Nutritional assessment with skinfold thickness and body-fat proportion in tribal and urban schoolchildren in Nashik district: A cross sectional study

Shyam V. Ashtekar, Manasi S. Padhyegurjar, Shekhar B. Padhyegurjar, Jagdish D. Powar

Department of Community Medicine, SMBT Institute of Medical Sciences and Research Centre (SMBT IMS and RC), Dhamangaon, Dt Nashik, Maharashtra, India

ABSTRACT

Context: Skinfold thickness (SFT) and body-fat (BF%) are infrequently used for childhood undernutrition. Aims: (a) Estimation of SFT at peripheral and truncal sites (b) Estimation of BF% from SFTs (c) Correlate SFT estimates with MUAC, BMI and Waist. (d) Compare rural/tribal SFTs with urban schoolchildren. Settings and Design: Ashram schools in rural/tribal settings and one urban school. Methods and Material: Using three stage sampling, four tribal schools were randomly selected and an urban school was added for comparison. A sub sample of 405 students in the age group of 7 to 15 years were included. Height, weight, MUAC and SFTs were measured BF% was estimated with Slaughter equation. Statistical Analysis: Using Excel, Epi Info 7.1 and R software, appropriate t tests were applied for comparisons, and correlation was estimated between the quantitative variables. Results: Average SFT among schoolchildren (405) was 6.64 mm. Girls (n = 215) had a BF% of 13.1%, while boys (n = 190) had BF at 11.5%. Average SFT for boys (6.69) and girls (6.48) had no statistically significant difference (t = 1.3, P = 0.1929). Boys had higher average peripheral SFT than truncal SFT while girls had higher truncal SFTs. In girls subscapular SFT was higher than triceps SFT. Median BF% in rural was lower than urban schoolchildren. BF% correlated strongly with BMI (0.56), Waist (0.63), Hip (0.61) and MUAC (0.59). Conclusion: SFT and BF % can be effectively used to detect undernutrition. Geographical and Gender differences are observed. SFT and BF% correlated well with BMI and MUAC.

Keywords: Ashram schools, body fat %, BMI, scheduled tribes, schoolchildren, skinfold thickness, slaughter equation, under-nutrition

Introduction

Out of India’s 1.21 billion people, 8.6% belong to Scheduled tribes (ST), mostly living in hilly and forest areas in several states. Economically backward, many STs suffer on health and nutrition grounds.[1] Residential Ashram schools in Tribal Sub-Plan Area are an important intervention by Government to improve health, nutrition and education with protected environment for about 300 days every year.[2]

The problem of under-nutrition is prominent in ST population.[3-4] Malnutrition in children is estimated in various ways including weight for age, height, Body Mass Index (BMI), mid-upper-arm-circumference (MUAC) etc. Skin Fold Thickness (SFTs) and Body fat proportions (BF%) are not adequately studied in India but a study conducted in 2017, has...
set BF% curves with Dexascan for North Indian children in 7 to 17 years, with median values for boys from 18 to 29% and for girls 22 to 38%. BF% can reflect a real-time sensitive information about energy stores of a child. Though direct methods such as MRI, Dexascan and Impedometry are used in many countries for BF%, simple estimations of SFTs with suitable equations can reasonably estimate BF%. BF% can be an important clue to both under-nutrition and obesity. Various studies recommend SFT measurements as the preferred screening tool in adolescents because SFT predicts BF% better than adolescent BMI and provides more accurate estimates of adiposity. A PubMed and Google scholar search with BF% and SFT yielded no articles on tribal schoolchildren in India. This study was a part of the project for estimation of food intakes and anthropology of tribal schoolchildren in Nashik district.

Aims and objectives

The objectives included (a) estimation of SFT at peripheral and truncal sites (b) estimation of BF% from SFTs (c) correlation of SFTs with other anthropometric measures like MUAC, BMI and Waist. (d) Compare rural-tribal estimates of SFTs with urban schoolchildren.

Subjects and Methods

Study settings

This study is a part of a nutritional intake research project conducted in Ashram schools. Nashik has six major tribal blocks. Out of these, four blocks (Dindori, Peth, Igatpuri, and Trimbak) were selected randomly by chit method. In the second stage of sampling, Chits bearing school names from four blocks were pooled in two categories – government and private schools. Dindori had 10 schools each in government and private category, while Peth had 10 and 4, Igatpuri 5 and 5, and Trimbak 11 and 13, respectively. Two schools from each pool were randomly selected by chit method. For comparative anthropometry, an urban school in Nashik was included on feasibility basis. Thus, the study was undertaken in two Government and two grant-in-aid private Ashram schools and an urban school from Nashik city, yielding 1929 students from 7 to 15 years. Height, weight and MUAC were assessed on this study population. In the third stage of sampling, a 20% subsample was taken for SFT, waist and hip measurement by selecting every 5th child in the list (n = 405). If the listed child was absent, next child was taken. The data collection was completed over four months.

Ethical consent and assent

The institutional Ethics Committee approved this study (SMBT/IEC/2017/Project - 61). Permission was obtained from the Tribal Development Commissioner and selected private trust schools. The schoolteachers were informed a day prior about actual visit date. School names and identities were protected for confidentiality in official communication. Assent of students was taken before study in each school at the time of morning prayers explaining the procedures with reference to school health check-ups.

Anthropometry

SFTs: The measurement of SFTs was done by male and female researcher separately on boys and girls, with a simple hand-held calliper, checked against a standard engineering steel ruler for 2 mm markings up to 70 mm. The printed instructions for correct pressure of calliper catch and handle were followed. (Instrument model: Beachbody, FBA_ACCBODFAT2101, 23.6 x 18.5 x 4.8 cm ASIN B003 JU3G4A). SFT was measured after removing upper clothes in privacy. Four SFT sites included Subscapular (angled 45% to spine), Supra-iliac (3 cm diagonally above iliac crest) and Triceps, Biceps (vertical skinfold on back and front of flexed arm), together making eight sites from both sides. If a reading exceeded or fell short of a 2 mm mark, the closest marking was taken as the adjusted reading. The total of eight sites was used to calculate Average Skin Fold Thickness (AvSFT). The average of four peripheral SFTs (biceps and triceps on two sides) were used to calculate Average peripheral SFT (AvPSFT). Average truncal SFT (AvTSFT) was calculated from subscapular and supra-iliac sites on two sides.

MUAC: 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 measured with a Shakir tape. An ordinary tailor tape was used in some cases with MUAC exceeding 25 cm.

BF %: Here we calculated BF% from sum of Triceps and subscapular skinfold on left side, using Slaughter equation for boys and girls as follows as per reference study:

\[
BF\% (boys) = 1.21*(T + SS) - 0.008*(T + SS)^2 - 1.7 \text{ White Males}
\]

\[
BF\% (girls) = 1.33*(T + SS) - 0.013*(T + SS)^2 - 2.5 \text{ All females}
\]

Body weight was recorded once with non-digital bathroom 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 app. The weighing machine was tested each day against a premeasured weight of sandbag wrapped in plastic. It did not show error of >0.1 kg when tested each day.

Height was taken with a stadimeter (Height 200 cm, No. 26 SM) fixed on wall, ensuring head, toes, buttocks, and shoulders touched the wall. Waist was measured at the midpoint between the lower border of the rib cage and the iliac crest. Hip was measured at the widest part of the hip.

Sample size and statistical methods

A pilot study was conducted in eleven boys and girls in 9th year at one Ashram school, for estimation of SFT (triceps and subscapular SFTs one side) and using it for BF% estimation yielding a mean BF% of 12.25% and standard deviation of
3.12%. Allowable error (L) at 5% of mean was used, hence ±0.61 Z1-α/2 = 2.576 (At 99%CI, two tailed). Estimate was done with formula n = {Z1-α/2)^2 \cdot \text{std dev}^2 \cdot 1/L^2}. So n = 173.6 and considering schools as clusters and taking design effect of 2, n will be 347.2 and taking 10% more due to non-response, n will be 381.92 i.e., 382.

Data entry was done using excel, and analysis done with Epi-Info 7.1 for appropriate t tests for comparisons, and correlation between quantitative variables. R software was used for boxplots.

**Results**

Table 1 summarizes demographic and anthropometric features of the study population, with SFT values, BF% with 95% Confidence Limits.

The study population had 80.8% rural-tribal and 19.2% urban schoolchildren. Average SFT of the study population (405) was 6.64 mm, contributed by AvPSFT (6.22 mm) and AvTSFT (7.06 mm). Girls (n = 215) had a BF% of 13.1%, while boys (n = 190) averaged at 11.5%; the difference being statistically highly significant (t = 4.1585. p<.0000). The BF% also differed between pooled rural (12.06%) and Urban (13.46%), (t = -2.8156, P = 0.0051). The pooled Rural-Urban differences in AvSFT were pronounced (U = 8.11 mm, R = 6.29 mm, t = -6.3334, P = 0.0000).

Table 2 shows SFT values by before-and-after-pubertal age groups, gender and urban-rural categories as follows (a) Differences in the average of eight SFT sites between boys and girls in pre and post-pubertal and urban-rural students were statistically not significant (b) Boys had generally higher Peripheral SFTs than girls except in the urban 13-15 y group (c) In contrast rural Girls had higher AvTSFT values than rural boys and this difference was highly significant. However, difference in AvTSFTs for urban girls and boys was statistically not significant.

Figure 1 shows Average Skinfold estimates of girls and boys for pooled rural-urban data across age. AvPSFT in boys is seen to be higher than that in girls except at age 10 and 14 years where these tend to mingle. AvTSFT in girls was higher than boys in all age groups.

Table 3 shows AvPSFT, AvTSFT and BF% estimates. Generally, the pre-pubertal rural boys and girls were found to have lower SFTs and BF% than their urban counterparts, with statistically significant P values. Rural boys and girls in pre-pubertal category had lower BF% than rural schoolchildren but this difference was statistically significant only among girls. The AvSFT, AvTSFT and BF% estimates in post-pubertal group had no significant urban-rural differences for both boys and girls separately.

Figure 2 shows BF% of Schoolchildren by age and gender. This suggests that BF% was higher in urban than rural girls. Also the urban boys showed higher BF% than rural boys but the observed difference was small in the 7 to 11 years group and then increased till 13 years of age, thereafter urban boys showed a decline in BF%.

Figure 3 shows boxplots of girls and boys in pre-pubertal and post-pubertal age groups in urban-rural comparison. Except for post-pubertal boys, all boxplots show lower median BF% in rural schoolchildren.

Table 4 shows correlation values between BF% and BMI, waist, hip and MUAC.

**Discussion**

**SFT and BF**

SFTs are widely used and recommended in many countries for measurement of BF%, though more for obesity and overweight

---

**Table 1: Summary Information about study population**

| Category                          | No. (+SD)          | No. (+SD)          |
|-----------------------------------|--------------------|--------------------|
| Girls (n=215) No. (%)             |                    |                    |
| Rural schoolchildren              | 175 (81%)          | 152 (80%)          |
| Urban schoolchildren              | 40 (19%)           | 38 (20%)           |
| Tribal schoolchildren as % of study population | 178 (82.78%) | 161 (84.75%) |
| Boys (n=190) No. (%)              |                    |                    |
| Mean Study Population Age (yrs)   | 11.38 (+2.50)      | 11.24 (+2.50)      |
| Mean Study Population Age (Kg)    | 26.32 (+8.88)      | 27.11 (+9.95)      |
| Mean Study Population Height (cms)| 132.92 (+14.55)    | 134.37 (+16.49)    |
| No. Confidence Limit (CL)         |                    |                    |
| Average SFT (pooled average of 8 body sites) (mm) | 6.79 (6.49 to 7.1) | 6.48 (6.12 to 6.84) |
| Average Peripheral SFT (mm)       | 5.75 (5.5 to 6.0)  | 6.71 (6.35 to 7.07) |
| Average Truncal SFT (mm)          | 7.82 (7.43 to 8.21)| 6.20 (5.79 to 6.61) |
| Average Subscapular SFT (mm)      | 8.70 (8.23 to 9.17)| 6.66 (6.26 to 7.06) |
| Average Abdominal SFT (mm)        | 6.95 (5.56 to 7.34)| 5.74 (5.3 to 6.18) |
| Average Triceps SFT (mm)          | 5.09 (4.8 to 5.36) | 6.24 (5.89 to 6.59) |
| Body fat as % of body composition  | 13.09 (12.52 to 13.66)| 11.48 (11.13 to 11.83) |
| BMI                               | 14.43 (14.12 to 14.74) | 14.56 (14.25 to 14.87) |
than underweight. The Measurement of SFT is an important and easy field-tool of obesity estimation.\cite{6,7,12} As the Hopkins study points out, SFTs remain a reliable tool to estimate BF in field situations.\cite{7} The UK study also suggested that the SFTs make a feasible and reliable method implying utility by trained paramedics.\cite{12} The Sao Paulo study reported that SFTs and MUAC and good indicators of BF% in children.\cite{13}

A UK multi-ethnic study commented that the BF% estimates with Slaughter equation showed good agreement with BMI, waist circumference, waist-to-height ratio.\cite{7,12} Studies in Europe, Africa and US among different ethnic groups reported BF% estimation through SFT equations.\cite{7,12,14}

### Table 2: Gender differences in average SFTs (AvSFT), average peripheral SFTs (AvPSFT) and average truncal SFTs (AvTSFT)

| Parameter                  | Category | Gender | n   | Mean  | SD   | t    | P    |
|----------------------------|----------|--------|-----|-------|------|------|------|
| AvSFT of 8 sites           | Rural    | Girls  | 105 | 5.83  | 1.48 | 1.1006 | 0.2724 |
|                            |          | Boys   | 94  | 5.61  | 1.27 |       |      |
|                            | Urban    | Girls  | 27  | 7.56  | 2.52 | 0.5458 | 0.5878 |
|                            |          | Boys   | 27  | 8.01  | 3.40 |       |      |
| AvPSFT (Biceps + triceps SFT) | Rural    | Girls  | 105 | 5.09  | 1.38 | 5.2378 | 0.0000 |
|                            |          | Boys   | 94  | 6.13  | 1.42 |       |      |
|                            | Urban    | Girls  | 27  | 6.43  | 1.65 | 2.9853 | 0.0048 |
|                            |          | Boys   | 27  | 8.39  | 2.99 |       |      |
| AvTSFT (subscapular + abdominal) | Rural    | Girls  | 105 | 6.57  | 1.84 | 6.5813 | 0.0000 |
|                            |          | Boys   | 94  | 5.09  | 1.29 |       |      |
|                            | Urban    | Girls  | 27  | 8.70  | 3.64 | 1.0472 | 0.2999 |
|                            |          | Boys   | 27  | 7.63  | 3.89 |       |      |

**Methods of SFT estimation**

The sites of SFT measurement are somewhat diverse. Some studies have used right sided readings while some have used left side.\cite{6,12} In this dataset, the mean left Subscapular SFT exceeded the right by 0.55 mm. (t Stat = -5.865 two-tail P = 9.3053E-09.) The mean left triceps SFT was also higher by 0.25 mm than the right one (t value=3.007, P two-tail 0.0027) This shows that choosing the side for SFTs makes a difference for BF%. To overcome this bias we measured both sides.

The instruments deployed in various studies range from simple to sophisticated ones offering range of accuracy of 0.1 mm to 2 mm with cost implications.

---

**Figure 1**: Average Skin Fold estimates across age

**Figure 2**: BF% of school children by age and Gender
This study was mainly about rural-tribal schoolchildren and mostly from inmates of Ashram schools. The sample size requirement of 204 was adequately met by a 20% systematic random subsample (n = 405) of 7–15-year age inclusion of the original study population of 1921 students. However, the urban component of this sample being small, we did only a descriptive exercise rather than a comparative rural-urban analysis.

The good correlation of BF% with BMI, waist, hip and MUAC in Table 4 suggest that the estimates are consistent with other studies. Hence SFTs offer a direct and robust measure of energy stores in the body. This aspect of SFTs and availability of low-cost and easy-to-use instruments make SFTs a good reader of nutrition programs and a handle for timely interventions. A study in marathoners showed that energy expenditures are quickly reflected in SFTs by way of depletion of fat stores after intense physical activity. This implies that SFTs can indicate fat stores sensitively.

BF% estimation is otherwise done in several ways like Dexascan and electric impedometers. The accuracy of slaughter equation for BF% estimation from SFTs is sensitive to ethnic categories. Two important studies from Mysore and Pune have given comparison of various equations for BF% estimation in children, but all of them including Slaughter’s show variation from direct estimates like dexascan or impedance biometry. Since Slaughter equation is widely reported and is applicable for our age group of 7-15 we chose to use this equation. It has its limitations like non-factoring of age and ethnicity hence there is need to work on its India-relevance. There are scant Indian studies on BF% estimates. The Delhi study using Dexascan and impedometer does not report SFT-based BF% estimates.

## SFT with age and gender

The first striking finding of the study was that average SFTs in girls and boys were under 7 mm, which are lower by even Indian optimum of 10 mm and that <6 mm is taken as undernutrition. However we did not find on PubMed and Cochrane database any substantive reports stating the cut-offs for the undernourished children of any age group. Triceps SFT values are commonly reported in many studies. This study (even with 19% urban subjects) had low median triceps SFTs of 6 mm, whereas a Polish study among 6 to 16 year age schoolchildren reported median values rising from 10 to 16 mm in girls and from 9 to 15 mm in boys. Hence the
lower SFTs in this study are striking. The authors of this study reported adequate food intakes the SFT outcomes here fail to be optimal.\cite{5}

Girls in this study have marginally higher average SFT than boys in pre and post pubertal age, but the differences are statistically not significant [Table 2]. Table 2 shows that all average SFT estimates rise with age as is expected, but in this study it all starts at low SFTs as compared to a similar age group of 6-16 years in a polish study.\cite{7}

The gender differences across the pre and post pubertal groups seen in AvPSFTs and AvTFSTs in this study are consistent with many other studies.\cite{6,7,14}

| Table 4: Correlation between body fat % (BF%) and other anthropometric measures |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Correlation     | Pooled (Girls and Boys) | Rural + Urban pooled | Rural | Urban |
| BF% with BMI    | R (Pearson) | 0.5469 | 0.5521 | 0.5868 | 0.5108 | 0.433 | 0.6689 | 0.8114 |
|                 | Spearman | 0.4546 | 0.4908 | 0.4341 | 0.4449 | 0.4349 | 0.6355 | 0.5341 |
|                 | P       | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| BF% with Waist  | R (Pearson) | 0.5884 | 0.5908 | 0.5626 | 0.554 | 0.4651 | 0.7179 | 0.7059 |
|                 | Spearman | 0.5282 | 0.5512 | 0.4685 | 0.515 | 0.4959 | 0.6834 | 0.4169 |
|                 | P       | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| BF% with Hip    | R (Pearson) | 0.5597 | 0.5623 | 0.4975 | 0.5245 | 0.4628 | 0.6372 | 0.5678 |
|                 | Spearman | 0.4996 | 0.5228 | 0.4311 | 0.4927 | 0.4817 | 0.5961 | 0.3748 |
|                 | P       | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| BF% with MUAC   | R (Pearson) | 0.5665 | 0.5927 | 0.5226 | 0.5381 | 0.4394 | 0.7106 | 0.6787 |
|                 | Spearman | 0.5012 | 0.5360 | 0.4361 | 0.5051 | 0.4554 | 0.6580 | 0.4837 |
|                 | P       | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

\*P<0.1, †P<0.05, ‡P<0.01, §P<0.00, ||P<0.0001

![Figure 3: Box Plots – Urban – Rural Comparision](image-url)
In this study boys showed higher Average Peripheral SFT than girls in both urban and rural categories. In contrast the AvTSFT in rural girls was higher than same age boys.

Further, the AvTSFT estimates in girls are higher than their AvPSFTs in this study. This is contrary to other studies where boys have little difference between peripheral and truncal SFTs, but girls showed higher triceps SFT than subscapular (truncal) SFT. This study shows that the girls have more truncal SFT than peripheral AvPSFT as seen in Table 2. Perhaps such differences could be due to ethnic traits peculiar to India, since both rural and urban girls in the study show similar findings.

In contrast to some studies that reported Triceps SFT in girls being higher than subscapular SFT, this study shows low Triceps SFT among rural girls as compared to subscapular SFT. This raises a question: is lower Triceps SFT among rural girls (than subscapular SFT) an ethnic response or whether girls have responded to lower nutrition by conserving subscapular SFT at the cost of Triceps SFT (which is a basically peripheral SFT) for pubertal growth? In other words, if girls had better nutrition, would the Triceps SFT overtake subscapular SFT? This needs further research.

BF%

Figure 2 shows that the BF%, being a function of SFTs, expectedly rises with age. The boxplots in Figure 3 suggest that rural median BF% is lower than urban in all but older boys and this exception may be due to a smaller urban sample.

The BF% estimates in these rural-tribal schoolchildren are notably lower than the Indian study for 8-9 yr age group based on Slaughter equation. The North Indian study reported BF% levels in 7-17 years age group, wherein the mean BF% levels by Dexascan rose from 19 to 22% in boys and 19 to 37% in girls. The present study findings show BF% levels at about 10% percentile of this important North Indian study. The estimates are also lower than reports from many developing countries. This study also suggests that rural children have lower BF% [Figure 2] than urban schoolchildren. Low BF% implies lower energy stores in the critical growth period. A US Mayan children study reported that heights had improved with better nutrition and less physical activity levels in period from 1992 to 2012. The Tribal children in Ashram schools are sedentary throughout schooling years, but despite this the estimated SFTs indicate poor BF% and energy reserves. The authors' earlier study suggested adequate macro-nutrient intakes among the Ashram school children. However even this adequate intake did not ensure betterment of SFT and BF%, and begs an answer on nutrition dynamics including health care, water and sanitation.

Another learning from this study is that SFTs vary across sites by gender and that girls had more truncal fat than peripheral fat. Hence using just Triceps skinfold may not correctly estimate SFTs in girls. SFT studies use either left or right Triceps SFT and Subscapular SFT. The left side usually measures higher as this study shows. The Slaughter equation uses the sum of these two for BF% estimates and hence needs more standardization.

BF% estimates can help in diagnosing energy stores in malnutrition, and this paper attempts the same. There are not many Indian studies on BF% and one large North Indian study uses Dexascan rather than SFTs. This study shows rural-urban differences in SFT and BF%. Indian children are not directly comparable to European or other ethnic groups for BF%. The concept of thin-fat-Indian propagated by D’Angelo S et al. suggests that Indian babies tend to have more internal adiposity that continues till adulthood and is detrimental by way of metabolic adversities. However, we need to read this study findings in the context of child undernutrition.

Implications

More Indian studies are necessary to develop age-sex curves of SFTs and equations for BF% for Indian children.

Key Messages

Skin Fold Thickness (SFT) and Body Fat percentage (BF%) are cost effective, easy to use. They can be used for detection of under-nutrition efficiently. Rural-tribal students show lower SFT and BF% than urban students. SFT and BF% correlate well with BMI and MUAC. Peripheral and truncal SFTs are gender-dependent.

Summary/Conclusion

The average rural-tribal schoolchildren show poor SFTs, BF% than urban, North Indian and other country studies. Body sites and left-right sides yield different SFTs. Even simple callipers can offer a ready, tangible and good diagnosis of nutrition status through skinfold thickness. This can be of good use in Primary Health Care set up. With training, the primary health care worker can easily detect malnutrition. This would be appropriate technology at its best. The estimated BF% had good correlation with MUAC, Hip, Waist and BMI. SFTs can be used for under-nutrition as well.

Limitations

Use of low accuracy callipers and small size of urban group were main limitations of the study. Dexascan and Impedometer could have added more value to this study.

Acknowledgments

The authors are grateful to SMBT IMSRC, The management, staff and students of Ahramschools and the Urban School, for their cooperation.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.
References

1. Government of India. Ministry of Tribal Affairs. Annual Report 2018-19. Available from: https://tribal.nic.in/writereaddata/AnnualReport/AREnglish1819.pdf. [Last accessed on 2021 Mar 31].

2. Government of India. Ministry of Health and Family Welfare, IIPS. National Family Health Survey (NFHS-4)-2015-16. Available from: http://rchiips.org/nfhs/NFHS-4Reports/India.pdf. [Last accessed on 2021 Mar 04].

3. Government of India. Ministry of Health and Family Welfare, IIPS. National Family Health Survey (NFHS-5) 2019-20. Fact Sheets: Key Indicators 22 States/UTs from phase-4. Available from: http://rchiips.org/NFHS/NFHS-5_FCTS/NFHS-5%20State%20Factsheet%20CompendiumPhase-4.pdf. [Last accessed on 2021 Apr 14].

4. Government of India. Ministry of Health and Family Welfare, IIPS. National Family Health Survey (NFHS-5) 2019-20. State Fact Sheet: Maharashtra. Available from: http://rchiips.org/nfhs/NFHS-5_FCTS/Maharashtra.pdf. [Last accessed on 2021 Apr 14].

5. Khadgawat R, Marwaha RK, Tandon N, Mehan N, Upadhyay AD, Sastry A, et al. Percentage body fat in apparently healthy school children from northern India. Indian Pediatr 2013;50:859-66.

6. Rönnecke E, Vogel M, Bussler S, Grafe N, Jurkutat A, Schlingmann M, et al. Population-based centile curves for triceps and subscapular skinfold thickness in Polish children and adolescents—The OLAF study. Obes Facts 2019;12:25–39.

7. Tuan NT, Wang Y. Adiposity assessments: Agreement between dual-energy X-ray absorptiometry and anthropometric measures in U.S. children: Agreement in adiposity assessments in children. Obesity 2014;22:1495–504.

8. Jaworski M, Kuśaga Z, Pludowski P, Grajda A, Gurzewska B, Napieralska E, et al. Population-based centile curves for triceps, subscapular, and abdominal skinfold thicknesses in Polish children and adolescents—The OLAF study. Eur J Pediatr 2012;171:1215–21.

9. Ashtekar S, Padhyegurjar M, Powar J. Protein calorie intakes and growth profiles in asham school students in Nashik district in Maharashtra. Indian J Public Health 2019;63:341.

10. Kehoe SH, Krishnaveni GV, Lubree HG, Wills AK, Guntupalli AM, Veena SR, et al. Prediction of body-fat percentage from skinfold and bio-impedance measurements in Indian school children. Eur J Clin Nutr 2011;65:1263–70.

11. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Nan Loan MD, et al. Skinfold equations for estimation of body fatness in children and youth. Hum Biol 1988;60:709–23.

12. West J, Santorelli G, Lennon L, O’Connell K, Corkett J, Wright J, et al. Beyond height and weight: A programme of school nurse assessed skinfold measurements from white British and South Asian origin children aged 4–5 years within the Born in Bradford cohort study. BMJ Open 2015;5:e008630.

13. Garófolo A, Lopez FA, Petrilli AS. High prevalence of malnutrition among patients with solid non-hematological tumors as found by using skinfold and circumference measurements. Sao Paulo Med J 2005;123:277–81.

14. Freedman DS, Ogden CL, Blanck HM, Borrud LG, Dietz WH. The abilities of body mass index and skinfold thicknesses to identify children with low or elevated levels of dual-energy x-ray absorptiometry determined body fatness. J Pediatr 2013;163:160-6.e1.

15. Knechtle B, Baumgartner S, Knechtle P, Rüst CA, Rosemann T, Bescós R. Changes in single skinfold thickness in 100 km ultramarathoners. Open Access J Sports Med 2012;3:147-57.

16. Paul KV, Bagga A, editors. Ghai Essential Pediatrics. 8th ed. CBS Publishers and Distributors Pvt Ltd; ISBN 978-81-239-1777-1; page 97.

17. Kuhle S, Ashley-Martin J, Maguire B, Hamilton DC. Percentile curves for skinfold thickness for Canadian children and youth. PeerJ 2016;4:e2247. doi: 10.7717/peerj.2247.

18. Monyeki KD, Kemper HC, Magkge PJ. Development and tracking of central patterns of subcutaneous fat of rural South African youth: Ellisras longitudinal study. BMC Pediatr 2009;9:74.

19. Ogechi UP, Akhakhia Ol, Ugwunna UA. Nutritional status and energy intake of adolescents in Umuahia Urban, Nigeria. Pak J Nutr 2007;6:641–6.

20. Ramirez-Velez R, Lopez-Cifuentes M, Correa-Bautista J, Gonzalez-Ruiz K, Gonzalez-Jimenez E, Cordoba-Rodriguez D, et al. Triceps and subscapular skinfold thickness percentiles and cut-offs for overweight and obesity in a population-based sample of schoolchildren and adolescents in Bogota, Colombia. Nutrients 2016;8:595.

21. Ripka WL, Ulbricht L, Gewehr PM. Body composition and prediction equations using skinfold thickness for body fat percentage in Southern Brazilian adolescents. Kiechl S, editor. PLoS One 2017;12:e0184854.

22. Gulliford M, Mahabir D, Rocke B, Chinn S, Rona R. Overweight, obesity and skinfold thicknesses of children of African or Indian descent in Trinidad and Tobago. Int J Epidemiol 2001;30:989–98.

23. Urlacher SS, Kramer KL. Evidence for energetic tradeoffs between physical activity and childhood growth across the nutritional transition. Sci Rep 2018;8:369.

24. D’Angelo S, Yajnik CS, Kumaran K, Joglekar C, Lubree H, Crozier SR, et al. Body size and body composition: A comparison of children in India and the UK through infancy and early childhood. J Epidemiol Community Health 2015;69:1147–53.