

Mid-Upper-Arm-Circumference as a Growth Parameter and its Correlation with Body Mass Index and Heights in Ashram School Students in Nashik District in Maharashtra, India

Shyam V. Ashtekar, Manasi Shekhar Padhyegurjar, Jagdish D. Powar, Shekhar Bhikaji Padhyegurjar

Department of Community Medicine, SMBT Institute of Medical Sciences and Research Centre, Nashik, Maharashtra, India

Abstract

Background: Under nutrition is a major problem among Indian schoolchildren. Yet, routine height and weight measurements in schools are not used for growth monitoring. This study attempts to evaluate mid-upper-arm-circumference (MUAC) as a quick assessment tool against body mass index (BMI) in schoolchildren. **Objective:** The objective of the study was to evaluate MUAC against BMI, height, and average skin fold thickness (ASFT) parameters and to estimate MUAC values across age, sex, and social categories. **Subjects and Methods:** The study was conducted in 2017–2018 in four randomly selected Ashram schools and an urban school in Nashik district. Girls (1187) and boys (1083) from age 6–18 were included, and height, weight, skinfold thickness, and MUAC were measured. MUAC was done on the left arm with Shakir's tape and tailor's tape (for MUAC >25 cm). Epi Info 7.1 and Excel were used for the data analysis. **Results:** MUAC had a consistently high correlation with BMI at all ages for boys ($r = 0.8786$, $P < 0.0001$) and girls ($r = 0.8586$, $P < 0.0001$). ASFT too was strongly correlated with MUAC ($r = 0.5945$, $P < 0.0001$). MUAC had strong but nonlinear correlation with heights in girls ($r = 0.7751$, $P < 0.0001$) and boys ($r = 0.8267$, $P < 0.0001$). MUAC was higher for girls than boys at all ages. MUAC values for scheduled tribe (ST) children were highly significantly lower than non-ST students. **Conclusion:** MUAC is a good and quick proxy tool for BMI and can serve as a sensitive nutritional indicator for school ages across socioeconomic categories. However, it is necessary to construct age-wise cutoff points and bandwidths using multicentric studies across income quintiles.

Keywords: Ashram school, body mass index, height, mid-upper-arm-circumference, undernutrition

INTRODUCTION

Growth and nutrition monitoring in children is an important issue for both administrators and families. ICDS and Rashtriya Bal Swasthya Karyakram monitor under-five and schoolchildren across India.^[1,2] Height and weight measurements are done annually in schools but hardly used corrective action on malnutrition. Height is slow to change and hence less useful for routine monitoring. On the contrary, weight changes are quicker but are height dependent.^[3] Although the body mass index (BMI) is a better combined tool, it requires calculations and age reference charts.^[4] Mid-upper-arm-circumference (MUAC) can be another useful tool for all stakeholders. There is a paucity of literature on this. The WHO too offers no MUAC charts for 6–18 years.^[5] MUAC has some potential virtues as a nutritional parameter.^[6-8] It is an easy-to-do and medium-term parameter. The research

question for this study was if MUAC can work as a good proxy anthropometric measure for growth and nutrition.

SUBJECTS AND METHODS

A two-stage sampling was used to first select (a) four of six tribal blocks in the district and then select (b) two Ashram schools each from government and private category from the selected blocks. First, of the six major tribal blocks (Trimbak, Peth,

Address for correspondence: Dr. Manasi Shekhar Padhyegurjar, Flat No. 1, Sanskruti Park, Akashwani, Samartha Chowk, Nashik - 422 007, Maharashtra, India.
E-mail: manasipg@gmail.com

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Dindori, Nashik, Kalwan, and Igatpuri), four blocks (Dindori, Peth, Igatpuri, and Trimbak) were selected by a chit method. Chits bearing school names from four blocks were pooled in two school categories – government and private. Dindori had 10 schools each in government and private category, while Peth had 10 and 4, Igatpuri had 5 and 5, and Trimbak 11 and 13, respectively. Two schools from each category were randomly selected. For comparative anthropometry, an urban school in Nashik was included on a feasibility basis.

Scheduled tribes (STs) in Maharashtra constitute 9% of the state population spread over 15 districts. The STs in Nashik district are mainly Kokna, Mahadev Koli, Varali, and Thakur making about 30% of ST population in the state.^[9] Tribal children commonly live in the Ashram schools from 6 to 16 years of age, for about 300 days annually in protected environment as regards nutrition, health care, water safety, sanitation, and without hard physical labor. The data collection was completed from November 2017 to February 2018.

Inclusion and exclusion criteria

Ashram schools with central kitchen supplies were excluded from the study.

Ethical consent and assent

This study was approved by the Institutional Ethics Committee. The tribal commissioner and private school trusts granted permission for the study. The school heads were informed a day prior about the actual visit date. School names and identities were protected for confidentiality in publications. Assent of students was obtained in each school at the time of morning prayers explaining that the procedures were nearly similar to routine health checkups.

Anthropometry

Anthropometry was done by male and female researchers for boys and girls separately based on recent guidelines.^[3]

Body weight was recorded once with nondigital scale, (Ideal Industries, Pune) with usual school clothes and without footwear or belt. The weighing machine did not show variation once adjusted for plane with spirit-level mobile application. Weighing machine was tested each day against a premeasured weight of sandbag wrapped in plastic. It did not show error of >0.2 kg.

Height was taken with a stadiometer (MCP Analog Measuring Tape, New Delhi) fixed on the wall with the head, toes, buttocks, and shoulders touching the wall. For MUAC, Shakir's tape (Indo surgical, New Delhi) was used. To locate the midpoint of the left arm, it was flexed at the right angle and mid-point was marked halfway between acromion and olecranon process. Then, the arm was allowed to hang freely. Tailor's tape (Tailor's Soft Flexible Tape for Measurements, SellnShip Deals Sea, Bangalore) was used for students with MUAC >25 cm.

Skin fold thickness was measured on a 20% systematic random subsample ($n = 540$). It was measured on four sites,

each on the left and right side as follows: subscapular (oblique fold), on vertical fold on triceps, biceps, and suprainguinal. A simple handheld caliper was used (SYGA Personal Body Fat Caliper Measurement Tool, Ahmedabad). Average skin fold thickness (ASFT) was worked out from the eight sites.

Sample size calculation

Since the study is focused on correlation coefficient (r), the previously published “ r ” is taken for sample size calculation. ($r = 0.897$).^[10] Apart from that, two-tailed alpha value for $P = 0.01$ is taken as 2.575 and one-tailed beta value for $P = 0.05$ is taken as 1.64, and with the sample size formula for larger samples, the sample size is calculated with the formula $n = ([Z 1 - \alpha/2 + Z 1 - \beta]^2 \div \text{anticipated } r^2) + 1$. Thus, the sample size is 24 and considering 10% loss, estimated to 27 for any group tested for correlation. Since the study had various subcategories such as urban–tribal, gender, and age groups, all the schoolchildren were included from our earlier study.^[11,12]

RESULTS

The sampled study population included age 6–18 years with 1187 girls and 1083 boys. By category, 87.7% girls and 86.7% boys were ST, the rest being General, SC, VJNT, and OBC. Table 1 shows mean, median, standard deviation (SD), and 75th percentile values of MUAC by age and gender. Table 2 shows Pearson correlation with t -statistics of MUAC with BMI for age and gender. Table 3 provides Pearson correlation of height and MUAC with t -statistics by age and gender.

Figure 1 shows scatter diagram of MUAC with BMI of all students of both sexes, suggesting high correlation. Figure 2 shows high but curvilinear correlation between MUAC and height of all boys and girls as age advances. MUAC was seen to have a strong correlation with ASFT for pool of 2270 students. ($r = 0.5945$, t -statistics: 17.1470, $P < 0.0001$, for girls $r = 0.7281$, t -statistics: 18.0571, $P < 0.0001$, Boys $r = 0.4691$, t -statistics: 8.3474, $P < 0.0001$). The mean ASFT for all ages for boys was 6.63 mm (SD 2.81 mm) and for girls, it was 7.31 mm (SD: 2.42), $P = 0.0058$.

The Pearson correlation coefficient for MUAC and BMI was separately calculated for STs and non-STs to validate its utility across caste-tribe variation, urban–rural differences, and different socioeconomic categories and estimates which were as follows:

General and OBC category ($n = 145$): For boys and girls together $r = 0.9043$, t -statistics: 35.9552, < 0.0001 ; for Boys $r = 0.9209$, t -statistics: 28.1594, $P < 0.0001$, for girls $r = 0.8972$, t -statistics: 24.3834, $P < 0.0001$. For STs ($n = 2059$): For boys and girls together $r = 0.8510$, t -statistics: 72.6762, $P < 0.0001$ for boys $r = 0.8512$, t -statistics: 49.6378, $P < 0.0001$, for girls $r = 0.8759$, t -statistics: 58.5228, $P < 0.0001$, implying high correlation between MUAC and BMI in ST and non-ST categories.

The regression equations to estimate MUAC (y) from age (x) by social categories were as follows:

Table 1: Mean, median, standard deviation, and 75 percentiles of mid-upper-arm-circumference in the study sample (n=2270)

Age (years)	MUAC								Mean MUAC difference girls - boys
	Girls (n=1187)				Boys (n=1083)				
	Mean	SD	Median	75%	Mean	SD	Median	75%	
6	15.58	0.967	16.00	16.40	14.78	1.125	14.60	15.50	0.8
7	15.92	1.302	15.90	16.40	15.26	1.120	15.00	16.00	0.66
8	16.39	1.383	16.00	17.10	15.74	1.372	15.60	16.30	0.65
9	16.43	1.286	16.50	17.00	16.21	1.665	15.90	17.00	0.22
10	17.13	1.697	17.00	18.00	16.91	1.720	16.50	17.50	0.22
11	17.88	1.879	17.70	19.00	17.27	2.296	16.80	18.00	0.61
12	18.45	1.809	18.00	20.00	17.51	1.867	17.20	18.00	0.94
13	19.43	2.131	19.50	20.50	18.42	1.908	18.00	19.50	1.01
14	20.31	2.002	20.00	21.50	19.87	2.552	19.80	21.00	0.44
15	21.02	2.024	21.00	22.50	20.78	2.736	20.50	22.00	0.24
16	21.76	2.205	21.50	22.80	21.74	2.386	21.50	23.10	0.02
17	21.95	1.682	22.00	23.00	22.10	1.954	21.70	23.70	-0.15
18	22.44	2.115	22.00	23.50	23.36	2.457	23.40	24.50	-0.92

SD: Standard deviation, MUAC: Mid-upper-arm-circumference

Table 2: Body mass index and mid-upper-arm-circumference of schoolchildren age 6-18 years (n=2270)

Age (years)	Girls (n=1187)					Boys (n=1083)				
	BMI	MUAC	Pearson r	T-stat	P	BMI	MUAC	Pearson r	T-stat	P
6	12.95	15.58	0.7065	4.23	0.0005	13.33	14.78	0.5277	2.56	0.0202
7	13.28	15.92	0.7343	8.52	<0.0001	13.49	15.26	0.6911	8.49	<0.0001
8	12.73	16.39	0.7008	8.04	<0.0001	13.63	15.73	0.8067	11.42	<0.0001
9	12.81	16.43	0.6533	8.09	<0.0001	13.87	16.21	0.858	16.36	<0.0001
10	13.04	17.13	0.7343	10.21	<0.0001	14.26	16.91	0.8668	15.5	<0.0001
11	13.81	17.88	0.77	13.33	<0.0001	14.17	17.27	0.8269	14.63	<0.0001
12	14.39	18.45	0.819	14.41	<0.0001	14.23	17.51	0.8798	18.33	<0.0001
13	15.27	19.43	0.8191	15.31	<0.0001	14.74	18.42	0.8642	16.56	<0.0001
14	16.00	20.31	0.8518	17.28	<0.0001	15.52	19.87	0.8921	19.44	<0.0001
15	16.53	21.02	0.7617	12.98	<0.0001	16.31	20.78	0.8675	16.45	<0.0001
16	17.26	21.76	0.7879	13.78	<0.0001	17.24	21.74	0.7698	11.82	<0.0001
17	17.52	21.95	0.7918	12.44	<0.0001	16.81	22.10	0.7571	10.43	<0.0001
18	18.06	22.44	0.8263	10.88	<0.0001	17.32	23.3632	0.6099	6.25	<0.0001
All ages			0.8506	54.44	<0.0001	All ages		0.8786	63.33	<0.0001

BMI: Body mass index, MUAC: Mid-upper-arm-circumference

ST category: girls: $y = (0.62346 \times x) + 11.25765$, boys $y = (0.735494 \times x) + 9.52552$.

For only General and OBC students: girls: $y = (0.679 \times x) + 11.814$, boys: $y = (0.828 \times x) + 10.534$

DISCUSSION

This study tested MUAC as a proxy indicator for the nutritional evaluation of schoolchildren. MUAC had high correlation with age, BMI, and ASFT in both boys and girls, with statistically highly significant *P* values. MUAC also showed a good correlation with heights in both sexes, but the relationship is curvilinear. Table 3 shows that among girls the observed high correlation of 'MUAC: Height' in early age groups declines steeply by puberty and thereafter. This suggests a sigmoid

curve, flattening after puberty. MUAC also showed statistically significant correlation ($r = 0.59$) with ASFT recorded in a 20% subsample. This supports the utility of MUAC as a good proxy coordinator for overall nutrition measurements and also body fat.^[3]

Role of mid-upper-arm-circumference in nutritional assessment

MUAC is a fairly simple measurement. For higher school ages, a 30 cm arm tape will be necessary. MUAC has been used as a unisex qualitative test (three color bands) for U5 (under 5 years children) malnutrition to detect severe acute malnutrition and moderate acute malnutrition.^[3] NFHS4 reports wasting, stunting, underweight statistics for U3 (under 3 years children) children but not MUAC.^[13] MUAC is also tried for outcome

Table 3: Height and mid-upper-arm-circumference of schoolchildren age 6-18 years (n=2270)

Age (years)	Girls (n=1187)					Boys (n=1083)				
	Height	MUAC	Pearson <i>r</i>	T-stat	P	Height	MUAC	Pearson <i>r</i>	T-stat	P
6	106.87	15.58	0.5346	2.68	0.015	109.28	14.78	0.8042	5.58	<0.0001
7	111.20	15.92	0.3042	2.51	0.0145	111.35	15.26	0.4864	4.95	<0.0001
8	117.71	16.39	0.3533	3.09	0.0029	116.48	15.73	0.4211	3.88	0.0002
9	119.20	16.43	0.4049	4.15	<0.0001	120.48	16.21	0.6644	8.71	<0.0001
10	125.43	17.13	0.532	5.93	<0.0001	125.82	16.91	0.4898	4.89	<0.0001
11	130.70	17.88	0.5707	7.68	<0.0001	132.12	17.27	0.6587	8.71	<0.0001
12	136.63	18.45	0.6405	8.43	<0.0001	135.73	17.51	0.6053	7.53	<0.0001
13	143.05	19.43	0.5448	6.97	<0.0001	142.75	18.42	0.6006	7.24	<0.0001
14	146.18	20.31	0.4919	6.01	<0.0001	149.68	19.87	0.6372	8.14	<0.0001
15	148.47	21.02	0.1782	2	0.0477	155.26	20.78	0.5447	6.12	<0.0001
16	149.34	21.76	0.2403	2.67	0.0088	158.63	21.74	0.2535	2.57	0.0118
17	149.74	21.95	-0.0009	0.0085	0.9932	158.97	22.10	0.4342	4.34	<0.0001
18	150.17	22.44	0.2746	2.12	0.0387	163.32	23.36	0.2073	1.72	0.0898
All ages			0.7741	42.09	<0.0001	All ages		0.8267	48.3	<0.0001

MUAC: Mid-upper-arm-circumference

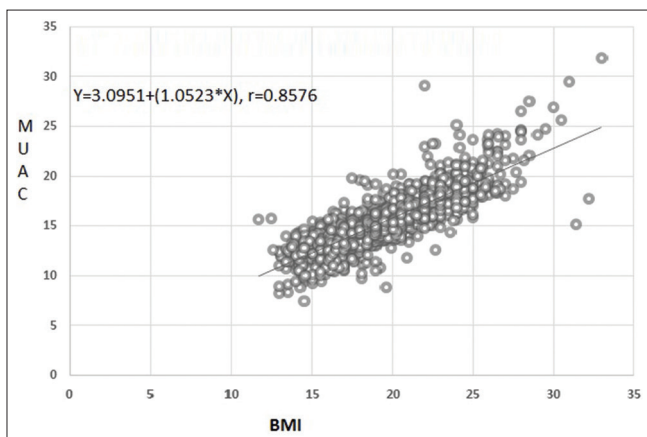


Figure 1: Body mass index and mid-upper-arm-circumference of boys and girls, all categories

prediction as for U5 mortality and disease recovery monitoring like in cancer management.^[14,15] However, it is underutilized as a direct quantitative assessment of nutrition, muscle mass, etc., for schoolchildren. MUAC was found sensitive to dietary improvement in a three-arm controlled study in Kenyan schoolchildren.^[16] This comparative study with differential nutritional supplements for 2 years showed that MUAC rose steeply in schoolchildren (7–14 years) consuming milk and meat, implying better proteins besides staples.

BMI is an age-independent ratio but cannot differentiate between fat and muscle. BMI is more dependent on weight than height. BMI is commonly used in adults for assessing underweight, overweight, or obesity, thanks to it being neutral to gender and age in adulthood. The utility of MUAC for quantitative nutritional assessment in schoolchildren is underdeveloped despite some attempts in various countries.^[7,8,16] Age-wise MUAC cutoff points are not available for schoolchildren. The strong correlation between BMI and MUAC has also been reported by three Indian studies, namely Dasgupta ($r = 0.822$), Jeykumar ($r = 0.593$), and

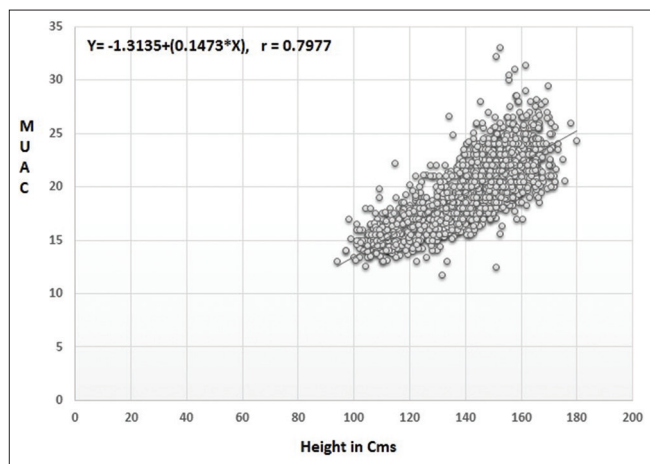


Figure 2: Scatter diagram of height and mid-upper-arm-circumference of boys and girls aged 16 to 18 years: all castes and tribes

Ashtekar ($r = 0.8974$).^[10,17,18] A study conducted in Bangladesh also concluded that MUAC correlates closely with BMI ($r = 0.81$).^[19]

Good correlation with other anthropometric and nutritional measurements

As with BMI or weight for height, MUAC cannot distinguish primary malnutrition from other causes; however, it is an effective marker of risk.^[7] A Chinese study reported MUAC use to determine overweight and obese children and suggested cutoffs of MUAC in Han children aged 7–12 years.^[20] Ashtekar has also reported high correlation of MUAC in adolescent girls and boys (age: 13 and 14 years, respectively) with waist ($r = 0.7618$), hip ($r = 0.8483$), weight ($r = 0.8817$), and moderate correlation with height ($r = 0.3948$). The latter finding about height concurs with this study in the part of the adolescent age group.^[10]

MUAC rises with age [Table 3]. However, flattening of the MUAC curve at higher ages is perhaps expected in a study

population where overall energy reserves are limited, as suggested by lower BMI and ASFT. MUAC could gain further beyond puberty with better nutrition and resistance exercises and sports.

Mid-upper-arm-circumference is sensitive to gender and social differences

Girls have a higher mean MUAC than boys till 15 years [Table 1], about 0.5 cm on an average across age groups till early adolescent age. This is due perhaps to more fat accumulation among girls around puberty. This study finding is supported by a Nigerian study wherein girls showed higher MUAC than boys of the same age. The MUAC-for-age Z-score growth curves are similar between sexes up to age 14 years, after which boys continue to grow faster than girls.^[8] A BMJ study from Kenya reported that MUAC curves generally follow WHO Z-scores till 60 months, with nearly the same trajectories for boys and girls till the 14th year. However, only a few studies have assessed MUAC growth in adolescents.^[7] In this study, the ASFT of pooled girls was also higher than boys, by 0.68 mm, and this was statistically highly significant. Hence, different MUAC cutoffs for adolescent boys and girls will be necessary.

Mid-upper-arm-circumference across social-categories

MUAC estimates are expected to vary across socioeconomic groups. In this study, the age-MUAC regression equations show higher estimates for non-ST as compared to ST schoolchildren. A Guyanese study found that East Indian children have lower MUAC along with lower heights than African children. Hence, MUAC could be ethnosensitive too.^[21] These ST and non-ST categories are also proxies for rural–urban and income classes in our study. MUAC estimates in this study reflect the expected differences well.

Influence of protein foods on mid-upper-arm-circumference

Studies suggest that better protein intakes through animal source foods (ASF) such as milk and meat over 2 years improve MUAC significantly over non-ASF taking children in otherwise similar conditions.^[16] Another study reported a MUAC linkage with biochemical evidence of better nutrient intakes.^[22] MUAC sensitivity to better protein intake gives MUAC an edge over BMI (BMI treats fat and muscle together).

Need for a school age mid-upper-arm-circumference tape

This study argues that MUAC can serve as a true and valid measurement of nutritional status in schoolchildren and is sensitive to age, gender, socioeconomic differences, and better protein intakes. Appropriate instruments need to be developed for girls and boys of different ages. This should be a multicentric exercise and covering income/social quintiles. The regression equation for middle income group (girls: $y = (0.679 \times x) + 11.814$, boys: $y = (0.828 \times x) + 10.534$) can help to construct MUAC bandwidths. MUAC summary statistics for age and sex [Table 1] will also be useful for building MUAC measurement scales for schoolchildren.

CONCLUSION

The big sample, high correlation, and highly significant *P* values in the study suggest a strong case for MUAC as a good proxy measure for undernutrition in schoolchildren. MUAC can speak about both energy stores and protein nutrition and is sensitive to differences in social categories.

Hence, MUAC can help as an on-the-spot, ready-to-use, and easy-to-grasp tool for students, teachers, and parents alike. Appropriate MUAC armbands for school boys and girls will help better monitoring of nutrition outcomes.

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Conflicts of interest

There are no conflicts of interest.

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