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Disease Risks of Childhood Obesity in China[1]

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Objective To estimate the relative risks of dyslipidemia, hypertension, diabetes mellitus, and metabolic syndromes among overweight and obese Chinese children compared with their normal weight counterparts. **Methods** Overweight and obesity were defined by age- and sex-specific BMI classification reference for Chinese children and adolescents. Pediatric metabolic syndrome (MetS) and each risk factor for MetS were defined using the criteria for US adolescents. Definition of hyper-TC, LDL, and dyslipidemia for adults was applied as well. General linear model factor analysis and chi-square test were used to compare the difference in metabolic indicators among normal weight, overweight, and obese groups. Multiple logistic regression analysis was performed to estimate the odds ratio of metabolic abnormalities between obesity, overweight, and normal weight children, after adjustment for living area, family economic level, age, sex, and daily exercise time and TV watching time, as well as different dietary indices in the model. **Results** Significant increases in blood lipids, glucose, and blood pressure were found among overweight and obese children as compared with their counterparts with normal weight. By applying WGOC-recommended BMI classification, the risks for hypertriglyceridemia, low HDL and dyslipidemia among overweight children were 1.9, 1.4, and 1.5 times, and was 3.3, 1.5, and 1.8 times among obese groups compared to their counterparts with normal weight after adjustment for age, sex, region, socioeconomic status, physical activity, and dietary intakes. The overweight and obese children (15-17.9 years) had a high-risk of developing hypertension, which was 2.3 and 2.9 times higher than their counterparts with normal weight. Above 90% obese adolescents had abdominal obesity, while less than 1% normal weight ones had abdominal obesity. No obese adolescents were free from any risk factors for MetS, while 36.9% of normal weight adolescents were from the risk factors. 83.3% obese boys and all obese girls had metabolic syndrome, while only 15.5% normal weight boys and 18.8% normal weight girls had metabolic syndrome. Four risk factors for metabolic syndrome were found in 8.3% obese boys while none in normal weight boys and girls. The prevalence of MetS among normal weight, overweight, and obesity groups was 1.5%, 18.3%, and 38.1% respectively. **Conclusion** The cardiovascular disease (CVD) risk factors are clustered in obese Chinese children. Our observations strongly suggest that efforts should be made to prevent the onset of overweight and its associated diseases during early childhood.

Key words: Chinese obese children; Metabolic syndrome (MetS); Hypertension; Lipids; Relative risk

INTRODUCTION

Although obesity-related morbidities occur more frequently in adults, cardiovascular risk factors can be identified in early life and obesity has been noted as a major determinant of adverse serum lipids and lipoproteins and blood pressure levels[1-2]. It has been shown in previous studies that the cardiovascular risk factors are clustered in obese children[3-8]. Results of the Bogalusa Heart Study indicate the elevated level of total cholesterol in overweight school children (5-17 years) was 2.4 times higher than that in children with a Quetelet index <85th percentile. The odd ratio was 2.4 for diastolic blood pressure (DSP), 3.0 for low-density lipoprotein cholesterol (LDL-C), 3.4 for high-density lipoprotein cholesterol (HDL-C), 4.5 for systolic blood pressure (SDP), 7.1 for hypertriglyceridemia (hyper-TG) and 12.6 for fasting insulin[3]. Data from the Third National Nutrition and Health Examination Survey (NHANES III, 1988-1996) in the United States also revealed that the prevalence of MetS is significantly related to weight status, being found among less than 0.1% of adolescents of normal weight (BMI below 85th percentile), rising to 6.8% among overweight adolescents (85th-95th BMI percentile), and an extraordinary 28.7% among obese adolescents (BMI≥95th percentile)[4].

A rapid westernization of children's blood cholesterol concentrations has been reported in

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Japan[9] and clustering of CVD risk factors has also been found among obese children in some cities of China[10-11]. However, there are no national population-based studies to investigate childhood obesity and its association with CVD risk factors in China, while rapid increment of child obesity has been reported in the past decade[12]. The purpose of the current study was to estimate the relative risks of dyslipidemia, hypertension, diabetes mellitus, and metabolic syndrome among overweight and obese Chinese children compared with their counterparts with normal weight.

SUBJECTS AND DEFINITIONS

2002 China Nationwide Nutrition and Health Survey (2002 CNNHS) is a nationally representative cross-sectional survey covering 31 provinces, autonomous regions, and municipalities directly under the Central Government (Hong Kong, Macao, and Taiwan are not included). The method of multi-step cluster sampling was adopted, 71 971 households were chosen from 132 counties/districts/cities (22 from each category: large, medium-sized and small cities, rural areas 1, 2, 3, 4 from high to low development). Among the 44 880 children aged 7-17.9 years, blood glucose and lipid profiles of 8480 children aged 7-17.9 years, waist circumference and blood pressure measured of 1160 children aged 15-17.9 years were finished. The samples were randomly selected according to the same proportion of each of the 132 counties/districts/cities. No blood pressure and waist measurements were done in children under age 15.

The fasting body weight, height, waist circumference, and blood pressure of the subjects were measured following the standardized procedures. The waist circumference was measured at the midpoint between the bottom of the rib cage and above the top of the iliac crest at the end of exhalation to nearest 0.1cm. Two seated resting blood pressures were measured to nearest 2 mmHg; the first and fifth Korotkoff sounds were used to represent the systolic and diastolic blood pressure. The means of these two measurements was recorded. Serum glucose level was measured with a spectrophotometer in 4 hours after the fasting blood sample was taken. Plasma total cholesterol, triglyceride, and HDL-C were measured enzymatically with Hitachi 7060 and 7180 auto-analyzers (Hitachi, Tokyo, Japan).

The following definitions were used:

(1) Pediatric metabolic syndrome (MetS)[13]. Analogous to adult treatment panel (ATP III), with ≥3 of the following 5 parameters:

- Hyper-TG: fasting triglycerides≥1.1 mmol/L;
- Low HDL: HDL < 1.3 mmol/L, except in boys aged 15 to 18 years, in whom the cut-off point was <1.17 mmol/L;
- Hyperglycemia: fasting glucose≥6.1 mmol/L;
- Central obesity: waist circumference>75th percentile for age and gender;
- Hyper-SBP: systolic blood pressure>90th percentile for gender, age, and height; Hyper-DBP: diastolic blood pressure>90th percentile for gender, age, and height; Hypertension: with hyper-SBP or hyper-DBP, or both[14]

(2) Diabetes mellitus: fasting blood glucose≥7.0 mmol/L[15]

The following parameters for adults were applied in this analysis, as there is no reference for children[16]:

(1) Hyper-TC: blood chlolesterol≥5.72 mmol/L;

(2) High LDL: LDL>3.64 mmol/L;

(3) Dyslipidemia: with (presence of) any one of hyper-TC, hyper-TG or low HDL;

(4) Overweight and obesity: age-, sex-, specific BMI references for Chinese children[17].

STATISTICS

The mean and standard deviation for each variable were analyzed by age and sex to reduce the potential differences due to maturation. A general linear model (GLM) factorial analysis of variance (ANOVA) was applied with the Tukey post-hoc comparisons in order to compare the metabolic profiles between normal weight, overweight, and obese groups, and to study the associations of gender, age, body weight (and their interactions) with metabolic profiles. The comparison of HDL-C between normal weight, overweight, and obese groups was classified by gender and age for the significant interactions between gender and age, and between age and weight status. As there were no first and second level interactions, the comparisons of fasting blood glucose, TG, TC, ratio of TG to HDL-C, SBP and DBP were made in total to increase the statistic power. So did the LDL-C by gender and the ratio of TC to HDL-C by age. Prevalence values among normal weight, overweight, and obese children were compared using χ^2 test for proportions for those children with or without the risk factors including adverse serum lipids and lipoprotein, diabetes mellitus, hypertension, and MetS. Multiple logistic regression analysis was employed to estimate the odds ratio of metabolic abnormalities between obese, overweight and normal weight groups. The confounding factors adjusted in the regression model included living area, family economic level, age, sex, daily exercise time and TV watching time, as well as

different dietary indices. All statistical analyses were performed with the SAS version 8.2, and a P value <0.05 was regarded statistically significant.

RESULTS

The characteristics of the subjects are summarized in Table 1. A total of 8861 subjects including 4728 boys and 4133 girls were included in the current analysis, 1856 of whom lived in urban areas and 7005 in rural areas. According to the Chinese Reference Standard, the overweight prevalence of children aged 7-12 years and 12-18 years was 4.1% and 5.6%, respectively, while the obesity prevalence was 2.5% and 1.6%, respectively. 0.2% of children aged 7-12 years and 0.4% children aged 12-18 years were classified as having diabetes mellitus (fasting serum glucose≥7.0 mmol/L). The overall prevalence of dsylipidemia, hypercholesterolemia, hypertriglyceridemia, and low HDL-C was 61.9% 0.3%, 18.2 %, and 56.1%, respectively. Elevated blood pressure was found in 16.0% of the children aged 15-18 years, while the overall prevalence of the metabolic syndrome was 3.3%, more than half children had at least one or more than one metabolic abnormality, and 19.8% had at least two.

Blood Pressure

No interaction was found between gender and weight status on SBP or DBP. Overweight and obese adolescents had significantly higher SBP (F=24.21, P<0.01) and DBP (F=18.81, P<0.01) than their counterparts with normal weight. The SBP and DBP of obese adolescents were about 10 mmHg and 5 mmHg higher than those of their counterparts with normal weight (Table 2).

The overweight children were 3.4, 2.7, and 3.3 times more likely to develop hyper-SBP, hyper-DBP, and hypertension, respectively, compared to their normal weight counterparts, while obese children were 5.0, 3.1 and 3.9 times more likely to develop those after adjustment for living area, gender, family economic level, daily exercise, walking, biking and TV watching time, and daily protein and energy, as well as ratio of sodium to potassium from diet. The hypertension rates in the normal weight, overweight and obese groups were 14.3%, 32.1%, and 40.9%, respectively (Table 3).

Serum Lipids and Lipoproteins

There were significant interactions between age and gender (F (1, 8230)=4.50; P=0.034) and between age and weight status (F (2, 8230)=4.03; P=0.018) for HDL-C. There was no significant difference in HDL-C level between each two groups aged 7-11.9 years. The average HDL-C was 47.9, 45.4 and 44.6 mg/dL in the normal weight, overweight, and obese groups aged 12-17.9 years (F=4.29, P=0.014), respectively. Significant differences in HDL-C level were found between normal weight and overweight or obese boys, but not in girls (Table 2). The rate of low HDL among the normal weight, overweight and obese groups was 56.0%, 57.8%, and 57.5%, respectively. Over 50% risk of the overweight and obese children for low HDL was found after adjustment for living area, gender, family economic level, daily exercise, walking, biking and TV watching time, and daily intake of egg, meat, cooking oil, and vegetable as well as energy (Table 3).

There were no first and second level interactions of gender, age, and weight status on TG levels. Significantly elevated TG level was found in both age groups with overweight and obesity, except for girls aged 12-17.9 years. The average TG level in normal weight, overweight, and obese groups was 75.4 mg/dL, 82.2 mg/dL, and 90.1 mg/dL, respectively. Significant differences in TG level were found between each two groups (F=21.85, P<0.01) (Table 2). The rate of hypertriglyceridemia in the normal weight, overweight, and obese groups was 17.5%, 25.2%, and 34.6%, respectively. After adjustment for the living area, gender, family economic level, daily exercise, walking, biking and TV watching time, and daily intake of egg, meat, cooking oil and vegetable, as well as energy, the odd ratio of hypertriglyceridemia doubled in the overweight group and tripled in the obese group as compared with their counterparts with normal weight (Table 3).

The average TC level in normal weight, overweight, and obese groups was 122.9 mg/dL, 130.7 mg/dL, and 136.6 mg/dL, respectively. Significant elevated TC was found in both age groups with overweight and obesity. Significant differences in TC level were found between each two groups (F=21.85, P<0.01) (Table 1). No significant difference in the hyper-TC rate was found among the normal weight, overweight, and obese groups (Table 3).

The overweight and obese boys in both age groups had significantly higher LDL-C levels than their counterparts with normal weight, while only obese girls had significantly higher LDL-C levels than normal weight girls. No significant difference in LDL-C level was found between the overweight and normal weight girls. The average LDL-C level in the normal weight, overweight, and obese groups was 57.6, 64.6, and 68.4 mg/dL, respectively (F=39.36, P<0.01). No significant difference in the hyper-LDL-C rate was found among the normal weight, overweight, and obese groups (Table 3).

TABLE 1

Characteristics of Subjects

	7-12 (Years)			12-18 (Years)		
	Boys	Girls	All	Boys	Girls	All
No. of Subjects						
Total	3125	2710	5835	1603	1423	3026
Urban	564	524	1088	403	365	768
Rural	2561	2186	4747	1200	1058	2258
Average Level ($\bar{x} \pm s$) *						
Height (cm)	133.9±11.5	134.0±11.9	133.9±11.7	159.6±10.7	154.8±7.4*	157.3±9.6
Weight (kg)	29.4±8.1	28.9±8.2*	29.1±8.2	47.6±11.2	45.9±8.6*	46.8±10.1
BMI (kg/m^2)	16.1±2.4	15.8±2.3*	16.0±2.3	18.4±2.7	19.1±2.8*	18.7±2.8
FBG (mg/dL)	84.3±10.8	82.7±9.4*	83.6±10.2	84.3±10.2	83.5±9.3*	83.9±9.8
HDLC (mg/dL)	50.1±11.2	49.2±10.7*	49.7±11.0	47.3±9.9	48.1±9.9*	47.7±9.9
TG (mg/dL)	72.5±32.9	78.9±33.6*	75.5±33.4	72.4±35.7	82.2±39.4*	77.0±37.8
TC (mg/dL)	124.6±26.5	125.0±25.6	124.8±26.1	118.0±25.0	125.0±26.6*	121.3±26.0
LDL (mg/dL)	58.8±22.0	58.7±21.3	58.8±21.7	55.1±21.4	59.2±22.2*	57.0±21.8
Waist	–	–	–	67.4±7.7	66.0±6.2*	66.8±7.1
SBP (mmHg)	–	–	–	108.8±12.2	104.7±10.5*	107.0±11.7
DBP (mmHg)	–	–	–	69.6±8.8	68.7±7.9	69.2±8.4
Abnormality Rate (%)**						
Overweight (WGOC)	5.2	2.8**	4.1	5.1	6.1**	5.6
Obesity (WGOC)	2.9	2.0**	2.5	1.7	1.4	1.6
Overweight (IOTF)	5.3	3.5**	4.5	5.3	5.1	5.2
Obesity (IOTF)	1.4	0.8**	1.2	0.8	0.4	0.6
Hyperglycemia	0.8	0.5	0.7	0.7	0.8	0.8
Diabetes Mellitus	0.2	0.2	0.2	0.5	0.4	0.4
Low HDL-C	53.5	56.5**	54.9	56.1	61.2**	58.5
High TG	14.9	21.2**	17.8	14.7	23.7**	18.9
High TC	0.4	0.3	0.3	0.4	0.2	0.3
High LDL-C	0.4	0.2	0.3	0.5	0.2	0.3
Dyslipidemia	58.1	63.2**	60.5	60.9	68.9**	64.6
Abdominal Obesity[1]	–	–	–	3.4	3.1	3.3
Hyper-SBP[1]	–	–	–	6.1	3.8	5.1
Hyper-DBP[1]	–	–	–	14.5	11.7	33.9
HP[1]	–	–	–	17.9	13.7**	16.0
MetS Risk Factors (%)[1]						
⩾1 Risk Factors	–	–	–	61.4	68.9**	64.8
⩾2 Risk Factors	–	–	–	18.4	21.6	19.8
⩾3 Risk Factors	–	–	–	3.3	3.3	3.3
⩾4 Risk Factors	–	–	–	0.5	0.0	0.3

Note. *Comparison between boys and girls, Students's *t*-test, *$P<0.05$. **Comparison between boys and girls, χ^2-test, **$P<0.05$. [1]Data were available only from adolescents aged 15-18 years; the sub-sample size was 1160.

TABLE 2

Distribution of Biochemical Indicators by BMI Percentile[1]

	BMI Percentiles (Boys)									BMI Percentiles (Girls)								
	<25th	25th-	35th-	45th-	55th-	65th-	75th-	85th-	95th-	<25th	25th-	35th-	45th-	55th-	65th-	75th-	85th-	95th-
7-12 years																		
BMI (kg/m^2)	14.3	15.3*	15.8*	16.3*	17.0*	17.7*	18.7*	20.7*	24.1*	13.9	14.9*	15.5*	16.0*	16.3*	17.0*	18.5*	20.5*	23.7*
TBG (mg/dL)	83.1	83.3	85.0	85.3*	85.6*	83.4	86.8*	88.5*	85.8	82.1	81.9	83.0	82.7	82.2	83.6	84.1	84.8	86.2
HDL-C (mg/dL)	50.0	50.6	49.9	49.7	49.9	49.8	49.7	51.1	50.9	50.0	49.4	49.1	48.5	48.4	48.2	49.1	48.7	47.9
TG (mg/dL)	71.8	71.1	68.2	73.4	73.4	76.8	71.9	77.7	84.2*	77.0	76.1	78.0	79.7	76.7	79.8	84.1	88.2	93.9*
TC (mg/dL)	123.9	122.6	122.1	124.8	123.3	123.4	129.2	135.5*	135.4*	124.8	125.2	124.4	122.7	122.6	122.3	128.7	132.2	137.2*
LDL-C (mg/dL)	58.3	56.6	57.6	59.1	58.2	56.9	63.8	67.5*	66.2*	58.1	59.2	58.3	56.8	57.5	57.5	61.3	64.4	68.9*
TG:HDL-C	1.5	1.5	1.5	1.6	1.6	1.7	1.6	1.6	1.8	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2.2*
TC:HDL-C	2.5	2.5	2.5	2.6	2.5	2.5	2.7	2.7*	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.8	3.0*
12-18 years																		
BMI (kg/m^2)	16.1	17.5*	18.0*	18.7*	19.4*	20.2*	21.7*	24.3*	28.2*	16.2	17.5*	18.2*	18.8*	19.4*	20.2*	21.7*	24.4*	28.1*
TBG (mg/dL)	83.7	83.9	84.9	83.9	83.9	84.3	85.6	85.8	87.5	82.9	83.7	82.7	84.5	84.3	82.5	83.5	85.2	83.8
HDL-C (mg/dL)	48.5	49.6	45.1*	45.7	47.9	47.0	45.2*	44.7*	44.2*	49.5	49.2	48.7	47.8	46.7	47.6	47.7	46.0	45.2
TG (mg/dL)	70.9	68.3	71.7	77.9	72.5	66.6	75.6	82.2	94.9*	84.6	79.0	75.1	82.9	79.9	83.4	82.0	85.1	100.3
TC (mg/dL)	118.0	119.5	112.7	113.3	119.4	118.4	117.8	125.8	133.3	124.6	125.4	124.8	123.7	123.5	123.7	126.4	125.7	144.7*
LDL-C (mg/dL)	54.1	55.1	52.0	52.0	55.8	57.0	56.1	63.2*	68.5*	57.0	59.1	59.8	57.8	59.4	58.0	61.6	61.2	77.6*
TG:HDL-C	1.5	1.5	1.7	1.8	1.6	1.5	1.7	2.0*	2.3*	1.8	1.7	1.6	1.9	1.8	1.8	1.8	2.0	2.3
TC:HDL-C	2.5	2.5	2.5	2.5	2.5	2.6	2.6	2.9*	3.1*	2.6	2.6	2.6	2.6	2.7	2.6	2.7	2.8*	3.2*
Waist (%)	62.5	65.1*	66.1*	68.6*	68.4*	71.1*	74.9*	81.3*	93.0*	60.7	62.0	64.0*	65.7*	65.5*	66.4*	69.6*	74.8*	83.2*
SBP (mmHg)	104.1	108.9*	109.1	107.9	114.1*	111.0*	114.5*	118.1*	120.8*	100.7	101.7	103.9	105.3	106.4*	105.3	106.5*	109.7*	113.7*
DBP (mmHg)	67.1	69.7	69.3	68.4	72.6*	71.0*	72.2*	74.6*	77.9*	66.1	66.3	68.8	69.0	68.3	68.7	70.7*	72.2*	73.9*

Note. [1]General linear model (GLM) factorial analysis with Tukey post-hoc comparisons, *P<0.05 relative to the BMI<25th percentile. [2]BMI: body mass index; FBG: fasting blood (serum) glucose; HDL-C: high density lipoprotein cholesterol; TG: triglyceride; TC: total cholesterol; LDL-C: low density lipoprotein cholesterol; TG:HDL-C: ratio of triglyceride to HDL cholesterol; TC: HDL-C: ratio of total to HDL cholesterol; Waist: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure.

TABLE 3

Rate and Odds Ratio of Metabolic Abnormalities in Overweight and Obese Groups in Comparison with Normal Weight Group

Metabolic	Sample	Normal Weight	Overweight			Obesity		
Abnormality	(*n*)	(%)[1]	(%)[1]	Odds Ratio	95%CI	(%)[1]	Odds Ratio	95%CI
Hyperglycemia	8480	0.7	1.6	2.3*	1.0-5.4	–	–	–
Low HDL	8119	56.0	57.8	1.4*	1.1-1.7	57.5	1.5*	1.1-2.1
Hyper-TG	8119	17.5	25.1	1.9*	1.5-2.4	34.6	3.3*	2.4-4.5
Hyper-TC	8118	0.3	0.5	1.0	0.2-4.3	0.6	1.0	0.1-7.5
High LDL	8096	0.3	0.5	1.1	0.3-5.0	1.1	2.3	0.5-10.2
Dyslipidemia	8119	61.7	65.0	1.5*	1.2-1.9	65.9	1.8*	1.3-2.5
Hyper-SBP	1143	4.2	12.8	3.4*	1.5-7.5	18.2	5.0*	1.5-16.4
Hyper-DBP	1143	12.1	24.4	2.7*	1.5-4.8	31.8	3.1*	1.2-8.1
Hypertension	1143	14.3	32.1	3.3*	1.9-5.6	40.9	3.9*	1.6-9.7
MetS	1090	1.5	18.3	15.4*	6.8-34.8	38.1	47.9*	16.0-143.1

Note. The rate of metabolic abnormalities. Adjusted for age, gender, region, economic level, physical activity pattern and dietary intakes. Hypertension data were only available for adolescents aged 15-17 years. Multiple regression analysis, Wald Chi-square of maximum likelihood estimates analysis, *$P<0.05$. HDL: high density lipoprotein cholesterol; TG: triglyceride; TC: total cholesterol; LDL: low density lipoprotein cholesterol; SBP: systolic blood pressure; DBP: diastolic blood pressure; MetS: metabolic syndrome.

Elevated ratio of TC: HDL-C was found in both age groups with overweight and obesity, while only obese children had a significantly higher TG: HDL-C ratio. Significant differences in TC: HDL-C ratio was found between each two groups of children aged 12-17.9 years (F=37.50, P<0.01) (Table 2).

The prevalence of dyslipidemia in the normal weight, overweight, and obese groups was 61.7%, 65.0%, and 65.9%, respectively. The risk for dyslipidemia in overweight and obese groups was 50% and 80% times higher than their counterparts with normal weight after adjustment for living area, gender, family economic level, daily exercise, walking, biking and TV watching time, and daily intake of egg, meat, cooking oil and vegetable, as well as energy (Table 3).

Fasting Blood Glucose and Relative Risk for Hyperglycemia

No first and second level interactions of gender, age, and weight status on fasting blood glucose level were found. The average level of fasting blood glucose in normal weight, overweight and obese groups was 83.5, 86.5, and 86.0 mg/dL, respectively. The overweight and obese groups had a significantly higher glucose level than their counterparts with normal weight (F=21.43, P<0.01) (Table 2).

The rate of hyperglycemia in children with overweight and normal weight was 1.6% and 0.7%, respectively. After adjustment for gender, dietary energy and carbohydrate intake, daily exercise time and TV watching time, the risk for hyperglycemia in overweight children was 1.3 times higher than their counterparts with normal weight (Table 3).

Diabetes mellitus was found in 0.2% normal weight, 0.8% overweight, and 0.6% obese children.

Metabolic Syndrome Risk Factors

The distribution of each element of metabolic syndrome (MetS) is shown in Table 4. Overweight and obese groups had much higher rate in any risk factor of MetS. Similar trends were found in boys and girls. More than 90% of obese adolescents had abdominal obesity, while only less than 1% of normal weight ones had it.

Compared with normal weight adolescents, overweight and obese groups had a higher proportion of one or more abnormalities of MetS (Table 4). No obese adolescents were free from any risk factors, while 36.9% of the normal weight adolescents were free from risk factors. 83.3% of obese boys and all obese girls had MetS, while only 15.5% of normal weight boys and 18.8% of normal weight girls had MetS. Four risk factors for MetS were found in 8.3% of obese boys while none in normal weight boys.

Totally, the prevalence of MetS ($\geqslant$3 of above risk factors) in normal weight, overweight, and obese groups was 1.5%, 18.3% and 38.1%, respectively, and was 1.6%, 22.6% and 33.3%, respectively, in normal weight, overweight, and obese boys, respectively, and 1.4%, 15.0%, 44.4% in normal weight, overweight, and obese girls, respectively (Table 4). 58.3% of the children with MetS were overweight or obese. Three cases with 4 or more metabolic abnormalities were all overweight or obese.

TABLE 4

Prevalence of Individual Metabolic Syndrome Risk Factors and Its Clustering Among Chinese Adolescents Aged 15-17.9 Years (%)

Risk Factors	Boys			Girls			All		
	Normal	OW	OB	Normal	OW	OB	Normal	OW	OB
Abdominal Obesity	0.3	28.1	91.7	1.1	6.8	88.9	0.7	15.8	90.5
Glycemia	0.8	1.8	0.0	0.6	1.3	1.4	0.7	1.6	0.6
Hyper-TG	14.0	23.0	30.9	21.4	28.3	40.6	17.5	25.1	34.6
Low HDL-C	54.5	51.8	56.4	57.8	66.5	59.4	56.0	57.8	57.5
Hypertension	16.0	41.2	46.2	12.2	25.0	33.3	14.3	32.1	40.9
⩾1 Risk Factors	59.5	80.7	100.0	67.1	75.0	100.0	63.1	77.5	100.0
⩾2 Risk Factors	15.5	45.2	83.3	18.8	35.0	100.0	16.3	39.4	94.5
⩾3 Risk Factors	1.6	22.6	33.3	1.4	15.0	44.4	1.5	18.3	38.1
⩾4 Risk Factors	0.0	6.5	8.3	0.0	0.0	0.0	0.0	2.8	4.8

Note. χ^2 test, all $P<0.05$ except some with zero value, and except the risk of low HDL-C. TG: triglyceride; HDL-C: high density lipoprotein cholesterol.

Comparison Between Urban and Rural Areas

In order to explore whether the health consequences of overweight and obesity also existed in rural areas, the differences in metabolic levels between normal weight, overweight and obese children living in rural areas, and those living in urban areas, are summarized in Tables 5-6. Although the health consequences of obesity were not as serious as those in urban areas, fasting blood glucose, TG, TC, LDL-C, TG/HDL-C, TC/HDL-C, waist, SBP, and DBP, the prevalence of overweight and obesity in rural children were much lower than those in urban children (Table 5). After controlling other confounding factors, the overweight children living in the rural areas showed a slightly lower (than that in urban areas) but significantly higher risks of hypertriglyceridemia (OR=1.9, 95% CI 1.4-2.6), dyslipidemia (OR=1.3, 95% CI 1.0-1.8), and hypertension (OR=4.0, 95% CI 1.9-8.4).

DISCUSSION

The obesity problem in China is not as serious as those in developed countries, but concomitant morbidities of childhood obesity are also found in Chinese children. The current results indicate that 0.2% of children aged 7-12 years and 0.4% of children aged 12-18 years are diagnosed as having diabetes mellitus. Low HDL, hypertriglyceridemia and abdomial obesity are also common, whereas hyperglycemia and hyper-LDL and hyper-TC are not so frequent. In our study, the definitions were referred to that for US adolescents, the prevalence of diabetes, hypertriglyceridemia and abdominal obesity might be underreported. Since the cut-off points of hypertension were sex-, age-, and height percentile, the prevalence rate of hypertension might be overreported. However, no such definitions are available for Chinese children by now, but fortunately the relative risks of overweight and obesity are not concealed.

Elevated blood pressure in obese adolescents is reported more and more frequently, with the increase of obese adolescents, and increases with worsening obesity[3-6]. The obese adolescents have a blood pressure distribution skewed to the right. The mean blood pressure for the obese group is more than one standard deviation to the right of the mean blood pressure for the general population[18]. Compared with other school children, an overweight youth living in developed countries is 2.4 times higher to have elevated diastolic blood pressure and 4.5 times higher to have an elevated systolic blood pressure[3]. The presence of hypertension in overweight children is 3.31 times higher than that in normal weight ones[6]. Though the childhood obesity has been increasing in the last two decades in China, our study showed that overweight and obese adolescents are 3.3 and 3.9 times higher to have hypertension compared with their normal weight counterparts. Our study also indicated that the average SBP and DBP of obese adolescents are about 10 mmHg and 5 mmHg higher than those of their counterparts with normal weight.

Childhood obesity is always associated with increased levels of LDL-cholesterol and triglycerides and decreased levels of HDL-cholesterol[1-2]. The relative risks for hypertriglyceridemia and LDL-hypercholesterolemia in overweight children is 2.64 and 1.63 times higher than those in normal weight children. Results of The Bogalusa Heart Study

TABLE 5

Metabolic Characteristics of Normal Weight, Overweight and Obese Children Living in Urban and Rural Areas ($\bar{x} \pm s$)

	Urban Areas			Rural Areas		
	Normal Weight	Overweight	Obese	Normal Weight	Overweight	Obese
FBG (mg/dL)	84.2±11.4[a]	87.3±11.9[b]	86.7±7.5[b]	83.3±9.7[a]	86.1±8.7[b]	85.4±11.0[b]
HDLc (mg/dL)	52.2±11.2[a]	49.3±10.8[b]	51.3±11.3[a,b]	48.3±10.4	47.4±10.1	46.1±10.6
TG (mg/dL)	70.3±30.3[a]	75.6±31.1[a]	96.0±44.3[b]	76.6±35.4[a]	86.2±38.9[b]	85.3±47.3[b]
TC (mg/dL)	130.4±28.2[a]	133.1±28.9[a]	149.7±35.2[b]	121.1±24.7[a]	129.2±27.2[b]	125.7±30.0[a,b]
LDLc (mg/dL)	63.0±22.9[a]	67.3±24.2[a]	77.4±28.1[b]	56.3±20.7[a]	63.0±23.1[b]	61.0±28.9[a,b]
TG:HDLc	1.4±0.8[a]	1.6±0.9[b]	2.0±1.2[c]	1.7±1.0[a]	1.9±1.1[b]	2.0±1.3[b]
TC:HDLc	2.5±0.5[a]	2.8±0.6[b]	3.0±0.6[c]	2.6±0.5[a]	2.8±0.6[b]	2.8±0.8[b]
Waist (cm)	67.0±5.7[a]	78.3±5.4[b]	89.7±5.6[c]	64.8±5.4[a]	76.8±6.8[b]	80.1±24.1[b]
SBP (mm Hg)	106.1±11.1[a]	111.7±9.4[b]	119.2±12.4[c]	106.4±11.6[a]	115.0±12.1[b]	110.0±9.0[a]
DBP (mm Hg)	69.3±8.3[a]	71.9±7.1[a,b]	76.9±9.2[b]	68.5±8.4 [a]	74.5±6.0[b]	72.0±6.9[a]

Note. General linear model (GLM) factorial analysis of variance (ANOVA) was applied with the Tukey post-hoc comparison, values not sharing the same letters (a–c) denote significant difference between normal weight, overweight or obese groups of the same gender and age groups, $P < 0.05$. Hypertension and waist circumference data were available only from adolescents aged 15-17 years. BMI: body mass index; FBG: fasting blood (serum) glucose; HDL-C: high density lipoprotein cholesterol; TG: triglyceride; TC: total cholesterol; LDL-C: low density lipoprotein cholesterol; TG:HDL-C: ratio of triglyceride to HDL cholesterol; TC: HDL-C: ratio of total to HDL cholesterol; Waist: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure.

TABLE 6

Frequency and Odds Ratio of Metabolic Abnormalities in Overweight and Obese Children and Adolescents

Metabolic	Sample	Normal Weight	Overweight			Obesity		
Abnormality	(*n*)	(%)	(%)	Odds Ratio	95%CI	(%)[1]	Odds Ratio	95%CI
Urban Area								
Low HDL	1706	42.2	52.1	1.8*	1.3-2.6	49.4	1.8*	1.1-2.9
Hypertriglyceridemia	1706	12.7	19.7	2.1*	1.3-3.4	40.7	6.6*	4.0-10.9
Dyslipidemia	1706	48.7	58.5	1.8*	1.3-2.6	66.7	3.0*	1.8-5.1
Hypertension	402	12.8	23.7	2.6*	1.0-6.4	42.1	3.5*	1.2-9.7
Rural Area								
Low HDL	6525	59.3	61.2	1.2	0.9-1.6	64.3	1.4	0.9-2.1
Hypertriglyceridemia	6525	18.6	28.5	1.9*	1.4-2.6	29.6	2.1*	1.3-3.2
Dyslipidemia	6525	64.8	69.0	1.3*	1.0-1.8	65.3	1.1	0.7-1.8
Hypertension	759	15.1	40.0	4.0*	1.9-8.4	–	–	–

Note. Adjusted for age, gender, region, economic level, physical activity pattern and dietary intakes. Hypertension data were available only from adolescents aged 15-17 years. Multiple regression analysis, Wald Chi-square of maximum likelihood estimates analysis, *P<0.05.

also indicate that overweight school children are 2.4, 3.0, 3.4, and 7.1 times higher to have an elevated level of total cholesterol and LDL-C, lower HDL and elevated TG, respectively compared to children with a Quetelet index <85th percentile[3]. Cook *et al*.[4] also reported that more than half obese adolescents have elevated triglyceridemia and LDL-C compared to less than one fifth in their normal weight counterparts. Significantly, elevated lipid and lipoprotein levels are also found among overweight and obese children in our study. The risks for hyper-triglycerolemia, low HDL, and dyslipidemia are 1.9, 1.4, and 1.5 times higher in overweight children, and are 3.3, 1.5, and 1.8 times higher in obese group than those in their counterparts with normal weight after the adjustment for age, sex, region, socioeconomic status, physical activity level, and dietary intakes.

Malecka-Tendera and Molnar[19] showed that hyperinsulinaemia is a common feature in obese children and adolescents. Overweight children are 11.7 times higher to have an abnormal glucose level[20] and 12.6 times higher to have an elevated level of fasting insulin[3]. Obese children are at high risk of developing diabetes mellitus or abnormal

fasting glucose level (odds ratio 5.1, 95%CI 1.51, 17.0)[21]. No detection of insulin level was one limitation of the current study, but we still found significantly elevated serum glucose levels in young children, and significantly higher risk of hyperglycemia in overweight group.

Weiss *et al*.[5] reported that the prevalence of metabolic syndrome is higher in obese children and adolescents, and increases with worsening obesity. The prevalence of MetS is lower than 0.1% in adolescents with normal weight (BMI<85th percentile), and increases to 6.8% in overweight adolescents (BMI 85th-95th percentile) and 28.7% in obese adolescents (BMI≥95th percentile). Only 11.5% of obese adolescents are free from any risk factors, while 68.6% of the normal weight adolescents are free from risk factors. Four risk factors are found in 5.8% of obese adolescents while none in normal weight ones. Applying the same criteria of MetS analogous to NCEP's ATP III to US adolescents[13], MetS was found in 18.3% overweight and 38.1% obese Chinese adolescents, and in 1.5% normal weight adolescents. No obese Chinese adolescents were free from any risk factors and 8.3% of obese boys had a cluster of at least 4 abnormalities of MetS.

Higher fat composition with the same BMI in Asian adults is always considered as the reason why the increased risks are related to obesity in Asians[22-27]. Compared to the US adolescents (0.3%, 11.5%, and 74.5% of the normal weight adolescents with BMI<85th, overweight ones with BMI ranging from 85th to 95th, and obese ones with BMI above 95th)[4], abdominal obesity is higher in Chinese adolescents. With the same cut-off points of abdominal obesity for US adolescents[13], 0.7%, 15.8%, and 90.5% Chinese adolescents are defined as abdominal obesity in the normal weight adolescents with BMI<85th, overweight adolescents with BMI ranging from 85th to 95th, and obese adolescents with BMI above 95th.

In summary, cardiovascular risk factors are clustered in obese Chinese children. Taking the persistence of obesity and its associated risk factors, and the huge cost for obesity caring into consideration[28], our observations strongly suggest that efforts should be made to prevent the onset of overweight and its associated diseases in early childhood.

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TABLE 2

Distribution of Biochemical Indicators by BMI Percentile[1]

	BMI Percentiles (Boys)									BMI Percentiles (Girls)								
	<25th	25th-	35th-	45th-	55th-	65th-	75th-	85th-	95th-	<25th	25th-	35th-	45th-	55th-	65th-	75th-	85th-	95th-
7-12 years																		
BMI (kg/m^2)	14.3	15.3*	15.8*	16.3*	17.0*	17.7*	18.7*	20.7*	24.1*	13.9	14.9*	15.5*	16.0*	16.3*	17.0*	18.5*	20.5*	23.7*
TBG (mg/dL)	83.1	83.3	85.0	85.3*	85.6*	83.4	86.8*	88.5*	85.8	82.1	81.9	83.0	82.7	82.2	83.6	84.1	84.8	86.2
HDL-C (mg/dL)	50.0	50.6	49.9	49.7	49.9	49.8	49.7	51.1	50.9	50.0	49.4	49.1	48.5	48.4	48.2	49.1	48.7	47.9
TG (mg/dL)	71.8	71.1	68.2	73.4	73.4	76.8	71.9	77.7	84.2*	77.0	76.1	78.0	79.7	76.7	79.8	84.1	88.2	93.9*
TC (mg/dL)	123.9	122.6	122.1	124.8	123.3	123.4	129.2	135.5*	135.4*	124.8	125.2	124.4	122.7	122.6	122.3	128.7	132.2	137.2*
LDL-C (mg/dL)	58.3	56.6	57.6	59.1	58.2	56.9	63.8	67.5*	66.2*	58.1	59.2	58.3	56.8	57.5	57.5	61.3	64.4	68.9*
TG:HDL-C	1.5	1.5	1.5	1.6	1.6	1.7	1.6	1.6	1.8	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2.2*
TC:HDL-C	2.5	2.5	2.5	2.6	2.5	2.5	2.7	2.7*	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.8	3.0*
12-18 years																		
BMI (kg/m^2)	16.1	17.5*	18.0*	18.7*	19.4*	20.2*	21.7*	24.3*	28.2*	16.2	17.5*	18.2*	18.8*	19.4*	20.2*	21.7*	24.4*	28.1*
TBG (mg/dL)	83.7	83.9	84.9	83.9	83.9	84.3	85.6	85.8	87.5	82.9	83.7	82.7	84.5	84.3	82.5	83.5	85.2	83.8
HDL-C (mg/dL)	48.5	49.6	45.1*	45.7	47.9	47.0	45.2*	44.7*	44.2*	49.5	49.2	48.7	47.8	46.7	47.6	47.7	46.0	45.2
TG (mg/dL)	70.9	68.3	71.7	77.9	72.5	66.6	75.6	82.2	94.9*	84.6	79.0	75.1	82.9	79.9	83.4	82.0	85.1	100.3
TC (mg/dL)	118.0	119.5	112.7	113.3	119.4	118.4	117.8	125.8	133.3	124.6	125.4	124.8	123.7	123.5	123.7	126.4	125.7	144.7*
LDL-C (mg/dL)	54.1	55.1	52.0	52.0	55.8	57.0	56.1	63.2*	68.5*	57.0	59.1	59.8	57.8	59.4	58.0	61.6	61.2	77.6*
TG:HDL-C	1.5	1.5	1.7	1.8	1.6	1.5	1.7	2.0*	2.3*	1.8	1.7	1.6	1.9	1.8	1.8	1.8	2.0	2.3
TC:HDL-C	2.5	2.5	2.5	2.5	2.5	2.6	2.6	2.9*	3.1*	2.6	2.6	2.6	2.6	2.7	2.6	2.7	2.8*	3.2*
Waist (%)	62.5	65.1*	66.1*	68.6*	68.4*	71.1*	74.9*	81.3*	93.0*	60.7	62.0	64.0*	65.7*	65.5*	66.4*	69.6*	74.8*	83.2*
SBP (mmHg)	104.1	108.9*	109.1	107.9	114.1*	111.0*	114.5*	118.1*	120.8*	100.7	101.7	103.9	105.3	106.4*	105.3	106.5*	109.7*	113.7*
DBP (mmHg)	67.1	69.7	69.3	68.4	72.6*	71.0*	72.2*	74.6*	77.9*	66.1	66.3	68.8	69.0	68.3	68.7	70.7*	72.2*	73.9*

Note. [1]General linear model (GLM) factorial analysis with Tukey post-hoc comparisons, $^*P<0.05$ relative to the BMI<25th percentile. [2]BMI: body mass index; FBG: fasting blood (serum) glucose; HDL-C: high density lipoprotein cholesterol; TG: triglyceride; TC: total cholesterol; LDL-C: low density lipoprotein cholesterol; TG:HDL-C: ratio of triglyceride to HDL cholesterol; TC: HDL-C: ratio of total to HDL cholesterol; Waist: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure.