. 72 ± 9 μm *vs* 81 ± 10 μm, respectively, $p<0.001$.

To study the relationship between hair growth parameters and curliness we focused on Brazilian hair types (*table 4*). In Brazil, a large diversity of hair is observed, reflecting the admixture of Brazilians from different ethnic groupings. We studied the hair growth parameters on four groups of hair curliness: straight hair (I-II), wavy hair (III), frizzy hair (IV-V) and tight-curled hair (VI-VIII). The curliest hairs (types VI-VIII) differed from the other hair types by a lower density (194 ± 66 hairs/cm^2 *vs* 231 ± 72 hairs/cm^2; $p<0.001$) and lower hair growth rate (339 ± 54 μm/24h *vs* 382 ± 50 μm/24h; $p<0.001$).

Total cohort mapping

The hair growth parameters (total density, T%, growth rate) were found to have independent variables. Using average values, PCA analysis allowed positioning, within a two-dimension space (2D), the 24 ethnic groups, representing more than 70% of the variance of the total data. Results of PCA analysis illustrated how the three hair growth parameters confer a graphical location to each ethnic group. Overall, HAC clustered the global cohort into 3 major "spheres" (*figure 6)* and average results for each cluster are shown in *table 5*.

The first cluster (the red one) is characterized by a weak density and a low growth rate, and is rather specific to the African hair type. Sub-clustering shows in one cluster the South and Western African as well as the African-American and the Caribbean groups. We find the Kanak in another cluster and Latino-Americans in the last one. All those groups are African ascendants. In cases of mixed origins, hair seems to retain the African hair type properties.

The second cluster (the green one) is characterized by a fast growth rate and is specific to the Asian hair type. Sub-clustering shows one which includes Chinese, Korean and Japanese hair: showing the important similarities of their hair growth parameters. Another cluster includes Thai, Indians and in a more unexpected way, North Africans. This class is singularized by high telogen percentage values, which may be a sign of a shorter hair life cycle.

The third cluster (the blue one) is characterized by high hair density and is specific to the Caucasian hair type. Sub-clustering shows a cluster including Brazilian, Caucasian-American and Caucasian-Australian, Spanish, French, Lebanese, Mexican, Peruvian and Russian groups, while another cluster includes Danish, Scottish and Polish groups and is distinguished by a particularly weak telogen percentage.

Expressing this data with all individual values, as shown in *figure 7*, allows representing the continuum of all individual values, of fuzzier "frontiers" than those illustrated by *figure 6*. Many overlaps are evidenced, illustrated by points of different colours that admix within the same region of the continuum. In brief, the rather large intra-ethnic variability shown in *figure 6* logically brings inter-ethnic overlays.

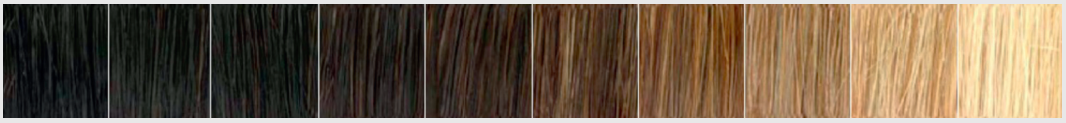
Discussion

The ethnic origins of subjects assessed here attempted to follow most criteria adopted by ethnologists. The latter combine, for such difficult tasks, the common origin of a given subject with his/her two preceding generations (parents and grandparents) together with a common language, all acknowledging that both criteria are less imprecise than genetic standards with regard the vast diversity in DNA polymorphism, worldwide. Interestingly, using language as a discriminant criterion confers to ethnic origin an intrinsic cultural component, thereby considering that humans and their origins cannot be restricted to mere (and complex) biological entities. Accordingly, it comes clear that terms such as "Danish" or "Thai" embraced in the present paper should be solely viewed as arbitrary shortcuts. They, in addition, concern subjects living in cities that may not perfectly reflect the ethnic profile of their respective countries.

The parameters of hair growth recorded by the present study show ranges of values that first confirm previous data [17] and, second, correspond to those of a normal hair status of non-alopecic young adults. Overall, gender shows little impact on such parameters, that is, comparable hair growth rates and T%, although the slightly lower density and the slightly higher telogen percentage in males might suggest a "silent" onset of alopecia [3, 8].

Heterogeneity between the three different scalp areas accounts for a major proportion of variance within the values of hair growth. This appears most pronounced for hair density, almost two times higher at the vertex than at the temple in all subjects. In about two thirds of volunteers, T% appears higher at the temporal area by 3% on average, and hairs grow faster on the vertex by +5 mm per year on average, as compared to the other two areas. These data

Table 3. Hair Color reference scale and distribution of the cohorts by natural hair tones.



1	2	3	4	5	6	7	8	9	10

Hair tone	1	2	3	4	5	6	7	8	9	10	total	% of subjects
Nb of subjects	231	489	456	245	178	166	86	55	14	2	1922	85.4

Table 4. Distribution of the cohorts by natural hair curliness.

Natural hair curliness	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**total**	**% of subjects**
Nb of volunteers	86	349	288	154	46	23	26	8	980	43.5

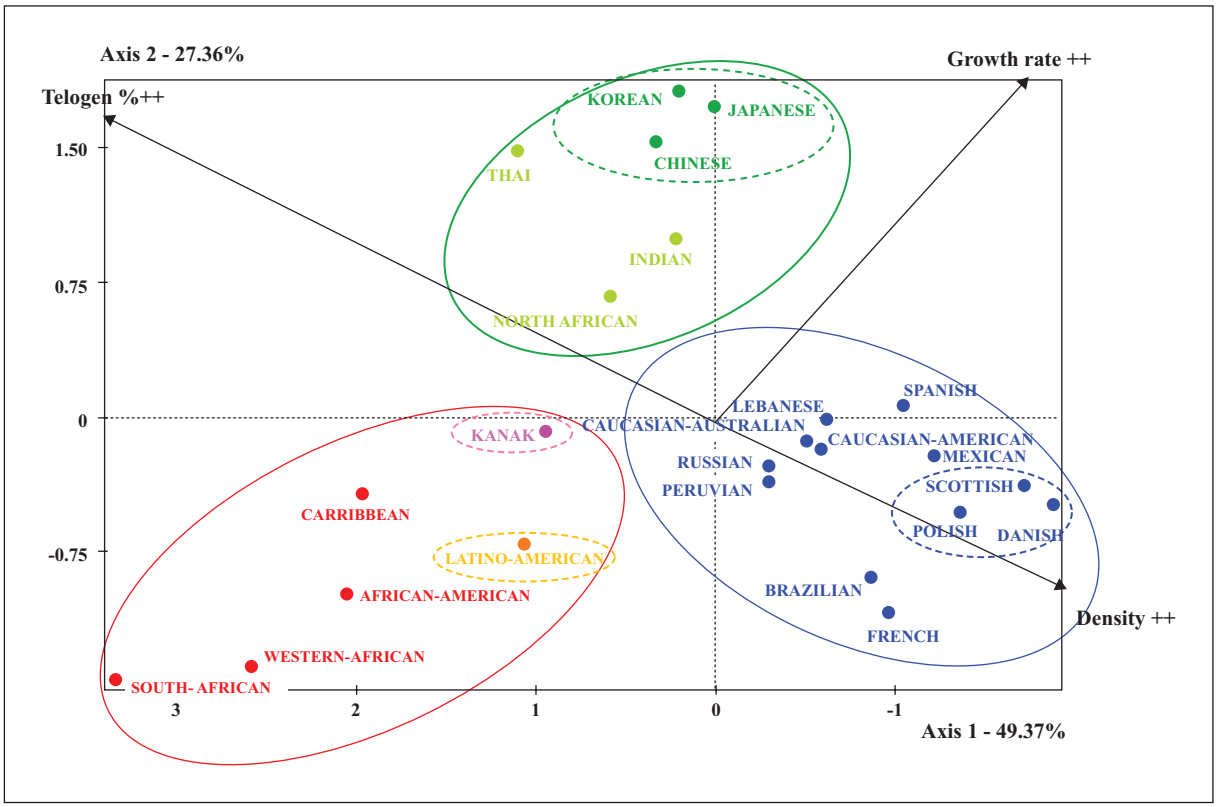


Figure 6. Groups mapping (PCA and HAC). Principal component analysis (PCA) followed by hierarchical ascendant classification (HAC) permitted the two-dimensional localization of mean populations when cross-analysing all three growth parameters (density, telogen % and growth rate), diameter is added as an illustration. Means of populations were localized in one of three distinct clusters corresponding to classical African, (cluster I), Asian (cluster II) and Caucasian (cluster III) hair types, which could then be further differentiated into distinct sub-clusters, including seven clusters in all.

confirm that these areas should be studied separately when attempting to accurately depict hair growth parameters at the individual level.

Overall, the present study confirms numerous previous findings [3, 18, 19, 21-27], showing an expected variability (hair density, growth rate…) among the 3 large African, Asian and Caucasian human sub-groups. In brief, Caucasian scalps harbour about 30% more hair than African or Asian scalps, whereas Asian hair shows the fastest growth, an Asian hair will be almost 5 cm longer after one year of growth than an African hair. As previously mentioned, these figures do not seem much affected by environmental factors, few differences being noted between subjects of a given subgroup living at different locations. Hair diameter, although not determined in all subjects, shows a range of variations in agreement with previous work [28] confirming that Asians

Table 5. Hair density, telogen percentage, growth rate and diameter (mean and standard deviation) by clusters, irrespective with gender.

Clusters		Population types	Hair density (hairs/cm^2)	%T	Hair growth rate (μm/day)	Hair diameter (μm)
1	1a	African-American, Caribbean South-African, Western-African	171	12	308	71
	1b	Kanak	168	10	356	-
	1c	Latino-American	208	13	343	-
	Means		**178**	**12**	**325**	**71**
2	2a	Chinese, Japanese, Korean	167	11	424	88
	2b	Indian, North-African, Thai	196	13	403	81
	Means		**182**	**12**	**413**	**84**
3	3a	Brazilian, Caucasian-American, Caucasian-Australian, French, Lebanese, Mexican, Peruvian, Russian, Spanish	215	10	384	75
	3b	Danish, Polish, Scottish	212	8	393	72
	Means		**214**	**10**	**386**	**73**

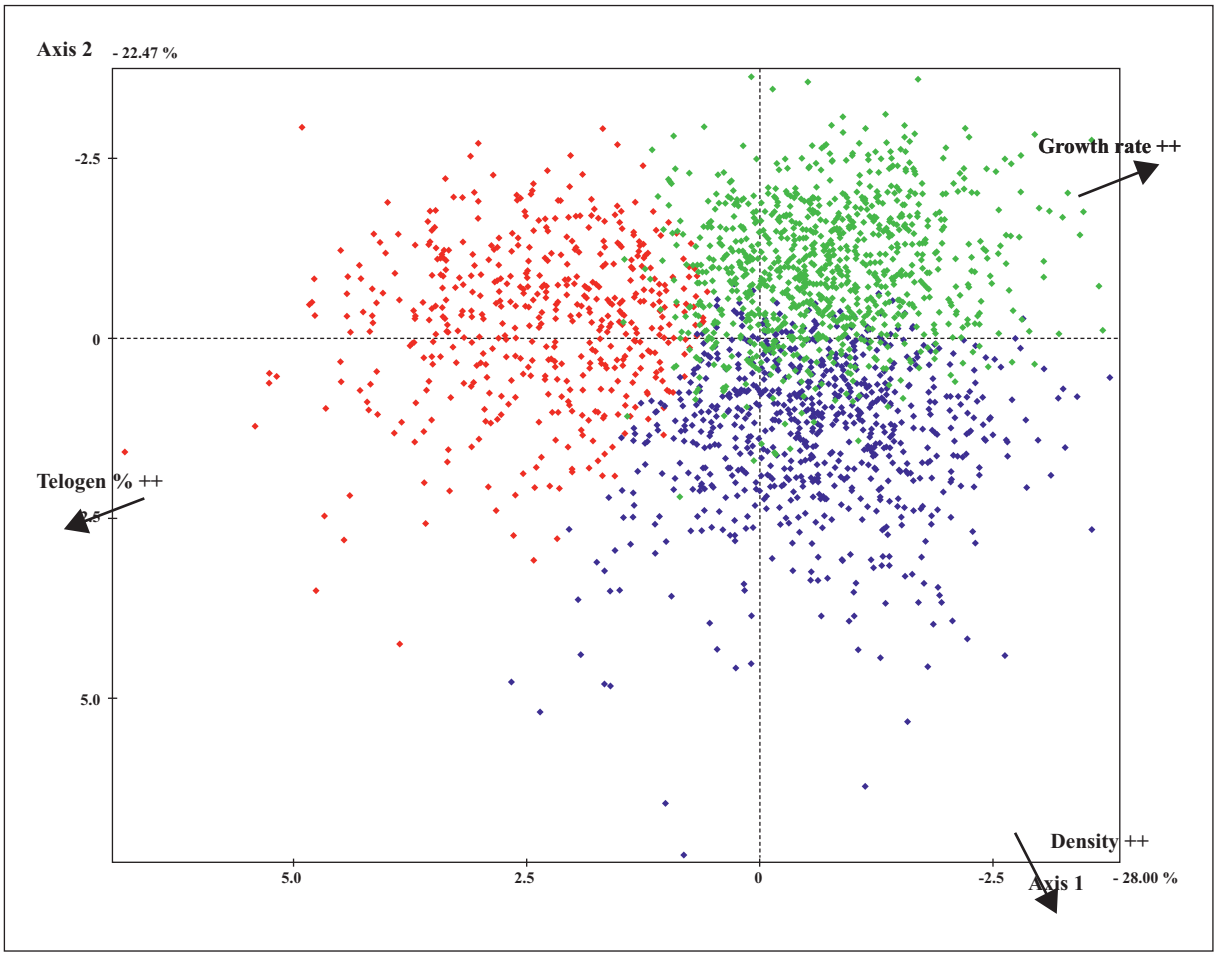


Figure 7. Individual data Continuum (PCA and HAC). The projection of individual hair growth parameters in the clusters previously defined by PCA and HAC (graph 5) demonstrates a complete continuum of data points, where population clusters are not readily apparent, reflecting overall population admixture. As in the previous PCA, in red, green, and blue, African, Asian and Caucasian hair types respectively.

have distinctly thicker hair. Interestingly, these thicker hairs are associated with the fastest growth, in agreement with a publication [29] showing inter-correlations between hair diameter, growth rate and inter-scale distance, at least on straight shaped hairs (Types I and II) [1].
The colour tones and degrees of curliness were additional factors aiming at enlarging the study. Although not assessed in all subjects (mostly curliness), some links deserve attention. Lighter hair tones (>6) were associated with thinner hairs and a lower T%. However, such findings need to be being tempered (or further explored) since subjects with 1-6 hair tones largely prevail (over 80%) worldwide [16]. Increased curliness seems associated with a smaller total hair density and a lower rate of growth.
The PCA and HAC allow summarizing hair growth parameters in three large clusters corresponding to the three traditional hair types: African, Asian and Caucasian. The first cluster is characterized by lower density and lower rate of growth, typical of the African hair type. In this cluster the Kanak and Latino-American groups are singularized by an advanced clustering. Their hair growth parameters seem to position them in the middle between African and Asian hair characteristics for the former and between those of African and European for the latter. The second cluster pool groups with the fast rate of growth and low density, typical of Asian type hair: the Chinese, Korean and Japanese groups presenting a big resemblance on hair growth parameters. An advanced clustering in this same cluster, singularized by high telogen percentage values, which may be the sign of a shorter hair life cycle, distinguishes Thai and Indian groups but also, more surprisingly, the North African group. The location of this last group is the only one which remains unexplained. However, positioning of the hair growth parameters of the Arabian peninsula is missing to complete our knowledge. The third cluster, characterized by high hair density, typical of Caucasian hair, points out the Danish, Scottish and Polish groups which are singularized by a lower telogen percentage. The average Brazilian hair growth parameters are positioned in the Caucasian hair type. However, when this group is split by hair curliness, the average hair growth parameters of Brazilian subjects with curliness VI to VIII move towards to the African hair type. The weak differences between cities seem irrelevant *vis à vis* the differences observed between ethnic groups. The effect(s) of the environment, only studied in three groups, need to be confirmed by a wider exploration.
Individual data, gathering all values *(figure 7)*, is probably the best illustration of the present study, which depicts a continuum of hair growth patterns among humans, of gross contours and overlaps. Intra and inter-individual heterogeneities of hair growth profiles, past migrations and their consequent genetic cross-breeding. . . are important driving factors that need future investigation with the help of ethnogeneticists. On the whole, these data chiefly encompass the domains of Dermatology or Cosmetology. They come as elements - among many others - of the vast, intriguing and fascinating domain of human biology. ■

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