Original Article

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Early Left Ventricular Structural Changes With Preserved Function in Overweight and Obese Adolescents: A Speckle-Tracking Echocardiography Study

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Abstract

Background: Overweight and obesity in adolescents are associated with dyslipidemia and may contribute to early cardiovascular remodelling. Speckle-tracking echocardiography (STE) is a sensitive imaging technique capable of detecting early myocardial functional alterations before the onset of clinical symptoms. This study aimed to evaluate the correlation between cardiac chamber dimensions, left ventricular (LV) geometry and function, and lipid profiles in overweight and obese adolescents.

Methods: A cross-sectional study was conducted from June to September 2023, involving 51 overweight and obese adolescents aged 15–18 years in Bandung, Indonesia. Anthropometric measurements, fasting lipid profiles (triglycerides, total cholesterol, LDL, HDL), and transthoracic echocardiography were obtained. LV dimensions, LV mass index (LVMI), ejection fraction (EF), fractional shortening (FS), and global longitudinal strain (GLS) were assessed. Associations were analyzed using Pearson correlation.

Results: Participants were predominantly male (64.7%) with a mean age of 16.3±0.6 years. Overweight (47.1%) and obesity (52.9%) were almost equally distributed with a mean BMI of 29.6±4.1 kg/m^2. LVMI correlated negatively with total cholesterol (r=−0.356; p=0.005), HDL (r=−0.351; p=0.006), and LDL (r=−0.280; p=0.023). The LV posterior wall thickness and LV end-diastolic diameter were also inversely correlated with selected lipid parameters. Interventricular septal thickness in systole correlated positively with triglycerides (r=0.270; p=0.028). No significant correlations were found between lipid profiles and LV function parameters, including EF, FS, and GLS (p>0.05).

Conclusions: In overweight and obese adolescents, lipid profiles are associated with early alterations in LV structural dimensions while LV systolic function remains preserved. These findings support the importance of early cardiovascular screening and lifestyle modification to reduce future cardiometabolic risk.

Keywords: Cardiac dimension, lipid profile, LV function, obesity, Speckle-tracking echocardiography

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Introduction

Over the past three decades, from 1990 to 2021, the combined prevalence of overweight and obesity among children and adolescents has doubled, while obesity alone has increased nearly threefold. In 2021, approximately 93.1 million children aged 5–14 years and 80.6 million adolescents aged 15–24 years were living with obesity. Projections at both national and regional level indicate that obesity prevalence will continue to rise through 2050, reaching an estimated 15.6% (186 million) among children aged 5–14 years and 14.2% (175 million) among adolescents aged 15–24 years.[1] Excess body weight during adolescence has widespread health consequences, affecting multiple organ systems, particularly cardiometabolic and cardiovascular systems.[2,3] One of the metabolic aspects most frequently affected is the lipid profile, with overweight and obese adolescents commonly exhibiting dyslipidemia.[4,5] Typical lipid abnormalities include elevated triglycerides, total cholesterol, and low-density lipoprotein (LDL) levels, accompanied by reduced high-density lipoprotein (HDL) concentrations.[4,5] In addition to metabolic disorders, excess adiposity during adolescence is also associated with early cardiovascular structural and functional alterations, potentially increasing cardiovascular risk in adulthood.[6]

Several studies have found that in obesity in childhood is associated with alterations in left ventricle (LV) structure and function.[7,8] In addition, overweight or obese adolescents have been reported to exhibit early sign of systolic and diastolic ventricular dysfunction.[9] Echocardiography remains a key non-invasive modality for evaluating the impact of overweight and obesity on LV structure and function.[10] However, conventional echocardiography techniques, such as M-mode measurement, have limitations in differentiating active myocardial movement from passive motion and in mapping the heart chambers. Advances in cardiac imaging, particularly speckle-tracking echocardiography (STE), allow mapping of the cardiac chambers and the detection of early alterations in myocardial function before clinical symptoms appear. STE can provide a global estimate of LV mechanics and information about three spatial dimensions of cardiac deformation.[11]

Although dyslipidemia is a well-known cardiovascular risk factor, its relationship with early alterations in LV structure and myocardial function during adolescence remains incompletely understood. Lipid abnormalities may influence cardiac remodeling through mechanisms such as myocardial lipid accumulation, chronic low-grade inflammation, and endothelial dysfunction, which may precede overt functional impairment. Therefore, this study aimed, for the first time in an Indonesian adolescent population, to investigate the correlation between lipid profiles and cardiac chamber dimensions as well as LV function assessed by STE among overweight and obese adolescents.

Methods

This observational study used a cross-sectional design conducted from June to September of 2023 in Bandung, Indonesia. To identifiy adolescents with overweight and obesity, a multistage sampling approach was applied. Seven senior high schools were randomly selected from a total of 151 schools in Bandung City; two schools refused to participate and five schools were included in this study as depicted in Figure 1. Anthropometric screening was performed using a calibrated digital scale (Seca 874) and a stadiometer (Seca 213). Adolescents classified as overweight or obese were subsequently selected by simple random sampling for further evaluation.

Inclusion criteria for this study were senior high school students aged 15–18 years who met the criteria for overweight (BMI-for-age >+1 SD) or obesity (BMI-for-age >+2 SD) according to the WHO Child Growth Reference 2007. The Exclusion criteria included a history of hypertension, diabetes mellitus, systemic lupus erythematosus, nephrotic syndrome, congenital or acquired heart disease, short stature, or any condition requiring long-term corticosteroid treatment. Participants using medications known to affect cardiac function, such as lipid-lowering drugs, anticoagulants, and antihypertensives were also excluded. Students who met the inclusion criteria and whose parents provided written informed consent were enrolled.

Initial data collection at the participating schools included medical history, anthropometric examination, heart rate, and blood pressure measurement. Body weight and height were measured following standardized procedures, with participants wearing light clothing and no footwear. Blood pressure and heart rate were recorded after a 5-minute rest in a seated position. Eligible participants were referred to Dr. Hasan Sadikin General Hospital, Bandung, for further examination.

Venous blood samples were collected after a 10–12 hours overnight fast for lipid profile analysis. Serum triglycerides, total cholesterol, LDL, and HDL, were measured using enzymatic colorimetric assays at the hospitals central laboratory. Transthoracic echocardiographic examinations were conducted by a pediatric cardiologist using a Philips CVx echocardiography machine. Standard echocardiographic measurements were obtained in accordance with the American Society of Echocardiography (ASE) guidelines, including LV ejection fraction (LVEF), fractional shortening (FS), LV mass index (LVMI), LV posterior wall thickness at end-diastole (LVPWd) and systole (LVPWs), interventricular septal thickness at-end diastole (IVSd) and systole (IVSs), LV end-

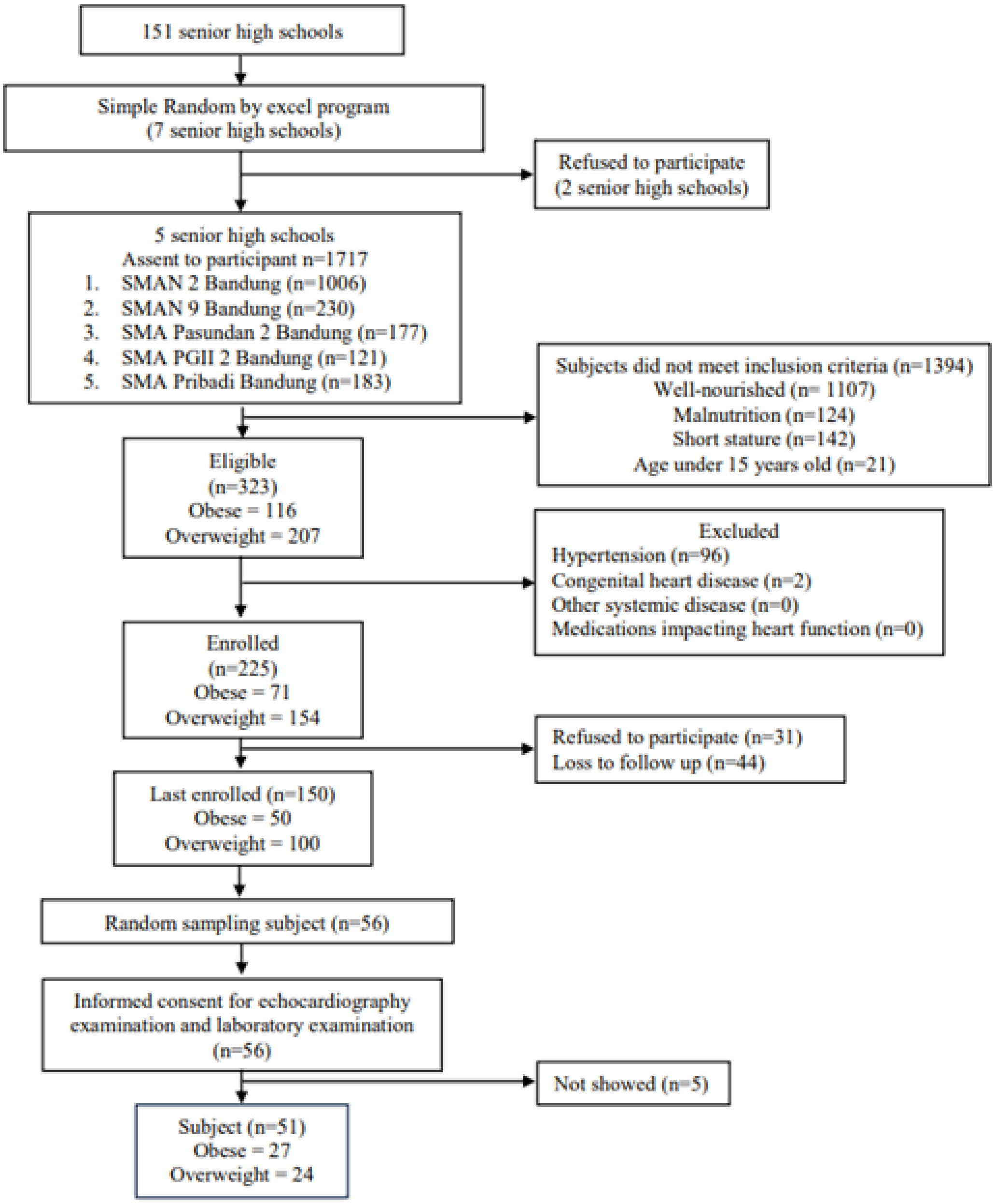

Figure 1 Flowchart of Participant Enrollment

diastolic diameter (LVEDD), and LV end-systolic diameter (LVESD).[12] Global longitudinal strain (GLS) was assessed using STE from three standard apical views (four-chambers, two-chambers, and three-chambers).

Statistical analysis was performed using SPSS for Windows, version 24.0. Numerical data were tested for normality using the Kolmogorov–Smirnov test, as the sample size exceeded 50 participants, in order to determine whether the data were normally or non-normally distributed. Pearson correlation analysis was used to evaluate the correlation between lipid profile parameters and cardiac dimensions or LV function, with statistical significance level set at $p<0.05$.

This study was conducted after obtaining ethical clearance approval from the Research Ethics Committee, Faculty of Medicine, Universitas Padjadjaran (approval number: 310/UN6.KEP/EC/2023).

Results

A total of 51 adolescents with overweight and obesity were included in this study. The

Table 1 Subject Characteristics (n=51)

Characteristics	Total
Age (years), mean ± SD	16.3 ± 0.6
Gender, n (%)	
Male	33 (64.7)
Female	18 (35.3)
Body weight (kg), mean ± SD	80.2 ± 13.3
Height (cm), mean ± SD	164 ± 8
BMI (kg/m2), mean ± SD	29.6 ± 4.1
BMI/U	2.08 ± 0.65
Nutritional status	
Overweight	24 (47.1%)
Obesity	27 (52.9.%)
Blood pressure (mmHg), mean ± SD	
Systolic	115 ± 5
Diastolic	73 ± 5
Heart rate (beats/min), mean ± SD	84 ± 11

Note: BMI= Body mass index, SD= Standard deviation

majority of participants were male (64.7%) with a mean age of 16.3 ± 0.6 years. Based on nutritional status classification, 24 participants (47.1%) were overweight and 27 participants (52.9%) as obese (Table 1).

There were several significant correlations between cardiac chamber dimension and lipid profile parameters among overweight and obese adolescents. A significant negative correlation was observed between LVMI and total cholesterol (r=−0.356; p=0.005), HDL (r=−0.351; p=0.006), and LDL (r=−0.280; p=0.023), indicating that higher lipid levels were associated with lower the LVMI. No significant correlation was observed between LVMI and triglycerides levels (p>0.05). Furthermore, a significant negative correlation was also observed between LVPWd and HDL (r=−0.283; p=0.022), whereas LVPWs did not show significant correlations with any lipid profile (p>0.05) (Table 2).

No significant correlations were found between IVSd and HDL (r=−0.294, p=0.018). However, IVSs demonstrated a significant positive correlation with triglyceride levels (r=0.270; p=0.028). In addition, LVEDD was negatively correlated with total cholesterol (r=−0.264; p=0.031), while LVESD did not demonstrate significant correlation with lipid profile parameters (p>0.05).

There was no correlation between LVEF and triglyceride levels (r=−0.045, p=0.376), total

Table 2 Correlation of Cardiac Chamber Dimensions and Lipid Profile in Overweight and Obese Adolescents

Cardiac Chamber Dimensions	Lipid Profile							
	Triglycerides (mg/dL)		Total Cholesterol (mg/dL)		HDL (mg/dL)		LDL (mg/dL)	
	r	p	r	p	r	p	r	p
LVMI (g/m^2)	0.072	0.308	−0.356	0.005*	−0.351	0.006*	−0.280	0.023*
LVPWd (mm)	0.219	0.062	−0.060	0.339	−0.283	0.022*	−0.033	0.410
LVPWs (mm)	0.009	0.476	−0.205	0.074	−0.217	0.063	−0.167	0.120
IVSd (mm)	0.129	0.183	−0.143	0.158	−0.294	0.018*	−0.106	0.230
IVSs (mm)	0.270	0.028*	−0.034	0.408	−0.284	0.022*	−0.042	0.385
LVEDD (mm)	0.084	0.278	−0.194	0.086	−0.264	0.031*	−0.164	0.125
LVESD (mm)	0.076	0.297	−0.152	0.144	−0.227	0.055	−0.131	0.180

Note: Pearson correlation analysis. p<0.05 indicates statistical significance, LVMI= Left ventricular mass index; LVPWd= Left ventricular posterior wall thickness at end-diastole; LVPWs = Left ventricular posterior wall thickness at end-systole; IVSd =Interventricular septal thickness at end-diastole; IVSs=Interventricular septal thickness at end-systole; LVEDD=Left ventricular end-diastolic diameter; LVESD= Left ventricular end-systolic diameter; HDL= High-density lipoprotein; LDL = Low-density lipoprotein.

Table 3 Correlation of LV Function and Lipid Profile in Overweight and Obese Adolescents

Lipid Profile (mg/dL)	LV Function					
	EF (%)		FS (%)		GLS (%)	
	r	p	r	p	r	p
Triglyceride	−0.045	0.376	−0.057	0.345	0.061	0.335
Total cholesterol	0.029	0.421	−0.045	0.377	0.052	0.359
HDL	0.065	0.324	0.051	0.361	−0.065	0.326
LDL	0.033	0.41	−0.042	0.385	0.062	0.334

Note: Pearson correlation analysis, EF= Ejection fraction, FS= Fractional shortening, GLS= Global longitudinal strain, HDL= High-density lipoprotein, LDL= Low-density lipoprotein

cholesterol (r=0.029, p=0.421), HDL (r=0.065, p=0.324), and LDL (r=0.033, p=0.410). Similarly, FS and GLS were not significantly correlated with any lipid profile parameters (p>0.05). Overall, LV function including EF, FS, and GLS showed no significant correlations with lipid profile in overweight and obese adolescents (p>0.05) (Table 3).

Discussion

This study has shown that several cardiac chamber dimensions are significantly correlated with lipid profiles in overweight and obese adolescents, while no significant relationships has been observed between lipid levels and LV functional parameters including EF, FS, and GLS. Specifically, significant negative correlations have been observed between LVMI and total cholesterol, HDL, and LDL suggesting that higher lipid concentrations are associated with lower LV mass index. Similar negative correlations have been identified between LVPWd and HDL, LVPWs and total cholesterol, and LVEDD and total cholesterol, indicating that higher lipid levels are linked to smaller ventricular dimensions or thinner walls. Conversely, a positive correlation has been found between IVSs and triglyceride levels, implying that greater triglyceride concentrations may be associated with increased septal wall thickness during systole.

However, despite these structural associations, no significant correlations have been shown between lipid parameters (triglycerides, total cholesterol, HDL, or LDL) and LV functional indices (EF, FS, GLS). Cardiovascular risks related to overweight and obesity have been well-substantiated in adults, as well as in children and adolescents, and previous studies have reported early subclinical myocardial dysfunction in obese pediatric populations.[13,14] The absence of functional impairment in this study suggests that, in adolescents, structural remodeling may precede measurable declines in systolic performance.

In this study, male participants are more prevalent, which contrast with findings from another Indonesian study where female are more dominant.[14] Additionally, the mean age of participants differs from that of earlier study examining LV myocardial function deformation in normotensive children using two-dimensional (2D) STE.[13] Differences in gender distribution, pubertal status, lifestyle factors, dietary habits, physical activity levels, and genetic background may also contribute to variability in the relationship between obesity, lipid profile, and cardiac function across populations.

This study has found a significant negative correlation between LVMI and total cholesterol, HDL, and LDL, however, no correlation has been found between LVMI and triglyceride levels. In contrast to these findings, studies from Serbia and Saudi Arabia have reported a positive correlation between triglycerides and LVMI in obese adolescents, whereas other lipid profiles include cholesterol, HDL, and LDL have no correlation with LVMI.[15,16] These discrepancies may be explained by differences in age, obesity severity, duration of dylipidemia, and metabolic burden. Long-term exposure to hyperlipidemia, associated with higher average cholesterol levels and increasing age has been reported in population aged 8–17 years with obesity.[17,18] In adolescents, increased in plasma volume and cardiac output associated with obesity may lead to enhanced left ventricular activity and LVM.[14]

Additionally, LVESD shows no correlation with any lipid profiles in this study. Alterations in LVEDD, however, may reflect diminished myocardial relaxation related to obesity-induced LV hypertrophy.[19] The positive association between triglyceride levels and IVSs suggests a localized hypertrophic response of the interventricular septum, potentially driven by lipid-induces myocardial energy imbalance or early inflammatory signaling.

Furthermore, no correlation between left ventricular function (EF, FS, and GLS) and lipid profile among adolescents with overweight and obesity in our study, Although previous studies have shown reduced myocardium deformation in obese adolescent, especially using GLS as a sensitive marker of subclinical dysfunction.[19,20] The EF, FS, and GLS are derived from LV chamber dimension and myocardial mechanics, however, preserved GLS in this study likely reflects the early stage of cardiometabolic exposure. Our findings differ from another study reporting inverse correlations between GLS and hypercholesterolemia or triglyceride levels,[9] but are consistent with another report showing weak or non-significant associations between lipid parameters and myocardial strain in adolescents.[8] Methodological differences, including the absence of a normal-weight control group, lower average BMI, and shorter duration of obesity, may explain these discrepancies.

Collectively, these findings suggests that in overweight and obese adolescents, lipid abnormalities may influence LV geometry before detectable impairment of systolic function occurs. LV functional deterioration may depend more strongly on the duration and severity of obesity rather than lipid levels alone.[15,21] Decline in systolic performance are more commonly observed in later stages of obesity or in presence of additional comorbidities.[22,23]

Although this study provides novel findings, the duration of overweight and obesity was not assessed, which may have limited the ability to detect associations with LV function. As the participants were adolescents without major cardiometabolic comorbidities such as hypertension or diabetes mellitus, the relatively short exposure period may have been insufficient to induce measurable functional impairment. Future longitudinal studies incorporating obesity duration, metabolic burden, and repeated echocardiographic assessment are needed to clarify the temporal progression from structural remodeling to functional decline.

In conclusion, early alterations in cardiac chamber dimensions among overweight and obese adolescents are associated with lipid profiles, serving as potential early warning signs of future cardiovascular risk. Assessment of lipid profile combined with echocardiography evaluation may help identify adolescents at risk for adverse cardiac remodeling. Early cardiovascular screening and lifestyle interventions remain essential strategies to reduce long-term cardiovascular risk and promote lifelong cardiometabolic health.

Authors' Contributions

WN contributed to the conduct of the study, including data collection and analysis. TH and SER supervised the research and provided conceptual input. PRA and RBK contributed expert input in pediatric cardiology, while DAG contributed expert input in pediatric nutrition. DDLH and RG provided additional research input and manuscript review.

Conflict of Interest

The authors declare no conflicts of interest.

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