Childhood obesity-related cardiovascular risk factors and carotid intima-media thickness

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The purpose of this study was to investigate the relationship between childhood obesity and carotid intima-media thickness (IMT). This is a cross-sectional study in obese children and non-obese control subjects. This study included 75 obese children and 40 non-obese control children. Systolic and diastolic blood pressure (SBP, DBP) values and waist and hip circumferences were measured. Fasting blood glucose and insulin concentrations, total cholesterol, triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were assayed. The carotid IMT was measured by high resolution B-mode ultrasonography. Waist/hip ratios, SBP and DBP were significantly increased in the obese group compared to the non-obese children (all $p<0.001$). The total cholesterol, LDL-C, HDL-C, and TG in the obese children were significantly different from values in the control subjects (all $p<0.001$). Compared to the controls, the obese children demonstrated significant differences in a number of clinical risk factors including body weight, body mass index (BMI), BMI-standard deviation score (SDS), SBP/DBP, waist circumference, hip circumference, and waist/hip ratio (all $p<0.001$). Compared to the controls, the obese children showed increased mean carotid IMT values [0.52 mm (95% confidence interval [CI], 0.40 - 0.64 mm) *vs.* 0.35 mm (95% CI, 0.24 - 0.38 mm), $p<0.001$]. Univariate correlation analysis revealed that the carotid IMT was closely related to the BMI-SDS, SBP/DBP, waist and hip circumferences, serum TG, cholesterol, LDL-C, HDL-C, fasting serum insulin level, and insulin resistance indices including the homeostasis model assessment of insulin resistance (HOMA-IR), fasting glucose-to-insulin ratio (FGIR), and quantitative insulin-sensitivity check index (QUICKI). Multiple regression analysis showed that the BMI-SDS, TG and QUICKI were independent predictive risk factors for increased carotid IMT. Measurements of BMI-SDS, blood pressure, waist and hip circumferences, serum TG levels, the QUICKI insulin resistance index, and carotid IMT by ultrasonography are suitable in pediatric patients in a clinical setting and may be used for screening of obese children.

Key words: childhood obesity, carotid intima-media thickness, risk factors.

Over the past two decades, the prevalence of childhood obesity has been increasing at an alarming rate, not only in developed countries but also in developing countries[1-4]. Obesity is associated with several cardiovascular risk factors including dyslipidemia, hyperinsulinemia, hypertension, and early atherosclerosis in adults as well as children and adolescents[5-9]. Children who are overweight and obese are more likely to become overweight and obese adults[10,11]. Exposure to these cardiovascular risk factors early in life can induce changes in the arteries that contribute to the development of atherosclerosis in adulthood[12]. The risk factor-specific guidelines for primary prevention in children and adolescents include the assessment of conventional risk factors such as serum lipids, blood pressure and obesity to identify children at high risk of future cardiovascular diseases[13]. However, the

Table I. Clinical Characteristics, Laboratory Data and Carotid IMT Values in Obese Children and Non-Obese Controls

	Obese children (n=75)	Controls (n=40)	p
Age (y)	10.79 ± 2.03	10.94 ± 2.10	0.717 [a]
Sex: male/female, n (%)	39 (52%) / 36 (48%)	23 (57.5%) / 17 (42.5%)	0.573 [b]
Pre-pubertal/pubertal, n (%)	25 (33.3%)/50 (66.7%)	14 (35%) / 26 (65%)	0.857 [b]
Height-SDS ± SD	0.011 ± 1.14	0.012 ± 0.78	0.112[c]
Weight-SDS ± SD	2.28 ± 0.76	0.10 ± 0.84	<0.001[c]
BMI-SDS ± SD	2.84 ± 0.49	0.29 ± 0.96	<0.001 [c]
SBP (mmHg)	113 (90-140)	98 (80-120)	<0.001 [c]
DBP (mmHg)	84 (50-100)	62 (50-80)	<0.001 [c]
Waist circumference (cm)	89.6 ± 7.65	66.2 ± 8.5	<0.001 [c]
Waist-SDS ± SD	4.39 ± 1.36	1.33 ± 1.30	<0.001 [c]
Hip circumference (cm)	95.0 ± 9.0	76.9 ± 8.6	<0.001 [c]
Waist / Hip ratio	0.94 ± 0.03	0.83 ± 0.11	<0.001 [c]
Triglycerides (mg/dl)	160 (65-377)	78.5 (42-176)	<0.001 [c]
Total cholesterol (mg/dl)	175 (99-305)	101 (66-168)	<0.001 [c]
LDL-cholesterol (mg/dl)	92 (30-233)	66.3 (36-110)	<0.001 [c]
HDL-cholesterol (mg/dl)	47 (13-86)	52.5 (43-92)	<0.001[c]
Total homocysteine (μmol/L)	8.2 (4.5-23.2)	8.2 (5-16)	0.812 [c]
Lipoprotein A (mg/L)	136 (15-1240)	93 (24-213)	0.004
Fasting glucose (mmol/L)	4.8 ± 0.4	4.7 ± 0.3	0.737 [c]
Fasting insulin (μU/mL)	14.5 ± 8.4	6.6 ± 1.2	<0.001[c]
HOMA-IR	3.11 ± 2.01	1.38 ± 0.26	<0.001 [c]
QUICKI	0.33 ± 0.03	0.36 ± 0.01	<0.001[c]
FGIR	7.63 ± 4.95	13.49 3.30	<0.001[c]
IMT (mm)	0.52 (0.40-0.64)	0.35 (0.24-0.38)	<0.001[c]

Results are expressed as mean ± standard deviation or median (min-max).
SDS: Standard deviation score. SD: Standard deviation. SBP: Systolic blood pressure. DBP: Diastolic blood pressure. LDL: Low-density lipoprotein. HDL: High-density lipoprotein. HOMA-IR: Homeostasis model assessment of insulin resistance. QUICKI: Quantitative insulin-resistivity check index. FGIR: Fasting glucose-insulin ratio. IMT: Intima-media thickness.
[a], Student's t test
[b], Pearson's chi-square test
[c], Mann-Whitney U test

mechanisms of how a given cluster of risk factors influences the early development of vascular pathology in children are incompletely understood.

Measurement of the carotid artery intima-media thickness (IMT) as an early marker of atherosclerosis is feasible, reliable and cost-effective[12,14-16]. Studies in adults have revealed that an increased carotid artery IMT is related to hypertension, dyslipidemia and obesity[17-19] and serves as an indicator of generalized atherosclerosis and a strong predictor of future cardiovascular morbidity and mortality[20,21]. Increased carotid artery IMT values in adulthood have been significantly associated with obesity indices in subjects who had been consistently obese from childhood to adulthood[22]. The existing evidence indicates that the prevention of atherosclerosis should begin in childhood; however, there is still no consensus regarding the definition of childhood obesity-related predictive risk factors for adulthood atherosclerotic cardiovascular diseases.

In the present study, we examined the association between childhood/adolescent obesity-related

risk factors for cardiovascular disease and carotid artery IMT as a marker of structural subclinical childhood atherosclerosis.

Material and Methods

Subjects and Study Protocol

Our study included 75 obese subjects (36 girls and 39 boys, mean age 10.8 ± 2.03 years, mean body mass index [BMI] 27.9 ± 3.67 kg/m^2, mean BMI-standard deviation score [BMI-SDS; see below for definition] 2.84 ± 0.49, 25 prepubertal and 50 pubertal) and 40 non-obese control subjects (17 girls and 23 boys, mean age 10.9 ± 2.11 years, mean BMI 18.2 ± 2.54 kg/m^2, mean BMI-SDS 0.29 ± 0.96, 14 prepubertal and 26 pubertal) whose clinical characteristics are listed in Table I. A detailed medical and family history was obtained from all subjects. Children were excluded if they had any condition known to influence body composition, insulin action or insulin secretion (e.g., glucocorticoid therapy, hypothyroidism, and Cushing syndrome) or a history of medication use that could affect the carotid artery IMT or lipid profile. At enrollment, obese and control subjects underwent physical examination including weight, standing height, BMI, and blood pressure measurements and the determination of puberty stage according to the criteria of Marshall and Tanner[23,24]. Height was measured without shoes using a Harpenden stadiometer (Harpenden, Holtain Ltd., UK) to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg on a standard beam scale with the subject dressed only in light underwear and without shoes. All the measurements were repeated twice. The height values were expressed as the SDSs relative to growth standards applicable at the time to adjust for sex, skew and variations in age[25]. The weight status was recorded as the BMI, calculated as follows: BMI = weight (kg)/height (m)^2. Because the BMI varies according to age, we standardized the value for age and sex by converting to a "z score"[26] and expressed the value as the BMI-SDS, which was calculated as follows: BMI-SDS = [individual measurement – population mean] / population SD. Obesity was defined as a BMI that exceeded the 97th percentile using the definition of the International Task Force of Obesity in Childhood and population-specific data[26,27]. A non-obese subject was defined as having a BMI less than the 95th percentile. The distribution of fat mass was expressed by the waist-to-hip ratio (waist circumference / hip circumference). The waist circumference was measured at its smallest point between the iliac crest and rib cage, and the hip circumference was measured at its largest width over the greater trochanters. Calculation of the waist SDS values was based on the national reference data for waist circumference of Turkish children[28]. Waist circumference for chronological age and sex was expressed as SDS according to the following formula:

Child's WC – Mean WC for age and sex

Waist circumference (WC) SDS =SD for WC at that age and sex

The subjects were categorized into two groups according to the pubertal stage (prepubertal: boys with pubic hair and gonadal stage I, girls with pubic hair and breast stage I; pubertal: boys with pubic hair and/or gonadal stage ≥II and girls with pubic hair and/or breast stage ≥II). The resting systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice in the right arm after a 10-minute (min) rest in the supine position by one investigator using a standard mercury sphygmomanometer and a validated protocol[29]. All subjects were considered hypertensive when the SBP and/or DBP was ≥ 95th percentile for age, sex and height according to a percentiles chart for Turkish children[30].

Biochemical Analysis

On the first visit after enrollment, blood samples were drawn after an overnight fast from both groups. The laboratory tests included the determination of serum concentrations of glucose, insulin, total cholesterol (TC), triglycerides (TGs), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), lipoprotein A, and homocysteine. Glucose was measured using the glucose-oxidase method. Fasting insulin was analyzed with a radioimmunochemical method (Pharmacia & Upjohn Diagnostics AB, Uppsala, Sweden). The detection limit was 0.5 μU/mL with intra- and interassay coefficients of variation <6%. Fasting TC, TGs and HDL-C concentrations were analyzed using enzymatic

Table II. The Frequencies of Blood Pressure Percentiles in Obese Children and Non-Obese Control Subjects

		Obese children n (%)	Controls n (%)	p
SBP percentile	< 50%	21 (28)	32 (80)	<0.001
	50% - 75%	27 (36)	8 (20)	<0.001
	75% - 90%	14 (18.7)	0 (0)	<0.001
	90% - 95%	3 (4)	0 (0)	<.001
	>95%	10 (13.3)	0 (0)	<0.001
DBP percentile	< 50%	15 (20)	29 (75.2)	<0.001
	50% - 75%	21 (28)	9 (22.5)	<0.001
	75% - 90%	20 (26.7)	1 (2.5)	<0.001
	90% - 95%	8 (10.7)	1 (2.5)	<0.001
	> 95%	11 (14.7)	0 (0)	<0.001

SBP: Systolic blood pressure. DBP: Diastolic blood pressure.

methods (Roche Diagnostics, Mannheim, Germany). LDL-C was calculated using the Friedewald equation[31]: LDL-C (mg/dl) = (TC – HDL-C – TG)/5. Cutoff points above the 95th percentile of healthy children were used to define dyslipidemia[32] and impaired fasting glucose according to international recommendations[33]. Children with TC levels ≥200 mg/dl were considered to have elevated cholesterol, whereas TC levels <170 mg/dl were considered acceptable. TC levels between 170 and 199 mg/dl were borderline. Children with LDL-C levels ≥130 mg/dl were considered to have elevated levels, whereas LDL-C levels <110 mg/dl were considered acceptable. Levels between 110 and 129 were borderline. Children with HDL-C ≥35 mg/dl were considered to have normal levels, whereas children with HDL-C <35 mg/dl were considered to have decreased levels. Children with TC levels ≥170 mg/dl, LDL-C levels ≥130 mg/dl, and TGs levels ≥150 mg/dl were examined for secondary causes (thyroid, liver and adrenal disorders), and all family members were screened for familial lipid disorders. Cases that had a secondary cause of hyperlipidemia or familial lipid disorders were excluded from the study. Total plasma homocysteine was measured by high performance liquid chromatography (HPLC). Intra- and interassay variations for the serum concentrations of this variable were <5%.

Indices of Insulin Resistance Derived from Fasting Blood Samples

We used the following indices for the determination of insulin resistance: the homeostasis model assessment of insulin resistance (HOMA-IR)[34], fasting glucose-to-insulin ratio (FGIR)[35] and quantitative insulin-sensitivity check index (QUICKI)[36]. The HOMA-IR was calculated with the following formula: HOMA-IR = [fasting insulin (μU/ml) x fasting glucose (mmol/L)] / 22.5. The FGIR was calculated as follows: FIGR = [fasting insulin (μU/ml) x fasting glucose (mg/dl)]. The QUICKI was calculated as follows: QUICKI = 1/ [log (I_0) + log (G_0)], where I_0 is the fasting insulin (μU/ml) and G_0 is the fasting glucose (mg/dl). The calculations were performed using a scientific calculator (Casio fx-82ES, Casio Computer Co., LTD, Tokyo, Japan).

Measurement of Carotid Intima-Media Thickness (IMT)

The carotid artery IMT was measured according to a previously described procedure[37]. All measurements were performed by a single trained physician (Z.B.) blinded to the participant's case status and obesity-related risk factors. After participants had rested for about 10 min, the subjects were examined in the supine position with the head turned slightly to the left and then the right. High-resolution B-mode ultrasonography of the right and left carotid arteries was performed with a linear 10-MHz transducer for the GE Logiq S6 ultrasound machine. The depth and gain settings of the B-mode image were optimized for the visualization of the posterior (far) wall of each common carotid artery. On longitudinal 2D ultrasound images of the carotid artery, the near and far arterial walls are displayed as two echogenic lines, the adventitia and intima,

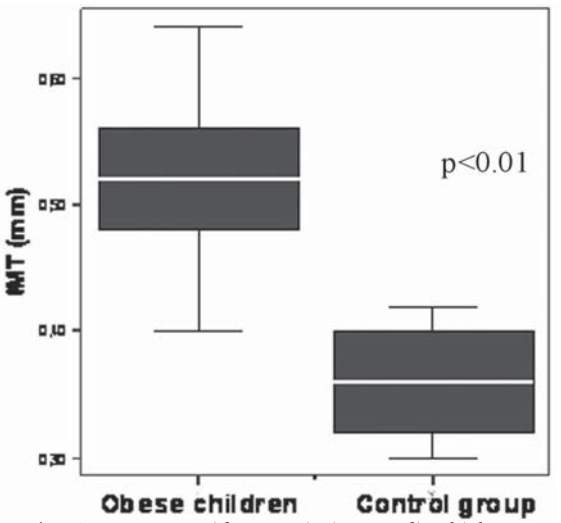

Fig. 1. Mean carotid artery intima-media thickness (IMT) in obese and control children.

separated by the hypoechoic media. The carotid artery IMT was defined as the distance between the leading edges of the lumen interface and the media-adventitia interface of the far wall. A minimum of four measurements of the common carotid far wall 10 mm proximal to the bifurcation on each side were taken, and the maximum value was taken for statistical calculations. The variation of the carotid artery IMT measurements between visits was 5.5%. The intra- and inter-observer variations were 0.3% and 1.5%, respectively.

The study plan was approved by the local ethics committee. Written informed consent was obtained from all participants over 12 years of age, and informed parental consent was obtained for all children regardless of age.

Statistical Analysis

Data were stored and analyzed using the SPSS 15.0 statistical package (SPSS Inc., Chicago, IL). The following variables were included in the analysis: clinical data (WSDS, HSDS, BMI-SDS, SBP, DBP, and pubertal status), biochemical parameters (fasting serum insulin and glucose concentrations, HOMA-IR, FGIR, QUICKI, and lipid profile), and carotid artery IMT. The data are expressed as the mean ± SD or median (min-max) where appropriate. Test selection was based on evaluating the variables for normal distribution using the Shapiro-Wilk test. If the variables had a normal distribution, Student's *t*-test was used. If the variable did not have a normal distribution, the analysis was done using the Mann-Whitney U test. Categorical data were evaluated by Pearson's chi-squared or Fisher's exact test where applicable. Statistical correlations were calculated by Spearman's correlation test. The carotid artery IMT (in mm) and BMI-SDS, as the dependent variable, and age, sex, pubertal stage, SBP-percentile, DBP-percentile, glucose, insulin, insulin resistance indices (HOMA-IR, FGIR, QUICKI), TC, TGs, LDL-C, and HDL-C, as independent variables, were analyzed in a stepwise multiple regression analysis. Logarithmic transformed data for carotid artery IMT and BMI-SDS were used because of the non-normal distribution. P-values <0.05 were considered significant.

Results

Assessment of Clinical Risk Profile

Clinical and laboratory characteristics for the

Table III. The Lipid Profile in Obese Children and Matched Healthy Control Subjects

		Obese children n (%)	Control subjects n (%)	p
Total cholesterol (mg/dl)	< 170 170-199	31 (41.3) 26 (34.7)	40 (100) 0 (0)	<0.001[a] <0.001[a]
	≥ 200	18 (24)	0 (0)	<0.001[a]
LDL-cholesterol (mg/dl)	< 110	52 (69.3)	39 (97.5)	<0.001[a]
	110-129	15 (20)	1 (2.5)	0.010[a]
	≥130	8 (10.7)	0 (0)	0.049[b]
HDL-cholesterol (mg/dl)	≥ 35	68 (91)	40 (100)	0.089[b]
	< 35	7 (9)	0 (0)	
Triglycerides (mg/dl)	< 150	29 (38.7)	39 (97.5)	<0.001[a]
	≥150	46 (61.3)	1 (2.5)	<0.001[a]

LDL: Low-density lipoprotein. HDL: High-density lipoprotein. [a]: Pearson's chi-square. [b]: Fisher's exact test.

obese and control children are summarized in Table I. The obesity and control groups showed no significant differences in terms of age, gender, Tanner stage of puberty (pubertal or prepubertal), or height SDS. Compared to the controls, the obese children demonstrated significant differences in a number of clinical risk factors including body weight, BMI, BMI-SDS, SBP, DBP, waist circumference, hip circumference, and waist/hip ratio (all $p<0.001$). The median SBPs in obese children and control subjects were 113 (94 - 138) mmHg and 98 (76 - 123) mmHg, respectively ($p<0.001$;). Ten (13.3%) of the 75 obese children had systolic and/or diastolic hypertension. None of the control subjects had hypertension. Compared to the controls, the obese children showed increased mean carotid IMT values [0.52 mm (95% confidence interval [CI], 0.40 - 0.64 mm) *vs.* 0.35 mm (95% CI, 0.24 - 0.38 mm), $p<0.001$; Fig. 1].

Assessment of Biochemical Risk Profile

Compared to the controls, the obese children demonstrated elevated TGs, TC and LDL-C (all $p<0.001$), whereas HDL-C was significantly lower in the obese children than in the controls ($p<0.001$). TC was within normal limits in 31 (41.3%) obese children and 40 (100%) controls (see I, $p<0.001$), but was borderline in 26 (34.7%) and elevated in 18 (24%) obese children. LDL-C was elevated in 8 (10.7%) obese children, but was not elevated in any of the control children ($p<0.001$). HDL-C levels were <35 mg/dl in 7 (9%) obese children. Forty-six (61.3%) obese children had elevated TGs; however, only one control subject had elevated TGs ($p<0.001$). The values of total homocysteine in the obese group, which were all within normal ranges, were slightly higher than in the controls, but the difference was not significant ($p=0.812$).

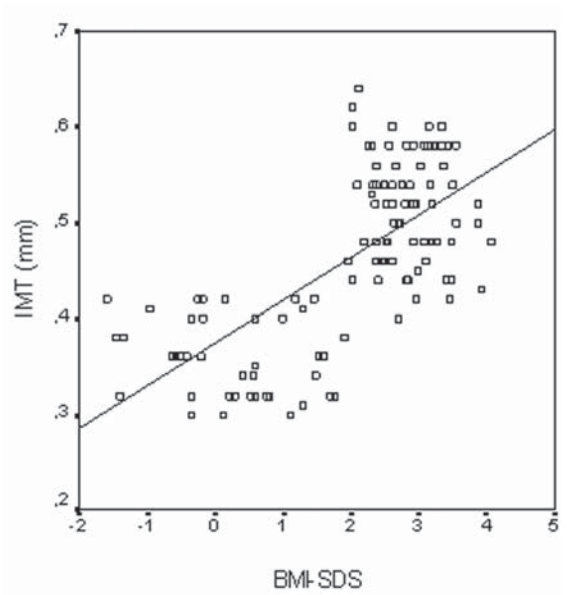

Fig. 2. Relationship between carotid artery IMT and BMI-SDS in obese and control children.

Results of Univariate and Multiple Regression Correlation Analyses Between the Risk Variables of Obesity and Carotid Artery IMT

Table IV shows the univariate correlations between the carotid artery IMT and the other variables associated with obesity. There were no significant relationships between the carotid artery IMT and clinical and laboratory parameters in the controls. The BMI was positively correlated with the carotid artery IMT (Fig. 2). The BMI and carotid artery IMT were positively correlated with the SBP and DBP percentiles, waist and hip circumferences, and waist-to-hip ratio in obese children. The waist and hip circumferences showed the most important correlation with the BMI and carotid IMT. TC, LDL-C and TGs also showed correlations with the BMI and carotid artery IMT. From the aspect of the lipid profile, TC was more correlated than the other lipids. HDL-C showed a significant negative correlation with the BMI and carotid artery IMT. The fasting insulin level, HOMA-IR, FGIR, and QUICKI also showed significant correlations with the BMI and carotid artery IMT, whereas fasting glucose, total homocysteine and lipoprotein A1 showed non-significant correlations with the BMI and carotid artery IMT (Table IV). In the multiple stepwise regression analysis, the BMI-SDS, TGs and QUICKI were correlated with increased carotid artery IMT even after adjusting SBP/DBP, serum lipid profile, fasting glucose and insulin levels, and insulin resistance indices (HOMA-IR, FGIR and QUICKI; Table V).

Discussion

Many studies have found that the BMI in childhood is significantly correlated with

Table IV. Univariate Spearman's Correlation Coefficients Between the Study Variables, Body Mass Index (BMI), and Carotid Intima-Media Thickness (IMT) in Obese Children and Non-Obese Controls

	BMI-SDS		IMT	
	rho	p	rho	p
BMI-SDS				
IMT	-	-	0.646	<0.001
SBP-percentile	0.646	<0.001	-	-
DBP-percentile	0.493	<0.001	0.420	<0.001
Waist circumference	0.480	<0.001	0.456	<0.001
Waist-SDS	0.801	<0.001	0.700	<0.001
Hip circumference	0,740	<0,001	0,604	<0.001
Waist / hip ratio	0.729	<0.001	0.634	<0.001
Total cholesterol	0.631	<0.001	0.580	<0.001
LDL-cholesterol	0.530	<0.001	0.623	<0.001
HDL-cholesterol	0.290	0.002	0.372	<0.001
Triglycerides	-0.341	<0.001	-0.333	<0.001
Fasting glucose	0.454	<0.001	0.582	<0.001
Fasting insulin	-0.005	>0.05	0.183	>0.05
HOMA-IR	0.569	<0.001	0.700	<0.001
FGIR	0.552	<0.001	0.690	<0.001
QUICKI	-0,585	<0.001	-0.682	<0.001
	-0.532	<0.001	-0.684	<0.001

SDS: Standard deviation score. SBP: Systolic blood pressure. DBP: Diastolic blood pressure. LDL: Low-density lipoprotein. HDL: High-density lipoprotein, HOMA-IR: Homeostasis model assessment of insulin resistance. FGIR: Fasting glucose-insulin ratio. QUICKI: Quantitative insulin-resistivity check index.

the BMI in adulthood[38]. Atherosclerosis is a slow and progressive disease that can start in childhood. The duration of obesity may also influence the extent of atherosclerosis. The risk factors of atherosclerosis such as dyslipidemia, obesity, hypertension, diabetes, and insulin resistance have been demonstrated in studies on adults[5-9,12,17-19]. Cross-sectional studies have shown that the carotid artery IMT is associated with the BMI level in adulthood[39,40]. However, information on the association of carotid artery IMT with different risk factors measured in childhood is limited and contradictory. Increased carotid artery IMT has been reported in children with familial hypercholesterolemia[41], diabetes[42,43], hypertension[44], and childhood obesity[45,46]. In our study, we found a significant thickening of the carotid artery IMT in obese children compared to non-obese controls. Previously reported values for the mean common carotid artery IMT in pediatric control subjects have shown a wide variation from 0.32 mm[47] to 0.64 mm[44], while other studies have reported values between these extremes, such as 0.42 mm[48] and 0.50 mm[45]. The mean common carotid IMT values in our control subjects and obese children were 0.35 mm and 0.52 mm, respectively.

Longitudinal studies from childhood to adulthood have suggested that being obese or overweight in childhood may be associated with several risk factors for heart disease and other chronic diseases[49,50]. With obesity, dyslipidemia and elevated blood pressure have been closely related to increased IMT and endothelial dysfunction. Obese children have significantly higher TGs, TC and LDL-C and elevated blood pressure compared to non-obese peers. Interestingly, there are contradictory reports in the literature. Woo et al.[51] studied a cohort of obese subjects of Chinese ethnicity that did not show elevated blood pressure and cholesterol levels compared to a control group and only observed a moderate increase in carotid artery IMT. Tounian et al.[45] did not observe any significant difference in the carotid artery IMT between severely obese children and lean control subjects. Reinehr et al.[52] reported that increasing carotid artery IMT was significantly associated with the degree of weight above normal, SBP, DBP, fasting serum glucose, and high sensitive C-reactive protein concentrations, whereas age, fasting

Table V. Multiple Stepwise Linear Regression Analysis to Evaluate the Correlation Between the IMT (mm) and Other Main Parameters in Obese Children and Non-Obese Controls

	β coefficient	95% confidence interval	t	p
Constant		-0.914 ± -0.272	-3.658	< 0.001
BMI-SDS	0.071	0.051 ± 0.091	6.981	< 0.001
Triglycerides	0.001	0.001 ± 0.002	4.517	< 0.001
QUICKI	-1.350	-2.200 ± -0.500	-3.148	< 0.001

BMI-SDS: Body mass index – standard deviation score. QUICKI: Quantitative insulin-resistivity check index.

insulin levels, TGs, and LDL-C and HDL-C concentrations were not significantly different between children with different carotid artery IMT values. In contrast, dyslipidemia and insulin resistance are important atherosclerotic risk factors[22,53]. Additionally, many studies have reported that the carotid artery IMT is associated with obesity-related risk factors including the BMI[12], hypertension[54], hypercholesterolemia[42], hypertriglyceridemia[55,56], and insulin resistance[57,58]. Many of our results agree with the results of these other studies. The carotid artery IMT was found to be higher in obese children than in non-obese control children. In the present study, the significantly increased carotid artery IMT may be related to the presence of multiple obesity-related risk factors for cardiovascular disease. From the aspect of general health, obese children have many predictive risk factors for developing cardiovascular disease in adult life including hypertension[59], hyperlipidemia[60], insulin resistance, and metabolic syndrome[61]. We found that the frequencies of hypertension, hypercholesterolemia, elevated LDL-C, decreased HDL-C, and hypertriglyceridemia in obese children were 13%, 24%, 10.7%, 9%, and 61.3%, respectively. Our study demonstrated that the carotid artery IMT was closely related to the BMI-SDS, SBP, DBP, waist and hip circumferences, serum TGs, TC, LDL-C, HDL-C, fasting serum insulin level, and insulin resistance indices including the HOMA-IR, FGIR and QUICKI. Multiple regression analysis showed that the BMI-SDS, TGs and QUICKI were independent predictive risk factors for carotid artery IMT.

In view of the present findings, measurements of BMI-SDS, blood pressure, waist and hip circumferences, serum TG levels, the QUICKI, and carotid IMT by ultrasonography, as a convenient non-invasive method, are suitable for pediatric patients in a clinical setting and may be used for screening or for monitoring therapeutic success in obese children.

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