THE USE OF MID–ARM CIRCUMFERENCE FOR SCREENING MALNUTRITION IN PRESCHOOL CHILDREN

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SUMMARY

Correlation analysis of mid-arm circumference (MAC), weight-for-age and weight-for-height obtained from 807 Malay preschool children aged 12-71 months show that MAC had a relatively low correlation with weight-for-age ($r = 0.59$, $p < 0.001$) and weight-for-height ($r = 0.63$, $p < 0.001$). MAC percentiles and sensitivity-specificity analysis indicate that when weight-for-age and weight-for-height were used separately to define 'true' malnutrition, MAC was not sensitive enough to detect Malaysian children with only mild to moderate protein-energy malnutrition (PEM). The value of MAC as a screening measure in malnutrition is only limited to identifying the more severe forms of PEM in young children and the present study indicates that a MAC of 13.0-13.7 cm may be used for identifying moderate to severe PEM and under 13.0 cm for severe PEM.

INTRODUCTION

The mid-arm circumference represents a summation of the bone, muscle and fat components of the arm and depletion of the latter two components in PEM, particularly of the marasmic type, can lead to a marked reduction in the indicator.[1]

When compared to the increase in the first 12 months after birth, MAC may be regarded as relatively constant from 12-71 months of age for it only changes by 1.5 cm. This has prompted the introduction of selected MAC values for simple and immediate classification of PEM in field surveys as in the case of the three-colour cord of Shakir and Morley,[2] and the use of a constant MAC standard in communities where the precise age of young children is not known.[3]

The use of MAC for screening malnutrition in young children has been extensively reviewed[4] and its ability to identify children who are considered malnourished by more accepted criteria such as weight-for-age and weight-for-height was evaluated in several countries by different workers.[5,6] Simple MAC was found to be highly associated with weight-for-age and weight-for-height, and that the measurement is more sensitive in detecting severe, rather than mild to moderate, malnutrition and acute, rather than chronic, PEM.[3,7] In areas where the true ages of young children cannot be verified, MAC without age correction can be used with little loss of sensitivity or specificity to identify children with low weight-for-age and low weight-for-height.[5] However, MAC was found to be unsuitable for measuring recent changes in nutritional status as occuring in short-term rehabilitation projects.[8]

In spite of numerous reports of the experience with the use of MAC in lesser-developed nations in the 1970s, there has been no in-depth study of the use of MAC on Malaysian preschool children other than the report of McKay.[9] Currently in Malaysia,

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MAC measurements are expressed as a percentage of the Wolanski standard, a value below 85% of standard is taken to indicate the existence of malnutrition. This complicates the use of the indicator making it difficult for auxillary health workers to comprehend despite the ease of taking the measurement itself. Thus at the village level in Malaysia, the use of MAC is either little understood or unknown when compared to the use of growth charts based on weight measurememts.

This study evaluates the suitability of the MAC measurement as a screening test for identifying Malaysian preschool children who are considered malnourished by the criteria of weight-for-age and weight-for-height, and attempts to establish an appropriate MAC 'cut-off' for the rapid detection of PEM in the field.

MATERIALS AND METHODS

Subjects from field studies

Anthropometric data of 807 Malay preschool children, aged 12 to 71 months, obtained from 37 rural villages in four states of Peninsular Malaysia were used in this study. The children were measured in four separate nutrition surveys conducted by the Institute for Medical Research, Kuala Lumpur in the poverty villages of Bukit Payong in Trengganu, Padang Endau in Johore, Baling in Kedah and Perak Tengah, Perak from 1972-1983.

Subjects admitted to hospital for severe PEM

These subjects comprised 26 children under six years who were predominantly of the Indian ethnic group and were diagnosed as severe PEM cases based on their weight-for-age achievements and clinical findings in the Pediatrics Department of the General Hospital, Kuala Lumpur. Their MAC measurements were considered separately from those obtained in the nutrition surveys.

Anthropometric measurements

MAC was taken at the mid-point of the left upper arm between the acromion and olecranon with a fibre-glass tape. The mid-point was initially located by careful measurement and later, visually, which has been reported to be quicker and just as reliable.[4] All MAC measurements in the Johore, Kedah and Perak surveys, and in the Pediatric Wards were made by the author and recorded to the nearest 0.1 cm.

Weights and heights were measured with a Seca weighing scale with a height attachment to the nearest 0.1 kg and 0.1 cm, respectively. The accuracy of the weighing scale and height attachment were checked periodically during the surveys. All footwear was removed before the measurements and a small correction was made for the children's clothing. An infantometer was used to measure the length of children who were too young to stand properly.

Treatment of data

Weight-for-age and weight-for-height achievements were determined using the National Centre for Health Statistics-Centre for Disease Control (NCHS-CDC) reference population.[10] The reference MAC values are those of Wolanski, smoothened by Burgess and Burgess.[11]

The subjects from the field studies were separated into different nutritional categories based on their degree of 'underweight' and 'wasting', and the MAC percentiles in these groups were examined separately for weight-for-age and weight-for-height:

Wt/age equal or above median–2SD: **normal to mild PEM**
Wt/age between median–2SD and median–3SD: **moderate PEM**
Wt/age below median–3SD: **severe PEM**
Wt/ht equal or above median–2SD: **normal to mild wasting**
Wt/ht below median–2SD: **moderate severe wasting**

Correlation analyses were performed for age, MAC, MAC-for-age, weight-for-age and weight-for-height in order to study the relationships between these measures. Sensitivity and specificity results of the MAC measurements were calculated using weight-for-age below median – 2SD and below median – 3SD, and weight-for-height below median – 2SD to define 'true' malnutrition.

RESULTS AND DISCUSSION

Correlation analysis

The linear correlations among age, MAC, MAC-for-age, weight-for-age and weight-for-height are shown in Table I. MAC was highly correlated with MAC-for-age ($r = 0.95$, $p < 0.001$) and both measures have closely similar correlations with weight-for-age and weight-for-height, indicating that MAC may be used in place of MAC-for-age for identifying malnutrition in the present study.

The correlation of MAC with weight-for-age ($r = 0.59$) and weight-for-height ($r = 0.63$) were relatively low although they fall within the range of 0.47 to 0.78 obtained by other workers.[6]

MAC was not constant but rather age-dependent in the higher age group used in this study as indicated by the significant correlation between age and MAC ($r = 0.34$, $p < 0.001$), and as clearly demonstrated in Table II where the subjects were divided into different age groups. This would mean that subjects with the same weight-for-age achievements (% standard) may have different MAC depending on their ages. The mean MAC in the various age groups are indicated in Table II, the difference between the youngest and oldest group being 1.0 cm.

TABLE I
CORRELATION MATRIX OF AGE, MAC, MAC–FOR–AGE, WEIGHT–FOR–AGE AND WEIGHT–FOR–HEIGHT (N = 807)

	Age	MAC	MAC/age	Wt/age	Wt/ht
Age	1.00				
MAC	0.34	1.00			
MAC/age	0.05*	0.95	1.00		
Wt/age	-0.12	0.59	0.66	1.00	
Wt/height	-0.02*	0.63	0.67	0.70	1.00

*Not significant ($p > 0.05$).
All other values of 'r' significant ($p < 0.001$).

MAC percentiles

Table III indicates the distribution of MAC measurements in the different nutritional categories. When weight-for-age was used as the criteria for 'true' malnutrition, there was considerable overlap of MAC values in the normal to mild PEM and the moderate PEM groups, and in the moderate and severe PEM groups. This can be expected from the relatively low correlation between weight-for-age and MAC obtained for the subjects.

More than half of the moderate PEM subjects had MAC measurements that fall above the 10th percentile (13.8 cm) in the normal to mild PEM group, while the MAC median of the moderate PEM

TABLE II
MEAN MAC ACHIEVEMENTS AND CORRELATION OF MAC WITH WEIGHT–FOR–AGE AND WEIGHT–FOR–HEIGHT IN DIFFERENT AGE GROUPS

Age group, months (sexes combined)	n	MAC, mean & SD (cm)	Correlation coefficient	
			Wt/age *vs* MAC	Wt/ht *vs* MAC
12 - 23	175	13.93 ± 1.15	0.71	0.68
24 - 35	138	14.35 ± 0.98	0.63	0.67
36 - 47	171	14.51 ± 1.05	0.59	0.67
48 - 59	187	14.83 ± 1.18	0.66	0.70
60 - 71	136	14.97 ± 1.06	0.64	0.65
All Subjects	807	14.51 ± 1.15	0.59	0.63

TABLE III
DISTRIBUTION OF MAC MEASUREMENTS IN CHILDREN OF DIFFERENT NUTRITIONAL CATEGORIES (THE HOSPITAL GROUP WITH SEVERE PEM IS INCLUDED FOR COMPARISON)

Nutritional category	n	Observed percentiles		
		10th (cm)	50th (cm)	90th (cm)
Weight-for-age:				
a. Normal to mild PEM (Equal or above median – 2SD)	445	13.8	15.0	16.4
b. Moderate PEM (Between median – 2SD and median – 3SD)	300	13.0	14.0	15.2
c. Severe PEM (Below median – 3SD)	62	11.7	13.3	14.0
Weight-for-height:				
a. Normal to borderline wasting (Equal or above median – 2SD)	724	13.4	14.5	16.0
b. Moderate – severe wasting (Below median – 2SD)	83	12.2	13.5	14.5
Hospital group with severe PEM	26	9.6	11.5	12.9

group equals the 90th percentile in the severe PEM category. Thus it is clear that it would not be possible to use a MAC cut-off to separate moderately malnourished children from those who were normal to mildly malnourished, or severely malnourished children from those who were only moderately malnourished in this study without including a significant proportion of 'false positives'.

It can be seen in Table III that the 90th MAC percentile (14.0 cm) in the severe PEM subjects approximates the 10th percentile in the normal to mild PEM group. Thus it is feasible here to use a cut-off of 13.9 cm to screen children suffering from moderate to severe PEM, a cut-off level which selected 10% of the normal-mild PEM children as false positives. This differs from the MAC of 12.5 - 14.0 cm used by Shakir to identify children with mild-moderate malnutrition or borderline PEM.[3]

It is interesting to note that about 90% of the hospital cases with severe PEM possessed MAC measurements under 13.0 cm, a level which coincides with the 10th percentile in the moderate PEM group. Of the total 807 children, 5.6% or 45 cases would be identified as severely malnourished by the cut-off of < 13.0 cm and only 4% of these MAC positives were from the normal-mild PEM group. This cut-off level for severe PEM is much higher than the < 12.5 cm recommended by Shakir for identifying a similar nutritional category of children.[3]

When weight-for-height was used as the criteria for true malnutrition, there was also a considerable overlap of MAC values in the normal to borderline wasting and moderate-severe wasting groups despite the slightly better correlation coefficient ($r = 0.63$) obtained for weight-for-height and MAC than for weight-for-age and MAC. In this case, the 10th percentile (13.4 cm) in the normal to borderline wasting group is close to the median (13.5 cm) in the group with moderate-severe wasting, making it difficult to use MAC for distinguishing moderate from mild wasting in this study. However, if MAC measurements below the 10th percentile i.e. below 12.2 cm of the moderate-severe wasting group is

TABLE IV
SENSITIVITY AND SPECIFICITY OF MAC MEASUREMENTS IN IDENTIFYING CHILDREN WITH LOW WEIGHT–FOR–AGE

MAC (cm)	Prevalence (%)	Defination of true malnutrition					
		Wt/age below median – 2SD			Wt/age below median – 3SD		
		Sensitivity	Specificity	Positive Predictive value	Sensitivity	Specificity	Positive Predictive value
< 12.5	2.7	6.1	100.0	100.0	22.6	98.9	63.6
< 13.0	5.6	11.9	99.6	95.6	33.9	96.8	46.7
< 13.5	15.4	29.8	96.0	85.7	54.8	87.7	27.0
< 14.0	30.6	53.6	88.3	78.9	88.7	74.2	22.3
< 14.5	48.6	71.8	70.3	66.3	96.8	25.4	15.3

arbitrarily taken to indicate severe acute malnutrition, only 0.5% of subjects who were not severely malnourished based on the weight-for-age criteria would be included.

Sensitivity and specificity analysis

Table IV shows the prevalence, sensitivity, specificity and positive predictive value for selected MAC cut-off values when using alternately, weight-for-age below median – 2SD and weight-for-age below median – 3SD of the NCHS-CDC reference to arbitrarily define 'true 'malnutrition.

As generally expected in sensitivity-specificity analysis, the use of a higher MAC cut-off level resulted in increased sensitivity at the expense of decreased specificity and decreased positive predictive value.[5] In order to obtain the most sensitive measure without sacrificing too much specificity using the more severe definition of malnutrition (wt/age below median – 3SD), a MAC cut-off between 13.5 and 14.0 cm i.e. 13.8 cm was apparently suitable for identifying children with severe PEM. This cut-off is much higher than that used by other workers for the same purpose.[2,3] However it must be noted that the weight-for-age cut-off of < median– 3SD used in this study is a less severe definition of severe PEM than the <60% Harvard Standard used by others in the past. Besides, the severely malnourished children identified by a MAC of < 13.8 cm in this study comprised a large proportion of false positives as indicated by the low positive predictive values in Table IV. Most of these false positives were actually moderately malnourished children as clearly indicated in Table V.

Weight-for-age has important limitations when used to define 'true' malnutrition since it does not distinguish acute from chronic malnutrition.[11] For the present children, only 15% of the 300 classified as moderate PEM cases based on weight-for-age could be considered to be suffering from acute malnutrition when based on weight-for-height achievements below median – 2SD. For children who had weight-for-age achievements below median – 3SD (severe PEM), the proportion with acute malnutrition or wasting was 48%.

TABLE V
PROPORTION OF MODERATELY MALNOURISHED CASES IN CHILDREN IDENTIFIED AS SEVERELY MALNOURISHED BY MAC BUT NOT WEIGHT–FOR–AGE (FALSE POSITIVES)

MAC cut-off level (cm)	% moderately malnourished children in false positives when true malnutrition is defined by wt/age below median – 3SD
<13.5	80.4
<14.0	72.9

TABLE VI
SENSITIVITY AND SPECIFICITY OF MAC MEASUREMENTS IN IDENTIFYING CHILDREN WITH LOW WEIGHT–FOR–HEIGHT

MAC (cm)	Prevalence (%)	Defination of true malnutrition: Wt/height below median - 2SD		
		Sensitivity	Specificity	Positive predictive value
<12.5	2.7	14.5	98.6	54.5
<13.0	5.6	28.9	97.1	53.3
<13.5	15.4	49.4	88.3	32.5
<14.0	30.6	84.3	75.6	28.3

Table VI indicates the prevalence, sensitivity, specificity and positive predictive value of MAC measurements in screening children with low weight-for-height.

Allowing for a balance between sensitivity and specificity, a MAC cut-off of < 14.0 cm is apparently suitable for use in identifying children with moderate to severe wasting or acute malnutrition. However, this relatively high cut-off includes as malnourished, a high proportion of false positives which agrees with the finding from MAC percentiles that MAC may not be sensitive enough to distinguish children with moderate wasting from those with only mild wasting.

CONCLUSIONS

The relatively low correlation of MAC with weight-for-age and weight-for-height, and the results from MAC percentiles and sensitivity-specificity analysis indicate that MAC is not sensitive enough to differentiate moderate from normal to borderline malnutrition in Malaysian preschool children. However, a MAC of 13.0 - 13.7 cm may be used for identifying moderate to severe PEM and under 13.0 cm for severely malnourished children requiring immediate rehabilitation. With this cut-off for severe PEM, the proportion of MAC positives who were actually not malnourished based on the weight-for-age criteria of malnutrition was only 4% in this study and thus would not tax the often limited resources available for nutritional rehabilitation programmes.

The underlying assumption in this study is that weight-for-age and weight-for-height are the most accurate measures of malnutrition which may not be so. However, until a more appropriate definition of malnutrition has been established, it may be premature to criticise MAC solely on the basis that it is not as sensitive or specific as weight-for-age in identifying malnutrition in children.

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