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ORIGINAL RESEARCH

Mid-arm Circumference as a Rapid Assessment Tool of Adolescent Nutrition Status in Three Rural Schools

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ABSTRACT

Introduction: Adolescent nutrition is often neglected because of greater focus on U5 children. A large mass of height–weight estimation is done in schools, but hardly evaluated, partly because body mass index (BMI) needs calculation.

Objectives: This rural study was undertaken to first estimate BMI, mid-upper arm circumference (MUAC), and waist:hip ratio (WHR) and thereafter to study the correlation of MUAC with BMI and also WHR to see how well MUAC can answer the need for a direct and rapid estimate of adolescent growth.

Materials and methods: This is a cross-sectional study with a convenience sample of three rural schools in Nashik district covering 261 students (M 128, F 131) in 8th and 9th divisions. Standard procedures were used for anthropometry including MUAC. Excel and Epi-Info were used for analysis.

Results: BMI scores were: for 13.5 years: boys 15.9 (1.9), girls 16.9 (2.9), BMI for 14.5 years: boys 16.31 (2.2), girls 17.9 (2.48). Gils had statistically significantly higher BMI than boys. Observed BMI values are about 25th percentile of Indian Academy of Pediatrics (IAP) growth curves and about 15th percentile of the World Health Organization (WHO) growth curves. MUAC in cm were: for 13.5 years: boys 19.89 (2.76), girls 19.94 (2.17) and for 14.5 years, boys 22.16 (2.36), girls 20.41 (2.51). The MUAC correlated well with BMI ($r = 0.8974$, $p = 0.0001$) in pooled data, but not with pooled WHR ($r = 0.24$, $p = 0.057$).

Conclusion: (a) There is need to monitor adolescent anthropometry and timely intervention (b) MUAC has strong correlation with weight, waist, hip, and BMI in the study population. Hence, MUAC can be a quick and simple tool for adolescent growth assessment.

Keywords: Adolescents, Body mass index, Mid-upper arm circumference.

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INTRODUCTION

Undernutrition is a continuum across childhood to adolescence and this is India's cause of concern. The undernourished adolescent girls also continue the momentum of undernutrition in the next generations. India has several initiatives like Integrated Child Development Services (ICDS), Right to Food or food security, and Mid-Day Meals (MDM) to overcome chronic undernutrition among girls and boys till adolescence. The importance of U5 nutrition as a foundation to future life is undeniable, but neglect of school-age should also be an important nutrition concern. There is need for both monitoring and effective growth interventions in school-age population. While India has a huge pile of data on heights and weights of schoolchildren through the Rashtriya Bal Swasthya Karyakram (RBSK), the data are hardly used to inform policymakers, administrators, parents, and students so that timely action can be taken at individual, family, or community level. Body mass index is an accepted measure of weight for height, but it takes another step for calculation entailing time and gadgets; hence, BMI is hardly ever used in this age group across rural schools. Although BMI is easy to calculate, in a large-scale operation like school health involving lakhs of children, it gets postponed and loses its value as a monitoring tool for teachers as well as parents or schoolchildren. In this situation, MUAC can potentially serve as a single direct measure for easy and quick feedback on the spot, as also statistical inference and appropriate monitoring.

Attempts have been made earlier to assess MUAC against BMI and other growth parameters in China and India.[1-3] However, MUAC cut-off points for normal and malnourished children have not been reported in the global literature.[4] Indian Academy of Pediatrics[5] has published MUAC growth curves for Indian children. This study adds to the Indian literature on MUAC among adolescents and its correlation with BMI.

Objectives

This rural study was undertaken to first estimate BMI, MUAC, and WHR and thereafter to study the correlation of MUAC with BMI and also WHR to see how well MUAC can answer the need for a direct and rapid estimate of adolescent growth.

MATERIALS AND METHODS

Study Settings and Material

This study was conducted in parts of Nashik district having both tribal and non-tribal population in academic year of 2016 to 2017. The selected schools were from three villages in the field practice area of a Medical College in Nashik district. These are local schools run by Zilla Parishad or grant-in-aid schools run by charitable trusts. All three schools were under Maharashtra State board of Secondary Education. Approval of the Institutional Ethics Committee was obtained. Written consent of school authorities and oral assent of the students were obtained.

Sample Size Calculation

This study was done on anthropometry data collected for our study on schoolbag weights and musculoskeletal pain in three rural schools and the study population had 261 students. We checked for required sample size for a correlation study.[6] Sample size determination was done with help of previous correlation coefficient from a study, (0.82).[2] At this strong correlation coefficient, the sample size is expected to be small, and hence, we used formula based on t-test. We used t_α value of 2.1 (double-tailed with 5% allowable error) at assumed df 18 and t_β as 0.84 (single-tailed with allowable error of 20%). The formula used was: $n = 2 + [\{(t_\alpha + t_\beta)^2 (1 - r)^2\}/r^2]$ $n = 2 + [\{(t_\alpha + t_\beta).$[7] The sample size "n" = 6.21 which is rounded to 7. If a lower correlation figure of 0.5 is used, the sample size becomes 27. The available study population of 261 students adequately satisfies the sample size for correlation (7–27) and a bigger sample increases strength of the study.

Inclusion Criteria

In the current study, all boys and girls present in 8th and 9th standards were included. The age groups are approximately 13.5 and 14.5 years respectively. All students attending on the visit day in selected standard and division were included. The visits were conducted in mid-week to ensure maximum attendance. The study included 126 students from 8th and 135 from 9th standards. Together, 128 boys and 131 girls were included.

Anthropometry

The investigating field team had three members. Students were explained about the process of measurement of height, weight, waist, hip, and MUAC. Weight and height were recorded by one investigator, MUAC by another, WHR for girls and boys by separate investigators of respective gender. Anthropometry procedures were followed based on recent guidelines subject to local availability of instruments.[8]

Body weight was recorded on a digital weighing scale, with usual school clothes on but no footwear and belt. Weighing scale was checked at the start of weight recordings, against pre-weighed dry sandbags wrapped in plastic. The digital weighing machine (OmronHN-283 serial number 201109-02704F) did not show variation once adjusted for plane with spirit level. The height was taken with a wall-fixed stadiometer. Waist was measured just below umbilicus with clothes on but belt if any removed. Hips were measured on maximum bulge, seen from sides with school clothes on. Both hip and waist were measured by the same investigator. For MUAC, the arm-midpoint was marked between acromion and radial styloid; on backside of arm in elbow-flexed position. The arm was then un-flexed to straight and relaxed position and MUAC measurement was done with a Shakir tape. An ordinary tailor tape was used in some cases with MUAC > 25 cm. While doing this, the investigator stood in front of the student.

Statistics

Excel was used for entry of data and later EpiInfo 7.2 software for analysis.

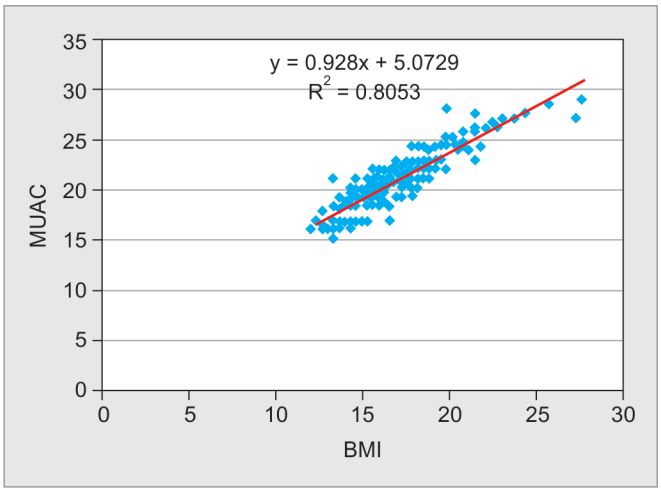
RESULTS

Students from three rural schools participated. Out of 305 enrolled students, 236 participated in the study in first visits and 25 of the 69 absent students were included, subsequently making the total 261 (standard 8th, girls 62, boys 64 and standard 9th girls 71, boys 64). Some absentee students were reported to be habitual either because of long walking distances.

Table 1 shows the height, weight, waist, and hip measurements of the students by standard and gender. There is no significant difference in the bodyweights of boys and girls in each of 8th and 9th standard ($p > 0.05$). Graph 1 is a scatter diagram of MUAC and BMI of all students. Table 2 shows the BMI for the study population and also IAP and WHO reference BMI percentiles for concerned age groups. Table 3 shows MUAC in relation to weight, height, waist, hip, WHR, and BMI. The high correlation (0.8974, $p < 0.0001$, confidence interval lower limit 0.77, double-tailed) between MUAC and BMI is a significant finding.

Table 1: Heights, weights, and MUAC of students

Standard (age)		*Height, cm*	*Weight, kg*	*MUAC, cm*	*Waist, cm*	*Hip, cm*
VIII (13.5 years)	Girls (62)	146.05 (5.99)	36.2 (7.90)	19.89 (2.76)	63.01 (7.175)	76.919 (8.1029)
	Boys (64)	148.15 (7.81)	35.21 (6.49)	19.94 (2.17)	62.92 (5.799)	74.2891 (6.1002)
	p-value for difference of means	0.0937	0.4459	0.9103	0.9354	0.0412
IX (14.5 years)	Girls (71)	150.15 (5.48)	40.51 (6.56)	22.16 (2.36)	63.53 (5.393)	82.102 (5.936)
	Boys (64)	153.73 (8.83)	38.79 (7.47)	20.41 (2.51)	63.08 (6.425)	76.2734 (5.774)
	p-value for difference of means	0.0062	0.1593	0.0001	0.1557	0.0000



Graph 1: Scatter diagram of MUAC and BMI of adolescents

In interviews with teachers, it was found that they were aware of the importance of height and weight measurements of schoolchildren and the readings were taken and recorded, but BMI was not calculated; MUAC is not part of the directives from State education department. Hence, effectively, neither BMI nor MUAC was actually used for feedback to parents and students. The topic of nutrition is taught in 9th and 8th standards.

DISCUSSION

Undernutrition among Adolescents

Malnutrition is a major problem in India, and the entire period of conception to adolescence calls for intervention. However, India is more focused currently on under five nutrition and the 1000-day approach that covers 9 months of pregnancy to 2 completed years of age to achieve maximum benefit. This is a sound policy as U2 growth is an important determinant of future growth. However, adolescent nutrition is important for several reasons including health and productivity. The issue has added relevance for girls, as birth weights also depend upon maternal nutrition and BMI.[9,10] The National Family Health Survey 4 (NFHS4) outcomes show that 30% birthweights in India are low birthweights.[11] It becomes imperative that adolescent nutrition must also be an important agenda, and there are two public interventions to improve the situation: (a) MDM for 6- to 14-year age

Table 2: Body mass index of students in relation to IAP and WHO growth curves

Standard		*BMI mean (SD)*	*Observed BMI in ref to IAP ref charts*	*Observed BMI in ref to WHO ref charts*	*WHR mean (SD)*
VIII	Girls (62)	16.85 (2.99)	Below 25th percentile	>15th percentile	0.8199 (0.0464)
	Boys (64)	15.93 (1.93)	Below 25th percentile	<15th percentile	0.8478 (0.0498)
	p-value for difference between means	0.043025			0.001474
IX	Girls (71)	17.91 (2.47)	Just below 25th percentile	>15th percentile	0.7747 (0.048)
	Boys (64)	16.31(2.20)	Below 25th percentile	<15th percentile	0.8137 (0.0521)
	p-value for difference between means	0.000111			0.00001

Table 3: Mid-upper arm circumference in correlation to weight, height, waist, hip, WHR, and BMI

Parameters	*Correlation coefficient for boys (128)*	*Correlation coefficient for girls (133)*	*Correlation: pooled girls and boys (261)*	*Remark*
MUAC with waist	0.7945 (p < 0.0001)	0.7438 (p < 0.0001)	0.7618 (p < 0.0001)	Strong correlation
MUAC with hip	0.8493 (p < 0.0001)	0.8883 (p < 0.0001)	0.8483 (p < 0.0001)	Strong correlation
MUAC with height	0.4535 (p < 0.0001)	0.4668 (p < 0.0001)	0.3978 (p < 0.0001)	Weak correlation
MUAC with weight	0.8418 (p < 0.0001)	0.9167 (p < 0.0001)	0.8817 (p < 0.0001)	Strong correlation
MUAC with BMI	0.8739 (p < 0.0001)	0.9111 (p < 0.0001)	0.8974 (p < 0.0001)	Strong correlation
MUAC with WHR	−0.1050 (p = 0.096)	0.1011 (p = 0.2561)	−0.1803 (p = 0.037)	No correlation

group since 2001 and (b) Deworming and weekly iron folic acid supplementation for adolescent girls.[12,13] The NFHS4 survey does not show any adolescent statistics and hence, there is no national estimation of growth trends in this age group. The current adolescent population is a cohort from NFHS3 (2005–2006) and has suffered from high rate of stunting (46%), wasting (16.5%), and underweight-for-age (36%) in Maharashtra. Both the latter parameters have worsened in NFHS4, calling for better nutritional support and monitoring for all age groups. However, the RBSK program, recording heights and weights of all schoolchildren in the country, does not offer summary statistics about growth of schoolchildren and does not include MUAC.[14]

Both WHO[15] and IAP[5] have published growth curves for age 0 to 18 years. The WHO charts for weight-for-age, height-for-age, weight for height, and BMI have been used by ICDS for U6 age group. The IAP charts show somewhat lower parameters as developed from Indian surveys. Thus, IAP growth curves somewhat challenge the universality of WHO growth curves. With these tools for growth tracking till 18 years, it should be possible to assess schoolchildren as regards growth parameters, such as height, weight, and BMI. But MUAC figures neither in WHO nor in IAP reference chart.[16] This may be due to various reasons, such as variability of the measurement, standardization of the tape, mid-arm level marking errors, and so on. The MUAC is currently used in the ICDS program as an additional measure for detecting acute malnutrition, employing the cut-off point of <11.5 cm for severe acute malnutrition (SAM), and 12.5 for moderate acute malnutrition for 1- to 4-year group.

The study shows (Table 1) estimates of weight, height, MUAC, waist and that boys and girls in 8th standard (aged about 13.5 years) have no significant difference, while hip measurement among girls has a slight edge over boys. This is explained by a growth spurt in this period. Height, weight, and waist of 9th standard boys and girls also have no significant difference due to the same effect, but MUAC in boys and waist in girls show significantly higher readings than the other gender, and this observed difference is due to respective hormonal surges as late adolescence sets in. Weights are not very useful without height context post-U5 groups. Height is a slow-to-change measure and is not very helpful for monitoring individual adolescent heights. This leaves only BMI for any realistic and operative monitoring of adolescent growth. This study, through BMI estimates, suggests undernutrition of this student population (Table 2) occupying about 25th and 15th percentiles in IAP and WHO growth curves respectively.[5,15] Being a rural community, with all the hardships and labor required of adolescent children coupled with lower nutritional provisions, can somewhat explain this shortcoming. This aligns with the NFHS4 findings showing lower growth status for rural children and adults.[11]

However, as the interviews with teachers revealed, there is no significant attempt by teachers, parents or health department through its RBSK team to monitor the situation and inform families to improve the nutritional situation. Since RBSK data tables were not available even at the level of directorate of health services managing the RBSK, it is apparent that RBSK anthropometry is not available as a monitoring tool for informing stakeholders in good time. The BMI calculation requires use of gadgets and an additional step of ratio calculation. Suitable charts and gadgets (BMI calculation disk) may not available to most public or funded schools. In this context, the question was whether MUAC can help as quick and reliable single measurement tool to inform all stakeholders—students, teachers and parents—about the current nutritional status.

Mid-upper Arm Circumference and Its Correlation with BMI

In this context, Table 3 and Graph 1 show that MUAC can be a very good proxy measure of BMI and regression equations can be built to estimate BMI from MUAC values. The MUAC has good correlation with weight, waist, hip and modest correlation with height. The MUAC is also a true body measure and not a ratio like BMI. The students and teachers can readily measure and monitor MUAC with a Shakir tape, though we need a 30-cm strip in place of the current 27 cm to accommodate late adolescence and higher socioeconomic strata.

The MUAC is seen mainly as an U5 measure for diagnosis of SAM, but even the NFHS4 does not include this important tool.[11] However, there is scientific literature now about its value for monitoring growth, as a proxy for BMI and as a predictor for outcomes.[1-5] An important review paper by Tang et al[4] reports good correlation of MUAC with BMI in adolescent age groups, and also mentions that there are no cut-off points about MUAC-for-age. The WHO[15] also do not mention MUAC as a measure of body mass or nutrition in adolescent age groups. Some Indian studies report good correlation of MUAC with BMI in adolescents.[2,3] Among the Indian studies, Dasgupta et al[2] reported that in 10- to 19-year schoolboys, MUAC correlated well with BMI (r = 0.822) and could diagnose malnutrition with a high sensitivity of 95 and 71% specificity. Our correlation findings (r = 0.8739; $p < 0.0001$) in this study for boys and girls pooled are consistent with Dasgupta et al[2] study (r = 0.822). A recent Pune study of 565 unmarried adolescent girls (16–18 years old) showed that BMI highly correlated

with MUAC (r = 0.593), and MUAC as a screening tool for malnutrition showed 28.57% sensitivity and 96.46% specificity.[3] Further studies among different age groups need to be carried out to arrive at standard cut-offs for MUAC. The MUAC is probably closer to lean body mass or muscle mass index than BMI as the latter cannot deal with fat and muscle proportions. An Indian study from Rajasthan on adolescent girls showing somewhat similar MUAC readings (13 years, 21.6 cm and 14 years, 22.16 cm) reported that the estimated protein intake deficits were 32 and 23% as compared with recommended dietary intakes (RDA) for the respective age groups, so also the calorie intakes were deficit by 34 and 26% compared with RDA.[17] A British study links muscle mass with animal protein intakes in healthy women.[18] But more work is necessary on this aspect with corroborative evidence of 24-hour urea-creatinine as reported from a central Mozambique study.[19] It is both obvious and plausible that MUAC reflects nutritional status—both intakes and outcomes. In the systematic review by Tang et al, MUAC was found to serve both as proxy for BMI and as a predictor of outcomes, such as birthweights or health improvements.[11] However, the report underlines that there is no literature on cut-off points for MUAC in relation to adolescent girls and boys.

Biceps-flexing is a popular concept among boys and adult men. The MUAC is close to this concept and can gain traction as a community tool for monitoring nutrition improvement. This has a potential to popularize its scientific use for medium-term growth measurement and monitoring. Weight gain or weight loss can be a relatively rapid event; while height gains are slow to happen at individual or community level, MUAC may serve as a medium-term growth monitor.

However, there are no reliable multicentric reports about how protein energy intakes influence MUAC in growth periods. Indian studies are necessary both on MUAC validation and on nutrition links of MUAC. About cut-off points for MUAC, which is part of the validation exercise, there is first the need to settle differences between WHO and IAP charts. The authors tend to support IAP growth curves over WHO growth curves and multicentric studies on MUAC. Regression projections from IAP BMI curves can help validate Indian MUAC curves.

LIMITATIONS

This study is limited to 8th and 9th standard rural schoolchildren, which is about 13 and 14 completed years. The study is based on a convenience sample taken initially for a schoolbag weight study and cannot be generalized. The caste and social composition of the study population is not identified; hence, any bearing of the socioeconomic factors on BMI and MUAC could not be explored. We have not studied or compared sensitivity and specificity of MUAC with BMI, as there was no third true parameter for nutritional status.

CONCLUSION

The MUAC showing high correlation with BMI, waist and hip measurements can offer a direct, simple, visible, and tangible means to measure and inform all the stakeholders. There is also a need to generate awareness among administrators, teachers, students, and families regarding low BMI of rural schoolchildren and the potential use of MUAC. Age-appropriate Shakir-like MUAC tapes can be distributed to schools and students and educate about potential connection of MUAC with better nutrition and performance outcomes in adult life. There is need to correlate MUAC with protein energy intakes among adolescents, and improve diets within available means of rural families.

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REFERENCES

1. Lu Q, Wang R, Lou DH, Ma CM, Liu XL, Yin FZ. Mid-upper arm circumference and arm-to-height ratio in evaluation of overweight and obesity in Han children. Pediatr Neonatol 2014 Feb;55(1):14-19.
2. Dasgupta A, Butt A, Saha TK, Basu G, Chattopadhyay A, Mukherjee A. Assessment of malnutrition among adolescents: can BMI be replaced by MUAC. Indian J Community Med 2010 Apr;35(2):276-279.
3. Jeyakumar A, Ghugre P, Gadhave S. Mid-Upper-Arm Circumference (MUAC) as a simple measure to assess the nutritional status of adolescent girls as compared with BMI. ICAN 2013 Feb;5(1):22-25.
4. Tang, AM.; Chung, M.; Dong, K.; Wanke, C.; Bahwere, P.; Bose, K.; Chakraborty, R.; Charlton, K.; Hong, S.; Nguyen, P.; et al. Determining a global mid-upper, arm circumference cutoff to assess underweight in adults (men and nonpregnant women). Washington (DC): FHI 360/FANTA; 2017. [cited 2018 Jan 18]. Available from: https://www.fantaproject.org/sites/default/files/resources/Global-MUAC-Cutoffs-nonPregnant-Adults-Jun2017.pdf.
5. Indian Academy of Pediatrics Growth Charts Committee, Khadilkar V, Yadav S, Agrawal KK, Tamboli S, Banerjee M, Cherian A, Goyal JP, Khadilkar A, Kumaravel V, et al. Revised IAP growth charts for height, weight and body mass index for 5- to 18-year-old Indian children. Indian Pediatr 2015 Jan;52(1):47-55.
6. Ashtekar SV, Powar JD, Aqsa S, Padhyegurjar SB, Padhyegurjar MS, Banginwar A. Schoolbag-weights and musculoskeletal complaints in three schools in rural Maharashtra. Natl J Community Med 2017 Oct;8(10):572-578.

7. Mahajan, BK. Methods in biostatistics. 7th ed. New Delhi: Jaypee; 2010. p. 177.
8. CDC. National Health and Nutrition Examination Survey (NHANES): anthropometry procedures manual. Atlanta (GA): National Center for Health Statistics; 2007. [cited 2016 May 12]. Available from: https://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf.
9. Spada E, Chiossi G, Coscia A, Monari F, Facchinetti F. Effect of maternal age, height, BMI and ethnicity on birth weight: an Italian multicenter study. J Perinat Med 2017 Dec.
10. Dharmalingam A, Navaneetham K, Krishnakumar CS. Nutritional status of mothers and low birth weight in India. Matern Child Health J 2009 Mar;14(2):290-298.
11. NFHS4. State fact sheet Maharashtra. Mumbai: IIPS; 2015-2016. [cited 2018 Jan 12]. Available from: http://rchiips.org/NFHS/pdf/NFHS4/MH_FactSheet.pdf, http://rchiips.org/NFHS/pdf/NFHS4/India.pdf.
12. MDM. MID day meal, guidelines. Maharashtra: Govt of Maharashtra. [cited 2018 Jan 20]. Available from: https://education.maharashtra.gov.in/mdm/files/Introduction%20Marathi.pdf.
13. Raghvendra, G. Operational guidelines for weekly IFA supplementation program for school based adolescents. [cited 2018 Jan 20]. Available from: https://www.researchgate.net/profile/Gumashta_Raghvendra/publication/23633763.
14. Rashtriya Bal Swasthya Karyakram (RBSK). Child Health Screening and Early Intervention Services under NRHM. New Delhi: Ministry of Health and Family Welfare; 2013. [cited 2018 Jan 18]. Available from: http://www.mdm.nic.in/Files/School%20Health%20Programme/Nutrition_Support/Rastriya_Bal_Swaasthya_Karyakram.pdf.
15. WHO. Growth reference 5-19 years. Geneva: WHO; 2007. [cited 2017 Dec 12]. Available from: http://www.who.int/growthref/who2007_bmi_for_age/en/.
16. Krishna, V. Indian nutrition policy finally on the move but states need to lead the way. New Delhi: Global Nutrition Report 2015. [cited 2018 Jan 17]. Available from: http://www.globalnutritionreport.org/2015/12/21/indian-national-nutrition-policy-finally-on-the-move-but-states-need-to-lead-the-way/.
17. Chaturvedi S, Kapil U, Gnanasekaran N, Sachdev HP, Pandey RM, Bhanti T. Nutrient intake amongst adolescent girls belonging to poor socioeconomic group of rural area of Rajasthan. Indian Pediatr 1996 Mar;33(3):197-201.
18. Aubertin-Leheudre M, Adlercreutz H. Relationship between animal protein intake and muscle mass index in healthy women. Br J Nutr 2009 Dec;102(12):1803-1810.
19. Kulathinal S, Freese R, Korkalo L, Ismael C, Mutanen M. Mid-upper arm circumference is associated with biochemically determined nutritional status indicators among adolescent girls in Central Mozambique. Nutr Res 2016 Aug;36(8):835-844.