Classification of Malnutrition According to Fat Content of Body of Children Measured by Bioelectric Impedance Analyser

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Introduction

Protein Energy Malnutrition (PEM) of children has been classified for long by considering age and anthropometric measurements. The purpose of classifying PEM into various degrees of severity was to find out the priorities for intervention and management of malnutrition. One of the most widely accepted classification has been the Gomez's classification[1] of PEM which describes children as suffering from different degrees of malnutrion according to weight for age.

Most commonly used age dependent and age independent indices[2] developed by anthropometric measurements to assess the severity of malnutrition of Children at community level are, Wt/Ht, Wt/Ht^2 (BMI), chest circumference, skinfold thickness, Quack-Stick test, MAC, MAC/HC, thigh circumference etc. These measurements have been widely tested and used. Standard anthropometric measurements have utility values to the extent that most children suffering from PEM can be identified, nevertheless, there also occurs gross errors[2] following such methods. Different studies showed that faults remained[3,4,5,6,7,8,9] in most of the approaches, since such measurements can not reach high scientific precissions due to lack of proper standardisation, interobserver errors and failure to determine actual age due to lack of education and maintenance of proper birth records.

For the purpose of advancing our knowledge of assessment of malnutrition, newer techniques have been developed. One of the recent methods of noninvasive assessment of nutritional status is the Total Body Electric Conductivity (TOBEC)[10,11,12]. In this method, the whole body of an adult, child or an infant is

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accomodated in a large selenoidal coil. The change in. electrical conductivity when the body is inside the device or when it is empty is proportional to the Lean Body Mass (LBM). The TOBEC method uses a large device which can be used only at the institutional levels.

The same principle of total body electrical conductivity is utilised with a small portable instrument, the Bioelectric Impedance Analyser[13] which can be used at field level to assess nutritional status of children and adults. With the found resistance of electrical conductivity, the Total Body Water (TBW) can be calculated from which Fat Free Body Mass (FFM), Fat Mass (FM) and prercentage of Fat Mass (%FM) of the body can be calculated by age specific linear regression equations[14].

Analysing the percentage of FM of the body, it was hypothesised that the results will set new standard of reference to classify malnutrition according to the fat content of the malnourished child.

Methodology

Initially 68 children of 13-24 months of age were studied by the BIA[13] and the %FM were found to be12.%, 20.4%. 22.6% and 24.1% for 3rd, 2nd, 1st degrees of malnutrition and normal children respectively. Expanding the study further from 8 months to 60 months, similar results were obtained confirming that %FM of children at different degrees of malnutrition and that of normal children tends to remain constant within a certain limit. Different degrees of malnutrition in this study, as discussed earlier, were classified according to principles laid by Gomez and the NCHS[15] standard was used for reference of weight.

A Bioelectric Impedance Analyser of model 101 was used to measure the electric impedance of the body of children. Children were either in empty stomach or allowed only a very light meal at least two hours before taking the impedance reading. Before taking the reading, it was ensured that their bladders were empty. Children were placed in supine position, the upper limbs kept in extended positions away from body contact and lower limbs also in extended positions away from body contact placed slightly apart from each other. The battery of the BIA was either charged overnight or was used with direct electric connection. Two electrodes were placed on the right hand, fixed with disposable electrodes, the red electrode cutting the mid points of the radial and ulnar tuberosities and the black one just behind the middle finger, adjacent to the metatarso-phalangeal joints. Similarly two electrodes were placed on the right foot, the red electrode cutting the midpoints of the medial and lateral malleoli at the distal ends of the tibia and fibula and the black one being placed just behind the middle toe adjacent to the metatarso-phalangeal joints. An electric impulse of 800 MA at 50 kHz[16] was then passed through the body of the child and reading of resistance (electric impedance) was recorded. A reading of reactance was also recorded. But for practical purposes, the results of the electric impedance only were used for analysing body fat.

Age of child was carefully recorded, and in case of illitarate parents, an events calender was used to determine age. Doubtful cases in which age could not be assertained properly were excluded from the study.

Weight of young children were taken by a hanging clock type salter scale with 50 grams graduation and for older children, a spring type foot scale with 100 grams graduation was used. Length and height of infants and children were measured with infantometers and stadiometers nearest to an error of one millimeter.

A linear regression equation[14] was then used to calculate the Total Body Water (TBW). Fat free Body mass (FFM) or Lean Body Mass (LBM) was then calculated using age specific formulas and age specific constants of body density. Then Fat Mass (FM) and percentage of Fat Mass (%FM) were calculated usuing standard formulas.

The 68 children studied from 13-24 months of age were then classified according to their weight for age in different degrees of malnutritions[1] and normal children[1]. The TBW, FFM, FM and %FM were then charted against different groups of malnutrition of children and children with normal weight.

The study was expanded further later following similar procedures to measure TBW, FFM, FM and %FM in children from 8-60 months of age, the total number of children studied being 206.

However, this paper will give only the detailed results of 68 children of 13 - 24 months of age and only the %FM of other groups of children from 8 - 60 months will be discussed to show the similarity of the results

The linear regression equations[14] used in this paper was first used to measure TBW in children suffering from malnutrition in Peru for children aged 3 - 36 monhts. We have used the same formula, considering that we were also studying children suffering from malnutrion. However, we used the results of TBW found to calculate the FFM, FM and %FM also which was a further improvement over the Peru study. It should be taken into note here that the Peru study was validated[14] for calculation of TBW of children suffering from malnutrition by O^{18} dilution technique of calculating TBW and both the results were highly comparable.

Results

Sixty-eight children of 13-24 months of age were studied by Bioelectic Impedance Analyser and the quantitative measures of TBW, FFM, %FM and FM were calculated by methods which have been elaborated above.

Table 1 shows the no. of children studied at 13 - 24 months age group. Table 2 shows the percentage of FM at different degrees of malnutrition. Two standard errors were calculated (2SE) to find out the 95% confidence limits of %FM in different degrees of malnutrition in general population of children of 13 - 24 months of age group. The 95% confidence limits of %FM of children have also been outlined in Table2.

Table 1. No. of children and their status of nutrtion (13 - 24 Months)

3rd Degree Malnutrition	2nd Degree Malnutrition	1st Degree Malnutrition	Normal Weight	Total No. of Children
18	17	23	10	68

Table 2. %FM of child population (13 - 24 Months)

Status of Nutrition	No. of Children	%FM	95% Confidence Limit
3rd Degree Malnutrition	18	12.2	10.3 - 14.3
2nd Degree Malnutrition	17	20.4	17.6 - 20.8
1st Degree Malnutrition	23	22.4	22.0 - 23.2
Normal Children	10	24.1	23.5 - 25.1

Table 3. Comparison of Mean %FM of Children (8- 60 Months)

Status of Nutrition	Percentage of Fat Mass				
	8-12 Months	13-24 Months	25 - 36 Months	37 - 48 Months	49 - 60 Months
3rd Degree Malnutrition	14.3	12.2	12.4	11.7	14.1
2nd Degree Malnutrition	19.3	20.4	20.5	19.8	20.8
1st Degree Malnutrition	21.3	22.6	22.7	22.5	22.7
Normal Children	24.2	24.1	24.0	24.1	25.7

Table 4. Means and Range of Means of %FM in Different Degrees of Nutritional Status of Children (8- 60 Months)

Status of Nutrition	Means of %FM	Range of Means of %FM
3rd Degree Malnutrition	13.0	12.2 - 14.3
2nd Degree Malnutrition	20.1	19.3 - 20.8
1st Degree Malnutrition	22.5	21.3 - 22.7
Normal Children	24.6	24.0 - 25.7

Table 5. Mean %FM of children in relation to nutritional status (8 - 60 months)

Means of %FM	Nutritional Status of children
%FM ≤ 13%	3rd Degree Malnutrition
%FM ≤ 20%	2nd Degree Malnutrition
%FM ≤ 22.5%	1st Degree Malnutrition
%FM > 22.5%	Child with Normal Nutrition

As was discussed earlier, this study was further extended from 8 months to 60 months to compare the %FM in children suffering from diffrent degrees of malnutrition at different age groups. The following table gives the comparison of %FM of children 8-60 months. Besides 68 children of 13 - 24 months of age, 31 children were of 8-12 months, 34 of 25 - 36 months, 27 of 37 - 48 months and 46 of 49-60 months of age groups, the total no. of children studied being 206.

Table 3 shows very close similarity of mean %FM in different degrees of malnutrition of different age groups of children from 8 - 60 month Table no 4 shows the range and means of %FM in different degrees of malnutrition in children studied in all age groups from 8 - 60 months.

A curve line drawn for the weight and %FM (Fig. 1) shows a upward slope which helps to understand that %FM increases directly in proportion to weight of the body of children, in other words proving that more severe the status of malnutrition, less is the %FM of the body. The four dots put at 1,2,3, and 4 along the curve line represents the mean %FM for mean weight of 3rd, 2nd, 1st degree malnutritions and normal weight, classified in accordance to Gomez classification in children aged 13 - 24 months, the corresponding sample sizes being 18,17, 23 and 10.

The results show a very close similarity of %FM in different degrees of nutritional status in different groups of children from 8 - 60 months. The results rightly prove that our hypothesis was correct, the interpretations of which can be understood by follwing Table 5.

Perhaps we can infer by saying that it is possible to classify malnutrition by calculating the predictive values of constants of %FM in different degrees of malnutrition, the constants being the means of %FM (8 - 60 months) as shown in Table 5.

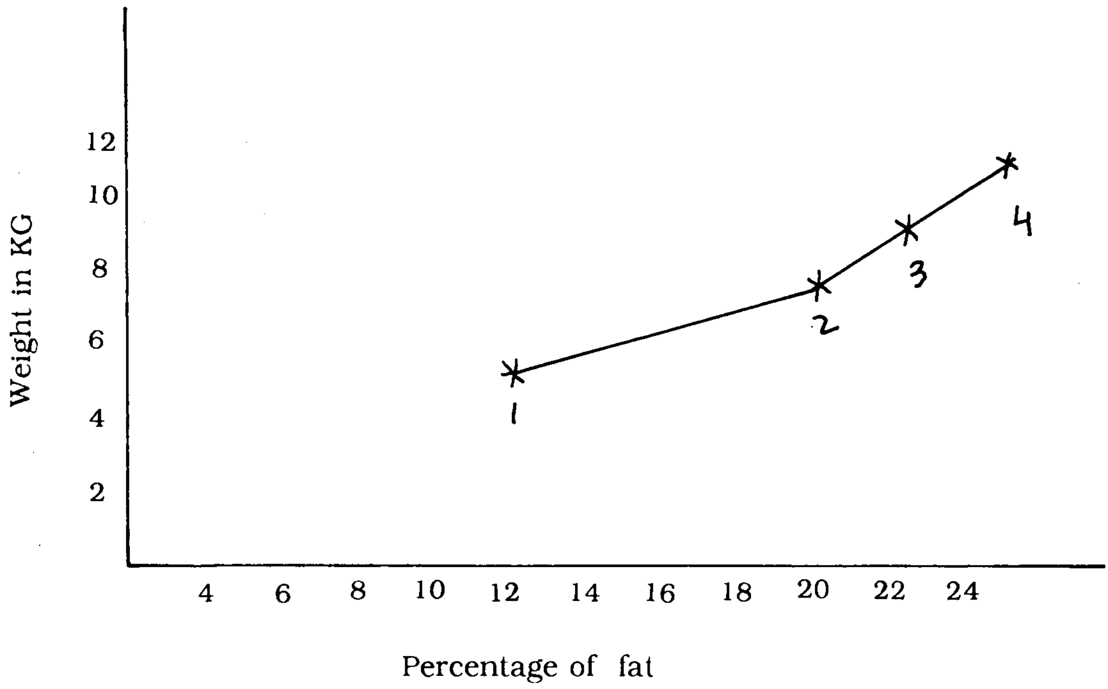

FIGURE-1

Discussion

To elaborate about the draw backs of the anthropometric indices based on anthropometric measurements for assessing PEM, it may be said that Gumeri et al[3] criticised the Gomez classification itself., since the cut-off points of weight in this classification were determined arbitrarily and had little physiological basis.

Rao et al[4] commented that Wt/Ht^2 (BMI) was a better index to assess malnutrition of long duration than that of Wt/Age only at the community level.

Anderson et al[5] in a comparative study of weight, height and arm circumference on 7304 children observed that the WHO set limit of 80% Wt/Ht excluded too many children with 3rd degree malnutrition.

Ramcharan et al[6] showed that Shakir strip measuring MAC gave 21.6% false positive and 31.0% false negative results.

Since the Quack-Stick method[7] is dependent on MAC which gives many false positive and false negative results, the reliability of Quack-Stick test needs further validation.

Comparing AC/HC and MAC with Wt/Age upto 60 months in 168 children, Agarwal et al[8] showed that while malnutrition was present in 86.9% of Children by Wt/Age measures, the same were 77.3% specific for AC/HC and 68.2% specific for MAC only.

Speaking about the skinfold thickness measurements to assess malnutrition, one study[9] comparing Lange and McGraw skinfold calipers showed that the median differences of value was 8% greater ($P < 0.01$) with Lange calipper and 5th, 50th and 95th percentile values of skinfolds were $11\frac{1}{2}$% 23% and 25% greater for the same. Values of skinfold thickness may be again sex and site specific.

It was thought that such errors could be avoided by using newer techniques for assessing nutritional status of children e.g. by the BIA[12,14,16]. Thinking of classifying malnutrition based on the %FM in the body of children was hypothetical, but logical in the sense that store of fat in the boby becomes used up first to maintain energy level and metabolic needs of the body when a child starts suffering from energy deficiency, It was, therefore, thought that the quantity and percentages of fat will be proportional to the exhaustion of fat store (see figure

1) in different degrees of malnutrition. The most severely affected child will have the least amount of fat store and so on.

The simplest method of measuring fat was thus utelised and the BIA readings of electrical impedance helped us to calculate the TBW, FFM, FM, and %FM in the body of the children suffering from different degrees of malnutrition. Since the method is painless and non-invasive, it was easy to convince the children to lie down quitely and a reading of BIA could be taken easily.

The findings, as discussed in the results were in conformity of the hypothesis.

The advantages of classifying malnutrition by BIA reading and calculating %FM by age specific linear regression equations for children and formulas based on age and sex specific constants of body density are manifold described as follows:

(1) It helps to avoid errors of arbitrary methods of anthropometric measurements for classifying malnutrition which have been discussed

(2) The BIA method is simple and non-invasive.

(3) The BIA equipment is small and portable, can be easily used at the community level, and it is cost effective.

(4) The results obtained are of high scientific precission.

We can conclude by saying that the concept of classifying malnutrition according to the %FM in the body of children is new and this study is the first of its kind which utilises the concept of electrical impedance for measuring the different compartments of the body.

Summary

Sixty eight children aged 13 to 24 months with defferent degrees of malnutrition including some children with normal weight, classified according to Gomez's classification, were studied. The weight references taken were that of NCHS standard. The body fat content of these children were measured by a Bioelectric Impedance Analyser using a standard regression equation. It was found that the mean percentages of body fat were 12.2%, 20.4% 22.6% and 24.1% for 3rd, 2nd, 1st degrees of malnutrition and normal children respectively. Expanding the study further, similar results were

obtained in children from 8 to 60 months of age.Conclusion was drawn from the obtained results that corresponding mean values of %FM for 3rd, 2nd, 1st degrees of malnutrition and children with normal nutrition, according to Gomez classification were 13%, 20%, 22.5% and 25%.

It was inferred that the malnutriton of children could be classified by measuring fat content of the body of children by a simple non-invasive technique using an instrument known as Bioelectric Impedance Analyser (BIA).

References

1. Gupte S. The short Text Book of Pediatrics, Joypee Brothers, Medical Publishers, New Delhi, India 1983, p99.
2. Bai KI, Sabbiha DV and Rao SK. Assessment of nutritional status of preshool children : a comparison of methods. J Trop pediatr, Oct 77;23(5): 224-5.
3. Gumeri M and Jutsum P. The Gomez classification. Time for a change? Bull WHO 1980, 50(5):773 - 77.
4. Raj KV. Radhaiah G, Raju SVS and Swaminath MC. Relative importance of various anthropometric measurements and indices for evaluation of nutritional. status. Indian Pediatr 1981 Apr; 18 (4) : 223 - 31.
5. Anderson MA. Comparison of anthropometric measures of nutritional status of preschool children in five developing coutries. 1979 Nov; 32(11): 2339 - 45.
6. Ramchandran K, Parmar BS, Jain Jk, Tandon BN and Gandhi PC. Limitations of film strip and Bangle test for idntification of malnourished children. The Am J Clin Nutr. 1978 Aug; 31(8): 1469 - 72.
7. Prasad R, Mathur PP, Prasad J, Sharma M and Dayal RS. 'Quack-Stick' in assessment of nutritional status of pre-school children. J Trop Pediatr 1982 Aug: 28(4):199-201.
8. Agarwal CM, Gupta SD, Jain JP and Joshi S. Age independint indices of malnutrition. Indian Pediatr 1980 Aug: 17(8):683-7.
9. Burgert SL, Anderson CM. A comparison of triceps skin fold values measured by the plastic McGraw calipper and Lange calipper. Am J Clin Nutr. 1979 July: 22(7):1531-33.
10. Preata et al. Comparison in mean total body electrical conductivity and lean body mass derived from body density; validation of a new body composition method. Metabolism 1983 May; 32(5):534-7.
11. Khaled MA, J Canlas BS, McCutcheon MJ and Mestre JR. Electrical impedence in assessing human body composition : the

TOBEC method. Am J Clin Nutr (Submitted).

12. Cochran WJ, Klish WJ, Wong WW and Klein PD. Total body electrical conductivity used to determine body compostion in infants. Pediatr Res 1986 Jun: 20(6): 561-4.

13. Khaled MA. McCutcheon MJ, Reddy S, Pearman PL, Hunter GR and Weinsier R. Electrical impedance in assessing human body composition: the BIA method. Am J Clin Nutr 1988; 47:789-92.

14. Fjeld CR, Freundt-Thurne J and Shoeller DA. Total body water measured by ^{18}O dilution and bioelectrec impedance in well and malnourished children. Pedatr Res 1990 ; 27(1):98-102.

15. Growth Charts, National Centre for Health Statistics (NCHS). Rockville, USA, 1976.

16. Lukasaki HC, Johnson PE, Bolonchuk WW and Lykken GI. Assessment of fat-free mass using biolotrioal impedence measurements of the human body. Am J Clin Nutr 1985 April; 41, 810-17.