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THE USE OF CHANGES IN HAIR ROOT MORPHOLOGY IN THE ASSESSMENT OF PROTEIN-CALORIE MALNUTRITION

ALLAN A. JOHNSON, M.N.S., MICHAEL C. LATHAM, M.B., M.P.H., F.F.C.M., D.T.M. AND H., AND DAPHNE A. ROE, M.D., M.R.C.P.

Division of Nutritional Sciences, Cornell University, Ithaca, New York

A study was carried out to evaluate the use of changes in hair root morphology in the assessment of protein-calorie malnutrition (PCM) among a group of Black West Indian children.

Significant differences in mean shaft diameter, mean % anagen, and mean % telogen were found only between the well-nourished and the severely malnourished groups. No significant differences in mean % atrophy, and in mean diameter of anagen bulbs were found among well-nourished children, children with mild-moderate PCM, severely malnourished children, and children hospitalized for conditions with a secondary effect on nutritional status.

The method was found to be time consuming; it can be used only for differentiating well-nourished from severely malnourished children; and it cannot be used for determining the prevalence of the different degrees of PCM. For these reasons, the method is not recommended for use in the field assessment of PCM.

The possible use of head hair in the assessment of protein-calorie malnutrition (PCM) has been considered for some time. PCM is a disease caused by a deficiency of protein and/or calories. It is characterized in its severe forms by kwashiorkor, in which the deficiency is more one of protein than of calories, and by nutritional marasmus in which there is a deficiency of both protein and calories. The general picture of mild-moderate PCM is of an underweight, disproportionate child, with a long-seeming body, thin limbs, and a head that appears too large [1]. Of the 11 signs which have been listed as indicative of PCM in young children [1], 4 deal with hair. These are dyspigmentation of the hair; easy pluckability of the hair; thin, sparse hair; and straight hair.

Comparative studies have been made of the hair of children with and without PCM with respect to a number of hair characteristics. Studies of hair pigmentation [2], rate of hair growth [3,4], tensile strength [5], mechanical strength [6], and hair shaft diameter [3,4,7,8] all indicate significant changes in these characteristics in children with severe PCM. Conflicting results have been obtained in studies of the sulfur amino acid [7,9–12], copper [13–15], and zinc [16] content of hair.

One of the newest of the techniques that have been proposed for the assessment of PCM is based on the use of changes in hair root morphology. Bradfield and Jelliffe [17], report that changes in hair root morphology can be standardized and classified, they are present in mild-moderate PCM, and are therefore useful as a "sensitive confirmatory indicator" of early malnutrition in community surveys. Bradfield and co-workers have used the technique in several different studies with some very striking results [17–23].

However, the limitations of the technique have not been adequately discussed in Bradfield's publications. In addition, few other workers have published results using the technique with the result that very little has been written that is critical or supportive. Malcolm, Balasubramaniam, and Edwards [24] found that the technique provided a rapid method for the measurement of marginal malnutrition in New Guinean children. Kanawati and McLaren [25], on the other hand, have postulated that epilation is traumatic to the subject and possibly to the hair, and that the procedure is tedious and time consuming. Crounse, Bollet, and Owens [26] mention that experienced observers are needed for the technique which is subjective and only semiquantitative. Both of these criticisms, however, appear not to be based on extensive practical experience with the method.

The present work was undertaken to evaluate the usefulness of the technique in the assessment of PCM in a group of Black West Indian children.

MATERIALS AND METHODS

The sample was made up of 55 Black Jamaican children, 7 months to 5 years of age, and was subdivided into 3 subsamples. Subsample 1 consisted of 29 children of canecutters employed at Parnassus Sugar Estate situated in the parish of Clarendon in Jamaica. Subsample 2 was made up of 5 children with nutritional marasmus and 9 with kwashiorkor admitted to the hospital of the University of the West Indies in Mona, Jamaica. These children had been hospitalized for a

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Reprint requests to: A. A. Johnson, Division of Nutritional Sciences, Cornell University, Ithaca, New York 14853.

maximum of 3 days prior to being included in the study. Subsample 3 consisted of 12 children admitted to the same hospital for conditions other than malnutrition but some of which are recognized as having a secondary effect on nutritional status. These were conditions such as gastroenteritis, parasitic infestations, glomerulonephritis, measles, and meningitis.

Hair root samples were obtained from each child by plucking hairs from the occipital area of the head using a modification of Bradfield's technique [22]. A small group of hairs was lifted firmly from the scalp and stretched taut, the pressure being firm enough to cause a lifting of the scalp in the area beneath the uplifted hairs. Five to ten hairs were tightly grasped with a pair of Bergh Culia epilation forceps placed as close to the scalp as possible, and the hairs rapidly epilated with a quick forceful pull. Between 50 and 100 hairs were plucked from the head of each child, care being taken to use different scalp locations on successive samples. Because of the shortness and curliness of the children's hair, it was not possible to use a single pluck as is possible with straight-haired children. After plucking, the samples were immediately placed in glassine envelopes which were then sealed with Scotch tape and stored in a refrigerator until examined.

For examination, hairs bearing intact roots were mounted, 3 at a time, in water on glass slides which were then covered with glass cover-slips. The specimens were examined at a power of 10× under a microscope (Reichert Wien Nr. 214724).

The hair roots were classified by growth stage into anagen, telogen, or atrophy as described by Bradfield [22]. For diagnostic purposes, catagen hair roots were included with the telogen hairs. Mean shaft diameter (in mm × 10^{-2}), mean bulb diameter (in mm × 10^{-2}), % anagen (including both anagen and atrophied hair roots), atrophy (expressed as % of anagen), and % telogen were determined for each child on an average of 25 hair roots.

Shaft diameter was measured on all hairs at a point immediately distal to the upper margin of the bulb, the sheaths not being included in the measurements. Bulb diameter was measured, along the maximum diameter of the bulb, on the anagen and atrophied hair roots. The external and internal root sheaths were not included in the measurement of the bulb diameters. All diameters were measured by means of an eyepiece micrometer (American Optical Corp. 1406A).

The weights and heights of the children were determined as described by Jelliffe [1]. Ages were verified by means of birth registration certificates. Waterlow's classification [27] was used to classify the canecutters' children as well nourished (weight/height ≥ 90% of standard), and mild-moderate PCM (weight/height between 71 and 89% of standard). Weight/height was used because it is a better index of current nutritional status than weight/age in which past nutritional history is superimposed on current nutritional status.

One-way analysis of variance and the Scheffe multiple range test were used to test for significant differences (at the 5% level) in shaft diameter and bulb diameter among the 4 groups, while the Kruskal-Wallis and the Mann-Whitney U tests were used for % anagen, % atrophy, and % telogen.

RESULTS

The Table shows the hair root characteristics by weight/height. The age range was similar in the 4 groups analyzed. A significant difference ($p < 0.05$) in shaft diameter was found between the well-nourished and the severely malnourished children, but none among groups 1, 2, and 4, and among groups 2, 3, and 4. No significant difference in bulb diameter was found among the groups, though there does appear to be a stepwise reduction in bulb diameter with increasing severity of PCM. The severely malnourished children showed a significantly higher % telogen than each of the other 3 groups, indicating a significant shift to the telogen phase of hair growth. No significant difference in % anagen and in % telogen was found among groups 1, 2, and 4. There was also no significant difference among the groups with regard to hair root atrophy.

DISCUSSION

The results pertaining to shaft diameter agree with work reported elsewhere [3,4,7,8] in that a significant difference in shaft diameter was found between well-nourished and severely malnourished children. So far as can be determined, no work has been published on changes in shaft diameter in children with mild-moderate PCM.

From the results on bulb diameter, it appears that in this study it was not appreciably affected by PCM. This disagrees with results published by Bradfield and co-workers which show a significant reduction in bulb diameter in severely malnourished children [17,19,20,23] and in children with mild-moderate PCM [17].

TABLE. *Hair-root characteristics by weight/height*

Group no.	No. of subjects	Shaft diameter (mm × 10^{-2}) mean ± 1 SD	Bulb diameter (mm × 10^{-2}) mean ± 1 SD	% anagen mean ± 1 SD	Atrophy (% of anagen) mean ± 1 SD	% telogen mean ± 1 SD
1[a]	23	5.4 ± 0.9*	11.5 ± 3.5*	80.1 ± 16.3*	34.0 ± 25.2*	19.9 ± 16.3*
2[b]	6	5.1 ± 0.3*,†	10.8 ± 3.1*	83.2 ± 13.7*	36.0 ± 22.2*	16.8 ± 13.7*
3[c]	14	4.4 ± 0.8†	10.3 ± 5.6*	48.1 ± 23.8†	34.3 ± 34.4*	51.9 ± 23.8†
4[d]	12	4.8 ± 1.3*,†	11.2 ± 3.9*	72.7 ± 29.4*	31.5 ± 27.6*	27.3 ± 29.4*

[a] Group 1: well-nourished children (weight/height = ⩾90% of standard) (Subsample 1).

[b] Group 2: children with mild-moderate PCM (weight/height = 71–89% of standard) (Subsample 1).

[c] Group 3: children with severe PCM (Subsample 2).

[d] Group 4: children hospitalized for conditions with a secondary effect on nutritional status (Subsample 3).

*,† Values in the same column with at least one common superscript are not significantly different from one another ($p > 0.05$).

The results obtained in this study with regard to % anagen and % telogen agree with results obtained in Bradfield et al's work with Andean Indian children [19,20]. In these children, significant differences in % anagen and in % telogen were found between well-nourished and severely malnourished children. Bradfield has not reported on changes in these two characteristics in children with mild-moderate PCM. However, the results reported here indicate a normal anagen–telogen ratio in these children.

Van Scott [28] reports that % anagen and consequently % telogen vary considerably in hair plucked from well-nourished children, % anagen ranging from 65 to 95%. In light of this large variation in % anagen and in % telogen even in well-nourished children, it is felt that when these characteristics are used to assess PCM, they should be interpreted with caution. In addition, a shift from anagen to telogen occurs following traumatic experiences and many illnesses such as high fevers accompanying infectious diseases [28].

Nammacher, Bradfield, and Arroyave [18] report that hair root atrophy increases significantly in severely malnourished children. The results reported here, however, do not indicate an increase in hair root atrophy with increasing severity of PCM. This suggests that hair root atrophy is not a reliable index of nutritional status. Maguire and Kligman [29] report that the hair root is a delicate tissue, and since some force is required to pluck hairs, it is difficult to know whether atrophy reflects nutritional stress or preparation technique. Until this uncertainty is removed, it is recommended that atrophied bulbs be excluded from all hair root measurements, particularly measurements of bulb diameter.

The results obtained for the children hospitalized for conditions with secondary effect on nutritional status indicate that these conditions have a similar effect on hair root morphology as does mild-moderate PCM. All of these children could be classified as having mild-moderate PCM on a weight/height basis.

Despite Bradfield's reports to the contrary [22], a very frequent criticism of the technique is that hair plucking is traumatic to the subject. However, this did not constitute a problem in this study. Though the hair plucking procedure was quite rapid, examination of the hair roots was found to be a tedious and time-consuming process. It took between 1 and 2 hr to prepare and examine the hair roots from each subject. This alone does not recommend the method for use in large-scale field studies.

Bradfield and Jelliffe have recommended the method for use in diagnosing mild-moderate PCM [17]. However, the results of the present study show that the method differentiates only well-nourished from severely malnourished children. This also does not recommend the method for routine use. One certainly does not need hair root morphology to identify severely malnourished children. The large standard deviations obtained for each of the hair root characteristics indicate considerable variation in the manner and in the extent to which PCM affects hair-root morphology. This means that the method should not be used for assessing the nutritional status of individuals, and consequently cannot be used for determining the prevalence of the different degrees of PCM.

For the reasons mentioned above, the authors do not consider the method to be a practical field technique for the assessment of PCM. It shows no advantages over other methods, including anthropometric measurements and clinical signs, currently used in developing countries for the field assessment of PCM.

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