ORIGINAL ARTICLE

Overweight, family history of diabetes and attending schools of lower academic grading are independent predictors for metabolic syndrome in Hong Kong Chinese adolescents

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Background: Overweight and metabolic syndrome (MES) are emerging in both adult and paediatric populations.

Aims: To study the prevalence of and associated risk factors for the MES, using the National Cholesterol Education Program definition, among Hong Kong Chinese adolescents studying in secondary schools.

Methods: This was a cross-sectional, population-based study. A sample of 2115 Chinese adolescents was randomly selected from 14 secondary schools throughout Hong Kong. Data on anthropometric parameters, fasting blood and urine samples were collected in the school setting. Information regarding the adolescent's family history of diabetes, perinatal history, socioeconomic status and school grading was evaluated.

Results: The prevalence of MES was 2.4% (95% confidence interval (CI) 1.8 to 3.1), with no significant difference between boys (2.9%) and girls (2%). The prevalence of various components of MES was 32.2% (30.2 to 34.2) for hypertension, 10.9% (9.6 to 12.2) for increased triglyceride, 9.0% (7.8 to 10.2) for central adiposity, 2.4% (1.7 to 3) for low high-density lipoprotein cholesterol and 0.3% (0.1 to 0.6) for impaired fasting glucose. On multivariate analysis, overweight (odds ratio 32.2; 95% CI 13.2 to 78.4), positive family history of diabetes (4.3; 1.3 to 14.1) and studying at schools of lower academic grading (5.5; 2.2 to 13.7) were found to be independent risk factors for MES.

Conclusion: A comparable prevalence of MES (2%) is observed in our study group Chinese adolescent girls and in US girls (2.1%), but a lower prevalence in Chinese boys (2.9%) than in US boys (6.1%). In our study, 41.8% harboured at least one component of the syndrome. Both families and schools should be alerted to this growing epidemic.

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There is now a burgeoning epidemic of diabetes and obesity, especially in areas undergoing rapid changes in lifestyle and socioeconomic development. This rising prevalence is partly attributed to the increasing population of obese children and adolescents.¹ In the recent National Health and Nutrition Examination Survey (NHANES) involving nearly 2500 adolescents in the United States, the prevalence of metabolic syndrome (MES) was reported to be 6.1% in males and 2.1% in females with obesity and Mexican American ethnicity as major risk factors.² Weiss *et al* studied 490 children and most of them were obese. They found that the prevalence of MES increased with the severity of obesity and reached 50% in severely obese youngsters.³

We have previously reported a local case-control study of 300 Hong Kong Chinese children aged between 9 and 12 years. Compared with non-obese children, obese children had a three- to six fold increased risk of having various components of MES, including hyperinsulinaemia, low high-density lipoprotein cholesterol (HDL-C), high low-density lipoprotein cholesterol (LDL-C), hypertriglyceridaemia and high blood pressure.⁴

In line with this rising trend of childhood overweight and obesity, Hong Kong has one of the highest prevalences of young-onset type 2 diabetes, with a reported rate of 2–4% in the population <40 years old where obesity and positive family history played important roles.^{5–6} More recently, urbanisation and socioeconomic influence have been associated with an increased risk of poor health, cardiovascular disease and its risk factors.^{7–9}

We hypothesise that Chinese adolescents living in a highly urbanised society such as Hong Kong have a high prevalence of

MES and that factors other than overweight, such as perinatal history, family history and socioeconomic factors, may have a contributory role in the development of MES.

SUBJECTS AND METHODS

Subjects

A full list of all Chinese secondary schools in Hong Kong was obtained from the Hong Kong Education Department. Hong Kong comprises three major geographical regions (Hong Kong Island, Kowloon and the New Territories) with a population of 6.7 million. Using a computer-generated coding system, we randomly selected schools from each of the three geographical regions to obtain a representative sample population of Hong Kong Chinese adolescents. Among a total of 477 schools, 53 schools were selected. From each participating school, six classes (Form 1 to Form 6, equivalent to Year 7 to Year 12 in the United States) were randomly selected with one class from each form to obtain a proportional number of healthy participants, aged 12–20 years. Those with chronic illnesses such as diabetes with or without drugs were excluded from the study.

In Hong Kong, the secondary schools are divided into three "bands" as determined by the Education Department of Hong Kong. Students are enrolled into different school bands according to their academic achievements in primary schools.

Abbreviations: ACR, albumin-creatinine ratio; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MES, metabolic syndrome; NCEP, National Cholesterol Education Program; NHANES, National health and Nutrition Examination Survey

Students with high academic achievements are enrolled into schools of better grading (band 1), whereas students with average and low academic performances are enrolled into schools of lower grading (band 2 or 3). The sampling was not stratified by school grades, and students were randomly selected into this study without prior information of the "bands" of the schools.

The study was initiated by the investigators by sending letters to principals of all selected schools to explain the rationale and design of the study. On approval by school principals, letters were sent to the parents of all selected school children explaining the nature of the screening programme with minimal interruption to normal school activities. All parents were asked to complete a questionnaire regarding perinatal history (birth weight and history of breast feeding), family history of diabetes affecting first-degree relatives medical history of the adolescent concerned and parental occupations, if any. The study was approved by the Ethical Committee, the Chinese University of Hong Kong, Hong Kong. All participants gave informed consent with parents' written consent.

Our team of research nurses visited each school during an allocated time in the morning. All students were advised to fast for at least 8 h before attending the session for measurement of anthropometric indices and blood and urine collection. Fasting state was affirmed before withdrawal of blood by direct questioning. Body weight (kg) and body height (m) were measured and the body mass index (BMI, kg/m^2) was calculated. Waist circumference and hip circumference were measured to the nearest 0.1 cm. The blood pressure was taken from the non-dominant arm after at least 5 min of rest by using an Omron electronic sphygmomanometer (Omron Tateisi Electronics, Kyoto, Japan). The Korotkoff sound V was taken as the diastolic blood pressure. The blood pressure was rechecked after 5 min if the initial reading had increased ($>140/90$ mm Hg). The average of the two readings was used for analysis. Pubertal stages and the presence of acanthosis nigricans in the students were been assessed in this study.

Fasting blood samples were collected for the measurement of biochemical parameters such as plasma glucose, total cholesterol, triglyceride, HDL-C and calculated LDL-C. A random spot specimen of urine was collected for the measurement of albumin-creatinine ratio (ACR). Plasma glucose was measured by a hexokinase method (Hitachi 911, analyzer Boehringer Mannheim, Mannheim, Germany). Both the intra-assay and inter-assay coefficients of variation for glucose were 2% at 6.6 mmol/l. Total cholesterol and triglyceride were assayed enzymatically with commercial reagents (Baker Instruments Corporation, Allentown, Pennsylvania, USA) on a Cobas Mira analyzer (Hoffmann-La Roche and Co, Basle, Switzerland). HDL-C and its subfractions were determined after fractional precipitation with dextran sulphate- MgCl_2 . LDL-C was calculated by using Friedewald's formula.¹⁰

DEFINITION OF MES

As no formal definition exists for MES in adolescents, we used the modified definition based on the National Cholesterol Education Program (NCEP) Adult Treatment Panel III described in the recent NHANES survey.² According to this definition, all participants meeting ≥ 3 of the following five criteria are considered as having MES²: high triglyceride, low HDL-C, central adiposity, hypertension and impaired glycaemia. On the basis of reference data from the NCEP Pediatric Panel Report,¹¹ triglyceride ≥ 1.24 mmol/l and HDL-C ≤ 1.03 mmol/l were used as criteria for components of MES. Because no local reference values for waist circumference exist for adolescents, central adiposity was arbitrarily defined as a waist circumference above the 90th centile value for age and

sex from this sample population. Hypertension was defined as blood pressure ≥ 90 th centile for age, sex and height based on the recent data released from the National Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents.¹² Impaired glycaemia was defined as fasting plasma glucose ≥ 6.1 mmol/l. The American Diabetes Association in 2003 changed the cut-off for impaired fasting glucose from 6.1 to 5.6 mmol/l.¹³ So far, however, no formal definition of MES in children has adopted this new cut-off value. Hence, we have maintained a fasting plasma glucose level of ≥ 6.1 mmol/l as the cut-off for impaired glycaemia. In addition, albuminuria, an important cardiovascular risk factor, was assessed, which was defined as ACR >3.5 mg/mmol.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS V. 12.0. All data were expressed as mean (SD) or geometric median (interquartile range). Plasma triglyceride and spot urine ACR values were logarithm transformed owing to skewed distributions. Odds ratios (OR) and prevalence rates were expressed with 95% confidence intervals (CI). χ^2 Tests and Student's *t* test were used for group comparisons. Logistic regression analysis was used to identify the independent predictors for MES using BMI, age, sex, family history of diabetes, birth weight, breast feeding, socioeconomic status, geographical regions and school banding as independent variables. All comparisons were made two-sided, and a *p* value <0.05 (two-tailed) was considered significant.

Sample size estimation

Most of the population-based studies in Caucasians and non-Caucasians show a 1–2% prevalence of diabetes among adolescents in this age range.¹⁴ In our two local epidemiological studies, the prevalence of diabetes in participants aged between 25 and 35 years was reported to be 1–2%, and 3–5% of this age group has MES.^{5, 15–17} On the basis of these figures, we hypothesise that the prevalence of diabetes in Hong Kong Chinese adolescents (12–18 years) is around 1%. The sample size required to estimate a proportion of 1% with 95% CI and a precision of 0.5% would be 1522. On the basis of these estimations and taking an additional 20% variability into consideration, we aimed to recruit at least 1800 participants.

RESULTS

Of the 53 schools selected, 14 schools consented and were recruited for the survey. From these 14 schools, random samples of 4598 students were identified from their six forms. Of these, 2115 school children consented and were enrolled into the study, giving a response rate of 46%. In all, 960 (45.4%) males and 1155 (54.6%) females with a mean age of 15.5 years (range 11–20 years; median 16 years) participated. Table 1 summarises the clinical and biochemical characteristics of the 2115 participants.

The overall prevalence of MES in these adolescents was 2.4% (95% CI 1.8% to 3.1%), with a similar rate between males (2.9%) and females (2.0%). Table 2 summarises the prevalence of MES and its constituent components stratified by age and sex. The prevalence of MES tends to peak at age 13 years in girls and at age 14 years in boys. Hypertension was most prevalent among other MES components, affecting 32.2% (95% CI 30.2 to 34.2) of participants, followed by increased triglyceride 10.9% (9.6 to 12.2), central adiposity 9.0% (7.8 to 10.2), low HDL-C 2.4% (1.7 to 3) and impaired fasting glycaemia 0.3% (0.1 to 0.6). Overall, 41.8% harbour at least one component of the syndrome, among whom 31.7% had one component of MES, 7.8% had two components, 2.1% had three components and 0.3% had four components. Of note, 13% of these adolescents also had albuminuria.

Table 1 Comparison of biochemical and clinical parameters of Hong Kong adolescents with and without MES

	Boys		Girls		Total	
	MES	Non-MES	MES	Non-MES	MES	Non-MES
Number (%)	28 (2.9)	932 (97.1)	23 (2.0)	1132 (98.0)	51 (2.4)	2064 (97.6)
Age (years)*	14.8 (1.9)	15.3 (2.0)	14.7 (2.0)	15.7 (2.0)	14.8 (1.9)	15.6 (2.0)
Biochemical parameters						
Fasting plasma glucose (mmol/l)	4.8 (0.4)	4.7 (0.4)	5.3 (2.3)†	4.7 (0.3)	5.0 (1.6)†	4.7 (0.4)
Total cholesterol (mmol/l)	4.6 (0.7)†	4.1 (0.7)	4.5 (1.0)	4.3 (0.7)	4.5 (0.9)†	4.2 (0.7)
Non-high-density lipoprotein cholesterol (mmol/l)	3.4 (0.6)†	2.5 (0.7)	3.3 (0.9)†	2.6 (0.6)	3.4 (0.8)†	2.6 (0.6)
High-density lipoprotein cholesterol (mmol/l)	1.2 (0.2)†	1.6 (0.3)	1.2 (0.2)†	1.7 (0.3)	1.2 (0.2)†	1.6 (0.3)
Low-density lipoprotein cholesterol (mmol/l)	2.6 (0.6)†	2.1 (0.6)	2.6 (0.9)*	2.2 (0.6)	2.6 (0.7)†	2.2 (0.6)
Triglyceride (mmol/l)	1.5 (1.3–2.0)†	0.7 (0.6–1.0)	1.5 (1.3–2.0)†	0.7 (0.6–0.9)	1.5 (1.3–2.0)†	0.7 (0.6–1.0)
Urinary albumin-creatinine ratio (mg/mmol)	0.6 (0.4–0.9)	0.5 (0.3–1.4)	1.2 (0.3–2.0)	0.7 (0.4–1.8)	0.6 (0.3–1.3)†	0.6 (0.3–1.6)
Clinical parameters						
Body mass index (kg/m ²)	27.1 (3.8)†	20.1 (3.6)	27.3 (4.7)†	19.5 (2.9)	27.2 (4.2)†	19.8 (3.3)
Waist (cm)	88.3 (8.8)†	70.7 (8.1)	82.3 (9.5)†	65.4 (6.3)	85.6 (9.5)†	67.8 (7.7)
Systolic blood pressure (mm Hg)	134.8 (11.7)†	120.5 (12.8)	127.5 (10.8)†	113.2 (11.3)	131.5 (11.8)†	116.5 (12.5)
Diastolic blood pressure (mm Hg)	79.6 (10.1)†	71.6 (9.6)	84.8 (8.2)†	72.8 (8.8)	81.9 (9.6)†	72.3 (9.2)
Perinatal and family history						
Birth weight (kg)	3.3 (0.6)	3.2 (0.5)	3.1 (0.5)	3.1 (0.5)	3.2 (0.6)	3.2 (0.5)
With ≥4 weeks of breast feeding	6 (22.2)	246 (27.5)	7 (30.4)	319 (29.0)	13 (26.0)	565 (28.3)
With family history of DM	3 (10.7)	15 (1.6)	2 (8.7)	17 (1.5)	5 (9.8)	32 (1.6)
Socioeconomic factors						
Studying in schools of higher grading	6(21.4)	346(37.1)	2(8.7)	601(53.1)	8(15.7)	947(45.9)
Working mother	14 (50.0)	417 (44.7)	9 (39.1)	434 (38.3)	23 (45.1)	851 (41.2)
Father in professional or managerial grade	1 (3.6)	72 (7.7)	2 (8.7)	89 (7.9)	3 (5.9)	161 (7.8)

DM, diabetes mellitus; MES, metabolic syndrome; N, number.

p Values comparing MES and non-MES using student's t test (with logarithm transformation, if necessary): *p<0.01, †p<0.001.

All parameters expressed as mean (SD) except for triglyceride and ‡spot urine albumin-creatinine ratio, which are expressed as median (interquartile range), or number (%) where appropriate.

No significant association was observed between formula feed, parental occupation or low birth weight with metabolic syndrome. On logistic regression analysis using age, sex, school regions, BMI ≥85th centile for age and sex (overweight), family history of diabetes, breast feeding, parental occupation, low birth weight and school grading (lower grading = 0, higher grading = 1) as independent variables, family history (OR 4.3; 95% CI 1.3 to 14.1), overweight (32.2; 13.2 to 78.4) and studying at schools of lower grading (5.5; 2.2 to 13.7) were identified as independent predictors for MES ($r^2 = 0.33$; (table 3).

DISCUSSION

Our study was limited by the volunteer nature of the respondents. Nevertheless, the response rate was about 50%, which is comparable with most volunteer surveys. Compared with the reference curves for BMI in the 1993 Hong Kong Growth Survey,¹⁸ a slightly greater proportion of adolescents in the upper quartile was noticed in our sampled population (28.2%) compared with that in the Growth Survey (25.0%). This may be due to a selection bias given the awareness of parents regarding the purpose of the study, but it may also represent an increase in the levels of adiposity over 10 years' time.

To allow comparisons between studies, we defined increased blood pressure as the ≥90th centile for age, sex and height

using data from the US National Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents as reference. Increased blood pressure was the most prevalent component of the metabolic syndrome affecting 32.2% of our adolescents, which is considerably higher than that observed in the NHANES survey (4.9%). The use of the reference blood pressure norm for adolescents in the States may account for this. However, given the higher intake of salt in Chinese diet, and that Chinese have one of the highest prevalences of hypertension in the world (nearly 30%),¹⁹ this high prevalence of raised blood pressure among our adolescents is not totally unexpected.

The best definition for MES in children is still unclear. Golley *et al* recently published data comparing the prevalence of MES using six different definitions in pre-pubertal children.²⁰ They found that the classification of MES in children depends strongly on the definition chosen, with MES prevalence estimates higher if insulin was part of the definition and child-specific cut-off points for metabolic indicators were used. For practical and financial reasons, insulin level was not measured in our study. In fact, the beauty of the NCEP criteria is the involvement of several simple clinical parameters only so that the diagnosis or screening of MES can be made easily in our day-to-day general practice. With the NCEP criteria, the prevalence of MES in Hong Kong adolescent girls was similar to

Table 2 Prevalence of MES and its constituent components stratified by age and sex in Hong Kong adolescents

Components of MES	Age (years)							Total
	12	13	14	15	16	17	18	
Boys (n)								
Waist circumference $\geq$ 90th centile for age and sex (%)	7.2	10.3	8.5	7.4	7.4	10.3	9.5	8.9
Blood pressure $\geq$ 90th centile for age, sex and height (%)	36.2	44.5	49.2	39.1	34.7	20.7	20.8	35.4
Low high-density lipoprotein cholesterol (%)	1.4	2.6	3.1	3.7	2.6	3.4	1.2	2.6
High triglyceride (%)	14.5	19.4	13.1	8.1	8.9	13.8	10.7	12.2
Impaired fasting glycaemia (%)	0	0	0.8	0	1.1	1.1	0	0.4
MES (%)	2.9	3.9	4.6	2.5	2.6	2.3	1.8	2.9
Girls (n)								
Waist circumference $\geq$ 90th centile for age and sex (%)	7.4	12.1	8.1	8.6	8.9	10.0	8.7	9.1
Blood pressure $\geq$ 90th centile for age, sex and height (%)	31.5	35.6	40.5	34.5	26.3	23.3	22.5	29.5
Low high-density lipoprotein cholesterol (%)	0	3.8	3.4	1.1	1.8	5.6	1.1	2.2
High Triglyceride (%)	11.1	17.4	13.5	11.5	8.5	8.9	4.3	9.8
Impaired fasting glycaemia (%)	0	0.8	0	0.6	0	0	0.4	0.3
MES (%)	0	7.6	2.0	1.7	0.7	3.3	0.7	2.0

MES, metabolic syndrome; N, number.

that in US girls (2.0 v 2.1%, respectively) but lower in adolescent boys in Hong Kong than in the US (2.9 v 6.1%).²

The global epidemic of diabetes is partly driven by the growing population of overweight or obese children and adolescents.²¹ In this survey, we observed a high prevalence of MES and its individual components in a fairly representative

sample of school adolescents from Hong Kong. Apart from overweight, family history of diabetes and type of school attended were found to be independent predictors for MES.

In agreement with our previous studies,^{4, 22} family history of diabetes was an independent predictor for MES, which may reflect shared genetic or environmental factors. The effect of

Table 3 Associations of metabolic syndrome with obesity, school districts, school banding, paternal occupations, family history of diabetes and perinatal history in Hong Kong adolescents

	Total number of participants	Percentage of participants with MES	OR (95% CI)	p Value
Sex				
Male	960	2.9	0.6 (0.3 to 1.2) 1.0	0.136
Female	1155	2.0		
District				
NT region	1333	2.9	1.0 (0.6 to 1.6) 1.0	0.996
Non-NT region	782	1.5		
Academic grading of school				
Higher grading	955	0.8	1.0 5.5 (2.2 to 13.7)	<0.001
Lower grading	1160	3.7		
Father in professional or managerial grade				
Yes	164	1.8	0.7 (0.2 to 2.6) 1.0	0.723
No	1951	2.5		
Mother as housewife				
Yes	874	2.6	1.0 1.3 (0.7 to 2.6)	0.368
No	1241	2.3		
Family history of diabetes				
Yes	37	13.5	4.3 (1.3 to 14.1) 1.0	0.017
No	2078	2.2		
At least 4 weeks of breast feeding				
Yes	578	2.2	1.0 0.9 (0.5 to 1.9)	0.823
No	1468	2.5		
Body mass index				
$\geq$ 85th centile	133	24.8	32.2 (13.2 to 78.4) 1.0	<0.001
<85th centile	1982	0.9		

MES, metabolic syndrome; NT, New Territories.

Logistic regression analysis using age, sex, school regions, body mass index, family history of diabetes, breast feeding, parental occupation, low birth weight and school grading as independent variables.

What is already known on this topic

- Overweight and metabolic syndrome are emerging in both adult and paediatric populations.

What this study adds

- The prevalence of metabolic syndrome in Chinese adolescent girls (2.0%) was similar to that in US girls (2.1%), but lower in Chinese boys (2.9%) than in boys in the US (6.1%).
- Overweight, a positive family history of diabetes and studying at schools of lower academic grading were independent risk factors for the metabolic syndrome in Chinese adolescents.

birth weight on MES and diabetes tends to adopt a “U” shape in most studies.^{23–25} However, this relationship was not seen in this study, which probably accounts for the low incidence (<2%) of low birth weight in our adolescents given the relative affluence of Hong Kong.

Most interestingly, in this school survey, we noted the association between a low risk for MES and band 1 school attendance. Although we did not obtain full details of the dietary habits and physical activity in this field study, it is plausible that parental background and a more balanced school curriculum in band 1 schools might be associated with an increased awareness of the importance of healthy lifestyles. Although these findings are hypothesis generating, our findings highlight the complex nature underlying this multifaceted syndrome with possible sociocultural and educational determinants.

CONCLUSIONS

In this large-scale school survey involving more than 2000 adolescents aged between 12 and 20 years living in an affluent society such as Hong Kong, we observed a high prevalence of overweight or obesity and components of MES. Apart from overweight and a family history of diabetes, we also noted the effects of school types on disease prevalence. In light of the healthcare implications of this global epidemic, more systematic surveys to identify socioeconomic, cultural and school determinants to improve our understanding of this complex syndrome need to be conducted.

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