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# BMJ Paediatrics Open

## Double burden of malnutrition among Indian school children

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Manuscripts

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3 Double burden of malnutrition among Indian school children  
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6 *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

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3 participants, together and separately, for each gender. Homogeneous subsets for BMI  
4 and MUAC were identified the three groups. Age-wise comparisons of BMI and MUAC  
5 were also conducted for each gender.  
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## 10 11 12 **Main outcome measures**

- 13  
14 1. To know if MUAC and BMI are correlated among both boys and girls.
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17 2. To study BMI and MUAC Z score distribution among the subjects.  
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## 20 21 22 **Results**

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24 Importantly, MUAC correlated positively with BMI among both boys and girls. The  
25 following BMI Z-score distribution was observed: obese, 21 (1.5%); overweight, 36  
26 (2.5%); pre-obese, 136 (9.4%); severe acute malnutrition (SAM), 5(0.3%); moderate  
27 acute malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141  
28 (9.8%). The distribution of categories of children based on MUAC Z-scores was: obese,  
29 19; overweight, 178; pre-obese, 135; SAM, 7; MAM, 181; undernourished, at risk of  
30 MAM/SAM, 181  
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## 41 42 43 **Conclusions**

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

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3 in developing countries concluded that child obesity is more prevalent among affluent  
4 groups within developing countries (4). This may be attributed to improved access to  
5 surplus/excess food and a higher degree of urbanization and technological progress in  
6 these economies that render activities less laborious, resulting in less energy  
7 expenditure (5). Thus, economic advancement seems inevitably associated with a  
8 rapidly increasing prevalence of obesity. Furthermore, childhood obesity is a strong  
9 predictor of adult obesity. For instance, a Japanese study revealed that approximately  
10 one-third of obese children grew into obese adults (6). Therefore, early detection of  
11 excessive weight gain, and action to prevent its progress, is more likely to succeed than  
12 attempting to reverse obesity later.  
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27 Body mass index (BMI)-for-age, the internationally recommended measure of obesity,  
28 suggests that Asians are at an increased risk of cardio-metabolic disorders, even at  
29 lower BMI levels, because of a considerably higher body fat percentage (7). Therefore,  
30 the World Health Organization (WHO) recommends lowering the BMI cut-offs for  
31 “overweight” among Asian adults (8) in light of the increased health risks. Therefore,  
32 early detection of an overweight status has become very important in Asia.  
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42 The selection of height-based parameters, such as BMI for the detection of  
43 overweight/obese children in low-resource settings, has limitations because of the  
44 shortage of stadiometers and trained paramedical staff. A simpler proxy for BMI that  
45 parallels the use of abdominal girth for detecting visceral obesity needs to be developed  
46 (9). The mid-upper arm circumference (MUAC) appears to be a promising alternative in  
47 this regard (10-14). A recent study from the Netherlands reaffirmed that, compared with  
48 BMI, MUAC is a valid measure for detecting overweight/obesity, and thus is a good  
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3 alternative to BMI (15). Health workers are familiar with MUAC measurement, as it has  
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5 been commonly used for identifying severe acute under-nutrition among young (6–60  
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7 months of age) children (16).  
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11 To our knowledge, few studies have focused on the coexistence of under- and over-  
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13 nutrition in India. The present study was conducted to document the extent of DBM  
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15 among Indian schoolchildren, a key group for intervention, using BMI and MUAC  
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17 distributions. The study also examined whether MUAC can be used as a proxy for BMI,  
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19 so that MUAC can detect trends toward obesity or severe acute malnutrition (SAM).  
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## 23 **Participants and Methods**

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27 **Setting:** This cross-sectional study was conducted with schoolchildren from the  
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29 outskirts of Pune, India. This study was part of the MIMER medical college and  
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31 hospital's outreach activities regarding annual school health check-ups. A schedule of  
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33 class-wise health check-ups was developed in consultation with the school authorities  
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35 who, in turn, sought parents' permission. The study had the approval of the ethics  
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37 committee of MIMER medical college and hospital, Talegaon Dabhade. A majority of  
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39 the children belonged to lower and lower-middle socioeconomic categories. Children  
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41 between 3-5 years were from a playgroup, and those between 6-12 years belonged to  
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43 grades 1-7.  
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49 **Anthropometric measurements:** Anthropometric measurements, such as MUAC,  
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51 height, and weight, were taken from each participant using standard techniques. Height  
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53 (cm) was measured on a stadiometer (Easy care) without shoes. Weight (kg) was  
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55 measured using a digital weighing machine (Meditrin Instruments) in light clothes and  
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3 without shoes. MUAC (cm) was measured using a non-elastic plastic tape at the  
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5 midway between the olecranon and acromion processes on the upper left arm. During  
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7 these measurements, the participant was in a comfortable standing position and was  
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9 asked to look straight ahead with his/her shoulders in a neutral position. The  
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11 participant's arm was straightened, and we ensured that the tape was neither too tight  
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13 nor too loose.  
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18 **Statistical tools:** Open Source Statistical Software PSPP version 1.0.1 was used for all  
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20 analyses, and a  $p$ -value  $\leq 0.05$  was considered statistically significant. Mean and  
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22 standard deviation (SD), median, inter-quartile range, and Z-scores for BMI and MUAC  
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24 were computed by sex for participants with complete measurements. Z-scores were  
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26 computed using age-specific and sex-specific reference data from the WHO (17). The  
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28 distribution of variables was calculated among all participants together and separately  
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30 for boys and girls. Homogeneous subsets for BMI and MUAC were identified in these  
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32 three groups. Age-wise comparisons of BMI and MUAC were calculated for both girls  
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34 and boys.  
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40 **Patient involvement:** Patients were not directly involved in the design of this study.  
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## 50 **Results**

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53 The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The  
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55 distribution of variables among all participants, girls and boys, is shown in Tables 1 and  
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3 2. Age, height, weight, and BMI were all significantly different between girls and boys;  
4 boys had higher values for all parameters. MUAC, BMI Z-scores, and MUAC Z-scores,  
5 however, did not significantly differ between boys and girls (suppl. files).  
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11 BMI and MUAC differed significantly for all participants combined, and separately for  
12 boys and girls, between the ages of 3 to 16 years. Tukey's HSD tests for multiple  
13 comparisons revealed a significant shift in mean BMI at 3, 6, and 10 years whereas for  
14 MUAC, the shift occurred at 4, 6, and 9 years. Thereafter, MUAC changed significantly  
15 almost every year until the age of 16. Thus, in contrast to BMI, MUAC had more age-  
16 dependent variability. BMI change with age was minimal among girls (only at age 14)  
17 compared to changes among boys at 6, 10, 12, and 14 years. Girls had six  
18 homogeneous subsets for MUAC, with the first significant rise at age 4, compared to  
19 nine subsets among boys, with the first shift at age 5. Thus, changes in BMI and MUAC  
20 were more frequent among boys (suppl. files).  
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35 Importantly, MUAC positively correlated with other anthropometric variables among  
36 girls. Correlations were significant with weight, height, BMI, and BMI Z-scores (Table 3).  
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38 These findings were similar for boys (Table 4).  
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44 Based on BMI Z-scores, the following distribution of overweight children was found:  
45 obese (Z-scores more than 3 SD) - 21 (1.5%), overweight (Z-scores between 2 and 3  
46 SD) - 36 (2.5%), and pre-obese (Z-scores between 1 and 2 SD)-136 (9.4%). At the  
47 other end of the spectrum, among undernourished children, the following distribution  
48 was found: SAM (Z-scores less than 3 SD) -5(0.3%), moderate acute malnutrition  
49 (MAM; Z-scores between -2 and -3 SD) -146 (10.1%), and undernourished at risk of  
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3 sliding to MAM or SAM (Z-score between -1 and -2 SD) - 141 (9.8%) (Table5). Drawing  
4 parallels to BMI, the distribution of various categories of children based on the MUAC Z-  
5 scores was as follows (Table 6): obese-19 (1.3%), overweight- 178 (12.3%), pre-obese-  
6 135 (9.3%), SAM- 7(0.5%), MAM- 181 (12.5%), and undernourished at risk of MAM or  
7 SAM -181 (12.5%). BMI and MUAC categories had no statistically significant  
8 association with gender (suppl. files). The distribution of nutrition conditions, based on a  
9 modified WHO classification, is provided in (Table 7).

## 20 **Discussion**

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23 The present study suggests that DBM has reached Indian school children of lower  
24 middle or lower socioeconomic statuses, which calls for urgent action. Importantly, the  
25 present results identify children at the brink of sliding into severe forms of over- and  
26 under-nutrition. The present study also suggests using a single and simpler method,  
27 MUAC, for detecting both forms of malnutrition by monitoring growth during routine  
28 health check-ups.  
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38 The World Health Assembly targets were considered in crafting the 2030 development  
39 agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end  
40 all forms of malnutrition.” The reference to “all forms of malnutrition” is important for  
41 acknowledging the existence of the double burden of under-nutrition and overweight.  
42 While the drivers of the double burden of malnutrition are varied and often insidious,  
43 their effects present a clear case for urgent action and demand an integrated response.  
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52 Using a single tool for detecting both forms of malnutrition integrates and simplifies the  
53 process.  
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3 To our knowledge, few studies have focused on this aspect of growth among children in  
4 India, as well as other emerging economies. Based on BMI Z-scores, 21(1.5%) and 36  
5 (3.9%) children were classified as obese and overweight, respectively. At the other end  
6 of the spectrum, a relatively small proportion, 5 (0.3%) and 5 (0.3 %), belonged to SAM  
7 and MAM categories, respectively. MUAC Z-scores suggested the following distribution:  
8 obesity -19(1.3%), overweight -43(4.3%), SAM -1(0.1%), and MAM-(0.4%). An even  
9 greater number of children were leaning towards obesity or overweight, as well as SAM  
10 or MAM. Children who are not yet at the BMI-for-age threshold for the current definition  
11 of childhood obesity or overweight (and SAM or MAM) may be at an increased risk of  
12 developing obesity or severe forms of under-nutrition. One of the present study's aims  
13 was to identify these target groups so that these children's needs could be addressed.  
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30 The first target group, pre-obese children (BMI or MUACZ-score between 1 and 2 SD),  
31 is at risk of progressing to overweight/obesity. The second group, undernourished  
32 children (BMI or MUACZ-score between -1 and -2 SD), is at risk of sliding into MAM or  
33 SAM. Based on the BMI Z-scores, 136 (9.4%) were pre-obese, and 181 (12.5%) were  
34 undernourished. The equivalent numbers for MUAC were 135 (9.3%) for obesity and  
35 181 (12.5%) for SAM and MAM risk, respectively. These target groups may develop  
36 more severe forms of malnutrition if corrective measures are delayed. The first step in  
37 that direction is to plan face-to-face counseling sessions with parents and children.  
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39 School programs are effective at preventing childhood obesity by fostering more  
40 physical activity and recommending healthier diets (18). Counseling for the target  
41 groups will have to be done, keeping in mind that within low-resource settings, places  
42 for play may be scarce, sports infrastructure may be poor, and recreational centers may  
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3 be lacking (19). Similarly, low family income is linked to greater consumption of low-  
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5 quality nutrition and fast food (20).  
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9 Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting  
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11 both under and over-nutrition during routine growth monitoring without a height-  
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13 dependent parameter, such as BMI (Figure). This is because BMI and MUAC are  
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15 significantly correlated with each other. However, monitoring for obesity should begin  
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17 even earlier, as the most rapid weight gain occurs between ages 2 and 6 among obese  
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19 adolescents (21).  
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24 While India's economy has been growing at an impressive rate, the country still has the  
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26 highest number of stunted children in the world (46.8 million), representing one-third of  
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28 the global total of stunted children under age 5 (22). Stunting is associated with being  
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30 overweight among children in countries that are undergoing a nutritional transition  
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32 (23). Economic improvements are accompanied by a conspicuous change in dietary  
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34 patterns in the form of increased fat intake (5). This, coupled with low physical activity,  
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36 contributes to an increasing prevalence of obesity among adults, which accompanies  
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38 the first wave of a cluster of non-communicable diseases, such as hypertension and  
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40 diabetes mellitus, called "the new world syndrome" (24).  
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46 It should be noted, however, that some children classified as obese under this system  
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48 may actually have a higher relative weight due to stunting rather than excess adiposity.  
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50 Moreover, classification of a child's or adolescent's weight status is complicated by the  
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52 fact that height and body composition are continually changing, and such changes often  
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54 occur at different rates and times within different populations. Charts showing BMI for  
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3 healthy children by age indicate an initial rapid rise in the first year, a subsequent  
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5 decline for the next 5 years, and then a slow rise into adulthood, making simple  
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7 universal adiposity indices of little value. Therefore, there has not been the same level  
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9 of agreement on the classification of obesity for children and adolescents as there is for  
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11 adults (25).  
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16 To summarize, until recently, India has considered under-nutrition to be a major  
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18 problem, and nutrition supplementation has been the key intervention. At the national  
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20 level, India is at stage 1 of the obesity transition with wide sub-national variations (26).  
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22 Our study may help in the surveillance effort to address underserved populations  
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24 (26). With improved availability of food, a double burden of malnutrition is emerging that  
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26 needs to be concurrently addressed. The present study observed the coexistence of  
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28 obesity, overweight, pre-obese, and SAM, MAM, and undernourished states among  
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30 Indian school children in lower-middle and lower socioeconomic levels. Second, the  
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32 present results revealed a significant correlation between BMI and MUAC. This study  
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34 provides evidence to suggest that MUAC is a valid, single measurement for identifying  
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36 this dual problem of aberrant growth and over-nutrition on the one hand and under-  
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38 nutrition on the other, through extended routine growth monitoring of children. However,  
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40 more studies are required to establish validity and reliability of this tool.  
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#### 47 **What is known about the subject?**

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

#### 54 **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.

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**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 <sup>2</sup> )	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-	7.37	1.66E-13
									Difference is significant		
MUAC	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-	6.23	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	-	0.50	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

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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) $\geq$ -1 to 0	641	44.4	44.4	87.0
	6) $\geq$ -2 to <-1	181	12.5	12.5	99.5
	7) $\geq$ -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 \*\*

<b>Condition</b>	Based on BMI z-scores	Based on MUACZ-scores
	No (%)	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)



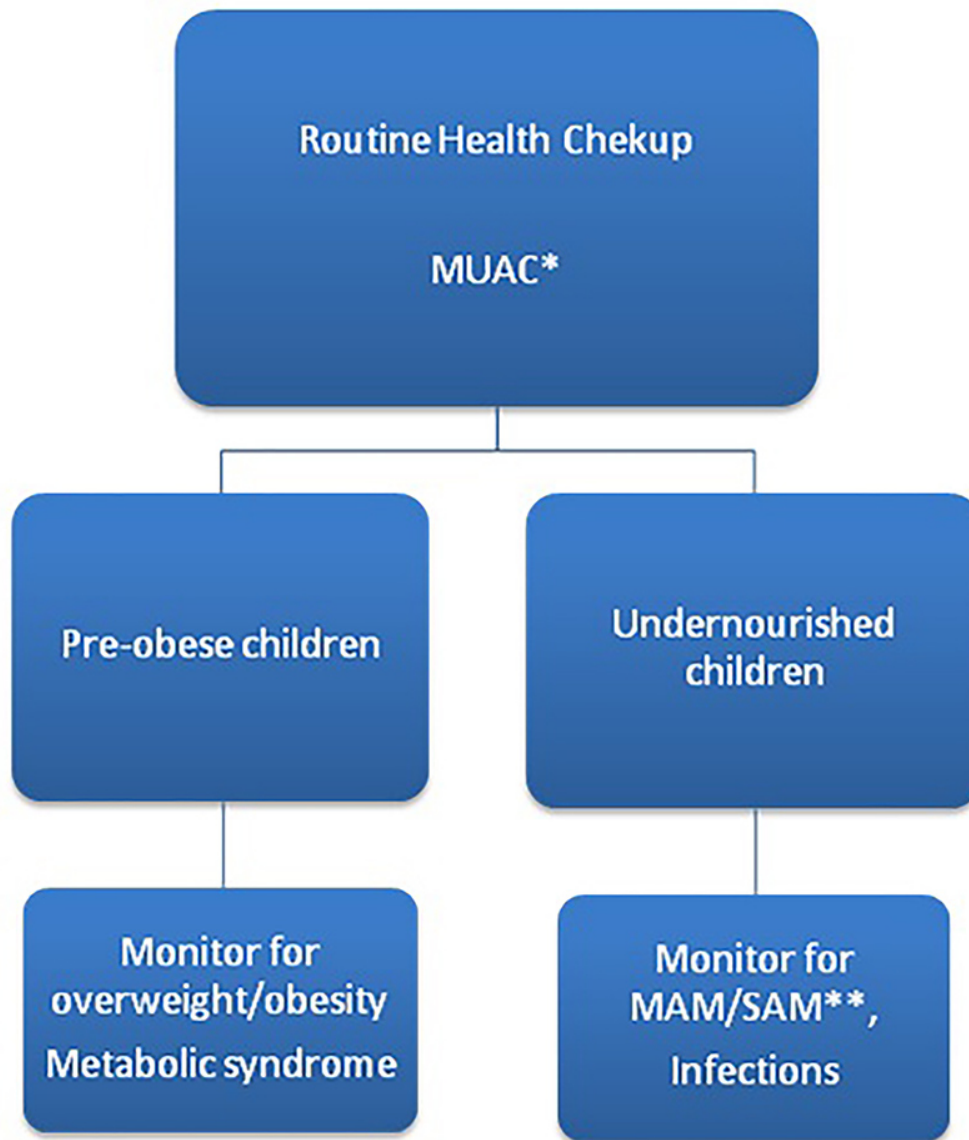
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Severely thin	BMI <-3SD 5 (0.3)	MUAC<-3 SD 1(0.1)
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\*\*Modified WHO Classification of nutrition conditions based on anthropometry

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

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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		

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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		

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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	10	15.38								
	2	5								
4	14	15.50	15.50							
	6	0	0							
5	13	16.19	16.19							
	2	4	4							
6	10	16.82	16.82	16.82						
	9	6	6	6						
7	15		16.97	16.97						
	6		9	9						
9	72			17.79	17.79					
				4	4					
8	65			17.97	17.97					
				2	2					

10	22 0				19.01 5	19.01 5				
11	18 2					20.16 1	20.16 1			
12	77						20.87 1			
13	30						22.90 7			
14	72						23.53 2	23.53 2		
15	72							24.65 8	24.65 8	
16	9								25.81 1	
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) $\geq -2$ to $< -1$	Count	39	102	141
	% within Sex	9.2%	10.0%	9.8%
7) $\geq -3$ 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 <sup>a</sup>	7	.636
Likelihood Ratio	4.931	7	.668
N of Valid Cases	1444		

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<sup>a</sup> 4 cells (25.0%) have expected count less than 5. The minimum expected count is 1.47.			

BMI = Body Mass Index

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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 <sup>a</sup>	7	.533
Likelihood Ratio	6.429	7	.491
N of Valid Cases	1444		

<sup>a</sup> 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:	<i>BMJ Paediatrics Open</i>
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

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15 4 Double burden of malnutrition among Indian school children **and its**  
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22 6 Short title: Measuring double burden of malnutrition  
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28 8 SubhashchandraDaga<sup>1\*</sup>, Sameer Mhatre<sup>2</sup>, Eric Dsouza<sup>3</sup>, Abhiram Kasbe<sup>4</sup>  
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## 11 12 13 20 **Abstract** 14 15

### 16 17 18 21 **Objective** 19

20 22 This cross-sectional study aimed to document the extent of double burden of malnutrition  
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22 (coexistence of over- and under-nutrition) among Indian schoolchildren from lower  
23 23  
24 socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used  
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26 as a proxy for body mass index (BMI).  
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### 31 26 **Design** 32

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34 27 **A cross-sectional study**  
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### 37 28 **Setting** 38

39 29 A school in the outskirts of a large city, with a majority of the children belonging to lower and  
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41 lower-middle socioeconomic categories.  
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### 45 31 **Subjects** 46 47 48

49 32 The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to  
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51 33 playgroups and grades 1-7.  
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### 54 34 **Measurements** 55 56 57 58 59 60

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3 35 Anthropometric measurements, such as participants' MUAC, height, and weight were measured  
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5 36 using standard techniques. Descriptive statistics for BMI and MUAC were obtained based on  
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7 37 gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The  
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9 38 distribution of variables was calculated for three groups: all participants together and separately  
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11 39 for each gender. Homogeneous subsets for BMI and MUAC were identified in the three groups.  
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14 40 Age-wise comparisons of BMI and MUAC were conducted for each gender.  
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#### 19 41 **Main outcome measures**

- 20 42 1. To know if MUAC and BMI are correlated among both boys and girls.
  - 21 43 2. To study BMI and MUAC Z score distribution among the subjects.
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#### 28 44 **Results**

29 45 The MUAC positively correlated with BMI in both boys and girls. The following BMI Z-score  
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31 46 distribution was observed: obese, 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%);  
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33 47 severe acute malnutrition (SAM), 5(0.3%); moderate acute malnutrition (MAM), 146 (10.1%);  
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35 48 undernourished, at risk of MAM/SAM, 141 (9.8%). The distribution of categories of children  
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37 49 based on MUAC Z-scores was: obese, 19 (1.3%), overweight, 178 (12.3%), pre-obese, 135  
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39 50 (9.3%), SAM, 7(0.5%), MAM, 181 (12.5%), and undernourished at risk of MAM or SAM, 181  
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41 51 (12.5%).  
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#### 48 52 **Conclusions**

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51 53 Obesity/overweight/pre-obese and SAM/MAM/undernourished states, undernutrition more than  
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53 54 overweight, coexist among Indian schoolchildren from lower middle/lower socioeconomic  
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3 55 categories. BMI and MUAC were significantly correlated. MUAC may identify both under-  
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5 56 nutrition and over-nutrition by early detection of aberrant growth.  
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Confidential: For Review Only

## 57 Introduction

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

69 The consequences of DBM are enormous. Early life under-nutrition is associated with  
70 approximately one-third of childhood deaths. The survivors, who become stunted during their  
71 first two years of life, are prone to infections and are unable to carry out physical work, study,  
72 and progress in school. Later in the life course, the double burden of disease is characterized by  
73 the coexistence of communicable (infectious disease) and non-communicable diseases. Prior to  
74 the 1970s, obesity was a relatively rare condition, even in the wealthiest of nations [3],  
75 whereas under-nutrition was a major problem, and nutrition supplementation was the main  
76 intervention. Thus, obesity is a relatively new problem in need of attention. A systematic review  
77 of obesity and socioeconomic status in developing countries concluded that child obesity is more  
78 prevalent among affluent groups within developing countries [4]. This may be attributed

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3 79 to improved access to surplus/excess food and a higher degree of urbanization and technological  
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5 80 progress in these economies that render activities less laborious, resulting in less energy  
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8 81 expenditure [5]. Thus, economic advancement seems inevitably associated with a rapidly  
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10 82 increasing prevalence of obesity. Furthermore, childhood obesity is a strong predictor of adult  
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12 83 obesity. For instance, a Japanese study revealed that approximately one-third of obese children  
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14 84 grew into obese adults [6]. Therefore, early detection of excessive weight gain, and action to  
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17 85 prevent its progress, is more likely to succeed than attempting to reverse obesity later.  
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20 86       Body mass index (BMI)-for-age, the internationally recommended measure of obesity,  
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22 87 suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI  
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25 88 levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health  
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27 89 Organization (WHO) recommends lowering the BMI cut-offs for “overweight” among Asian  
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30 90 adults [8] in light of the increased health risks. Therefore, early detection of an overweight status  
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32 91 has become very important in Asia.  
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35 92       The selection of height-based parameters, such as BMI for the detection of  
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37 93 overweight/obese children in low-resource settings, has limitations because of the shortage of  
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40 94 stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of  
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42 95 abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm  
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44 96 circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent  
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47 97 study from the Netherlands reaffirmed that, compared with BMI, MUAC is a valid measure for  
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49 98 detecting overweight/obesity, and thus is a good alternative to BMI [15]. Health workers are  
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51 99 familiar with MUAC measurement, as it has been commonly used for identifying severe acute  
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54 100 under-nutrition among young (6–60 months of age) children [16].  
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3 101 To our knowledge, few studies have focused on the coexistence of under- and over-  
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5 102 nutrition in India. The present study was conducted to document the extent of DBM among  
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7 103 Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The  
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9 104 study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect  
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11 105 trends toward obesity or severe acute malnutrition (SAM).  
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## 15 106 **Participants and Methods**

### 16 107 **Setting**

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22 108 This cross-sectional study was conducted with schoolchildren from the outskirts of Pune,  
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24 109 India. This study was part of the MIMER medical college and hospital's outreach activities  
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26 110 regarding annual school health check-ups. A schedule of class-wise health check-ups was  
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28 111 developed in consultation with the school authorities who, in turn, sought parents' permission.  
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30 112 The study had the approval of the ethics committee of MIMER medical college and hospital,  
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32 113 Talegaon Dabhade. A majority of the children belonged to lower and lower-middle  
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34 114 socioeconomic categories. Children between 3–5 years were from a playgroup, and those  
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36 115 between 6–12 years belonged to grades 1–7.  
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### 42 116 **Anthropometric measurements**

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45 117 Anthropometric measurements, such as MUAC, height, and weight, were taken from  
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47 118 each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy  
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49 119 care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin  
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51 120 Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic  
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53 121 plastic tape at the midway between the olecranon and acromion processes on the upper left arm.  
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3 122 During these measurements, the participant was in a comfortable standing position and was  
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5 123 asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm  
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8 124 was straightened, and we ensured that the tape was neither too tight nor too loose.  
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## 10 11 125 **Statistical tools**

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14 126 Open Source Statistical Software PSPP version 1.0.1 was used for all analyses, and a *p*-  
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16 127 value  $\leq 0.05$  was considered statistically significant. Mean and standard deviation (SD), median,  
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18 128 inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants  
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20 129 with complete measurements. Z-scores were computed using age-specific and sex-specific  
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23 130 reference data from the WHO [17]. The distribution of variables was calculated among all  
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26 131 participants together and separately for boys and girls. Homogeneous subsets for BMI and  
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28 132 MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were  
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30 133 calculated for both girls and boys.  
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## 32 33 134 **Patient involvement**

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36 135 Patients were not directly involved in the design of this study.  
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## 136 Results

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

141 BMI and MUAC showed age-wise differences for all participants combined, and separately for  
142 boys and girls, between the ages of 3 to 16 years. Tukey's HSD tests for homogeneous  
143 subsets revealed a significant shift in mean BMI at 3, 6, and 10 years whereas for MUAC, the  
144 shift occurred at 4, 6, and 9 years. Thereafter, MUAC changed significantly almost every year  
145 until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI  
146 change with age was minimal in girls (only at age 14) compared to changes in boys at 6, 10,  
147 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at  
148 age of 4 years, compared to nine subsets in boys, with the first shift at age 5. Thus, changes in  
149 BMI and MUAC were more frequent in boys (supplementary files). **Importantly, MUAC was**  
150 **positively correlated with weight, height, and BMI both in both girls and boys (Tables 3**  
151 **and 4).**

152 Based on BMI Z-scores, the following distribution of overweight children was found: obese (Z-  
153 scores more than 3 SD) - 21 (1.5%), overweight (Z-scores between 2 and 3 SD) - 36 (2.5%), and  
154 pre-obese (Z-scores between 1 and 2 SD) - 136 (9.4%). At the other end of the spectrum, among  
155 undernourished children, the following distribution was found: SAM (Z-scores less than 3 SD) -  
156 5 (0.3%), moderate acute malnutrition (MAM; Z-scores between -2 and -3 SD) - 146 (10.1%), and  
157 undernourished at risk of sliding to MAM or SAM (Z-score between -1 and -2 SD) - 141 (9.8%)

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3 158 (Table and Figure 2). Drawing parallels to BMI, the distribution of various categories of  
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5 159 children based on the MUAC Z-scores was as follows (Table 6 and Figure 3): obese-19 (1.3%),  
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7 160 overweight- 178 (12.3%), pre-obese-135 (9.3%), SAM- 7(0.5%), MAM- 181 (12.5%), and  
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9 161 undernourished at risk of MAM or SAM -181 (12.5%). BMI and MUAC categories had no  
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11 162 statistically significant association with gender (suppl. files). The distribution of nutrition  
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13 163 conditions, based on a modified WHO classification, is provided in (Table 7).  
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## 18 164 Discussion

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21 165 The present study suggests that DBM has reached Indian school children of lower middle  
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23 166 or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results  
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25 167 identify children at the brink of sliding into severe forms of over- and under-nutrition. The  
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27 168 present study also suggests using a single and simpler method, MUAC, for detecting both forms  
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29 169 of malnutrition by monitoring growth during routine health check-ups.  
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33 170 The World Health Assembly targets were considered in crafting the 2030 development  
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35 171 agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms  
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37 172 of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the  
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39 173 existence of the double burden of under-nutrition and overweight. While the drivers of the  
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41 174 double burden of malnutrition are varied and often insidious, their effects present a clear case for  
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43 175 urgent action and demand an integrated response. Using a single tool for detecting both forms of  
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45 176 malnutrition integrates and simplifies the process.  
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50 177 To our knowledge, few studies have focused on this aspect of growth among children in  
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52 178 India, as well as other emerging economies. Based on BMI Z-scores, 21(1.5%) and 36 (3.9%)  
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54 179 children were classified as obese and overweight, respectively. At the other end of the spectrum,  
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3 180 a relatively small proportion, 5 (0.3%) and 5 (0.3 %), belonged to SAM and MAM categories,  
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5 181 respectively. MUAC Z-scores suggested the following distribution: obesity -19(1.3%),  
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7 182 overweight -43(4.3%), SAM -1(0.1%), and MAM-(0.4%). An even greater number of children  
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10 183 were leaning towards obesity or overweight, as well as SAM or MAM. Children who are not yet  
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12 184 at the BMI-for-age threshold for the current definition of childhood obesity or overweight (and  
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14 185 SAM or MAM) may be at an increased risk of developing obesity or severe forms of under-  
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17 186 nutrition. One of the present study's aims was to identify these target groups so that these  
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19 187 children's needs could be addressed.

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23 188 The first target group, pre-obese children (BMI or MUACZ-score between 1 and 2 SD),  
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25 189 is at risk of progressing to overweight/obesity. The second group, undernourished children (BMI  
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27 190 or MUACZ-score between -1 and -2 SD), is at risk of sliding into MAM or SAM. Based on the  
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30 191 BMI Z-scores, 136 (9.4%) were pre-obese, and 181 (12.5%) were undernourished. The  
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32 192 equivalent numbers for MUAC were 135 (9.3%) for obesity and 181 (12.5%) for SAM and  
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34 193 MAM risk, respectively. More children were at risk of severe undernutrition than of  
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37 194 overnutrition. These target groups may develop more severe forms of malnutrition if corrective  
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39 195 measures are delayed. The first step in that direction is to plan face-to-face counseling sessions  
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41 196 with parents and children. School programs are effective at preventing childhood obesity by  
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43 197 fostering more physical activities and recommending healthier diets [18]. Counseling for the  
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46 198 target groups will have to be done, keeping in mind that within low-resource settings, places for  
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48 199 play may be scarce, sports infrastructure may be poor, and recreational centers may be lacking  
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50 200 [19]. Similarly, low family income is linked to greater consumption of low-quality nutrition and  
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53 201 fast food [20].

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3 202           Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting  
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5 203 both under and over-nutrition during routine growth monitoring without a height-dependent  
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7 204 parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated  
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10 205 with each other. However, monitoring for obesity should begin even earlier, as the most rapid  
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12 206 weight gain occurs between ages 2 and 6 years among obese adolescents [21].  
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16 207           While India's economy has been growing at an impressive rate, the country still has the  
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18 208 highest number of stunted children in the world (46.8 million), representing one-third of the  
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20 209 global total of stunted children under age 5 [22]. Stunting is associated with being overweight  
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22 210 among children in countries that are undergoing a nutritional transition [23]. Economic  
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24 211 improvements are accompanied by a conspicuous change in dietary patterns in the form of  
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26 212 increased fat intake [5]. This, coupled with low physical activity, contributes to an increasing  
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28 213 prevalence of obesity among adults, which accompanies the first wave of a cluster of non-  
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30 214 communicable diseases, such as hypertension and diabetes mellitus, called "the new world  
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32 215 syndrome" [24].  
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38 216           It should be noted, however, that some children classified as obese under this system may  
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40 217 actually have a higher relative weight due to stunting rather than excess adiposity. Moreover,  
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42 218 classification of a child's or adolescent's weight status is complicated by the fact that height and  
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44 219 body composition are continually changing, and such changes often occur at different rates and  
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46 220 times within different populations. Charts showing BMI for healthy children by age indicate an  
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48 221 initial rapid rise in the first year, a subsequent decline for the next 5 years, and then a slow rise  
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51 222 into adulthood, making simple universal adiposity indices of little value. Therefore, there has not  
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3 223 been the same level of agreement on the classification of obesity for children and adolescents as  
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5 224 there is for adults [25].  
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9 225 To summarize, until recently, India has considered under-nutrition to be a major problem,  
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11 226 and nutrition supplementation has been the key intervention. At the national level, India is at  
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13 227 stage 1 of the obesity transition with wide sub-national variations [26]. Our study may help in the  
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15 228 surveillance effort to address underserved populations [26]. With improved availability of food, a  
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17 229 double burden of malnutrition is emerging that needs to be concurrently addressed. The present  
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19 230 study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and  
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21 231 undernourished states among Indian school children in lower-middle and lower socioeconomic  
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23 232 levels. Second, the present results revealed a significant correlation between BMI and MUAC.  
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25 233 This study provides evidence to suggest that MUAC is a valid, single measurement for  
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27 234 identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-  
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29 235 nutrition on the other, through extended routine growth monitoring of children. However, more  
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31 236 studies are required to establish validity and reliability of this tool.  
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3 237 **What is known about the subject?**  
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5 238 • Emerging economies face a dual problem of under-nutrition and over-nutrition.

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8 239 • Detecting this problem using height-based parameters is not easy in a low-resource  
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10 240 setting.

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12 241 **What this study adds?**  
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15 242 This study suggests that MUAC is a simple, valid, and single measure for identifying this dual  
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17 243 problem in a low-resource setting.  
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26  
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29 248 confirm no support from any organization for the submitted work; no financial relationships with  
30  
31 249 any organizations that might have an interest in the submitted work in the previous three years;  
32  
33 250 no other relationships or activities that could appear to have influenced the submitted work.  
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40 252 **Author contributions**  
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42 253 **SD-Conceptualization; Data analysis; Manuscript writing.**  
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45 254 SM-Data collection; data analysis; manuscript writing.  
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48 255 AK- Data analysis; manuscript writing.  
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50 256 ED- Data collection; manuscript writing.  
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338 **Table 1**339 Comparison of various variables between girls and boys  
340

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

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

342 \*Difference is statistically significant.

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

344 **Table 2**  
 345 Distribution of variables among all Subjects  
 346

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

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

349 **Table 3**  
 350 Correlations between anthropometric parameters among girls (N=424)  
 351

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

352 \*\* Correlation is significant at the 0.01 level (2-tailed).  
 353

354 **Table 4**  
 355 Correlations between anthropometric parameters among boys (N=1020)  
 356

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

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

358 **Table 5**  
 359 Distribution of BMI Z-scores  
 360

<b>BMI (Z Score) Internal</b>	<b>No.</b>	<b>Percentage</b>
>+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%
<b>Total</b>	1444	100.0%

361 BMI=Body Mass Index

362 **Table 6**  
 363 Distribution of MUAC Z-scores  
 364

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%
<b>Total</b>	1444	100.0%

MUAC=Mid-upper-arm circumference

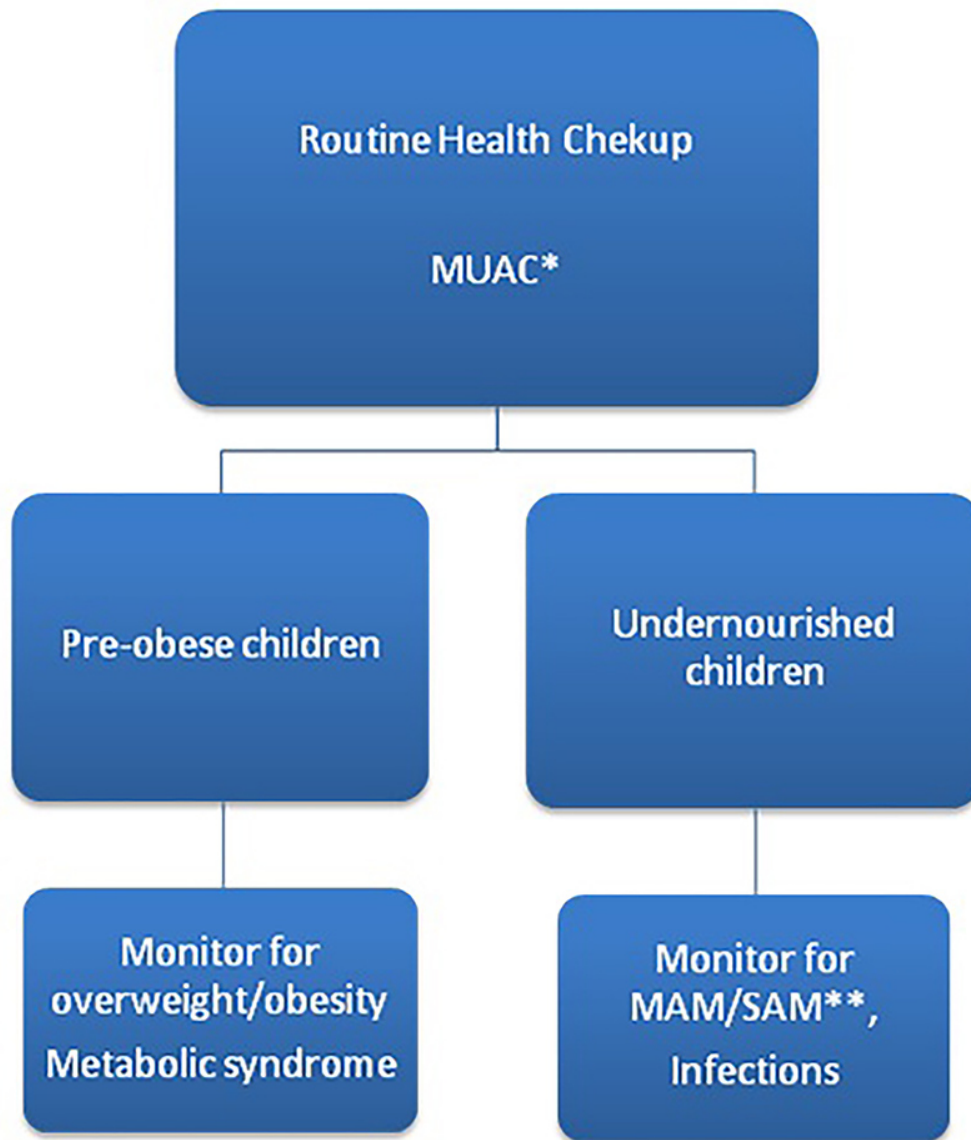
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394 **Table 7**  
 395 Distribution of nutrition conditions based on BMI and MUAC Z-scores \*\*  
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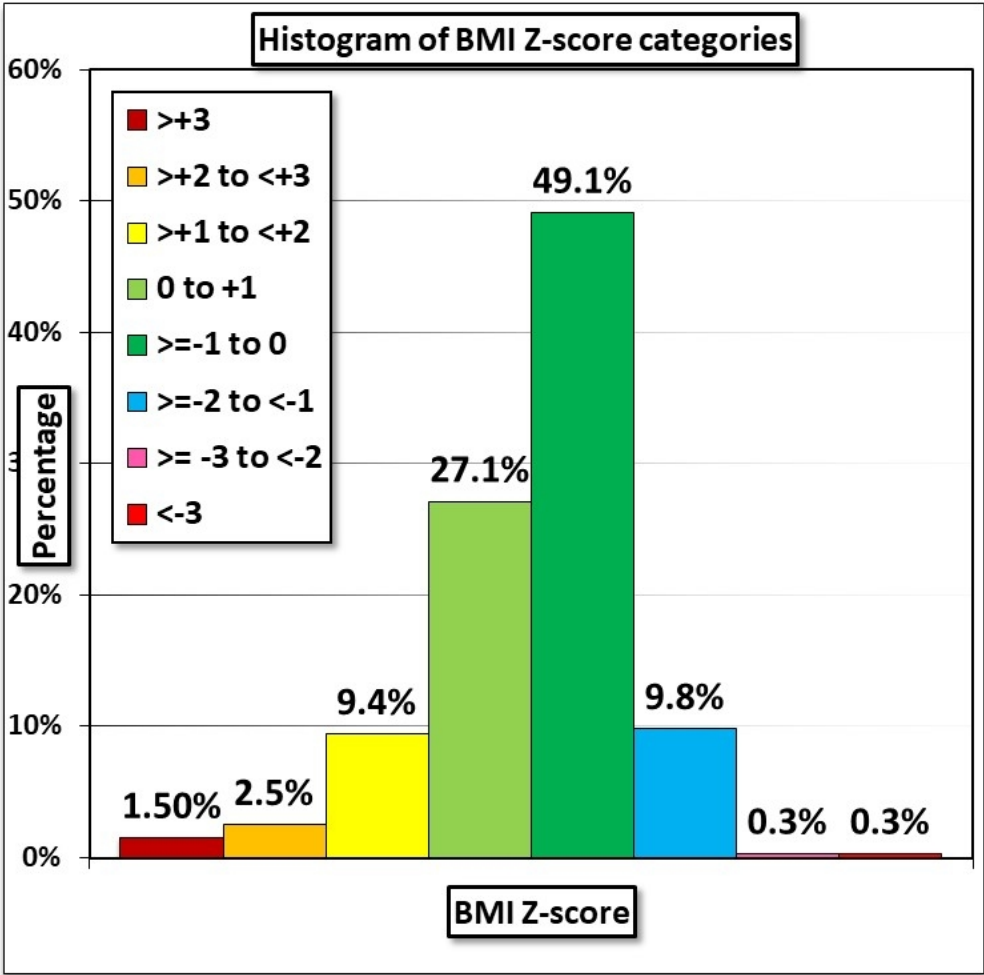
Condition	Based on BMI z-scores No (%)	Based on MUACZ-scores No (%)
<b>Pre-obese</b>	BMI >1 to 2 SD 136 (9.4%)	MUAC >1 to 2SD 135 (9.3%)
<b>Overweight</b>	BMI >2 to 3 SD 36 (2.5%)	MUAC >2 to 3SD 43 (3.0%)
<b>Obese</b>	BMI >3SD 21 (1.5%)	MUAC >3SD 19(1.3%)
<b>Possible risk of underweight</b>	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
<b>Thin</b>	BMI <-2 to -3 SD 5 (0.3%)	MUAC <-2 to -3SD 6 (0.4%)
<b>Severely thin</b>	BMI <-3SD 5 (0.3%)	MUAC <-3 SD 1(0.1%)

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

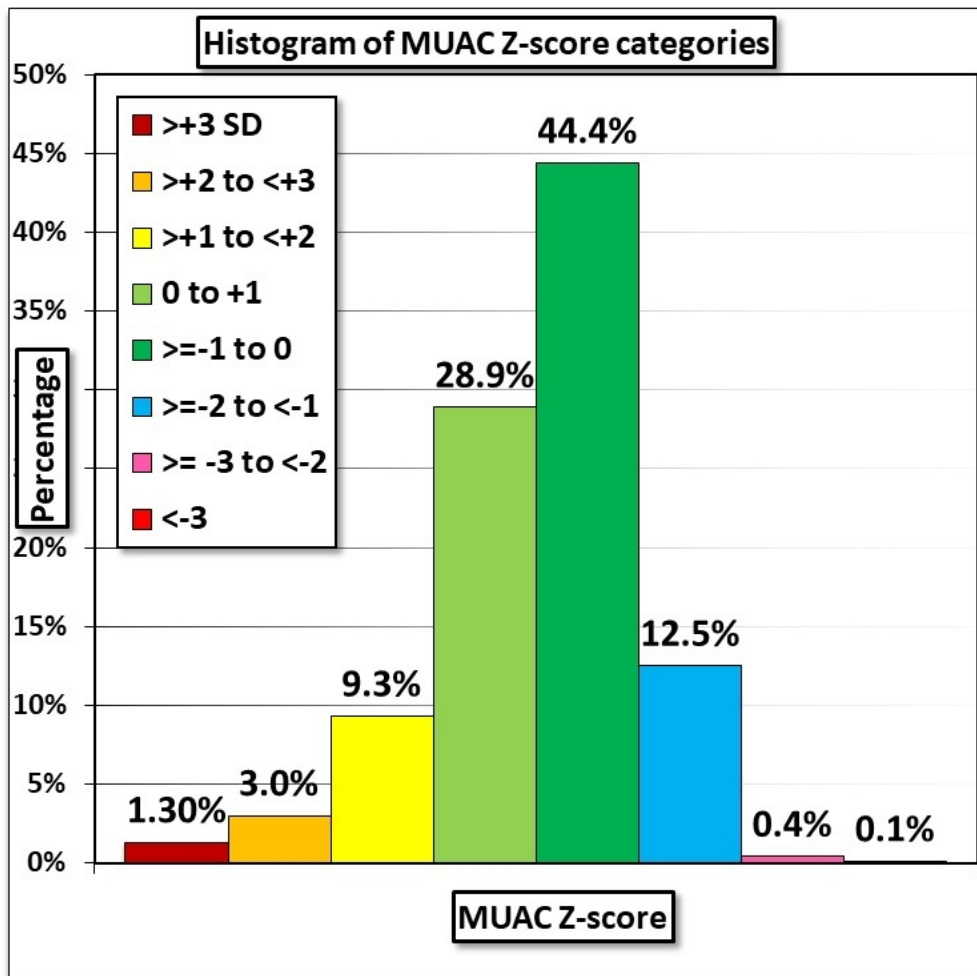


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**Table 8**  
**Age-wise distribution of BMI among all Subjects**

Age (years)	BMI			
	Mean	SD	Median	IQR
<b>3</b>	13.37	1.34	13.26	1.61
<b>4</b>	13.04	1.69	13.07	1.46
<b>5</b>	13.01	1.13	12.80	1.02
<b>6</b>	13.85	2.09	13.39	1.55
<b>7</b>	13.54	1.48	13.20	1.90
<b>8</b>	13.94	2.22	13.37	2.01
<b>9</b>	13.70	1.73	13.36	1.66
<b>10</b>	14.74	2.84	13.97	2.77
<b>11</b>	15.48	3.03	14.89	3.60
<b>12</b>	15.89	3.01	15.63	3.87
<b>13</b>	18.22	3.34	17.51	3.30
<b>14</b>	18.33	3.88	17.28	4.53
<b>15</b>	19.09	4.32	18.01	6.52
<b>16</b>	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
<b>Sig.</b>		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
<b>3</b>	15.39	1.24	15.20	1.50
<b>4</b>	15.50	1.16	15.50	1.10
<b>5</b>	16.19	1.17	15.95	1.20
<b>6</b>	16.83	2.07	16.50	1.95
<b>7</b>	16.98	1.75	16.70	2.00
<b>8</b>	17.97	2.11	17.50	1.61
<b>9</b>	17.79	1.78	17.50	2.08
<b>10</b>	19.02	2.63	18.50	3.45
<b>11</b>	20.16	3.04	19.50	3.93
<b>12</b>	20.87	2.79	20.50	4.00
<b>13</b>	22.91	2.79	22.50	2.60
<b>14</b>	23.53	3.64	23.00	4.95
<b>15</b>	24.66	3.73	23.50	5.23
<b>16</b>	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
<b>Sig.</b>		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 between BMI (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 between MUAC (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:	<i>BMJ Paediatrics Open</i>
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

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78 **Abstract**  
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13 **Objective**  
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15 35 This cross-sectional study **in a single school** aimed to document the extent of double burden of  
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17 36 malnutrition (coexistence of over- and under-nutrition) among Indian schoolchildren from lower  
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19 37 socioeconomic groups, and to determine if mid-upper arm circumference (MUAC) can be used  
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22 38 as a proxy for body mass index (BMI).  
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26 **Design**  
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29 40 A cross-sectional study **in a single school**  
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32 **Setting**  
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34 42 A school in the outskirts of a large city, with a majority of the children belonging to lower and  
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37 43 lower-middle socioeconomic categories.  
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40 **Subjects**  
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43 45 The total number of participants was 1,444, comprising 424 girls and 1,020 boys belonging to  
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46 46 playgroups and grades 1-7.  
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49 **Measurements**  
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52 48 Anthropometric measurements, such as participants' MUAC, height, and weight were measured  
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55 49 using standard techniques. Descriptive statistics for BMI and MUAC were obtained based on  
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3 50 gender; Z-scores were computed using age-specific and sex-specific WHO reference data. The  
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5 51 distribution of variables was calculated for three groups: all participants together and separately  
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8 52 for each gender. Homogeneous subsets for BMI and MUAC were identified in the three groups.  
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10 53 Age-wise comparisons of BMI and MUAC were conducted for each gender.  
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#### 14 54 **Main outcome measures**

- 15 55 1. To know if MUAC and BMI are correlated among both boys and girls.
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19 56 2. To study BMI and MUAC Z score distribution among the subjects.  
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#### 24 57 **Results**

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26 58 The MUAC positively correlated with BMI in both boys and girls. The following BMI Z-score  
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28 59 distribution was observed: severe acute malnutrition (SAM), 5(0.3%); moderate acute  
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31 60 malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%); obese,  
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33 61 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%). The distribution of categories of  
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35 62 children based on MUAC Z-scores was: SAM, 7(0.5%), MAM, 181 (12.5%), and  
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37 63 undernourished at risk of MAM or SAM, 181 (12.5%); obese, 19 (1.3%), overweight, 178  
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40 64 (12.3%), pre-obese, 135 (9.3%).  
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#### 43 65 **Conclusions**

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46 66 SAM/MAM/undernourished states and obesity/overweight/pre-obese, undernutrition more than  
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48 67 overweight, coexist among Indian schoolchildren from lower middle/lower socioeconomic  
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51 68 categories. BMI and MUAC were significantly correlated. MUAC **identifies** both under-  
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54 69 nutrition and over-nutrition by early detection of aberrant growth  
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## 70 Introduction

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

82 Later in the life course, the double burden of disease is characterized by the coexistence  
83 of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s,  
84 obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-  
85 nutrition was a major problem, and nutrition supplementation was the main intervention. Thus,  
86 obesity is a relatively new problem in need of attention. A systematic review of obesity and  
87 socioeconomic status in developing countries concluded that child obesity is more prevalent  
88 among affluent groups within developing countries [4]. This may be attributed to improved  
89 access to surplus/excess food and a higher degree of urbanization and technological progress in  
90 these economies that render activities less laborious, resulting in less energy expenditure [5].  
91 Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese



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3 92 study revealed that approximately one-third of obese children grew into obese adults  
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5 93 [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress,  
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8 94 is more likely to succeed than attempting to reverse obesity later.  
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11 95 Body mass index (BMI)-for-age, the internationally recommended measure of obesity,  
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13 96 suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI  
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15 97 levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health  
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17 98 Organization (WHO) recommends lowering the BMI cut-offs for “overweight” among Asian  
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19 99 adults [8] in light of the increased health risks. Therefore, early detection of an overweight status  
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23 100 has become very important in Asia.  
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25  
26 101 The selection of height-based parameters, such as BMI for the detection of  
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28 102 overweight/obese children in low-resource settings, has limitations because of the shortage of  
29  
30 103 stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of  
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32 104 abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm  
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34 105 circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent  
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36 106 study from the Netherlands reaffirmed that, compared with BMI, MUAC is a valid measure for  
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38 107 detecting overweight/obesity, and thus is a good alternative to BMI [15]. Health workers are  
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40 108 familiar with MUAC measurement, as it has been commonly used for identifying severe acute  
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43 109 under-nutrition among young (6–60 months of age) children [16].  
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47 110 To our knowledge, few studies have focused on the coexistence of under- and over-  
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49 111 nutrition in India. The present study was conducted to document the extent of DBM among  
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51 112 Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The  
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3 113 study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect  
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5 114 trends toward obesity or severe acute malnutrition (SAM).  
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## 9 115 **Participants and Methods**

### 10 11 12 116 **Setting** 13 14 15

16 117 A **single school** cross-sectional study was conducted with schoolchildren from the outskirts  
17  
18 118 of Pune, India. This study was part of the MIMER medical college and hospital's outreach  
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20 119 activities regarding annual school health check-ups. A schedule of class-wise health check-ups  
21  
22 120 was developed in consultation with the school authorities who, in turn, sought parents'  
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24 121 permission. The study had the approval of the ethics committee of MIMER medical college and  
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26 122 hospital, Talegaon Dabhade. A majority of the children belonged to lower and lower-middle  
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28 123 socioeconomic categories. Children between 3–5 years were from a playgroup, and those  
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30 124 between 6–12 years belonged to grades 1–7.  
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### 35 125 **Anthropometric measurements** 36 37 38

39 126 Anthropometric measurements, such as MUAC, height, and weight, were taken from  
40  
41 127 each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy  
42  
43 128 care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin  
44  
45 129 Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic  
46  
47 130 plastic tape at the midway between the olecranon and acromion processes on the upper left arm.  
48  
49 131 During these measurements, the participant was in a comfortable standing position and was  
50  
51 132 asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm  
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53 133 was straightened, and we ensured that the tape was neither too tight nor too loose.  
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### 134 **Statistical tools**

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

### 143 **Patient involvement**

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

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## 148 **Results**

149 The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The  
150 distribution of variables among all participants, girls and boys, is shown in figures 1 and 2. Age,  
151 height, weight, MUAC, and BMI were all significantly different between girls and boys; boys  
152 had higher values for all parameters (Suppl. Files: table 1 and 2). As expected, BMI and MUAC  
153 showed age-wise differences for all participants, combined and separately, for boys and girls,  
154 between the ages of 3 to 16 years (Suppl. Files: tables 3 and 4). Tukey's HSD (honest significant  
155 difference) tests for homogeneous subsets revealed a significant shift in mean BMI at 3, 6, and  
156 10 years (Suppl. Files: table 5) whereas for MUAC, the shift occurred at 4, 6, and 9 years (Suppl.  
157 files: table 6). Thereafter, MUAC changed significantly almost every year until the age of 16.  
158 Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI change with age was  
159 minimal in girls (only at age 14) compared to changes in boys at 6, 10, 12, and 14 years. Girls  
160 had six homogeneous subsets for MUAC, with the first significant rise at age of 4 years,  
161 compared to nine subsets in boys, with the first shift at age 5. Thus, changes in BMI and MUAC  
162 were more frequent in boys. MUAC was positively correlated with weight, height, and BMI both  
163 in girls and boys (Suppl. Files: tables 7 and 8).

## 165 **Discussion**

166 The present study suggests that DBM has reached Indian school children of lower middle  
167 or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results  
168 identify children at the brink of sliding into severe forms of under – and over- nutrition. The

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3 169 present study also suggests using a single and simpler method, MUAC, for detecting both forms  
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5 170 of malnutrition by monitoring growth during routine health check-ups.  
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9 171 The World Health Assembly targets were considered in crafting the 2030 development  
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11 172 agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms  
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13 173 of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the  
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15 174 existence of the double burden of under-nutrition and overweight. While the drivers of the  
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17 175 double burden of malnutrition are varied and often insidious, their effects present a clear case for  
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19 176 urgent action and demand an integrated response. Using a single tool for detecting both forms of  
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21 177 malnutrition integrates and simplifies the process.  
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25 178 To our knowledge, few studies have focused on this aspect of growth among children in India, as  
26  
27 179 well as other emerging economies. The girls were outnumbered by boys (424 vs. 1020). This  
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29 180 may be because of the traditional gender norms that push girls into helping household chores and  
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31 181 sibling care that result in dropouts. Based on BMI Z-scores, 5 (0.3%) and 5 (0.3 %), belonged to  
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33 182 SAM and MAM categories, respectively and 21(1.5%) and 36 (3.9%) children were classified as  
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35 183 obese and overweight, respectively. MUAC Z-scores suggested the following distribution: SAM  
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37 184 -1(0.1%), and MAM-(0.4%), obesity-19 (1.3%), overweight-43 (4.3%). An even greater number  
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39 185 of children were leaning towards SAM or MAM as well as obesity or overweight. Children who  
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41 186 are not yet at the BMI-for-age threshold for the current definition of SAM or MAM (and  
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43 187 childhood obesity or overweight) may be at an increased risk of developing severe forms of  
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45 188 under-nutrition or obesity. One of the present study’s aims was to identify these target groups so  
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47 189 that these children’s needs could be addressed.  
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3 190 The first target group, undernourished children (BMI or MUAC Z-score between -1 and -  
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5 191 2 SD), is at risk of sliding into MAM or SAM. The second group, pre-obese children (BMI or  
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7 192 MUAC Z-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. Based on  
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9  
10 193 the BMI Z-scores, 181 (12.5%) were undernourished and 136 (9.4%) were pre-obese. The  
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12 194 equivalent numbers for MUAC were 181 (12.5%) for SAM and MAM risk and 135 (9.3%) for  
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15 195 obesity, respectively. More children were at risk of severe undernutrition than of overnutrition.  
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17 196 These target groups may develop more severe forms of malnutrition if corrective measures are  
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19 197 delayed. The first step in that direction is to plan face-to-face counseling sessions with parents  
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21 198 and children. School programs are effective at preventing childhood obesity by fostering more  
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23 199 physical activities and recommending healthier diets [18]. Counseling for the target groups will  
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26 200 have to be done, keeping in mind that within low-resource settings, places for play may be  
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28 201 scarce, sports infrastructure may be poor, and recreational centers may be lacking [19].  
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31 202 Similarly, low family income is linked to greater consumption of low-quality nutrition and fast  
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33 203 food [20].  
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36 204 Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting  
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38 205 both under and over-nutrition during routine growth monitoring without a height-dependent  
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40 206 parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated  
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42 207 with each other. However, monitoring for obesity should begin even earlier, as the most rapid  
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44 208 weight gain occurs between ages 2 and 6 years among obese adolescents [21].  
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49 209 While India's economy has been growing at an impressive rate, the country still has the highest  
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51 210 number of stunted children in the world (46.8 million), representing one-third of the global total  
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53 211 of stunted children under age 5 [22]. Stunting is associated with being overweight among children  
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3 212 in countries that are undergoing a nutritional transition [23].Economic improvements are  
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5 213 accompanied by a conspicuous change in dietary patterns in the form of increased fat intake [5]  
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7 214 compounded by exposure to food advertising on television leading to fast food and soft drink  
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10 215 consumption and obesity [24]. This, coupled with low physical activity, contributes to an  
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12 216 increasing prevalence of obesity among adults, which accompanies the first wave of a cluster of  
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14 217 non-communicable diseases, such as hypertension and diabetes mellitus, called “the new world  
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16 218 syndrome” [25]. It should be noted, however, that there has not been the same level of agreement  
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19 219 on the classification of obesity for children and adolescents as there is for adults [26].  
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23 220 To summarize, until recently, India has considered under-nutrition to be a major problem,  
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25 221 and nutrition supplementation has been the key intervention. At the national level, India is at  
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27 222 stage 1 of the obesity transition with wide sub-national variations [27]. Our study may help in the  
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29 223 surveillance effort to address underserved populations [27]. With improved availability of food, a  
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31 224 double burden of malnutrition is emerging that needs to be concurrently addressed. The present  
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33 225 study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and  
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35 226 undernourished states among Indian school children in lower-middle and lower socioeconomic  
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37 227 levels. Second, the present results revealed a significant correlation between BMI and MUAC.  
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39 228 This study provides evidence to suggest that MUAC is a valid, single measurement for  
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41 229 identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-  
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43 230 nutrition on the other, through extended routine growth monitoring of children. However, more  
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46 231 studies are required to establish validity and reliability of this tool.  
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3 **233 What is known about the subject?**  
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- 5 **234** • Emerging economies face a dual problem of under-nutrition and over-nutrition.  
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8 **235** • Detecting this problem using height-based parameters is not easy in a low-resource  
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10 **236** setting.

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12 **237 What this study adds?**  
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15 **238** This study suggests that MUAC is a simple, valid, and single measure for identifying this dual  
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17 **239** problem in a low-resource setting and, undernutrition is a bigger problem than obesity.  
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21 **241**  
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32 **245** confirm no support from any organization for the submitted work; no financial relationships with  
33  
34 **246** any organizations that might have an interest in the submitted work in the previous three years;  
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36 **247** no other relationships or activities that could appear to have influenced the submitted work.  
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40 **248**

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42 **249 Author contributions**  
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45 **250 SD-Conceptualization; Data analysis; Manuscript writing.**  
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47 **251** SM-Data collection; data analysis; manuscript writing.  
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50 **252** AK- Data analysis; manuscript writing.  
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52 **253** 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
<b>MUAC</b>	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	p-value		7.34E-152	1.21E-63	6.86E-107
<b>Body weight (Kg)</b>	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	p-value	7.34E-152		2.85E-129	1.93E-86
<b>Height (cm)</b>	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	p-value	1.21E-63	2.85E-129		2.16E-16
<b>BMI</b>	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	p-value	6.86E-107	1.93E-86	2.16E-16	

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

342 **Table 2**  
 343 **Correlations between anthropometric parameters among boys (N=1020)**  
 344

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

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

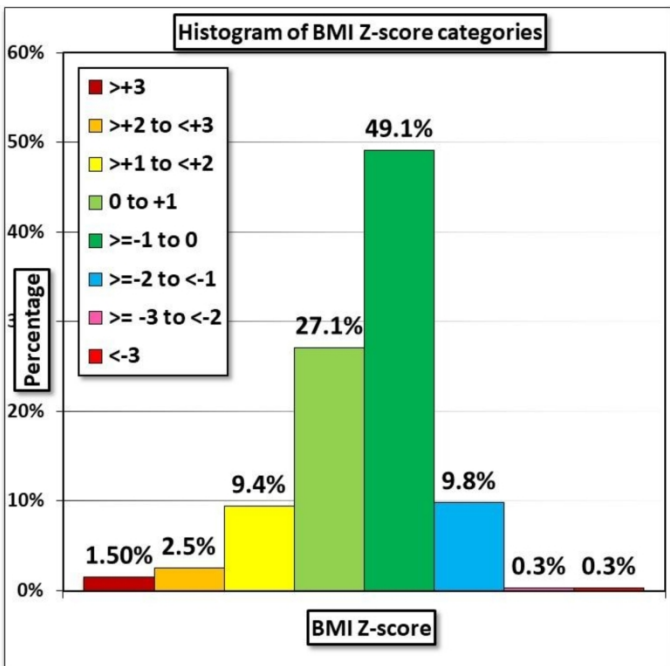
**Table 3**  
**Distribution of nutrition conditions based on BMI and MUAC Z-scores \*\***

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

\*\*Modified WHO Classification of nutrition conditions based on anthropometry

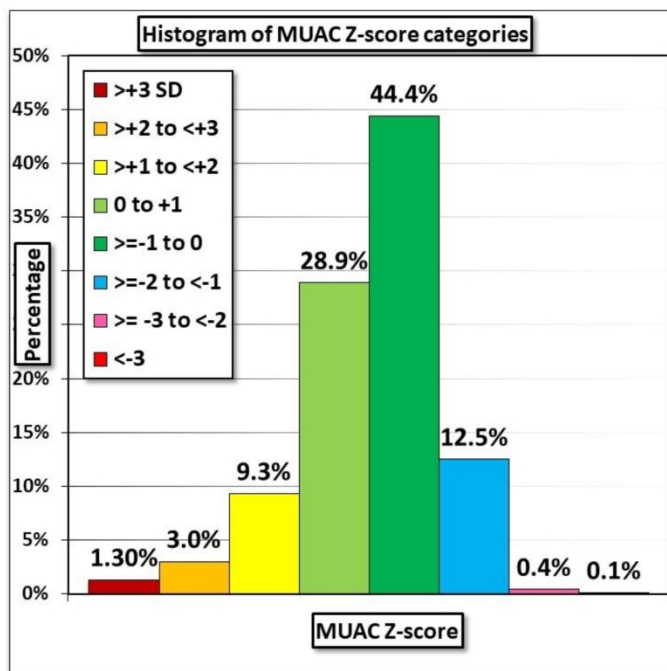
BMI = Body Mass Index; MUAC = Mid-upper-arm circumference

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215x279mm (300 x 300 DPI)

**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
<b>Age (years)</b>	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	<b>2.44E-07 *</b>
<b>Height (cm)</b>	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	<b>3.44E-11 *</b>
<b>Body weight (kg)</b>	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	<b>5.41E-13 *</b>
<b>BMI</b>	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	<b>1.66E-13 *</b>
<b>MUAC</b>	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	<b>4.59E-10 *</b>

^ 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

**Table 2 (S)**  
**Distribution of variables among all participants**

<b>Variables</b>	<b>Mean</b>	<b>SD</b>	<b>Median</b>	<b>IQR</b>	<b>Minimum</b>	<b>Maximum</b>
<b>Age (years)</b>	8.46	3.50	9.00	6.00	3.00	16.00
<b>Body weight (kg)</b>	27.04	13.77	23.10	16.20	9.00	97.50
<b>Height (cm)</b>	131.45	21.16	130.00	32.00	84.00	188.00
<b>Height (meters)</b>	1.31	0.21	1.30	0.32	0.84	1.88
<b>BMI</b>	14.69	3.10	13.78	2.89	6.58	36.10
<b>MAC</b>	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
<b>Sig.</b>		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
<b>Sig.</b>		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:	<i>BMJ Paediatrics Open</i>
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

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Manuscripts

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10 3 measurement: A cross-sectional study in a single school  
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14 4 Short title: Measuring double burden of malnutrition  
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## 18 **Abstract**

### 19 **Objective**

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

### 24 **Subjects**

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

### 27 **Measurements**

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

### 34 **Main outcome measures**

- 35 1. To know if MUAC and BMI are correlated among boys and girls.
- 36 2. To study BMI and MUAC Z score distribution among the participants.

## 37 Results

38 MUAC was positively correlated with BMI in both boys and girls. The following BMI Z-score  
39 distribution was observed: severe acute malnutrition (SAM), 5 (0.3%); moderate acute  
40 malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%); obese,  
41 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%). The distribution of categories of  
42 children based on MUAC Z-scores was: SAM, 7 (0.5%), MAM, 181 (12.5%), and  
43 undernourished at risk of MAM or SAM, 181 (12.5%); obese, 19 (1.3%), overweight, 178  
44 (12.3%), pre-obese, 135 (9.3%).

## 45 Conclusions

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

## 51 Introduction

52 The double burden of under-nutrition and over-nutrition is an emerging international  
53 problem. According to estimates from 129 countries with available data, 57 experience serious  
54 problems of both undernourished children and overweight adults [1]. The relationship between  
55 under-nutrition and overweight status and obesity is deeper than coexistence. The double burden  
56 of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within  
57 individuals, households, and populations and across the life course. "Across the life course"

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3 58 refers to the phenomenon that under-nutrition early in life contributes to an increased propensity  
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5 59 for over-nutrition during adulthood [2]. The occurrence of DBM is attributed to a complex  
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7 60 interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic  
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9 61 transitions, etc.) from high fertility and early deaths to low fertility and aging populations and  
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11 62 epidemiological transitions from communicable to non-communicable diseases [2].  
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16 63 Later in the life course, the double burden of disease is characterized by the coexistence  
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18 64 of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s,  
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20 65 obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-  
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22 66 nutrition was a major problem, and nutrition supplementation was the main intervention. Thus,  
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24 67 obesity is a relatively new problem in need of attention. A systematic review of obesity and  
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26 68 socioeconomic status in low and middle income countries concluded that child obesity is more  
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28 69 prevalent among affluent groups in such countries [4]. This may be attributed to improved access  
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30 70 to surplus/excess food and a higher degree of urbanization and technological progress in these  
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32 71 economies that render activities less laborious, resulting in less energy expenditure [5].  
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34 72 Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese  
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36 73 study revealed that approximately one-third of obese children grew into obese adults  
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38 74 [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress,  
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40 75 is more likely to succeed than attempting to reverse obesity later.  
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47 76 Body mass index (BMI)-for-age, the internationally recommended measure of obesity,  
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49 77 suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI  
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51 78 levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health  
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53 79 Organization (WHO) recommends lowering the BMI cut-offs for being considered “overweight”  
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3 80 among Asian adults [8] in light of the increased health risks. Early detection of overweight status  
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5 81 has become very important in Asia.  
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8 82 The selection of height-based parameters, such as BMI for the detection of  
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10 83 overweight/obese children in low-resource settings, has limitations because of the shortage of  
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12 84 stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of  
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14 85 abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm  
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16 86 circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent  
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18 87 study from the Netherlands reaffirmed that, compared with BMI, MUAC is a valid measure for  
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20 88 detecting overweight/obesity, and thus is a good alternative to BMI [15]. Health workers are  
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22 89 familiar with MUAC measurement, as it has been commonly used for identifying severe acute  
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24 90 under-nutrition among young (6–60 months of age) children [16].  
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30 91 To our knowledge, few studies have focused on the coexistence of under- and over-  
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32 92 nutrition in India. The present study was conducted to document the extent of DBM among  
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34 93 Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The  
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36 94 study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect  
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38 95 trends toward obesity or severe acute malnutrition (SAM).  
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## 43 96 **Participants and Methods**

### 44 45 46 97 **Setting**

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49 98 A single schoolcross-sectional study was conducted with schoolchildren from the  
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51 99 outskirts of Pune, India. This study was part of the MIMER medical college and hospital's  
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53 100 outreach activities regarding annual school health check-ups. A schedule of class-wise health  
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3 101 check-ups was developed in consultation with the school authorities who, in turn, sought parents'  
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5 102 permission. The study had the approval of the ethics committee of MIMER medical college and  
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7 103 hospital, TalegaonDabhade. A majority of the children belonged to lower and lower-middle  
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9 104 socioeconomic categories. Children between 3 and 5 years were from a playgroup, and those  
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11 105 between 6 and 12 years belonged to grades 1–7.  
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### 16 106 **Anthropometric measurements**

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19 107 Anthropometric measurements, such as MUAC, height, and weight, were taken from  
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21 108 each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy  
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23 109 Care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin  
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25 110 Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic  
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27 111 plastic tape at the midway between the olecranon and acromion processes on the upper left arm.  
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29 112 During these measurements, the participant was in a comfortable standing position and was  
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31 113 asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm  
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33 114 was straightened, and we ensured that the tape was neither too tight nor too loose.  
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### 39 115 **Statistical tools**

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41 116 Open Source Statistical Software PSPP version 1.0.1 was used for all analyses, and a p-  
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43 117 value  $\leq 0.05$  was considered statistically significant. Mean and standard deviation (SD), median,  
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45 118 inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants  
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47 119 with complete measurements. Z-scores were computed using age-specific and sex-specific  
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49 120 reference data from the WHO [17]. The distribution of variables was calculated among all  
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51 121 participants together and separately for boys and girls. Homogeneous subsets for BMI and  
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3 122 MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were  
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5 123 calculated for both girls and boys.  
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#### 8 124 **Patient involvement**

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11 125 Patients were not directly involved in the design of this study.  
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### 14 126 **Results**

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18 127 The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The  
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20 128 distribution of Z- scores among all participants is shown in Figures 1 and 2. Age, height, weight,  
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22 129 MUAC, and BMI were all significantly different between girls and boys; boys had higher values  
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24 130 for all parameters (Suppl. Files: Tables 1 and 2). As expected, BMI and MUAC showed age-wise  
25  
26 131 differences for all participants, combined and separately, for boys and girls, between the ages of  
27  
28 132 3 to 16 years (Suppl. Files: Tables 3 and 4). Tukey's honest significant difference (HSD) test for  
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30 133 homogeneous subsets revealed a significant shift in mean BMI at 3, 6, and 10 years (Suppl.  
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32 134 Files: Table 5), whereas for MUAC, the shift occurred at 4, 6, and 9 years (Suppl. Files: Table  
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34 135 6). Thereafter, MUAC changed significantly almost every year until the age of 16. Thus, in  
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36 136 contrast to BMI, MUAC had more age-dependent variability. BMI change with age was minimal  
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38 137 in girls (only at age 14) compared to changes in boys at 6, 10, 12, and 14 years. Girls had six  
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40 138 homogeneous subsets for MUAC, with the first significant rise at age 4 years, compared to nine  
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42 139 subsets in boys, with the first shift at age 5. Thus, changes in BMI and MUAC were more  
43  
44 140 frequent in boys. MUAC was associated with weight, height, and BMI both in girls and boys  
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46 141 (Tables 1 and 2).  
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54 142  
55 143 **Table 1**  
56 144 **Correlations between anthropometric parameters among girls (N=424)**  
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Variables		MUAC	Body weight (kg)	Height (cm)	BMI
MUAC	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	<i>p</i> -value		7.34E-152	1.21E-63	6.86E-107
Body weight (kg)	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	<i>p</i> -value	7.34E-152		2.85E-129	1.93E-86
Height (cm)	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	<i>p</i> -value	1.21E-63	2.85E-129		2.16E-16
BMI	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	<i>p</i> -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(**)
	<i>p</i> -value		0.0001	9.60E-210	2.21E-281
Body weight (kg)	Pearson Correlation	.911(**)	1	.886(**)	.861(**)
	<i>p</i> -value	0.0001		0.0001	1.25E-301
Height (cm)	Pearson Correlation	.780(**)	.886(**)	1	.564(**)
	<i>p</i> -value	9.60E-210	0.0001		1.02E-86
BMI	Pearson Correlation	.847(**)	.861(**)	.564(**)	1
	<i>p</i> -value	2.21E-281	1.25E-301	1.02E-86	

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

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

153 **Table 3**  
 154 **Distribution of nutrition conditions based on BMI and MUAC Z-scores \*\***  
 155

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

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

158

## 159 Discussion

160 The present study suggests that DBM has reached Indian school children of lower middle  
 161 or lower socioeconomic statuses, which calls for urgent action. Importantly, the present results  
 162 identify children at the brink of sliding into severe forms of under- and over-nutrition. The

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2  
3 163 present study also suggests using a single and simpler method, MUAC, for detecting both forms  
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5 164 of malnutrition by monitoring growth during routine health check-ups.  
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8 165 The World Health Assembly targets were considered in crafting the 2030 development  
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10 166 agenda and are referred to in target 2.2 of the Sustainable Development Goals to “end all forms  
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12 167 of malnutrition.” The reference to “all forms of malnutrition” is important for acknowledging the  
13  
14 168 existence of the double burden of under-nutrition and overweight status. While the drivers of the  
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16 169 double burden of malnutrition are varied and often insidious, their effects present a clear case for  
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18 170 urgent action and demand an integrated response. Using a single tool for detecting both forms of  
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20 171 malnutrition integrates and simplifies the process.  
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24  
25 172 To our knowledge, few studies have focused on this aspect of growth among children in  
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27 173 India, as well as other emerging economies. The girls were outnumbered by boys (424 vs.  
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29 174 1,020). This may be due to the traditional gender norms that push girls into helping with  
30  
31 175 household chores and sibling care, resulting in school dropouts. Based on BMI Z-Scores, 5  
32  
33 176 (0.3%) and 5 (0.3%) belonged to SAM and MAM categories, respectively, and 21 (1.5%) and 36  
34  
35 177 (3.9%) children were classified as obese and overweight, respectively. MUAC Z-scores  
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37 178 suggested the following distribution: SAM -1 (0.1%), MAM-(0.4%), obesity-19 (1.3%),  
38  
39 179 overweight-43 (4.3%). An even greater number of children were leaning toward SAM or MAM  
40  
41 180 as well as obesity or overweight. Children who are not yet at the BMI-for-age threshold for the  
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43 181 current definition of SAM or MAM (and childhood obesity or overweight) may be at an  
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45 182 increased risk of developing severe forms of under-nutrition or obesity. One of the present  
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47 183 study’s aims was to identify these target groups so that these children’s needs could be  
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52 184 addressed.  
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3 185 The first target group, undernourished children (BMI or MUACZ-score between -1 and -  
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5 186 2 SD), is at risk of sliding into MAM or SAM. The second group, pre-obese children (BMI or  
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7 187 MUACZ-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. Based on  
8  
9 188 the BMI Z-scores, 181 (12.5%) were undernourished, and 136 (9.4%) were pre-obese. The  
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11 189 equivalent numbers for MUAC were 181 (12.5%) for SAM and MAM risk and 135 (9.3%) for  
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13 190 obesity, respectively. More children were at risk of severe undernutrition than of overnutrition.  
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15 191 These target groups may develop more severe forms of malnutrition if corrective measures are  
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17 192 delayed. The first step in that direction is to plan face-to-face counseling sessions with parents  
18  
19 193 and children. School programs are effective at preventing childhood obesity by fostering more  
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21 194 physical activities and recommending healthier diets [18]. Counseling for the target groups will  
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23 195 have to be done, keeping in mind that within low-resource settings, places for play may be  
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25 196 scarce, sports infrastructure may be poor, and recreational centers may be lacking [19].  
26  
27 197 Similarly, low family income is linked to greater consumption of low-quality nutrition and fast  
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29 198 food [20].  
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36 199 Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting  
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38 200 both under and over-nutrition during routine growth monitoring without a height-dependent  
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40 201 parameter, such as BMI (Figure 1). This is because BMI and MUAC are significantly correlated  
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42 202 with each other. However, monitoring for obesity should begin even earlier, as the most rapid  
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44 203 weight gain occurs between ages 2 and 6 years among obese adolescents [21].  
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49 204 While India's economy has been growing at an impressive rate, the country still has the  
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51 205 highest number of stunted children in the world (46.8 million), representing one-third of the  
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53 206 global total of stunted children under age 5 [22]. Stunting is associated with being overweight  
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3 207 among children in countries that are undergoing a nutritional transition [23].Economic  
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5 208 improvements are accompanied by a conspicuous change in dietary patterns in the form of  
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7 209 increased fat intake [5]compounded by exposure to food advertising on television leading to fast  
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10 210 food and soft drink consumption and obesity [24].This, coupled with low physical activity,  
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12 211 contributes to an increasing prevalence of obesity among adults, which accompanies the first  
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14 212 wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus,  
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16 213 called “the new world syndrome” [25]. It should be noted, however, that there has not been the  
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18 214 same level of agreement on the classification of obesity for children and adolescents as there is  
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20 215 for adults [26].  
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25 216 To summarize, until recently, India has considered under-nutrition to be a major problem,  
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27 217 and nutrition supplementation has been the key intervention. At the national level, India is at  
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29 218 stage 1 of the obesity transition with wide sub-national variations [27]. Our study may help in the  
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31 219 surveillance effort to address underserved populations [27]. With improved availability of food, a  
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33 220 double burden of malnutrition is emerging that needs to be concurrently addressed. The present  
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35 221 study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and  
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37 222 undernourished states among Indian school children in lower-middle and lower socioeconomic  
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39 223 levels. Second, the present results revealed a significant correlation between BMI and MUAC.  
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41 224 This study provides evidence to suggest that MUAC is a valid, single measurement for  
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43 225 identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-  
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45 226 nutrition on the other, through extended routine growth monitoring of children. However, more  
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49 227 studies are required to establish the validity and reliability of this tool.  
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3 **228 What is known about the subject?**  
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- 5 229 • Emerging economies face a dual problem of under-nutrition and over-nutrition.  
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8 230 • Detecting these problems using height-based parameters is not easy in a low-resource  
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10 231 setting.

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12 **232 What this study adds?**  
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14  
15 233 This study suggests that MUAC is a simple, valid, and single measure for identifying this dual  
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17 234 problem in a low-resource setting, and undernutrition is a bigger problem than obesity.  
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19 235  
20  
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29 239 confirm no support from any organization for the submitted work; no financial relationships with  
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31 240 any organizations that might have an interest in the submitted work in the previous three years;  
32  
33 241 no other relationships or activities that could appear to have influenced the submitted work.  
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39 **243 Author contributions**  
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41  
42 244 SD-Conceptualization; Data analysis; Manuscript writing.  
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44  
45 245 SM-Data collection; data analysis; manuscript writing.  
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47  
48 246 AK-Data analysis; manuscript writing.  
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51 247 ED-Data collection; manuscript writing.  
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**Table 1**

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

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

336 **Table 2**  
 337 **Correlations between anthropometric parameters among boys (N=1020)**  
 338

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

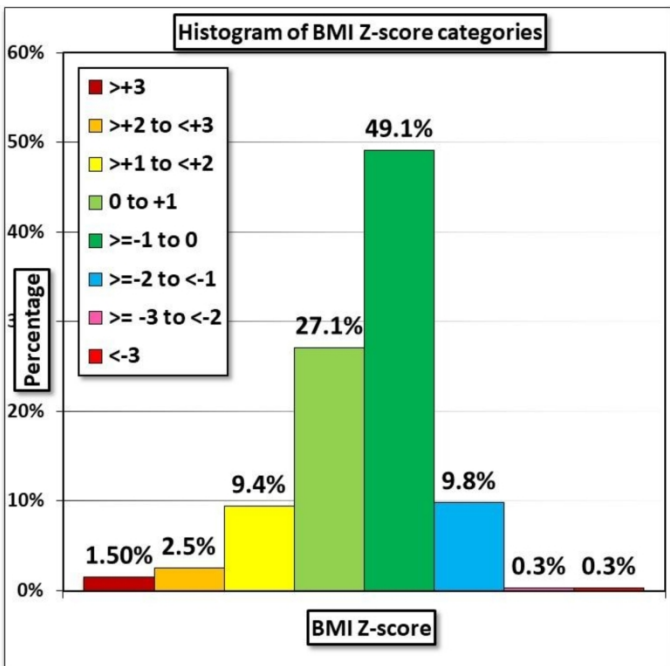
339 \*\* Correlation is significant at the 0.01 level (2-tailed).

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

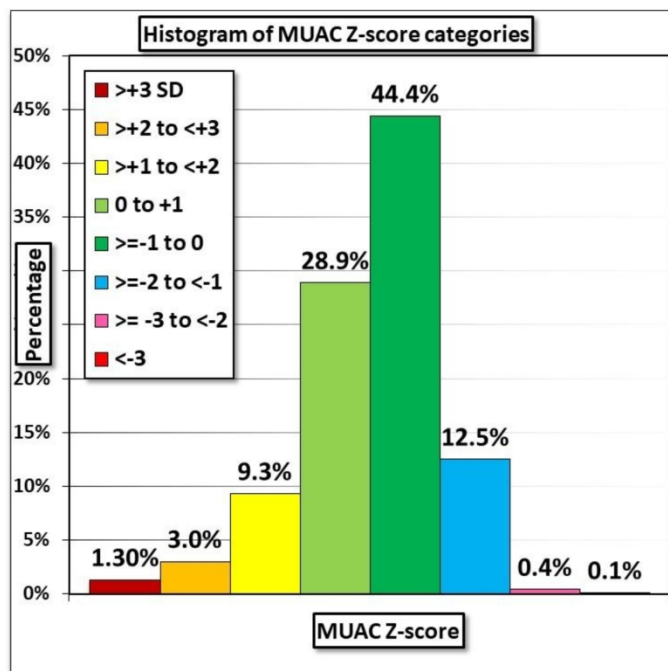
<b>Condition</b>	<b>Based on BMI Z-scores No (%)</b>	<b>Based on MUACZ-scores No (%)</b>
<b>Pre-obese</b>	BMI >1 to 2 SD 136 (9.4%)	MUAC>1to2SD 135 (9.3%)
<b>Overweight</b>	BMI>2 to 3 SD 36 (2.5%)	MUAC>2 to 3SD 43 (3.0%)
<b>Obese</b>	BMI >3SD 21 (1.5%)	MUAC>3SD 19(1.3%)
<b>Possible risk of underweight</b>	BMI <-1 to -2 SD 141 (9.8%)	MUAC ≤ -1 to -2SD 181 (12.5%)
<b>Thin</b>	BMI <-2 to -3 SD 5 (0.3%)	MUAC<-2 to -3SD 6 (0.4%)
<b>Severely thin</b>	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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215x279mm (300 x 300 DPI)



**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
<b>Age (years)</b>	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	<b>2.44E-07 *</b>
<b>Height (cm)</b>	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	<b>3.44E-11 *</b>
<b>Body weight (kg)</b>	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	<b>5.41E-13 *</b>
<b>BMI</b>	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	<b>1.66E-13 *</b>
<b>MUAC</b>	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	<b>4.59E-10 *</b>

^ 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

**Table 2 (S)**  
**Distribution of variables among all participants**

<b>Variables</b>	<b>Mean</b>	<b>SD</b>	<b>Median</b>	<b>IQR</b>	<b>Minimum</b>	<b>Maximum</b>
<b>Age (years)</b>	8.46	3.50	9.00	6.00	3.00	16.00
<b>Body weight (kg)</b>	27.04	13.77	23.10	16.20	9.00	97.50
<b>Height (cm)</b>	131.45	21.16	130.00	32.00	84.00	188.00
<b>Height (meters)</b>	1.31	0.21	1.30	0.32	0.84	1.88
<b>BMI</b>	14.69	3.10	13.78	2.89	6.58	36.10
<b>MUAC</b>	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
<b>3</b>	13.37	1.34	13.26	1.61
<b>4</b>	13.04	1.69	13.07	1.46
<b>5</b>	13.01	1.13	12.80	1.02
<b>6</b>	13.85	2.09	13.39	1.55
<b>7</b>	13.54	1.48	13.20	1.90
<b>8</b>	13.94	2.22	13.37	2.01
<b>9</b>	13.70	1.73	13.36	1.66
<b>10</b>	14.74	2.84	13.97	2.77
<b>11</b>	15.48	3.03	14.89	3.60
<b>12</b>	15.89	3.01	15.63	3.87
<b>13</b>	18.22	3.34	17.51	3.30
<b>14</b>	18.33	3.88	17.28	4.53
<b>15</b>	19.09	4.32	18.01	6.52
<b>16</b>	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
<b>3</b>	15.39	1.24	15.20	1.50
<b>4</b>	15.50	1.16	15.50	1.10
<b>5</b>	16.19	1.17	15.95	1.20
<b>6</b>	16.83	2.07	16.50	1.95
<b>7</b>	16.98	1.75	16.70	2.00
<b>8</b>	17.97	2.11	17.50	1.61
<b>9</b>	17.79	1.78	17.50	2.08
<b>10</b>	19.02	2.63	18.50	3.45
<b>11</b>	20.16	3.04	19.50	3.93
<b>12</b>	20.87	2.79	20.50	4.00
<b>13</b>	22.91	2.79	22.50	2.60
<b>14</b>	23.53	3.64	23.00	4.95
<b>15</b>	24.66	3.73	23.50	5.23
<b>16</b>	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
<b>Sig.</b>		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
<b>Sig.</b>		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**

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Manuscripts

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7 2 Double burden of malnutrition among Indian school children and its  
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10 3 measurement: A cross-sectional study in a single school  
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14 4 Short title: Measuring double burden of malnutrition  
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## 18 **Abstract**

### 19 **Objective**

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

### 24 **Subjects**

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

### 27 **Measurements**

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

### 34 **Main outcome measures**

- 35 1. To know if MUAC and BMI are correlated among boys and girls.
- 36 2. To study BMI and MUAC Z score distribution among the participants.

## 37 Results

38 MUAC was positively correlated with BMI in both boys and girls. The following BMI Z-score  
39 distribution was observed: severe acute malnutrition (SAM), 5(0.3%); moderate acute  
40 malnutrition (MAM), 146 (10.1%); undernourished, at risk of MAM/SAM, 141 (9.8%); obese,  
41 21 (1.5%); overweight, 36 (2.5%); pre-obese, 136 (9.4%). The distribution of categories of  
42 children based on MUAC Z-scores was: SAM, 7(0.5%), MAM, 181 (12.5%), and  
43 undernourished at risk of MAM or SAM, 181 (12.5%); obese, 19 (1.3%), overweight, 178  
44 (12.3%), pre-obese, 135 (9.3%).

## 45 Conclusions

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

## 51 Introduction

52 The double burden of under-nutrition and over-nutrition is an emerging international  
53 problem. According to estimates from 129 countries with available data, 57 experience serious  
54 problems of both undernourished children and overweight adults [1]. The relationship between  
55 under-nutrition and overweight status and obesity is deeper than coexistence. The double burden  
56 of malnutrition (DBM) refers to the coexistence of both under-nutrition and over-nutrition within  
57 individuals, households, and populations and across the life course. “Across the life course”

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3 58 refers to the phenomenon that under-nutrition early in life contributes to an increased propensity  
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5 59 for over-nutrition during adulthood [2]. The occurrence of DBM is attributed to a complex  
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7 60 interplay of nutritional transitions (shifting from an active to a sedentary lifestyle, demographic  
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9 61 transitions, etc.) from high fertility and early deaths to low fertility and aging populations and  
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11 62 epidemiological transitions from communicable to non-communicable diseases [2].  
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16 63 Later in the life course, the double burden of disease is characterized by the coexistence  
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18 64 of communicable (infectious disease) and non-communicable diseases. Prior to the 1970s,  
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20 65 obesity was a relatively rare condition, even in the wealthiest of nations [3], whereas under-  
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22 66 nutrition was a major problem, and nutrition supplementation was the main intervention. Thus,  
23  
24 67 obesity is a relatively new problem in need of attention. A systematic review of obesity and  
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26 68 socioeconomic status in low and middle income countries concluded that child obesity is more  
27  
28 69 prevalent among affluent groups in such countries [4]. This may be attributed to improved access  
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30 70 to surplus/excess food and a higher degree of urbanization and technological progress in these  
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32 71 economies that render activities less laborious, resulting in less energy expenditure [5].  
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34 72 Furthermore, childhood obesity is a strong predictor of adult obesity. For instance, a Japanese  
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36 73 study revealed that approximately one-third of obese children grew into obese adults  
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38 74 [6]. Therefore, early detection of excessive weight gain, and action to prevent its progress,  
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40 75 is more likely to succeed than attempting to reverse obesity later.  
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47 76 Body mass index (BMI)-for-age, the internationally recommended measure of obesity,  
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49 77 suggests that Asians are at an increased risk of cardio-metabolic disorders, even at lower BMI  
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51 78 levels, because of a considerably higher body fat percentage [7]. Therefore, the World Health  
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53 79 Organization (WHO) recommends lowering the BMI cut-offs for being considered “overweight”  
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3 80 among Asian adults [8] in light of the increased health risks. Early detection of overweight status  
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5 81 has become very important in Asia.  
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8 82 The selection of height-based parameters, such as BMI for the detection of  
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10 83 overweight/obese children in low-resource settings, has limitations because of the shortage of  
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12 84 stadiometers and trained paramedical staff. A simpler proxy for BMI that parallels the use of  
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14 85 abdominal girth for detecting visceral obesity needs to be developed [9]. The mid-upper arm  
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16 86 circumference (MUAC) appears to be a promising alternative in this regard [10–14]. A recent  
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18 87 study from the Netherlands reaffirmed that, compared with BMI, MUAC is a valid measure for  
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20 88 detecting overweight/obesity, and thus is a good alternative to BMI [15]. Health workers are  
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22 89 familiar with MUAC measurement, as it has been commonly used for identifying severe acute  
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24 90 under-nutrition among young (6–60 months of age) children [16].  
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30 91 To our knowledge, few studies have focused on the coexistence of under- and over-  
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32 92 nutrition in India. The present study was conducted to document the extent of DBM among  
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34 93 Indian schoolchildren, a key group for intervention, using BMI and MUAC distributions. The  
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36 94 study also examined whether MUAC can be used as a proxy for BMI, so that MUAC can detect  
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38 95 trends toward obesity or severe acute malnutrition (SAM).  
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## 43 96 **Participants and Methods**

### 44 45 46 97 **Setting**

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49 98 A single school cross-sectional study was conducted with schoolchildren from the  
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51 99 outskirts of Pune, India. This study was part of the MIMER medical college and hospital's  
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53 100 outreach activities regarding annual school health check-ups. A schedule of class-wise health  
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3 101 check-ups was developed in consultation with the school authorities who, in turn, sought parents'  
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5 102 permission. The study had the approval of the ethics committee of MIMER medical college and  
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7 103 hospital, Talegaon Dabhade. A majority of the children belonged to lower and lower-middle  
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9 104 socioeconomic categories. Children between 3 and 5 years were from a playgroup, and those  
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11 105 between 6 and 12 years belonged to grades 1–7.  
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### 16 106 **Anthropometric measurements**

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19 107 Anthropometric measurements, such as MUAC, height, and weight, were taken from  
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21 108 each participant using standard techniques. Height (cm) was measured on a stadiometer (Easy  
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23 109 Care) without shoes. Weight (kg) was measured using a digital weighing machine (Meditrin  
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25 110 Instruments) in light clothes and without shoes. MUAC (cm) was measured using a non-elastic  
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27 111 plastic tape at the midway between the olecranon and acromion processes on the upper left arm.  
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29 112 During these measurements, the participant was in a comfortable standing position and was  
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31 113 asked to look straight ahead with his/her shoulders in a neutral position. The participant's arm  
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33 114 was straightened, and we ensured that the tape was neither too tight nor too loose.  
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### 39 115 **Statistical tools**

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41 116 Open Source Statistical Software PSPP version 1.0.1 was used for all analyses, and a p-  
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43 117 value  $\leq 0.05$  was considered statistically significant. Mean and standard deviation (SD), median,  
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45 118 inter-quartile range, and Z-scores for BMI and MUAC were computed by sex for participants  
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47 119 with complete measurements. Z-scores were computed using age-specific and sex-specific  
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49 120 reference data from the WHO [17]. The distribution of variables was calculated among all  
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51 121 participants together and separately for boys and girls. Homogeneous subsets for BMI and  
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3 122 MUAC were identified in these three groups. Age-wise comparisons of BMI and MUAC were  
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5 123 calculated for both girls and boys.  
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#### 8 124 **Patient involvement**

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11 125 Patients were not directly involved in the design of this study.  
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### 14 126 **Results**

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18 127 The total number of participants was 1,444, comprising 424 girls and 1,020 boys. The  
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20 128 distribution of Z- scores among all participants is shown in Figures 1 and 2. Age, height, weight,  
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22 129 MUAC, and BMI were all significantly different between girls and boys; boys had higher values  
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24 130 for all parameters (**Suppl. Files: Tables 1 (S) and 2 (S)**). As expected, BMI and MUAC showed  
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26 131 age-wise differences for all participants, combined and separately, for boys and girls, between  
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28 132 the ages of 3 to 16 years (**Suppl. Files: Tables 3 (S) and 4 (S)**). Tukey's honest significant  
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30 133 difference (HSD) test for homogeneous subsets revealed a significant shift in mean BMI at 3, 6,  
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32 134 and 10 years (**Suppl. Files: Table 5 (S)**), whereas for MUAC, the shift occurred at 4, 6, and 9  
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34 135 years (**Suppl. Files: Table 6 (S)**). Thereafter, MUAC changed significantly almost every year  
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36 136 until the age of 16. Thus, in contrast to BMI, MUAC had more age-dependent variability. BMI  
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38 137 change with age was minimal in girls (only at age 14) compared to changes in boys at 6, 10,  
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40 138 12, and 14 years. Girls had six homogeneous subsets for MUAC, with the first significant rise at  
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42 139 age 4 years, compared to nine subsets in boys, with the first shift at age 5. Thus, changes in BMI  
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44 140 and MUAC were more frequent in boys. MUAC was associated with weight, height, and BMI  
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50 141 both in girls and boys (Tables 1 and 2).  
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4 144 **Table 1**  
5 145 **Correlations between anthropometric parameters among girls (N=424)**  
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Variables		MUAC	Body weight (kg)	Height (cm)	BMI
<b>MUAC</b>	Pearson Correlation	1	.897(**)	.700(**)	.826(**)
	<i>p</i> -value		7.34E-152	1.21E-63	6.86E-107
<b>Body weight (kg)</b>	Pearson Correlation	.897(**)	1	.866(**)	.776(**)
	<i>p</i> -value	7.34E-152		2.85E-129	1.93E-86
<b>Height (cm)</b>	Pearson Correlation	.700(**)	.866(**)	1	.385(**)
	<i>p</i> -value	1.21E-63	2.85E-129		2.16E-16
<b>BMI</b>	Pearson Correlation	.826(**)	.776(**)	.385(**)	1
	<i>p</i> -value	6.86E-107	1.93E-86	2.16E-16	

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29 147 \*\* Correlation is significant at the 0.01 level (2-tailed).  
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156 **Table 2**157 **Correlations between anthropometric parameters among boys (N=1020)**

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

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

160 The distribution of clinical categories of nutritional status with respect to BMI and

161 MUAC is shown in Table 3.

162 **Table 3**163 **Distribution of nutrition conditions based on BMI and MUAC Z-scores \*\***

164

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

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

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

167

## 168 Discussion

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

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

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3 181 To our knowledge, few studies have focused on this aspect of growth among children in  
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5 182 India, as well as other emerging economies. The girls were outnumbered by boys (424 vs.  
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7 183 1,020). This may be due to the traditional gender norms that push girls into helping with  
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9 184 household chores and sibling care, resulting in school dropouts. Based on BMI Z-Scores, 5  
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11 185 (0.3%) and 5 (0.3%) belonged to SAM and MAM categories, respectively, and 21(1.5%) and 36  
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13 186 (3.9%) children were classified as obese and overweight, respectively. MUAC Z-scores  
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15 187 suggested the following distribution: SAM -1(0.1%), MAM-(0.4%), obesity-19 (1.3%),  
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17 188 overweight-43 (4.3%).An even greater number of children were leaning toward SAM or MAM  
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19 189 as well as obesity or overweight. Children who are not yet at the BMI-for-age threshold for the  
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21 190 current definition of SAM or MAM (and childhood obesity or overweight) may be at an  
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23 191 increased risk of developing severe forms of under-nutrition or obesity. One of the present  
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25 192 study's aims was to identify these target groups so that these children's needs could be  
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27 193 addressed.  
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34 194 The first target group, undernourished children (BMI or MUACZ-score between -1 and -  
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36 195 2 SD), is at risk of sliding into MAM or SAM. The second group, pre-obese children (BMI or  
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38 196 MUACZ-score between 1 and 2 SD), is at risk of progressing to overweight/obesity. Based on  
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40 197 the BMI Z-scores, 181 (12.5%) were undernourished, and 136 (9.4%) were pre-obese. The  
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42 198 equivalent numbers for MUAC were 181 (12.5%) for SAM and MAM risk and 135 (9.3%) for  
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44 199 obesity, respectively. More children were at risk of severe undernutrition than of overnutrition.  
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46 200 These target groups may develop more severe forms of malnutrition if corrective measures are  
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48 201 delayed. The first step in that direction is to plan face-to-face counseling sessions with parents  
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50 202 and children. School programs are effective at preventing childhood obesity by fostering more  
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52 203 physical activities and recommending healthier diets [18]. Counseling for the target groups will  
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3 204 have to be done, keeping in mind that within low-resource settings, places for play may be  
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5 205 scarce, sports infrastructure may be poor, and recreational centers may be lacking [19].  
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8 206 Similarly, low family income is linked to greater consumption of low-quality nutrition and fast  
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10 207 food [20].

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13 208 Importantly, MUAC as a single tool can facilitate this cohesive intervention by detecting  
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15 209 both under and over-nutrition during routine growth monitoring without a height-dependent  
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17 210 parameter, such as BMI (Figure1). This is because BMI and MUAC are significantly correlated  
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19 211 with each other. However, monitoring for obesity should begin even earlier, as the most rapid  
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21 212 weight gain occurs between ages 2 and 6 years among obese adolescents [21].  
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26 213 While India's economy has been growing at an impressive rate, the country still has the  
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28 214 highest number of stunted children in the world (46.8 million), representing one-third of the  
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30 215 global total of stunted children under age 5 [22]. Stunting is associated with being overweight  
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32 216 among children in countries that are undergoing a nutritional transition [23]. Economic  
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34 217 improvements are accompanied by a conspicuous change in dietary patterns in the form of  
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36 218 increased fat intake [5] compounded by exposure to food advertising on television leading to fast  
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38 219 food and soft drink consumption and obesity [24]. This, coupled with low physical activity,  
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40 220 contributes to an increasing prevalence of obesity among adults, which accompanies the first  
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42 221 wave of a cluster of non-communicable diseases, such as hypertension and diabetes mellitus,  
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44 222 called "the new world syndrome" [25]. It should be noted, however, that there has not been the  
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46 223 same level of agreement on the classification of obesity for children and adolescents as there is  
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48 224 for adults [26].  
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3 225 To summarize, until recently, India has considered under-nutrition to be a major problem,  
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5 226 and nutrition supplementation has been the key intervention. At the national level, India is at  
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8 227 stage 1 of the obesity transition with wide sub-national variations [27]. Our study may help in the  
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10 228 surveillance effort to address underserved populations [27]. With improved availability of food, a  
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12 229 double burden of malnutrition is emerging that needs to be concurrently addressed. The present  
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14 230 study observed the coexistence of obesity, overweight, pre-obese, and SAM, MAM, and  
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16 231 undernourished states among Indian school children in lower-middle and lower socioeconomic  
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18 232 levels. Second, the present results revealed a significant correlation between BMI and MUAC.  
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20 233 This study provides evidence to suggest that MUAC is a valid, single measurement for  
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22 234 identifying this dual problem of aberrant growth and over-nutrition on the one hand and under-  
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24 235 nutrition on the other, through extended routine growth monitoring of children. However, more  
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26 236 studies are required to establish the validity and reliability of this tool.  
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3 237 **What is known about the subject?**  
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5 238 • Emerging economies face a dual problem of under-nutrition and over-nutrition.

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8 239 • Detecting these problems using height-based parameters is not easy in a low-resource  
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10 240 setting.

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12 241 **What this study adds?**  
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15 242 This study suggests that MUAC is a simple, valid, and single measure for identifying this dual  
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17 243 problem in a low-resource setting, and undernutrition is a bigger problem than obesity.  
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40 252 **Author contributions**  
41

42 253 SD-Conceptualization; Data analysis; Manuscript writing.  
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45 254 SM-Data collection; data analysis; manuscript writing.  
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48 255 AK-Data analysis; manuscript writing.  
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50 256 ED-Data collection; manuscript writing.  
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342 **Table 1**  
343 **Correlations between anthropometric parameters among girls (N=424)**  
344

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

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

346 **Table 2**  
 347 **Correlations between anthropometric parameters among boys (N=1020)**  
 348

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

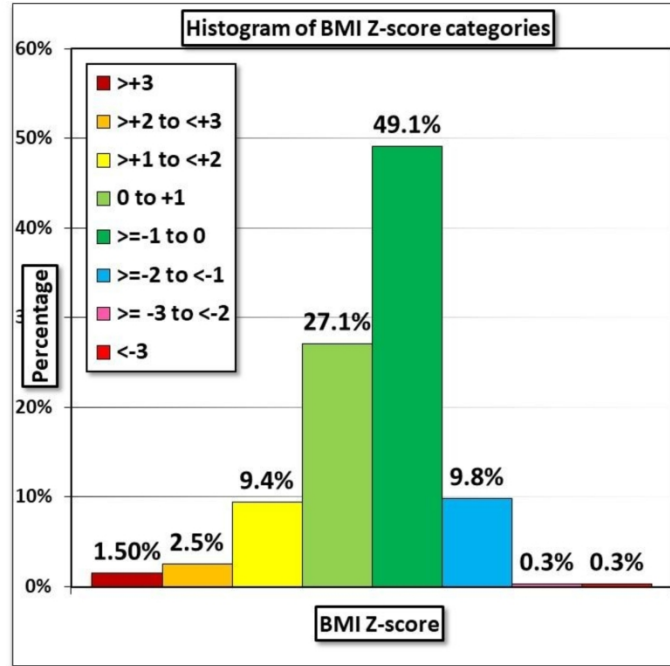
349 \*\* Correlation is significant at the 0.01 level (2-tailed).

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

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

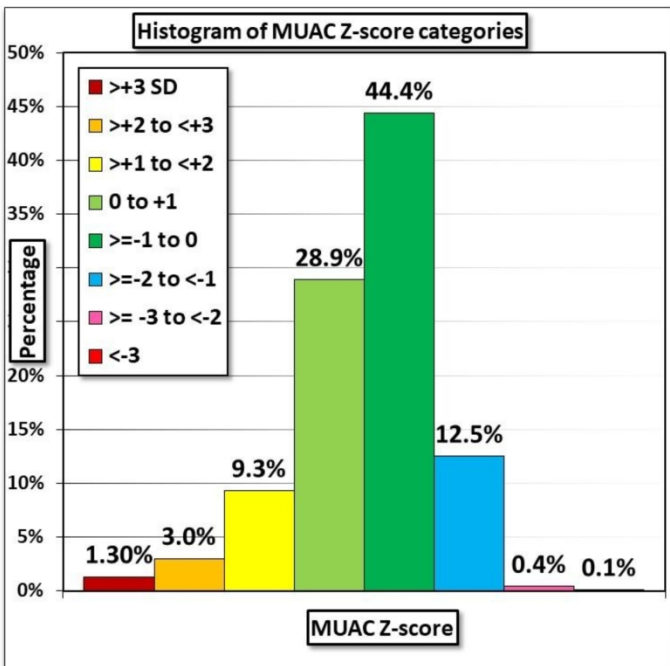
\*\*Modified WHO Classification of nutrition conditions based on anthropometry  
 BMI = Body Mass Index; MUAC = Mid-upper-arm circumference

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**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
<b>Age (years)</b>	7.63	2.82	7.00	5.00	8.80	3.69	9.00	5.00	-5.162	<b>2.44E-07 *</b>
<b>Height (cm)</b>	125.16	16.95	125.00	26.00	134.06	22.16	133.15	34.00	-6.626	<b>3.44E-11 *</b>
<b>Body weight (kg)</b>	22.48	8.83	20.20	10.40	28.93	14.96	24.20	19.40	-7.215	<b>5.41E-13 *</b>
<b>BMI</b>	13.84	2.33	13.20	2.14	15.04	3.31	13.98	3.24	-7.374	<b>1.66E-13 *</b>
<b>MUAC</b>	17.52	2.61	16.85	3.30	18.94	3.83	17.95	5.00	-6.233	<b>4.59E-10 *</b>

^ 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

**Table 2 (S)**  
**Distribution of variables among all participants**

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

Confidential: For Review Only

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