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Detection of moderate protein-energy malnutrition in pre-school children

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Summary

Several biochemical and anthropometric tests were used to define the states of mild or moderate protein-energy malnutrition among 810 children aged under five years in the forest region of Southern Cameroon. The results show that the percentage and the identity of children classified as undernourished may be different according to the anthropometric test employed. The mean values of most of the biochemical variables assayed decrease in the groups affected with moderate weight and arm deficiencies. A system is proposed for the evaluation of the nutritional status based on the simultaneous use of four anthropometric tests. Some biochemical parameters may be useful for establishing a diagnosis.

Introduction

Previous research (JELLIFFE, 1966) has shown that children up to five years of age constitute the highest risk group for protein-energy malnutrition. Moreover, without wishing to underestimate the value of clinical cases, most cases of malnutrition observed in Africa are mild or moderate in form and are therefore difficult to screen. The recognition of these forms is very important from a public health standpoint.

In order to define the states of protein-energy malnutrition various authors have proposed some simple anthropometric criteria such as weight for age (GOMEZ *et al.*, 1956), weight for height (WATERLOW, 1972), arm circumference for age (JELLIFFE & JELLIFFE, 1969) and ratio arm circumference/head circumference (KANAWATI & MACLAREN, 1970). While it would be expected that these various measurements would yield the same data, recent publications by JEANNEE *et al.* (1976) and VIJAYARAGHAVAN & GOWRINATH-SASTRY (1976) have shown that children classified as malnourished according to one test could be classified as normal according to another, especially in cases of moderate deficiencies. It thus seems that detection based on a single anthropometric test could lead to false or incomplete results and that more satisfactory results would be obtained if a battery of tests was used. For this reason, we have chosen four anthropometric tests and seven biochemical variables in which levels decrease in severe forms of protein-energy malnutrition as shown by several workers (WHITEHEAD, 1965; INGENBLEEK *et al.*, 1972; SMITH *et al.*, 1973; NEUMANN *et al.*, 1975; REEDS & LADITAN, 1976).

In the present work, we have attempted to define the possibilities of simultaneous utilization of several anthropometric tests as well as the possibility of using biochemical indicators to detect [illegible] of malnutrition.

Subjects and Material

The study involved 810 children from the forest region of Southern Cameroon, whose staple diet consists primarily of cassava, plantain and various tubers. Sampling was performed in such a way as to assure the representation of all age groups up to five years. Birthdays were taken from birth certificates. With the exception of a typical case of marasmus secondary to measles, no case of severe malnutrition was observed.

The following four anthropometric criteria were chosen: weight for age, weight for height, arm circumference for age and the ratio of arm/head circumferences. All the measurements were performed according to standard procedures described by JELLIFFE (1966). The results are expressed as percentage of Harvard standards expected (STUART & STEVENSON, 1959) for weight criteria and Wolanski's standards (JELLIFFE, 1966) for arm circumference for age. For each of these criteria the children were classified as shown in Table I. Finally, we determined for each criterion a threshold beneath which a state of moderate malnutrition could be suspected. The levels of these thresholds were chosen among all those corresponding to moderate anthropometric deficiencies so as to obtain a maximum of agreement between all criteria when paired. It should be recalled that a level of agreement is defined as the percentage of children who are simultaneously classified by two criteria in the categories "well to do healthy children" or "malnourished" according to the thresholds tested. Thus, the greater the agreement between two criteria, the more precise is the definition of a state of undernutrition according to these criteria. The thresholds are the following: weight for age, 80%, of the standard; weight for height, 90%; arm circumference for age, 85%, and ratio of arm/head circumferences, 0·290. The significance of these thresholds will be discussed in relation to the biochemical tests. A classification of the children is proposed, based on considerations of the four criteria and the thresholds chosen (Table II): Group 0—children whose four criteria are greater than the thresholds; Groups 1, 2, 3, 4—children having one, two, three and four criteria which are lower than the thresholds.

Blood was taken by venous puncture in the femoral vein, using the system of "vacutainer" tubes. Urine was collected once in the morning. After coagulation and centrifugation of blood, the serum obtained as well as urine were stored at −18°C before the analysis. The following variables were assayed: total protein by the method of GORNALL (1949); electrophoretic fractions of serum

Table I—Biochemical data of children classified according to several anthropometric tests [a]

		No. of children	Total protein g/100 ml	Albumin g/100 ml	Albumin / Globulins	Prealbumin mg/100 ml	Transferrin mg/100 ml	Complement C3 mg/100 ml	Hydroxy-proline index
Percentage	>91	400	6·92 ± 0·04^{c}	3·71 ± 0·02^{c}	1·21 ± 0·01^{c}	12·9 ± 0·2^{c}	300·6 ± 3·1^{c}	86·6 ± 0·8^{c}	3·5 ± 0·1^{c}
expected	90-81	264	6·96 0·05^{c}	3·67 0·03^{c}	1·13 0·01^{d}	12·3 0·3^{c}	293·0 3·8^{c}	84·3 1·0^{c}	3·0 0·1^{d}
weight	80-71	113	7·04 0·07^{c}	3·64 0·03^{c}	1·09 0·02^{d}	12·3 0·3^{c}	290·0 5·8^{c}	84·6 1·9^{c}	2·8 0·1^{d}
for age	70-61	24	6·87 0·13^{b}	3·52 0·08^{b}	1·07 0·03^{b}	10·7 0·6^{b}	268·8 11·3^{b}	77·5 3·3^{b}	2·1 0·2^{b}
	≤60	9	6·24 0·27^{b}	3·12 0·19^{b}	1·02 0·07^{b}	9·9 1·5^{b}	212·4 35·4^{b}	63·5 3·3^{b}	2·1 0·3^{b}
Percentage	>91	641	6·89 ± 0·03^{c}	3·67 ± 0·02^{c}	1·17 ± 0·01^{c}	12·7 ± 0·1^{c}	297·3 ± 2·5^{c}	85·6 ± 0·7^{c}	3·3 ± 0·1^{c}
expected	90-81	149	7·10 0·04^{d}	3·70 0·04^{c}	1·12 0·02^{d}	12·2 0·3^{c}	284·2 5·0^{d}	83·5 1·4^{c}	2·7 0·1^{d}
weight	80-71	16	6·46 0·12^{b}	3·46 0·10^{b}	1·18 0·15^{b}	10·8 0·9^{b}	268·8 15·1^{b}	78·2 5·3^{b}	2·2 0·3^{b}
for height	≤70	4	6·35 0·54^{b}	3·22 0·39^{b}	1·04 0·13^{b}	9·5 2·9^{b}	227·5 57·1^{b}	68·8 12·9^{b}	2·4 0·3^{b}
Percentage	>86	610	6·94 ± 0·03^{c}	3·71 ± 0·02^{c}	1·18 ± 0·01^{c}	12·9 ± 0·1^{c}	299·6 ± 2·5^{c}	86·5 ± 0·7^{c}	3·4 ± 0·1^{c}
expected	85-81	133	6·89 0·07^{c}	3·59 0·04^{d}	1·10 0·02de	11·9 0·3^{d}	284·0 5·4^{d}	82·4 1·4^{d}	2·7 0·1^{d}
arm circ.	80-71	62	6·97 0·10^{c}	3·53 0·05^{d}	1·10 0·05^{ce}	10·8 0·4^{e}	274·3 7·6^{d}	77·4 2·6^{d}	2·6 0·2^{d}
for age	≤70	5	6·83 0·19^{b}	2·91 0·22^{b}	1·01 0·10^{b}	8·2 0·9^{b}	184·4 49·3^{b}	50·4 11·4^{b}	2·2 0·5^{b}
ratio	>0·311	357	6·99 ± 0·04^{c}	3·76 ± 0·02^{c}	1·20 ± 0·01^{c}	13·1 ± 0·2^{c}	301·5 ± 3·2^{c}	88·6 ± 0·9^{c}	3·5 ± 0·1^{c}
arm circ./	0·310-0·291	246	6·93 0·05^{ce}	3·67 0·03^{c}	1·15 0·01^{d}	12·4 0·2^{d}	300·0 3·9^{c}	85·8 0·8^{d}	3·1 0·1^{d}
head circ.	0·290-0·271	153	6·77 0·06de	3·51 0·04^{d}	1·12 0·03de	12·0 0·3^{d}	274·9 4·7^{d}	79·5 1·3^{e}	2·6 0·1^{e}
	≤0·270	54	6·73 0·12de	3·48 0·06^{d}	1·08 0·03^{e}	10·7 0·4^{e}	259·0 10·0^{d}	77·5 2·9^{e}	2·8 0·2^{e}

(a) values given mean ± s.e.m.
(b) number of children too small for valuable statistical comparisons.
(c, d, e) for each anthropometric and biochemical test, values with no common superscript are significantly different from one another ($P < 0·05$).

Table II—Anthropometric and biochemical data of children simultaneously classified by four anthropometric tests [(a)]

	Groups				
	0	1	2	3	4
No. of children	482	110	98	67	53
Weight for age percentage	$99{\cdot}0 \pm 0{\cdot}6^{b}$	$94{\cdot}4 \pm 0{\cdot}9^{c}$	$87{\cdot}2 \pm 0{\cdot}9^{d}$	$80{\cdot}9 \pm 1{\cdot}1^{e}$	$71{\cdot}5 \pm 1{\cdot}1^{f}$
Weight for height percentage	$103{\cdot}6 \pm 0{\cdot}5^{b}$	$95{\cdot}5 \pm 0{\cdot}7^{c}$	$92{\cdot}8 \pm 0{\cdot}8^{d}$	$88{\cdot}1 \pm 0{\cdot}7^{e}$	$84{\cdot}5 \pm 0{\cdot}7^{f}$
Arm circ. for age percentage	$96{\cdot}6 \pm 0{\cdot}3^{b}$	$89{\cdot}2 \pm 0{\cdot}3^{c}$	$85{\cdot}2 \pm 0{\cdot}4^{d}$	$81{\cdot}7 \pm 0{\cdot}4^{e}$	$78{\cdot}1 \pm 0{\cdot}3^{f}$
Arm circ./Head circ.	$0{\cdot}321 \pm 0{\cdot}001^{b}$	$0{\cdot}300 \pm 0{\cdot}002^{c}$	$0{\cdot}286 \pm 0{\cdot}002^{d}$	$0{\cdot}281 \pm 0{\cdot}002^{d}$	$0{\cdot}268 \pm 0{\cdot}002^{e}$
Total protein g/100 ml	$6{\cdot}90 \pm 0{\cdot}03^{b}$	$6{\cdot}98 \pm 0{\cdot}07^{b}$	$6{\cdot}92 \pm 0{\cdot}07^{b}$	$7{\cdot}02 \pm 0{\cdot}11^{b}$	$6{\cdot}77 \pm 0{\cdot}11^{b}$
Albumin g/100 ml	$3{\cdot}72 \pm 0{\cdot}01^{b}$	$3{\cdot}65 \pm 0{\cdot}07^{bc}$	$3{\cdot}59 \pm 0{\cdot}04^{c}$	$3{\cdot}65 \pm 0{\cdot}07^{bc}$	$3{\cdot}42 \pm 0{\cdot}06^{d}$
Albumin/Globulins	$1{\cdot}19 \pm 0{\cdot}01^{b}$	$1{\cdot}15 \pm 0{\cdot}02^{bc}$	$1{\cdot}11 \pm 0{\cdot}03^{cd}$	$1{\cdot}09 \pm 0{\cdot}02^{d}$	$1{\cdot}05 \pm 0{\cdot}03^{d}$
Prealbumin mg/100 ml	$13{\cdot}2 \pm 0{\cdot}3^{b}$	$12{\cdot}5 \pm 0{\cdot}3^{bc}$	$11{\cdot}8 \pm 0{\cdot}4^{cd}$	$11{\cdot}5 \pm 0{\cdot}5^{cd}$	$11{\cdot}3 \pm 0{\cdot}5^{d}$
Transferrin mg/100 ml	$302{\cdot}4 \pm 2{\cdot}8^{b}$	$286{\cdot}5 \pm 5{\cdot}7^{c}$	$285{\cdot}8 \pm 8{\cdot}8^{c}$	$284{\cdot}5 \pm 8{\cdot}8^{c}$	$256{\cdot}4 \pm 8{\cdot}9^{d}$
Complement C3 mg/100 ml	$86{\cdot}9 \pm 0{\cdot}8^{b}$	$85{\cdot}6 \pm 1{\cdot}7^{bc}$	$81{\cdot}7 \pm 1{\cdot}7^{cd}$	$78{\cdot}8 \pm 2{\cdot}2^{d}$	$79{\cdot}4 \pm 2{\cdot}8^{d}$
Hydroxyproline index	$3{\cdot}4 \pm 0{\cdot}1^{b}$	$3{\cdot}2 \pm 0{\cdot}1^{c}$	$2{\cdot}7 \pm 0{\cdot}1^{d}$	$2{\cdot}4 \pm 0{\cdot}1^{e}$	$2{\cdot}5 \pm 0{\cdot}2^{de}$

(a) values given mean ± s.e.m.
(b, c, d, e, f) values in the same horizontal line with no common superscripts are significantly different from one another ($P < 0{\cdot}05$).

protein on strips of acetate cellulose stained with Ponceau red; prealbumin, transferrin and the third component of complement by radial immunodiffusion on plates and with "Behringwerke" control serum; urine hydroxyproline index as described by WHITEHEAD (1967). Comparisons of means were performed with Student's 't' test. Significance is given for $P < 0{\cdot}05$.

Results

Table I includes all the biochemical results from children classified according to the various anthropometric tests.

Classification according to weight for age: only the albumin/globulins ratio and the hydroxyproline index show a significant decrease for the group having a weight less than 90% expected. The decreases observed in the group less than 70% could not be statistically interpreted because of the small number of individuals.

Classification according to weight for height: a significant decrease is observed for albumin/globulins ratio, transferrin and hydroxyproline index, beginning with the 90% threshold. The number of individuals below 80% is too small to enable us to reach any conclusion about the significance of the decreases.

Classification according to arm circumference for age: all the parameters assayed except total protein have mean values which are significantly reduced in the group of children whose arm circumference is lower than 85% expected.

Classification according to the ratio of arm/head circumferences: the albumin/globulins ratio, prealbumin, complement C3, and hydroxyproline index all have mean values which are signficantly lower in the group below 0·310. The other variables decrease below 0·290.

Table II indicates the means values of the anthropometric and biochemical parameters of the children classified according to the number of anthropometric criteria lower than the thresholds chosen. Group 0 may thus be considered a group of control children. The only significant differences observed between Groups 0 and 1 involve transferrin and hydroxyproline index. With the exception of total protein, all the biochemical parameters of Groups 2, 3 and 4 have values which are significantly different from those of Group 0. The decrease appears to be continuous from Group 0 to Group 4 for most of the variables.

Discussion

The first result of our study is to show that there is a decrease of the mean level of several serum and urine variables in those groups of children exhibiting moderate weight and arm deficiencies. It should be noted that the significant decreases of the biochemical parameters most often agree well with the thresholds determined by agreement calculations. Thus, at the threshold of 85% for arm circumference for age and 0·290 for the ratio of arm/head circumference, all the biochemical variables except total protein have mean values which are significantly depressed. The lower sensitivity of total proteins may be explained by an increase of gamma-globulins which compensates the decrease of the other protein fractions. The weight thresholds seem to be less satisfactorily verified since only some parameters (transferrin, albumin/globulins and hydroxyproline index) exhibit decreased values beneath these thresholds. In our population, the weight criteria, which incidentally are often taken as a reference, thus seem less sensitive than the arm tests for defining states of moderate malnutrition. This does not, however, mean that they should be abandoned, since in certain cases they are capable of detecting undernourished children who would otherwise be classified as "well to do healthy" by arm tests only.

The second finding of our study is to show the importance of employing several tests for estimating a prevalence of malnutrition in a population, as well as for detecting individual cases. Concerning the estimation of a prevalence, the numbers of children for each class (Table I) show that, for the thresholds chosen and in spite of the maximum level of agreement, the percentages of children classified as undernourished are somewhat different as a function of the criterion: 18% for weight for age, 21% for weight for height and 25% for the arm tests. Concerning screening for malnutrition cases, examination of the individual data shows that children classified as undernourished by one test are not always so by another, For moderate deficiencies the maximum levels of agreement vary between 75% (weight for age and ratio of arm/head circumference) and 90% (arm circumference for age and ratio of arm/head circumferences). Thus, up to 25% of the children can be classified differently by two tests. We offer here a confirmation of previous researches (Jeannee *et al.*, 1976; Vijayaraghavan & Gowrinath Sastri, 1976) which showed that the various anthropometric tests are not necessarily interchangeable. For this reason we propose more fully to define the state of protein-energy malnutrition in children by simultaneously utilizing four criteria (Table II). Thus, 482 and 53 children from the 810 are classed as "well to do healthy" and undernourished respectively by all four criteria. The mean values of all the biochemical parameters, except the total protein, are significantly lower in Groups 2, 3 and 4 than in Group 0. It appears that Group 2 may be considered as the stage at which malnutrition is really effective in spite of the moderation of anthropometric deficiencies observed. Group 1, on the other hand (children presenting only one deficient criterion), has only two parameters, transferrin and hydroxyproline index, whose mean values are lower than those of Group 0. Group 1 could be considered a group of children at the limit of malnutrition and who should be monitored.

Our system, based only on anthropometric measurements, seems satisfactory for evaluating the prevalence of malnutrition. To the extent that the children of Group 1 may be considered as suffering from mild malnutrition, prevalence is 40% in our sample of population. If indications concerning the degree of malnutrition are desired, all that is necessary is to consult the real values of the deficiencies of each test. If the nutritional state at the level of the individual is to be established with precision, several biochemical assays should be included whenever possible. The importance of inter-individual variations of the biochemical values in a group of children leads us to recommend a diagnosis based on several parameters. The hydroxyproline index, which is very sensitive and which requires only a urine sample, appears to us to be a highly valuable diagnostic tool. However, recent work by Wenlock (1977) has shown that malaria could depress this index. This fact must be taken into account when considering the significance of the index in malarial areas. Prealbumin and transferrin, assayed with 5 ml of serum (blood taken by a simple finger puncture), have a great interest. For the population studied, transferrin seems to be a more sensitive indicator than prealbumin. They indicate together an alteration of the liver function which leads to depressed synthesis. It should be also recalled that transferrin concentrations are modified in cases of severe anaemia (Ingenbleek *et al.*, 1975).

Finally we would insist on the fact that our study has been carried out in Southern Cameroon where the staple is plantain, cassava and other tubers. On this type of diet biochemical abnormalities leading to the kwashiorkor type of protein-energy malnutrition are quite likely. This could probably account for such a good agreement between the anthropometry and the biochemistry, even for moderate deficiencies. We are now attempting to assess the effect of moderate protein-energy malnutrition on biochemical variables in Northern Cameroon where the staple is sorghum.

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