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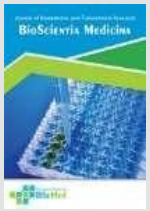

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Vascular Architecture Alterations Independent of Lipid Profiles: The Paradoxical Dissociation between Dyslipidemia and Carotid Intima-Media Thickness in Obese Adolescents

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A B S T R A C T

Background: Adolescent obesity is a global epidemic that initiates subclinical atherosclerosis. While lipid profiles are traditional markers, their correlation with structural vascular changes in the pediatric population remains a subject of intense academic debate. This study evaluates the relationship between traditional lipid parameters and carotid intima-media thickness (CIMT) in obese high school students. **Methods:** An observational cross-sectional study was conducted between January 2025 and January 2026 involving 45 obese adolescents aged 15 to 18 years in Padang, Indonesia. Nutritional status was determined using the CDC 2000 growth charts, specifically targeting those with a body mass index at or above the 95th percentile. CIMT was measured via high-resolution B-mode ultrasonography. Lipid profiles, including total cholesterol, triglycerides, HDL, and LDL, were analyzed through laboratory testing. Statistical analysis utilized Fisher's exact test through SPSS version 22. **Results:** The subjects, of whom 68.9 percent were female, had a median BMI of 29.34 ± 2.03 kg/m². Remarkably, 68.9 percent exhibited CIMT thickening above the 75th percentile. Bivariate analysis revealed no significant association between CIMT and total cholesterol (p=0.402), triglycerides (p=0.696), HDL (p=0.563), or LDL (p=1.000). **Conclusion:** Vascular remodeling in obese adolescents occurs independently of circulating lipid levels, suggesting that chronic inflammation may drive early atherosclerosis before clinical dislipidemia manifests.

1. Introduction

The escalating prevalence of obesity has transformed from a clinical concern into a paramount threat to global public health, fundamentally altering the epidemiological landscape of non-communicable diseases. The World Health Organization (WHO) has provided alarming data indicating that the burden of this metabolic crisis is shifting increasingly toward younger demographics.[1] As of 2020, approximately 39 million children under the age of five were classified as overweight or obese, while a staggering 340 million children and adolescents aged 5 to 19 years were affected by overweight or obesity. This trajectory suggests that the coming generation faces an unprecedented risk of metabolic morbidity.

Indonesia, as a rapidly developing nation undergoing significant nutritional transitions, is not immune to this global phenomenon. The World Obesity Federation has identified Indonesia as one of the countries experiencing the most rapid acceleration in obesity prevalence over recent decades.[2] The nation currently faces a significant public health challenge,

ranking fourth globally in the absolute number of school-aged children and adolescents predicted to suffer from obesity by the year 2030. National health surveys, specifically the Basic Health Research (Riskesdas), have documented a consistent upward trend in nutritional issues among adolescents. The prevalence of obesity in the 16–18-year age group nationally rose from 1.4% in 2010 to 7.3% in 2013, eventually reaching 13.5% in 2018.

This national crisis is mirrored and even amplified at the regional level. In West Sumatra, the prevalence of obesity rose from 7.5% to 11.5% between 2013 and 2018. More specifically, data from the Padang City Health Office in 2021 revealed a concerning shift in the demographic burden of the disease: the prevalence of obesity among high school students has surpassed that of elementary and junior high school cohorts. This statistical peak suggests that the late adolescent phase serves as a cumulative tipping point, reflecting the aggregated impact of years of sedentary lifestyles and dietary habits characterized by high fat and sugar intake. Observations in major educational institutions in Padang, such as SMAN 3 and SMA Adabiah, confirm that a significant proportion of students—up to 11.6%—are already grappling with obesity.[3]

Obesity is defined not merely by weight, but by the excessive accumulation of adipose tissue, calculated via body mass index (BMI). However, the pathophysiology of obesity extends far beyond physical mass. It is a complex state of energy imbalance where caloric intake consistently exceeds energy expenditure, influenced by a multifaceted interplay of genetic susceptibility, dietary behaviors, and environmental factors such as the industrial availability of processed foods and reduced physical activity.[4] In adolescents, obesity is frequently characterized by the accumulation of visceral fat, or central obesity. This visceral adipose tissue is not an inert storage depot; it is a metabolically active endocrine organ. It secretes a variety of pro-inflammatory cytokines, including Interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-alpha), which contribute to a state of chronic, low-grade systemic inflammation. This inflammatory milieu is a critical driver of vascular pathology. The cytokines released by dysfunctional adipocytes induce oxidative stress and endothelial dysfunction, processes that likely precede the overt manifestation of dyslipidemia. The consequences of this early metabolic dysregulation are severe. The Harvard Growth Study provided longitudinal evidence that adolescent males with excess body weight face a twofold increase in the risk of mortality from cardiovascular disease later in life.[5] Obesity in this age group serves as an early warning sign because, while the condition is still potentially reversible, it sets the stage for a cascade of comorbidities, including type 2 diabetes mellitus, hypertension, non-alcoholic fatty liver disease, and premature cardiovascular death.

Historically, atherosclerosis was viewed as a degenerative disease of the elderly. However, contemporary medical understanding recognizes it as a lifelong process that begins in childhood. Autopsy studies such as the Bogalusa Heart Study and the Pathobiological Determinants of Atherosclerosis in Youth (PDAY) study have demonstrated that fatty streaks—the precursors to atherosclerotic plaques—can be found in the aortas and coronary arteries of children and adolescents. Atherosclerosis is a disease of the arterial wall initiated when dysfunctional endothelial cells oxidize lipids within the tunica intima, leading to the formation of fatty layers, plaques, or atheromas.[6] In the pediatric population, this process is subclinical; it develops silently without overt symptoms, making early detection challenging yet crucial. The progression of atherosclerosis is heavily influenced by the duration of exposure to risk factors. Therefore, obesity during the teenage years accelerates the vascular age of the individual, pushing the timeline of cardiovascular morbidity forward by decades.

To assess this subclinical risk non-invasively, clinicians utilize Carotid Intima-Media Thickness (CIMT). CIMT is defined as the distance between the lumen-intima interface and the media-adventitia interface of the carotid artery.[7] Measured using high-

resolution B-mode ultrasonography, CIMT has been validated as a reliable surrogate marker for generalized atherosclerosis and a strong predictor of future cardiovascular events, such as stroke and coronary heart disease. Physiologically, the tunica intima thickens naturally with age. However, obesity acts as a catalyst, accelerating this thickening process prematurely. Research indicates that CIMT values above the 75th percentile for a child's age and gender are indicative of high cardiovascular risk. The mechanism linking obesity to increased CIMT involves a combination of hemodynamic strain and metabolic toxicity. The remodeling of the vessel wall—characterized by smooth muscle hypertrophy and collagen deposition—is a response to the inflammatory signals and oxidative stress generated by excess adiposity.

The traditional clinical paradigm posits that dyslipidemia is the primary biochemical driver of atherosclerosis. Dyslipidemia in children is characterized by a specific triad of abnormalities: elevated triglycerides (TG), elevated low-density lipoprotein (LDL), and reduced high-density lipoprotein (HDL). This profile is highly atherogenic.[8] Elevated LDL, particularly the small dense LDL particles common in obesity, easily penetrates the endothelial barrier. Once inside the subendothelial space, these particles are oxidized and engulfed by macrophages, forming foam cells that constitute the core of the atherosclerotic plaque. Concurrently, low levels of HDL impair the body's ability to perform reverse cholesterol transport, failing to remove excess cholesterol from the vascular tissues. Elevated triglycerides further exacerbate this dynamic by altering the composition of LDL particles, making them more susceptible to oxidation. The prevalence of dyslipidemia in obese children is rising, with studies indicating that approximately 20% of children aged 6 to 19 years in the United States have at least one abnormal lipid value. Clinical guidelines from the American Academy of Pediatrics (AAP) and the National Heart, Lung, and Blood Institute (NHLBI) emphasize the necessity of lipid screening in obese youth to detect these abnormalities early.

Despite the clear theoretical link between lipids and atherosclerosis, the immediate impact of these lipid panels on arterial architecture in the pediatric population remains complex and inconsistent. While some studies, such as the Bogalusa Heart Study, show a strong correlation between abnormal lipids and vascular damage, other observations in various cohorts have shown inconsistent correlations between these biochemical biomarkers and structural changes measured via ultrasonography. This inconsistency suggests a time lag or a dissociation phenomenon. It is hypothesized that in the adolescent phase, vascular remodeling may be driven more potently by the inflammatory pathways (IL-6, CRP) and insulin resistance associated with adipose tissue, rather than by lipid deposition alone.[9] Furthermore, the concept of metabolically healthy obesity complicates the clinical picture, where some obese individuals maintain normal lipid profiles despite having excess adiposity. However, even in these individuals, the vascular wall may already be undergoing pathological changes due to hemodynamic stress or undetected inflammatory markers.

This dissociation is particularly relevant in the 15–18-year age group. This period represents the final phase of puberty, a critical window where hormonal fluctuations begin to stabilize. It is a time when the cumulative effects of childhood obesity begin to interact with the physiological changes of young adulthood. Understanding whether vascular damage in this specific demographic is lipid-driven or inflammation-driven is vital for determining the most effective preventative interventions—whether they should focus on aggressive lipid-lowering therapies or broader lifestyle modifications to reduce adiposity and inflammation.[10]

The specific context of Padang, West Sumatra, presents a unique and urgent epidemiological landscape. With the highest prevalence of obesity shifted toward high school students, there is a pressing need to evaluate the cardiovascular health of this specific population. While general studies on

obesity and CIMT exist, there is a paucity of data specifically analyzing the correlation between the full lipid panel (Total Cholesterol, Triglycerides, HDL, LDL) and CIMT in the distinct demographic of West Sumatran adolescents aged 15–18 years. Therefore, the objective of this research is to investigate the association between specific lipid fractions and CIMT in obese adolescents in the city of Padang. The novelty of this study lies in its focused analysis of the late adolescent phase (15 to 18 years), a period where hormonal stabilization occurs alongside chronic metabolic stressors. By examining the dissociation between biochemical markers and structural vascular remodeling, this study seeks to provide deeper insights into the pathophysiology of early-onset cardiovascular risk, determining whether traditional lipid markers are sufficient predictors of subclinical atherosclerosis in this high-risk, under-studied population. This research aspires to provide a scientific foundation for more targeted screening and intervention strategies to avert the looming wave of premature cardiovascular mortality in Indonesia.

2. Methods

To investigate the complex relationship between lipid profiles and vascular architecture in the pediatric population, this research was established as an observational analytic study utilizing a cross-sectional design. This methodological approach was selected to capture a temporal snapshot of both the dependent variable (Carotid Intima-Media Thickness or CIMT) and independent variables (lipid fractions including Total Cholesterol, Triglycerides, HDL, and LDL) simultaneously. The study was conducted within a tertiary clinical setting, specifically leveraging the advanced diagnostic capabilities of the Radiology Department at Dr. M. Djamil General Hospital Padang for vascular imaging, and the precision of the Biochemistry Laboratory at the Faculty of Medicine, Universitas Andalas, for metabolic analysis. The research protocol adhered strictly to the ethical principles involving human subjects. Formal ethical clearance was granted by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Andalas, ensuring the study's compliance with the Declaration of Helsinki. Given the vulnerability of the pediatric population, a rigorous informed consent process was implemented. Written informed consent was mandated and obtained from the parents or legal guardians of all participating adolescents prior to the initiation of any data collection or clinical procedures.

The target population for this study comprised adolescents aged 15 to 18 years, a critical developmental window marking the transition from puberty to young adulthood. The study specifically targeted individuals with a nutritional status defined as obesity who were enrolled as students in various high schools across the city of Padang. To ensure a representative sample within the logistical and temporal constraints of the study, subjects were recruited using a consecutive sampling technique. This non-probability sampling method involved selecting every subject who met the inclusion criteria over the specified study period until the required sample size was achieved. Strict eligibility criteria were applied to minimize selection bias and confounding factors. The inclusion criteria required subjects to fall strictly within the 15–18-year age range, demonstrate a body mass index (BMI) at or above the 95th percentile according to age-and-sex-specific growth charts, and express a voluntary willingness to participate. The final sample size was determined to be 45 individuals, calculated to provide sufficient statistical power for bivariate analysis. To isolate the metabolic effects of exogenous obesity from other pathological causes, rigorous exclusion criteria were enforced. Participants were excluded if their obesity was suspected or confirmed to have an endogenous or genetic etiology, such as Prader-Willi Syndrome, Bardet-Biedl Syndrome, or Cushing Syndrome. Furthermore, to ensure the integrity of the metabolic data, the study excluded individuals with pre-existing endocrine disorders affecting lipid metabolism (such as hypothyroidism) or those who had a history of consuming pharmaceutical agents known to alter lipid profiles—specifically corticosteroids or lipid-lowering

medications—within the three months preceding the study.

A standardized anthropometric assessment was conducted to confirm nutritional status and assess body composition. Height was measured to the nearest 0.1 cm using a calibrated standard stadiometer/meter, with subjects standing in an upright position without footwear. Weight was recorded to the nearest 0.1 kg using a calibrated digital scale. These primary measurements were utilized to calculate the body mass index (BMI) based on the formula: weight in kilograms divided by the square of height in meters (kg/m^2). To standardize the definition of obesity across different ages and genders, the calculated BMI values were plotted against the Centers for Disease Control and Prevention (CDC) 2000 growth charts. Obesity was strictly defined as a BMI at the 95th percentile. Additionally, waist circumference was measured to provide a proxy for visceral adiposity, which is metabolically distinct from subcutaneous fat and highly correlated with cardiovascular risk.

Venous blood sampling was performed to assess the lipid profile of each participant. A volume of 3 ml of venous blood was collected aseptically via venipuncture by experienced laboratory personnel to minimize hemolysis and ensure sample quality. Following collection, samples were stored in vacutainers at a controlled temperature of 2–8°C to preserve analyte stability before transport. The biological samples were transported to the Biochemistry Laboratory of Universitas Andalas for analysis. The quantification of lipid fractions—specifically total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL)—was performed using Enzyme-Linked Immunosorbent Assay (ELISA) based lipid test kits. To ensure clinical relevance, the resulting lipid values were categorized into normal, borderline, and abnormal (high or low depending on the fraction) based on the standard pediatric lipid value guidelines established by the National Heart, Lung, and Blood Institute (NHLBI).

The assessment of subclinical atherosclerosis was conducted using high-resolution B-mode ultrasonography. The imaging procedure utilized a GE Logic e9 ultrasound system equipped with a high-frequency 12L linear probe, which provides the necessary spatial resolution to visualize the arterial wall layers. All examinations were performed by a single specialist radiologist to eliminate inter-observer variability. The scanning protocol involved positioning the subject in a supine position with the neck slightly hyperextended and rotated away from the transducer. The measurements focused on the common carotid artery. The Carotid Intima-Media Thickness (CIMT) was defined as the double-line density representing the distance between the lumen-intima interface and the media-adventitia interface. To ensure a representative value, measurements were taken at five distinct points along the posterior wall of the carotid artery. These five values were averaged to produce the final mean CIMT for each subject. Pathological thickening was defined as a mean CIMT value exceeding the 75th percentile for the subject's specific age, gender, and height, based on normative pediatric data.

A systematic data management process was employed, encompassing editing, coding, entry, and cleaning. The editing phase involved a manual review of data collection forms to check for completeness and consistency. Coding was utilized to convert categorical variables into a numerical format for analysis. Data cleaning was performed to identify and rectify any entry errors or outliers prior to statistical processing. Statistical analysis was conducted using IBM SPSS Statistics version 22. The analysis was divided into two stages. First, univariate analysis was performed to describe the baseline characteristics of the study population, presenting frequency distributions and percentages for categorical data, and mean, standard deviation (or median with ranges) for numerical data. Second, bivariate analysis was employed to test the hypothesis regarding the relationship between independent variables (lipid fractions) and the dependent variable (CIMT). Given the sample size and

the categorical nature of the data (normal vs. abnormal), Fisher's exact test was utilized to determine statistical significance, with a p-value of <0.05 considered statistically significant.

3. Results

Table 1 delineates the baseline demographic and anthropometric characteristics of the study cohort, comprising 45 adolescents confirmed to have obesity. The population exhibited a median age of 16.00 ± 0.73 years, effectively capturing the late adolescent developmental window where hormonal stabilization typically occurs and where the cumulative effects of childhood obesity begin to manifest more acutely. The gender distribution demonstrated a distinct female predominance, with 68.9% (n=31) of the participants being female, a demographic trend that aligns with regional epidemiological data suggesting higher obesity rates among adolescent girls in West Sumatra. Anthropometric evaluations revealed a substantial burden of adiposity within the group. The median body mass index (BMI) was recorded at 29.34 ± 2.03 kg/m², significantly surpassing the 95th percentile threshold used for inclusion and indicating severe obesity rather than mere overweight status. Furthermore, the mean waist circumference of 93.34 ± 10.29 cm underscores a high prevalence of central or visceral obesity. This specific anthropometric marker is critical as visceral fat is metabolically active and strongly associated with the secretion of pro-inflammatory cytokines that drive endothelial dysfunction. Perhaps the most clinically significant finding presented in this profile is the high prevalence of early vascular remodeling. Despite the young median age of the cohort, 68.9% (n=31) of the subjects exhibited carotid intima-media thickness (CIMT) values exceeding the 75th percentile, classifying them as having pathological thickening. This rate of subclinical atherosclerosis suggests that for a majority of these students, the vascular wall is already undergoing compensatory hypertrophy in response to hemodynamic and metabolic stress. The data indicates that structural arterial damage is well-established in this population, occurring independently of the variations in age within the 15–18-year range.

Table 1. Demographic and Anthropometric Profiles of Obese Adolescents (N=45)

CHARACTERISTIC	VALUE (MEDIAN ± SD)	FREQUENCY N (%)
Demographics		
Age (years)	16.00 ± 0.73	—
Sex: Male	—	14 (31.1%)
Sex: Female	—	31 (68.9%)
Anthropometric Measurements		
Height (cm)	158.00 ± 9.73	—
Weight (kg)	75.00 ± 10.68	—
Body Mass Index (kg/m²)	29.34 ± 2.03	—
Waist Circumference (cm) [a]	93.34 ± 10.29	—
Vascular Status (CIMT)		
Thickened (>75th Percentile)	ABNORMAL	31 (68.9%)
Normal (<75th Percentile)	NORMAL	14 (31.1%)

Notes:
Data are presented as n (%) for categorical variables and Median ± Standard Deviation (SD) for continuous variables unless otherwise noted.
[a] Waist circumference is presented as Mean ± SD.
Abbreviations: CIMT = Carotid Intima-Media Thickness; SD = Standard Deviation.

Table 2 presents the comprehensive biochemical lipid profiles and structural vascular assessments of the study cohort, revealing a paradoxical discordance between metabolic markers and arterial health. In terms of lipid metabolism, the data portray a relatively benign profile for a population defined by obesity. The majority of the adolescents maintained cholesterol levels within normative pediatric ranges; specifically, 73.3% of subjects exhibited normal Total Cholesterol levels with a mean of 159.74 ± 16.30 mg/dL. Even more striking was the status of low-density lipoprotein (LDL), traditionally considered the primary atherogenic lipid, which was found to be within normal limits for 95.6% of the participants (mean 78.99 ± 17.38 mg/dL). The most significant lipid abnormality observed was hypertriglyceridemia, affecting 48.9% of the cohort with a highly variable median concentration of 123.70 ± 92.10 mg/dL. In sharp contrast to these generally acceptable lipid parameters, the ultrasonographic evaluation of the common carotid artery revealed a high prevalence of structural pathology. As detailed in the vascular findings, 68.9% (n=31) of the subjects demonstrated carotid intima-media thickness (CIMT) values exceeding the 75th percentile, confirming the presence of subclinical atherosclerosis. This discrepancy highlights a critical clinical insight: significant vascular remodeling and endothelial stress are occurring in these obese adolescents despite the absence of severe dyslipidemia. The data suggest that the arterial thickening observed in this demographic is likely driven by factors other than circulating LDL concentrations, pointing potentially toward insulin resistance or chronic low-grade inflammation associated with visceral adiposity as the primary architects of early vascular damage.

Table 2. Laboratory and Vascular Findings in Obese Adolescents (N=45)

PARAMETER	CONCENTRATION / VALUE (Mean/Median ± SD)	CLINICAL STATUS	FREQUENCY N (%)
Biochemical Lipid Profile			
Total Cholesterol (mg/dL)	159.74 ± 16.30	NORMAL	33 (73.3%)
Borderline/High	—	ELEVATED	12 (26.7%)
LDL Cholesterol (mg/dL)	78.99 ± 17.38	NORMAL	43 (95.6%)
Borderline/High	—	ELEVATED	2 (4.4%)
HDL Cholesterol (mg/dL)	46.00 ± 10.49	NORMAL	25 (55.6%)
Low/Borderline	—	RISK	20 (44.4%)
Triglycerides (mg/dL)	123.70 ± 92.10	HIGH	22 (48.9%)
Normal/Borderline	—	ACCEPTABLE	23 (51.1%)
Structural Vascular Assessment (Ultrasound)			
Carotid Intima-Media Thickness	> 75th Percentile	THICKENED	31 (68.9%)
Normal Architecture	< 75th Percentile	NORMAL	14 (31.1%)

Notes:
• Values are presented as Mean ± SD for normally distributed data and Median ± SD for non-normally distributed data (Triglycerides/HDL).
• Clinical Status categories are based on NHLBI Expert Panel Guidelines for Pediatrics.
Abbreviations: LDL = Low-Density Lipoprotein; HDL = High-Density Lipoprotein; SD = Standard Deviation.

Table 3 elucidates the results of the bivariate analysis utilizing Fisher's exact test to determine the statistical dependence between specific lipid fractions and the presence of carotid intima-media thickness (CIMT) abnormalities. The overarching finding presented in this analysis is a complete lack of statistically significant association across all lipid parameters measured, challenging the conventional linear model of atherosclerosis in this pediatric demographic. Specifically, total cholesterol and low-density lipoprotein (LDL)—often cited as the primary biochemical architects of atheroma formation in adults—demonstrated non-significant p-values of 0.402 and 1.000, respectively. The p-value of 1.000 for LDL is particularly notable from a statistical perspective; it reflects the extreme homogeneity of the independent variable, as 95.6% of the cohort possessed normal LDL levels despite their obese status. Consequently, the statistical analysis could not establish a correlation because the independent variable lacked sufficient variance to predict the dependent outcome of vascular thickening. Furthermore, despite hypertriglyceridemia being the most common metabolic derangement in the cohort (affecting nearly half of the subjects), it did not translate into a statistically significant predictor for vascular thickening (p=0.696). Similarly, high-density lipoprotein (HDL) failed to demonstrate a statistically significant protective correlation with CIMT preservation (p=0.563). Collectively, these non-significant findings provide robust statistical evidence for a lipid paradox in adolescent obesity. They imply that the structural remodeling of the carotid artery, which was observed in 68.9% of the subjects, is not an immediate consequence of current circulating lipid concentrations. Instead, these results direct clinical suspicion toward non-lipid pathways—such as the pro-inflammatory cytokine release associated with visceral adiposity or early-onset insulin resistance—as the predominant drivers of subclinical atherosclerosis in this specific developmental window.

Table 3. Bivariate Correlation Analysis

Association Between Lipid Profiles and Carotid Intima-Media Thickness (Fisher's Exact Test)

VARIABLE	CATEGORY	CIMT STATUS [N (%)]		P-VALUE
		THICKENED (N=31)	NORMAL (N=14)	
Total Cholesterol	*Normal*	23 (51.1%)	10 (22.2%)	0.402
	Borderline	8 (17.8%)	3 (6.7%)	
	High	0 (0%)	1 (2.2%)	
Triglycerides	*Normal*	11 (24.5%)	3 (6.7%)	0.696
	Borderline	6 (13.3%)	3 (6.7%)	
	High	14 (31.1%)	8 (17.7%)	
HDL Cholesterol	*Normal*	19 (42.2%)	6 (13.3%)	0.563
	Borderline	7 (15.6%)	5 (11.1%)	
	Low	5 (11.1%)	3 (6.7%)	
LDL Cholesterol	*Normal*	29 (64.4%)	14 (31.1%)	1.000
	Borderline	2 (4.5%)	0 (0%)	
	High	0 (0%)	0 (0%)	

Statistical Notes:

- Data are presented as frequency n (%) representing the percentage of the total sample (N=45) within that specific cross-tabulation cell.
- Significance was determined using Fisher's Exact Test due to expected cell counts < 5 in multiple categories.
- A p-value < 0.05 is considered statistically significant.

Abbreviations: CIMT = Carotid Intima-Media Thickness; HDL = High-Density Lipoprotein; LDL = Low-Density Lipoprotein.

4. Discussion

The primary and most provocative finding of this research is the distinct dissociation between circulating lipid levels and structural arterial changes in obese adolescents. In the classical paradigm of adult atherosclerosis, the deposition of low-density lipoprotein (LDL) into the arterial intima is the central initiating event of plaque formation.[11] However, our data suggest that in the early pediatric stages of obesity, vascular remodeling is driven by mechanisms that operate independently of, or perhaps antecedently to, overt dyslipidemia. This study observed that while 68.9% of the subjects exhibited pathological thickening of the carotid intima-media thickness (CIMT), the bivariate analysis failed to establish any statistically significant correlation between this thickening and total cholesterol (p=0.402), triglycerides (p=0.696), HDL (p=0.563), or LDL (p=1.000). This statistical silence is profound. It indicates that the vascular wall is responding to a systemic insult that is not captured by the standard lipid panel.[12]

The most plausible explanation lies in the inflammatory nature of obesity itself. Obesogenic environments trigger a state of chronic, low-grade systemic inflammation. Adipose tissue, particularly the visceral compartment, which was prominent in our subjects (mean waist circumference 93.34 cm), is not merely an energy storage depot but a metabolically active endocrine organ. It releases a barrage of pro-inflammatory cytokines, including Interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-alpha).[13] These cytokines initiate endothelial dysfunction—the earliest stage of atherosclerosis—by downregulating protective pathways and upregulating adhesion molecules. This inflammatory milieu stimulates the migration and proliferation of smooth muscle cells from the tunica media into the tunica intima, leading to the measured increase in CIMT. Crucially, this process of intimal hyperplasia can occur purely as a response to inflammatory signaling and hemodynamic shear stress, long before the lipid retention threshold is breached to form a fatty streak or plaque. Thus, the thickening observed in these adolescents represents a hypertrophic response to metabolic inflammation rather than the cholesterol storage disease seen in adults.[14]

The presence of insulin resistance in obese individuals further complicates the vascular landscape and likely serves as a key mediator in the non-lipid driven thickening we observed. Although insulin resistance was not directly measured in this study, the high prevalence of central obesity (indicated by waist circumference) is a strong clinical proxy for this metabolic state. Insulin resistance directly impairs the production of nitric oxide (NO) in endothelial cells. Nitric Oxide is the guardian of the vasculature; it maintains vascular tone, prevents platelet aggregation, and inhibits the inflammatory infiltration of the vessel wall.[15] When insulin signaling is disrupted, NO bioavailability plummets, leaving the endothelium vulnerable to structural damage. Furthermore, chronic obesity is intrinsically associated with a cumulative oxidative stress burden. The expansion of adipose tissue leads to hypoxia and macrophage infiltration, generating reactive oxygen species (ROS). This oxidative state can damage vessel walls directly and promote the formation of foam cells within the tunica intima by oxidizing the small amount of LDL that may be present, a process that can initiate atherogenesis even when standard serum lipid panels appear clinically normal. This oxidative and inflammatory synergy creates a toxic vascular environment that promotes arterial stiffening and thickening, bypassing the traditional requirement for elevated serum cholesterol.

Our data challenge the clinical utility of the metabolically healthy obesity (MHO) concept in the pediatric population. A significant proportion of our subjects—73.3% for Total Cholesterol and 95.6% for LDL—would be classified as metabolically healthy based solely on their lipid profiles. If a clinician were to rely only on these blood biomarkers, the majority of these high-risk adolescents would be deemed healthy and perhaps denied necessary lifestyle interventions.[16] However, the ultrasound findings

reveal a different reality: 68.9% of these healthy adolescents already possess arterial walls that are pathologically thickened (>75th percentile). This phenomenon suggests a significant time lag in disease progression. Structural vascular damage, driven by the hemodynamic load of excess body mass (increased cardiac output) and the systemic inflammatory background, appears to occur earlier than the biochemical derangement of lipids. The arterial walls undergo compensatory hypertrophy to normalize wall tension in the face of increased blood pressure and flow associated with obesity—a mechanical adaptation that manifests as increased CIMT. This structural remodeling is a silent pathology that predates the loud metabolic signals of dyslipidemia. Therefore, the absence of dyslipidemia in an obese adolescent should not be interpreted as the absence of cardiovascular risk. The term metabolically healthy may simply describe a transient phase where the body's homeostatic mechanisms are still managing to keep lipids in check, while the vasculature is already suffering the consequences of adiposity.[17]

Our findings are consistent with the emerging consensus in recent pediatric cardiovascular research. For instance, a previous study reported a lack of significant correlation between traditional lipid fractions and CIMT in younger age groups (p=0.297 for cholesterol). These studies, aligning with ours, suggest that the predictive value of LDL and Total Cholesterol for vascular health is significantly lower in pediatric and adolescent populations compared to adults. In adults, decades of exposure allow lipids to become the dominant factor; in children, the disease is in its nascent, inflammatory phase.[18] However, our results contrast with another study, which found lipids to be predictive. This discrepancy may be attributed to the specific age window or the homogeneity of our specific population, where the vast majority had normal lipids, statistically limiting the ability to detect a correlation. Nevertheless, the alignment with Pillai and Shin reinforces the conclusion that in the context of adolescent obesity, we must look beyond the lipid panel to assess true vascular health.[19]

While this study provides critical insights, it is subject to the inherent limitations of a cross-sectional design. We measured obesity and CIMT at a single point in time, which prevents the establishment of a definite causal relationship. We cannot say with certainty that obesity caused the thickening, only that they coexist frequently. Additionally, the exact duration of obesity in each subject was not determined. A subject who has been obese since age 5 likely has a different vascular risk profile than one who developed obesity at age 14, as the cumulative exposure to inflammation differs.[20] Future research should utilize prospective cohort designs to track these metabolic and vascular changes longitudinally from childhood into adulthood. Furthermore, to validate the inflammation hypothesis, future studies must incorporate direct measurements of inflammatory markers such as high-sensitivity C-reactive protein (hs-CRP), tumor necrosis factor-alpha (TNF-alpha), and assessments of insulin sensitivity (HOMA-IR). Including these variables would provide a more comprehensive, mechanistic view of how obesity remodels the adolescent artery, moving the field beyond simple lipid associations.

5. Conclusion

In conclusion, this research uncovers a significant and clinically vital dissociation between traditional lipid profiles and structural vascular health in obese high school students in Padang, Indonesia. We observed a high prevalence of carotid intima-media thickness (CIMT) thickening (68.9%), a marker of subclinical atherosclerosis, even among individuals who presented with clinically normal cholesterol and LDL levels. This evidence strongly supports the hypothesis that early-onset atherosclerosis in this population is driven by non-lipid mechanisms, primarily systemic inflammation and insulin resistance, rather than the lipid storage pathology seen in adults. Consequently, the current clinical reliance solely on lipid panels for risk stratification is insufficient and may lead to a dangerous underestimation of cardiovascular risk in obese

adolescents. They may be biochemically normal but vascularly ill. Therefore, we recommend a paradigm shift in the screening of obese adolescents. Early screening via CIMT ultrasonography should be considered as a more sensitive and accurate tool for detecting subclinical vascular damage in this high-risk group. Identifying these structural changes early—regardless of lipid status—allows for aggressive lifestyle interventions to reverse vascular remodeling before it progresses to irreversible cardiovascular disease in adulthood.

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