Anthropometric measurements for the prediction of the metabolic syndrome: a cross-sectional study on adolescents and young adults from southern india

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ABSTRACT

Objectives To determine which anthropometric measurement correlates best with the metabolic abnormalities associated with the metabolic syndrome in adolescents and young adults.

Design Cross-sectional study.

Setting Schools, high schools and universities.

Participants 1359 adolescents and young adults aged 14—25 years.

Main outcome measures Anthropometric predictors of metabolic abnormalities as classified by International Diabetes Federation definition.

Results The waist circumference (OR 1.56, 95% CI 1.0 to 2.43: p≤0.01) and the abdominal skin fold thickness (OR 1.44, 95% CI 1.02 to 2.04, p≤0.01) above the third quintile cut-offs were found to be significantly associated with metabolic abnormalities. The sensitivity of either one of these measurements in predicting metabolic abnormalities was 66.1% with a negative predictive value of 82.8%. Hyperglycaemia was significantly associated with an abdominal skin fold thickness over the fourth quintile alone (OR 1.63, 95% CI 1.24 to 2.1). All the anthropometric measurements correlated well with elevated triglycerides and hypertension.

Conclusions In a large community-based cross-sectional survey of subjects aged 14—25 years, the waist circumference and the abdominal skin fold thickness are important predictors of the metabolic abnormalities associated with metabolic syndrome. This simple clinical tool may help in a primary care setting to identify subjects who require a further biochemical evaluation and would considerably reduce the cost of unwarranted testing.

INTRODUCTION

The Metabolic Syndrome (MetS) is characterised by a constellation of cardiometabolic risk factors such as dyslipidaemia, hypertension, glucose intolerance, hyperinsulinaemia and central or visceral adiposity[1] MetS is no longer considered a syndrome of adults, as its origin in utero is well established,[2] and this clustering of cardiometabolic risk factors is also shown in children and adolescents.[3 4] However, the concept of MetS in this age group has been debated extensively, owing to the non-availability of a proper definition[5] and the influence of pubertal hormones on growth, insulin resistance and body composition and redistribution of body fat.[6 7] Yet, several investigators have attempted to study the MetS in this age group based on evidence that this risk factor clustering is fairly stable, and its occurrence in childhood can be tracked to adulthood.[8–10] Therefore, it is imperative to identify children and adolescents with an elevated risk factor profile for early planning and implementation of the preventive strategies and reducing the burden of cardiovascular disease (CVD) and type 2 diabetes (T2DM) in the community.

Obesity, and central adiposity in particular, is a major public health concern and is a key predeterminant of CVD and T2DM risk.[11–13] Longitudinal studies have shown that obesity is associated with insulin resistance,[14] dyslipidaemia,[15] type 2 diabetes[16] and the long term occurrence of vascular complications[17 18] in children and adolescents. Although several anthropometric indices serve as simple clinical tools for the measurement of central adiposity, it is not particularly clear which surrogate marker is the most reliable predictor of metabolic risk factor accumulation in children and adolescents. Body mass index (BMI) measurements in childhood are associated with abnormal metabolic clustering in adulthood.[9] However, the usefulness of BMI is limited for the following reasons: (1) its inability to distinguish fat from muscle mass; (2) its tendency to under-represent body fat distribution; and (3) its inability to measure central adiposity in a direct fashion.[19] Studies in adolescents have shown that waist circumference (WC) correlated well with clustering of metabolic abnormality (MAB) and hypertension.[20] The Bogalusa Heart study is the only study that has published age- and gender-specific WC cut-offs for children and adolescents based on adverse CVD risk factor profiles.[5] The predictive ability of waist:hip ratio (WHR)[21] and waist:height ratio (WhtR)[22 23] for CVD risk are reported in adults, but it appears unlikely that these measurements could predict the intra-abdominal fat depot in the younger age groups.[24] Skin fold thickness (SFT) measurements have shown a reasonably strong association with increased body fat percentage and associated morbidity, both in children and in adolescents,[25 26] yet some consider these factors to be of limited clinical utility.

In this cross-sectional study, we aimed to investigate the diagnostic capability of various anthropometric indices in predicting the MAB, as defined by IDF criteria in the diagnosis of MetS. We hypothesise that if simple anthropometric measurements are able to identify the majority of children with MAB, the number of subjects requiring additional laboratory tests could be reduced, resulting in considerable cost savings. Additionally, these measurements could be widely utilised in a primary care setting as an effective tool for cardiometabolic risk stratification and early management.

MATERIALS AND METHODS

One thousand three hundred and fifty-nine subjects from 11 different schools and vocational training centres aged 14–25 years took part in this cross-sectional survey. The study was approved by the institutional review board, and informed consent was obtained from all individuals aged more than 18 years of age and from parents of those subjects aged less than 18 years. Demographic, lifestyle information and medical histories were obtained by one-to-one interviews with the subjects. Subjects who were fasting for a period of less than 8 h and taking medications such as insulin, glucocorticoids or anticonvulsants which would alter the blood glucose levels were excluded from the study.

Anthropometric measurements

The anthropometric measurements were recorded by a standard procedure ensuring interobserver reliability. The height was measured to the nearest centimetre with the use of a tape stuck to the wall with the head positioned in the Frankfurt plane. The weight was measured to the nearest 0.1 kg with the use of digital bathroom scales, which were checked on a daily basis using a standard weight. The WC was measured at the smallest girth between the costal margin and the iliac crest. The hip circumference was measured at the widest circumference between the anterior superior iliac crests and the ischial tuberosities using a non-stretchable tape and rounded off to the nearest 0.1 cm. The SFT was measured at three regions—subscapular, triceps and abdomen using a Harpenden calliper (CMS Instruments, London). Subscapular skin fold thickness (SS-SFT) was measured 1–2 cm diagonally from the inferior angle of scapula. The triceps skin fold thickness (Tri-SFT) was measured at the midpoint of the upper arm between the acromion process and the tip of the olecranon process, and the abdominal skin fold thickness (Ab-SFT) was measured at a lateral distance of approximately 2 cm from the umbilicus. The pubertal staging was performed using Tanner's staging.

The blood pressure was recorded manually using a standard sphygmomanometer 3–5 min after the subjects were made comfortable, and the mean of three readings at an interval of 5 min rounded off to the nearest millimetre of Hg was recorded.

Venous blood was drawn after 8 h of fasting for estimating the lipid profile. Estimations of the serum total cholesterol and triglycerides were by the standard enzymatic procedures and HDL cholesterol by a direct assay method. The biochemical assays were done on a Hitachi 912 auto analyser using reagents from Roche Diagnostics (Mannheim, Germany) with the appropriate quality control methods. The capillary blood sugar was recorded at fasting and 2 h postprandially using a glucometer (Accu-chek -Active CV1.9–2.3%).

MAB stratification

Subjects were considered to have an MAB if two or more of the following abnormalities based on IDF criteria[27] for diagnosis of MetS were present: (1) triglycerides were ≥150 mg/dl (>1.7 mmol/l); (2) high-density lipoprotein (HDL) cholesterol: males <40 mg/dl (<1.03 mmol/l), females <50 mg/dl (1.29 mmol/l); (3) fasting plasma glucose was ≥100 mg/dl (≥5.6 mmol/l); (4) blood pressure was ≥130/≥85 mm Hg.

STATISTICAL METHODS

All data were analysed using SPSS 11.0 for Windows. The baseline characteristics of the study subjects are presented using descriptive statistics inclusive of mean±SD for continuous variables, median and range for skewed variables and the frequency with the percentage for categorical variables. The Spearman rank correlation was computed among the anthropometric measurements and the individual components of MetS. Sex-adjusted quintiles were computed for the anthropometric measurements. These quintile cut-off values were used to define the risk groups by selecting subjects falling above either the third or fourth quintile values, respectively. A multiple logistic regression analysis was performed to determine the anthropometric risk factors for MAB, and the adjusted ORs along with the 95% CIs are presented. The predictive ability of those risk factors that were significantly associated with a MAB is presented using diagnostic test methods. The diagnostic test measurements such as sensitivity, specificity, positive and negative predictive values (PPV and NPV) were calculated for each of the anthropometric measurement against components of MAB. The receiver operating characteristic curve (ROC) and the area under the ROC curve (AUROC) were constructed for all the statistically significant anthropometric measurements against MAB.

RESULTS

The characteristics of the study subjects are shown in table 1. MetS was present in 301 (22.1%) subjects among those studied. The mean age was similar in both groups (17.82±2.22 among MAB present and 17.57±2.34 among MAB absent). The male gender had a greater preponderance for MAB when compared with females (males 64.1%, females 35.9%). Subjects with at least one MAB were 741 (54.5%), two were 196 (26.7%), three were 31 (2.3%), and all four abnormalities were 3 (0.2%). The most prevalent MAB was a low HDL, 808 (59.5%) followed by an impaired fasting glucose in 388 (28.4%), hypertriglyceridaemia in 111 (8.2%) and elevated blood pressure in 73 (5.4%) subjects.

The sex-adjusted quintiles for anthropometric measurements are presented in supplementary table 1. The adjusted ORs providing estimates of risk for MAB are presented separately for the ≥third or ≥fourth quintiles of anthropometric measurements in table 2. Subjects above the third quintile in WC (≥69 cm both male and female) and Ab-SFT (≥1.10 cm in males and ≥1.70 cm in females) had a higher risk association with MAB with adjusted ORs 1.56 (CI 1.02 to 2.43) and 1.44 (CI 1.02 to 2.04) respectively. Ab-SFT, above the fourth quintile (≥1.78 cm in males and ≥2 cm in females), was found to be significantly associated with MAB with an adjusted OR 2.05 (CI 1.37 to 3.06) in this study group.

The sensitivity, specificity, PPV and NPV of WC and Ab-SFT against MAB are presented in supplementary table 2. The risk of predicting a MAB over the third quintile cut-offs for either WC or Ab-SFT had the highest sensitivity of 66.1% and NPV of 82.8%. Ab-SFT alone over the fourth quintile had the highest specificity (81.1%) and an NPV (81.5%). The OR and 95% CI of various anthropometric measurements against individual components of MetS are presented in table 3. All anthropometric measurements over the third quintile were significantly associated with elevated triglycerides and blood pressure; however, none of the measurements could predict a low HDL-C and elevated fasting blood glucose. The Ab-SFT alone over the fourth quintile was significantly associated with hyperglycaemia (OR 1.63; 95% CI 1.24 to 2.13). The AUROC for the WC quintiles was 0.584 (0.55 to 0.62), that for SFT-abdomen quintiles was 0.603 (0.57 to 0.64), and both were 0.606 (0.57 to 0.64).

The correlations among the anthropometric measurements and the components of MetS are summarised in table 4. The diagnostic ability of various anthropometric measurements in predicting MAB is given in the supplementary table 1.

Table 1 Baseline characteristics of the study subjects

Variables	Metabolic abnormality present (n=301)		Metabolic abnormality absent (n=1058)	
	Male	Female	Male	Female
Height (cm)*	168.16±6.74	155.44±5.63	166.17±7.55	155.23±5.87
Weight (kg)*	62.29±13.27	50.31±11.07	56.41±10.87	50.40±10.37
Body mass index (kg/m^2)*	21.99±4.33	20.80±4.31	20.83±3.81	20.92±4.16
Waist circumference (cm)*	72.55±11.11	69.00±9.56	68.17±8.66	68.09±8.81
Waist:hip ratio*	0.83±0.07	0.76±0.06	0.81±0.06	0.78±0.07
Skin fold:subscapular (cm)†	0.96 (0.12 to 3.88)	1.1 (0.52 to 3.50)	0.84 (0.11 to 4.10)	1.10 (0.07 to 3.10)
Skin fold:triceps (cm)†	0.90 (0.10 to 3.80)	1.60 (0.40 to 4.00)	0.75 (0.12 to 4.00)	1.32 (0.06 to 3.60)
Skin fold:abdomen (cm)†	1.2 (0.10 to 4.44)	1.71 (0.24 to 5.00)	0.90 (0.11 to 5.00)	1.4 (0.05 to 4.00)
Systolic blood pressure (mm Hg)*	125.09±15.40	112.73±13.39	117.41±12.46	111.08±12.05
Diastolic blood pressure (mm Hg)*	77.63±12.07	73.13±11.56	71.49±9.13	72.23±9.46
Fasting blood sugar (mg/dl)*	I00.99±11.39	109.68±10.34	91.77±10.24	91.37±10.32
Postprandial blood sugar (mg/dl)*	100.03±20.45	100.16±21.79	95.07±16.79	92.82±17.08
Total cholesterol (mmol/l)†	148 (47 to 313)	150 (87 to 252)	145 (78 to 286)	153 (56 to 281)
Triglyceride (mmol/l)†	116 (29 to 408)	81 (37 to 313)	73 (20 to 345)	68 (30 to 501)
High-density lipoprotein (mmol/l)†	36 (17 to 93)	41.5 (27 to 64)	39 (18 to 215)	50 (16 to 117)
Low-density lipoprotein (mmol/l)†	86 (18 to 206)	93.5 (43 to 180)	80 (21 to 204)	76 (27 to 184)
Smoking‡	13 (6.7%)	0	38 (4.7%)	0
Family history of diabetes‡	38 (19.7%)	30 (27.8%)	144 (18%)	55 (21.4%)
Family history of hypertension‡	21 (10.9%)	12 (11.1%)	76 (9.5%)	41 (16%)
Family history of ischemic heart disease‡	3 (1.6%)	0	6 (0.7%)	5 (1.9%)
Consanguineous parentage‡	51 (26.4%)	23 (21.3%)	209 (26.1%)	66 (25.7%)

Metabolic abnormality is referred to if an individual satisfies two or more of the following: triglycerides was ≥150 mg/dl (>1.7 mmol/l), high-density lipoprotein cholesterol was <40 mg/dl (<1.03 mmol/l), fasting plasma glucose was ≥100 mg/dl (≥5.6 mmol/l), or blood pressure was ≥130/≥85 mm Hg.
*Mean±SD.
†Median (minimum—maximum).
‡Frequency (percentage).

DISCUSSION

In this cross-sectional study among subjects aged 14 to 25 years from Southern India, the prevalence of MetS was 22.1% based on the IDF criteria. The WC and Ab-SFT were the most significantly associated anthropometric measurements with MAB, after adjusting for gender. Either one of these measurements above the third quintile had a high sensitivity (66.1%) and NPV (82.8%) in predicting MAB. The highest quintile for Ab-SFT had a specificity (81.1%) and NPV (81.5%) in detecting a MAB. The skin fold measurements correlated well with all the components of MetS. The anthropometric indices were significantly associated with elevated triglycerides and blood pressure, but none for low HDL and elevated blood glucose except Abd-SFT. Other commonly used anthropometric measures (BMI, WHR, WhtR, skin fold measurements at subscapular and triceps) are poor indicators for cardiometabolic risk in this age group.

Adiposity measurements in adolescents

Adolescence is an unique period of accelerated growth and maturation under the influence of neuro-hormonal changes of both late childhood and early adulthood. This accelerated growth phase is characterised by changes in the body composition, fat redistribution, increased fat-free mass and bone mineral content.[6 28] It is clearly demonstrated that central rather than peripheral distribution of body fat poses a greater risk for obesity-related morbidities. Central adiposity is associated with abnormal biomarkers of CVD risk such as IR, dyslipidaemia, hypertension, IGT/T2DM. Increasing body weight parallels an increase in clustering of MAB associated with MetS.[29] Therefore, surrogate markers of central adiposity would help to identify subjects with a potential risk of developing cardiovascular events earlier in adulthood. Attempts have also been made by several investigators using various surrogate markers of anthropometry in achieving the same goal.

Comparison with other studies

The diagnostic ability of the anthropometric measurements during adolescence and early adulthood has demonstrated a varied predictability. In this study, multiple logistic regression models have shown that the WC and Ab-SFT above third or the fourth quintile cut-offs were significantly associated with clustering of MAB. Our results are consistent with previously published literature on WC. WC was the only strongest

Table 2 Multiple logistic regression model for anthropometric measurements

Variables	Adjusted OR (above third quintile)	95% CI	Adjusted OR (above fourth quintile)	95% CI
Waist circumference (cm)	1.56	1.0 to 2.43	1.24	0.71 to 2.15
Body mass index (kg/m^2)	1.23	0.87 to 1.73	1.21	0.81 to 1.81
Waist:hip ratio	0.86	0.62 to 1.19	0.81	0.56 to 1.18
Waist:height ratio	0.98	0.62 to 1.57	1.19	0.67 to 2.12
Skinfold thickness—subscapular (cm)	0.81	0.57 to 1.15	1.04	0.70 to 1.55
Skinfold thickness—triceps (cm)	1.32	0.94 to 1.85	0.88	0.59 to 1.32
Skinfold thickness—abdominal (cm)	1.44	1.02 to 2.04	2.05	1.37 to 3.06

Table 3 ORs (95% CI) for anthropometric measurements against individual components of metabolic syndrome

	Hypertriglyceridaemia*	Low high-density lipoprotein cholesterol†	High glucose‡	Hypertension§
Waist circumference				
Above third quintile	4.17 (2.69 to 6.47)	1.07 (0.86 to 1.33)	1.09 (0.86 to 1.38)	2.85 (1.73 to 4.70)
Above fourth quintile	3.57 (2.40 to 5.32)	0.96 (0.74 to 1.26)	1.23 (0.93 to 1.63)	4.71 (2.91 to 7.61)
Body mass index				
Above third quintile	3.97 (2.60 to 6.05)	1.25 (1.00 to 1.56)	0.91 (0.71 to 1.16)	4.62 (2.71 to 7.88)
Above fourth quintile	4.14 (2.78 to 6.18)	1.10 (0.84 to 1.44)	0.86 (0.64 to 1.17)	5.54 (3.42 to 8.97)
Waist:hip ratio				
Above third quintile	2.6 (1.46 to 3.21)	1.08 (0.87 to 1.35)	1.02 (0.80 to 1.29)	2.37 (1.46 to 3.84)
Above fourth quintile	1.80 (1.17 to 2.76)	1.02 (0.78 to 1.33)	1.09 (90.81 to 1.45)	1.93 (1.15 to 3.22)
Waist:height ratio				
Above third quintile	4.1 (2.69 to 6.30)	1.02 (0.82 to 1.20)	1.08 (0.85 to 1.37)	3.23 (1.96 to 5.33)
Above fourth quintile	4.19 (2.81 to 6.25)	1.10 (0.84 to 1.45)	0.98 (0.73 to 1.32)	4.40 (2.72 to 7.11)
Skin fold thickness—triceps				
Above third quintile	2.7 (1.79 to 4.0)	0.86 (0.70 to 1.07)	1.1 (0.87 to 1.4)	2.65 (1.62 to 4.33)
Above fourth quintile	2.16 (1.43 to 3.28)	0.86 (0.66 to 1.12)	1.12 (0.84 to 1.49)	3.07 (1.89 to 4.99)
Skin fold thickness—subscapular				
Above third quintile	4.10 (2.67 to 6.31)	0.99 (0.79 to 1.23)	0.82 (0.64 to 1.04)	2.88 (1.76 to 4.74)
Above fourth quintile	3.30 (2.21 to 4.93)	0.87 (0.67 to 1.13)	1.06 (0.79 to 1.41)	3.44 (2.12 to 5.56)
Skin fold thickness—abdominal				
Above third quintile	3.58 (2.35 to 5.47)	0.76 (0.61 to 0.94)	1.23 (0.97 to 1.56)	3.62 (2.16 to 6.09)
Above fourth quintile	2.80 (1.88 to 4.19)	0.83 (0.64 to 1.07)	1.63 (1.24 to 2.13)	3.89 (2.41 to 6.27)

*Triglycerides ≥150 mg/dl (>1.7 mmol/l).
†HDL cholesterol <40 mg/dl (<1.03 mmol/l).
‡Fasting plasma glucose ≥100 mg/dl (≥5.6 mmol/l).
§Blood pressure ≥130/≥85 mm Hg.

modifiable predictor, with a similar predictive power to all metabolic, anthropometric and vascular predictors combined in 5–9-year-old children in predicting diabetes.[30] The Bogalusa Heart Study has shown a positive correlation between WC and SFT to lipid and insulin concentrations in children and adolescents.[31] Recently, Burns *et al* showed that a WC >90th percentile cut-off in 8–18-year-old youths is associated with an atherogenic lipoprotein profile with increased biomarkers of vascular smooth muscle dysfunction suggestive of childhood origin of atherosclerosis.[32] Sievenpiper *et al* have shown a strong correlation between plasma insulin AUC and the truncal SFT, suggesting that SFT measurements are useful adjuncts to the other anthropometric measurements for predicting abnormal glucose and insulin secretion.[33] When relationships between general and regional adiposity to insulin sensitivity was investigated, truncal skin fold thickness was a better predictor of insulin sensitivity.[34] Ab-SFT was significantly associated with MAB, and in particular the cut-off over the fourth quintile was the only parameter that was significantly associated with hyperglycaemia (OR 1.63 to 95% CI 1.24 to 2.13; p<0.001) in the current setting consistent with the results of the Bogalusa Heart study which demonstrated that the skin fold and WC are more valid indicators of lipid and insulin concentrations in children and adolescents.[31] SFT measurements reflect subcutaneous fat depots in both truncal and central regions. Subcutaneous adipose tissue accumulation plays a major role in obesity-related insulin resistance[34] and is also related to abnormalities in altered glucose–insulin homeostasis.[33 35] Abate *et al* also showed that insulin sensitivity is better predicted by specific adipose sites when assessed by hyperinsulinaemic euglycaemic clamp compared with total body fat, signifying that subcutaneous fat is an important predictor of altered glucose insulin homeostasis. Although the sum of the SFT measurements and the ratios have shown to be associated with morbidities, a single SFT measurement during adolescence has also been shown to be a reliable predictor of adult percentage body fat and complement other body-fat measurements in predicting abnormal glucose and insulin regulation.[33 36 37] Our results are consistent and favour abdominal adiposity as an important clinical predictor of MAB in this age group.

Table 4 Correlation matrix between measures of adiposity and metabolic factors

	Body mass index	Waist: hip ratio	Waist: height ratio	Skin fold thickness —subscapular	Skin fold thickness —triceps	Skin fold thickness —abdomen	Glucose	Triglyceride	High-density lipoprotein —cholesterol	Systolic blood pressure	Diastolic blood pressure
Waist circumference	0.686*	0.628*	0.920*	0.570*	0.429*	0.578*	0.025	0.246*	−0.012	0.304*	0.294*
Body mass index		0.313*	0.716*	0.525*	0.420*	0.495*	−0.044	0.281*	−0.073*	0.231*	0.269†
Waist:hip ratio			0.566*	0.209*	0.047*	0.209*	−0.015	0.131*	−0.017	0.180*	0.153*
Waist:height ratio				0.580*	0.518*	0.582*	0.035	0.226*	0.072	0.175*	0.267*
Skin fold thickness—Subscapular					0.670*	0.747*	0.021	0.181*	0.062†	0.188*	0.192*
Skin fold thickness—triceps						0.751*	0.070†	0.101*	0.118	0.030	0.120
Skin fold thickness—abdomen							0.099†	0.169*	0.084*	0.175*	0.198*

*p≤0.01.
†p≤0.001.

In a clinical setting, the presence of an increased BMI, generally, is a sign for initiating further testing for MetS. An elevated BMI during adolescence is attributed to an increase in fat-free mass, rather than increments in the body-fat compartment, and this forms an important limitation to its use in screening for MetS. Because of the high sensitivity and specificity of BMI, children with even higher muscle mass are often mistakenly classified as being overweight or obese.[36] However, in a prospective follow-up study of 342 children from the age of 8 to 15 years, it has been shown that the potential for CVD risk clustering was seven times higher for increased BMI and four times higher for WC.[9] In the current study, BMI cut-off values, even at the highest quintile (23.62 in males and 23.80 in females), did not show any associated risk of MAB. The low PPV of the BMI signifies that although BMI may help in categorising obesity, it is not a reliable predictor for MAB in this age group. Though, BMI may serve as a screening marker for childhood obesity[38], it may not reflect cardiometabolic risk clustering in children In addition, our study did not show any association between MAB and WHR or WhtR.

All measurements above the third quintile had a high sensitivity and NPV in identifying elevated triglycerides, blood glucose, low HDL and hypertension, but their specificity was low. The diagnostic ability of the anthropometric measurements over the third quintile showed a high NPV for MAB and moderate sensitivity and specificity. If cut-offs are placed at the fourth quintile, the specificity and the NPV improved, at the expense of a low sensitivity and PPV.

Body composition varies among different ethinic groups. WC has shown to be an important predictor of metabolic abnormalities across all ethnic groups. The importance of SFT measurements, though underplayed owing to difficulties in the use of caliper for measurements, is still shown to be a reliable indicator of percentage body fat and glucose intolerance, especially in adolescence. Therefore, the results of our study may be generalised to other ethnic groups; however, we strongly recommend that the cut-off points be highly ethnic-specific.

Limitations and strengths of the study

The sample size is sufficiently large, but the subjects were not randomly selected; hence our study is not truly representative of the general population. In this cross-sectional study, no specific age cut-off was chosen to study the prevalence. We admit that an age-based subgroup analysis would have helped estimate the prevalence of MAB in younger age group, but this was not done as it deviates from the actual objective the current study. Further prospective studies are planned to answer this. Owing to unestablished cut-offs in the age group studied, we used gender-adjusted quintile cut-offs for anthropometric measurements. The predictive power of anthropometric measurements was examined for MAB including hypertension and not for actual cardiovascular events, and so longitudinal studies are required to demonstrate the true association in terms of evolution of CVD outcome. Although it is established that the amount of body fat and the distribution pattern of fat itself are strongly related to gender and pubertal development staging, data on Tanner's pubertal staging were available only for a limited number of participants in our study and were not included in our analysis. It is possible that the use of pubertal staging with adjusted cut-off values for WC and SFT-abdomen could have strengthened the predictive ability of these measurements.

CONCLUSIONS

Our data suggest that WC and Ab—SFT are reliable predictors of MAB in adolescents and young adults. Our results give practical guidelines to primary care physicians to implement SFT measurements in addition to WC in predicting MAB in this age group. These measurements could serve as important clinical tools for cardiometabolic risk stratification and help in minimising the traditional practice of additional testing in all individuals with increased BMI and help in considerable cost cutting on unwarranted tests.

What is already known in this topic

- The Metabolic Syndrome is a risk factor for cardiovascular disease and diabetes that affects all ages.
- Simple and reliable clinical measurements in a primary setting will help in stratifying children and young adults at risk.
- The waist circumference is an important predictor for the Metabolic Syndrome in adults.

What this paper adds

- The waist circumference and abdominal skin fold thickness measurements are important predictors of the metabolic abnormalities in adolescents and young adults.
- Subjects above the third quintile cut-offs for anthropometric measurements require further blood testing and appropriate management.
- These simple clinical tools in a primary care setting will be meaningful to diagnose and predict future risk.
- Body mass index is not a reliable predictor of cardiometabolic risk clustering in younger age groups.

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