Report

Worldwide diversity of hair curliness: a new method of assessment

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Abstract

Background For many years, cosmetic scientists have attempted to measure the physical features of human hair, such as its shape and colour, as these can be artificially modified using cosmetic products. With regard to hair shape, previous anthropologic studies have emphasized its variability within and between human ethnic groups. Many studies have broadly distinguished three ethnic human subgroups: African, Asian, and Caucasian. Such a broad classification cannot account for the great complexity of human biological diversity, resulting from multiple, past or recent mixed origins. The verbal description of hair shape ranges from the classic to the more sophisticated, with terms such as straight, wavy, curly, frizzy, kinky, woolly, helical, etc. Although these descriptions evoke a global appearance, they remain confusing as their definitions and limits are unclear. Assessments are therefore required to more accurately define such verbal attributes.

Objective The work reported here attempts to address the following issues: (i) to define hair types according to specific shape criteria through objective and simple measurements; and (ii) to define such hair types without referring to human ethnicity.

Methods Measurements of four parameters related to hair curliness (curve diameter, curl index) or kinking of the hair (numbers of waves, numbers of twists) were performed on hair from 2449 subjects from 22 different countries. Principal components analysis and hierarchical ascendant classification were used to identify homogeneous groups of hair and to determine key variables for the assignment of group membership. Finally, a segmentation tree was prepared in order to establish simple rules for predicting group membership of new subjects.

Results and conclusions This study has shown that it is possible to classify the various hair types found worldwide into eight main groups. The approach involves objective descriptors of hair shape, and is more reliable than traditional methods relying on categories such as curly, wavy, and kinky. Applied to worldwide human diversity, it avoids reference to the putative, unclear ethnic origin of subjects. Briefly, a straight hair type I is just that, and whether it originates from a Caucasian or an Asian subject is not at issue. The hair types defined here also more adequately reflect the large variation of hair shape diversity around the world, and may possibly help to trace past mixed origins amongst human subgroups.

Introduction

There is a great diversity of hair worldwide: diversity of color, diversity of length, diversity of curliness, etc. The broad spectrum of the natural color of hair can be assessed using either an instrumental method, such as a spectrocolorimeter, or a sensorial method, matching tones and shades. The measurement of length is obvious. But what about The measurement of curliness?

Curliness has commonly been assessed using words such as straight, wavy, curly and frizzy, a variety of attributes of subjective nature with no clear definition and limits. Moreover the conventional classification has distinguished three types of hair only, i.e. Asian, African and Caucasian which does not take account of past or recent mixed origins and now appears to be an over simplistic and inadequate categorisation. Accordingly, a new method based on the evaluation of four hair morphologic parameters has been developed.[1] This method provides an objective and precise classification system without referring to geographic origin.

The aim of the present work was first: (i) to test the robustness of the results obtained earlier by increasing the

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Table 1 Hair sampling

Region of origin	Place of sampling	*n*
Australia	Melbourne	76
Brazil	Rio de Janeiro	210
China	Shanghai/Beijing/Guangzhou/Paris	265
Denmark	Copenhagen	47
France	Paris	101
Germany	Karlsruhe	99
India	Mumbai	179
Japan	Tokyo	40
South Korea	Seoul	36
Lebanon	Beirut	74
Mexico	Mexico City	106
North Africa	Casablanca/Paris	217
Poland	Warsaw	35
Peru	Lima	111
Russia	St Petersburg	86
Spain	Valencia	50
South Africa	Johannesburg/Cape Town	158
Thailand	Bangkok	116
UK	Glasgow	58
USA	Chicago	100
	New York	71
West Indies	Paris	98
West Africa	Accra/Paris	116
Total		2449

sample size and extending the geographical areas included; and second to propose a simplified method.

Materials and Methods

Volunteers

One thousand and seven new volunteers were added to the first 1442 volunteers,[1] resulting in a total amount of 2449 volunteers recruited in 22 regions of the world spread over the five continents (Table 1), in order to encompass a large diversity of curliness. All of these volunteers were instructed about the purpose and details of the study, and gave their informed consent. The only criterion required for inclusion was to have hair without any perm, straightening, or relaxing treatments.

Method for evaluation

Single hairs selected at random were collected from three different areas of the head: vertex, temples, and nape. Each hair was cut at a fully extended length of 6 cm from the root. After a standardized protocol of washing, rinsing, and drying, four parameters[2–4] were measured on each single hair cut at a fully extended length of 6 cm from the root. The hair was laid on a glass plate without any mechanical stress, in order to maintain its natural shape. The first recorded parameter was the curve diameter (CD), which was measured using a CD meter derived from Bailey and Schliebe:[2] a transparent template made up of concentric arcs of increasing diameter. The second parameter was the curl index (*i*),

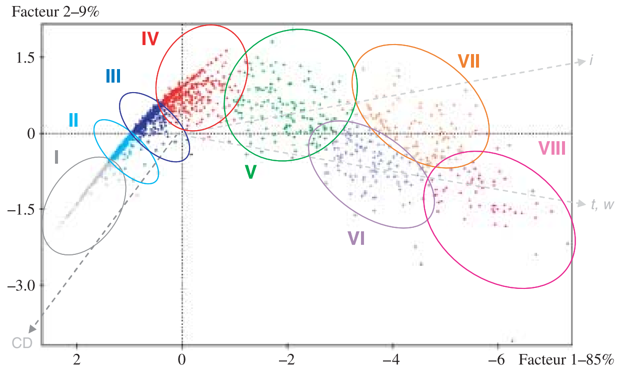

Figure 1 Illustration of eight cluster partition on the principal component 1/principal component 2 (PC1/PC2) plane derived from principal components analysis (PCA)

denoting to the ratio of the stretched length of the hair (6 cm) to its length at rest (L_1), which is the distance between the two furthest points apart of the hair when no stress is applied. The third parameter was the highest number of waves (*w*) when the hair was pulled or constrained to four-fifths of its length.[1] The fourth parameter was the number of twists (*t*), i.e. natural constrictions detected along the fiber.[3]

Statistics

SPAD version 5.6 (Decisia, Paris, France), SAS version 8.2 (SAS Institute Inc., Cary, NC, USA), and SPSS Answer Tree version 3.1 (SPSS Inc., Chicago, IL, USA) were used to analyze the collected data. In a first step, principal components analysis (PCA), followed by a hierarchical ascendant classification (HAC), was carried out in order to identify homogeneous groups of hair. In a second step, a segmentation tree analysis was performed to establish simple rules for assigning group membership of new subjects.

Results

For PCA, the first two principal components accounted for more than 94% of the variance. HAC confirmed an optimal partition into eight clusters. These are illustrated for the first two principal components derived from PCA carried out on the four variables CD, *i*, *w*, and *t* (Fig. 1). The segmentation tree shown in Fig. 2 summarizes the rules of classification into eight hair curliness types. As *t* and *w* are highly correlated, only three variables are needed to define the hair groups, i.e. CD, *i* and *w*. The first four types of curliness are distinguished by CD values, whereas the combination of *i* and *w* further differentiates the other four types. These analyses, performed on an increased number of data with an extended geographic sampling, led to results that fully tally with those obtained previously.[1] Confirmation of the same eight types of curliness defined by the same cut-off values of the parameters demonstrates the robustness of our curliness classification.

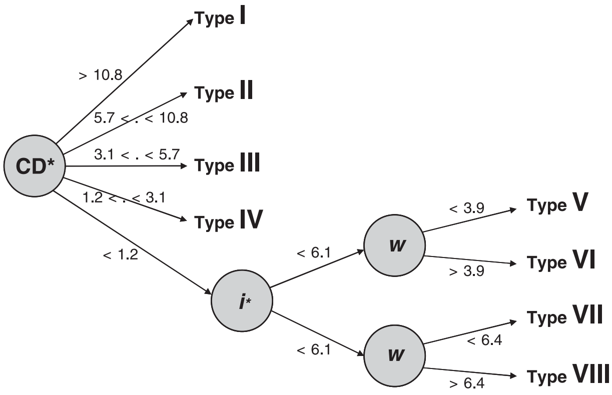

Figure 2 Segmentation tree

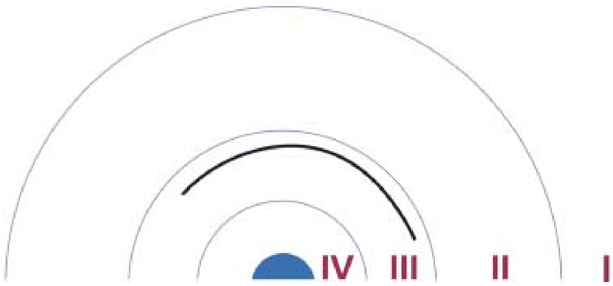

Figure 3 Curve diameter (CD) meter

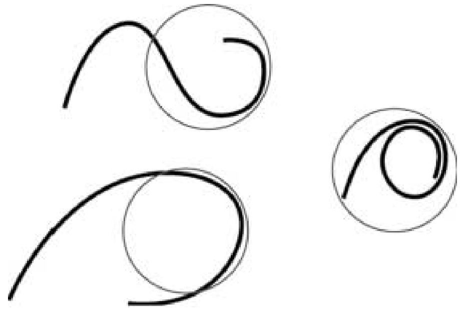

Figure 4 Curl meter

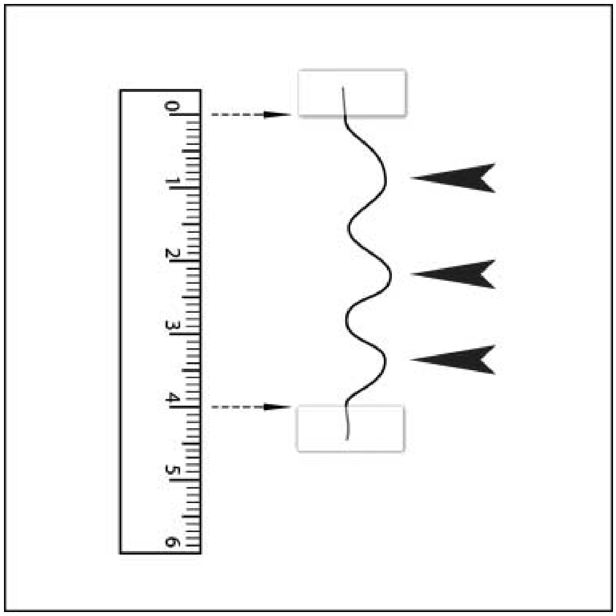

Figure 5 Wave crests assessment

Based on these results, a simple method was developed to quickly and simply determine hair curliness types. This new method applies to a piece of hair with an extended length of 6 cm. To assess natural curliness, the hair must be washed and dried without any stress (styling, etc.) in order to keep its natural shape. The method requires very simple materials: two glass plates, tape, a simplified CD meter, a curl meter, and a ruler. The CD meter includes the four cut-off values derived from the segmentation tree for the classification of types I–IV. The curl meter is made of a 0.98-cm-diameter circle, allows the segmentation of types V and VI vs. VII and VIII. The ruler helps to constrain the hair to 80% of its length in order to separate type V from VI and VII from VIII.

More precisely, this simplified method can be described in three steps. Initially, the hair is carefully laid on a glass plate, without applying any mechanical stress, in order to allow it to maintain its natural shape. A second glass plate is gently placed onto the hair, carefully avoiding any side shifting or sliding.

The first step is the evaluation of the curvature using the CD meter. The area of the CD meter where the smallest curvature is located indicates whether the hair is type I, II, III, or IV (Fig. 3). If the smallest curvature is included in the filled circle, the hair is type V, VI, VII, or VIII. Two others steps are needed to classify the hair.

The second step is the test of curliness using the curl meter. The curl meter is placed on the glass plate in order to determine whether or not the hair fits entirely inside the circle (Fig. 4).

The third and last step consists of counting the number of wave crests. The cover plate is removed. One end of the hair is taped in front of 0 cm on the ruler and the other end is taped at 4 cm. The two ends of the hair are taped on the bottom glass plate. Each self-stick strip covers 0.5 cm of hair fiber, and the distance between the two tapes is fixed to 4 cm thanks to the ruler. After replacing the cover plate, the hair takes a sigmoid form from which the highest number of wave crests is counted (Fig. 5).

Based on the curl meter result, and on the number of wave crests, the hair type (V, VI, VII, or VIII) can be defined with the following rules. If the entire hair is included in the curl meter and the number of crests is from one to five, the hair type is VII. If the entire hair is included in the curl meter and

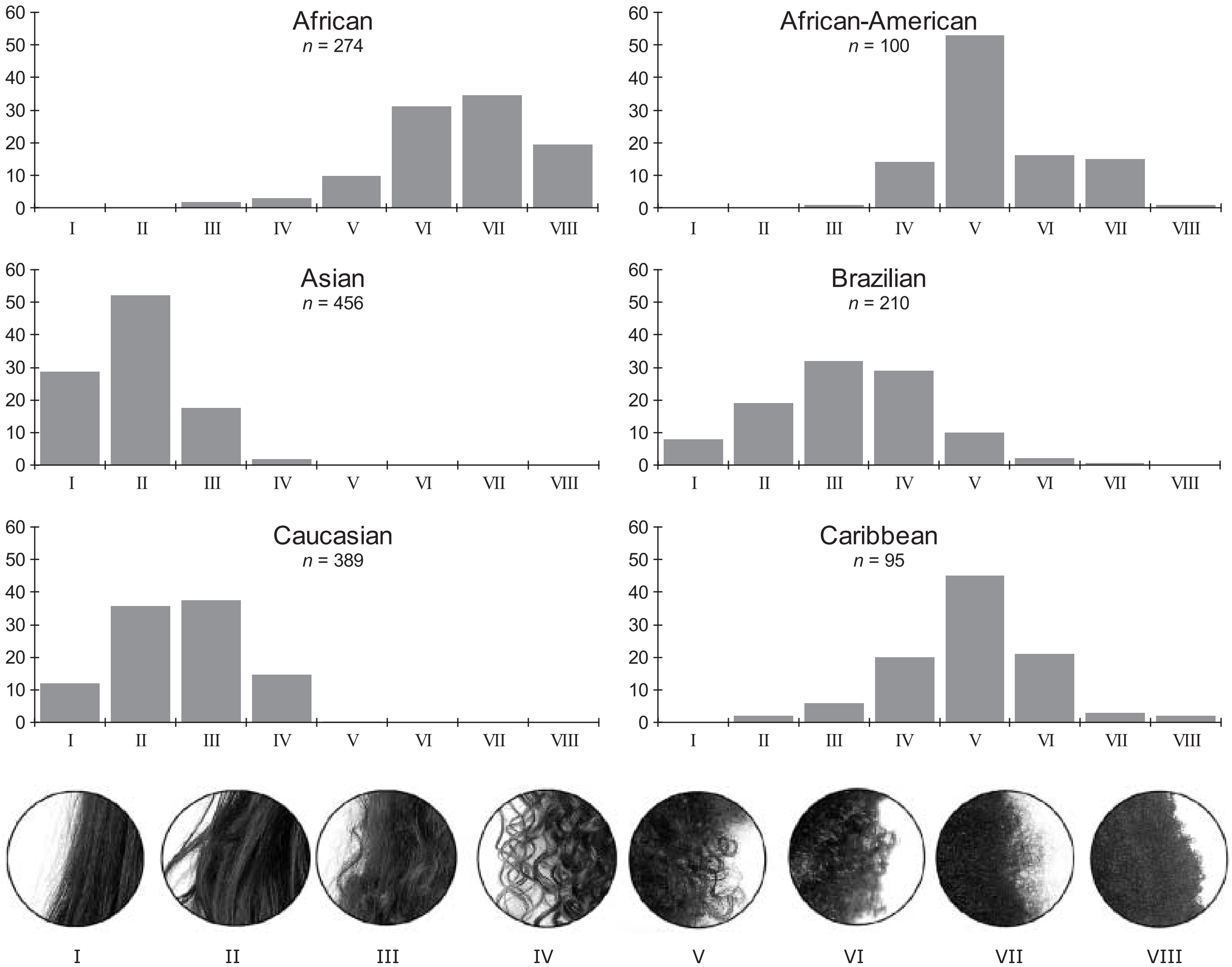

Figure 6 Re-partitioning of hair into the eight curliness types

the number of crests is six or more, the hair type is VIII. If the entire hair is not included in the curl meter and the number of crests is from one to three, the hair type is V. If the entire hair is not included in the curl meter and the number of crests is four or more, the hair type is VI.

When crossing the three conventional hair types (i.e. African, Asian, and Caucasian) with the new eight curliness levels, the old classification appears to be over-simplifying and to hide the diversity within each type. Moreover, when applied to mixed origin populations the new method try reveals the wide spectrum of curliness (Fig. 6). The molecular aspects of this wide diversity of curliness and shape are currently under study.[3,5,6]

Conclusion

The present work allowed us to establish a reliable method to define and assign eight types of hair curliness using morphologic parameters, without referring to ethnic origin.

This very simple method, whose robustness has been proven, can be an additional tool to assess of natural curliness, but also to follow the related alteration of hair curliness disease[7,8] or medicine.[9–12]

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