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Myocardial Performance Index and Carotid Intima-Media Thickness in Children with Metabolically Healthy and Metabolically Unhealthy Obesity

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ABSTRACT

Objective: To compare the myocardial performance index (MPI) and carotid intima-media thickness (cIMT) of children who are metabolically healthy obese (MHO) and metabolically unhealthy obese (MUO) with children without obesity.

Methods: This study included obese patients between 6 and 17 years of age and age- and gender-matched healthy children. Two groups of obese patients were investigated: MUO and MHO.

Results: There were 62 obese (MUO=30; MHO=32) and 30 healthy controls included. Compared to controls, the MPI score and cIMT of both obese groups were significantly larger (p=0.004 and p=0.003, respectively). However, there was no significant difference in MPI and cIMT between the MUO and MHO groups. Moreover, there were independent associations between higher MPI and body mass index-standard deviation score (BMI-SDS) (β=0.312, p=0.002) and between higher cIMT and waist circumference-SDS (WC-SDS) (β=0.371, p=0.003).

Conclusion: The primary outcome of the study indicated that while both MPI and cIMT values were elevated in obese children compared to non-obese controls, there was no significant difference between MUO and MHO groups. This suggests that obesity itself, irrespective of metabolic health, is associated with increased cardiovascular risks. BMI-SDS and WC-SDS were useful markers for identifying children at cardiovascular risk in this cohort.

Keywords: BMI, childhood obesity, waist circumference

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What is already known on this topic?

Obesity in children increases cardiovascular risk factors. Myocardial performance index (MPI) and carotid intima-media thickness (cIMT) are established measures of subclinical cardiovascular abnormalities. Body mass index (BMI) and, particularly, waist circumference (WC) have been associated with cardiometabolic risk and subclinical cardiovascular alterations in children with obesity. However, whether these cardiovascular abnormalities differ according to metabolic health status remains unclear.

What this study adds?

This study demonstrates that both metabolically healthy and metabolically unhealthy children with obesity have increased MPI and cIMT compared with non-obese controls, with no significant differences between the two obesity phenotypes. Higher MPI was independently associated with BMI-standard deviation score (SDS), whereas higher cIMT was independently associated with WC-SDS, suggesting that the degree of adiposity may contribute to early cardiovascular alterations irrespective of metabolic health status.

Introduction

Childhood obesity is a global problem leading to various endocrine, metabolic, and cardiovascular comorbidities (1). Changes in eating habits and a general decrease in physical activity associated with modern life-styles have made obesity an endemic disease in many societies.

Adults with obesity who do not exhibit risk factors for metabolic ill-health, such as dyslipidemia, insulin resistance (IR), and hypertension, are termed metabolically healthy obese (MHO). In contrast, those who have one or more of these risk factors are defined as metabolically unhealthy obese (MUO) (2,3). First described and investigated in adults with obesity, these phenotypes have also been extensively studied and confirmed in children and adolescents with obesity (3). Obesity plays an important role in the development of metabolic syndrome (MS). However, not all adults and children with severe obesity have MS or MUO.

The most common cardiovascular disorders (CVDs) due to obesity are increased left ventricular mass, myocardial dysfunction, and increased carotid intima-media thickness (cIMT) (4,5). These early indicators of subclinical CVD have been shown in both pediatric and adult obese cohorts (6,7,8,9). However, the impact of obesity-related conditions, such as IR, dyslipidemia, and arterial hypertension on the development of these CVDs is not yet clear in children.

In recent years, tissue Doppler imaging (TDI) has been more widely adopted to evaluate early changes in left ventricular systolic and diastolic function. Myocardial performance index (MPI) measured with TDI is less affected by age, heart rate, or preload compared to conventional pulsed wave Doppler (cPWD) echocardiography (10,11). The cIMT is a well-known marker of the atherosclerotic process and is a valuable indicator for long-term follow-up of children at high risk of atherosclerosis (12,13).

It has been widely shown that MPI and cIMT are increased in adults with obesity. However, to the best of our knowledge, there are few studies investigating the relationship of obesity-related metabolic factors with the increase in MPI and cIMT in children and adolescents. Therefore, the aim of this study was to compare MPI and cIMT of both MHO and MUO children and adolescents with healthy controls. A further aim was to evaluate the effects of obesity-related metabolic factors.

Methods

Study Design

This study included obese patients between 6 and 17 years of age in the pediatric endocrinology outpatient clinic of a single center. The patients with obesity were divided into two groups, MUO and MHO, based on the same criteria used for adults. The control group comprised age- and gender-matched healthy children and adolescents.

A post-hoc power analysis was conducted to ensure that our sample size was adequate for detecting significant differences in MPI and cIMT between MHO and MUO children, as well as non-obese controls. Based on previous studies in similar populations, an effect size (Cohen's d) of 0.5 was estimated for the cardiovascular measures. Using a two-sided alpha level of 0.05 and a desired power of 0.80, G*Power software calculations indicated that a minimum of 27 participants per group would be required to achieve sufficient statistical power.

This study was approved by the University of Health Sciences Türkiye, Kanuni Sultan Suleyman Training and Research Hospital Clinical Research Ethics Committee (approval no.: 2019/57, date: 22.03.2019). Written informed consent was obtained from the parents of patients and controls. The research related to human use has complied with all the relevant national regulations, and institutional policies and by the tenets of the Helsinki Declaration.

Patients with missing data, secondary obesity, any kind of chronic disease or systemic diseases, and use of medications known to alter blood pressure or lipid or glucose metabolism were excluded. Control subjects were selected from healthy children admitted to the hospital for mild illnesses with a BMI between the 25th and 75th percentile.

Height was measured to the nearest millimeter with a wall-mounted stadiometer, and weight was measured to the nearest 100 g by SECA digital scale with minimal clothes and without shoes. BMI was calculated by dividing the body weight in kilograms by height in meters squared. On the BMI reference curve, which was appropriate for Turkish children and adjusted for age and gender, those with BMI values at or above the 95th percentile were defined as "obese" (14). Waist circumference (WC) was measured using a nonelastic tape at the level of the umbilicus with the child standing and breathing normally. Waist measurements were evaluated using the percentile curves for WC for healthy Turkish children (15). Standard deviation scores (SDS) for BMI and WC were computed using the least mean squares (LMS) method and using the reference data for Turkish children (15,16).

Blood Pressure Measurements

Blood pressure (BP) measurements were made three times at 2-minute intervals on the right arm, in a seated patient, after at least five minutes of rest, by the auscultation method (ERKA®, Germany) with appropriate cuff size according to the age and constitution of the child. The last two BP measurements were averaged for analysis. Systolic BP (SBP) and diastolic BP (DBP) measurements of all patients were evaluated according to the American Academy of Pediatrics 2017 hypertension guideline and based on these data, we calculated the blood pressure SDS-score (16). SBP and/or DBP values that were >90th percentile were defined as elevated blood pressure, and values ≥95th percentile were defined as hypertension.

Biochemical Measurements

Glucose, insulin, triglycerides, total cholesterol, low-density lipoprotein (LDL)-cholesterol, and high-density lipoprotein (HDL)-cholesterol were measured in blood samples taken in the morning after a 12-hour fast. Blood glucose levels were measured by the glucose oxidase method and serum lipid profiles were measured using routine enzymatic methods. Insulin measurements were made using the immunofluorometric method (Modular E170 analyzer, Roche Diagnostics, Mannheim, Germany). The homeostasis model assessment of IR (HOMA-IR) was calculated to estimate IR using the following formula: [HOMA-IR=fasting plasma glucose (mg/dL) x fasting plasma insulin (μU/mL)/405] (6,9).

Assessment of Metabolic Status

The definition of MHO in children and adolescents is controversial and heterogeneous. There are two commonly used definitions for pediatric MS; modified National Cholesterol Education Program criteria and modified International Diabetes Federation criteria (17,18). Metabolic risk factors in both definitions are similar, but the cut-offs of the components are different. Moreover, the definitions are not clear for children under 10 years of age. For this reason, Damanhoury et al. (3) collaborated with 46 international experts and published a classification of the definitions of MHO and MUO in children in 2018. Based on this classification, standard MUO phenotype was defined as the presence of at least one of the following risk factors: SBP and/or DBP> 90th percentile; fasting blood glucose >100 mg/dL; HDL cholesterol <40 mg/dL, triglycerides >100 mg/dL (children <10 years) or >130 mg/dL (children >10 years). Individuals who met the obesity criteria but did not meet any of these criteria were considered to be MHO. Furthermore, following the suggestions of some earlier studies, we included IR, defined by HOMA-IR with thresholds >2.5 for prepubertal and >3.16 for pubertal (Tanner stage ≥2) participants, in our classification criteria (19,20). Detailed cut-off values and thresholds applied in this study, especially for age-specific thresholds are shown in Table 1.

Echocardiographic Measurements

Echocardiographic assessments were performed using the General Electric Medical Systems ViVid 7 Pro dimension

Table 1. Metabolic risk factor cut-off values used for classification of MUO

Parameter	Age group	Threshold
Systolic or diastolic BP	All ages	>90th percentile
Fasting blood glucose	All ages	>100 mg/dL
HDL cholesterol	All ages	<40 mg/dL
Triglycerides	<10 years	>100 mg/dL
Triglycerides	≥10 years	>130 mg/dL
HOMA-IR	Prepubertal	>2.5
HOMA-IR	Pubertal (Tanner ≥2)	>3.16

BP: blood pressure, HDL: high-density lipoprotein, HOMA-IR: homeostatic model assessment for insulin resistance, MUO: metabolically unhealthy obese

echocardiography device (GE Vingmed Ultrasound AS, Horten, Norway) equipped with TDI technology. All measurements were performed according to American Society of Echocardiography guidelines (21). Participants were examined in the left lateral position by the same experienced pediatric cardiologist blinded to clinical and laboratory outcomes. TDI was obtained from the apical four-chamber view, where the sample volume was placed on the septal and lateral sides of the mitral annulus.

For the calculation of MPI, systolic myocardial velocity (Sm), ejection time (ET), and isovolumetric contraction time (IVCT) as systolic parameters, and early (Em) and late (Am) diastolic velocities, the Em/Am ratio, and the isovolumetric relaxation time (IVRT) as diastolic parameters, were measured by TDI. We measured the IVRT from the end of the S-wave to the beginning of the E-wave and IVCT from the beginning of the first positive deflection after the Q-wave to the onset of the S-wave. ET was measured from the beginning to the end of the S-wave. The MPI (IVRT + IVCT/ET) was calculated to assess the LV global (systolic+diastolic) function. The results recorded from three cardiac cycles were averaged.

Vascular Assessment

The cIMT was measured using B-mode high-resolution ultrasonography (Toshiba Aplio 300 Ultrasound, Japan). Measurements were performed in the supine position, with the neck slightly hyperextended, and 1 to 2 cm proximal to the bifurcation of both common carotid arteries. The SDSs for cIMT were calculated using the LMS method and height-specific normative values (22).

Statistical Analysis

All statistical evaluations were performed using SPSS software, version 26.0 (IBM Inc., Armonk, NY, USA). The visual (histogram, probability plots) and analytic methods (Kolmogorov-Smirnov) were used to evaluate the distribution of continuous variables. Discrete variables are expressed as counts (percentage), continuous variables with normal distribution were calculated as mean±SD, and continuous variables with non-normal distribution as median. Differences in the means of MUO, MHO, and control subjects were initially tested by ANOVA. To identify specific group differences, post-hoc comparisons were conducted using the Tukey HSD test. Associations between variables were assessed by Pearson or Spearman's analysis, depending on the distribution type of the variable. The variables that showed a p value of 0.05 in the univariate analysis were tested in a stepwise linear regression analysis for the assessment of risk factors. A $p<0.05$ was considered statistically significant for all statistical evaluations.

Results

Of the 62 children with obesity included in the study, 32 (51.6%) were MHO and 30 (48.4%) patients had MUO. The control group consisted of 30 healthy normal-weight children. There were no significant differences between the groups regarding age and gender. Post-hoc comparisons showed that BMI, BMI-SDS, WC, WC-SDS, DBP, and DBP-SDS were similar in MUO and MHO groups, but significantly higher than the controls (Table 2). SBP, SBP-SDS, and HOMA-IR were significantly different between the three groups, while glucose and LDL levels were similar. Triglyceride was significantly higher and HDL lower in the MUO group compared to the other two groups.

When TDI and carotid ultrasonography findings were evaluated, the ET and Em/Am values of the three groups were significantly different, but the Sm, IVCT, Em, and IVRT were similar (Table 3). The MPI and cIMT means of obese groups were significantly higher than controls. However, there were no difference between the MPI and cIMT values obtained from the MUO and MHO patients.

All clinical and laboratory results were analyzed by univariate analysis to identify cardiometabolic risk factors affecting LV diastolic dysfunction (increase in MPI) and subclinical atherosclerosis (increase in cIMT) in patients with obesity (Table 4). Both MPI and cIMT were positively correlated with BMI-SDS, WC-SDS, SBP-SDS, and DBP-SDS. Moreover, MPI was found to be positively related to HOMA-IR, and cIMT was found to be negatively correlated with HDL. Finally, we identified an independent association between high MPI and BMI-SDS ($\beta=0.312$, $p=0.002$), and between cIMT and WC-SDS ($\beta=0.371$, $p=0.003$) in stepwise linear regression analysis (Table 5).

Discussion

This study showed that MPI and cIMT increased in children with both MUO and MHO and that BMI and WC were important predictors of these increases. Our findings reinforce the suggestion that the degree of obesity in children may be the important risk factor for increased MPI and cIMT and this is independent of metabolic abnormalities.

Left ventricular hypertrophy, systolic/diastolic dysfunction, and increased cIMT have been recognized as subclinical indicators of CVD in children and adults with obesity (9,13,23,24,25). Detection of cardiovascular structural and functional changes during the subclinical period in obese patients are important during clinical follow-up and in determining the prognosis. Studies into subclinical LV diastolic dysfunction and atherosclerosis in children with obesity are more limited than in adults. The strongest aspect of the present study is the comparison of MPI and cIMT measurements of children with and without

hypertension, hyperglycemia, IR, or dyslipidemia, that is MUO versus MHO, respectively.

In children and adults with obesity, structural and functional cardiac changes are frequently investigated using the cPWD echocardiography method (6,8). However, studies evaluating MPI using TDI in children with obesity are limited (11).

Obesity-related increased preload volume causes significant impairments in diastolic myocardial velocities (11,26). Similar to previous studies, we detected a significant increase in Am wave velocity and therefore a significant decrease in the Em/Am ratio. In addition to the low Em/Am ratio, we found that the MPI was significantly higher in the MUO and MHO groups compared to individuals without obesity. This generalized increase in both obese sub-groups was caused by the shortening of ET without significant changes in tissue Doppler-derived IVRT and IVCT.

Table 2. Demographic and anthropometric characteristics and laboratory findings of the study groups

	MUO (n=30)	MHO (n=32)	Control (n=30)	p value
Age (year)	13.3±2.5	13.2±3.1	12.3±2.3	0.160
Male n (%)	16 (53.3)	17 (53.1)	16 (53.3)	0.992
BMI (kg/m^2)	29.3±5.7	29.8±4.4	19.3±2.2**	<0.001
BMI-SDS	2.22±0.92	2.50±0.73	0.02±0.57**	<0.001
WC (cm)	97.9±13.8	98.1±12.9	76.8±8.9**	<0.001
WC-SDS	2.12±0.71	2.26±0.79	0.65±0.82**	<0.001
SBP (mmHg)	131.8±14.3	125.6±12.6	108.9±7.3	<0.001*
SBP-SDS	1.87±0.70	1.44±0.84	0.40±0.37	<0.001*
DBP (mmHg)	86.2±10.8	82.0±9.1	67.2±5.3**	<0.001
DBP-SDS	1.83±0.71	1.61±0.68	0.48±0.40**	<0.001
Triglycerides (mg/dL)	134.1±76.3**	101.9±42.1	96.0±22.0	0.013
HDL (mg/dL)	39.2±6.8 **	49.3±9.9	49.3±9.8	<0.001
LDL (mg/dL)	81.9±20.5	80.0±20.1	74.6±18.9	0.422
Glucose (mg/dL)	84.0±7.1	82.9±4.4	83.2±5.9	0.759
HOMA-IR	5.30±2.25	2.47±0.79	1.57±0.48	<0.001*

*The results of all groups were statistically different from each other
**The results were significantly different from the other two groups
MUO: metabolically unhealthy obese, MHO: metabolically healthy obese, BMI: body mass index, SDS: standard deviation scores, WC: waist circumference, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL: high density lipoprotein, LDL: low-density lipoprotein, HOMA-IR: homeostatic model assessment for insulin resistance

Table 3. Comparison of tissue Doppler imaging and carotid ultrasonography findings

	MUO (n=30)	MHO (n=32)	Control (n=30)	p value
Systolic parameters				
Sm (cm/s)	9.90±1.01	9.83±1.05	9.76±1.12	0.717
ET (ms)	253.0±34.5	262.1±36.5	288.3±34.2	0.001*
IVCT (ms)	33.2±9.6	33.3±8.0	33.0±10.8	0.990
Diastolic parameters				
Em (cm/s)	18.0±4.2	18.0±4.0	17.5±2.7	0.818
Am (cm/s)	12.8±4.7	13.9±3.1	9.9±1.8**	<0.001
Em/Am ratio	1.50±0.35	1.32±0.23	1.81±0.24	<0.001*
IVRT (ms)	24.3±5.0	26.1±6.0	23.4±2.7	0.083
MPI	0.23±0.07	0.23±0.06	0.20±0.05**	0.004
cIMT (μm)	389.0±57.3	385.9±55.7	369.3±48.9**	0.003

*The results of all groups were statistically different from each other
**The results were significantly different from the other two groups
MUO: metabolically unhealthy obese, MHO: metabolically healthy obese, Sm: systolic myocardial velocity, ET: ejection time, IVCT: isovolumetric contraction time, Em: early diastolic velocity, Am: late diastolic velocity, IVRT: isovolumetric relaxation time, MPI: myocardial performance index, cIMT: carotid intima-media thickness

TDI-derived MPI is a relatively new parameter used to evaluate systolic and diastolic myocardial function. In addition, MPI reflects increased LV filling pressure and decreased left ventricular compliance (10,27,28). Our data are consistent with previous MPI studies in children with obesity (26,29,30,31).

The cause of this myocardial dysfunction remains unclear, although the severity and duration of obesity, chronic volume overload, IR, and hemodynamic and metabolic changes have all been implicated (32). LV systolic and diastolic dysfunction secondary to obesity has been associated with MS-related hypertension, dyslipidemia, and IR accompanying obesity. Some studies have shown that subclinical myocardial dysfunction identified by MPI was correlated with BMI and IR (11,29,31). In our study, MPI was significantly higher in both the MUO and MHO groups than in children without obesity, with no significant difference between the two obesity groups. MPI was positively correlated with both BMI-SDS (r=0.289, p=0.003) and WC-SDS (r=0.262, p=0.006), whereas stepwise linear regression analysis identified BMI-SDS as the only independent factor associated with higher MPI (β=0.312, p=0.002). These findings suggest that the degree of adiposity may contribute to subclinical myocardial dysfunction independently of metabolic health status. However, participants were not specifically categorized according to obesity severity; therefore, a direct comparison between obese and severely obese children could not be performed. Further studies specifically stratifying children according to the severity of obesity are needed to confirm this association.

Childhood obesity is associated with changes in cardiac structure and function, as well as various biomarkers of subclinical atherosclerosis such as cIMT. Similar to our results, elevated cIMT has been documented in numerous investigations involving children with obesity (13,33,34). This finding is indicative of the presence of subclinical atherosclerosis in patients with obesity, regardless of metabolic health. There is no consensus on the results regarding the increase in cIMT in patients with and without MS. Although some studies report higher cIMT in children with MS, other studies have reported that cIMT is not different between obese children with and without MS (13,35). In agreement with the studies of Zhao et al. (33) and Farello et al. (34), we found that cIMT values of obese groups were higher than controls, but cIMT was not different between obese groups with MUO or MHO. Therefore, we believe that obesity may be an important risk factor for increased cIMT even in the absence of metabolic abnormalities. The lack of difference in MPI and cIMT between MHO and MUO groups may be influenced by factors, such as the overall degree of obesity, genetic predispositions, lifestyle factors, and underlying subclinical inflammation that can affect cardiovascular outcomes regardless of metabolic health status.

In the present study, cIMT was positively correlated with BMI-SDS (r=0.239, p=0.010), WC-SDS (r=0.248, p=0.008), SBP-SDS, and DBP-SDS, and negatively correlated with HDL cholesterol. In stepwise linear regression analysis, WC-SDS was the only independent factor associated with higher cIMT (β=0.371, p=0.003). Similar to our findings, Sonmez et al. (13) reported an independent association between higher WC and increased cIMT in children with obesity. These findings support an association between the degree of adiposity, particularly central adiposity, and subclinical vascular alterations. However, because our

Table 4. Risk factors of myocardial performance index and carotid intima-media thickness

	MPI		cIMT	
	r	p value	r	p value
BMI-SDS	0.289	0.003	0.239	0.010
WC-SDS	0.262	0.006	0.248	0.008
SBP-SDS	0.185	0.039	0.194	0.032
DBP-SDS	0.195	0.031	0.222	0.017
HOMA-IR	0.237	0.011		
HDL			-0.210	0.022

Spearman's correlation analysis (only significant correlations shown)
MPI: myocardial performance index, cIMT: carotid intima-media thickness, BMI: body mass index, SDS: standard deviation scores, WC: waist circumference, SBP: systolic blood pressure, DBP: diastolic blood pressure, HOMA-IR: homeostatic model assessment for insulin resistance, HDL: high density lipoprotein

Table 5. Independent predictors of myocardial performance index and carotid intima-media thickness in all obese patients

Dependent variable	Independent variable	β-coefficient	SE	p value
MPI	BMI-SDS	0.312	0.011	0.002
cIMT	WC-SDS	0.371	0.041	0.003

MPI: myocardial performance index, cIMT: carotid intima-media thickness, BMI: body mass index, SDS: standard deviation scores, WC: waist circumference

participants were not stratified according to obesity severity, this relationship should be interpreted as an association rather than evidence of a direct effect of obesity severity on cIMT.

BMI and WC are the most common anthropometric measures for predicting abdominal obesity. In recent years, an increasing number of studies support the use of WC instead of BMI in children with obesity (36,37). Besides, derived WC cut points for children to identify cardiovascular risk factors have been suggested in some countries (38,39).

Study Limitations

This study has some limitations. First, it was a cross-sectional study with a relatively small number of cases. Further prospective, long-term studies with a larger number of patients are needed to determine the effects of obesity on myocardial functions and atherosclerosis. Lack of obesity duration and weight status history were further limitations. Furthermore, participants were not stratified according to the severity of obesity, which limited our ability to directly assess differences in MPI and cIMT across different degrees of obesity.

Conclusion

The present study demonstrated increased MPI and cIMT as markers of subclinical diastolic dysfunction and atherosclerosis in children with obesity. The similarity of these two markers between MUO and MHO patients and the detection of an independent relationship between MPI and BMI-SDS, and cIMT and WC-SDS suggest that the degree of adiposity may be associated with MPI and cIMT independently of metabolic health status. Our results demonstrated the diagnostic value of MPI and cIMT for routine and widespread use in children with obesity due to their ease of application and reproducibility. Moreover, BMI and WC appear to be valuable and easy indicators of early CVD in children with obesity. Long-term multicenter prospective studies will provide better insight into early screening of cardiovascular risk factors in children with obesity.

Ethics

Ethics Committee Approval: This study was approved by the University of Health Sciences Türkiye, Kanuni Sultan Suleyman Training and Research Hospital Clinical Research Ethics Committee (approval no.: 2019/57, date: 22.03.2019).

Informed Consent: Written informed consent was obtained from the parents of patients and controls.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Nazlican Civilibal Tang, Concept: Nazlican Civilibal Tang, Ata Mert Civilibal, Design: Nazlican Civilibal Tang, Ata Mert Civilibal, Data Collection or Processing: Nazlican Civilibal Tang, Kazim Oztarhan, Helen Bornaun, Sumeyra Dogan, Analysis or Interpretation: Nazlican Civilibal Tang, Kazim Oztarhan, Literature Search: Nazlican Civilibal Tang, Kazim Oztarhan, Writing: Nazlican Civilibal Tang, Kazim Oztarhan, Helen Bornaun, Sumeyra Dogan, Ata Mert Civilibal.

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References

1. Styne DM, Arslanian SA, Connor EL, Farooqi IS, Murad MH, Silverstein JH, Yanovski JA. Pediatric obesity-assessment, treatment, and prevention: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab. 2017;102:709-757.
2. Prince RL, Kuk JL, Ambler KA, Dhaliwal J, Ball GD. Predictors of metabolically healthy obesity in children. Diabetes Care. 2014;37:1462-1468. Epub 2014 Feb 26
3. Damanhoury S, Newton AS, Rashid M, Hartling L, Byrne JLS, Ball GDC. Defining metabolically healthy obesity in children: a scoping review. Obes Rev. 2018;19:1476-1491. Epub 2018 Aug 28
4. Daniels SR, Loggie JM, Khoury P, Kimball TR. Left ventricular geometry and severe left ventricular hypertrophy in children and adolescents with essential hypertension. Circulation. 1998;97:1907-1911.
5. Sorof JM, Alexandrov AV, Cardwell G, Portman RJ. Carotid artery intimal-medial thickness and left ventricular hypertrophy in children with elevated blood pressure. Pediatrics. 2003;111:61-66.
6. Atabek ME, Akyüz E, Selver Eklioğlu B, Çimen D. The relationship between metabolic syndrome and left ventricular mass index in obese children. J Clin Res Pediatr Endocrinol. 2011;3:132-138.
7. Berenson GS. Childhood risk factors predict adult risk associated with subclinical cardiovascular disease: the Bogalusa Heart Study. Am J Cardiol. 2002;90:3L-7L.
8. Bostanci BK, Civilibal M, Elevli M, Duru NS. Ambulatory blood pressure monitoring and cardiac hypertrophy in children with metabolic syndrome. Pediatr Nephrol. 2012;27:1929-1935.
9. Alkholy UM, Ahmed IA, Karam NA, Ali YF, Yosry A. Assessment of left ventricular mass index could predict metabolic syndrome in obese children. J Saudi Heart Assoc. 2016;28:159-166. Epub 2015 Jul 2
10. Fernandes JMG, de Oliveira Romão B, Rivera IR, Mendonça MA, Costa FA, Lira Handro MS, Campos O, ÂAV DP, Moisés VA. Clinical value of myocardial performance index in patients with isolated diastolic dysfunction. Cardiovasc Ultrasound. 2019;17:17. Epub 2019 Aug 13
11. Kibar AE, Pac FA, Ballı S, Oflaz MB, Ece I, Bas VN, Aycan Z. Early subclinical left-ventricular dysfunction in obese nonhypertensive children: a tissue Doppler imaging study. Pediatr Cardiol. 2013;34:1482-1490.
12. Stein JH, Korcarz CE, Hurst RT, Lonn E, Kendall CB, Mohler ER, Najjar SS, Rembold CM, Post WS, American Society of Echocardiography Carotid Intima-Media Thickness Task Force. Use of carotid ultrasound to identify subclinical vascular disease and evaluate cardiovascular disease risk: a consensus statement from the American Society of Echocardiography Carotid Intima-Media Thickness Task Force. Endorsed by the Society for Vascular Medicine. J Am Soc Echocardiogr. 2008;21:93-111; quiz 189-190.
13. Sönmez HE, Canpolat N, Ağbaş A, Taşdemir M, ÖB E, Alikaşifoğlu M, Sever L, Çalışkan S. The relationship between the waist circumference and increased carotid intima thickness in obese children. Child Obes. 2019;15:468-475. Epub 2019 Jun 27

14. Neyzi O, Bundak R, Gökçay G, Günöz H, Furman A, Darendeliler F, Baş F. Reference values for weight, height, head circumference, and body mass index in Turkish children. J Clin Res Pediatr Endocrinol. 2015;7:280-293.

15. Hatipoglu N, Ozturk A, Mazicioglu MM, Kurtoglu S, Seyhan S, Lokoglu F. Waist circumference percentiles for 7- to 17-year-old Turkish children and adolescents. Eur J Pediatr. 2008;167:383-389. Epub 2007 May 9

16. Flynn JT, Falkner BE. New clinical practice guideline for the management of high blood pressure in children and adolescents. Hypertension. 2017;70:683-686. Epub 2017 Aug 21

17. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA. 2001;285:2486-2497.

18. Zimmet P, Alberti KG, Kaufman F, Tajima N, Silink M, Arslanian S, Wong G, Bennett P, Shaw J, Caprio S, International Diabetes Federation Consensus Group. The metabolic syndrome in children and adolescents: an IDF consensus report. Pediatr Diabetes. 2007;8:299-306.

19. Nso-Roca AP, Cortés Castell E, Carratalá Marco F, Sánchez Ferrer F. Insulin resistance as a diagnostic criterion for metabolically healthy obesity in children. J Pediatr Gastroenterol Nutr. 2021;73:103-109.

20. Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C. Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. Pediatrics. 2005;115:e500-e503. Epub 2005 Mar 1

21. Sahn DJ, DeMaria A, Kisslo J, Weyman A. Recommendations regarding quantitation in M-mode echocardiography: results of a survey of echocardiographic measurements. Circulation. 1978;58:1072-1083.

22. Jourdan C, Wühl E, Litwin M, Fahr K, Trelewicz J, Jobs K, Schenk JP, Grenda R, Mehls O, Tröger J, Schaefer F. Normative values for intima-media thickness and distensibility of large arteries in healthy adolescents. J Hypertens. 2005;23:1707-1715.

23. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, Allen K, Lopes M, Savoye M, Morrison J, Sherwin RS, Caprio S. Obesity and the metabolic syndrome in children and adolescents. N Engl J Med. 2004;350:2362-2374.

24. DeFronzo RA, Ferrannini E. Insulin resistance: a multifaceted syndrome responsible for NIDDM, obesity, hypertension, dyslipidemia, and atherosclerotic cardiovascular disease. Diabetes Care. 1991;14:173-194.

25. Başaran C, Erfidan G, Özdemir-Şimşek Ö, Arslansoyu-Çamlar S, Alaygut D, Mutlubaş F, Karadeniz C, Dündar BN, Kasap-Demir B. Pulse wave analysis in obese children with and without metabolic syndrome. J Clin Res Pediatr Endocrinol. 2023;15:397-405.

26. Mehta SK, Holliday C, Hayduk L, Wiersma L, Richards N, Younoszai A. Comparison of myocardial function in children with body mass indexes ≥25 versus those <25 kg/m2. Am J Cardiol. 2004;93:1567-1569.

27. Gaibazzi N, Petrucci N, Ziacchi V. Left ventricle myocardial performance index derived either by conventional method or mitral annulus tissue-Doppler: a comparison study in healthy subjects and subjects with heart failure. J Am Soc Echocardiogr. 2005;18:1270-1276.

28. Su HM, Lin TH, Voon WC, Lee KT, Chu CS, Lai WT, Sheu SH. Differentiation of left ventricular diastolic dysfunction, identification of pseudonormal/restrictive mitral inflow pattern and determination of left ventricular filling pressure by Tei index obtained from tissue Doppler echocardiography. Echocardiography. 2006;23:287-294.

29. Koç F, Tokaç M, Kaya C, Kayrak M, Yazıcı M, Karabağ T, Vatankulu MA, Ayhan S, Demir K. Diastolic functions and myocardial performance index in obese patients with or without metabolic syndrome: a tissue Doppler study. Turk Kardiyol Dern Ars. 2010;38:400-404.

30. Levent E, Gökşen D, Ozyürek AR, Darcan S, Coker M. Usefulness of the myocardial performance index (MPI) for assessing ventricular function in obese pediatric patients. Turk J Pediatr. 2005;47:34-38.

31. Willens HJ, Chakko SC, Lowery MH, Byers P, Labrador E, Gallagher A, Castrillon JC, Myerburg RJ. Tissue Doppler imaging of the right and left ventricle in severe obesity (body mass index >35 kg/m2). Am J Cardiol. 2004;94:1087-1090.

32. Alpert MA. Obesity cardiomyopathy: pathophysiology and evolution of the clinical syndrome. Am J Med Sci. 2001;321:225-236.

33. Zhao M, López-Bermejo A, Caserta CA, Medeiros CCM, Kollias A, Bassols J, Romeo EL, Ramos TDA, Stergiou GS, Yang L, Xargay-Torrent S, Amante A, Gusmão TME, Grammatikos E, Zhang Y, Prats-Puig A, de Carvalho DF, Yang L, Carreras-Badosa G, Simões MO, Hou Y, Mas-Pares B, Shui W, Guo T, Wang M, Chen H, Lou X, Zhang Q, Zhang Y, Bovet P, Magnussen CG, Xi B, International Childhood Vascular Structure Evaluation Consortium. Metabolically healthy obesity and high carotid intima-media thickness in children and adolescents: International Childhood Vascular Structure Evaluation Consortium. Diabetes Care. 2019;42:119-125.

34. Farello G, Antenucci A, Stagi S, Mazzocchetti C, Ciocca F, Verrotti A. Metabolically healthy and metabolically unhealthy obese children both have increased carotid intima-media thickness: a case control study. BMC Cardiovasc Disord. 2018;18:140.

35. Elshorbagy HH, Fouda ER, Kamal NM, Bassiouny MM, Fathi WM. Evaluation of epicardial fat and carotid intima-media thickness in obese children. Iran J Pediatr. 2016;26:e2968.

36. McCarthy HD. Body fat measurements in children as predictors for the metabolic syndrome: focus on waist circumference. Proc Nutr Soc. 2006;65:385-392.

37. Moreno LA, Pineda I, Rodríguez G, Fleta J, Sarría A, Bueno M. Waist circumference for the screening of the metabolic syndrome in children. Acta Paediatr. 2002;91:1307-1312.

38. Cook S, Auinger P, Huang TT. Growth curves for cardio-metabolic risk factors in children and adolescents. J Pediatr. 2009;155:S6.

39. Liu A, Hills AP, Hu X, Li Y, Du L, Xu Y, Byrne NM, Ma G. Waist circumference cut-off values for the prediction of cardiovascular risk factors clustering in Chinese school-aged children: a cross-sectional study. BMC Public Health. 2010;10:82.