Cut-offs of mid-upper arm circumference to predict the double burden of malnutrition among Indian pre-adolescent children (5-9 years): Insights from Comprehensive National Nutrition Survey data 2016-18

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Sri Lanka Journal of Child Health, 2022; **51**(2): 189-195
DOI: http://dx.doi.org/10.4038/sljch.v51i2.10116

Abstract

Introduction: In low and middle-income countries, there is a growing trend of the double burden of malnutrition in children. Most popular way of screening nutritional status of children is use of anthropometric measures, where the Mid-Upper Arm Circumference (MUAC) is important for its operational simplicity. Despite several studies favouring MUAC, studies of optimal cut-off defining malnutrition are few in India.

Objectives: To assess the prediction of the double burden of malnutrition by MUAC in Indian pre-adolescent children using the Comprehensive National Nutrition Survey (CNNS) data 2016-18.

Method: The participants were 36,347 children (18,992 boys, 17,355 girls) aged 5–9 years. I have done Spearman's rank correlation to determine the relationship between MUAC and Z score of Body Mass Index (BAZ) and height for age (HAZ). To assess the ability of MUAC to classify the double burden of malnutrition accurately, I did Receiver Operating Characteristic (ROC) analysis after stratification for age and sex.

Results: There was significant correlation of MUAC with BAZ (r= 0.61) and HAZ (r = 0.42). Areas under ROC curve: 0.78, 0.71, 0.85, and 0.84 for thinness, stunting, overweight, and obesity, respectively. It was observed that optimal MUAC cut-off values for prediction of thinness and stunting were 16.0 cm and 16.1 cm respectively. In contrast, optimal cut-offs for prediction of overweight and obesity were 18.8 cm and 19.5 cm respectively. These cut-offs of MUAC differed after stratification by age group and sex.

Conclusions: MUAC is a good predictor of malnutrition in national representative Indian children aged 5 to 9 years. However, MUAC identifies over-nutrition with higher accuracy than under-nutrition in this age group.

(Keywords: Malnutrition, Children, MUAC, Stunting, Overweight, Obesity, India, Cut-offs)

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(Received on 22 August 2021: Accepted after revision on 17 September 2021)
The authors declare that there are no conflicts of interest
Personal funding was used for the project.

Introduction

The double burden of child malnutrition is a significant public health issue in India like in the rest of the world[1]. The World Bank reported in 2019 that India has the second-largest percentage of stunted children (38%) after Afghanistan (41%) in South Asian countries[2]. One-third of 151 million stunted children around the world reside in India[3,4]. On the other hand, overweight and obesity rates in children and adolescents are increasing in the higher socio-economic and lower-income groups where underweight is still a significant concern[5].

Therefore, early detection of childhood undernutrition and overweight/obesity is required for nutritional intervention to manage the harmful impact on children's growth and development, academic performances, metabolic syndrome, and even adult mortality[6,7,8]. Majority of research on assessment of child nutritional status used World Health Organization (WHO) Child Growth Standards as Height for Age (HAZ), Weight for Age (WAZ), Weight for Height (WZH) and Body Mass Index (BMI) for Age (BAZ)[9]. However, besides these anthropometric indices, Mid Upper Arm Circumference (MUAC) is being used in recent years to screen many children across the nation in a shorter period due to its simplicity and reliability[10]. MUAC is generally used in detecting nutritional status among infants and under-five children with severe acute undernutrition. Recently, several studies showed the importance of using MUAC in children and adolescents for detecting undernutrition as well as overweight and obesity[10-14]. Another recent study from Sri Lankan children showed the validity of using MUAC for detecting under-nutrition and over-nutrition based on anthropometric indices among the pre-adolescent children[15].

In India, using MUAC for estimating under-nutrition is mainly based on a cross-sectional community/regional-based population. Despite that, studies are mainly confined to pre-school children or adolescents[16-21]. Study among pre-adolescent children aged 5-9 years is sporadic in detecting the double burdens of malnutrition and less representative in world literature[22]. However, they belong to the transitional stage between pre-school and adolescent children. Moreover, there are not many efforts to find out the cut-off values of MUAC for identifying under-nourished and over-nourished pre-adolescent children based on a national representative sample.

Objectives
To assess the prediction of the double burden of malnutrition by MUAC in Indian pre-adolescent children using Comprehensive National Nutrition Survey (CNNS) data 2016-18[23].

Method
Study participants: Present study participants comprised 36,347 children aged 5-9 years of CNNS after clearing all abnormal and missing values (Total survey children 38,355, absent MUAC data 1465, flagged observation of BMI-for-age 497, flagged observation of height-for-age 37, and outlier of MUAC 9). This survey was conducted during 2016-18 with a collaborative effort by UNICEF, Population Council and Ministry of Health and Family Welfare, Government of India. The survey used a multi-stage stratified sampling design for selecting a representative sample from settlements, households and individuals across 30 states in India. Single children were selected from a single household. More detailing of sample size was reported in the CNNS report during 2019[23].

Ethical issues: This present study was a multi-stakeholder survey programme. International Ethical approval was obtained from the Population Council's Institutional Review Board in New York. National approval was obtained from the ethics committee of the Postgraduate Institute of Medical Education and Research in Chandigarh, India. Ethical approvals were obtained before initiating the survey from the competent authorities as well as from the study participants. However, ethical approval was not required for the current data analysis. I obtained permission for using the data from the competent authority.

Anthropometric measurements: The 2016-18 CNNS collected anthropometric data by measuring the height (cm), weight (kg) and MUAC (cm) of all sampled children aged 5-9 years in the selected households. For data collection, they used the Computer Assisted Personal Interviewing (CAPI) method using a mini laptop. A flat wooden square was placed on the floor for weight and height measures, and the level was tested with a spirit level to ensure a level surface. Weights were measured with electronic digital scales. MUAC was measured twice using standard fiberglass tapes on the right arm after identifying the midpoint of the upper arm and applying standard pressure while measuring the circumference; then, an average value was used for the analysis. Height (cm) and MUAC were measured to the closest 0.1 cm, and weight was taken to the closest 0.1 kg. All measurements were taken with minimum clothing. Two trained anthropometrists had taken all the anthropometric measures after following the standardization. The fieldworkers calibrated all anthropometric tools periodically. For assessing intra and inter-observer errors, technical error of measurement (TEM) was computed for anthropometric measures and published elsewhere. BMI was calculated by computing weight in kg/height in metres^2. After that, BMI for age (BAZ) and Height for age (HAZ) Z-scores were determined using the WHO International Child Growth Standard. Stunting was classified as HAZ < -2 SD, whereas thinness was defined as BAZ <-2 SD. In contrast, overweight and obesity were classified as BAZ > +1 SD and BAZ > 2 SD, respectively[24].

Statistical analysis: For the statistical analyses, participants were stratified into younger children (aged 5–7 years) or older children (aged 8-9 years) and also into gender (boys and girls). I calculated descriptive statistics of anthropometric measures and indices. To explain, I estimated the strength of the linear relationship and its direction between MUAC and anthropometric nutritional indices (HAZ and BAZ), Spearman's rank correlations. I computed Receiver Operating Characteristic (ROC) curves and the area under the curve (AUC) separately for assessing the sensitivity and specificity of various cut-offs of MUAC for thinness, overweight, obesity and stunting from the present sample. AUC values of more than 80% were considered highly accurate[25]. Finally, the Youden Index was calculated and used to identify optimal cut-offs after stratifying by age group (younger or older) and gender. The statistical analysis was performed by STATA 17.0 version software (licensed), StataCorp LLC, USA.

Results
For this study, a total of 36,347 Indian children (18,992 boys, 17,355 girls) out of 38,355 children were included (aged 5–9 years) in the present analysis after screening the CNNS pre-adolescent anthropometric data. Table 1 shows the anthropometric characteristics of the study

population based on the age group and sex of the studied children. It noted that the mean values of BAZ and HAZ were negative for both the age groups and sex. Importantly, the mean MUAC differed by 1.16 cm between the two age groups. It was observed that 18.98% of children showed stunting and 18.58% thinness. On the other hand, 7.79% of children were overweight, and 2.88% were obese of all studied children.

Table 1: ***Anthropometric measures and indices of study population, according to age group and sex***

Variable	Total		Younger Group (5–7 Years)				Older Group (8–9 Years)			
			Boys (n = 7904)		Girls (n = 7573)		Boys (n = 11088)		Girls (n = 9782)	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Age (years)	7.37	1.40	6.02	0.62	6.03	0.64	8.46	0.78	8.43	0.78
Height (cm)	117.30	10.31	110.36	7.44	109.43	7.49	123.75	8.18	122.70	8.25
Weight (kg)	19.64	4.72	17.11	2.97	16.58	2.90	22.17	4.75	21.57	4.59
BAZ	-1.23	1.14	-1.20	1.16	-1.18	1.03	-1.32	1.25	-1.21	1.11
HAZ	-1.09	1.25	-1.15	1.31	-1.13	1.28	-1.01	1.23	-1.08	1.21
MUAC (cm)	16.27	1.85	15.51	1.40	15.63	1.37	16.79	2.03	16.88	1.94

SD: standard deviation; BAZ: body-mass-index-for-age z-score; HAZ: height-for-age z-score; MUAC, mid-upper arm circumference

Figure 1 depicts the correlations (Spearman's rank) between MUAC and other anthropometric indices BAZ and HAZ. The correlation was statistically significant; a moderate correlation was found between MUAC and BAZ (r = 0.63 and 0.69 for the younger and older group, respectively) (p = 0.000). On the other hand, a relatively weak correlation between MUAC and HAZ (r = 0.42 and 0.46 for the younger and older group, respectively) (p = 0.000) was observed.

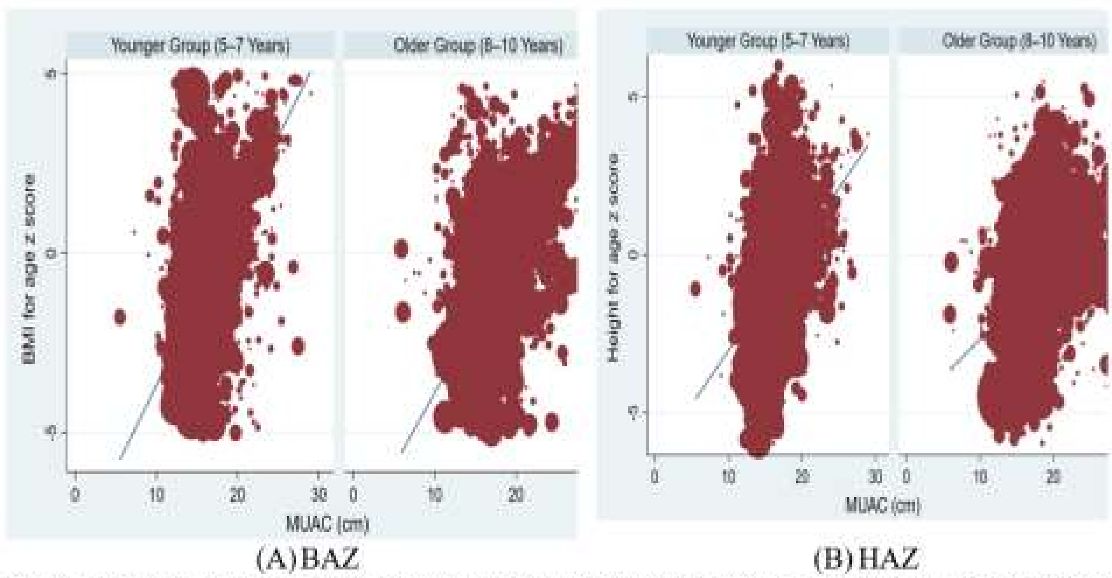

Figure 1: Correlation between Mid-Upper Arm Circumference (MUAC) and (A) Body mass index Z score (BAZ) and (B) Height for Age Z score (HAZ), according to age group (5–7 year vs 8–9 year)

Figure 2 illustrates the ROC curves for the ability of MUAC to correctly identify thinness, stunting, overweight, and obesity among the studied children. It was noted that MUAC identified overweight and obesity with high accuracy (AUC = 0.85 for overweight and 0.84 for obesity) but predicted thinness and stunting with only moderate accuracy (AUC = 0.78 and 0.71, respectively)

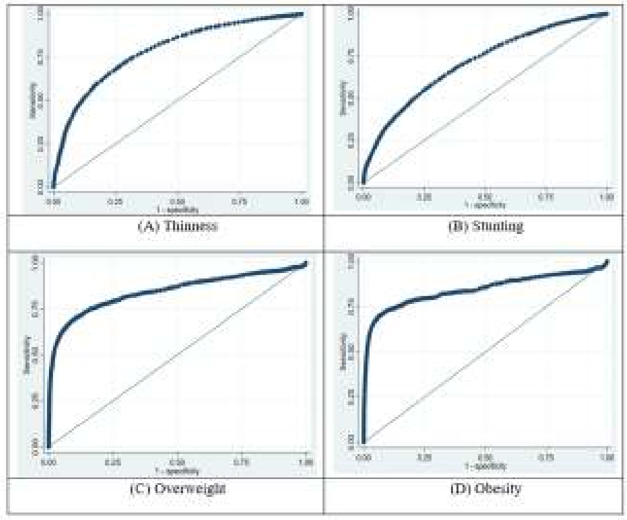

Figure 2: ***ROC curves for mid-upper arm circumference prediction of: (A) Thinness (B) Stunting (C) Overweight and (D) Obesity***

Table 2 describes the optimal MUAC cut-off values calculated for Indian children aged 5–9 years. The optimal MUAC cut-offs were 16.0 cm, 16.1 cm, 18.8 cm, and 19.5 cm to predict thinness, stunting, overweight, and obesity, respectively. Remarkably, the high sensitivity and specificity cut-offs of MUAC for overweight and obesity showed even after stratification for age and sex. In contrast, higher optimal MUAC cut-offs were observed in the older group and children and about the same in boys and girls.

Table 2: ***Optimal MUAC cut-off values, with stratification by age group and sex, in schoolchildren aged 5–9 years (n = 36347)***

Variables	Cut-off (cm)	Sensitivity	Specificity	AUC
Thinness	16.0	0.69	0.75	0.78
Stunting	16.1	0.65	0.65	0.71
Overweight	18.8	0.68	0.91	0.85
Obesity	19.5	0.72	0.92	0.84
With stratification by age group and sex				
Thinness				
Younger Group (5–7 Years)	15.2	0.77	0.72	0.80
Older Group (8–9 Years)	16.4	0.74	0.78	0.82
Overweight				
Younger Group (5–7 Years)	17.6	0.64	0.91	0.82
Older Group (8–9 Years)	19.4	0.75	0.91	0.87
Thinness				
Male	16.1	0.66	0.77	0.78
Female	15.8	0.72	0.72	0.79
Overweight				
Male	18.6	0.71	0.90	0.85
Female	18.9	0.67	0.90	0.82

Discussion

In this present analysis, I tried to understand the validity of using MUAC and identify cut-off values to predict the double burden of malnutrition in Indian pre-adolescent children aged 5–9 years using national representative CNNS data. It was observed that MUAC was a more accurate predictor of overnutrition compared to undernutrition. Within undernutrition, MUAC more accurately identified thinness than stunting, and on the other hand, in the case of overnutrition, MUAC more accurately identified obesity than overweight. However, as a whole, MUAC correlated with all forms of malnutrition in the studied children. The stunting was less accurate by using MUAC because it may not be affected by the height alone. It is the sum of muscle, bone, and fat in the midpoint of the arm[15].

The optimal MUAC cut-off for thinness (16.0 cm) observed in Indian children was lower than the 16.7 cm found in the Sri Lankan children but higher than the 14.5 cm in African children aged 5–9 years[26].

These variations may be a reflection of racial differences and consequences of previous growth and development among the studied children.

Regarding the prediction of overnutrition, the optimal MUAC cut-offs for overweight (17.6 cm and 19.4 cm for younger and older age groups) proposed for current Indian children were comparatively lower than that Sri Lankan children (19.1 cm and 20.6 cm for the younger and older groups, respectively) as well as Dutch children (19.2 cm to 23.0 cm) for overweight in the similar age group[14,15]. In the case of obesity of the present children, the threshold MUAC cut-off was 19.5 cm irrespective of age and sex. However, this cut-off value was comparatively lower than the 21.8 cm for Sri Lankan children, 23.2 cm for South African boys and 26.2 cm for British girls aged 9–11 years[27]. It may be due to the low prevalence of overweight and obesity in the studied children. A multi-ethnic study on children and adolescent in India showed similar findings that cut-offs of thinness was 16.0 cm and of obesity was 20.0 cm among children 5-9 years[28].

Therefore, it will be essential to incorporate MUAC for growth and nutritional monitoring specifically for pre-adolescent (5-9 years) children at regular intervals. Pre-adolescent growth and nutritional status have played a crucial role in optimal growth in the later adolescent stage. However, study among this group has often been neglected. Therefore, like pre-school and adolescent Indian children, the present study stresses the importance of studying the pre-adolescent group using MUAC for nutritional status assessment. Despite the large sample size of the present study, there are some limitations. Firstly, the present study did not consider the rest of the children's health conditions in the form of morbidity and mortality. MUAC has a standard limitation to predict overweight and obese children with low skeletal muscle mass. Certainly, MUAC has often been used in emergency conditions for screening children under severe food insecurity. However, this study established to use of MUAC in the general population under normal living conditions and was meaningfully represented. Secondly, the study sample comprised different Indian ethnic groups with diverse genetic pre-disposition and living conditions. The participants were nationally representative, and samples were randomly done from various Indian states and data were analysed using proper analytical weightage. Even so, in the absence of national consensus on the optimal MUAC threshold for malnutrition in children between 5-9 years, the findings of this study have provided essential input and also strengthen the FANTA III research agendas[29].

Conclusions

MUAC is a good predictor of malnutrition in national representative Indian children aged 5 to 9 years. However, MUAC identifies over-nutrition with higher accuracy than under-nutrition in this age group.

Acknowledgements

I am thankful to the Ministry of Health and Family Welfare, Government of India, UNICEF, and Population Council for providing me with the data for comprehensive VDD and Anthropometric analysis. I am incredibly grateful to Dr Arjan de Wagt, Chief Nutrition, UNICEF, India, and Mr Robert Johnston, Nutritional Specialist at UNICEF, for their kind cooperation in getting the raw CNNS data. Besides, I am genuinely thankful to all the CNNS survey partners, namely Aditya and Megha Mittal, for financial support, AIIMS, New Delhi, CDSA, CDC, ICMR, NIN and others, for their technical support.

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