Original Article

Factor analysis of the metabolic syndrome components in urban Asian Indian adolescents

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There is paucity of data on the association of various risk factors of the metabolic syndrome in urban Asian Indian adolescents. This cross-sectional study included 948 subjects (527 males; 421 females) aged 14-19 y, selected randomly from New Delhi, India. Principal component factor analysis included variables such as: body mass index (BMI), waist circumference (WC), triceps (TR) and subscapular (SS) skinfold thickness, systolic and diastolic blood pressures, fasting blood glucose, serum triglycerides, high-density lipoprotein cholesterol and fasting insulin. Factor scores were used to generate a cumulative risk scale and identify independent correlates of high cumulative risk. Three factors namely: obesity/insulin factor (BMI, WC, TR, SS and fasting insulin) explained 40.9% and 35.5%, 'blood pressure' factor explained 14.1% and 14.2%, and the 'metabolic' factor (glucose/triglycerides) explained 10.4% and 10.8% of the variance data in males and females, respectively. Overweight and hyperinsulinemia in both genders and high SS in males were independently associated with high cumulative risk. More than one factor is associated with the metabolic syndrome in Asian Indian adolescents. Obesity (generalized, abdominal and truncal sub-cutaneous) accounts for the maximum variance in clustering and appears to be the stronger correlate of high cumulative risk rather than hyperinsulinemia.

Key Words: factor analysis, metabolic syndrome, hyperinsulinemia, adolescents, Asian Indians

INTRODUCTION

The association of multiple factors like central obesity, dyslipidemia, hypertension and impaired glucose tolerance characterizes the metabolic syndrome. It predisposes the individuals to a high risk for the development of type 2 diabetes mellitus (T2DM) and coronary artery disease (CAD). However, variations in manifestations of components of the metabolic syndrome are known to occur in accordance with age and ethnicity.[1,2] Evaluation of children and adolescents for metabolic syndrome could identify patients at increased risk of the metabolic syndrome, T2DM and CAD in adulthood.[3] Furthermore, it is important to clarify which factor is more important and more closely associated with the metabolic syndrome, so that interventions could be appropriately and more selectively designed.

Insulin resistance is considered to be the central pathophysiologic factor in the development of the metabolic syndrome; however the underlying mechanism is not completely understood. It is associated with adverse body composition features like excess body fat, abdominal adiposity, and excess truncal subcutaneous adipose tissue (SCAT) in urban Asian Indian adolescents.[4] Obesity is one of the most important determinants of insulin resistance. It has been reported that the prevalence of the metabolic syndrome has increased rapidly among children and adolescents and increases directly with the degree of obesity.[5] The National Health and Nutrition Examination Survey III (NHANES III) indicated that the prevalence of the metabolic syndrome is 4% in 12–19 y-old non-obese adolescents vs. 30% in obese adolescents in USA.[6]

Asian Indians have been shown to have an increased susceptibility towards the development of the metabolic syndrome, increasing the risk of T2DM and CAD. Increasing amounts of research has been done in Asian Indian adults, but limited data exist on the clustering, association, and relative importance of the metabolic syndrome components in adolescents. Importantly, a rapid increase in the prevalence of obesity in adolescents has been reported in developing countries including India. Our recent data show that nearly 24% of school-going

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children in New Delhi are overweight or obese.[7] In addition, about 34% of Asian Indian adolescents (14-19 y) showed fasting hyperinsulinemia and 4.2% had the metabolic syndrome as defined by ethnically appropriate modification of the NCEP ATP III definition for Asian Indians.[8] A significant association with regard to insulin resistance, adiponectin, and subclinical inflammation has also been noted in Asian Indian adolescents by us.[3,4,9,10]

Exploratory factor analysis is a statistical method used to reduce multiple inter-correlating variables to a smaller number of uncorrelated latent factors or dimensions. This technique is useful in understanding the clustering of various inter-correlated variables. It is also an easy method to determine the risk scores for the study population and for each individual factor along with cumulative risk. The metabolic syndrome, a clustering of various phenotypic and metabolic variables correlated with each other, may be a suitable medical condition for factor analysis. Exploratory factor analysis has been used by several investigators in disparate populations and ethnicities to determine the clustering of the metabolic syndrome variables in adults and adolescents. In Asian Indians, factor analysis has previously been conducted in adolescents from Southern[11] and Eastern[12] parts of India. However, analyses in these studies have been hampered by limited number of subjects and failure to consider some important factors in calculation. Further, no attempt was made to develop a cumulative risk scale in these studies. Using confirmatory factor analysis, a method which may be helpful for hypothesis testing, various investigators have attempted to define a single factor underlying the metabolic syndrome in adults[13,14] and adolescents.[15]

In the present study, we explored the factor structure of the metabolic syndrome variables in urban Asian Indian adolescents from north India using principal component analysis. We further used the summary factors to develop a cumulative risk scale.

MATERIALS AND METHODS

Characteristics of the Study Sample

The present study included data from 948 adolescents (527 males; 421 females) aged 14-19 y, selected from the Epidemiological Study of Adolescents and Young adults (ESAY) study (n = 1447). Briefly, the ESAY study included adolescents and young adults aged 14-25 y, selected from various schools and colleges in Delhi, using a multi-stage cluster sampling methodology based on the modified World Health Organization Expanded Program of Immunization Sampling Plan as described previously.[8] Education level of the participants ranged from the 9th grade to the 2nd year of college. A very small proportion of subjects either smoked (overall 2.5%; males 4.4% and females 0.2%) or consumed alcohol (overall 2.1%; males 3.4% and females 0.4%). Institutional ethics committee of All India Institute of Medical Sciences, New Delhi, approved the study and a written informed consent was obtained from subjects 18 y or older and from the parents/guardians of subjects younger than 18 y.

Anthropometry

Body weight (to the nearest 0.1 kg) and height (to the nearest 0.1 cm) were recorded without shoes and only light indoor clothes. BMI was calculated using the formula; weight (kg)/height (m)^2. The waist circumference (WC) was measured midway between the iliac crest and the lower-most margin of the ribs. Means of three readings were recorded to the nearest 0.1 cm. Triceps (TR) and sub-scapular (SS) skinfold thicknesses were measured carefully using Lange skinfold callipers in accordance to the methodology described earlier.[16]

Blood Pressure Measurement

Blood pressure was measured with a standard mercury sphygmomanometer (Industrial Electronic and Allied Products, Pune, India) which was periodically validated against a Hawksley Random Zero Sphygmomanometer (Hawksley, Lancing, Sussex, UK). Measurements were made using the appropriate cuff size after the subject had rested for 5 minutes in the sitting position. Systolic blood pressure (SBP) and Diastolic blood pressure (DBP) were categorized according to the appearance (phase1) and disappearance (phase 5) of the Korotkoff sounds, respectively.

Biochemical Parameters

Fasting venous blood samples were drawn for estimation of fasting blood glucose (FBG), and serum lipids [high-density lipoprotein cholesterol (HDL-c) and serum triglycerides (TG)] using standard kits (Randox Lab, UK). Serum insulin was measured with a commercially available radio immunoassay kit (MEDICORP INC, Montreal, Canada) on a gamma counter (Stratec Biomedical Systems, Pfrozheim, Germany).

Definitions

Overweight was defined as a BMI $\geq$ 85th percentile for age and gender ($\geq$ 23 kg/m^2 for both males and females). High truncal SCAT was defined as a value of SS $\geq$ 90th percentile (males > 26.7 mm and females > 31 mm) of the ESAY study population aged 14-19 years. As standardized cut-offs for fasting insulin are not available for Asian Indian adolescents, hyperinsulinemia was defined as fasting insulin values of > 75th percentile for age and gender (males > 136.7 pmol/L and females >179, pmol/L).

Statistical Analysis

Data were managed on an excel spreadsheet. The descriptive variables of the study population were presented as mean ± standard deviation for males and females. A p value of <0.05 was considered significant. Pearson's correlation coefficients were derived for all the variables. Principal component analysis of factor analysis was performed for both genders separately. Variables included were: BMI, WC, SBP, DBP, TR, SS, FBG, TG, HDL-c and fasting serum insulin levels. To standardize these variables, z scores were created before factor analysis. The following three steps were followed: (1) extraction of the factors to produce a minimum number of factors that explain the variance in the data; (2) rotation of the extracted factors to transform them into uncorrelated interpretable factors and (3) interpretation of the rotated factors solution. An eigenvalue of > 1 was used for extraction of factors with subsequent varimax rotation. Variables with factor loading $\geq$ 0.4 were used for interpreta-

Table 1. Clinical, anthropometric and biochemical profiles (mean ± SD)

Variables	Males (n=527)	Females (n=421)	*p* value
Age	16.5 ± 1.4	16.8 ± 1.6	NS
Systolic blood pressure (mm Hg)	114.8 ± 9.9	110.5 ± 8.9	<0.001
Diastolic blood pressure (mm Hg)	74.4 ± 7.4	73.0 ± 6.9	0.002
Body mass index (kg/m^2)	19.6 ± 3.3	20.0 ± 3.3	NS
Waist circumference (cm)	69.9 ± 8.7	66.8 ± 7.6	<0.001
Triceps skinfold (mm)	12.7 ± 6.4	17.6 ± 6.0	<0.001
Subscapular skinfold (mm)	14.0 ± 8.9	19.1 ± 7.6	<0.001
Fasting blood glucose (mg/dL)	90.0 ± 9.3	89.5 ± 8.5	NS
Serum triglycerides (mg/dL)	85.8 ± 32.3	90.2 ± 28.7	0.03
High-density lipoprotein cholesterol (mg/dL)	47.0 ± 6.7	51.0 ± 9.2	<0.001
Fasting serum insulin (pmol/L)	114.4 ± 42.0	149.3 ± 51.7	<0.001

NS, Not significant

tion on the rotated matrix. Bartlett's test of sphericity was highly significant (p<0.001 for both males and females), indicating good model acceptability.

In the process of factor analysis, factor scores are generated for each subject for each of the component in the factors extracted. These factor scores were added together to generate a risk score for each individual factor. As standardized variables were used in the analysis (mean of 0 and standard deviation of 1), a score > 2.0, signifying a value > 2 standard deviations for an individual factor was defined as a high risk score. A cumulative risk score was created by adding all the scores for each individual factor together for each subject. High cumulative risk was defined as a cumulative risk score of > 95th percentile (> 3.26). Logistic regression analysis (odds ratio, OR, and confidence intervals) with adjustments for age were performed to assess the independent correlates of high cumulative risk in males and females separately. All statistical calculations were carried out using SPSS 15.0 statistical software (Chicago, USA).

RESULTS

Description of Study Sample (Table 1)

The mean values of age and BMI were comparable among males and females. Males had a significantly higher WC (p<0.001), whereas both TR and SS skinfold thicknesses were significantly higher in females (p<0.001 for both). Mean values of SBP and DBP were significantly higher in males (p<0.001 and 0.002, respectively). Females had significantly higher levels of TG, HDL-c and fasting serum insulin (p = 0.03, p<0.001 and p<0.001, respectively) than males, whereas FBG was comparable.

Factor Analysis

Table 2. Correlations among the metabolic syndrome variables

	WC	TR	SS	SBP	DBP	FBG	Insulin	TG	HDL-c
Males									
BMI	0.90*	0.81*	0.83*	0.36*	0.27*	0.02	0.32*	0.20*	-0.02
WC		0.80*	0.84*	0.38*	0.28*	0.04	0.32*	0.19*	-0.08**
TR			0.87*	0.29*	0.23*	0.07**	0.39*	0.19*	-0.07
SS				0.33*	0.30*	0.09**	0.36*	0.14*	-0.12*
SBP					0.57*	0.05	0.14*	0.05	-0.16*
DBP						0.11*	0.07	0.03	-0.18*
FBG							0.04	0.07	-0.11*
Insulin								0.12*	-0.01
TG									0.08**
HDL-c									
Females									
BMI	0.80*	0.69*	0.80*	0.19*	0.25*	-0.05	0.37*	0.15*	-0.02
WC		0.51*	0.68*	0.22*	0.27*	-0.10**	0.26*	0.10**	-0.03
TR			0.73*	0.12*	0.15*	-0.02	0.35*	0.22*	0.003
SS				0.17*	0.22*	-0.04	0.40*	0.20*	-0.07
SBP					0.53*	0.07	0.05	0.06	-0.05
DBP						0.07	0.09**	0.09**	-0.06
FBG							0.003	0.08**	-0.02
Insulin								0.11**	-0.02
TG									0.02

Bartlett's test of sphericity p<0.0001

*:p < 0.01, **:p <0.05

BMI, Body mass index; WC, Waist circumference; TR, Triceps skinfold thickness; SS, Subscapular skinfold thickness; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FBG, Fasting blood glucose; Insulin, Serum insulin levels; TG, Serum triglycerides; HDL-c, High-density lipoprotein cholesterol

Table 3. Factor Loadings of principal component analysis with varimax rotation

Components	Factor 1 (Obesity/Insulin)		Factor 2 (Blood Pressure)		Factor 3 (Metabolic)	
	Males	Females	Males	Females	Males	Females
BMI	0.924	0.907	0.150	0.170	-0.018	-0.044
WC	0.911	0.799	0.195	0.243	0.005	-0.156
TR	0.909	0.828	0.115	0.011	0.078	0.115
SS	0.899	0.901	0.207	0.118	0.059	0.023
SBP	0.295	0.086	0.744	0.847	-0.120	0.089
DBP	0.187	0.155	0.801	0.830	-0.041	0.115
FBG	-0.047	-0.134	0.236	0.120	0.853	0.734
Insulin	0.494	0.535	-0.072	-0.071	0.175	0.155
TG	0.281	0.248	-0.184	-0.061	0.498	0.685
HDL-c	0.067	-0.002	-0.550	-0.230	-0.179	0.162
% Variance Explained	40.92	35.50	14.09	14.25	10.43	10.86
Cumulative Variance	40.92	35.50	55.01	49.75	65.44	60.61

BMI, Body mass index; WC, Waist circumference; TR, Triceps skinfold thickness; SS, Subscapular skinfold thickness; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FBG, Fasting blood glucose; Insulin, Serum insulin levels; TG, Serum triglycerides; HDL-c, High-density lipoprotein cholesterol

The correlations among the variables used in the factor analysis are presented in Table 2. All variables were significantly correlated with each other. There were some gender differences in the correlations. Correlation of FBG was significant only with TR, SS, DBP and HDL-c in males and with WC, TG in females. Fasting insulin levels did not correlate with FBG and HDL-c in both genders and with DBP in males and SBP in females. There was no correlation of HDL-c levels with any of the variables in females. In males, HDL-c levels did not correlate with BMI, TR and insulin levels. Serum levels of TG did not correlate with SBP in both genders, with DBP and FBG in males and with HDL-c in females. The results of factor analysis are presented in Table 3. The principal component analysis yielded essentially three factors in both males and females. Obesity parameters (BMI, WC, TR and SS) along with fasting insulin loaded onto the first factor, which was labelled as 'obesity/insulin' factor, and explained ~41% and 35% variance in the measured variables in males and females, respectively. The loading patterns were similar in both males and females. The second factor, labelled as 'blood pressure' factor loaded both SBP and DBP. Additionally, HDL-c loaded negatively onto this factor in males only. The third factor explaining the least variance was 'metabolic factor' consisting of FBG and TG. The total variance explained by these 3 factors was 65.4% and 60.6% in males and females, respectively.

Factor Scores and Cumulative Risk

The median (range) values of the factor scores for the entire study population for the three factors were: obesity/insulin factor: -0.21 (-1.97 to 4.39); blood pressure factor: -0.02 (-3.44 to 3.38); metabolic factor: -0.04 (-3.22 to 4.41) and for the cumulative risk scale scores -0.10 (-6.93 to 7.29). Of the total study population, 90.5% (n = 856) did not have a high risk score for any of the three factors, 8.5% (n = 81) had a high risk score for any one, 0.7% (n=6) for any two and 0.3% (n=3) for all the three factors. The number of individuals with high risk score was highest for the obesity/insulin factor (4.7%, n=45) followed by the blood pressure factor (2.6%, n=24) and the metabolic factor (3.5%, n=33) with no significant gender differences. High cumulative risk scores were present in 5.4% (n=51) of the subjects, of which 19.6% (n=10) were not at risk for any of the three defined factors, whereas 64.7% (n=33), 9.8% (n=5) and 5.9% (n=3) subjects were at risk for any one, any two and all three factors, respectively.

Table 4. Weight status, hyperinsulinemia and truncal SCAT in relation to high risk (risk score >2.0)

%(n)	Normal weight	Overweight	Normal insulin	Hyperinsulinemia	Normal subscapular skinfold thickness	High subscapular skinfold thickness
Factor 1						
Not at high risk	9.7(807)	69.8(97)	98.2(699)	86.%(205)	99.4(862)	51.8(42)
High risk	0.3(2)	30.2(42)*	1.8(13)	13.5(32)*	0.6(5)	48.2(39)*
Factor 2						
Not at high risk	98.3(795)	92.8(129)	97.2(692)	97.9(232)	98.0(850)	91.4(74)
High risk	1.7(14)	7.2(10) *	2.8(20)	2.1(5)	2.0(17)	8.6(7)*
Factor 3						
Not at high risk	96.9(784)	95.7(133)	97.1(691)	95.4(226)	96.8(839)	96.3(78)
High risk	3.1(25)	4.3(6)	2.9(21)	4.6(11)	3.2(28)	3.7(3)

*:$p< 0.01$

For definitions of overweight, hyperinsulinemia and high subscapular skinfold thickness, please refer to the 'definitions' section.

SCAT: subcutaneous adipose tissue

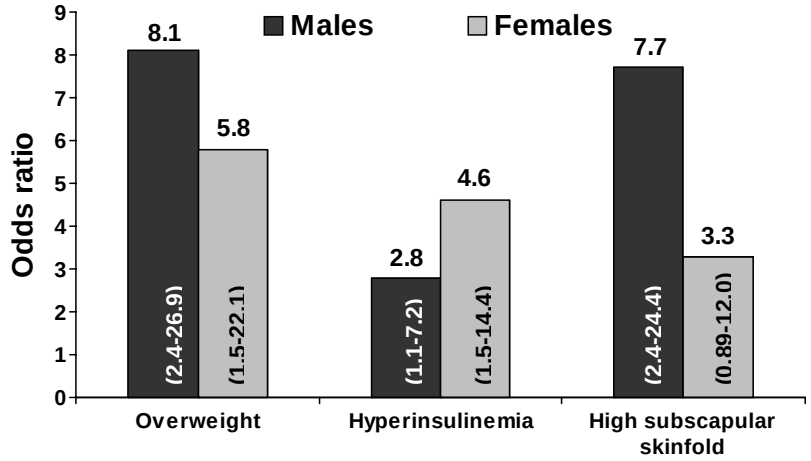

Figure 1. Comparison of odds ratios, adjusted for age, for high cumulative risk (defined as cumulative sum of the factor scores of >95th percentile [>3.26]) in adolescents with overweight (BMI ≥85th percentile), high truncal subcutaneous adipose tissue (subscapular skinfold thickness ≥90th percentile) and hyperinsulinemia (fasting insulin levels in the highest quartile). Values in parenthesis indicate 95% confidence intervals.

Effect of Overweight, High Truncal SCAT and Hyperinsulinemia on Risk Status

Overweight and high truncal SCAT were significantly related to high risk for obesity/insulin and blood pressure factors (p<0.01 for both), whereas hyperinsulinemia was significantly related to high risk for obesity/insulin factor only (p<0.01, Table 4). Using logistic regression analysis including age as a covariate, overweight status [OR (95% CI): 8.1 (2.4-26.9), p<0.01], high truncal SCAT [OR (95% CI): 7.7 (2.4-24.4), p<0.01] and hyperinsulinemia [OR (95% CI): 2.8 (1.1-7.2), p=0.02] were independently associated with high cumulative risk, in males. However, only overweight status [OR (95% CI): 5.8 (1.5-22.1), p=0.01] and hyperinsulinemia [OR (95% CI): 4.6 (1.5-14.4), p<0.01] were independently associated with high cumulative risk, in females (Figure 1). Association of high truncal SCAT with high cumulative risk did not reach significance [OR (95% CI): 3.3 (0.89-12.0), p=0.07]. Overweight and high truncal SCAT in males and overweight in females were stronger correlates than hyperinsulinemia for high cumulative risk**.**

DISCUSSION

Factor analysis can be used to predict cumulative risk scores and may be helpful in longitudinal studies in understanding the natural history of cardiovascular disease and for developing appropriate preventive and control measures. This is the first study in Asian Indian adolescents to predict cumulative high risk for the metabolic syndrome using factor analysis. Three independent factors, namely obesity/insulin, blood pressure and metabolic factors, explaining 65% and 61% variance of the metabolic syndrome in males and females respectively, were generated. These observations are in accordance with the previous data that suggested the lack of a single unifying mechanism for the metabolic syndrome. In addition, obesity was found to be a much stronger correlate of cardiovascular risk than hyperinsulinemia in both the genders. Of all the factors, insulin loaded only on the obesity factor, signifying a strong relationship.

In our study, the obesity/insulin factor explained the maximum variance (40%) and is in concordance with the fact that adiposity is an important risk factor of the metabolic syndrome. These observations were similar to the study involving adolescents from eastern parts of India, in which two factors i.e. central body fat and truncal SCAT explained 46% of the variance.[12] It was interesting to note that in the present study, generalized obesity was a stronger correlate of high cumulative risk than hyperinsulinemia in both genders, whereas truncal obesity was a stronger correlate of high cumulative risk than hyperinsulinemia in males only. In addition, the highest number of subjects (4.7%) with "high risk" score was noted with the obesity/insulin factor. Similarly, Goodman *et al.*[17] reported that the adiposity factor predicted the highest (26%) variance of the metabolic syndrome in a study involving white, black and Hispanic American adolescents. They also found that obesity had the highest number of at risk individuals (5.1%) and was a more powerful correlate of cumulative risk than hyperinsulinemia.

Asian Indians have been shown to have excess abdominal adiposity, especially truncal SCAT as compared to white Caucasians.[18,19] It should be noted that we and others have shown truncal SCAT to be a better predictor of insulin resistance in Asian Indian population than intra-abdominal adipose tissue (IAAT), which is considered a more important correlate of metabolic risk in white Caucasians.[2,20,21] Measures of peripheral and truncal SCAT (TR and SS, respectively) have been included individually for the first time in factor analysis of components of the metabolic syndrome in adolescents. In the present study, TR and SS showed stronger correlations with fasting insulin levels than BMI and WC. This is similar to our previous observations where high SS was significantly associated with hyperinsulinemia, independent of overweight and hypercholesterolemia.[9] In another study, we have reported that the odds of having hyperinsulinemia were higher in Asian Indian subjects with high TR (8.0) and SS (10.1) as compared to the overweight (4.7).[20]

Most investigators have reported 3-4 factors responsible for the clustering of components of the metabolic syndrome in adolescents of Asian and other ethnicities. These studies, including the present study, have used exploratory factor analysis for converging upon a large number of variables to few uncorrelated factors. Data are limited in Asian Indian adolescents in this regard. A study involving adolescents from the eastern parts of India identified 4 factors i.e. central body fat distribution, centralized subcutaneous fat, lipids-blood glucose, and blood pressure to have explained 76% and 74% of the variance in boys and girls, respectively.[12] However, the measure of insulin resistance was not included in this study. Another study on adolescents in south India identified 3 factors: blood pressure, lipid and glucose.[11] In this study, WC loaded on all the factors and fasting insulin loaded on two of the three factors. However, these authors used lower cut-off points for factor loadings (>0.3) and did not include any measure of SCAT. If the cut-off points of the study by Ramachandran *et al.*[11] is revised to >0.4, WC would load only on the blood pressure factor and fasting insulin on the glucose factor. In our study, a cut-off point of 0.4 was used, as this indicates that the measured variable shares at least 15% variance with the factor.[12,17] Further, fasting serum insulin was used as a measure of insulin resistance, which has been proposed as a good surrogate estimate of insulin resistance and a potential component of metabolic syndrome by other investigators.[15] No overlap was observed between the factors, and insulin loaded only on adiposity factor in our study, unlike in earlier studies where it loaded on more than one factor in biracial population (whites and blacks) in USA.[22]

Recently confirmatory factor analysis, which uses predefined risk factors/variables for analyzing their ability to explain the variance of the metabolic syndrome, has been utilized to explain a single factor existence for the metabolic syndrome in adults[13,14] and adolescents.[15] Shen *et al.*[13] proposed and tested a metabolic syndrome factor uniting insulin resistance, obesity, lipids and blood pressure in adults. Obesity and insulin resistance were observed to be the most essential features of the metabolic syndrome, followed by lipids and blood pressure. Similar to these observations, in our study the obesity/insulin factor explained the maximum variance. In another study, Pladevall *et al.*[14] tested a single factor model in three different datasets. This study used TG/HDL-c ratio and mean arterial pressure instead of individual parameters and HOMA-IR. The one-factor model was favored over the four-factor model across the three datasets. Li *et al.*[15] used confirmatory factor analysis in a study involving adolescent boys and girls of different ethnicities and racial groups (Caucasians, African-American and Mexican-American). They proposed four simple and directly measured variables; waist circumference, serum triglycerides, fasting serum insulin, and systolic blood pressure, as the potential phenotypic traits of the metabolic syndrome in adolescents. However, these investigators considered a factor loading more than 0.3 as significant. The authors also concluded that the proposed model would be generalizable across gender and ethnicity but did not include Asian Indians.

The factors explaining the variance of the metabolic syndrome in urban Asian Indian adolescents in the current study were the similar in males and females, except that HDL loaded negatively in males. High cumulative risk did not reflect high risk across all factor domains, suggesting the importance of a global approach in assessing risk clustering. Among subjects with high cumulative risk, 64% were high risk for only 1 factor and only 5.9% were at risk for all the 3 factors whereas, 19.6% were not at high risk for any factor. Likewise, Goodman *et al.*[17] reported, that 66% were at risk for any 1 factor and 18% were not at risk for any factor in American adolescents attending grades 7-12. Wijndaele *et al.*[23] recently proposed a continuous metabolic syndrome risk score in adults. The risk score was generated by summing up the individual principal component scores weighted according to their relative contribution to the explained variance. We also analyzed our data using sum of the weighted scores (weights being their relative contribution to the explained variance on individual components). In both the approaches i.e. weighted and non-weighted scores, overweight, hyperinsulinemia and high SCAT were observed to be the independent correlates of high cumulative risk, with comparable odds ratios (data not shown).

Different results on factor analysis have been obtained by other investigators, depending on the methodology of analysis, number of factors included and ethnic group. Park *et al.*[24] reported 3 factors in Korean adolescents: obesity-leptin-lipid factor, blood pressure factor, and glucose-cholesterol factor in males, however, the sample population (68 males and 80 females) was small. The Childhood and Adolescence Surveillance and Prevention of Adult Non-Communicable Disease (CASPIAN) study[25] in Iranian adolescents also identified 3 factors: lipids, adiposity, and blood pressure, similar to the present study. However, the studies by Park *et al.*[21] and Kelishadi *et al.*[25] did not include measure of insulin resistance and SCAT as additional risk factors of the metabolic syndrome. Study among the Canadian youth[26] revealed three factors (BMI/insulin/lipids, BMI/insulin/glucose and diastolic/systolic blood pressure), whereas another study,[17] involving US adolescents found three factors with similar factor loadings: adiposity, cholesterol and carbohydrate/metabolic factor, explaining about 67% and 68% variance of the metabolic syndrome, respectively. Bogalusa Heart study revealed only 2 factors: a blood pressure factor and a metabolic syndrome factor, explaining 50% of the variance in blacks and whites of the 12-17 y age groups.[22]

One of the main limitations of the present study is its cross-sectional nature. Identification of individual risk factors in a single cross-sectional analysis has limited value in the occurrence of a disease. Some questions remain unanswered in a cross-sectional analysis, e.g. 1) whether the factors identified in the analysis represent different pathophysiological processes requiring different interventions; 2) how these factors interact with each other to produce clinical disease, and 3) whether these factors predict the occurrence of disease better than the individual variables. The answers to these questions can be obtained in a longitudinal study.

CONCLUSION

The factor analysis of cardiovascular risk clustering in Asian Indian adolescents suggests that multiple factors account for the clustering of the metabolic syndrome components. Obesity (generalized, abdominal and subcutaneous) accounts for the maximum variance in clustering and appears to be a more powerful correlate of cardiovascular risk than hyperinsulinemia in Asian Indian adolescents. Insulin resistance, considered as the central factor underlying the clustering of risk, is strongly associated only with obesity and not with other components of the metabolic syndrome. Early identification of these risk factors in adolescents can prevent the increasing risk of CAD and T2DM.

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AUTHOR DISCLOSURES

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Original Article

Factor analysis of the metabolic syndrome components in urban Asian Indian adolescents

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印度都市的青少年代謝症候群組成因素分析

少有印度都市青少年，其各種代謝症候群危險因子的相關性數據。這個橫斷性研究自印度新德里市，隨機選取 948 名研究對象(527 名男性；421 名女性)，年齡為 14-19 歲。主成分因素分析包含的變數有：身體質量指數(BMI)、腰圍(WC)、三頭肌(TR)及肩胛下(SS)皮脂厚度、收縮壓及舒張壓、禁食血糖、血清三酸甘油酯、高密度脂蛋白膽固醇及禁食胰島素。使用因素分數產生累積危險性量表，並找出與高累積危險性的獨立相關性。三類因素可解釋男性及女性的變異量分別為：肥胖/胰島素因子(BMI、WC、TR、SS 及禁食胰島素) 40.9%及35.5%，血壓因子 14.1%及 14.2%，而代謝性因子(葡萄糖/三酸甘油酯) 10.4%及10.8%。男女的體重過重及高胰島素血症及男性的高 SS 與高累積危險性是獨立相關。與印度青少年代謝症候群相關的因素不只一項。在聚集中，肥胖(全身性、腹部及軀幹皮下脂肪)解釋了最大的變異量，且顯示它與高累積危險性有強相關，而非高胰島素血症。

關鍵字：因素分析、代謝症候群、高胰島素血症、青少年、印度人