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Influence of hair volume and texture on hair body of tresses

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Synopsis

A technique is described for the instrumental measurement of hair body of hair tresses. It is shown that panelists frequently assess hair body as a function of the volume occupied by the hair. Subsequently, image analysis was used to assess hair body by measuring a pseudo- three-dimensional volume of hair tresses. The image analyzer data correlate significantly with visual assessment of tress hair body (by panelists): R~ 0.9 to 0.97 ($p = 0.0001$). Many marketplace hair treatments can be evaluated utilizing this technique.

One limit of the method occurs when the hair has been treated such that the fibers are extremely curled (black Afro-American hair). The contribution of texture to hair body is also described.

INTRODUCTION

Body is one of the most desirable properties a hair care product can impart to hair. The desire to have hair with body is expressed frequently, and universally, by consumers who are always searching for a product that delivers on this promise.

Understanding the terms that consumers use to describe certain hair conditions is an important step in identifying their needs and developing products to address them. The translation of these terms into physically measurable quantities is sometimes difficult. Combability is a hair property that is easily measured (1,2). On the other hand, body is one of those terms that is difficult and complex to assess because the term *body* is made up of several interactive components (3,4).

Using principal component analysis, consumer research carried out in both the UK and USA has shown (5) that three major words together describe body:

- Volume (bulk, thickness)
- Springiness (bounce)
- Stiffness (set, not soft)

These factors are in turn affected by length of hair, thickness and stiffness of individual hairs, sparseness of hair, curl, etc. In fact, hair body is associated with mass structural strength and resiliency (3). Optima for the above three characteristics may be very different for different individuals because of hair type, and may differ between persons of different countries because of climate, customs, expectations, etc.

An in-house survey (n = 150; men and women) showed only ~15% of the respondents used *stiff* to describe hair body, but volume, bounce (springiness), and thickness descriptors were each used by ~90% of the respondents. Volume and thickness were the most frequently cited hair body characteristics. The former can be evaluated visually, while the latter is inferred, and appears to require a textural examination of the hair to confirm the degree to which the attribute is present. Thickness can be considered a "volume + texture" attribute.

Our initial research with panelists suggests that both volume and texture contribute to hair body. We concluded that volume contributes most to the perception of hair body, especially when the judgement is solely visual (no tactile contribution). The visual impact of voluminous hair moving in a controlled manner is a universal description of hair with body. In the past year, volume has in many cases superseded body as a claim of hair care products and many "volumizing" products are now available in the US market. Texture should be more important for self evaluation than when the evaluation is made about someone else's hair. In the latter case evaluation is usually only visual.

Products that impart body to hair can be divided into two main groups:

- Permanent treatments; e.g., permanent waving solutions, hair bleaches
- Temporary effects; e.g., shampoo, conditioner, or fixative type treatments

The former are chemical treatments that affect the making and breaking of covalent bonds in the hair and, in the case of permanent waving, the amount or degree of curl of the hair. The hair appears to have more body due to the increased curl and the manner in which the fibers interact. Temporary treatments are used more often by consumers, but these also deliver smaller effects. For both types of treatments a textural change of the hair surface may, and in the permanent case will, occur. This textural change can affect the perception of hair body in either a positive or negative manner. This paper reports an instrumental means for measuring hair volume using image analysis, i.e., an instrumental hair body assessment. The results are compared with panelist assessments made using visual and visual-plus-tactile evaluations. For certain treatments, e.g., permanent waves where the hair volume change is relatively large, volume measurement alone will suffice. However, for a few surface treatments, e.g., where the hair volume change is relatively small and the texture change is relatively large, hair texture and hair volume may both need to be evaluated and the results combined to give the most meaningful measure of hair body.

EXPERIMENTAL

IMAGE ANALYZER EVALUATIONS

A Zeiss Kontron Ibas 2000 image analyzer was used to obtain an instrumental measure of hair body. Hair tresses were measured by simply hanging the test tress next to a standard (control) body (hair tress), capturing the images on the analyzer screen, and determining and recording the tress areas. (The same control body—a 30 g tress of Oriental hair, sprayed with hair spray until rigid—was used for all experiments). The camera used to capture images was a Sony XC-77CE miniature CCD video camera module with an Olympus 50-mm F2 auto-macro lens.

Hair body was evaluated as a ratio of the test tress area to the control area. An average of four images per tress (imaged at 90° to each other) was used for the assessment. This provides a "three-dimensional" measurement of hair body, similar to a human assessment. Four images (and not two) were necessary, since the tress was rotated manually (exact angles of rotation cannot be verified) and not by an automated device. These measurements can be made rapidly: three minutes or less per tress, including setup.

PANELISTS' EVALUATIONS

Evaluations were made by panelists who evaluated hair attributes (volume, texture, etc.) using their own personal experience criteria. For the most part, a panel of ten evaluators (five women and five men) was used. In some experiments this panel was supplemented by other assessors.

"Visual" hair body was evaluated by panelists observing a tress from all directions. For "visual + feel" hair body assessments, panelists also touched the hair fibers while estimating body in the previously described manner.

HAIR AND TREATMENTS

Light brown European hair, dark brown Oriental hair, and black Afro-American hair, all purchased from DeMeo Brothers, New York, were employed in experiments described in this paper. Some of this hair was permed for experimental use utilizing commercially available home permanent wave kits. Tresses were made by weighing the hair (1 to 6 g for experiments reported here) and binding the root end with a rubber band. In all cases, before final treatment and after fashioning into tresses, hair was washed twice (one-minute wash; one-minute rinse, 43°C) with 20% surfactant (ammonium lauryl sulfate) to ensure an initially clean fiber surface, and combed twenty strokes to make sure that tresses were of uniform combability. After drying, the tresses were weighed and hair was removed (if necessary) to provide tresses with the required quantity of hair for the experiment. For Experiments I and II, tresses of varying weights (and type) were used; in Experiments III, IV, and V, 3.5 g of virgin European hair was utilized. "Temporary" surface treatment regimens were applied to hair following manufacturers' instructions. When only an active ingredient was used, treatment time was thirty seconds followed by a thirty-second rinse.

Hair treatments for Experiments III and IV were as follows:

- A, a quaternized protein (2% laurdimonium hydrolyzed animal protein) that increased hair volume but did not appreciably alter hair feel
- B, a particulate treatment (2% barium sulfate) that both increased hair volume and provided a rough feel to hair
- C, a "heavy" hair conditioner, based on cetearyl alcohol, keratin and stearalkonium chloride, that left hair very soft and smooth to touch but did not enhance hair volume
- D, a surfactant (20% ammonium lauryl sulfate)—clean hair with no post-shampoo treatment

- E, a post-shampoo product containing panthenol, aloe vera, proteins, and botanicals that claimed to increase hair body and thicken hair
- F, a hair styling gel (post-shampoo product) that thickens and stiffens hair, thus increasing hair body, bounce, and hold
- G, a hair pomade, based on petrolatum and mineral oil, that caused fibers to adhere closely, giving a greasy, matted look (and feel) to hair

RESULTS AND DISCUSSION

To test the assumption that hair body can be adequately assessed by measuring the volume the hair occupies, panelists were exposed to a set of seventeen tresses, widely varying in volume (Experiment I). Figure 1 shows tresses representative of the hair body range of this experiment. Untrained panelists were asked to give rank and visual ratings (1 to 10 scale) to the tresses for hair body on the basis of visual examination only. Tresses included those prepared from straight hair, clean hair, greased hair, and hair with a natural or permanent wave. Also included were five tresses assembled from black Afro-American hair (very curly hair).

Using a planimeter, tress areas were outlined from photographs of the hair tresses, and paper replicas of them fashioned and weighed. This procedure assumes that the two-dimensional tress area is representative of the three-dimensional tress volume. A non-parametric test (Spearman rank correlation) was applied to the data, yielding a Rho value of 0.865, $Z = 3.461$ ($p < 0.001$). Figure 2 summarizes these data and shows the correlation between visually assigned panelist hair body ratings and the paper weights of the (seventeen) tresses. The black Afro-American hair tresses caused confusion among panelists, resulting in extreme ranking positions. These tresses were judged to have very little hair body by some panelists and a lot of body by other panelists. When these data

Figure 1. Photograph of hair tresses representative of those used in hair body/volume experiment (Afro-American hair on far left).

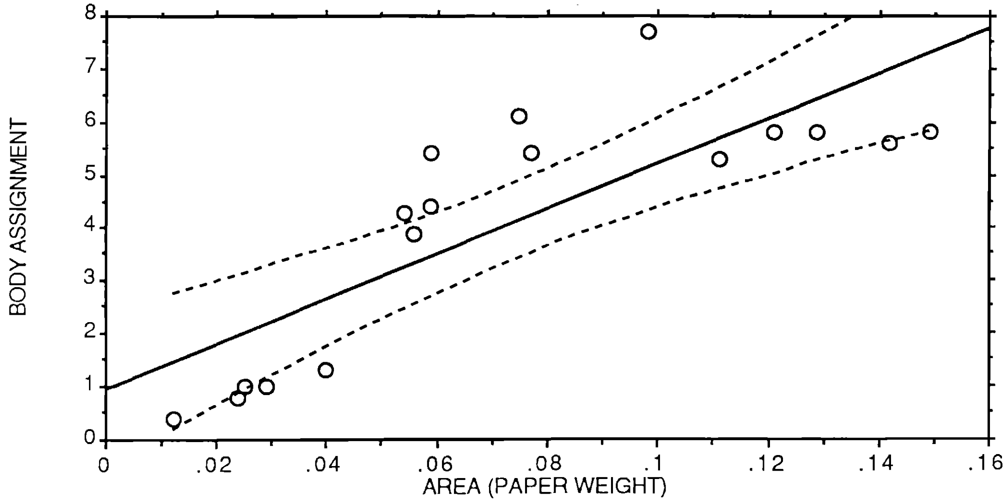

Figure 2. Body assignment vs area (paper weight), including black Afro-American hair. ---- 95% Confidence bands for the true mean of Y.

were excluded from the correlation, Rho increased to 0.975, $Z = 3.235$ ($p < 0.001$), implying a highly significant relationship between tress area and panelist assessment (Figure 3). We conclude that the technique is a valid method to estimate hair body with straight, wavy, or curly hair (see Figure 1) but perhaps not hair body for kinky hair like that of the Afro-American tress depicted on the far left of Figure 1.

Following the correlation achieved between panelist hair body ratings and tress area (Experiment I), we decided to measure tress area in a more sensitive and convenient manner using an image analyzer. Ten tresses representing a wide range in hair volume, and similar to those used previously, were prepared (Experiment II). No black Afro-

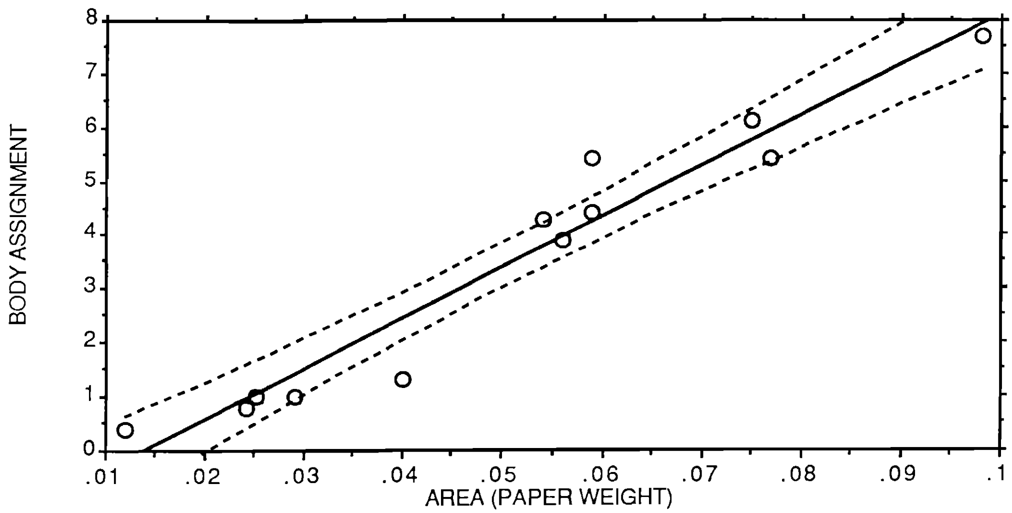

Figure 3. Body assignment vs area (paper weight), excluding black Afro-American hair. ---- 95% Confidence bands for the true mean of Y.

American hair tresses were included. The tress volumes were measured using the described image analysis technique, and subsequently panelists rated tress body visually (see Table I). Analysis of the data by Spearman's rank correlation method gave a Rho value of 0.952, $Z = 2.855$ ($p = 0.0022$), reflecting a highly significant relationship between image analysis tress area and panelist assessment of hair body.

Having satisfactorily validated the use of image analysis to measure hair body (volume) in Experiment II, we carried out further experiments designed to examine the contribution of texture to hair body. In Experiments I and II, the relative volume difference between smallest and largest tresses is considerable: eightfold for the planimeter experiment and fourfold for the image analysis experiment. This difference comes about because no attempt was made to use exactly the same tresses from Experiment I; the experiments were independent of each other. Subsequent experiments were carried out using surface treatments that resulted in smaller volume and large textural changes to the hair.

SURFACE TREATMENTS AND IMAGE ANALYSIS OF HAIR BODY

Hair surface treatments A, B, C, and G (listed in Experimental) were chosen to provide a range of hair body and texture (three replicates per treatment—Experiment III). The size of the hair volume contribution was relatively limited because the effects of these treatments occur primarily at or near the hair fiber surface. The sequence of evaluations, carried out to ensure minimal handling of tresses, was:

- Instrumental evaluation of hair body (image analysis)
- Visual assessment of hair body by panelists
- Hair body evaluation, using visual and tactile assessment (panelists)

"VISUAL" EVALUATION OF HAIR BODY VS IMAGE ANALYSIS

Image analyzer data show the four treatments to confer significantly different amounts of body to the hair (one-way ANOVA; $p = 0.05$) (Table II; hair body decreasing in treatment order A, B, C, G respectively). Panelists rated these treatments in the same order, but statistically the protein- and particulate-treated tresses (A and B) were not significantly different.

Table I
Experiment II: Image Analysis Ratios and Panelists' Rating Data

Tress	Image analysis ratio	Panelists' rating
1	0.50	0.95
2	0.58	1.55
3	0.75	1.80
4	1.16	3.70
5	1.30	4.90
6	1.48	5.65
7	1.08	5.35
8	1.44	6.40
9	1.61	7.50
10	1.90	9.05

Table II
Experiment III: Image Analysis Body vs Panelists' Visual Assessments and Panelists' Visual-Plus-Textural Evaluation

	Image analysis body (ratio)	Panelists (visual body)	Panelists ("visual + feel")
Most body	A* (1.51)	A	A*
↓	B* (1.36)	B	B
	C* (1.04)	C*	C
Least body	G* (0.53)	G*	G*

* Significantly different at p = 0.05 level.

If the data are separated by sex of panelist, there is no significant difference in the evaluations of the twelve female and nine male assessors. When panelist rating data are correlated with image analyzer values, non-parametric analysis shows Rho = 0.85, $p < 0.001$ (twenty-one panelists). This is a highly significant relationship given that the image analyzer is measuring tress "volume" (really a 2-D image) but panelists are incorporating true volume and visually apparent textural components into their assessments.

The surface treatments in Experiment III, while providing for a wide range in hair texture, also resulted in relatively large differences in hair volume between treatments, particularly for the pomade (G) versus the quaternized protein (A) (a threefold difference). In a subsequent experiment (IV) the hair surface treatments, B, C, D, E, and F (see Experimental section) were chosen to provide a range of hair body and texture, but with a smaller volume difference than for Experiment III (approximately a 1.6-fold difference between largest and smallest volume changes; see Table III). Three replicates per treatment were used, and the sequence of evaluations was as described previously for Experiment III.

Table III tabulates the image analysis data and panelists' visual ratings for the five sets of treated tresses for Experiment IV. The panelists were more discriminating in their assessment of visual hair body than image analysis in this experiment. Since the hair volume differences in this experiment are relatively small, the panelists may be building other parameters besides volume into their visual evaluations, e.g., stiffness, dryness. Nevertheless, a significant correlation between panelist rating data and image analyzer volume values shows Rho = 0.94, p = 0.0001 (non-parametric Spearman).

Table III
Experiment IV: Image Analysis Body vs Panelists' (Visual Body) Treatment Rankings

	Image analysis (body)	Image analysis (hair body ratio)	Panelists (visual body)
Most body	D*	1.08 ± 0.04	D*
↓	E	0.95 ± 0.13	E
	B	0.95 ± 0.07	B
	F	0.71 ± 0.13	F*
Least body	C	0.65 ± 0.16	C*

* Significantly different at p = 0.05.

IMAGE ANALYSIS VS BODY ("VISUAL + FEEL")

In Experiments III and IV the final hair body assessment by panelists included both visual and tactile evaluations. This was done to examine the contribution of texture to hair body. The question arises of how different is a "visual" vs "visual + feel" panelist evaluation of body and how does "visual + feel" evaluation agree with the image analysis body measurement. Inspection of the data for Experiment III (Table II) shows the same rankings from image analysis body measurements and visual assessments (by panelists) and "visual + feel" assessments (by panelists). However, statistical analysis of the data shows subtle differences in the ability to distinguish among these three evaluations, with image analysis body assessment being the most sensitive of the three evaluation methods for these four treatments.

The data from Experiment IV are slightly different (see Table IV). Although the rankings of the image analysis evaluation and the panelists' visual assessments are in the same order, the visual assessment appears to be more sensitive. However, the textural assessment causes a reversal in the body ranking of treatments B and F in this experiment (although it should be noted that this reversal is not statistically significant by the "visual + feel" evaluation of body).

Table V compares Spearman rank correlation coefficients from the two experiments and shows highly significant correlations of visual body and image analysis or "visual + feel" body and image analysis in both experiments. However, the correlation coefficient does decrease for Experiment IV when the textural component of body is included. This result may be explained by the relative volume and textural changes of the treatments being considered. In Experiment III, where the textural component did not alter the rank order of the body measurements, the relative volume difference between treatments was almost twice that of Experiment IV (see Table V) when the texture component began to play a role. This observation suggests that image analysis is a good measure of hair body even when there is a relatively large textural difference between hair samples. However, when large textural differences are being examined with relatively small volume changes of the order of 1.6 or less, then the relationship between image analysis of hair body and the perception of hair body may weaken.

BODY ASSESSMENT BY MEN AND WOMEN

An analysis of body "visual + feel" ratings by men and women from Experiments III and IV suggests that hair treated with the particulate treatment B are assessed differently

Table IV
Experiment IV: Image Analysis Body vs Panelists' Visual Assessments and Panelists Visual-Plus-Textural Evaluation

	Image analysis body	Panelists (visual body)	Panelists ("visual + feel")
Most body	D*	D*	D*
↓	E	E	E
	B	B	F
	F	F*	B
Least body	C	C*	C

* Significantly different at $p = 0.05$ level.

Table V
Experiments III and IV: Spearman Rank Correlation Coefficients (Rho) for Image Analysis vs Visual and Image Analysis vs "Visual + Feel" Panelist Evaluations

	Image analysis vs visual body	Image analysis vs "visual + feel" body	Relative volume change in test
Experiment III	0.85*	0.84*	3.0
Experiment IV	0.94**	0.71*	1.6

* $p < 0.001$.
** $p = 0.0001$.

by the two sexes. In each experiment, the women evaluated tresses from treatment B to have less body than the men rated them to have. The "visual + feel" rating (of the women) was also lower than that for visual evaluation alone. This hair has a rough, dry feel that the women dislike. The men, however, do not seem to regard the rough feel as negatively as the women, and these men continue to assess the particulate-treated tresses as hair with good body. For example, for Experiment IV the statistical analysis of hair body ("visual + feel") ratings by men and women shows ($p = 0.05$):

	Women	Men
Most body	D	D*
	E	E
↓	F*	B
	C	F
Least body	B	C*

These data serve to emphasize:
(i) the influence of hair texture on hair body assessment;
(ii) that the sex of the assessor may influence whether the textural component is perceived to enhance or diminish hair body, particularly when the hair volume change is small.

EVALUATION OF TECHNIQUE TO DISCRIMINATE WITHIN A PRODUCT TYPE

Finally, we conducted an experiment (Experiment V) to determine the sensitivity of the image analysis/hair body method to distinguish between formulations within a product type—in this case shampoos. The two shampoos chosen were:

- A conditioning shampoo, A, consisting of anionic surfactant and insoluble silicone suspended with an acylating suspending agent
- A conditioning shampoo, B, consisting of anionic surfactant with paraffin wax suspended with an acylating agent

Six tresses of equivalent weight (3.5 g) and initial combability were selected, and were then repeatedly washed with either shampoo A or shampoo B (three tresses per shampoo treatment). After five washes the hair body of the tresses was determined using the described image analysis method. The data showed that the hair washed with Shampoo B occupied a larger volume, i.e., had more body, than that shampooed with Shampoo A (ANOVA: 90% confidence level, $p = 0.056$). Similar results were found after ten washes (ANOVA: 90% confidence level, $p = 0.068$). Combining the results, it is concluded that these two shampoos alter hair body differently (>98% probability, $p = 0.018$) and that Shampoo B-washed tresses have more hair body than tresses washed with Shampoo A.

The tresses were also evaluated by an expert panel. They judged the hair treated with Shampoo B to be cleaner, fuller, and "drier" and to have more body than the A-treated hair. The latter tresses were assessed to be more conditioned, softer, and slightly limp. Friedman analysis of the data showed the two treatments significantly different at >99% confidence level.

This experiment demonstrates the utility of the image analysis technique for instrumentally evaluating, and differentiating between, hair body effects of shampoos, that is, after treatments that alter hair fiber surfaces in a relatively small manner. These two shampoos differ basically in the use of paraffin wax (B) and silicone (A) as the active conditioning materials. This image analysis hair body technique essentially assesses the different surface effects of these two compounds delivered from a shampoo. Hence this experiment provides further evidence of the utility of this technique for the cosmetic chemist.

CONCLUSIONS

A method has been developed to quantify hair body in terms of volume changes in tresses measured either via planimetry or by image analysis. For large volume differences (eight- and fourfold respectively), hair body can be evaluated as hair volume irrespective of textural changes. We have shown, too, that the image analysis technique can distinguish between formulations within a product type (shampoos) and that the data agree with expert panel (subjective) evaluations. We have also presented panelist data that indicate a textural component is sometimes a part of self-assessment of hair body.

As hair increases in curvature, hair body and hair volume generally increase. However, there are individual preferences and limitations to curvature changes as the kinky region of curvature is approached. One limitation in the correlation of the image analysis technique with panelists' evaluation of hair body occurs if the hair is extremely curly (black Afro-American hair). Hair texture may also play a role in body evaluations, particularly when the relative volume differences between treatments is small (approximately 1.6-fold or less). We conclude that image analysis is a valid technique to assess hair body of hair samples that encompass a wide range of volume and textural differences.

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