Original Article

Impacts of Types and Degree of Obesity on Non-Alcoholic Fatty Liver Disease and Related Dyslipidemia in Chinese School-Age Children?

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Abstract

Objective To explore the impacts of types and degree of obesity on non-alcoholic fatty liver disease (NAFLD) and related lipids disturbance in Chinese school-age children.

Methods A total of 1 452 school-age Children of 7 to 17 years were recruited in Beijing with representative cluster sampling method. Data of anthropometric measurements including weight, height and waist circumference were collected from March to May of 2007. Body mass index（BMI）was calculated. Blood samples were obtained and lipid profiles including triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured, while glutamate-pyruvate transaminase (ALT) and glutamic-oxalacetic transaminase (AST) were determined to evaluate liver function. The liver was also scanned by sonography, and abnormal hepatic sonograms were documented. NAFLD was diagnosed according to the criteria recommended by the Fatty Liver and Alcoholic Liver Disease Study Group under the Chinese Liver Disease Association. Analysis of covariance (ANOVA), Chi-square test for trend and binary logistic regression analysis were performed.

Results The dyslipidemia and ultrasonographic fatty liver deteriorated with the degree of obesity defined either by BMI or waist circumference. Compared with BMI, waist circumference contributed more to the development of dyslipidemia, fatty liver and NAFLD. The highest levels of TG, TC, LDL-C, and lowest level of HDL-C were seen in the mixed obese group followed by abdominal obese, peripheral obese and non-obese ones. Adjusted for gender and age, the odds ratios (ORs) and their 95% confidence intervals of peripheral obesity, abdominal obesity and mixed obesity were 0, 10.93 (0.98-121.96) and 79.16 (10.95-572.44) for predicting NAFLD; 12.61 (1.24-127.78), 19.39 (5.23-71.85), and 93.21 (29.56-293.90) for predicting ultrasonographic fatty liver; 1.78 (0.59-5.44), 3.01 (1.91-4.77), and 4.64 (3.52-6.12) for predicting dyslipidemia, respectively compared with the non-obese control group. The trend of hazards over groups was statistically significant (P<0.01).

Conclusion The levels of lipid profile and the prevalence of NAFLD and dyslipidemia increased in parallel with the degree of obesity; As compared with the non-obese control, the mixed obesity had the strongest association with NAFLD and dyslipidemia, followed by abdominal obesity and peripheral obesity in Chinese school-age Children.

Key words: Obesity type; Degree of obesity; Dyslipidemia; NAFLD; School-age Children

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INTRODUCTION

Obesity is increasing worldwide at a dramatic speed among children today. Children and adolescents are affected not only with obesity itself but also with its adverse consequences[1-2]. Studies have shown the relationship between obesity and several diseases in adults, such as hypertension, type 2 diabetes mellitus, dyslipidemia, non-alcoholic fatty liver disease (NAFLD) and cardiovascular morbidity[3-5]. Although the prevalence of these diseases varies significantly among ethnic groups, NAFLD is increasingly recognized as an important and common factor affecting approximately 20% of the general population[6-8].

NAFLD was initially thought to be a benign condition largely limited to middle-aged obese women with diabetes. However, recent studies have shown that it is a far more complex disease that is found in both men and women, as well as in children, especially in overweight and obese school-age children[9]. It may develop to end stage liver disease and is closely associated with obesity and insulin resistance that are dramatically increasing among children. This could potentially make NAFLD the most common liver disease in the pediatric population. Although limited information is currently available on the natural history of the disease in the pediatric population, a few cross-sectional studies and a single longitudinal cohort study with a 16 years follow-up[10] have shown that NAFLD among children may have a progressive clinical course with the development of cirrhosis just like in adults. Timely discovery and early intervention for the high-risk obese children can reduce and delay this progressive clinical course. Thus, it is of great importance to investigate obese children and to seek sensitive indices as predictors of early hepatic lesion and related dyslipidemia.

To investigate the impacts of obesity on NAFLD and related dyslipidemia we used the quintiles of Z-scores of body mass index (BMI) and waist circumference to cluster all the subjects into 5 levels to represent the degree of peripheral obesity and abdominal obesity in this study, respectively. Using the combination of BMI and waist circumference, all the participants were categorized into four groups [non-obesity, peripheral obesity, abdominal obesity, and mixed obesity (with both peripheral and abdominal obesity)]. The characteristic of NAFLD and dyslipidemia are further examined for the different obesity types in Chinese school-age children.

MATERIALS AND METHODS

Subjects

A cluster sampling technique was used in this study. Four elementary schools and four middle schools in Haidian district in Beijing were selected. Four classes in each grade were selected and all students of the selected classes were asked to participate in the survey. A fact sheet explaining the purpose and procedure of the survey was given to each student and their parents, and the parents of all the participants were invited to complete a questionnaire listing demographic information including gestation, birth weight, feeding pattern and family or personal history of risk factors for obesity and liver diseases. In total, 1 452 school-children aged 7-17 years were enrolled from these eight schools. The study was approved by the Ethics Committee of the Capital Institute of Pediatrics.

Anthropometric Measurement

A team of trained research staff collected the anthropometric data. All instruments were standardized before the examination and the balances were zero calibrated. Standing height without shoes was measured twice with a standard scale to the nearest 0.1 cm[11]. Body weight and fat mass percentage (FMP) were measured with the lightest clothing to the nearest 0.1 kg by an electronic weighting scale (Tanita TBF-300A, Japan). Waist circumference was measured midway between the lowest rib and the superior border of the iliac crest with an inelastic measuring tape at the end of normal expiration to the nearest 0.1 cm[12]. The data inconsistencies were checked twice by two team members.

Laboratory Test

Blood samples were collected from all the participants in the field at approximately 8:00 AM after an overnight fast. Serum glutamate-pyruvate transaminase (ALT), aspartate aminotransferase (AST), triglycerides (TG), cholesterol (TC), high density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured through standard laboratory methods (Automatic Biochemical Detector, TECHNICON RA1000, USA).

Liver Scan

Liver echography was performed by the same operator implementing standard criteria (TOSHIB SSA-340A Color Doppler Imaging) and the results of ultrasonographic fatty liver were recorded[13].

Definition and Standards

Obesity: The sex-, age-specific BMI cutoffs[14] recommended by the Working Group on Obesity in China were used to define obesity. Abdominal obesity: Those whose waist circumferences were equal or greater than the 90th percentiles for age and gender of schoolchildren in China (Supplemental Table 1)[15] were defined as abdominal obesity. NAFLD: Ultrasonographic fatty liver refers to the accumulation of fat, mainly TG, in hepatocytes that exceeds 5% of the liver weight. NAFLD was diagnosed according to the criteria recommended by the Fatty Liver and Alcoholic Liver Disease Study Group under the Chinese Liver Disease Association[16]. Dyslipidemia: Hypertriglyce ridemia, TG⩾1.70 mmol/L(150 mg/dL); Hypercholesterolemia, TC⩾5.18 mmol/L(200 mg/dL); Low levels of serum high-density lipoprotein, HDL-C<1.04 mmol/L (40 mg/dL); High levels of serum low-density, LDL-C⩾ 3.37 mmol/L (130 mg/dL)[17], and dyslipidemia was defined as including at least one of the four lipid profiles displayed above.

Grouping

Degree of Obesity: Z-score, the deviation of the value for an individual from the median value of the reference population, was used to evaluate the degree of obesity. The reference population to calculate Z-BMI (Z-score of BMI, Z-BMI) was that from the national survey in school-aged children and adolescents[18]. The reference population for Z-WC (Z-score of waist circumference , Z-WC) was that from the national survey in school-aged children and adolescents(Supplemental Table 2). The quintiles of Z-BMI were used to cluster the participants into 5 degrees of obesity, and the quintiles of Z-WC were used to cluster the participants into 5 degrees of abdominal obesity.

$$\text{Z-score or SD-score} = \frac{\text{(observed value)} - \text{(median reference value)}}{\text{standard deviation of reference population}}$$

Types of obesity: The types of obesity including peripheral obesity, abdominal obesity, mixed obesity and non-obesity (control) were defined according to the combination of BMI and waist circumferen ce. Peripheral obesity refers to subjects with high BMI (obesity) but normal waist circumference, and abdominal obesity means subjects with high waist circum ference but normal BMI (normal weight or overweight), and the mixed obesity indicates that obesity was determined by both BMI and waist circumference. The characteristic of the four types of obesity were described as follows. (Table 1)

Table 1. Definition of Obesity Types

Obesity Types	BMI	Waist Circumference
Non-obese	Normal	Normal
Peripheral obesity	Obesity	Normal
Abdominal obesity	Normal	Obesity
Mixed obesity	Obesity	Obesity

Statistical Analysis

Variables including TG, ALT, and AST were skewed distribution and natural logarithmical transformations were perform ed before analysis. Analysis of covariance (ANOVA) was used to compare the levels of serum lipid and transaminase among groups with different degree of obesity and different obesity types, and Chi-square test was used for categorical variables. Binary logistic regression model were performed to compare the relative risk of dyslipidemia, ultrasonographic fatty liver and NAFLD among different levels of obesity degree, and the contribution of BMI and waist circumference to dyslipidemia, ultrasono graphic fatty liver and NAFLD. Age and gender were controlled as covariates. *Z*-scores of BMI and waist circumference were calculated with the formula as below: $P<0.05$ was denoted as statistical significance.

RESULTS

Characteristics of the Subjects

In total, 810 boys and 642 girls participated in the survey, and the sex ratio (male/female) was 1.26. The differences between boys and girls for waist circumference, FMP and the prevalence of ultrasonographic fatty liver and NAFLD were statistically significant (Table 2). The levels of BMI and waist circumference were higher and the conditions of ultrasonographic fatty liver and NAFLD were more serious in boys than in girls ($P<0.01$). Age and gender were adjusted in the following analysis.

Table 2. Demographic and Other Data on Boys and Girls ($\bar{X} \pm s$)

Items	Boys (*n*=810)	Girls (*n*=642)	*t test*
Age(year)	12.5±2.8	12.4±2.6	0.407
BMI(kg/m^2)	23.6±5.5	23.0±5.4	2.078
WC(cm)	77.4±14.8	72.1±12.5*	7.207
FMP(%)	24.6±8.4	30.0±11.0*	-10.747
TC(mmol/L)	4.12±.068	4.18±0.67	-1.623
TG(mmol/L)	0.98(0.73-1.30)	1.01(0.76-1.34)	-1.373^a
HDL-C (mmol/L)	1.42±0.35	1.44±0.34	-0.871
LDL-C (mmol/L)	2.24±0.57	2.28±0.56	-1.097
ALT (U/L)	22±24	16±18	5.209
AST (U/L)	25±12	22±9	5.947
Ultrasonographic Fatty Liver (%)	16.3(132/808)	10.1(65/641)*	11.37^b
NAFLD (%)	6.8(55/808)	2.3(15/641)*	15.314^b

Note. a, Data were expressed as geometric mean and followed by inter-quartile and natural logarithm transformation were used before analysis; b, χ^2 in chi-square test; $^*P$<0.01.

To compare the impact of BMI and waist circumference on the NAFLD and related dyslipidemia, *Z*-scores of BMI and waist circumference were used to replace the original records, and were calculated with the following formula: *Z*-score = $(x-\bar{x})/s$, here *x* means observed value, $\bar{x}$ means the mean value of the reference population, and *s* means the standard deviation of the reference population. The quintiles of *Z*-BMI and *Z*-WC were used to cluster the participants into 5 groups with different levels of obesity degree. In ANOVA, after adjusting for gender and age, the levels of TC, TG and LDL-C increased, but the level of HDL-C decreased with the obesity degree. The trend chi-square analysis showed that the prevalence rates of ultrasonographic fatty live and NAFLD increased with the obesity degree (Table 3).

The dyslipidemia, ultrasonographic fatty liver and NAFLD were used as the dependent variables, while Z-BMI and Z-WC as the independent variables in binary logistic regression. After adjusting for gender and age, waist circumference contributed more to the variation of dyslipidemia, ultrasonographic fatty liver and NAFLD than BMI (Table 4).

BMI was recommended as an index of peripheral obesity and waist circumference as one of indices of abdominal obesity. Four obesity types were defined according to both BMI and waist circumference. The levels of TC, TG, LDL-C, ALT, and AST increased and the level of HDL-C decreased with the sequence of peripheral obesity, abdominal obesity and mixed obesity, while the prevalence of ultrasonographic fatty liver and NAFLD increased with the same sequence of the obesity types (Table 5).

Compared with the non-obese control, the *ORs* in the binary regression analysis proclaimed that there was the highest risk for dyslipidemia, ultrasonographic fatty liver and NAFLD in mixed obesity, followed by abdominal obesity and peripheral obesity (Table 6).

DISCUSSION

How does NAFLD develop? Ultrasonographic fatty liver is defined when the accumulation of fat, mainly triglycerides, in hepatocytes exceeds 5% of the liver weight, and NAFLD refers to ultrasonographic fatty liver accompanied with liver function disruption[19].

NAFLD primarily results from insulin resistance, and it usually happens as part of the metabolic changes which may also cause type 2 diabetes mellitus and dyslipidemia. Furthermore it refers to a wide spectrum of diseases ranging from simple hepatic steatosis to non-alcoholic steatohepatitis (NASH). The incidence of NAFLD is increasing due to increased risk for obesity, diabetes, and insulin-resistance syndrome[20]. A number of studies have proved that excessive body fat, mainly in the form of abdominal obesity, is strongly associated with dyslipidemia, high blood pressure, hyperinsulinemia, and high fasting glucose levels[21]. Accumulation of hepatic triglyceride happens when lipid influx and de novo synthesis exceeds hepatic lipid export and utilization. Insulin resistance, as an important driving force, promotes lipolysis of peripheral adipose tissue, which in turn increases free fatty acid (FFA) influx into the liver. Hyperinsulinemia and hyperglycemia also promote

Table 3. The Changes of the Risk Factors with the Degree of Obesity

Index[a]	Levels	Lipid profiles(mmol/L)				Liver function (U/L)		Ultrasonographic fatty	NAFLD [%(n/N)][b]
		TC	TG	HDL-C	LDL-C	ALT	AST	Liver[%(*n*/*N*)][b]	
Z-BMI	quintile1	4.08±0.05	0.8(0.7-1.0)	1.65±0.02	2.00±0.04	11(9-14)	22(19-26)	0(0/203)	0(0/203)
	quintile2	4.10±0.04	0.9(0.7-1.1)	1.56±0.02	2.06±0.03	12(10-15)	22(19-25)	0.6(2/331)	0.3(1/331)
	quintile3	4.06±0.04	1.0(0.8-1.3)	1.40±0.02	2.24±0.03	15(11-18)	21(17-24)	5.5(14/255)	0.7(2/255)
	quintile4	4.20±0.04	1.1(0.8-1.5)	1.35±0.02	2.40±0.03	17(12-23)	21(18-26)	15.5(46/297)	3.4(10/297)
	quintile5	4.25±0.04	1.2(0.9-1.5)	1.27±0.02	2.49±0.03	23(14-34)	24(19-29)	37.2(135/363)	15.7(57/363)
F		5.488	33.84	64.505	30.031	94.057	11.564	228.115	129.505
P		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Z-WC	quintile1	4.09±0.04	0.8(0.7-1.0)	1.62±0.02	2.01±0.03	13(4-14)	22(13-23)	0(0/289)	0(0/289)
	quintile2	4.08±0.04	0.9(0.7-1.1)	1.56±0.0.2	2.07±0.03	13(9-14)	21(19-26)	0.7(2/291)	0.3(1/291)
	quintile3	4.08±0.04	1.0(0.8-1.4)	1.41±0.02	2.26±0.03	14(10-16)	20(18-25)	5.2(15/290)	1.0(3/290)
	quintile4	4.20±0.04	1.1(0.8-1.5)	1.32±0.02	2.42±0.03	18(11-19)	22(17-25)	14.5(42/290)	5.5(16/290)
	quintile5	4.29±0.04	1.2(0.9-1.6)	1.23±0.02	2.53±0.03	25(13-26)	25(18-27)	47.8(138/289)	17.3(50/289)
F		6.163	39.970	71.511	33.772	111.223	15.482	293.877	99.446
P		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note. TG, ALT and AST were expressed as geometric mean and (P_{25}-P_{75}); a, the quintiles of the Z-score of BMI and waist circumference were used to classify all the participants into 5 levels; b, trend chi-square analysis was used and χ^2 was calculated.

Table 4. Comparison of BMI and Waist Circumference in Binary Logistic Regression Analysis as Predictors of NAFLD and Dyslipidemia

Dependent Variables	Independent Variables	β_i	*s(βi)*	*Wald*χ^2	*P*	*OR*	95% *CI*
HTG	Z-BMI	0.388	0.054	51.039	0.000	1.474	1.325-1.640
	Z-WC	0.486	0.059	68.681	0.000	1.626	1.449-1.824
HTC	Z-BMI	0.257	0.064	16.073	0.000	1.293	1.140-1.466
	Z-WC	0.314	0.067	21.797	0.000	1.368	1.200-1.561
LHDL-C	Z-BMI	0.392	0.051	58.370	0.000	1.479	1.338-1.636
	Z-WC	0.443	0.055	65.666	0.000	1.557	1.399-1.734
HLDL-C	Z-BMI	0.487	0.065	56.890	0.000	1.627	1.434-1.847
	Z-WC	0.573	0.070	67.162	0.000	1.774	1.547-2.035
Dyslipidemia	Z-BMI	0.411	0.040	105.350	0.000	1.508	1.394-1.631
	Z-WC	0.505	0.044	133.275	0.000	1.657	1.521-1.805
Ultrasonographic Fatty Liver	Z-BMI	1.033	0.075	187.459	0.000	2.809	2.423-3.257
	Z-WC	1.404	0.101	194.675	0.000	4.070	3.341-4.957
NAFLD	Z-BMI	0.951	0.103	84.897	0.000	2.589	2.115-3.169
	Z-WC	1.206	0.124	94.013	0.000	3.339	2.617-4.261

Note. We use Z-scores of BMI and waist circumference to replace the original records.

Table 5. The Levels of the Risk Factors in the Different Types in ANOVA or Trend Chi-square Analyses

Besity Types[a]	Lipid Profiles(mmol/L)				Liver Function(U/L)		Ultrasonographic Fatty Liver[%(*n*/*N*)][b]	NAFLD[%(*n*/*N*)][b]
	TC	TG	HDL-C	LDL-C	ALT	AST		
Non-obese(681)	4.08±0.03	0.9(0.7-1.1)	1.57±0.01	2.06±0.02	12(10-15)	21(19-25)	0.4(3/680)	0.1(1/680)
Peripheral Obesity (22)	4.24±0.14	1.1(0.9-1.4)	1.51±0.07	2.30±0.11	17(12-24)	21(18-27)	4.5(1/22)	0(0/22)
Abdominal Obesity (112)	4.01±0.06	1.1(0.8-1.5)	1.35±0.03	2.27±0.05	14(11-18)	21(17-24)	8.9(10/112)	1.8(2/112)
Mixed Obesity (637)	4.24±0.03	1.2(0.9-1.5)	1.29±0.01	2.46±0.02	21(23-29)	23(18-28)	28.8(183/635)	10.6(67/635)
F	8.285	71.035	93.005	61.215	120.399	7.675	219.043	74.237
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note. TG, ALT, and AST were expressed as geometric mean and (P_{25}-P_{75}); a, both BMI and waist circumference were used to classify all the participants into 4 types; b, trend chi-square analysis was used and χ^2 was calculated.

Table 6. Odds Ratios of Obesity Types in Binary Logistic Regression Analyses in Predicting NAFLD and Dyslipidemia

Obesity Types	HTG	HTC	LHDL-C	HLDL-C	Dislipidemia	Fatty Liver	NAFLD
Non-obese	1	1	1	1	1	1	1
Peripheral Obesity	1.17 (0.15-9.11)	1.00 (0.13-7.76)	2.83 (0.60-13.26)	0.000	1.78 (0.59-5.44)	12.61 (1.24-127.78)	0.000
Abdominal Obesity	5.00 (2.55-9.82)	0.63 (0.19-2.11)	3.89 (2.19-6.94)	2.44 (0.92-6.44)	3.01 (1.91-4.77)	19.39 (5.23-71.85)	10.93 (0.98-121.96)
Mixed Obesity	6.01 (3.81-9.48)	2.37 (1.51-3.72)	4.42 (2.98-6.56)	7.03 (4.02-12.31)	4.64 (3.52-6.12)	93.21 (29.56-293.90)	79.16 (10.95-572.44)

de novo lipogenesis, and indirectly inhibit FFA oxidation[22]. Lipids excreted by the liver may also be impaired among individuals with NAFLD because of defective incorporation of triglyceride in apolipoprotein carrier proteins[23]. The abdominal obesity increases plasma levels of free fatty acid (FFA) because these adipocytes have higher lipolytic activity. Consequently, the abdominal obesity increases the FFA levels in the portal circulation, and insulin resistance may also account for such an increase[24-25]. A large amount of FFA increases triglycerides serum levels, and may exceed the synthetic capacity of very low-density lipoprotein (VLDL), promoting its storage in the liver, which is known as fatty liver[26]. However，related studies among children and adolescents were limited.

The results of this study showed that the lipid disturbance was associated with the levels of ultrasonographic fatty liver and NAFLD. Both of them were affected by the degree of obesity, especially by the fat deposit in abdomen. Our data showed that waist circumference better accounted for the conformance between fatty liver and NAFLD in school-age children in China.

Epidemic of NAFLD in children and adolescents: The incidence of NAFLD has increased since the first case of pediatric non-alcoholic steatohepatitis (NASH) was described in 1983[27]. However, the actual prevalence of NAFLD and NASH in children remains largely unknown because of the lack of population-based studies and reliable noninvasive screening tools. By using liver echography, a large study of school-age children in Japan showed that the prevalence of NAFLD was 2.6%[21]. A recent study in necropsy specimens in San Diego has suggested a higher prevalence: 17% of children aged between 9 to 19 years had fatty liver disease[28]. Moreover, several studies in different countries selectively examined the prevalence of NAFLD in groups of obese children and found that it might range from 23% to 77%[29-30]. In the National Health and Nutrition Examination survey conducted in the United States from 1988 to 1994, more than 20% of the children aged 12 to 17 years were overweight (85th percentile of BMI in kg/m^2 for age) and 8% to 17% were obese (95th percentile of BMI for age) in different ethnic groups. Among younger children more than 10% aged 6 to 12 years were overweight[31]. Among adolescents, 60% with elevated ALT levels were either overweight or obese, who, though having the modest alcohol consumption, were at an increased risk of developing obesity related liver disease[32]. In 228 obese Japanese children aged 6 to 15 years, hyperinsulinemia was an important contributor to the development of fatty liver, apparently more than anthropometric data, blood glucose, or serum lipids[33].

Interventions for NAFLD in obese pediatric population: With the increasing prevalence of obesity and type 2 diabetes mellitus in the general population, NAFLD has become a common diagnosis in clinical practice. NAFLD affects one out of three adults and one out of ten school-aged children in the United States. Mortality in patients with NAFLD is significantly higher than in the general population of the same age and gender with liver-related complications[34]. Among obese school-age children, the prevalence of NAFLD is significantly higher, ranging from 10% to 25%[31,35-36] based on elevated ALT compared with 42% to 77% based on echography[37].

Obesity in children has become a public health concern worldwide. Patients diagnosed with NAFLD should undergo evaluation and treatment of accompanying metabolic risk factors, such as obesity, glucose intolerance, and dyslipidemia in order to reduce the risk of morbidity and mortality from cardiovascular disease. Data from studies performed mainly in tertiary medical centers showed that the prevalence of NAFLD in obese children was reported to range from 20% to 77%[37]. Because alcohol consumption and hepatic viral infections are uncommon at this age[38] fatty liver in children is caused predominantly by NAFLD. Obesity, hyperglycemia and hypertriglyceridemia are the most important risk factors for NAFLD in adults, and insulin resistance is hypothesized to play a central role in its pathogenesis. Based on current evidences, NAFLD should be considered a manifestation of the metabolic syndrome. There is increasing evidence that obesity, hyperglycemia and insulin resistance are risk factors for NAFLD in children[39-40]. Timely discovery and early intervention for the high-risk obese children can reduce and delay this progressive clinical course. Thus, it is of great importance to investigate the obese children and to seek the sensitive index predicting early hepatic lesion and related dyslipidemia. Our data have shown that the mixed obesity has the strongest association with NAFLD and related dyslipidemia followed by abdominal obesity and peripheral obesity. So the mixed obesity, as the highest risk factors, should attract greatest attention from health-care workers and the society.

Some limitations of this study: The results of this study showed that the levels of lipid profile and the prevalence of NAFLD and dyslipidemia increased with the degree of obesity, while the mixed obesity had the strongest association with NAFLD and dyslipidemia, followed by abdominal obesity and peripheral obesity in Chinese school-age children. The sample size was limited and there were only 22 subjects and non NAFLD in the peripheral obesity group. Such a small number of subjects was insufficient to calculate *OR*. While the pattern displayed by dyslipidemia, fatty liver and NAFLD with the sequence of non-obesity, peripheral obesity, abdominal obesity and mixed obesity showed a higher risk of the fat deposit in abdomen to human health, fat depositing in both abdomen and other parts of the body had the strongest association with dyslipidemia, ultrasonographic fatty liver and NAFLD. Hence, we should pay more attention to the obese school-age children, especially to those with abdominal obesity and mixed obesity, help them manage their weight and lead a healthy life. As a limitation of this study, its conclusion is drawn from a cross-sectional survey, and therefore the findings need to be further explored by other studies.

Supplemental Table 1. Optimal Cut-off Points (cm) of Waist Circumference

Age(y)	90th Percentile	
	Boys	Girls
7	63.6	60.2
8	66.8	62.5
9	70.0	65.1
10	73.1	67.8
11	75.6	70.4
12	77.4	72.6
13	78.6	74.0
14	79.6	74.9
15	80.5	75.5
16	81.3	75.8
17	82.1	76.0

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Abbreviations: BMI, body mass index; NAFLD, non-alcoholic fatty liver disease; ANOVA, analysis of variance; SD, standard deviation.

Supplemental Table 2. Mean and SD (cm) of Waist Circumference

Age	Boys			Girls		
(y)	*N*	Mean	SD	*N*	Mean	SD
7	5618	55.6	6.7	5269	53.3	6.0
8	5609	57.4	7.5	5457	54.7	6.4
9	5548	59.9	8.3	5221	56.6	6.8
10	5594	62.2	8.9	5471	58.9	7.5
11	5657	64.5	9.6	5481	61.0	7.5
12	5510	66.0	9.7	5502	63.4	7.7
13	5536	67.3	9.2	5412	64.9	7.3
14	5276	68.6	9.0	5232	66.1	7.1
15	5422	70.0	8.9	5387	67.1	6.8
16	5255	70.9	8.4	5226	67.9	6.7
17	5330	71.5	8.3	5295	67.9	6.6

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