BMJ Paediatrics Open

Double burden of malnutrition among Indian school children

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2019-000505
Article Type:	Original article
Date Submitted by the Author:	12-Apr-2019
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Keywords:	General Paediatrics, Growth, Obesity, School Health, Tropical Paediatrics

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Short title: Double burden of malnutrition

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Abstract

Objective

To document the extent of double burden of malnutrition (coexistence of over- and under-nutrition) among Indian schoolchildren from lower socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used as a proxy for body mass index (BMI).

Design

A cross-sectional study

Setting

A school from the outskirts of a large city with a majority of the children belonging to lower and lower-middle socioeconomic categories

Subjects

The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to playgroups and grades 1-7.

Interventions

Anthropometric measurements, such as MUAC, height, and weight, were taken from each participant using standard techniques. Descriptive statistics for BMI and MUAC were obtained based on gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The distribution of variables was calculated among all participants, together and separately, for each gender. Homogeneous subsets for BMI and MUAC were identified the three groups. Age-wise comparisons of BMI and MUAC were also conducted for each gender.

Main outcome measures

1. To know if MUAC and BMI are correlated among both boys and girls.

2. To study BMI and MUAC Z score distribution among the subjects.

Results

Importantly, MUAC correlated positively with BMI among both boys and girls. The following BMI Z-score distribution was observed: obese, 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%); severe acute malnutrition (SAM), 5(0.3%); moderate acute malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%). The distribution of categories of children based on MUAC Z-scores was: obese, 19; overweight, 178; pre-obese, 135; SAM, 7; MAM, 181; undernourished, at risk of MAM/SAM, 181

Conclusions

Obesity/overweight/pre-obese and SAM/MAM/undernourished states coexist among Indian schoolchildren from lower middle/lower socioeconomic categories. BMI and MUAC were significantly correlated. MUAC may identify both under-nutrition and over-nutrition by early detection of aberrant growth.

Introduction

The double burden of under-nutrition and over-nutrition is emerging as a major problem. According to estimates from 129 countries with available data, 57 experience serious problems of both undernourished children and overweight adults (1). The relationship between under-nutrition and overweight status and obesity is more than coexistence. The double burden of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within individuals, households, and populations and across the life course. “Across the life course” refers to the phenomenon that under-nutrition early in life contributes to an increased propensity for over-nutrition during adulthood (2). The occurrence of DBM is attributed to a complex interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic transitions, etc.) from high fertility and early deaths to low fertility and aging populations and epidemiological transitions from communicable to non-communicable diseases(2).

The consequences of DBM are enormous. Early life under-nutrition is associated with approximately one-third of childhood deaths. The survivors, who become stunted during their first two years of life, are prone to infections and are unable to carry out physical work, study, and progress in school. Later in the life course, the double burden of disease is characterized by the coexistence of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s, obesity was a relatively rare condition, even in the wealthiest of nations (3), whereas under-nutrition was a major problem, and nutrition supplementation was the main intervention. Thus, obesity is a relatively new problem in need of attention. A systematic review of obesity and socioeconomic status in developing countries concluded that child obesity is more prevalent among affluent groups within developing countries (4). This may be attributed to improved access to surplus/excess food and a higher degree of urbanization and technological progress in these economies that render activities less laborious, resulting in less energy expenditure (5). Thus, economic advancement seems inevitably associated with a rapidly increasing prevalence of obesity. Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese study revealed that approximately one-third of obese children grew into obese adults (6). Therefore, early detection of excessive weight gain, and action to prevent its progress, is more likely to succeed than attempting to reverse obesity later.

Body mass index (BMI)-for-age, the internationally recommended measure of obesity, suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI levels, because of a considerably higher body fat percentage (7). Therefore, the World Health Organization (WHO) recommends lowering the BMI cut-offs for “overweight” among Asian adults (8) in light of the increased health risks. Therefore, early detection of an overweight status has become very important in Asia.

The selection of height-based parameters, such as BMI for the detection of overweight/obese children in low-resource settings, has limitations because of the shortage of stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of abdominal girth for detecting visceral obesity needs to be developed (9). The mid-upper arm circumference (MUAC) appears to be a promising alternative in this regard (10-14). A recent study from the Netherlands reaffirmed that, compared with BMI,MUAC is a valid measure for detecting overweight/obesity, and thus is a good alternative to BMI (15).Health workers are familiar with MUAC measurement, as it has been commonly used for identifying severe acute under-nutrition among young (6–60 months of age) children (16).

To our knowledge, few studies have focused on the coexistence of under- and over-nutrition in India. The present study was conducted to document the extent of DBM among Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect trends toward obesity or severe acute malnutrition (SAM).

Participants and Methods

Setting: This cross-sectional study was conducted with schoolchildren from the outskirts of Pune, India. This study was part of the MIMER medical college and hospital's outreach activities regarding annual school health check-ups. A schedule of class-wise health check-ups was developed in consultation with the school authorities who, in turn, sought parents' permission. The study had the approval of the ethics committee of MIMER medical college and hospital, Talegaon Dabhade. A majority of the children belonged to lower and lower-middle socioeconomic categories. Children between 3-5 years were from a playgroup, and those between 6-12 years belonged to grades 1-7.

Anthropometric measurements: Anthropometric measurements, such as MUAC, height, and weight, were taken from each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic plastic tape at the midway between the olecranon and acromion processes on the upper left arm. During these measurements, the participant was in a comfortable standing position and was asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm was straightened, and we ensured that the tape was neither too tight nor too loose.

Statistical tools: Open Source Statistical Software PSPP version 1.0.1was used for all analyses, and a *p*-value ≤0.05 was considered statistically significant. Mean and standard deviation (SD), median, inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants with complete measurements. Z-scores were computed using age-specific and sex-specific reference data from the WHO (17). The distribution of variables was calculated among all participants together and separately for boys and girls. Homogeneous subsets for BMI and MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were calculated for both girls and boys.

Patient involvement: Patients were not directly involved in the design of this study.

Results

The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The distribution of variables among all participants, girls and boys, is shown in Tables 1 and

2. Age, height, weight, and BMI were all significantly different between girls and boys; boys had higher values for all parameters. MUAC, BMI Z-scores, and MUAC Z-scores, however, did not significantly differ between boys and girls (suppl. files).

BMI and MUAC differed significantly for all participants combined, and separately for boys and girls, between the ages of 3 to 16 years. Tukey's HSD tests for multiple comparisons revealed a significant shift in mean BMI at 3, 6, and 10 years whereas for MUAC, the shift occurred at 4, 6, and 9 years. Thereafter, MUAC changed significantly almost every year until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI change with age was minimal among girls (only at age 14) compared to changes among boys at 6, 10, 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at age4, compared to nine subsets among boys, with the first shift at age 5. Thus, changes in BMI and MUAC were more frequent among boys (suppl. files).

Importantly, MUAC positively correlated with other anthropometric variables among girls. Correlations were significant with weight, height, BMI, and BMI Z-scores (Table3). These findings were similar for boys (Table 4).

Based on BMI Z-scores, the following distribution of overweight children was found: obese (Z-scores more than 3 SD) - 21 (1.5%), overweight (Z-scores between 2 and 3 SD) - 36 (2.5%), and pre-obese (Z-scores between 1 and 2 SD)-136 (9.4%). At the other end of the spectrum, among undernourished children, the following distribution was found: SAM (Z-scores less than 3 SD) -5(0.3%), moderate acute malnutrition (MAM; Z-scores between -2 and -3 SD) -146 (10.1%), and undernourished at risk of sliding to MAM or SAM (Z-score between -1 and -2 SD) - 141 (9.8%) (Table5). Drawing parallels to BMI, the distribution of various categories of children based on the MUAC Z-scores was as follows (Table 6): obese-19 (1.3%), overweight- 178 (12.3%), pre-obese-135 (9.3%), SAM- 7(0.5%), MAM- 181 (12.5%), and undernourished at risk of MAM or SAM -181 (12.5%). BMI and MUAC categories had no statistically significant association with gender (suppl. files). The distribution of nutrition conditions, based on a modified WHO classification, is provided in (Table 7).

Discussion

The present study suggests that DBM has reached Indian school children of lower middle or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results identify children at the brink of sliding into severe forms of over- and under-nutrition. The present study also suggests using a single and simpler method, MUAC, for detecting both forms of malnutrition by monitoring growth during routine health check-ups.

The World Health Assembly targets were considered in crafting the 2030 development agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the existence of the double burden of under-nutrition and overweight. While the drivers of the double burden of malnutrition are varied and often insidious, their effects present a clear case for urgent action and demand an integrated response. Using a single tool for detecting both forms of malnutrition integrates and simplifies the process.

To our knowledge, few studies have focused on this aspect of growth among children in India, as well as other emerging economies. Based on BMI Z-scores, 21(1.5%) and 36 (3.9%) children were classified as obese and overweight, respectively. At the other end of the spectrum, a relatively small proportion, 5 (0.3%) and 5 (0.3 %), belonged to SAM and MAM categories, respectively. MUAC Z-scores suggested the following distribution: obesity -19(1.3%), overweight -43(4.3%), SAM -1(0.1%), and MAM-(0.4%). An even greater number of children were leaning towards obesity or overweight, as well as SAM or MAM. Children who are not yet at the BMI-for-age threshold for the current definition of childhood obesity or overweight (and SAM or MAM) may be at an increased risk of developing obesity or severe forms of under-nutrition. One of the present study's aims was to identify these target groups so that these children's needs could be addressed.

The first target group, pre-obese children (BMI or MUACZ-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. The second group, undernourished children (BMI or MUACZ-score between -1 and -2 SD), is at risk of sliding into MAM or SAM. Based on the BMI Z-scores, 136 (9.4%) were pre-obese, and 181 (12.5%) were undernourished. The equivalent numbers for MUAC were 135 (9.3%) for obesity and 181 (12.5%) for SAM and MAM risk, respectively. These target groups may develop more severe forms of malnutrition if corrective measures are delayed. The first step in that direction is to plan face-to-face counseling sessions with parents and children. School programs are effective at preventing childhood obesity by fostering more physical activity and recommending healthier diets (18). Counseling for the target groups will have to be done, keeping in mind that within low-resource settings, places for play may be scarce, sports infrastructure may be poor, and recreational centers may be lacking (19). Similarly, low family income is linked to greater consumption of low-quality nutrition and fast food (20).

Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting both under and over-nutrition during routine growth monitoring without a height-dependent parameter, such as BMI (Figure). This is because BMI and MUAC are significantly correlated with each other. However, monitoring for obesity should begin even earlier, as the most rapid weight gain occurs between ages 2 and 6among obese adolescents (21).

While India’s economy has been growing at an impressive rate, the country still has the highest number of stunted children in the world (46.8 million), representing one-third of the global total of stunted children under age 5(22).Stunting is associated with being overweight among children in countries that are undergoing a nutritional transition (23).Economic improvements are accompanied by a conspicuous change in dietary patterns in the form of increased fat intake (5). This, coupled with low physical activity, contributes to an increasing prevalence of obesity among adults, which accompanies the first wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus, called “the new world syndrome” (24).

It should be noted, however, that some children classified as obese under this system may actually have a higher relative weight due to stunting rather than excess adiposity. Moreover, classification of a child’s or adolescent’s weight status is complicated by the fact that height and body composition are continually changing, and such changes often occur at different rates and times within different populations. Charts showing BMI for healthy children by age indicate an initial rapid rise in the first year, a subsequent decline for the next 5 years, and then a slow rise into adulthood, making simple universal adiposity indices of little value. Therefore, there has not been the same level of agreement on the classification of obesity for children and adolescents as there is for adults (25).

To summarize, until recently, India has considered under-nutrition to be a major problem, and nutrition supplementation has been the key intervention. At the national level, India is at stage 1 of the obesity transition with wide sub-national variations (26). Our study may help in the surveillance effort to address underserved populations (26).With improved availability of food, a double burden of malnutrition is emerging that needs to be concurrently addressed. The present study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and undernourished states among Indian school children in lower-middle and lower socioeconomic levels. Second, the present results revealed a significant correlation between BMI and MUAC. This study provides evidence to suggest that MUAC is a valid, single measurement for identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-nutrition on the other, through extended routine growth monitoring of children. However, more studies are required to establish validity and reliability of this tool.

What is known about the subject?

- Emerging economies face a dual problem of under-nutrition and over-nutrition.
- Its detection is not easy with height-based parameters in low resource setting.

What this study adds?

- This study suggests that MUAC is a simple, valid, and single measurement for identifying this dual problem in the above setting.

A funding statement: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

No competing interests: All authors have completed the ICMJE uniform disclosure form at and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Author contribution:

SD-Conceptualization; Data analysis; Manuscript writing.

SM-Data collection; data analysis; manuscript writing.

AK- Data analysis; manuscript writing.

ED- Data collection; manuscript writing.

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Table 1

Descriptive statistics for age, sex, and anthropometric characteristics

Variables ^	Girls (n=424)				Boys (n=1,020)				Mann-Whitney Test	
	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Z-value	p-value
Age (years)	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	2.44E-07
									Difference is significant	
Height (cm)	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	3.44E-11
									Difference is significant	
Body	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.4	-7.21	5.41E-

weight (kg)								0	5	13
									Difference is significant	
BMI (kg/m^2)	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	1.66E-13
									Difference is significant	
MUAC	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	4.59E-10
									Difference is significant	
BMI (Z-Score)	0.00	0.99	-0.22	1.09	-0.01	1.00	-0.21	1.06	-0.501	0.616
									Difference is not significant	
MUAC (Z-	0.00	0.99	-0.13	1.22	0.00	0.99	-0.17	1.14	-0.08	0.936

score)									1	
									Difference is not significant	

^ All data failed Shapiro–Wilk Normality Tests. Hence, Mann-Whitney U Rank Sum Tests were applied.

Ordinal data requiring a Mann-Whitney U Rank Sum Test.

BMI=Body Mass Index; MUAC=Mid-upper-arm circumference

Table 2

Distribution of variables among all participants

Variables	Mean	SD	Median	IQR	Minimum	Maximum
Age (years)	8.46	3.50	9.00	6.00	3.00	16.00
Body weight (kg)	27.04	13.77	23.10	16.20	9.00	97.50
Height (cm)	131.45	21.16	130.00	32.00	84.00	188.00
BMI	14.69	3.10	13.78	2.89	6.58	36.10
MUAC	18.53	3.57	17.50	4.30	12.20	35.00

SD = standard deviation; IQR = inter-quartile range; BMI = Body Mass Index; MUAC = Mid-upper-arm circumference

Table 3

Correlations between anthropometric parameters among girls (N=424)

		MUAC	Body weight	Height	BMI	BMI (Z-score) Internal
MUAC	Pearson Correlation	1	.897**	.700**	.826**	.567**
	Sig. (2-tailed)		7.340E-152	1.207E-063	6.856E-107	2.020E-037
Body weight	Pearson Correlation	.897**	1	.866**	.776**	.422**
	Sig. (2-tailed)	7.340E-152		2.851E-129	1.933E-086	9.136E-020
Height	Pearson Correlation	.700**	.866**	1	.385**	.055
	Sig. (2-tailed)	1.207E-063	2.851E-129		2.156E-016	.2594

BMI	Pearson Correlation	.826**	.776**	.385**	1	.831**
	Sig. (2-tailed)	6.856E-107	1.933E-086	2.156E-016		2.161E-109
BMI (Z-score) Internal	Pearson Correlation	.567**	.422**	.055	.831**	1
	Sig. (2-tailed)	2.020E-037	9.136E-020	.2594	2.161E-109	

** Correlation is significant at the 0.01 level (2-tailed).

MUAC = Mid-upper-arm circumference; BMI = Body Mass Index

Table 4

Correlations between anthropometric parameters among boys (N=1020)

		MUAC	Body weight	Height	BMI	BMI (Z-score) Internal
MUAC	Pearson Correlation	1	.911**	.780**	.847**	.472**
	Sig. (2-tailed)		.00000	9.603E-210	2.206E-281	1.066E-057
Body weight	Pearson Correlation	.911**	1	.886**	.861**	.383**
	Sig. (2-tailed)	.0000		.00000	1.248E-301	6.748E-037
Height	Pearson Correlation	.780**	.886**	1	.564**	.049
	Sig. (2-tailed)	9.603E-210	.00000		1.024E-086	.1168
BMI	Pearson	.847**	.861**	.564**	1	.748**

	Correlation					
	Sig. (2-tailed)	2.206E-281	1.248E-301	1.024E-086		1.462E-183
BMI (Z-score) Internal	Pearson Correlation	.472**	.383**	.049	.748**	1
	Sig. (2-tailed)	1.066E-057	6.748E-037	.1168	1.462E-183	
** Correlation is significant at the 0.01 level (2-tailed).						

MUAC = Mid-upper-arm circumference; BMI = Body Mass Index

Table 5

Distribution of BMI Z-scores

BMI (z-score) Internal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1)>+3	21	1.5	1.5	1.5
	2)>+2 to <+3	36	2.5	2.5	3.9
	3)>+1 to <+2	136	9.4	9.4	13.4
	4)0 to +1	391	27.1	27.1	40.4
	5)≥-1 to 0	709	49.1	49.1	89.5
	6)≥-2 to <-1	141	9.8	9.8	99.3
	7)≥-3 to <-2	5	.3	.3	99.7
	8)<-3	5	.3	.3	100.0
	Total	1444	100.0	100.0	

Table 6

Distribution of MUAC Z-scores

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1)>+3 SD	19	1.3	1.3	1.3
	2)>+2 to <+3	43	3.0	3.0	4.3
	3)>+1 to <+2	135	9.3	9.3	13.6
	4)0 to +1	418	28.9	28.9	42.6
	5)≥-1 to 0	641	44.4	44.4	87.0
	6)≥-2 to <-1	181	12.5	12.5	99.5
	7)≥-3 to <-2	6	.4	.4	99.9
	8)<-3	1	.1	.1	100.0
	Total	1444	100.0	100.0	

Table 7

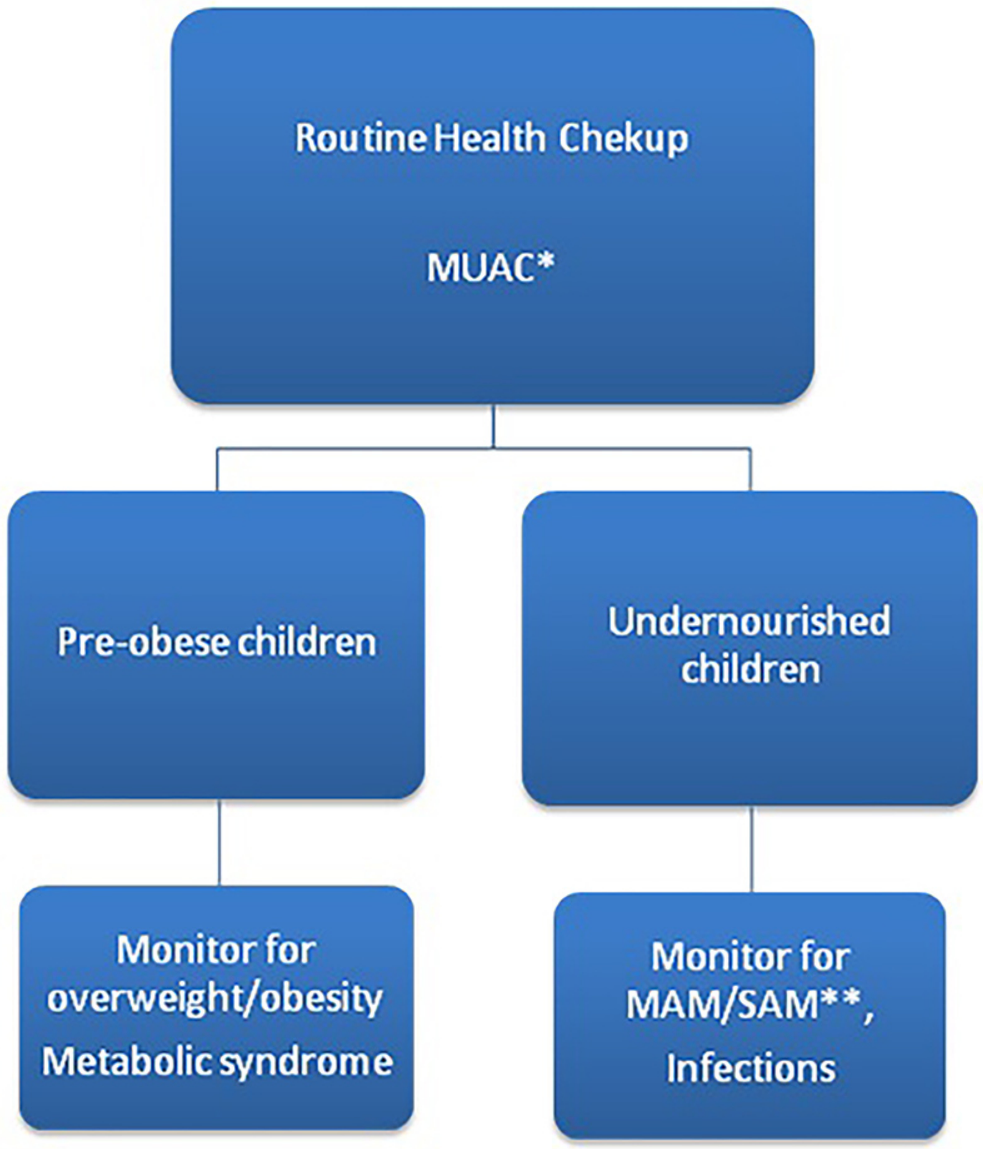
Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	Based on BMI z-scores No (%)	Based on MUACZ-scores No (%)
Pre-obese	BMI >1 to 2 SD 136 (9.4)	MUAC>1to 2SD 135 (9.3)
Overweight	BMI>2 to 3 SD 36 (2.5)	MUAC>2 to 3SD 43 (3)
Obese	BMI >3SD 21 (1.5)	MUAC>3SD 19(1.3)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8)	MUAC ≤ -1 to -2SD 181 (12.5)
Thin	BMI <-2 to -3 SD 5 (0.3)	MUAC<-2 to -3SD 6 (0.4)

Severely thin	BMI <-3SD 5 (0.3)	MUAC<-3 SD 1(0.1)

**Modified WHO Classification of nutrition conditions based on anthropometry

BMI = Body Mass Index; MUAC = Mid-upper-arm circumference



282x327mm (72 x 72 DPI)

Table 1

Age-wise comparisons of BMI among all subjects

Age (years)	Mean	SD	Median	IQR	F-value	p-value
3	13.37	1.34	13.26	1.61	56.066	5.73E-118
4	13.04	1.69	13.07	1.46	Difference is significant	
5	13.01	1.13	12.80	1.02		
6	13.85	2.09	13.39	1.55		
7	13.54	1.48	13.20	1.90		
8	13.94	2.22	13.37	2.01		
9	13.70	1.73	13.36	1.66		
10	14.74	2.84	13.97	2.77		
11	15.48	3.03	14.89	3.60		
12	15.89	3.01	15.63	3.87		
13	18.22	3.34	17.51	3.30		
14	18.33	3.88	17.28	4.53		
15	19.09	4.32	18.01	6.52		
16	21.38	5.89	23.55	11.09		

One-Way ANOVA applied. SD = standard deviation; IQR = inter-quartile range

Table 2

Age-wise comparisons of MUAC among all participants

Age (years)	Mean	SD	Median	IQR	F-value	p-value
3	15.39	1.24	15.20	1.50	140.727	1.10E-244
4	15.50	1.16	15.50	1.10	Difference is significant	
5	16.19	1.17	15.95	1.20		
6	16.83	2.07	16.50	1.95		
7	16.98	1.75	16.70	2.00		
8	17.97	2.11	17.50	1.61		
9	17.79	1.78	17.50	2.08		
10	19.02	2.63	18.50	3.45		
11	20.16	3.04	19.50	3.93		
12	20.87	2.79	20.50	4.00		
13	22.91	2.79	22.50	2.60		
14	23.53	3.64	23.00	4.95		
15	24.66	3.73	23.50	5.23		
16	25.81	4.63	27.20	7.75		

One-Way ANOVA applied. SD = standard deviation; IQR = inter-quartile range

Table 3

Homogeneous Subsets: BMI (Tukey's HSD)

Age (years)	No.	Subset for alpha = 0.05					
		1	2	3	4	5	6
5	132	13.011					
4	146	13.038					
3	102	13.366	13.366				
7	156	13.537	13.537				
9	72	13.696	13.696				
6	109	13.852	13.852	13.852			
8	65	13.939	13.939	13.939			
10	220		14.740	14.740	14.740		
11	182			15.481	15.481		
12	77				15.892		
13	30					18.224	
14	72					18.325	
15	72					19.094	

16	9						21.380
Sig.		0.836	0.232	0.059	0.529	0.892	1.000

Means for groups in homogeneous subsets are displayed.

BMI = Body Mass Index

Table 4

Homogeneous subsets: MUAC – Tukey’s HSD (all subjects)

Age (years)	No.	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
3	102	15.385								
4	146	15.500	15.500							
5	132	16.194	16.194							
6	109	16.826	16.826	16.826						
7	156		16.979	16.979						
9	72			17.794	17.794					
8	65			17.972	17.972					

10	220				19.015	19.015				
11	182					20.161	20.161			
12	77						20.871			
13	30							22.907		
14	72							23.532	23.532	
15	72								24.658	24.658
16	9									25.811
Sig.		0.102	0.08	0.421	0.314	0.423	0.961	0.987	0.452	0.412

Means for groups in homogeneous subsets are displayed.

MUAC = Mid-upper-arm circumference

Table 5

Cross tabulation of BMI (Z-score) internal and gender

			Gender		Total
			Female	Male	
BMI (Z-score) Internal	1)>+3	Count	5	16	21
		% within Sex	1.2%	1.6%	1.5%
	2)>+2 to <+3	Count	11	25	36
		% within Sex	2.6%	2.5%	2.5%
	3)>+1 to <+2	Count	47	89	136
		% within Sex	11.1%	8.7%	9.4%
	4)0 to +1	Count	109	282	391
		% within Sex	25.7%	27.6%	27.1%
	5)≥-1 to 0	Count	209	500	709
		% within Sex	49.3%	49.0%	49.1%

	6)≥-2 to <-1	Count	39	102	141
		% within Sex	9.2%	10.0%	9.8%
	7)≥-3 to <-2	Count	3	2	5
		% within Sex	.7%	.2%	.3%
	8)<-3	Count	1	4	5
		% within Sex	.2%	.4%	.3%
Total		Count	424	1020	1444
		% within Sex	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.199[a]	7	.636
Likelihood Ratio	4.931	7	.668
N of Valid Cases	1444		

[a] 4 cells (25.0%) have expected count less than 5. The minimum expected count is 1.47.			

BMI = Body Mass Index

Table 6

Cross tabulation of MUAC (Z-score) internal and gender

			Gender		Total
			Female	Male	
MAC (Z-score) Internal	1)>+3	Count	3	16	19
		% within Sex	.7%	1.6%	1.3%
	2)>+2 to <+3	Count	17	26	43
		% within Sex	4.0%	2.5%	3.0%
	3)>+1 to <+2	Count	38	97	135
		% within Sex	9.0%	9.5%	9.3%
	4)0 to +1	Count	131	287	418
		% within Sex	30.9%	28.1%	28.9%
	5)≥-1 to 0	Count	178	463	641
		% within Sex	42.0%	45.4%	44.4%
	6)≥-2 to <-1	Count	55	126	181

		% within Sex	13.0%	12.4%	12.5%
	7)≥ -3 to <-2	Count	2	4	6
		% within Sex	.5%	.4%	.4%
	8)<-3	Count	0	1	1
		% within Sex	.0%	.1%	.1%
Total		Count	424	1020	1444
		% within Sex	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.054[a]	7	.533
Likelihood Ratio	6.429	7	.491
N of Valid Cases	1444		

[a] 4 cells (25.0%) have expected count less than 5. The minimum expected count is .29.

BMJ Paediatrics Open

Double burden of malnutrition among Indian school children and its measurement

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2019-000505.R1
Article Type:	Original research
Date Submitted by the Author:	15-Jun-2019
Complete List of Authors:	Daga, Subhashchandra; Pacific Medical College and Hospital, Pediatrics Mhatre, Sameer; Smt Kashibai Navale Medical College and General Hospital, Paediatrics Kasbe, Abhiram ; Topiwala National Medical College DSouza, Eric; MIMER
Keywords:	General Paediatrics, Growth, Obesity, School Health, Tropical Paediatrics

Double burden of malnutrition among Indian school children **and its measurement**

Short title: Measuring double burden of malnutrition

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Abstract

Objective

This cross-sectional study aimed to document the extent of double burden of malnutrition (coexistence of over- and under-nutrition) among Indian schoolchildren from lower socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used as a proxy for body mass index (BMI).

Design

A cross-sectional study

Setting

A school in the outskirts of a large city, with a majority of the children belonging to lower and lower-middle socioeconomic categories.

Subjects

The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to playgroups and grades 1-7.

Measurements

Anthropometric measurements, such as participants' MUAC, height, and weight were measured using standard techniques. Descriptive statistics for BMI and MUAC were obtained based on gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The distribution of variables was calculated for three groups: all participants together and separately for each gender. Homogeneous subsets for BMI and MUAC were identified in the three groups. Age-wise comparisons of BMI and MUAC were conducted for each gender.

Main outcome measures

1. To know if MUAC and BMI are correlated among both boys and girls.

2. To study BMI and MUAC Z score distribution among the subjects.

Results

The MUAC positively correlated with BMI in both boys and girls. The following BMI Z-score distribution was observed: obese, 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%); severe acute malnutrition (SAM), 5(0.3%); moderate acute malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%). The distribution of categories of children based on MUAC Z-scores was: obese, 19 (1.3%), overweight, 178 (12.3%), pre-obese, 135 (9.3%), SAM, 7(0.5%), MAM, 181 (12.5%), and undernourished at risk of MAM or SAM, 181 (12.5%).

Conclusions

Obesity/overweight/pre-obese and SAM/MAM/undernourished states, undernutrition more than overweight, coexist among Indian schoolchildren from lower middle/lower socioeconomic categories. BMI and MUAC were significantly correlated. MUAC may identify both under-nutrition and over-nutrition by early detection of aberrant growth.

Introduction

The double burden of under-nutrition and over-nutrition is emerging as a major problem. According to estimates from 129 countries with available data, 57 experience serious problems of both undernourished children and overweight adults [1]. The relationship between under-nutrition and overweight status and obesity is more than coexistence. The double burden of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within individuals, households, and populations and across the life course. “Across the life course” refers to the phenomenon that under-nutrition early in life contributes to an increased propensity for over-nutrition during adulthood [2]. The occurrence of DBM is attributed to a complex interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic transitions, etc.) from high fertility and early deaths to low fertility and aging populations and epidemiological transitions from communicable to non-communicable diseases [2].

The consequences of DBM are enormous. Early life under-nutrition is associated with approximately one-third of childhood deaths. The survivors, who become stunted during their first two years of life, are prone to infections and are unable to carry out physical work, study, and progress in school. Later in the life course, the double burden of disease is characterized by the coexistence of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s, obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-nutrition was a major problem, and nutrition supplementation was the main intervention. Thus, obesity is a relatively new problem in need of attention**.** A systematic review of obesity and socioeconomic status in developing countries concluded that child obesity is more prevalent among affluent groups within developing countries [4]. This may be attributed to improved access to surplus/excess food and a higher degree of urbanization and technological progress in these economies that render activities less laborious, resulting in less energy expenditure [5]. Thus, economic advancement seems inevitably associated with a rapidly increasing prevalence of obesity. Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese study revealed that approximately one-third of obese children grew into obese adults [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress, is more likely to succeed than attempting to reverse obesity later.

Body mass index (BMI)-for-age, the internationally recommended measure of obesity, suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health Organization (WHO) recommends lowering the BMI cut-offs for "overweight" among Asian adults [8] in light of the increased health risks. Therefore, early detection of an overweight status has become very important in Asia.

The selection of height-based parameters, such as BMI for the detection of overweight/obese children in low-resource settings, has limitations because of the shortage of stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent study from the Netherlands reaffirmed that, compared with BMI,MUAC is a valid measure for detecting overweight/obesity, and thus is a good alternative to BMI [15].Health workers are familiar with MUAC measurement, as it has been commonly used for identifying severe acute under-nutrition among young (6–60 months of age) children [16].

To our knowledge, few studies have focused on the coexistence of under- and over-nutrition in India. The present study was conducted to document the extent of DBM among Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect trends toward obesity or severe acute malnutrition (SAM).

Participants and Methods

Setting

This cross-sectional study was conducted with schoolchildren from the outskirts of Pune, India. This study was part of the MIMER medical college and hospital's outreach activities regarding annual school health check-ups. A schedule of class-wise health check-ups was developed in consultation with the school authorities who, in turn, sought parents' permission. The study had the approval of the ethics committee of MIMER medical college and hospital, Talegaon Dabhade. A majority of the children belonged to lower and lower-middle socioeconomic categories. Children between 3–5 years were from a playgroup, and those between 6–12 years belonged to grades 1–7.

Anthropometric measurements

Anthropometric measurements, such as MUAC, height, and weight, were taken from each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic plastic tape at the midway between the olecranon and acromion processes on the upper left arm.

During these measurements, the participant was in a comfortable standing position and was asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm was straightened, and we ensured that the tape was neither too tight nor too loose.

Statistical tools

Open Source Statistical Software PSPP version 1.0.1was used for all analyses, and a *p*-value ≤0.05 was considered statistically significant. Mean and standard deviation (SD), median, inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants with complete measurements. Z-scores were computed using age-specific and sex-specific reference data from the WHO [17]. The distribution of variables was calculated among all participants together and separately for boys and girls. Homogeneous subsets for BMI and MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were calculated for both girls and boys.

Patient involvement

Patients were not directly involved in the design of this study.

Results

The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The distribution of variables among all participants, girls and boys, is shown in Tables 1 and 2. Age, height, weight, MUAC, and BMI were all significantly different between girls and boys; boys had higher values for all parameters.

BMI and MUAC showed age-wise differencesfor all participants combined, and separately for boys and girls, between the ages of 3 to 16 years. Tukey's HSD tests for homogeneous subsetsrevealed a significant shift in mean BMI at 3, 6, and 10 years whereas for MUAC, the shift occurred at 4, 6, and 9 years. Thereafter, MUAC changed significantly almost every year until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI change with age was minimal in girls (only at age 14) compared to changes in boys at 6, 10, 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at age of 4 years, compared to nine subsets in boys, with the first shift at age 5. Thus, changes in BMI and MUAC were more frequent in boys (supplementary files**). Importantly, MUAC was positively correlated with weight, height, and BMI both in both girls and boys (Tables 3 and 4).**

Based on BMI Z-scores, the following distribution of overweight children was found: obese (Z-scores more than 3 SD) - 21 (1.5%), overweight (Z-scores between 2 and 3 SD) - 36 (2.5%), and pre-obese (Z-scores between 1 and 2 SD)-136 (9.4%). At the other end of the spectrum, among undernourished children, the following distribution was found: SAM (Z-scores less than 3 SD) - 5(0.3%), moderate acute malnutrition (MAM; Z-scores between -2 and -3 SD) -146 (10.1%), and undernourished at risk of sliding to MAM or SAM (Z-score between -1 and -2 SD) - 141 (9.8%)

(Table **and Figure 2**). Drawing parallels to BMI, the distribution of various categories of children based on the MUAC Z-scores was as follows (Table 6 and **Figure 3**): obese-19 (1.3%), overweight- 178 (12.3%), pre-obese-135 (9.3%), SAM- 7(0.5%), MAM- 181 (12.5%), and undernourished at risk of MAM or SAM -181 (12.5%). BMI and MUAC categories had no statistically significant association with gender (suppl. files). The distribution of nutrition conditions, based on a modified WHO classification, is provided in (Table 7).

Discussion

The present study suggests that DBM has reached Indian school children of lower middle or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results identify children at the brink of sliding into severe forms of over- and under-nutrition. The present study also suggests using a single and simpler method, MUAC, for detecting both forms of malnutrition by monitoring growth during routine health check-ups.

The World Health Assembly targets were considered in crafting the 2030 development agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the existence of the double burden of under-nutrition and overweight. While the drivers of the double burden of malnutrition are varied and often insidious, their effects present a clear case for urgent action and demand an integrated response. Using a single tool for detecting both forms of malnutrition integrates and simplifies the process.

To our knowledge, few studies have focused on this aspect of growth among children in India, as well as other emerging economies. Based on BMI Z-scores, 21(1.5%) and 36 (3.9%) children were classified as obese and overweight, respectively. At the other end of the spectrum, a relatively small proportion, 5 (0.3%) and 5 (0.3 %), belonged to SAM and MAM categories, respectively. MUAC Z-scores suggested the following distribution: obesity -19(1.3%), overweight -43(4.3%), SAM -1(0.1%), and MAM-(0.4%). An even greater number of children were leaning towards obesity or overweight, as well as SAM or MAM. Children who are not yet at the BMI-for-age threshold for the current definition of childhood obesity or overweight (and SAM or MAM) may be at an increased risk of developing obesity or severe forms of under-nutrition. One of the present study's aims was to identify these target groups so that these children's needs could be addressed.

The first target group, pre-obese children (BMI or MUACZ-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. The second group, undernourished children (BMI or MUACZ-score between -1 and -2 SD), is at risk of sliding into MAM or SAM. Based on the BMI Z-scores, 136 (9.4%) were pre-obese, and 181 (12.5%) were undernourished. The equivalent numbers for MUAC were 135 (9.3%) for obesity and 181 (12.5%) for SAM and MAM risk, respectively. More children were at risk of severe undernutrition than of overnutrition. These target groups may develop more severe forms of malnutrition if corrective measures are delayed. The first step in that direction is to plan face-to-face counseling sessions with parents and children. School programs are effective at preventing childhood obesity by fostering more physical activities and recommending healthier diets [18]. Counseling for the target groups will have to be done, keeping in mind that within low-resource settings, places for play may be scarce, sports infrastructure may be poor, and recreational centers may be lacking [19]. Similarly, low family income is linked to greater consumption of low-quality nutrition and fast food [20].

Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting both under and over-nutrition during routine growth monitoring without a height-dependent parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated with each other. However, monitoring for obesity should begin even earlier, as the most rapid weight gain occurs between ages 2 and 6 years among obese adolescents [21].

While India's economy has been growing at an impressive rate, the country still has the highest number of stunted children in the world (46.8 million), representing one-third of the global total of stunted children under age 5 [22].Stunting is associated with being overweight among children in countries that are undergoing a nutritional transition [23].Economic improvements are accompanied by a conspicuous change in dietary patterns in the form of increased fat intake [5]. This, coupled with low physical activity, contributes to an increasing prevalence of obesity among adults, which accompanies the first wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus, called "the new world syndrome" [24].

It should be noted, however, that some children classified as obese under this system may actually have a higher relative weight due to stunting rather than excess adiposity. Moreover, classification of a child's or adolescent's weight status is complicated by the fact that height and body composition are continually changing, and such changes often occur at different rates and times within different populations. Charts showing BMI for healthy children by age indicate an initial rapid rise in the first year, a subsequent decline for the next 5 years, and then a slow rise into adulthood, making simple universal adiposity indices of little value. Therefore, there has not been the same level of agreement on the classification of obesity for children and adolescents as there is for adults [25].

To summarize, until recently, India has considered under-nutrition to be a major problem, and nutrition supplementation has been the key intervention. At the national level, India is at stage 1 of the obesity transition with wide sub-national variations [26]. Our study may help in the surveillance effort to address underserved populations [26]. With improved availability of food, a double burden of malnutrition is emerging that needs to be concurrently addressed. The present study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and undernourished states among Indian school children in lower-middle and lower socioeconomic levels. Second, the present results revealed a significant correlation between BMI and MUAC. This study provides evidence to suggest that MUAC is a valid, single measurement for identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-nutrition on the other, through extended routine growth monitoring of children. However, more studies are required to establish validity and reliability of this tool.

What is known about the subject?

- Emerging economies face a dual problem of under-nutrition and over-nutrition.
- Detecting this problem using height-based parameters is not easy in a low-resource setting.

What this study adds?

This study suggests that MUAC is a simple, valid, and single measure for identifying this dual problem in a low-resource setting.

Funding statement: This research received no specific grant from any funding agency in public, commercial, or not-for-profit sectors.

Declaration of interests: All authors have completed the ICMJE uniform disclosure form at and confirm no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Author contributions

SD-Conceptualization; **Data analysis**; **Manuscript writing**.

SM-Data collection; data analysis; manuscript writing.

AK- Data analysis; manuscript writing.

ED- Data collection; manuscript writing.

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Table 1

Comparison of various variables between girls and boys

Variables ^	**Girls (n=424)**				**Boys (n=1020)**				**Mann-Whitney Test**	
	Mean	**SD**	**Median**	**IQR**	**Mean**	**SD**	**Median**	**IQR**	**Z-value**	**p-value**
Age (years)	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	**2.44E-07 ***
Height (cm)	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	**3.44E-11 ***
Body weight (Kg)	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	**5.41E-13 ***
BMI	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	**1.66E-13 ***
MUAC	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	**4.59E-10 ***

^ All Data failed 'Normality Test'. Hence Mann-Whitney U Rank Sum Test applied.

*Difference is statistically significant.

BMI=Body Mass Index; MUAC=Mid-upper-arm circumference

Table 2

Distribution of variables among all Subjects

Variables	Mean	SD	Median	IQR	Minimum	Maximum
Age (years)	8.46	3.50	9.00	6.00	3.00	16.00
Body weight (Kg)	27.04	13.77	23.10	16.20	9.00	97.50
Height (cm)	131.45	21.16	130.00	32.00	84.00	188.00
Height (meters)	1.31	0.21	1.30	0.32	0.84	1.88
BMI	14.69	3.10	13.78	2.89	6.58	36.10
MAC	18.53	3.57	17.50	4.30	12.20	35.00

SD = standard deviation; IQR = inter-quartile range; BMI = Body Mass Index; MUAC =Mid-upper-arm circumference

Table 3

Correlations between anthropometric parameters among girls (N=424)

Variables		MUAC	Body weight (Kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
Body weight (Kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

** Correlation is significant at the 0.01 level (2-tailed).

Table 4

Correlations between anthropometric parameters among boys (N=1020)

Variables		**MUAC**	**Body weight (Kg)**	**Height (cm)**	**BMI**
MUAC	Pearson Correlation	1	.911(**)	.780(**)	.847(**)
	p-value		0.0001	9.60E-210	2.21E-281
Body weight (Kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	p-value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	p-value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	p-value	2.21E-281	1.25E-301	1.02E-86	

** Correlation is significant at the 0.01 level (2-tailed).

358 **Table 5**

359 Distribution of BMI Z-scores

360

BMI (Z Score) Internal	**No.**	**Percentage**
>+3	21	1.5%
>+2 to <+3	36	2.5%
>+1 to <+2	136	9.4%
0 to +1	391	27.1%
>=-1 to 0	709	49.1%
>=-2 to <-1	141	9.8%
>= -3 to <-2	5	0.3%
<-3	5	0.3%
Total	1444	100.0%

361 BMI=Body Mass Index

Table 6
Distribution of MUAC Z-scores

MAC (Z Score) Internal	**No.**	**Percentage**
>+3 SD	19	1.3%
>+2 to <+3	43	3.0%
>+1 to <+2	135	9.3%
0 to +1	418	28.9%
>=-1 to 0	641	44.4%
>=-2 to <-1	181	12.5%
>= -3 to <-2	6	0.4%
<-3	1	0.1%
Total	1444	100.0%

MUAC=Mid-upper-arm circumference

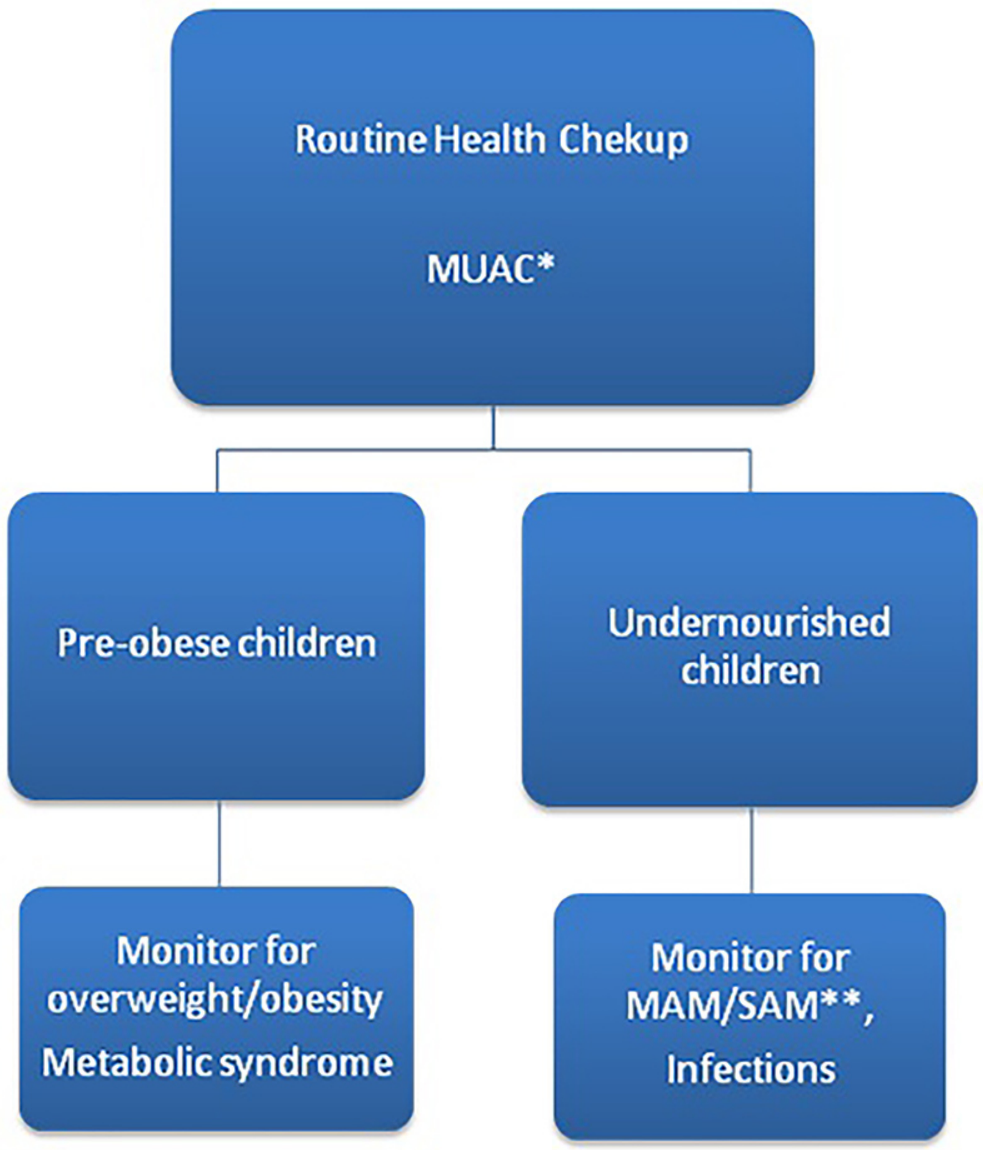
Table 7

Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	**Based on BMI z-scores No (%)**	**Based on MUACZ-scores No (%)**
Pre-obese	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to 2SD 135 (9.3%)
Overweight	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)
Obese	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
Thin	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
Severely thin	BMI <-3SD 5 (0.3%)	MUAC<-3 SD 1(0.1%)

**Modified WHO Classification of nutrition conditions based on anthropometry

BMI = Body Mass Index; MUAC = Mid-upper-arm circumference



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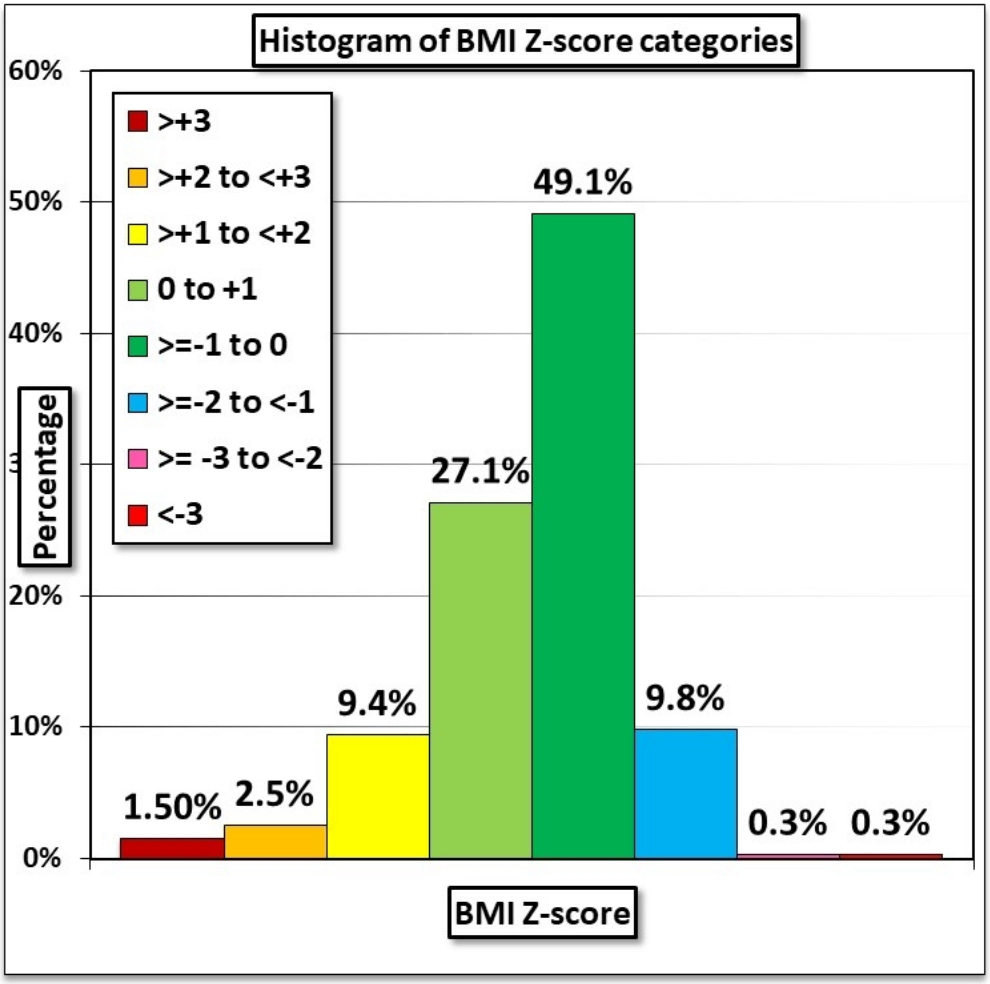
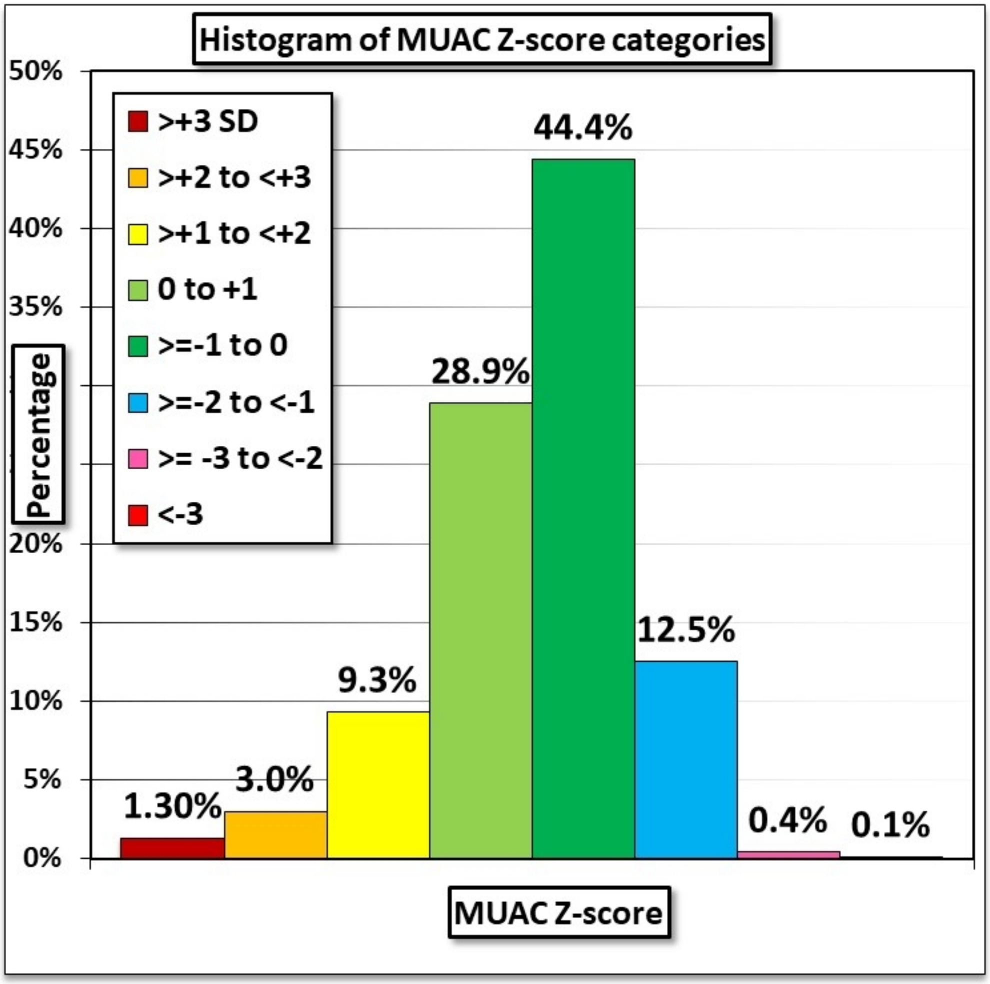


158x157mm (120 x 120 DPI)



158x157mm (120 x 120 DPI)

Table 8
Age-wise distribution of BMI among all Subjects

Age (years)	BMI			
	Mean	**SD**	**Median**	**IQR**
3	13.37	1.34	13.26	1.61
4	13.04	1.69	13.07	1.46
5	13.01	1.13	12.80	1.02
6	13.85	2.09	13.39	1.55
7	13.54	1.48	13.20	1.90
8	13.94	2.22	13.37	2.01
9	13.70	1.73	13.36	1.66
10	14.74	2.84	13.97	2.77
11	15.48	3.03	14.89	3.60
12	15.89	3.01	15.63	3.87
13	18.22	3.34	17.51	3.30
14	18.33	3.88	17.28	4.53
15	19.09	4.32	18.01	6.52
16	21.38	5.89	23.55	11.09

SD = standard deviation; IQR = inter-quartile range

Table 9
Homogeneous Subsets: BMI: Tukey HSD

Age (years)	No.	Subset for alpha = 0.05					
		1	2	3	4	5	6
5	132	13.011					
4	146	13.038					
3	102	13.366	13.366				
7	156	13.537	13.537				
9	72	13.696	13.696				
6	109	13.852	13.852	13.852			
8	65	13.939	13.939	13.939			
10	220		14.740	14.740	14.740		
11	182			15.481	15.481		
12	77				15.892		
13	30					18.224	
14	72					18.325	
15	72					19.094	
16	9						21.380
Sig.		0.836	0.232	0.059	0.529	0.892	1.000

Means for groups in homogeneous subsets are displayed.
BMI = Body Mass Index

Table 10
Age-wise distribution of MUAC among all Subjects

Age (years)	MUAC			
	Mean	SD	Median	IQR
3	15.39	1.24	15.20	1.50
4	15.50	1.16	15.50	1.10
5	16.19	1.17	15.95	1.20
6	16.83	2.07	16.50	1.95
7	16.98	1.75	16.70	2.00
8	17.97	2.11	17.50	1.61
9	17.79	1.78	17.50	2.08
10	19.02	2.63	18.50	3.45
11	20.16	3.04	19.50	3.93
12	20.87	2.79	20.50	4.00
13	22.91	2.79	22.50	2.60
14	23.53	3.64	23.00	4.95
15	24.66	3.73	23.50	5.23
16	25.81	4.63	27.20	7.75

SD = standard deviation; IQR = inter-quartile range

Table 11

Homogeneous Subsets: MUAC: Tukey HSD (Table No. 4)

Age (years)	No.	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
3	102	15.385								
4	146	15.500	15.500							
5	132	16.194	16.194							
6	109	16.826	16.826	16.826						
7	156		16.979	16.979						
9	72			17.794	17.794					
8	65			17.972	17.972					
10	220				19.015	19.015				
11	182					20.161	20.161			
12	77						20.871			
13	30							22.907		
14	72							23.532	23.532	
15	72								24.658	24.658
16	9									25.811
Sig.		0.102	0.08	0.421	0.314	0.423	0.961	0.987	0.452	0.412

Means for groups in homogeneous subsets are displayed.
MUAC = Mid-upper-arm circumference

Table 12
Association among the cases betweenBMI (Z-Score) Internal and Gender

BMI (Z Score) Internal		Gender		Total
		Female	Male	
>+3	No.	5	16	21
	%	1.2%	1.6%	1.5%
>+2 to <+3	No.	11	25	36
	%	2.6%	2.5%	2.5%
>+1 to <+2	No.	47	89	136
	%	11.1%	8.7%	9.4%
0 to +1 ^	No.	109	282	391
	%	25.7%	27.6%	27.1%
>=-1 to 0 ^	No.	209	500	709
	%	49.3%	49.0%	49.1%
>=-2 to <-1 ^	No.	39	102	141
	%	9.2%	10.0%	9.8%
>= -3 to <-2 ^	No.	3	2	5
	%	0.7%	0.2%	0.3%
<-3 ^	No.	1	4	5
	%	0.2%	0.4%	0.3%
Total	No.	424	1020	1444
	%	100.0%	100.0%	100.0%

Chi-Square Test	Value	df	p-value	Association is-
Pearson Chi-Square $	5.199	7	0.636	Not significant
Pearson Chi-Square ^	2.262	3	0.520	Not significant

$ 4 cells (25.0%) have expected count less than 5. ^ Row data pooled and Chi-Square test reapplied.
BMI = Body Mass Index

Table 13

Association among the cases betweenMUAC (Z-Score) Internal and Gender

MUAC (Z Score) Internal		Gender		Total
		Female	Male	
>+3 SD	No.	3	16	19
	%	0.7%	1.6%	1.3%
>+2 to <+3	No.	17	26	43
	%	4.0%	2.5%	3.0%
>+1 to <+2	No.	38	97	135
	%	9.0%	9.5%	9.3%
0 to +1 ^	No.	131	287	418
	%	30.9%	28.1%	28.9%
>=-1 to 0 ^	No.	178	463	641
	%	42.0%	45.4%	44.4%
>=-2 to <-1 ^	No.	55	126	181
	%	13.0%	12.4%	12.5%
>= -3 to <-2 ^	No.	2	4	6
	%	0.5%	0.4%	0.4%
<-3 ^	No.	0	1	1
	%	0.0%	0.1%	0.1%
Total	No.	424	1020	1444
	%	100.0%	100.0%	100.0%

Chi-Square Test	Value	df	p-value	Association is-
Pearson Chi-Square $	6.054	7	0.533	Not significant
Pearson Chi-Square ^	3.929	3	0.269	Not significant

$ 4 cells (25.0%) have expected count less than 5. ^ Row data pooled and Chi-Square test reapplied.

MUAC = Mid-upper-arm circumference

BMJ Paediatrics Open

Double burden of malnutrition among Indian school children and its measurement: A cross-sectional study in a single school

Short title: Measuring double burden of malnutrition

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2019-000505.R2
Article Type:	Original research
Date Submitted by the Author:	20-Sep-2019
Complete List of Authors:	Daga, Subhashchandra; Pacific Medical College and Hospital, Pediatrics Mhatre, Sameer; Smt Kashibai Navale Medical College and General Hospital, Paediatrics Kasbe, Abhiram ; Topiwala National Medical College DSouza, Eric; MIMER
Keywords:	General Paediatrics, Obesity, School Health, Tropical Paediatrics, Growth

Double burden of malnutrition among Indian school children and its measurement: A cross-sectional study in a single school

Short title: Measuring double burden of malnutrition

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Abstract

Objective

This cross-sectional study **in a single school** aimed to document the extent of double burden of malnutrition (coexistence of over- and under-nutrition) among Indian schoolchildren from lower socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used as a proxy for body mass index (BMI).

Design

A cross-sectional study **in a single school**

Setting

A school in the outskirts of a large city, with a majority of the children belonging to lower and lower-middle socioeconomic categories.

Subjects

The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to playgroups and grades 1-7.

Measurements

Anthropometric measurements, such as participants' MUAC, height, and weight were measured using standard techniques. Descriptive statistics for BMI and MUAC were obtained based on

gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The distribution of variables was calculated for three groups: all participants together and separately for each gender. Homogeneous subsets for BMI and MUAC were identified in the three groups. Age-wise comparisons of BMI and MUAC were conducted for each gender.

Main outcome measures

1. To know if MUAC and BMI are correlated among both boys and girls.

2. To study BMI and MUAC Z score distribution among the subjects.

Results

The MUAC positively correlated with BMI in both boys and girls. The following BMI Z-score distribution was observed: severe acute malnutrition (SAM), 5(0.3%); moderate acute malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%); obese, 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%). The distribution of categories of children based on MUAC Z-scores was: SAM, 7(0.5%), MAM, 181 (12.5%), and undernourished at risk of MAM or SAM, 181 (12.5%); obese, 19 (1.3%), overweight, 178 (12.3%), pre-obese, 135 (9.3%).

Conclusions

SAM/MAM/undernourished states and obesity/overweight/pre-obese, undernutrition more than overweight, coexist among Indian schoolchildren from lower middle/lower socioeconomic categories. BMI and MUAC were significantly correlated. MUAC **identifies** both under-nutrition and over-nutrition by early detection of aberrant growth

Introduction

The double burden of under-nutrition and over-nutrition is emerging as a major problem. According to estimates from 129 countries with available data, 57 experience serious problems of both undernourished children and overweight adults [1]. The relationship between under-nutrition and overweight status and obesity is more than coexistence. The double burden of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within individuals, households, and populations and across the life course. "Across the life course" refers to the phenomenon that under-nutrition early in life contributes to an increased propensity for over-nutrition during adulthood [2]. The occurrence of DBM is attributed to a complex interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic transitions, etc.) from high fertility and early deaths to low fertility and aging populations and epidemiological transitions from communicable to non-communicable diseases [2].

Later in the life course, the double burden of disease is characterized by the coexistence of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s, obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-nutrition was a major problem, and nutrition supplementation was the main intervention. Thus, obesity is a relatively new problem in need of attention**.** A systematic review of obesity and socioeconomic status in developing countries concluded that child obesity is more prevalent among affluent groups within developing countries [4]. This may be attributed to improved access to surplus/excess food and a higher degree of urbanization and technological progress in these economies that render activities less laborious, resulting in less energy expenditure [5]. Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese study revealed that approximately one-third of obese children grew into obese adults [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress, is more likely to succeed than attempting to reverse obesity later.

Body mass index (BMI)-for-age, the internationally recommended measure of obesity, suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health Organization (WHO) recommends lowering the BMI cut-offs for "overweight" among Asian adults [8] in light of the increased health risks. Therefore, early detection of an overweight status has become very important in Asia.

The selection of height-based parameters, such as BMI for the detection of overweight/obese children in low-resource settings, has limitations because of the shortage of stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent study from the Netherlands reaffirmed that, compared with BMI,MUAC is a valid measure for detecting overweight/obesity, and thus is a good alternative to BMI [15].Health workers are familiar with MUAC measurement, as it has been commonly used for identifying severe acute under-nutrition among young (6–60 months of age) children [16].

To our knowledge, few studies have focused on the coexistence of under- and over-nutrition in India. The present study was conducted to document the extent of DBM among Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect trends toward obesity or severe acute malnutrition (SAM).

Participants and Methods

Setting

A **single school** cross-sectional study was conducted with schoolchildren from the outskirts of Pune, India. This study was part of the MIMER medical college and hospital's outreach activities regarding annual school health check-ups. A schedule of class-wise health check-ups was developed in consultation with the school authorities who, in turn, sought parents' permission. The study had the approval of the ethics committee of MIMER medical college and hospital, Talegaon Dabhade. A majority of the children belonged to lower and lower-middle socioeconomic categories. Children between 3–5 years were from a playgroup, and those between 6—12 years belonged to grades 1–7.

Anthropometric measurements

Anthropometric measurements, such as MUAC, height, and weight, were taken from each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic plastic tape at the midway between the olecranon and acromion processes on the upper left arm. During these measurements, the participant was in a comfortable standing position and was asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm was straightened, and we ensured that the tape was neither too tight nor too loose.

Statistical tools

Open Source Statistical Software PSPP version 1.0.1was used for all analyses, and a *p*-value ≤0.05 was considered statistically significant. Mean and standard deviation (SD), median, inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants with complete measurements. Z-scores were computed using age-specific and sex-specific reference data from the WHO [17]. The distribution of variables was calculated among all participants together and separately for boys and girls. Homogeneous subsets for BMI and MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were calculated for both girls and boys.

Patient involvement

Patients were not directly involved in the design of this study.

Results

The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The distribution of variables among all participants, girls and boys, is shown in figures 1 and 2. Age, height, weight, MUAC, and BMI were all significantly different between girls and boys; boys had higher values for all parameters (Suppl. Files: table 1 and 2). As expected, BMI and MUAC showed age-wise differences for all participants, combined and separately, for boys and girls, between the ages of 3 to 16 years (Suppl. Files: tables 3 and 4). Tukey's HSD (honest significant difference) tests for homogeneous subsets revealed a significant shift in mean BMI at 3, 6, and 10 years (Suppl. Files: table 5) whereas for MUAC, the shift occurred at 4, 6, and 9 years (Suppl. files: table 6). Thereafter, MUAC changed significantly almost every year until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI change with age was minimal in girls (only at age 14) compared to changes in boys at 6, 10, 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at age of 4 years, compared to nine subsets in boys, with the first shift at age 5. Thus, changes in BMI and MUAC were more frequent in boys**.** MUAC was positively correlated with weight, height, and BMI both in girls and boys (Suppl. Files: tables 7 and 8).

Discussion

The present study suggests that DBM has reached Indian school children of lower middle or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results identify children at the brink of sliding into severe forms of under – and over- nutrition. The present study also suggests using a single and simpler method, MUAC, for detecting both forms of malnutrition by monitoring growth during routine health check-ups.

The World Health Assembly targets were considered in crafting the 2030 development agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the existence of the double burden of under-nutrition and overweight. While the drivers of the double burden of malnutrition are varied and often insidious, their effects present a clear case for urgent action and demand an integrated response. Using a single tool for detecting both forms of malnutrition integrates and simplifies the process.

To our knowledge, few studies have focused on this aspect of growth among children in India, as well as other emerging economies. The girls were outnumbered by boys (424 vs. 1020). This may be because of the traditional gender norms that push girls into helping household chores and sibling care that result in dropouts. Based on BMI Z-scores, 5 (0.3%) and 5 (0.3 %), belonged to SAM and MAM categories, respectively and 21(1.5%) and 36 (3.9%) children were classified as obese and overweight, respectively. MUAC Z-scores suggested the following distribution: SAM -1(0.1%), and MAM-(0.4%), obesity-19 (1.3%), overweight-43 (4.3%). An even greater number of children were leaning towards SAM or MAM as well as obesity or overweight. Children who are not yet at the BMI-for-age threshold for the current definition of SAM or MAM (and childhood obesity or overweight) may be at an increased risk of developing severe forms of under-nutrition or obesity. One of the present study’s aims was to identify these target groups so that these children’s needs could be addressed.

The first target group, undernourished children (BMI or MUAC Z-score between -1 and -2 SD), is at risk of sliding into MAM or SAM. The second group, pre-obese children (BMI or MUAC Z-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. Based on the BMI Z-scores, 181 (12.5%) were undernourished and 136 (9.4%) were pre-obese. The equivalent numbers for MUAC were 181 (12.5%) for SAM and MAM risk and 135 (9.3%) for obesity, respectively. More children were at risk of severe undernutrition than of overnutrition. These target groups may develop more severe forms of malnutrition if corrective measures are delayed. The first step in that direction is to plan face-to-face counseling sessions with parents and children. School programs are effective at preventing childhood obesity by fostering more physical activities and recommending healthier diets [18]. Counseling for the target groups will have to be done, keeping in mind that within low-resource settings, places for play may be scarce, sports infrastructure may be poor, and recreational centers may be lacking [19]. Similarly, low family income is linked to greater consumption of low-quality nutrition and fast food [20].

Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting both under and over-nutrition during routine growth monitoring without a height-dependent parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated with each other. However, monitoring for obesity should begin even earlier, as the most rapid weight gain occurs between ages 2 and 6 years among obese adolescents [21].

While India's economy has been growing at an impressive rate, the country still has the highest number of stunted children in the world (46.8 million), representing one-third of the global total of stunted children under age 5 [22].Stunting is associated with being overweight among children in countries that are undergoing a nutritional transition [23].Economic improvements are accompanied by a conspicuous change in dietary patterns in the form of increased fat intake [5] compounded by exposure to food advertising on television leading to fast food and soft drink consumption and obesity [24]. This, coupled with low physical activity, contributes to an increasing prevalence of obesity among adults, which accompanies the first wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus, called “the new world syndrome” [25]. It should be noted, however, that there has not been the same level of agreement on the classification of obesity for children and adolescents as there is for adults [26].

To summarize, until recently, India has considered under-nutrition to be a major problem, and nutrition supplementation has been the key intervention. At the national level, India is at stage 1 of the obesity transition with wide sub-national variations [27]. Our study may help in the surveillance effort to address underserved populations [27]. With improved availability of food, a double burden of malnutrition is emerging that needs to be concurrently addressed. The present study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and undernourished states among Indian school children in lower-middle and lower socioeconomic levels. Second, the present results revealed a significant correlation between BMI and MUAC. This study provides evidence to suggest that MUAC is a valid, single measurement for identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-nutrition on the other, through extended routine growth monitoring of children. However, more studies are required to establish validity and reliability of this tool.

What is known about the subject?

- Emerging economies face a dual problem of under-nutrition and over-nutrition.
- Detecting this problem using height-based parameters is not easy in a low-resource setting.

What this study adds?

This study suggests that MUAC is a simple, valid, and single measure for identifying this dual problem in a low-resource setting and, undernutrition is a bigger problem than obesity.

Funding statement: This research received no specific grant from any funding agency in public, commercial, or not-for-profit sectors.

Declaration of interests: All authors have completed the ICMJE uniform disclosure form at and confirm no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Author contributions

SD-Conceptualization; **Data analysis**; **Manuscript writing**.

SM-Data collection; data analysis; manuscript writing.

AK- Data analysis; manuscript writing.

ED- Data collection; manuscript writing.

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Table 1

Correlations between anthropometric parameters among girls (N=424)

Variables		**MUAC**	**Body weight (Kg)**	**Height (cm)**	**BMI**
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
Body weight (Kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

** Correlation is significant at the 0.01 level (2-tailed).

Table 2
Correlations between anthropometric parameters among boys (N=1020)

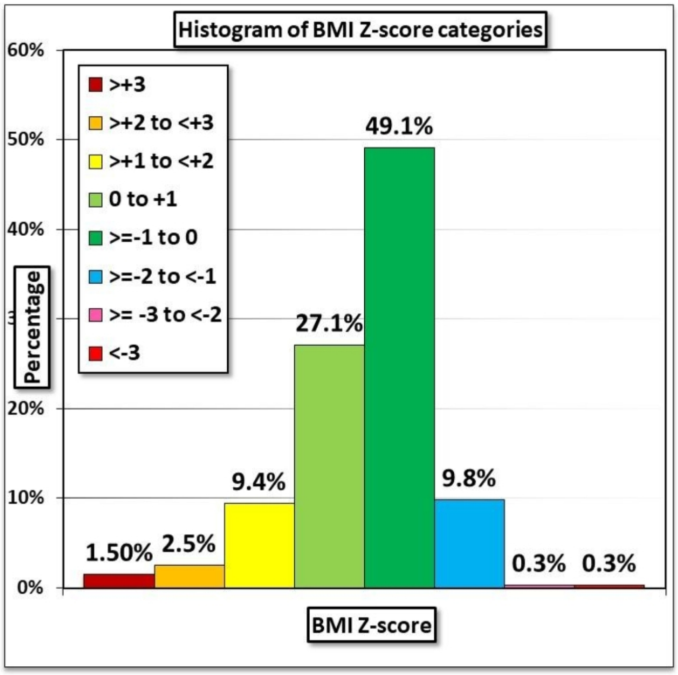
Variables		MUAC	Body weight (Kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.911(**)	.780(**)	.847(**)
	p-value		0.0001	9.60E-210	2.21E-281
Body weight (Kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	p-value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	p-value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	p-value	2.21E-281	1.25E-301	1.02E-86	

** Correlation is significant at the 0.01 level (2-tailed).

Table 3
Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	**Based on BMI Z-scores No (%)**	**Based on MUAC Z-scores No (%)**
Pre-obese	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to 2SD 135 (9.3%)
Overweight	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)
Obese	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
Thin	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
Severely thin	BMI <-3SD 5 (0.3%)	MUAC<-3 SD 1(0.1%)

**Modified WHO Classification of nutrition conditions based on anthropometry
BMI = Body Mass Index; MUAC = Mid-upper-arm circumference



215x279mm (300 x 300 DPI)

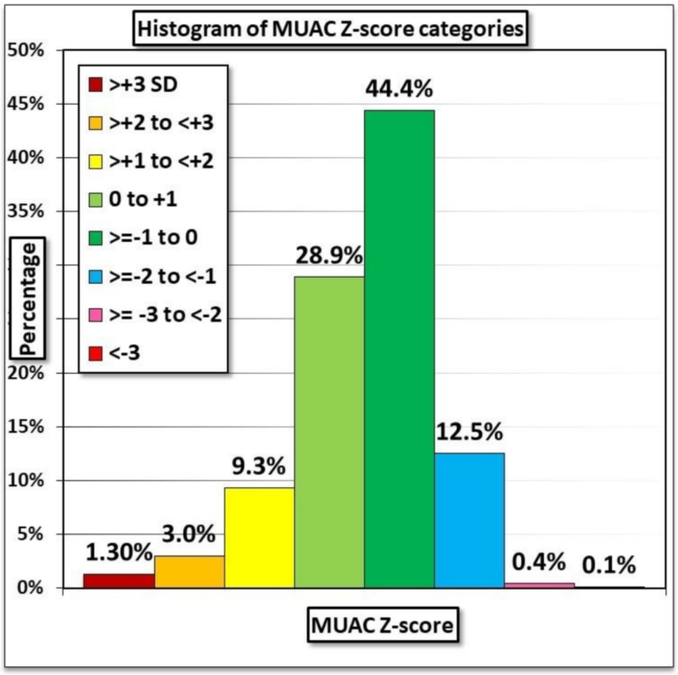


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Table 1 (S)
Comparison of variables between girls and boys

Variables ^	Girls (n=424)				Boys (n=1020)				Mann-Whitney Test	
	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Z-value	p-value
Age (years)	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	**2.44E-07 ***
Height (cm)	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	**3.44E-11 ***
Body weight (kg)	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	**5.41E-13 ***
BMI	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	**1.66E-13 ***
MUAC	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	**4.59E-10 ***

^ All data failed a" Normality Test," so a Mann-Whitney U Rank Sum Test was applied.
* Difference is statistically significant.
BMI=Body Mass Index; MUAC=Mid-upper-arm circumference

Table2 (S)
Distribution of variables among all participants

Variables	Mean	SD	Median	IQR	Minimum	Maximum
Age (years)	8.46	3.50	9.00	6.00	3.00	16.00
Body weight (kg)	27.04	13.77	23.10	16.20	9.00	97.50
Height (cm)	131.45	21.16	130.00	32.00	84.00	188.00
Height (meters)	1.31	0.21	1.30	0.32	0.84	1.88
BMI	14.69	3.10	13.78	2.89	6.58	36.10
MAC	18.53	3.57	17.50	4.30	12.20	35.00

SD = standard deviation; IQR = inter-quartile range; BMI = Body Mass Index; MUAC =Mid-upper-arm circumference

Table 3 (S)
Age-wise distribution of BMI among all participants

Age (years)	BMI			
	Mean	SD	Median	IQR
3	13.37	1.34	13.26	1.61
4	13.04	1.69	13.07	1.46
5	13.01	1.13	12.80	1.02
6	13.85	2.09	13.39	1.55
7	13.54	1.48	13.20	1.90
8	13.94	2.22	13.37	2.01
9	13.70	1.73	13.36	1.66
10	14.74	2.84	13.97	2.77
11	15.48	3.03	14.89	3.60
12	15.89	3.01	15.63	3.87
13	18.22	3.34	17.51	3.30
14	18.33	3.88	17.28	4.53
15	19.09	4.32	18.01	6.52
16	21.38	5.89	23.55	11.09

SD = standard deviation; IQR = inter-quartile range

Table 4 (S)
Age-wise distribution of MUAC among all participants

Age (years)	MUAC			
	Mean	SD	Median	IQR
3	15.39	1.24	15.20	1.50
4	15.50	1.16	15.50	1.10
5	16.19	1.17	15.95	1.20
6	16.83	2.07	16.50	1.95
7	16.98	1.75	16.70	2.00
8	17.97	2.11	17.50	1.61
9	17.79	1.78	17.50	2.08
10	19.02	2.63	18.50	3.45
11	20.16	3.04	19.50	3.93
12	20.87	2.79	20.50	4.00
13	22.91	2.79	22.50	2.60
14	23.53	3.64	23.00	4.95
15	24.66	3.73	23.50	5.23
16	25.81	4.63	27.20	7.75

SD = standard deviation; IQR = inter-quartile range

Table 5 (S)
Homogeneous Subsets: BMI: Tukey HSD

Age (years)	No.	Subset for alpha = 0.05					
		1	2	3	4	5	6
5	132	13.011					
4	146	13.038					
3	102	13.366	13.366				
7	156	13.537	13.537				
9	72	13.696	13.696				
6	109	13.852	13.852	13.852			
8	65	13.939	13.939	13.939			
10	220		14.740	14.740	14.740		
11	182			15.481	15.481		
12	77				15.892		
13	30					18.224	
14	72					18.325	
15	72					19.094	
16	9						21.380
Sig.		0.836	0.232	0.059	0.529	0.892	1.000

Means for groups in homogeneous subsets are displayed.
BMI = Body Mass Index

Table 6 (S)
Homogeneous Subsets: MUAC: Tukey HSD (Table No. 4)

Age (years)	No.	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
3	102	15.385								
4	146	15.500	15.500							
5	132	16.194	16.194							
6	109	16.826	16.826	16.826						
7	156		16.979	16.979						
9	72			17.794	17.794					
8	65			17.972	17.972					
10	220				19.015	19.015				
11	182					20.161	20.161			
12	77						20.871			
13	30							22.907		
14	72							23.532	23.532	
15	72								24.658	24.658
16	9									25.811
Sig.		0.102	0.08	0.421	0.314	0.423	0.961	0.987	0.452	0.412

Means for groups in homogeneous subsets are displayed.
MUAC = Mid-upper-arm circumference

Table 7 (S)
Association among the cases between BMI (Z-Score) internally and by gender

Internal BMI (Z-Score)		Gender		Total
		Female	Male	
>+3	No.	5	16	21
	%	1.2%	1.6%	1.5%
>+2 to <+3	No.	11	25	36
	%	2.6%	2.5%	2.5%
>+1 to <+2	No.	47	89	136
	%	11.1%	8.7%	9.4%
0 to +1 ^	No.	109	282	391
	%	25.7%	27.6%	27.1%
>=-1 to 0 ^	No.	209	500	709
	%	49.3%	49.0%	49.1%
>=-2 to <-1 ^	No.	39	102	141
	%	9.2%	10.0%	9.8%
>= -3 to <-2 ^	No.	3	2	5
	%	0.7%	0.2%	0.3%
<-3 ^	No.	1	4	5
	%	0.2%	0.4%	0.3%
Total	No.	424	1020	1444
	%	100.0%	100.0%	100.0%

Chi-Square Test	Value	df	p-value	Association
Pearson’s Chi-Square $	5.199	7	0.636	Not significant
Pearson’s Chi-Square ^	2.262	3	0.520	Not significant

$ 4 cells (25.0%) have expected count less than 5. **^ Row data pooled and Chi-Square test reapplied.**

BMI = Body Mass Index

Table 8 (S)

Association among the cases between MUAC (Z-Score) internally and by gender

Internal MUAC (Z-Score)		Gender		Total
		Female	Male	
>+3 SD	No.	3	16	19
	%	0.7%	1.6%	1.3%
>+2 to <+3	No.	17	26	43
	%	4.0%	2.5%	3.0%
>+1 to <+2	No.	38	97	135
	%	9.0%	9.5%	9.3%
0 to +1 ^	No.	131	287	418
	%	30.9%	28.1%	28.9%
>=-1 to 0 ^	No.	178	463	641
	%	42.0%	45.4%	44.4%
>=-2 to <-1 ^	No.	55	126	181
	%	13.0%	12.4%	12.5%
>= -3 to <-2 ^	No.	2	4	6
	%	0.5%	0.4%	0.4%
<-3 ^	No.	0	1	1
	%	0.0%	0.1%	0.1%
Total	No.	424	1020	1444
	%	100.0%	100.0%	100.0%

Chi-Square Test	Value	df	p-value	Association
Pearson's Chi-Square $	6.054	7	0.533	Not significant
Pearson's Chi-Square ^	3.929	3	0.269	Not significant

$ 4 cells (25.0%) have expected count less than 5. **^ Row data pooled and Chi-Square test reapplied.**

MUAC = Mid-upper-arm circumference

BMJ Paediatrics Open

Double burden of malnutrition among Indian school children and its measurement: A cross-sectional study in a single school

Short title: Measuring double burden of malnutrition

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2019-000505.R3
Article Type:	Original research
Date Submitted by the Author:	15-Nov-2019
Complete List of Authors:	Daga, Subhashchandra; Pacific Medical College and Hospital, Pediatrics Mhatre, Sameer; Smt Kashibai Navale Medical College and General Hospital, Paediatrics Kasbe, Abhiram ; Topiwala National Medical College DSouza, Eric; MIMER
Keywords:	General Paediatrics, Obesity, School Health, Tropical Paediatrics, Growth

Double burden of malnutrition among Indian school children and its measurement: A cross-sectional study in a single school

Short title: Measuring double burden of malnutrition

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Abstract

Objective

This cross-sectional study set in a single school on the outskirts of a large city aimed to document the extent of double burden of malnutrition (coexistence of over- and under-nutrition) among Indian schoolchildren from lower socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used as a proxy for body mass index (BMI).

Subjects

The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to playgroups and grades 1–7.

Measurements

Anthropometric measurements, such as participants’MUAC, height, and weight were measured using standard techniques. Descriptive statistics for BMI and MUACwere obtained based on gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The distribution of variables was calculatedforthree groups:girls, boys, and all participants. Homogeneous subsets for BMI and MUAC were identified in the three groups. Age-wise comparisons of BMI and MUACwere conducted for each gender.

Main outcome measures

1. To know if MUAC and BMI are correlated among boys and girls.

2. To study BMI and MUAC Z score distribution among the participants.

Results

MUACwas positively correlated with BMI inboth boys and girls. The following BMI Z-score distribution was observed: severe acute malnutrition (SAM), 5(0.3%); moderate acute malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%); obese, 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%). The distribution of categories of children based on MUAC Z-scores was: SAM, 7(0.5%), MAM, 181 (12.5%), and undernourished at risk of MAM or SAM, 181 (12.5%); obese, 19 (1.3%), overweight, 178 (12.3%), pre-obese, 135 (9.3%).

Conclusions

SAM/MAM/undernourished states and obesity/overweight/pre-obese states, indicating undernutrition more than overweight, coexist among Indian schoolchildren from lower middle/lower socioeconomic categories. BMI and MUAC were significantly correlated. MUACidentifies both under-nutrition and over-nutrition by early detection of aberrant growth.

Introduction

The double burden of under-nutrition and over-nutrition is an emerging international problem. According to estimates from 129 countries with available data, 57 experience serious problems of both undernourished children and overweight adults [1]. The relationship between under-nutrition and overweight status and obesity is deeper than coexistence. The double burden of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within individuals, households, and populations and across the life course. “Across the life course” refers to the phenomenon that under-nutrition early in life contributes to an increased propensity for over-nutrition during adulthood [2]. The occurrence of DBM is attributed to a complex interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic transitions, etc.) from high fertility and early deaths to low fertility and aging populations and epidemiological transitions from communicable to non-communicable diseases [2].

Later in the life course, the double burden of disease is characterized by the coexistence of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s, obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-nutrition was a major problem, and nutrition supplementation was the main intervention. Thus, obesity is a relatively new problem in need of attention**.** A systematic review of obesity and socioeconomic status in low and middle incomecountries concluded that child obesity is more prevalent among affluent groups in such countries [4]. This may be attributed to improved access to surplus/excess food and a higher degree of urbanization and technological progress in these economies that render activities less laborious, resulting in less energy expenditure [5]. Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese study revealed that approximately one-third of obese children grew into obese adults [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress, is more likely to succeed than attempting to reverse obesity later.

Body mass index (BMI)-for-age, the internationally recommended measure of obesity, suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health Organization (WHO) recommends lowering the BMI cut-offs for being considered “overweight” among Asian adults [8]in light of the increased health risks. Early detection of overweight status has become very important in Asia.

The selection of height-based parameters, such as BMI for the detection of overweight/obese children in low-resource settings, has limitations because of the shortage of stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent study from the Netherlands reaffirmed that, compared with BMI,MUAC is a valid measure for detecting overweight/obesity, and thus is a good alternative to BMI [15].Health workers are familiar with MUAC measurement, as it has been commonly used for identifying severe acute under-nutrition among young (6–60 months of age) children [16].

To our knowledge, few studies have focused on the coexistence of under- and over-nutrition in India. The present study was conducted to document the extent of DBM among Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect trends toward obesity or severe acute malnutrition (SAM).

Participants and Methods

Setting

A single schoolcross-sectional study was conducted with schoolchildren from the outskirts of Pune, India. This study was part of the MIMER medical college and hospital's outreach activities regarding annual school health check-ups. A schedule of class-wise health check-ups was developed in consultation with the school authorities who, in turn, sought parents' permission. The study had the approval of the ethics committee of MIMER medical college and hospital, TalegaonDabhade. A majority of the children belonged to lower and lower-middle socioeconomic categories. Children between 3 and 5 years were from a playgroup, and those between 6 and 12 years belonged to grades 1–7.

Anthropometric measurements

Anthropometric measurements, such as MUAC, height, and weight, were taken from each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy Care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic plastic tape at the midway between the olecranon and acromion processes on the upper left arm. During these measurements, the participant was in a comfortable standing position and was asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm was straightened, and we ensured that the tape was neither too tight nor too loose.

Statistical tools

Open Source Statistical Software PSPP version 1.0.1was used for all analyses, and a p-value ≤0.05 was considered statistically significant. Mean and standard deviation (SD), median, inter-quartile range, and Z-scores for BMI and MUACwere computed by sex for participants with complete measurements. Z-scores were computed using age-specific and sex-specific reference data from the WHO [17]. The distribution of variables was calculated among all participants together and separately for boys and girls. Homogeneous subsets for BMI and

MUACwere identified in these three groups. Age-wise comparisons of BMI and MUACwere calculated for both girls and boys.

Patient involvement

Patients were not directly involved in the design of this study.

Results

The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The distribution of Z- scores among all participants is shown in Figures 1 and 2. Age, height, weight, MUAC, and BMI were all significantly different between girls and boys; boys had higher values for all parameters (Suppl. Files: Tables 1 and 2). As expected, BMI and MUAC showed age-wise differences for all participants, combined and separately, for boys and girls, between the ages of 3 to 16 years (Suppl. Files: Tables 3 and 4). Tukey's honest significant difference (HSD) test for homogeneous subsets revealed a significant shift in mean BMI at 3, 6, and 10 years (Suppl. Files: Table 5), whereas for MUAC, the shift occurred at 4, 6, and 9 years (Suppl. Files: Table 6). Thereafter, MUAC changed significantly almost every year until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI change with age was minimal in girls (only at age 14) compared to changes in boys at 6, 10, 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at age 4 years, compared to nine subsets in boys, with the first shift at age 5. Thus, changes in BMI and MUAC were more frequent in boys. MUAC was associated with weight, height, and BMI both in girls and boys (Tables 1 and 2).

Table 1
Correlations between anthropometric parameters among girls (N=424)

145

Variables		MUAC	Body weight (kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
Body weight (kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

146 ** Correlation is significant at the 0.01 level (2-tailed).

147 **Table 2**

148 **Correlations between anthropometric parameters among boys (N=1020)**

149

Variables		MUAC	Body weight (kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.911(**)	.780(**)	.847(**)
	p-value		0.0001	9.60E-210	2.21E-281
Body weight (kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	p-value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	p-value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	p-value	2.21E-281	1.25E-301	1.02E-86	

150 ** Correlation is significant at the 0.01 level (2-tailed).

The distribution of clinical categories of nutritional status with respect to BMI and MUAC is shown in Table 3.

Table 3
Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	Based on BMI Z-scores No (%)	Based on MUACZ-scores No (%)
Pre-obese	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to2SD 135 (9.3%)
Overweight	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)
Obese	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
Thin	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
Severely thin	BMI <-3SD 5 (0.3%)	MUAC<-3 SD 1(0.1%)

**Modified WHO Classification of nutrition conditions based on anthropometry
BMI = Body Mass Index; MUAC = Mid-upper-arm circumference

Discussion

The present study suggests that DBM has reached Indian school children of lower middle or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results identify children at the brink of sliding into severe forms of under- and over-nutrition. The present study also suggests using a single and simpler method, MUAC, for detecting both forms of malnutrition by monitoring growth during routine health check-ups.

The World Health Assembly targets were considered in crafting the 2030 development agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the existence of the double burden of under-nutrition and overweight status. While the drivers of the double burden of malnutrition are varied and often insidious, their effects present a clear case for urgent action and demand an integrated response. Using a single tool for detecting both forms of malnutrition integrates and simplifies the process.

To our knowledge, few studies have focused on this aspect of growth among children in India, as well as other emerging economies. The girls were outnumbered by boys (424 vs. 1,020). This may be due tothe traditional gender norms that push girls into helping with household chores and sibling care, resulting in school dropouts. Based on BMI Z-Scores, 5 (0.3%) and 5 (0.3%) belonged to SAM and MAM categories, respectively, and 21(1.5%) and 36 (3.9%) children were classified as obese and overweight, respectively. MUAC Z-scores suggested the following distribution: SAM -1(0.1%), MAM-(0.4%), obesity-19 (1.3%), overweight-43 (4.3%).An even greater number of children were leaning toward SAM or MAM as well as obesity or overweight. Children who are not yet at the BMI-for-age threshold for the current definition of SAM or MAM (and childhood obesity or overweight) may be at an increased risk of developing severe forms of under-nutrition or obesity. One of the present study’s aims was to identify these target groups so that these children’s needs could be addressed.

The first target group, undernourished children (BMI or MUACZ-score between -1 and -2 SD), is at risk of sliding into MAM or SAM. The second group, pre-obese children (BMI or MUACZ-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. Based on the BMI Z-scores, 181 (12.5%) were undernourished, and 136 (9.4%) were pre-obese. The equivalent numbers for MUACwere 181 (12.5%) for SAM and MAM risk and 135 (9.3%) for obesity, respectively. More children were at risk of severe undernutrition than ofovernutrition. These target groups may develop more severe forms of malnutrition if corrective measures are delayed. The first step in that direction is to plan face-to-face counseling sessions with parents and children. School programs are effective at preventing childhood obesity by fostering more physical activities and recommending healthier diets [18]. Counseling for the target groups will have to be done, keeping in mind that within low-resource settings, places for play may be scarce, sports infrastructure may be poor, and recreational centers may be lacking [19]. Similarly, low family income is linked to greater consumption of low-quality nutrition and fast food [20].

Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting both under and over-nutrition during routine growth monitoring without a height-dependent parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated with each other. However, monitoring for obesity should begin even earlier, as the most rapid weight gain occurs between ages 2 and 6yearsamong obese adolescents [21].

While India's economy has been growing at an impressive rate, the country still has the highest number of stunted children in the world (46.8 million), representing one-third of the global total of stunted children under age 5 [22].Stunting is associated with being overweight among children in countries that are undergoing a nutritional transition [23].Economic improvements are accompanied by a conspicuous change in dietary patterns in the form of increased fat intake [5]compounded by exposure to food advertising on television leading to fast food and soft drink consumption and obesity [24].This, coupled with low physical activity, contributes to an increasing prevalence of obesity among adults, which accompanies the first wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus, called “the new world syndrome” [25]. It should be noted, however, that there has not been the same level of agreement on the classification of obesity for children and adolescents as there is for adults [26].

To summarize, until recently, India has considered under-nutrition to be a major problem, and nutrition supplementation has been the key intervention. At the national level, India is at stage 1 of the obesity transition with wide sub-national variations [27]. Our study may help in the surveillance effort to address underserved populations [27]. With improved availability of food, a double burden of malnutrition is emerging that needs to be concurrently addressed. The present study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and undernourished states among Indian school children in lower-middle and lower socioeconomic levels. Second, the present results revealed a significant correlation between BMI and MUAC. This study provides evidence to suggest that MUAC is a valid, single measurement for identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-nutrition on the other, through extended routine growth monitoring of children. However, more studies are required to establish the validity and reliability of this tool.

What is known about the subject?

- Emerging economies face a dual problem of under-nutrition and over-nutrition.
- Detectingthese problems using height-based parameters is not easy in a low-resource setting.

What this study adds?

This study suggests that MUAC is a simple, valid, and single measure for identifying this dual problem in a low-resource setting, and undernutrition is a bigger problem than obesity.

Funding statement: This research received no specific grant from any funding agency in public, commercial, or not-for-profit sectors.

Declaration of interests: All authors have completed the ICMJE uniform disclosure form and confirm no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Author contributions

SD-Conceptualization; Data analysis; Manuscript writing.

SM-Data collection; data analysis; manuscript writing.

AK-Data analysis; manuscript writing.

ED-Data collection; manuscript writing.

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Table 1

333 **Correlations between anthropometric parameters among girls (N=424)**
334

Variables		**MUAC**	**Body weight (kg)**	**Height (cm)**	**BMI**
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
Body weight (kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

335 ** Correlation is significant at the 0.01 level (2-tailed).

Table 2
Correlations between anthropometric parameters among boys (N=1020)

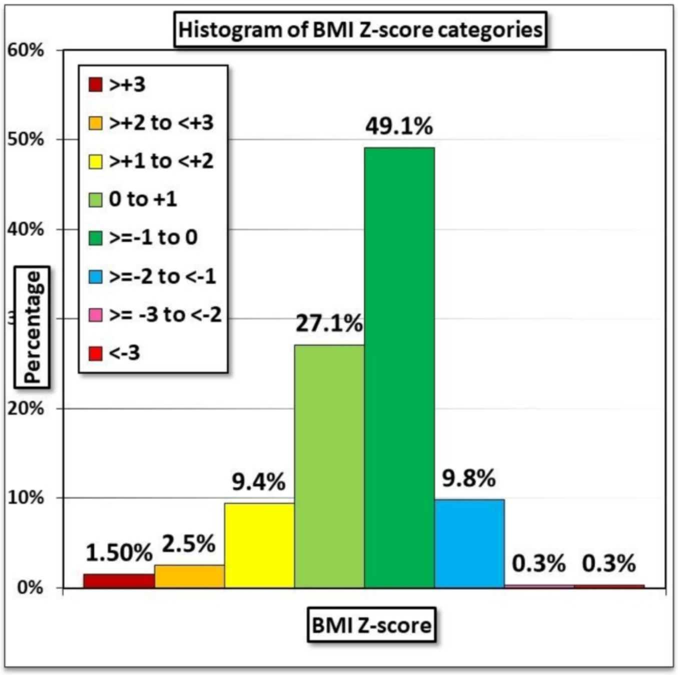
Variables		**MUAC**	**Body weight (kg)**	**Height (cm)**	**BMI**
MUAC	Pearson Correlation	1	.911(**)	.780(**)	.847(**)
	p-value		0.0001	9.60E-210	2.21E-281
Body weight (kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	p-value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	p-value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	p-value	2.21E-281	1.25E-301	1.02E-86	

** Correlation is significant at the 0.01 level (2-tailed).

Table 3
Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	**Based on BMI Z-scores** **No (%)**	**Based on MUACZ-scores** **No (%)**
Pre-obese	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to2SD 135 (9.3%)
Overweight	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)
Obese	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
Thin	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
Severely thin	BMI <-3SD 5 (0.3%)	MUAC<-3 SD 1(0.1%)

**Modified WHO Classification of nutrition conditions based on anthropometry
BMI = Body Mass Index; MUAC = Mid-upper-arm circumference



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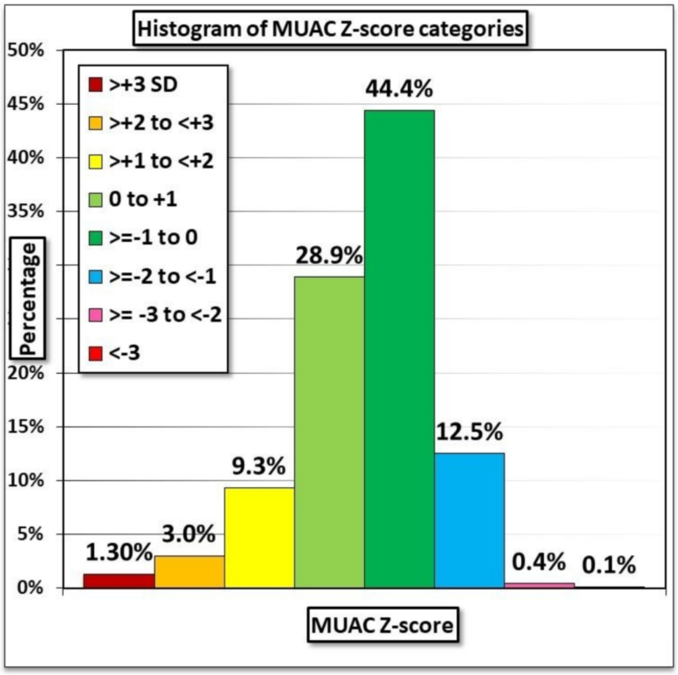

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Table 1 (S)
Comparison of variables between girls and boys

Variables ^	**Girls (n=424)**				**Boys (n=1020)**				**Mann-Whitney Test**	
	Mean	**SD**	**Median**	**IQR**	**Mean**	**SD**	**Median**	**IQR**	**Z-value**	**p-value**
Age (years)	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	**2.44E-07 ***
Height (cm)	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	**3.44E-11 ***
Body weight (kg)	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	**5.41E-13 ***
BMI	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	**1.66E-13 ***
MUAC	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	**4.59E-10 ***

^ All data failed a" Normality Test," so a Mann-Whitney U Rank Sum Test was applied.
* Difference is statistically significant.
BMI=Body Mass Index; MUAC=Mid-upper-arm circumference

Table2 (S)
Distribution of variables among all participants

Variables	Mean	SD	Median	IQR	Minimum	Maximum
Age (years)	8.46	3.50	9.00	6.00	3.00	16.00
Body weight (kg)	27.04	13.77	23.10	16.20	9.00	97.50
Height (cm)	131.45	21.16	130.00	32.00	84.00	188.00
Height (meters)	1.31	0.21	1.30	0.32	0.84	1.88
BMI	14.69	3.10	13.78	2.89	6.58	36.10
MUAC	18.53	3.57	17.50	4.30	12.20	35.00

SD = standard deviation; IQR = inter-quartile range; BMI = Body Mass Index; MUAC =Mid-upper-arm circumference

Table 3 (S)
Age-wise distribution of BMI among all participants

Age (years)	BMI			
	Mean	SD	Median	IQR
3	13.37	1.34	13.26	1.61
4	13.04	1.69	13.07	1.46
5	13.01	1.13	12.80	1.02
6	13.85	2.09	13.39	1.55
7	13.54	1.48	13.20	1.90
8	13.94	2.22	13.37	2.01
9	13.70	1.73	13.36	1.66
10	14.74	2.84	13.97	2.77
11	15.48	3.03	14.89	3.60
12	15.89	3.01	15.63	3.87
13	18.22	3.34	17.51	3.30
14	18.33	3.88	17.28	4.53
15	19.09	4.32	18.01	6.52
16	21.38	5.89	23.55	11.09

SD = standard deviation; IQR = inter-quartile range

Table 4 (S)
Age-wise distribution of MUAC among all participants

Age (years)	MUAC			
	Mean	SD	Median	IQR
3	15.39	1.24	15.20	1.50
4	15.50	1.16	15.50	1.10
5	16.19	1.17	15.95	1.20
6	16.83	2.07	16.50	1.95
7	16.98	1.75	16.70	2.00
8	17.97	2.11	17.50	1.61
9	17.79	1.78	17.50	2.08
10	19.02	2.63	18.50	3.45
11	20.16	3.04	19.50	3.93
12	20.87	2.79	20.50	4.00
13	22.91	2.79	22.50	2.60
14	23.53	3.64	23.00	4.95
15	24.66	3.73	23.50	5.23
16	25.81	4.63	27.20	7.75

SD = standard deviation; IQR = inter-quartile range

Table 5 (S)
Homogeneous Subsets: BMI: Tukey HSD

Age (years)	No.	Subset for alpha = 0.05					
		1	2	3	4	5	6
5	132	13.011					
4	146	13.038					
3	102	13.366	13.366				
7	156	13.537	13.537				
9	72	13.696	13.696				
6	109	13.852	13.852	13.852			
8	65	13.939	13.939	13.939			
10	220		14.740	14.740	14.740		
11	182			15.481	15.481		
12	77				15.892		
13	30					18.224	
14	72					18.325	
15	72					19.094	
16	9						21.380
Sig.		0.836	0.232	0.059	0.529	0.892	1.000

Means for groups in homogeneous subsets are displayed.
BMI = Body Mass Index

Table 6 (S)
Homogeneous Subsets: MUAC: Tukey HSD (Table No. 4)

Age (years)	No.	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
3	102	15.385								
4	146	15.500	15.500							
5	132	16.194	16.194							
6	109	16.826	16.826	16.826						
7	156		16.979	16.979						
9	72			17.794	17.794					
8	65			17.972	17.972					
10	220				19.015	19.015				
11	182					20.161	20.161			
12	77						20.871			
13	30							22.907		
14	72							23.532	23.532	
15	72								24.658	24.658
16	9									25.811
Sig.		0.102	0.08	0.421	0.314	0.423	0.961	0.987	0.452	0.412

Means for groups in homogeneous subsets are displayed.
MUAC = Mid-upper-arm circumference

Table 7 (S)
Association among the cases between BMI (Z-Score) internally and by gender

Internal BMI (Z-Score)		Gender		Total
		Female	Male	
>+3 (Obese)	No.	5	16	21
	%	1.2%	1.6%	1.5%
>+2 to <+3 (Overweight)	No.	11	25	36
	%	2.6%	2.5%	2.5%
>+1 to <+2 (Pre-obese)	No.	47	89	136
	%	11.1%	8.7%	9.4%
0 to +1 ^ (Normal)	No.	109	282	391
	%	25.7%	27.6%	27.1%
>=-1 to 0 ^ (Normal)	No.	209	500	709
	%	49.3%	49.0%	49.1%
>=-2 to <-1 ^ (ROU**)	No.	39	102	141
	%	9.2%	10.0%	9.8%
>= -3 to <-2 ^ MAM (Thin)	No.	3	2	5
	%	0.7%	0.2%	0.3%
<-3 ^ SAM (Severely thin)	No.	1	4	5
	%	0.2%	0.4%	0.3%
Total	No.	424	1020	1444
	%	100.0%	100.0%	100.0%

BMI = Body Mass Index. ROU= Risk of underweight. MAM= Moderate acute malnutrition. SAM= Severe acute malnutrition

Table 8 (S)

Association among the cases between MUAC (Z-Score) internally and by gender

Internal MUAC (Z-Score)		Gender		Total
		Female	Male	
>+3 SD (Obese)	No.	3	16	19
	%	0.7%	1.6%	1.3%
>+2 to <+3 (Overweight)	No.	17	26	43
	%	4.0%	2.5%	3.0%
>+1 to <+2 (Pre-obese)	No.	38	97	135
	%	9.0%	9.5%	9.3%
0 to +1 ^ (Normal)	No.	131	287	418
	%	30.9%	28.1%	28.9%
>=-1 to 0 ^ (Normal)	No.	178	463	641
	%	42.0%	45.4%	44.4%
>=-2 to <-1 ^ (ROU)	No.	55	126	181
	%	13.0%	12.4%	12.5%
>= -3 to <-2 ^ (MAM)	No.	2	4	6
	%	0.5%	0.4%	0.4%
<-3 ^ (SAM)	No.	0	1	1
	%	0.0%	0.1%	0.1%
Total	No.	424	1020	1444
	%	100.0%	100.0%	100.0%

MUAC = Mid-upper-arm circumference. ROU= Risk of underweight. MAM= Moderate acute malnutrition. SAM= Severe acute malnutrition

BMJ Paediatrics Open

Double burden of malnutrition among Indian school children and its measurement: A cross-sectional study in a single school

Short title: Measuring double burden of malnutrition

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2019-000505.R4
Article Type:	Original research
Date Submitted by the Author:	02-Dec-2019
Complete List of Authors:	Daga, Subhashchandra; Pacific Medical College and Hospital, Pediatrics Mhatre, Sameer; Smt Kashibai Navale Medical College and General Hospital, Paediatrics Kasbe, Abhiram ; Topiwala National Medical College DSouza, Eric; MIMER
Keywords:	General Paediatrics, Obesity, School Health, Tropical Paediatrics, Growth

Double burden of malnutrition among Indian school children and its measurement: A cross-sectional study in a single school

Short title: Measuring double burden of malnutrition

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Abstract

Objective

This cross-sectional study set in a single school on the outskirts of a large city aimed to document the extent of double burden of malnutrition (coexistence of over- and under-nutrition) among Indian schoolchildren from lower socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used as a proxy for body mass index (BMI).

Subjects

The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to playgroups and grades 1–7.

Measurements

Anthropometric measurements, such as participants' MUAC, height, and weight were measured using standard techniques. Descriptive statistics for BMI and MUAC were obtained based on gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The distribution of variables was calculated for three groups: girls, boys, and all participants. Homogeneous subsets for BMI and MUAC were identified in the three groups. Age-wise comparisons of BMI and MUAC were conducted for each gender.

Main outcome measures

1. To know if MUAC and BMI are correlated among boys and girls.

2. To study BMI and MUAC Z score distribution among the participants.

Results

MUAC was positively correlated with BMI in both boys and girls. The following BMI Z-score distribution was observed: severe acute malnutrition (SAM), 5(0.3%); moderate acute malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%); obese, 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%). The distribution of categories of children based on MUAC Z-scores was: SAM, 7(0.5%), MAM, 181 (12.5%), and undernourished at risk of MAM or SAM, 181 (12.5%); obese, 19 (1.3%), overweight, 178 (12.3%), pre-obese, 135 (9.3%).

Conclusions

SAM/MAM/undernourished states and obesity/overweight/pre-obese states, indicating undernutrition more than overweight, coexist among Indian schoolchildren from lower middle/lower socioeconomic categories. BMI and MUAC were significantly correlated. MUAC identifies both under-nutrition and over-nutrition by early detection of aberrant growth.

Introduction

The double burden of under-nutrition and over-nutrition is an emerging international problem. According to estimates from 129 countries with available data, 57 experience serious problems of both undernourished children and overweight adults [1]. The relationship between under-nutrition and overweight status and obesity is deeper than coexistence. The double burden of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within individuals, households, and populations and across the life course. “Across the life course” refers to the phenomenon that under-nutrition early in life contributes to an increased propensity for over-nutrition during adulthood [2]. The occurrence of DBM is attributed to a complex interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic transitions, etc.) from high fertility and early deaths to low fertility and aging populations and epidemiological transitions from communicable to non-communicable diseases [2].

Later in the life course, the double burden of disease is characterized by the coexistence of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s, obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-nutrition was a major problem, and nutrition supplementation was the main intervention. Thus, obesity is a relatively new problem in need of attention**.** A systematic review of obesity and socioeconomic status in low and middle income countries concluded that child obesity is more prevalent among affluent groups in such countries [4]. This may be attributed to improved access to surplus/excess food and a higher degree of urbanization and technological progress in these economies that render activities less laborious, resulting in less energy expenditure [5]. Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese study revealed that approximately one-third of obese children grew into obese adults [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress, is more likely to succeed than attempting to reverse obesity later.

Body mass index (BMI)-for-age, the internationally recommended measure of obesity, suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health Organization (WHO) recommends lowering the BMI cut-offs for being considered “overweight” among Asian adults [8] in light of the increased health risks. Early detection of overweight status has become very important in Asia.

The selection of height-based parameters, such as BMI for the detection of overweight/obese children in low-resource settings, has limitations because of the shortage of stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent study from the Netherlands reaffirmed that, compared with BMI,MUAC is a valid measure for detecting overweight/obesity, and thus is a good alternative to BMI [15].Health workers are familiar with MUAC measurement, as it has been commonly used for identifying severe acute under-nutrition among young (6–60 months of age) children [16].

To our knowledge, few studies have focused on the coexistence of under- and over-nutrition in India. The present study was conducted to document the extent of DBM among Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect trends toward obesity or severe acute malnutrition (SAM).

Participants and Methods

Setting

A single school cross-sectional study was conducted with schoolchildren from the outskirts of Pune, India. This study was part of the MIMER medical college and hospital's outreach activities regarding annual school health check-ups. A schedule of class-wise health check-ups was developed in consultation with the school authorities who, in turn, sought parents' permission. The study had the approval of the ethics committee of MIMER medical college and hospital, Talegaon Dabhade. A majority of the children belonged to lower and lower-middle socioeconomic categories. Children between 3 and 5 years were from a playgroup, and those between 6 and 12 years belonged to grades 1–7.

Anthropometric measurements

Anthropometric measurements, such as MUAC, height, and weight, were taken from each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy Care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic plastic tape at the midway between the olecranon and acromion processes on the upper left arm. During these measurements, the participant was in a comfortable standing position and was asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm was straightened, and we ensured that the tape was neither too tight nor too loose.

Statistical tools

Open Source Statistical Software PSPP version 1.0.1was used for all analyses, and a p-value ≤0.05 was considered statistically significant. Mean and standard deviation (SD), median, inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants with complete measurements. Z-scores were computed using age-specific and sex-specific reference data from the WHO [17]. The distribution of variables was calculated among all participants together and separately for boys and girls. Homogeneous subsets for BMI and

MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were calculated for both girls and boys.

Patient involvement

Patients were not directly involved in the design of this study.

Results

The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The distribution of Z- scores among all participants is shown in Figures 1 and 2. Age, height, weight, MUAC, and BMI were all significantly different between girls and boys; boys had higher values for all parameters (**Suppl. Files: Tables 1 (S) and 2 (S)**). As expected, BMI and MUAC showed age-wise differences for all participants, combined and separately, for boys and girls, between the ages of 3 to 16 years (Suppl. Files: **Tables 3 (S) and 4 (S).** Tukey's honest significant difference (HSD) test for homogeneous subsets revealed a significant shift in mean BMI at 3, 6, and 10 years (Suppl. Files**: Table 5 (S),** whereas for MUAC, the shift occurred at 4, 6, and 9 years (Suppl. Files: **Table 6 (S)).** Thereafter, MUAC changed significantly almost every year until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI change with age was minimal in girls (only at age 14) compared to changes in boys at 6, 10, 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at age 4 years, compared to nine subsets in boys, with the first shift at age 5. Thus, changes in BMI and MUAC were more frequent in boys. MUAC was associated with weight, height, and BMI both in girls and boys (Tables 1 and 2).

Table 1

Correlations between anthropometric parameters among girls (N=424)

Variables		**MUAC**	**Body weight (kg)**	**Height (cm)**	**BMI**
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
Body weight (kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

** Correlation is significant at the 0.01 level (2-tailed).

Table 2
Correlations between anthropometric parameters among boys (N=1020)

Variables		MUAC	Body weight (kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.911(**)	.780(**)	.847(**)
	p-value		0.0001	9.60E-210	2.21E-281
Body weight (kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	p-value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	p-value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	p-value	2.21E-281	1.25E-301	1.02E-86	

** Correlation is significant at the 0.01 level (2-tailed).

The distribution of clinical categories of nutritional status with respect to BMI and MUAC is shown in Table 3.

Table 3
Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	Based on BMI Z-scores No (%)	Based on MUACZ-scores No (%)
Pre-obese	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to2SD 135 (9.3%)
Overweight	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)

Obese	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
Thin	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
Severely thin	BMI <-3SD 5 (0.3%)	MUAC<-3 SD 1(0.1%)

**Modified WHO Classification of nutrition conditions based on anthropometry
BMI = Body Mass Index; MUAC = Mid-upper-arm circumference

Discussion

The present study suggests that DBM has reached Indian school children of lower middle or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results identify children at the brink of sliding into severe forms of under- and over-nutrition. The present study also suggests using a single and simpler method, MUAC, for detecting both forms of malnutrition by monitoring growth during routine health check-ups.

The World Health Assembly targets were considered in crafting the 2030 development agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the existence of the double burden of under-nutrition and overweight status. While the drivers of the double burden of malnutrition are varied and often insidious, their effects present a clear case for urgent action and demand an integrated response. Using a single tool for detecting both forms of malnutrition integrates and simplifies the process.

To our knowledge, few studies have focused on this aspect of growth among children in India, as well as other emerging economies. The girls were outnumbered by boys (424 vs. 1,020). This may be due to the traditional gender norms that push girls into helping with household chores and sibling care, resulting in school dropouts. Based on BMI Z-Scores, 5 (0.3%) and 5 (0.3%) belonged to SAM and MAM categories, respectively, and 21(1.5%) and 36 (3.9%) children were classified as obese and overweight, respectively. MUAC Z-scores suggested the following distribution: SAM -1(0.1%), MAM-(0.4%), obesity-19 (1.3%), overweight-43 (4.3%).An even greater number of children were leaning toward SAM or MAM as well as obesity or overweight. Children who are not yet at the BMI-for-age threshold for the current definition of SAM or MAM (and childhood obesity or overweight) may be at an increased risk of developing severe forms of under-nutrition or obesity. One of the present study's aims was to identify these target groups so that these children's needs could be addressed.

The first target group, undernourished children (BMI or MUACZ-score between -1 and -2 SD), is at risk of sliding into MAM or SAM. The second group, pre-obese children (BMI or MUACZ-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. Based on the BMI Z-scores, 181 (12.5%) were undernourished, and 136 (9.4%) were pre-obese. The equivalent numbers for MUAC were 181 (12.5%) for SAM and MAM risk and 135 (9.3%) for obesity, respectively. More children were at risk of severe undernutrition than of overnutrition. These target groups may develop more severe forms of malnutrition if corrective measures are delayed. The first step in that direction is to plan face-to-face counseling sessions with parents and children. School programs are effective at preventing childhood obesity by fostering more physical activities and recommending healthier diets [18]. Counseling for the target groups will have to be done, keeping in mind that within low-resource settings, places for play may be scarce, sports infrastructure may be poor, and recreational centers may be lacking [19]. Similarly, low family income is linked to greater consumption of low-quality nutrition and fast food [20].

Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting both under and over-nutrition during routine growth monitoring without a height-dependent parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated with each other. However, monitoring for obesity should begin even earlier, as the most rapid weight gain occurs between ages 2 and 6 years among obese adolescents [21].

While India's economy has been growing at an impressive rate, the country still has the highest number of stunted children in the world (46.8 million), representing one-third of the global total of stunted children under age 5 [22].Stunting is associated with being overweight among children in countries that are undergoing a nutritional transition [23].Economic improvements are accompanied by a conspicuous change in dietary patterns in the form of increased fat intake [5]compounded by exposure to food advertising on television leading to fast food and soft drink consumption and obesity [24].This, coupled with low physical activity, contributes to an increasing prevalence of obesity among adults, which accompanies the first wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus, called “the new world syndrome” [25]. It should be noted, however, that there has not been the same level of agreement on the classification of obesity for children and adolescents as there is for adults [26].

To summarize, until recently, India has considered under-nutrition to be a major problem, and nutrition supplementation has been the key intervention. At the national level, India is at stage 1 of the obesity transition with wide sub-national variations [27]. Our study may help in the surveillance effort to address underserved populations [27]. With improved availability of food, a double burden of malnutrition is emerging that needs to be concurrently addressed. The present study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and undernourished states among Indian school children in lower-middle and lower socioeconomic levels. Second, the present results revealed a significant correlation between BMI and MUAC. This study provides evidence to suggest that MUAC is a valid, single measurement for identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-nutrition on the other, through extended routine growth monitoring of children. However, more studies are required to establish the validity and reliability of this tool.

What is known about the subject?

- Emerging economies face a dual problem of under-nutrition and over-nutrition.
- Detecting these problems using height-based parameters is not easy in a low-resource setting.

What this study adds?

This study suggests that MUAC is a simple, valid, and single measure for identifying this dual problem in a low-resource setting, and undernutrition is a bigger problem than obesity.

Funding statement: This research received no specific grant from any funding agency in public, commercial, or not-for-profit sectors.

Declaration of interests: All authors have completed the ICMJE uniform disclosure form and confirm no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Author contributions

SD-Conceptualization; Data analysis; Manuscript writing.

SM-Data collection; data analysis; manuscript writing.

AK-Data analysis; manuscript writing.

ED-Data collection; manuscript writing.

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Table 1
Correlations between anthropometric parameters among girls (N=424)

Variables		MUAC	Body weight (kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
Body weight (kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

** Correlation is significant at the 0.01 level (2-tailed).

Table 2
Correlations between anthropometric parameters among boys (N=1020)

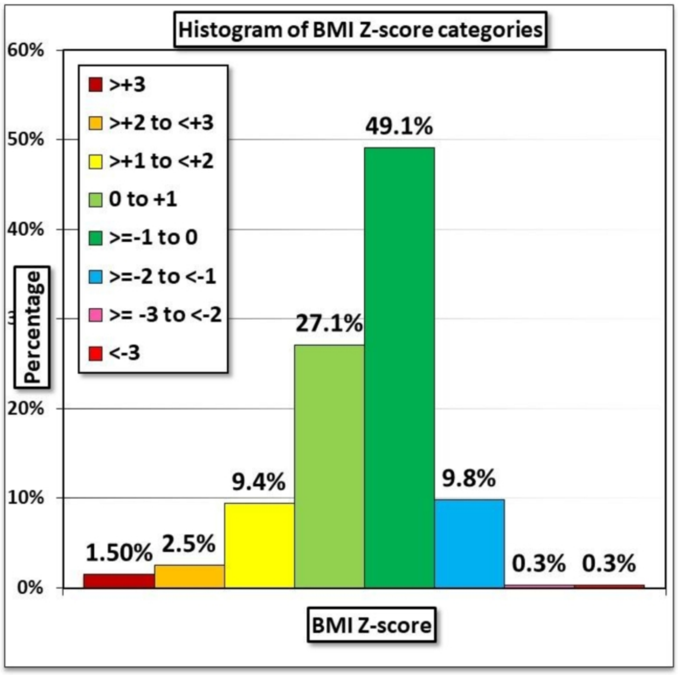
Variables		MUAC	Body weight (kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.911(**)	.780(**)	.847(**)
	p-value		0.0001	9.60E-210	2.21E-281
Body weight (kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	p-value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	p-value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	p-value	2.21E-281	1.25E-301	1.02E-86	

** Correlation is significant at the 0.01 level (2-tailed).

Table 3
Distribution of nutrition conditions based on BMI and MUAC Z-scores **

Condition	**Based on BMI Z-scores No (%)**	**Based on MUACZ-scores No (%)**
Pre-obese	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to2SD 135 (9.3%)
Overweight	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)
Obese	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
Possible risk of underweight	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
Thin	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
Severely thin	BMI <-3SD 5 (0.3%)	MUAC<-3 SD 1(0.1%)

**Modified WHO Classification of nutrition conditions based on anthropometry
BMI = Body Mass Index; MUAC = Mid-upper-arm circumference



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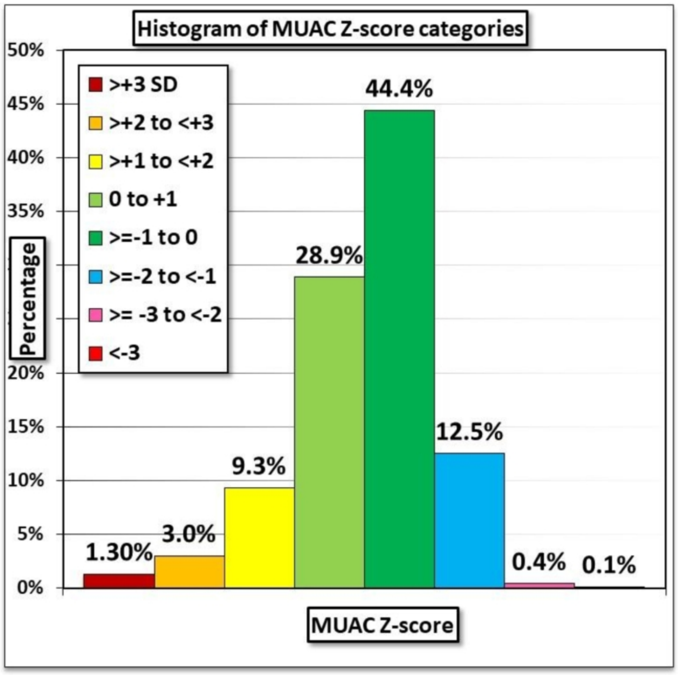

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Table 1 (S)
Comparison of variables between girls and boys

Variables ^	**Girls (n=424)**				**Boys (n=1020)**				**Mann-Whitney Test**	
	Mean	**SD**	**Median**	**IQR**	**Mean**	**SD**	**Median**	**IQR**	**Z-value**	**p-value**
Age (years)	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	**2.44E-07 ***
Height (cm)	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	**3.44E-11 ***
Body weight (kg)	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	**5.41E-13 ***
BMI	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	**1.66E-13 ***
MUAC	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	**4.59E-10 ***

^ All data failed a” Normality Test,” so a Mann-Whitney U Rank Sum Test was applied.
* Difference is statistically significant.
BMI=Body Mass Index; MUAC=Mid-upper-arm circumference

Table2 (S)
Distribution of variables among all participants

Variables	Mean	SD	Median	IQR	Minimum	Maximum
Age (years)	8.46	3.50	9.00	6.00	3.00	16.00
Body weight (kg)	27.04	13.77	23.10	16.20	9.00	97.50
Height (cm)	131.45	21.16	130.00	32.00	84.00	188.00
Height (meters)	1.31	0.21	1.30	0.32	0.84	1.88
BMI	14.69	3.10	13.78	2.89	6.58	36.10
MUAC	18.53	3.57	17.50	4.30	12.20	35.00

SD = standard deviation; IQR = inter-quartile range; BMI = Body Mass Index; MUAC =Mid-upper-arm circumference

Table 3 (S)
Age-wise distribution of BMI among all participants

Age (years)	BMI			
	Mean	SD	Median	IQR
3	13.37	1.34	13.26	1.61
4	13.04	1.69	13.07	1.46
5	13.01	1.13	12.80	1.02
6	13.85	2.09	13.39	1.55
7	13.54	1.48	13.20	1.90
8	13.94	2.22	13.37	2.01
9	13.70	1.73	13.36	1.66
10	14.74	2.84	13.97	2.77
11	15.48	3.03	14.89	3.60
12	15.89	3.01	15.63	3.87
13	18.22	3.34	17.51	3.30
14	18.33	3.88	17.28	4.53
15	19.09	4.32	18.01	6.52
16	21.38	5.89	23.55	11.09

SD = standard deviation; IQR = inter-quartile range

Table 4 (S)
Age-wise distribution of MUAC among all participants

Age (years)	MUAC			
	Mean	SD	Median	IQR
3	15.39	1.24	15.20	1.50
4	15.50	1.16	15.50	1.10
5	16.19	1.17	15.95	1.20
6	16.83	2.07	16.50	1.95
7	16.98	1.75	16.70	2.00
8	17.97	2.11	17.50	1.61
9	17.79	1.78	17.50	2.08
10	19.02	2.63	18.50	3.45
11	20.16	3.04	19.50	3.93
12	20.87	2.79	20.50	4.00
13	22.91	2.79	22.50	2.60
14	23.53	3.64	23.00	4.95
15	24.66	3.73	23.50	5.23
16	25.81	4.63	27.20	7.75

SD = standard deviation; IQR = inter-quartile range

Table 5 (S)
Homogeneous Subsets: BMI: Tukey HSD

Age (years)	No.	Subset for alpha = 0.05					
		1	2	3	4	5	6
5	132	13.011					
4	146	13.038					
3	102	13.366	13.366				
7	156	13.537	13.537				
9	72	13.696	13.696				
6	109	13.852	13.852	13.852			
8	65	13.939	13.939	13.939			
10	220		14.740	14.740	14.740		
11	182			15.481	15.481		
12	77				15.892		
13	30					18.224	
14	72					18.325	
15	72					19.094	
16	9						21.380
Sig.		0.836	0.232	0.059	0.529	0.892	1.000

Means for groups in homogeneous subsets are displayed.
BMI = Body Mass Index

Table 6 (S)
Homogeneous Subsets: MUAC: Tukey HSD (Table No. 4)

Age (years)	No.	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
3	102	15.385								
4	146	15.500	15.500							
5	132	16.194	16.194							
6	109	16.826	16.826	16.826						
7	156		16.979	16.979						
9	72			17.794	17.794					
8	65			17.972	17.972					
10	220				19.015	19.015				
11	182					20.161	20.161			
12	77						20.871			
13	30							22.907		
14	72							23.532	23.532	
15	72								24.658	24.658
16	9									25.811
Sig.		0.102	0.08	0.421	0.314	0.423	0.961	0.987	0.452	0.412

Means for groups in homogeneous subsets are displayed.
MUAC = Mid-upper-arm circumference