Mid-upper-arm circumference development and its validity in assessment of undernutrition

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As part of a prospective, longitudinal study that was carried out in Hanoi, Vietnam (as from 1981), mid-upper-arm circumference (MUAC) measurements, and the weight and height of children were taken from children for the first year of life. These measurements were recorded monthly, 12–36 months: 3-monthly, 36–72 months: 6-monthly and yearly for children beyond 72 months. The aim of this study was to observe development of MUAC of children on a longitudinal basis. Mid-upper-arm circumference increases by about 1 cm for boys and 1.5 cm for girls between 1 and 5 years. To recognise malnutrition, the cut-off level of MUAC 13.5 cm gave high values for sensitivity and specificity only for children aged 6–12 months. The cut-off levels of 14.0, 14.5 and 15.0 cm were more appropriate for children aged 13–24, 25–36 and 37–60 months. These results suggest that a single cut-off point of MUAC 13.5 cm cannot be used in screening moderate malnutrition for all children under age 5 but should be elevated with the increasing age of children.

Key words: cut-off levels of mid-upper-arm circumference, mid-upper-arm circumference, nutritional assessment, sensitivity, specificity.

Introduction

The arm contains subcutaneous fat and muscle mass. In developing countries, where people may undergo a reduced food intake, lower subcutaneous fat and muscle mass tend to parallel decreased mid-upper-arm circumference (MUAC) and as a result are useful in the diagnosis of undernutrition.[1,2] It is an important tool in screening for undernutrition especially when weight and stature measurements are too demanding or are impossible, such as in emergency situations, and when the precise age of the child is unknown, since it has been suggested that MUAC is relatively independent of age for children between 1 and 5 years.[3]

Arm circumference indicators of nutritional status have advantages for field use because of their simplicity and low cost;[4–6] while weight-for-age and weight-for-height indicators require an accurate portable scale and knowledge of age, as well as a reference table for field use.

The MUAC cut-off points that are used in order to distinguish between normal and malnourished children vary. In some cases, a single cut-off point was chosen for children aged 1–5 years.[7,8] In other studies, a series of cut-off points were used to classify degrees of malnutrition.[9]

The validity of MUAC indices in the assessment of nutritional status is still disputed. Some investigators claim that MUAC can differentiate normal children from those with malnutrition,[9–11] whereas others contest this finding.[12]

Most studies of MUAC indicators were cross-sectional. The objective of the present study is to investigate the development of MUAC on a longitudinal basis. This paper also uses the concepts of sensitivity and specificity[13] in evaluating the performance of MUAC measurements as a screening test for identifying children judged as malnourished by the weight-for-age (W/A) and weight-for-height (W/H) indices.

Subjects and methods

Subjects

A prospective, longitudinal study has been carried out in Hanoi from 1981. The study design and data collection was implemented by staff members of the National Institute of Nutrition in Hanoi. Two of the four districts of Hanoi were randomly selected from which maternity hospitals were identified. Newborn infants from selected maternities fulfilling the following criteria: (i) birth weight not less than 2500 g, (ii) normal and single birth, (iii) without physical abnormalities, (iv) 'Viet' ethnic group, and (v) parents with normal health status were chosen to participate.

There were four cohorts (year of birth): 1981, 1982, 1983 and 1984. In 1981 and 1982, 90 newborn infants were selected for each year and in 1983 and 1984 60 newborns were selected. A total of 31.7% of children (n = 96) up to the age 60 months did not complete the study due to changes in housing location. Some 205 children (123 boys and 82 girls), who were regularly followed up to 5 years of age, are included in this report.

Data collection

The children were followed up at their home. Anthropometric measurements of the children were conducted monthly

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from birth to 12 months. From 12 to 36 months the children were monitored every 3 months and from 36 to 72 months measurements were taken every 6 months. After that age data collection was carried out on a yearly basis. The methods of measurements were followed according to the recommendation of WHO.[14] The date of monitoring was the birth date ± 4 days for the first 3 years and the birth date ± 10 days for the children aged more than 3 years old.

A plastic tape was used to measure the MUAC. The midpoint of the left upper arm was determined by measuring the length from the tip of the shoulder to the tip of the elbow and the length was divided by two. The tape was wrapped around the straightened arm at that midpoint and the tape inspected to ensure it was neither too tight nor too loose. The measurement was recorded to the nearest 0.1 cm.

The weights of the children were obtained using a Testut weighing scale (Testut, Paris, France) with a precision of 0.01 kg. The scale was controlled twice per day with a known weight (5 kg) and the subject was weighed with the minimum of clothing. The weights were recorded to the nearest 0.1 kg.

The recumbent lengths of the children less than 24 months were measured using the babyboard (UNICEF, Copenhagen, Denmark) and the measurements were read to the nearest 0.1 cm. A microtoise (UNICEF) was used to measure the height of children (24 months) and the measurements were also recorded to the nearest 0.1 cm. All data were recorded for each child.

Statistical analysis

Data analysis was carried out by using the computer program EPI-INFO (version 6.01) and statistical Package for Social Science (SPSSPC+; SPSS, Chicago, IL, USA). Anthropometric indicators W/A and W/H were compared to the National Centre for Health Statistics (NCHS) reference data.[15] The cut-off point of – 2 Z-scores (SD) was used to classify the nutritional status of the children. The MUAC increment[16] was used to assess the development of MUAC of the children followed up.

The analysis of variance (ANOVA) was used for comparison between groups. Student's *t*-test was used for comparison of the means of two groups. The difference in prevalence data between groups was tested using chi-squared or Fisher's exact test. Pearson's correlation coefficient was also used for testing correlation between variables.

Sensitivity and specificity results were calculated using Z-score < – 2 W/A and W/H to define children 'truly' malnourished (Table 1). Sensitivity was defined as the percentage of true positive for malnutrition that were identified when the MUAC was below the given threshold. Specificity was defined as the percentage of true negative for malnutrition that were defined when the MUAC was above the given threshold.

Analysis of collected data was carried out in the SEAMEO-TROPMED Regional Centre for Community Nutrition, Jakarta, Indonesia.

Ethical considerations

Collected data have been used for study purposes only. The parents of the children followed up were informed about the purpose of the study and of the name of research institution before agreeing to participate. Assurance was given that their cooperation was voluntary and that no negative consequences would result to those who decided not to participate in the study. Also, the parents were informed that they could skip any question they did not want to answer. Study protocol was approved by the Ethical Committee of the National Institute of Nutrition in Hanoi.

Results

Table 1 details the MUAC data measured in boys and girls up to 10 years of age. It was found that the MUAC of the boys from 6 to 36 months of age increased only very slightly (0.4 cm). At the age of 60 months MUAC was ≈ 1 cm higher compared with that of the boys at 36 months. Similar but less marked results were found among the girls. The MUAC of girls was smaller than that of boys for all ages from birth to 9-years-old. After this age MUAC was almost the same for both sexes.

Mid-upper-arm circumference gain during the first year was very high (3.49 cm for boys and 2.99 cm for girls), then followed by very low increments of MUAC (< 0.5 cm/year from 2 to 10-years-old). At the age of 12 and 13 years increased growth rate in MUAC was observed and its standard deviation became larger for male and female children (Fig. 1).

Table 1. Development of mid-upper-arm circumference (cm) by age and sex of the children compared with National Center for Health Statistics (NCHS) reference standards quoted by Gibson (1990)

Age (months)	Boys *n*	Mean ± SD (% of NCHS)		Girls *n*	Mean ± SD (% of NCHS)	
1	128	11.1 ± 0.9		84	10.7 ± 0.8	
2	128	12.4 ± 1.0		84	11.8 ± 0.9	
3	128	13.3 ± 1.1		84	12.5 ± 1.0	
4	128	13.8 ± 1.0		84	12.9 ± 1.0	
5	128	14.0 ± 1.1		84	13.2 ± 1.0	
6	128	14.2 ± 1.1		84	13.4 ± 1.0	
7	128	14.2 ± 1.1		84	13.4 ± 1.1	
8	128	14.2 ± 1.1		84	13.5 ± 0.9	
9	128	14.2 ± 1.0		84	13.5 ± 1.0	
10	128	14.1 ± 1.0		84	13.4 ± 1.0	
11	128	14.2 ± 1.0		84	13.3 ± 0.9	
12	128	14.6 ± 0.9	91.8	84	13.7 ± 0.9	87.8
15	128	14.3 ± 1.1		84	13.8 ± 0.9	
18	128	14.3 ± 0.9		84	13.9 ± 0.9	
21	128	14.3 ± 0.8		84	13.9 ± 0.8	
24	128	14.8 ± 0.9	91.3	84	14.2 ± 0.8	88.7
27	128	14.6 ± 0.8		84	14.2 ± 0.8	
30	128	14.8 ± 0.8		84	14.4 ± 0.9	
33	128	14.8 ± 0.8		84	14.5 ± 0.9	
36	128	14.6 ± 0.8	87.4	84	14.6 ± 1.0	87.4
42	128	15.1 ± 0.9		84	14.9 ± 0.9	
48	127	15.5 ± 0.9	90.6	84	15.1 ± 0.9	89.3
54	123	15.6 ± 0.9		82	15.2 ± 0.8	
60	123	15.7 ± 0.9	89.7	82	15.4 ± 0.8	88.0
66	123	15.8 ± 0.9		82	15.6 ± 0.8	
72	122	16.0 ± 0.9	89.4	82	15.7 ± 0.8	89.2
84	122	16.1 ± 0.8	86.1	82	15.8 ± 0.7	86.3
96	122	16.4 ± 0.9	86.3	82	16.2 ± 1.0	83.1
108	122	16.7 ± 0.9	83.5	82	16.7 ± 1.1	79.5
120	120	17.7 ± 0.8	81.4	71	16.9 ± 0.9	80.4

Table 2 indicates the prevalence of moderate malnutrition for the cut-off point (MUAC < 13.5 cm) of children from 6 to 60 months on a longitudinal basis in relation to the W/A and W/H indices. Mid-upper-arm circumference gave a higher prevalence of malnutrition in the first year (6–12 months) when compared with W/A and W/H; it then decreased with increasing age. From 12 to 60 months the prevalence of malnutrition indentified by W/A were higher than that of MUAC and W/A.

Sensitivity and specificity of the selected cut-off levels of the MUAC indicator in relation to true malnutrition as defined by W/A and W/H are shown in Table 3. According to these findings the cut-off level of the MUAC of 13.5 cm gave high values for both sensitivity and specificity (sensitivity 71% and specificity 80 for W/A vs. sensitivity 83 and specificity 71 for W/H) for those aged 6–12 months. Cut-off levels of 14.0, 14.5 and 15.0 cm were found to be most appropriate for the ages of 13–24, 25–36 and 37–60 months, respectively.

Table 4 shows the result of the Pearson's correlation test which was used to assess the relationship between MUAC of children and their weight, and W/A and W/H from birth to 5-years-old. All correlations had a significant association with their weight, WAZ (weight-for-age Z-score) and WHZ (weight-for-height Z-score) for all ages ($P < 0.001$). There were moderate positive correlations ($0.50 < r < 0.75$) for the majority of age groups. Strong positive correlations ($r > 0.75$) were found during infancy.

Table 3. Prevalence, sensitivity and specificity of mid-upper-arm circumference (MUAC) indicators in identifying with low weight-for-height (W/H) and weight-for-age (W/A) for the 205 children from 6 to 60 months old

		W/A< –2SD		W/H< –2SD	
MUAC	Prevalence	Sensitivity	Specificity	Sensitivity	Specificity
6–12 months					
< 11.5	1.4	7	100	17	99
< 12.0	2.4	11	100	25	98
< 12.5	5.9	25	95	33	95
< 13.0	15.3	44	92	58	86
< 13.5*	31.4	71	80	83	71
< 14.0	50.2	89	60	100	51
13–24 months					
< 11.5	0.6	2	100	4	100
< 12.0	0.8	2	100	4	99
< 12.5	2.4	7	100	10	98
< 13.0	6.2	15	98	26	94
< 13.5	15.8	32	92	31	85
< 14.0*	35.2	60	77	61	66
< 14.5	55.1	83	59	80	46
25–36 months					
< 13.0	2.0	6	100	15	99
< 13.5	6.0	16	98	21	95
< 14.0	14.5	33	94	41	87
< 14.5*	35.7	61	76	68	66
< 15.0	55.6	80	56	88	46
< 15.5	80.0	97	30	97	21
37–60 months					
< 13.0	0.5	1	100	4	100
< 13.5	1.2	4	100	10	100
< 14.0	2.6	7	99	16	98
< 14.5	12.3	25	93	40	90
< 15.0*	26.7	62	84	60	82
< 15.0	26.7	62	84	60	82
< 15.5	52.2	79	90	90	51
< 16.0	69.7	91	39	94	32

*Best cut-off level for children according to age group.

Discussion

The results of present study with regard to MUAC increments for children between 12 and 60 months are in agreement with some previous studies.[3,7,17] Mid-upper-arm circumference increases by ≈ 1 cm for boys and 1.5 cm for girls between 1 and 5 years. Compared with the NCHS median, the MUAC of children from 1- to 7-years-old were

Table 2. Prevalence of malnutrition identified by mid-upper-arm circumference (MUAC) compared with weight-for-age (W/A) and weight-for-height (W/H) for the 205 children from 6 to 60 months

	Indices of malnutrition (%)								
Age	MUAC < 13.5			W/A < –2SD			W/H < –2SD		
(months)	Boys	Girls	Combined	Boys	Girls	Combined	Boys	Girls	Combined
6	21.1	46.4	31.3	3.1	4.8	4.7	0	0	0
7	18.0	48.8	30.2	3.9	9.5	6.1	0	0	0
8	20.3	42.9	29.2	6.3	8.3	7.4	0.8	1.2	1.0
9	17.2	47.6	29.2	10.9	15.5	12.7	1.6	4.8	2.8
10	22.7	44.0	31.1	14.8	25.0	20.8	1.6	6.0	3.3
11	18.8	46.1	31.3	18.8	34.5	26.9	3.1	7.1	6.1
12	17.0	33.3	17.5	21.7	21.4	21.7	4.7	3.6	4.4
15	17.2	33.3	23.0	29.7	38.1	33.0	4.7	3.6	3.8
18	11.7	27.4	17.9	32.5	33.3	34.4	3.9	6.0	5.2
21	9.4	20.2	13.7	33.8	44.0	40.6	5.5	6.0	5.9
24	3.1	11.9	6.6	37.5	48.8	45.3	3.1	7.1	4.7
27	4.7	11.9	7.5	30.5	38.1	33.5	1.6	4.8	3.3
30	5.5	8.3	6.6	28.1	40.0	37.3	2.4	2.4	2.4
33	3.1	8.3	5.2	25.8	40.5	34.0	4.7	4.7	4.7
36	1.6	9.5	4.7	21.1	36.9	27.4	7.8	9.7	8.5
42	2.3	1.2	1.9	24.2	40.5	33.0	8.6	9.7	9.0
48	1.6	1.2	1.4	29.2	33.3	31.2	6.8	8.3	7.1
54	0.8	1.2	0.9	26.0	38.1	35.1	6.3	7.1	6.8
60	0.8	0	0.5	33.1	31.0	32.2	9.4	7.1	8.1

Table 4. Correlation ($P < 0.001$) between mid-upper-arm circumference (MUAC) and weight, weight-for-age Z-scores (WAZ), weight-for-height Z-Scores (WHZ) of the 205 children from 6 to 60 months old

Age (months)	Correlation between MUAC and Weight	WAZ	WHZ
6	0.75	0.72	0.54
7	0.76	0.72	0.48
8	0.78	0.76	0.52
9	0.76	0.71	0.50
10	0.76	0.70	0.54
11	0.76	0.69	0.58
12	0.80	0.70	0.48
15	0.81	0.69	0.49
18	0.81	0.66	0.52
21	0.67	0.66	0.52
24	0.78	0.64	0.54
27	0.63	0.60	0.49
30	0.64	0.63	0.50
33	0.65	0.65	0.55
36	0.62	0.61	0.51
42	0.52	0.52	0.48
48	0.60	0.58	0.49
54	0.59	0.57	0.53
60	0.60	0.55	0.49

around 90% of the NCHS median, from 8 to 11 years about 80% and it increased after that (Table 1). It was also found that the MUAC gain of children at the age of 12–13 years was relatively higher than the previous years and its standard deviation became larger. This suggests that with the beginning of puberty a new phase of growth starts (Fig. 2).

From these findings it appears that the prevalence of moderate malnutrition as determined by MUAC cut-off values (13.5 cm) differs from those obtained by W/A and W/H indices. Similar results have been reported in other populations.[17–19]

Spearman's correlation coefficient test showed that in this study increases in MUAC tends to be parallelled with weight gains of children. These result confirm that MUAC measurements allow differentiation between normal and underweight[9,10] and normal and wasted[11] children.

The cut-off points of the MUAC, which have been used, are varied. Anderson[7] and Trowbridge[8] used a single cut-off point (e.g. 13.5 cm) for children aged 1–5 years, whereas in another study, a series of cut-off points was used to classify degrees of malnutrition.[9] In a recent study by Bern and Nathanail,[22] a higher MUAC of 14.0 cm was considered to be the most sensitive cut-off point in the detection of children with low W/H.

The results of the present study indicate that a cut-off level of MUAC of 13.5 cm gave high values for both sensitivity and specificity compared with W/A and W/H indices only for children aged 6–12 months. With increasing age, sensitivity decreases, in the age group 37–60 months, to only 4% in boys and 10% in girls. The data suggest that the cut-off level of MUAC 13.5 cm cannot be used in screening moderate malnutrition for all children under 5 years but should be stratified according to age group.

Some tapes measure only with one marked cut-off (13.5 cm, e.g. Talc, Hertz, UK), in case they are used then only for the restricted age group (6–12 months old children). If this is not feasible for practical reasons and wider age ranges have to be assessed, then different tapes for specific age group measurements have to be used (e.g. UNICEF tape) and plotted to age.

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中上臂圍發育及其在營養不良評估中的精確性

摘　要

1981 年在越南河內市進行了一個有希望的縱向研究，測量兒童的中上臂圍（ MUAC ）和出生後一年的身高體重。這些測量是每月一次，共 12 — 36 個月，三個月一次，共 36 – 72 個月，六個月或一年一次，共 72 個月。該研究的目的是從縱向觀察兒童的中上臂圍（ MUAC ）發育。結果發現，在 1 — 5 歲兒童，男童中上臂圍增加約 1 厘米，女童約 1.5 厘米，中上臂圍增長至 13.5 厘米即行停止，僅爲 6 – 12 個月兒童的一個敏感而特殊的營養不良數據，中上臂圍增長至 14.0 ，14.5 和 15.0 厘米才停止，則更適合年齡在 13 - 24 ， 25 — 36 和 37 — 60 個月的營養不良兒童。這些結果指出，單用中上臂圍 13.5 厘米就停止增長這個指標是不能找出所有 5 歲以下的中等度營養不良兒童。

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