The metabolic syndrome in healthy, multiethnic adolescents in Toronto, Ontario: The use of fasting blood glucose as a simple indicator

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BACKGROUND: The prevalence of the metabolic syndrome (MetS) is increasing worldwide and prevention represents a major challenge. Usually identified in middle age, the MetS has pediatric roots and there are variable incidence rates between ethnic groups. Due to the difficulty of diagnosis, it remains largely undetected in adolescents.

OBJECTIVES: To assess the presence of the MetS features in healthy, normal-weight, multiethnic adolescents and to determine whether fasting blood glucose (FBG) could function as a simple indicator of its presence.

METHODS: A convenience sample of secondary school students was used in a cross-sectional study. General linear model ANCOVA adjusted for multiple pairwise comparisons by the post hoc Tukey-Kramer test was used to assess differences among the tertiles of FBG.

RESULTS: A total of 182 adolescents from 62 Greater Toronto Area secondary schools in Ontario were recruited (44% Caucasian, 34% South Asian and 22% Chinese), with a mean ($\pm$ SD) age of 17.4 ± 0.9 years, a mean body mass index of 22.1 ± 3.4 kg/m² and a mean FBG of 4.92 ± 0.4 mmol/L. Analysis with general linear model ANCOVA across the tertiles of FBG (3.83 mmol/L to 4.78 mmol/L, 4.79 mmol/L to 5.08 mmol/L, and 5.09 mmol/L to 6.45 mmol/L) showed significant linear increases of body mass index ($P < 0.005$), waist circumference ($P < 0.001$), systolic blood pressure ($P < 0.001$) and diastolic blood pressure ($P < 0.05$) with increasing FBG. Stepwise multiple regression analysis indicated systolic blood pressure ($\beta = 0.0078$, partial $R^2 = 0.039$, $P = 0.007$) and waist circumference ($\beta = 0.0081$, partial $R^2 = 0.025$, $P = 0.035$) were independent predictors of the increased FBG level.

CONCLUSIONS: MetS markers were present in a sample of healthy multiethnic adolescents in the Greater Toronto Area. FBG could be used as a simple indicator of the MetS to allow for early detection of the presence of the MetS and the introduction of preventive lifestyle measures. Further studies with larger sample sizes should address the accuracy of FBG for diagnosing the MetS.

Key Words: Fasting blood glucose; Healthy adolescents; Metabolic syndrome

Le syndrome métabolique chez des adolescents en santé d'origines multiethniques de Toronto, en Ontario : Le recours à la glycémie à jeun à titre de simple indicateur

HISTORIQUE : La prévalence du syndrome métabolique (Smét) augmente de par le monde, et la prévention représente un énorme défi. Généralement repéré à l'âge mûr, le Smét a des origines pédiatriques et un taux d'incidence variable entre les groupes ethniques. En raison de la difficulté à le diagnostiquer, il demeure en grande partie non décelé à l'adolescence.

OBJECTIFS : Évaluer la présence de caractéristiques de Smét chez des adolescents en santé de poids normal et d'origine multiethnique et déterminer si la glycémie à jeun (GÀJ) pourrait servir d'indicateur simple de sa présence.

MÉTHODOLOGIE : Les auteurs ont fait appel à un échantillon de commodité d'élèves du secondaire pour mener une étude transversale. Ils ont utilisé le modèle linéaire général ANCOVA rajusté afin de faire des comparaisons multiples par paires au moyen du test de Tukey-Kramer post-hoc pour évaluer les différences entre les tertiles de GÀJ.

RÉSULTATS : Au total, les auteurs ont recruté 182 adolescents de 62 écoles secondaires de la grande région de Toronto, en Ontario (44 % de Blancs, 34 % de Sud-Asiatiques et 22 % de Chinois), d'un âge moyen ($\pm$ ÉT) de $17,4 \pm 0,9$ ans, à l'indice de masse corporelle moyen de $22,1 \pm 3,4$ kg/m² et à la GÀJ moyenne de $4,92 \pm 0,4$ mmol/L. L'analyse au moyen du modèle linéaire général ANCOVA entre les tertiles de GÀJ (3,83 mmol/L à 4,78 mmol/L, 4,79 mmol/L à 5,08 mmol/L et 5,09 mmol/L à 6,45 mmol/L) a révélé une augmentation linéaire significative de l'indice de masse corporelle ($P < 0,005$), du tour de taille ($P < 0,001$), de la tension systolique ($P < 0,001$) et de la tension diastolique ($P < 0,05$) avec l'augmentation de la GÀJ. Selon l'analyse de régression multiple par étape, la tension systolique ($\beta = 0,0078$, R^2 partiel = 0,039, $P = 0,007$) et le tour de taille ($\beta = 0,0081$, R^2 partiel = 0,025, $P = 0,035$) étaient des prédicteurs indépendants d'une GÀJ élevée.

CONCLUSIONS : Les marqueurs de Smét étaient présents dans un échantillon d'adolescents en santé d'origines multiethniques de la grande région de Toronto. La GÀJ pourrait être utilisée comme indicateur simple de Smét afin de favoriser la détection rapide de sa présence et l'intégration de mesures préventives au mode de vie. D'autres études comportant de plus grands échantillons devraient porter sur la précision de la GÀJ pour diagnostiquer le Smét.

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Increasing evidence indicates that the rate of atherogenic cardiovascular disease (ACVD) is strongly associated with the metabolic syndrome (MetS) (1). Despite the deficit of basic and clinical information on adolescent MetS compared with that available for adults, it is now clear that its origins can be traced back to childhood (2-3). It is a pediatric problem that is 'silent' in youth, but becomes apparent later in life. Data from the Third National Health and Nutrition Examination Survey (NHANES III) (4-7) indicate that the prevalence of the MetS among adolescents in the United States and Canada is 6% to 11%, and is 30% to 50% among obese adolescents. The varying prevalence rates reflect different definitions of pediatric MetS because there is no standard definition. The risk for further development of cardiovascular disease (CVD) in children with the MetS is high, and early indicators for CVD, such as carotid artery intima-media thickness and atherosclerotic plaques, have been shown to develop in childhood (8,9); carotid hyper trophy is already detectable in children with the MetS (10).

Presence of the MetS in adolescents can only be diagnosed with a barrage of clinical and anthropometric tests that use modified adult criteria proposed by the Adult Treatment Panel III (ATP III) (11) and more recently, criteria modified by the International Diabetes Federation (2). For children 10 years of age or older, the MetS can be diagnosed by abdominal obesity and the presence of two or more other clinical features (ie, elevated triglycerides, low high-density lipoprotein [HDL] cholesterol, high blood pressure or increased plasma glucose) (2). This makes its detection complicated and unpractical, especially in healthy youth with no symptoms or obvious indications, such as obesity or positive family history. Another hurdle in identifying the MetS in adolescents is the difference among ethnicities, a point particularly important in countries with a high proportion of immigrants, such as Canada (12). Ethnic-specific waist circumference cut-offs have been incorporated into the new worldwide definition of the MetS for adults (13). More than one-half of the Toronto, Ontario, population is made up of immigrants. Another one-quarter are second generation immigrants; most of whom, at present, come from China and South Asia (12). Our previous study confirmed ethnic differences showing that Canadian adults of South Asian origin have higher rates of CVD compared with Canadians of European and Chinese origin (14).

Although the details of the transition from the MetS in adolescents to CVD in adults are not clear, compelling evidence indicates that the pathological processes and metabolic variables associated with the MetS can be tracked from adolescence to adulthood (15,16). Considering that the MetS in adulthood results in increased risk of CVD, the detection and prevention of the MetS during adolescence should be a priority.

Although not considered to have comparable clinical utility (17), simple laboratory measurements, such as fasting blood glucose (FBG), may have predictive value for MetS identification in a multiethnic adolescent population. The association between elevated FBG and the MetS has been suggested previously (2-4); however, population-based studies of FBG levels in a multiethnic healthy adolescent population are lacking.

Given the medical consequences of the MetS in adulthood and challenges in detecting its presence in multiethnic youth, the purpose of the present study was twofold: to investigate the presence of the MetS in a healthy multiethnic adolescent population in the Greater Toronto Area (GTA), and to determine whether FBG could be used as a simple indicator. The present study was the first of this type in North America to look at the three largest groups of ethnic migrants in the same study as one population group – a real-life model. Detecting the MetS in adolescence could initiate long-term interventions early in life, particularly weight loss and lifestyle modifications (18-20) that can halt progression of the MetS to ACVD.

METHODS

Participants

One hundred eighty-two adolescents (128 females and 54 male) 15 to 19 years of age, from 62 GTA high schools were recruited as a

convenience sample to participate in the study. Participants were derived from the University of Toronto Mentorship Program and were selected to this program because of their interest in nutrition and medical research.

The inclusion criteria were adolescent age (15 to 19 years), high school student status and otherwise healthy Canada-born individuals from parents belonging to the same ethnicity and living in Canada for more than 10 years. Individuals with diabetes or other chronic illness, or with a body mass index (BMI) of greater than 27 kg/m² were excluded. Proportionately, 80% of the students were from public schools, 15% from Catholic schools and 5% from private schools, representing a typical school profile in Ontario. The ethnic distribution was 44% Caucasians (European origin), 34% South Asians (India, Sri Lanka, Pakistan) and 22% Chinese. Although the age range of the population was 15 to 19 years, only six adolescents were 15 years of age. Therefore, adult MetS criteria were applied to the population.

The present study ('little s.h.a.r.e.' [Study of Health of Adolescents and Role of Ethnicity]) is an extension of the large Study of Health Assessment and Risk in Ethnic Groups (SHARE) conducted in an adult population. It was performed at the Clinical Nutrition and Risk Factor Modification Centre of St Michael's Hospital (Toronto, Ontario), and was approved by the St Michael's Hospital Research Ethics Board. All subjects gave written informed consent before starting the study.

Laboratory methods

The subjects were tested in the morning after 10 h to 12 h of fasting. A 35 µL capillary blood sample was obtained by finger prick in heparin-coated capillary glass tubes. Blood samples were analyzed by the desktop Cholestech LDX Analyzer (Cholestech Corporation, USA), which combines enzymatic methodology and solid-phase technology to measure total cholesterol, HDL, low-density lipoprotein (LDL), triglycerides and glucose. The Cholestech analyzers are often used in population studies and are considered as good screening tools. According to the manufacturer, the Cholestech LDX Analyzer meets all relevant National Cholesterol Education Program guidelines and is certified by the Centers for Disease Control and Prevention's Cholesterol Reference Method Laboratory Network (21). It has been validated for point-of-care lipid measurements in clinical practice (22).

Anthropometric and clinical measurements

Each participant wore light clothing and no shoes when his or her fasting body weight was measured to the nearest 0.1 kg using a calibrated digital scale (SECA Delta model 707, Vogel & Halke GmbH & Co, Germany). Height was measured to the nearest 0.5 cm on a standardized, wall-mounted stadiometer (Perspective Enterprises, USA) with the subject barefooted and head held in the Frankfort horizontal position. The BMI was calculated as weight (kg) divided by height (m) squared. While the subjects were standing, after gently exhaling, waist circumference was measured to the nearest 0.5 cm, using flexible non-stretchable measuring tape, as the minimal circumference measurable on the horizontal plane between the lowest portion of the rib cage and iliac crest (23). Hip circumferences were measured to the nearest 0.5 cm at the widest point. Total body fat (%) was assessed by the near-infrared method with FUTREX-5000 (Futrex Inc, USA). Blood pressure was measured three consecutive times, each at least 2 min apart, using a digital blood pressure monitor (HEM-907, Omron Healthcare Inc, USA) with an appropriately sized cuff, from the dominant arm with the subject seated quietly for at least 5 min. The average of three readings was recorded for analysis.

Statistical analysis

Statistical analysis was performed with NCSS 2000 software (NCSS, USA). The results are expressed as the mean ± SD with a level of significance at P<0.05. The variables used in the present study (anthropometric parameters, blood pressure and blood lipids) are routinely analyzed using parametric methods, which were used in the present study. Pearson correlation coefficient was used to assess the association between FBG and anthropometric and laboratory

TABLE 1
Correlations between fasting blood glucose, and anthropometric measurements, blood pressure and plasma lipid parameters

Parameter	Fasting blood glucose	
	r	P
Anthropometric measurements		
Body mass index	0.229	0.002
Waist circumference	0.282	<0.001
Hip circumference	0.222	0.003
Waist-hip ratio	0.207	0.005
Waist-height ratio	0.189	0.01
Body fat	-0.080	0.92
Blood pressure		
Systolic	0.303	<0.001
Diastolic	0.189	0.01
Mean arterial	0.163	0.03
Pulse	0.2	0.007
Blood lipids		
Total cholesterol	-0.065	0.39
Low-density lipoprotein	0.09	0.23
High-density lipoprotein	-0.187	0.01
Triglycerides	-0.033	0.66
Low-density lipoprotein/high-density lipoprotein ratio	0.16	0.04

variables. The general linear model (GLM) ANCOVA adjusted for multiple pairwise comparisons by the post hoc Tukey-Kramer test was used to assess differences among the tertiles of FBG. Stepwise multiple regression analysis, including variables significantly correlating with FBG in bivariate analysis, was also performed to determine independent predictors of increasing FBG.

RESULTS

The study population included 182 multiethnic adolescents (54 males and 128 females) with a mean age of 17.4 ± 0.9 years; BMI 22.1 ± 3.4 kg/m², FBG 4.9 ± 0.4 mmol/L, systolic and diastolic blood pressure 106 ± 10 mmHg and 70 ± 7 mmHg (respectively), and total cholesterol 4.2 ± 0.8 mmol/L. Significant positive correlations were noted between FBG and BMI, waist circumference, hip circumference, waist-hip ratio, waist-height ratio, systolic blood pressure, diastolic blood pressure, mean arterial pressure, pulse pressure and LDL/HDL ratio (Table 1). Among those parameters, systolic blood pressure and waist circumference expressed relatively stronger relationships with FBG ($r=0.303$, $P<0.001$; and $r=0.282$, $P<0.001$, respectively). At the same time, FBG negatively correlated with HDL (Table 1). According to the MetS applied definition, the MetS prevalence within the population was 6%.

To reach the objectives of the study, participants were divided into tertiles according to their FBG level. Tertile 1 corresponded to FBG levels of 3.83 mmol/L to 4.78 mmol/L, tertile 2 was 4.79 mmol/L to 5.08 mmol/L, and tertile 3 was 5.09 mmol/L to 6.45 mmol/L. The analyses were performed for each of the studied anthropometric measures, blood pressure and plasma lipid parameters using the GLM test for linear trend with multiple linear analyses across the tertiles (Table 2). GLM ANCOVA was controlled for sex and age for all characteristics, additionally controlled for anthropometric parameters to evaluate blood pressure and plasma lipids, and controlled for sex, age and blood pressure parameters to evaluate anthropometric measurements and plasma lipids. There was a significant linear increase across the tertiles for both anthropometric measurements (BMI, waist and hip circumferences, waist-hip ratio, waist-height ratio, and percentage body fat) and blood pressure (systolic, diastolic

and mean arterial pressure) with increasing FBG. There were no differences among the tertiles in blood lipids (Table 2).

Stepwise multiple regression analysis indicated systolic blood pressure ($\beta=0.0078$, partial $R^2=0.039$, $P=0.007$) and waist circumference ($\beta=0.0081$, partial $R^2=0.025$, $P=0.035$) as independent predictors of the increased FBG level.

DISCUSSION

Presence of the MetS can only be diagnosed with a constellation of clinical and anthropometric tests, making its detection complicated and unpractical in youth; thus, a simple single test should be established for easy detection. The present study aimed to develop an easy-to-use screening method to detect the MetS in nonsymptomatic multiethnic adolescents who could initiate dietary and lifestyle interventions early and reduce metabolic risks. To our knowledge, the present study is the first to investigate the use of FBG as an indicator for the MetS in multiethnic adolescents. To achieve the objective, we divided the data according to tertiles of FBG – a simple, single screening test – and showed significant linear FBG increase with increasing anthropometric measurements and blood pressure. Furthermore, by multivariate analysis, we found independent associations of FBG with waist circumference and systolic blood pressure, both of which are independent markers of the MetS.

While there have been many recent publications on the MetS in adults, pediatric data have received less attention, and no unified definition of the MetS exists in children and adolescents. As many as 40 different definitions of the syndrome have been used in pediatric research (24). It has been demonstrated that the MetS in childhood predicts adult MetS, type 2 diabetes and ACVD 25 to 30 years later (25,26). Long-term cohort studies (27) have also shown compromised vascular function in young adults with the MetS diagnosed in childhood and adolescence. Using the National Cholesterol Education Program definition, the MetS prevalence within the studied population was 6%, which is on the lower end of the adolescent MetS prevalence of 6% to 11% found in other studies (4-7). This was because our whole population group was on the lower end of the BMI, having more Caucasians and usually very healthy Chinese.

Cardiovascular risk and risk of future diabetes increase continually with increasing FBG, and there is no evidence of a threshold value of impaired fasting glucose (28). Presently, impaired fasting glucose is defined as an FBG level of 5.6 mmol/L or greater (29). In our study, one-third of the students were in the highest FBG tertile (5.09 mmol/L to 6.45 mmol/L) and were shown to have significantly higher incidence rates of the MetS features than the rest of the group.

Others have made comparable observations regarding the importance of FBG. In a study of a nationally representative sample of 915 American adolescents aged 12 to 19 years, Williams et al (4) found that adolescents with impaired FBG have features of insulin resistance syndrome. While the overall prevalence of impaired fasting glucose was 7%, it was higher in overweight adolescents (18%). Adolescents with impaired FBG had significantly higher hemoglobin A1C, fasting insulin, total cholesterol, LDL, triglycerides and systolic blood pressure, and lower HDL cholesterol than those with normal FBG concentrations (4). A meta-regression analysis (30) of published data from 20 studies in adults demonstrated that compared with a glucose level of 4.2 mmol/L, a fasting glucose level of 6.1 mmol/L was associated with a cardiovascular event RR of 1.33 (30).

Abdominal fat distribution as measured by waist circumference was repeatedly shown to be a better predictor of various indexes of glucose-insulin homeostasis in adolescents than BMI alone (31). Waist circumference, a convenient indicator for visceral obesity, was used by ATP III (11) and is available in NHANES III (4). The outcomes of waist circumference measurements in our study showed highly significant differences among FBG tertiles and it was identified as an independent predictor of FBG level in multivariate analysis.

Systolic, diastolic and mean arterial pressure increased consistently with FBG across the tertiles, indicating a monotonic relationship that

TABLE 2

Tertiles of fasting blood glucose, and associated mean values of anthropometric, blood pressure and plasma lipid parameters in 182 adolescents

Parameter	Fasting blood glucose, mmol/L			P*	P†	P‡
	Tertile 1, 3.83–4.78	Tertile 2, 4.79–5.08	Tertile 3, 5.09–6.45			
Anthropometric measurements						
Body mass index, kg/m ²	20.9±2.9	21.6±2.4	23.1±3.9	<0.001	–	<0.001
Waist circumference, cm	68.1±7.7	68.9±6.0	74.0±10.0	<0.001	–	<0.001
Hip circumference, cm	93.4±7.0	95.0±5.5	97.9±7.7	<0.001	–	<0.001
Waist-hip ratio	0.73±0.06	0.73±0.05	0.75±0.06	0.067	–	0.011
Waist-height ratio	0.42±0.04	0.42±0.04	0.44±0.05	0.006	–	0.005
Body fat, %	23.7±6.9	22.0±7.2	24.6±7.9	0.007	–	0.009
Blood pressure, mmHg						
Systolic	102.6±11.9	104.5±8.7	110.1±11.1	<0.001	<0.001	–
Diastolic	68.2±7.6	70.3±6.5	71.9±7.4	0.001	0.001	–
Mean arterial	79.7±8.4	81.7±6.3	83.0±13.2	0.031	0.013	–
Pulse	34.3±8.2	34.2±7.9	37.4±9.0	0.058	0.095	–
Blood lipids, mmol/L						
Total cholesterol	4.16±0.85	4.24±0.70	4.14±0.70	0.78	0.73	0.96
LDL	2.07±0.80	2.36±0.67	2.29±0.72	0.25	0.49	0.27
HDL	1.43±0.29	1.38±0.34	1.31±0.28	0.08	0.79	0.24
Triglycerides	1.28±0.65	1.06±0.53	1.25±0.58	0.91	0.61	0.8
LDL/HDL ratio	1.5±0.7	1.83±0.77	1.9±0.9	0.059	0.33	0.096

Data presented as mean ± SD. *P-value for linear trend corrected for sex and age; †P-value for linear trend corrected for sex, age and anthropometric parameters;

‡P-value for linear trend corrected for sex, age and blood pressure parameters. HDL High-density lipoprotein; LDL Low-density lipoprotein

was confirmed by stepwise multiple regression analysis, although the correlations in this analysis were weak and should not be considered conclusive. This is consistent with existing evidence indicating a positive association of increasing FBG with elevated blood pressure and other CVD risk factors (32).

Hyperlipidemia in childhood and adolescence is difficult to connect with clinical atherosclerotic events in later adult years. Although initial levels of serum lipids and lipoproteins are predictive of follow-up levels (15), a substantial proportion of children initially identified as having elevated levels were found to have levels closer to the mean in follow-up re-examinations. On the other hand, data from the population-based Bogalusa Heart Study (16) identified an association between elevated blood lipids in childhood and adulthood. In our study, no relation of FBG with blood lipids was found across the tertiles or in multivariate analysis. McGill et al (33) demonstrated that even in the presence of a favourable lipoprotein profile, such as in our population, nonlipid risk factors, including impaired glucose tolerance, high blood pressure and obesity, have substantial effects on the extent and severity of coronary and aortic atherosclerosis in youth. This highlights the need for evaluation of nonlipid risk factors, particularly FBG, in adolescents to predict juvenile atherosclerosis and to introduce preventive measures in a timely manner.

There is increasing evidence that rates of ACVD and FBG vary in relation to ethnicity. Recent data from our SHARE study have shown that in Canadian adults, the MetS prevalence is 42% among Native Canadians (mean FBG 5.63±1.2 mmol/L), 26% among South Asians (FBG 5.5±1.1 mmol/L), 22% among Europeans (FBG 5.2±0.8 mmol/L) and 11% among the Chinese (FBG 5.2±1.1 mmol/L) (1,14). This highlights the need for systematic comparisons of the MetS prevalence among ethnic groups and the potential of detailed investigations among 'high-risk' populations to contribute new insights about the etiology and pathogenesis of the MetS and ACVD. Ethnic differences may additionally play an important role in the identification of the MetS in adolescents, a fact important when evaluating and establishing a screening tool for this condition.

Limitations

Our study should be interpreted in light of its limitations. The primary limitation is that we used adult criteria of FBG and other MetS features were modelled accordingly. Another limitation is that our study was performed on a convenience sample, making us unable to perform stratified randomization (eg, by sex or ethnicity). However, the ethnic distribution in the sample reflected demographic statistics for the GTA. In addition, although South Asians have a health risk comparable with that of Caucasians regarding lipid and glucose metabolism, a healthy BMI is two to three units higher in a Caucasian population (1). Moreover, our study was conducted among high school students interested in nutrition and medical research; therefore, our results might be underestimated because these children are interested in health and nutrition, and are probably taking better care of themselves.

CONCLUSIONS

Markers of the MetS were present in a sample of healthy multiethnic adolescents in the GTA. FBG could be used as a simple indicator of the MetS to allow for early detection of the presence of the MetS and the introduction of preventive lifestyle measures. Concurrent use of a single finger-prick FBG test with conventional anthropometric and laboratory measurements may provide a better picture of developing the MetS, and the impact of these data may be far-reaching. The present study was the first of this type conducted in adolescents among the three largest and 'typical' Canadian ethnicities; thus, as a preliminary study, it may stimulate more research in this highly understudied area. Further studies with larger sample sizes should address the accuracy of FBG for diagnosing the MetS. Health practitioners should be aware of hidden clustering of metabolic abnormalities in adolescents.

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