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Body composition and cardiovascular risk: correlation of fat mass, muscle mass, and visceral fat with atherogenic index of plasma in young adults

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ABSTRACT

Background: Variations in body composition, particularly fat mass, muscle mass, and visceral adiposity, are known to influence lipid profiles and correlate with cardiovascular risk. The Atherogenic Index of Plasma (AIP) is an indicator marker for lipid-related cardiovascular disease. This study examines the association between body composition and AIP in young adults.

Methods: An analytical cross-sectional study was conducted using purposive sampling among 167 students aged 17–22 years at Hasanuddin University. Anthropometric measurements (body weight, height, and waist circumference), were obtained using standardized procedures. Body composition (fat mass, muscle mass, visceral fat, bone mass, and total body water) was assessed using a Tanita BC-730 bioelectrical impedance analyzer (BIA). Venous blood samples were collected following overnight fast, triglyceride and HDL-C levels measured using enzymatic methods. Bivariate analysis was performed to examine correlations between body composition parameters and the Atherogenic Index of Plasma (AIP). Multiple linear regression with backward elimination was used to identify independent predictors of AIP.

Results: Females had significantly higher fat mass (36.6%) and lower muscle mass (59.95%) compared to males (18.4% and 77.6%, respectively; $p < 0.001$). There was no significant difference in visceral fat between sexes. AIP showed a positive correlation with fat mass ($r = 0.231$, $p = 0.003$) and visceral fat ($r = 0.417$, $p < 0.001$), and a negative correlation with muscle mass ($r = –0.219$, $p = 0.004$). In multivariate analysis, visceral fat emerged as the only independent predictor of AIP ($\beta = 0.426$, $p < 0.001$).

Conclusions: Visceral fat emerged as the only independent predictor with significant effect on AIP. AIP and body composition screening may support early prevention strategies in youth.

KEYWORDS

Lipid profile, atherogenic index, visceral fat, physiological parameters, cardiometabolic biomarkers.

INTRODUCTION

Obesity, characterized by excessive fat accumulation that impairs health, has become a critical global health concern. According to the World Health Organization (2024), as of 2022, 2.5 billion adults aged 18 years and older were overweight, including over 890 million with obesity, representing 43% of the adult population a stark increase from just 25% in 1990[1]. The global rise in obesity over recent decades has been accompanied by an increasing prevalence of metabolic syndrome, a condition that significantly elevates the risk of developing cardiovascular disease[2]. Body composition is a key risk factor for metabolic and cardiovascular diseases, and is strongly influenced by both dietary patterns and physical activity[3]. Beyond total body fat, body composition, which includes fat mass, muscle mass, bone mass, and total body water, offers a more comprehensive picture of metabolic health. A growing body of evidence suggests that higher fat mass and lower muscle mass are associated with unfavorable lipid profiles and increased cardiovascular risk. Specifically, alterations in body composition have been linked to elevated Atherogenic Index of Plasma

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(AIP), making it a useful indicator in assessing lipid-related risk across varying body types. In parallel, fat distribution, particularly the contrast between visceral and subcutaneous (distributed) fat, has gained attention as a key determinant of metabolic and cardiovascular risk. As emphasized by Koceva et al. (2024), visceral fat, more commonly found in men, is not only more metabolically active but also more dangerous than subcutaneous fat, which is predominant in women[4].

Unlike subcutaneous fat, visceral adipose tissue (VAT) surrounds internal organs and actively contributes to systemic inflammation, insulin resistance, and atherogenic lipid profiles, substantially elevating the risk of cardiovascular disease (CVD), type 2 diabetes, and metabolic syndrome[5]. Importantly, individuals with a normal Body Mass Index (BMI) but high visceral fat may face greater health risks than those with a high BMI and predominantly subcutaneous fat[6]. This distinction underscores the clinical importance of where fat is stored, rather than how much fat is stored.

Common anthropometric indicators such as Waist Circumference (WC) and Waist-to-Hip Ratio (WHR) are more accurate in predicting visceral fat compared to BMI. Additionally, biochemical markers like the Atherogenic Index of Plasma (AIP) the base-10 logarithmic ratio of triglycerides to HDL cholesterol have demonstrated strong correlations with visceral adiposity and cardiovascular risk[7]. These simple, cost-effective indicators offer valuable tools for early detection of fat-related metabolic complications.

Young adults represent a crucial population for early prevention because they are undergoing major lifestyle transitions that shape long-term health. Physical inactivity, poor dietary patterns, and limited access to routine health check-ups in this age group can lead to early-onset obesity and metabolic disturbances[8]. Although these changes often occur without noticeable symptoms[9], elevated AIP may already signal underlying cardiovascular risk. Identifying these risks early offers a valuable window for intervention before clinical manifestations appear.

Globally, the prevalence of overweight and obesity among young adults is rising, largely due to sedentary behaviors and unhealthy diets. In Indonesia, the 2018 Basic Health Research reported obesity rates of 4.8% among adolescents aged 13–15 and 13.5% in those aged 16–18[10]. By 2023, the national adult obesity rate had increased from 21.8% (2018) to 23.4%[11] At the provincial level, adult obesity rates range from 10.4% to 30.1%, indicating that up to one in three adults may be classified as obese[12].

Adolescents are especially vulnerable to nutritional problems due to rapid growth and development, which affect body composition, physical activity levels, weight, and bone mass[13]. Lifestyle choices during the transition to adulthood, such as diet and physical activity, greatly influence body composition. High body fat, particularly visceral fat, is linked to poor lipid profiles like high triglycerides and low HDL cholesterol, which increase the Atherogenic Index of Plasma (AIP), a marker of cardiovascular risk[14].

Given the increasing prevalence of obesity and associated metabolic disorders, it is imperative to move beyond generalized measures of adiposity and focus on the specific contributions of fat distribution to cardiometabolic risk. While indices such as BMI remain widely used in both clinical and epidemiological settings, they fail to differentiate between metabolically benign and harmful fat compartments. Accordingly, this study seeks to elucidate the differential health risks posed by visceral adiposity compared to subcutaneous (distributed) fat, with particular emphasis on their associations with the Atherogenic Index of Plasma (AIP), a validated surrogate marker of lipid-related cardiovascular risk. By examining these relationships in a young adult population, the present research aims to contribute to a more nuanced understanding of adipose tissue function and distribution, thereby supporting the development of targeted screening protocols and early intervention strategies tailored to individuals at elevated metabolic risk.

MATERIALS AND METHODS

Study Design

This study employed an analytical observational design with a cross-sectional approach, conducted among young adult participants at Hasanuddin University, Makassar, Indonesia. Anthropometric and biochemical data were collected to examine the relationship between body fat distribution and cardiovascular risk indicators.

Data Collection

Anthropometric Measurements: Body weight was measured using a calibrated analog scale, with participants wearing a single layer of standardized clothing to minimize measurement error. Height was measured using a wall-mounted stadiometer, and Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m²). Based on the World Health Organization (WHO) classification, participants were categorized into four BMI groups: underweight (BMI < 18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30.0 kg/m²) [15]. Waist circumference was measured at the midpoint between the lowest rib and the iliac crest using a non-elastic measuring tape. Abdominal obesity was classified according to the International Diabetes Federation (IDF) criteria for Asian populations, with cut-off points of ≥90 cm for males and ≥80 cm for females, indicating increased risk for metabolic syndrome[16]. All instruments were calibrated prior to measurement, and anthropometric assessments were conducted by trained clinical nutrition personnel following standardized procedures.

Body composition was measured using bioelectrical impedance analysis (BIA) with a Tanita Body Fat Analyzer (Model BC-730; Tanita Corporation of America Inc., Arlington Heights,

IL, USA). Participants stood barefoot on the device platform, wearing light clothing and free of any personal items such as phones, wallets, keys, bags, or accessories. The measurement was conducted according to the manufacturer's instructions, with participants standing in an upright position, arms relaxed at their sides, and heels properly aligned on the device's footplate electrodes. Fat Mass Percentage was classified into five categories based on sex-specific standards.

For females, underfat was defined as <21%, standard ranges included 21–26% (standard minus) and 27–33% (standard plus), while 34–39% was categorized as overfat and ≥40% as obese. For males aged 17–21 years, underfat was defined as <8%, with standard minus and standard plus ranging from 8–13% and 14–20%, respectively. Fat Mass Percentage of 21–25% were considered overfat, and values ≥26% were classified as obese.

Visceral fat levels were classified into standard clinical categories to assess abdominal adiposity risk. A visceral fat rating of 1–9 was considered normal, indicating a healthy range. Ratings of 10–14 were categorized as high, suggesting increased abdominal fat and potential metabolic risk. A rating of 15 or above was classified as very high, indicating a significantly elevated risk for cardiometabolic disorders. These classifications for Fat Mass Percentage and visceral fat rating were based on the manufacturer's guidelines as outlined in the Tanita Body Composition Guide for the BC-730[17].

Total Body Water (TBW) represents the percentage of body weight composed of water and is a key indicator of hydration status and overall body composition. In general, a healthy TBW range is approximately 50–65% for males and 45–60% for females.

Biochemical analysis: Venous blood samples (3–5 mL) were collected from each participant following a 16-hour overnight fast to ensure accurate lipid profiling. Triglyceride levels were analyzed using the enzymatic colorimetric GPO-PAP method, while high-density lipoprotein cholesterol (HDL-C) levels were measured using the homogeneous enzymatic colorimetric method. All blood samples were processed and analyzed by Prodia Clinical Laboratory, a certified and standardized facility adhering to quality control protocols for clinical diagnostics.

The Atherogenic Index of Plasma was calculated using the formula: $\log_{10}$ (TG/HDL-C), where TG denotes fasting triglyceride concentration and HDL-C denotes high-density lipoprotein cholesterol concentration, both expressed in mmol/L. AIP values were interpreted according to established risk thresholds: −0.3 to 0.1 as low risk, 0.1 to 0.24 as intermediate risk, and >0.24 as high risk for cardiovascular disease[18].

Participants

The study population consisted of young adult students from health-related faculties at Hasanuddin University. A total of 167 participants were selected through purposive sampling based on predetermined inclusion and exclusion criteria. Inclusion criteria comprised individuals aged 17 to 22 years with no prior medical history or use of medications affecting glucose or lipid metabolism. Participants were excluded if they were currently or recently engaged in weight-loss programs, reported tobacco use or alcohol consumption, had incomplete data, declined to participate in the study, or refused to provide a blood sample for biochemical analysis.

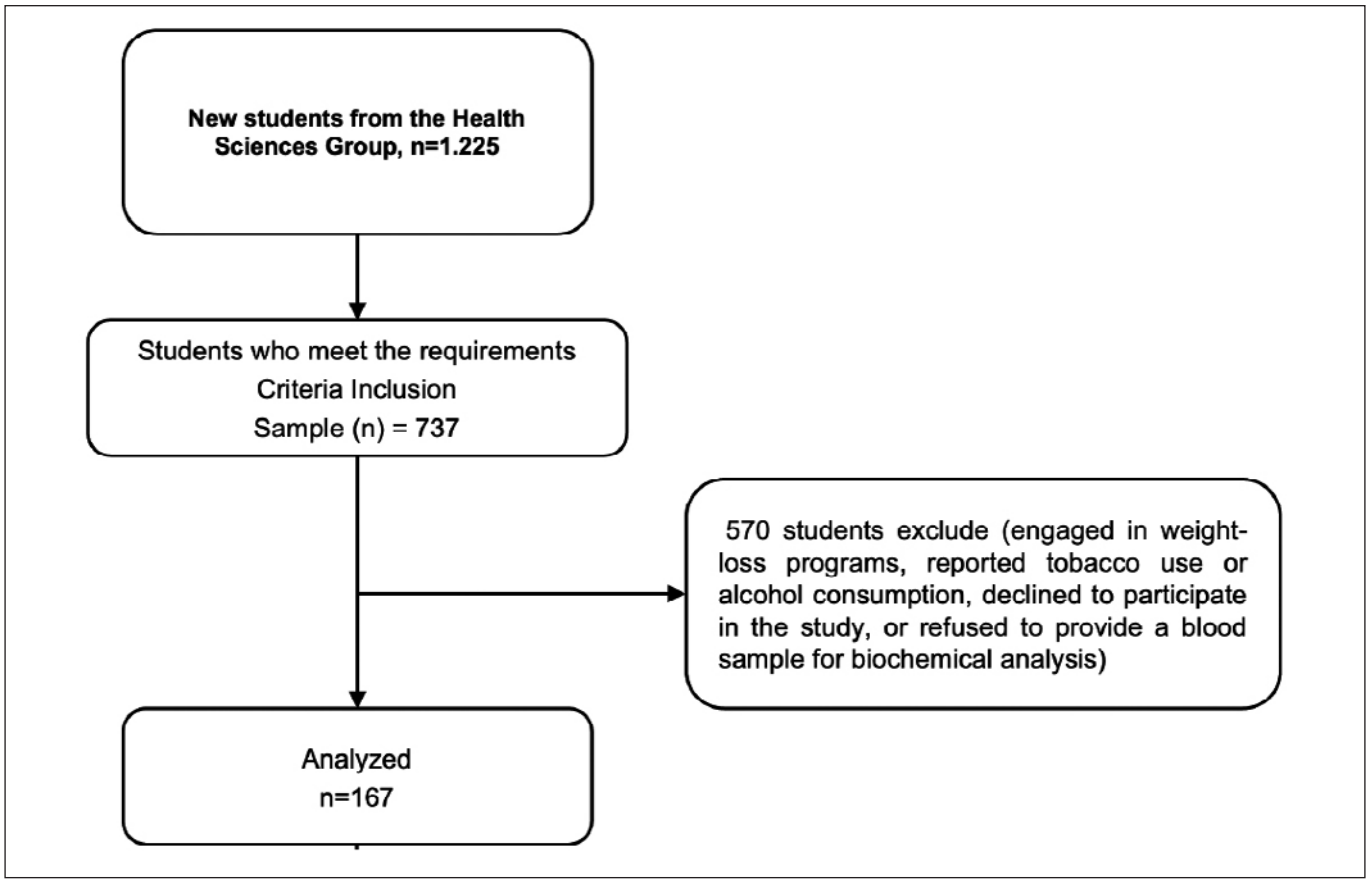
Statistical Analysis

A frequency distribution, presented through graphical and tabular formats, serves as the result of univariate analysis and is employed to describe the basic characteristics of the dataset. To evaluate the quantitative relationships between Fat Mass Percentage, Muscle Mass Percentage, and Visceral Fat, and the Atherogenic Index of Plasma (AIP) among young adults, bivariate analysis is conducted. The choice of correlation method depends on the distribution of the data: the Pearson correlation coefficient is used for normally distributed data, while Spearman's rank correlation is applied for non-parametric data. Data normality is assessed prior to analysis to ensure the appropriateness of the statistical tests applied.

Furthermore, multiple linear regression analysis is performed using the backward elimination method to identify the most significant predictors of AIP among the independent variables. This approach systematically removes non-significant variables from the model in a stepwise manner to obtain the most parsimonious and explanatory model. Data normality was assessed using the Shapiro-Wilk test. Multiple linear regression analysis was performed using backward stepwise elimination. All candidate variables (bone mass, total body water, waist circumference, and visceral fat) were initially included in the model. Variables were eliminated stepwise based on statistical significance ($p > 0.05$) and multicollinearity (VIF ≥ 10) criteria. The final model retained only variables that independently predicted AIP. All analyses were conducted using SPSS version 30 (IBM Corp., Armonk, NY).

Ethical approval

This study received ethical approval from the Research Ethics Committee of Universitas Hasanuddin, under recommendation number 30/UN4.6.4.5.31/PP36/2025. Prior to data collection, all participants were provided with detailed information regarding the study's objectives, procedures, potential risks, and benefits. Written informed consent was obtained from each participant. The research was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki, ensuring the rights, safety, confidentiality, and well-being of all participants were upheld throughout the study.



Picture 1. Flowchart of the Study

RESULTS

Participant Characteristics

Table 1 presents the distribution of respondent characteristics based on sex. Of the 167 respondents, comprising 41 males and 126 females, no statistically significant differences were observed between sexes in age, BMI, waist circumference, or physical activity level ($p > 0.05$). The distribution of BMI categories indicated a high prevalence of obesity in both groups, with 68.3% of males and 63.5% of females classified as obese. Central obesity was more prevalent among females (67.5%) than males (43.9%), although the difference in waist circumference was not statistically significant.

Table 2 presents the distribution of body composition parameters among 167 respondents, stratified by sex. Significant differences were observed in all major indicators of body composition, with the exception of visceral fat ($p = 0.141$). Females demonstrated significantly higher fat mass percentages (36.6% vs. 18.4%) compared to males ($p < 0.001$). The distribution of fat mass categories further indicated that a greater proportion of females (69.1%) were classified as overweight or obese, while the majority of males (60.9%) were in the standard category. Conversely, males exhibited significantly higher muscle mass in percentage (77.6% vs. 59.95%), total body water percentage (52.5% vs. 45.75%), and bone mass (3.2 kg vs. 2.4 kg), all with p-values < 0.001. No significant sex-based difference was identified in visceral fat distribution.

Table 3 summarizes the distribution of triglyceride levels, HDL cholesterol, and the Atherogenic Index of Plasma (AIP) among 167 young adult participants, stratified by sex. No significant difference was found in triglyceride levels between males and females, with both groups showing identical median values of 80 mg/dL ($p = 0.810$). Over 90% of participants in both groups had triglyceride levels within the normal range. HDL cholesterol levels differed significantly between groups ($p = 0.003$), with females showing a higher median value (52 mg/dL) than males (46 mg/dL). Despite this, low HDL levels were still prevalent, especially among females (42.1%). Although AIP values did not differ significantly between sexes ($p = 0.240$), a greater proportion of males were categorized in the high-risk group (58.5%) compared to females (49.2%).

Table 4 presents the distribution of anthropometric, body composition, laboratory, and physical activity characteristics according to Atherogenic Index of Plasma (AIP) categories:

Table 1. Baseline Characteristics of Respondents by Sex (n=167)

Variable	Male (n=41)	Female (n=126)	p-value
Age	18 (17-22)	18 (17-20)	0.439
BMI (Kg/m²)	26 (17.2-46.7)	26.55 (16.9-42.3)	0.822[2]
Underweight (<18.5)	3 (7.3%)	5 (4%)	
Normal-weight (18.5≤25)	4 (9.8%)	20 (15.9%)	
Overweight (25≤30)	6 (14.6%)	21 (16.7%)	
Obese (≥30)	28 (68.3%)	80 (63.5%)	
Waist Circumference (cm)	87 (64-130)	84 (60-120)	0.075[2]
Central Obesity (≥90cm for male; <80cm for female)	18 (43.9%)	85 (67.5%)	
Normal (<90cm for male; <80cm for female)	23 (56.1%)	41 (32.5%)	

[1] Independent T-test; [2] Mann Whitney Test; * Significance = p<0.05.

Table 2. Comparison of Body Composition Parameters by Sex (n=167)

Variable	Male (n=41)	Female (n=126)	p-value
Fat Mass (%)	18.4 (6.70-42.5)	36.6 (11.5-53.2)	0.000[2]*
Underfat	4 (9.8%)	2 (1.6%)	
Standard Minus / Plus	25 (60.9%)	37 (29.4%)	
Overfat / Obese	12 (29.2%)	87 (69.1.1%)	
Muscle Mass (%)	77.6 (55.3-89.9)	59.95 (43.7-86.73)	0.000[2]*
Visceral fat (index)	7.5 (1-20)	6 (1-13.5)	0.141[2]
Normal (1-9)	29 (70.7%)	112 (88.9%)	
Risk (10-14)/ High risk (≥15)	12 (29.2%)	14 (11.4%)	
Total Body Water (%)	52.5 (33.2-60.1)	45.75 (21.6-55.3)	0.000[2]*
Low	9 (22%)	51 (40.5%)	
Normal	32 (78%)	75 (59.5%)	
Bone Mass (Kg)	3.2 (2.2-4.3)	2.4 (1.4-4.1)	0.000[1]*

[1] Independent T-test; [2] Mann Whitney Test; * Significance = p<0.05.

low risk (<0.11), medium risk (0.11–0.24), and high risk (>0.24). Statistically significant differences were observed across AIP groups in multiple parameters ($p < 0.05$).

Participants in the high-risk AIP category had significantly higher BMI (median: 27.85 kg/m²) and a greater proportion classified as obese (79.1%) compared to the low (47.4%) and medium risk groups (54.6%) ($p = 0.0003$). Waist circumference was also significantly greater in the high-risk group (88 cm) compared to other categories ($p = 0.0003$), with central obesity observed in 73.3% of high-risk individuals.

Fat Mass Percentage was significantly elevated in the high-risk group (median: 36.9%) compared to the low-risk group

Table 3. Comparison of Lipid Profile and AIP by Sex (n=167)

Variable	Male (n=41)	Female (n=126)	p-value
Triglycerides (mg/dL)	80 (33-319)	80 (32-286)	0.810[2]
Normal <150 mg/dL	37 (90.2%)	115 (91.3%)	
Borderline High 150 – 199 mg/dL	2 (4.9%)	8 (6.3%)	
High 200 – 499 mg/dL	2 (4.9%)	3 (2.4%)	
HDL (mg/dL)	46 (29-72)	52 (28-85)	0.003[2]*
Low (male ≤40; female ≤50)	14 (34.1%)	53 (42.1%)	
Normal (male >40; female >50)	27 (65.9%)	73 (57.9%)	
Atherogenic Index of Plasma (AIP)	0.24 (-0.25-0.94)	0.187 (-0.28-1.01)	0.240[2]
Low Risk (<0.11)	11 (26.8%)	48 (38.1%)	
Medium Risk (0.11-0.24)	6 (14.6%)	16 (12.7%)	
High Risk (>0.24)	24 (58.5%)	62 (49.2%)	

[1] Independent T-test; [2] Mann Whitney Test; * Significance = p<0.05.

Tabla 4. Comparison of Metabolic and Physiological Parameters Across Atherogenic Index of Plasma Categories (n=167)

Variable	Atherogenic Index of Plasma (AIP) Category			p-value
	Low Risk (<0.11) (n=59)	Medium Risk (0.11-0.24) (n=22)	High Risk (>0.24) (n=86)	
Sex				
Male	11 (18.6%)	6 (27.3%)	24 (27.9%)	0.423[1]
Female	48 (81.4%)	16 (72.7%)	62 (72.1%)	
BMI (Kg/m^2)	24.8 (17.9-39.5)	25.05 (16.9-32.5)	27.85 (17.2-46.7)	
Underweight	2 (3.4%)	3 (13.6%)	3 (3.5%)	
Normal-weight	17 (28.8%)	2 (9.1%)	5 (5.8%)	0.000[3]*
Overweight	12 (20.3%)	5 (22.7%)	10 (11.6%)	
Obese	28 (47.4%)	12 (54.6%)	68 (79.1%)	
Circumference Waist (cm)	82 (63-110)	80.5 (60-106)	88 (64-130)	
Central Obesity	28 (47.5%)	12 (54.5%)	63 (73.3%)	0.000[3]*
Normal	31 (52.5%)	10 (45.5%)	23 (26.7%)	

[1] Chi Square test; [2] One Way Anova test; [3] Kruskal Wallis test; * significant = p<0.05.

Table 4 continuation. Comparison of Metabolic and Physiological Parameters Across Atherogenic Index of Plasma Categories (n=167)

Variable	Atherogenic Index of Plasma (AIP) Category			p-value
	Low Risk (<0.11) (n=59)	Medium Risk (0.11-0.24) (n=22)	High Risk (>0.24) (n=86)	
Body Composition				
Fat Mass (%)	33.8 (7.3-52.6)	33.25 (9.3-43.6)	36.9 (6.7-53.2)	0.044[3]*
Underweight	2 (3.4%)	1 (4.5%)	3 (3.5%)	
Standard Minus / Plus	26 (44%)	12 (54.6%)	24 (27.9%)	
Overweight / Obese	30 (52.5%)	9 (40.9%)	59 (68.6%)	
Muscle Mass (%)	62.9 (44.5-87.96)	63.03 (53.1-86.29)	60.2 (43.7-89.9)	0.063[3]
Visceral fat (index)	5 (1-14.5)	5.5 (1-11)	7.5 (1-20)	0.000[3]
Normal	55 (93.2%)	20 (90.9%)	66 (76.7%)	
Risk	4 (6.8%)	2 (9.1%)	20 (23.3%)	
Total Body Water (%)	47.3 (21.6-59.8)	48.7 (44.3-58.2)	45.7 (33.2-60.1)	0.007[3]*
Low	16 (27.1%)	2 (9.1%)	42 (48.8%)	
Normal	43 (72.9%)	20 (90.9%)	44 (51.2%)	
Bone Mass (Kg)	2.3 (1.5-4.2)	2.45 (1.4-3.7)	2.7 (1.6-4.3)	0.000[2]
Laboratory				
Triglycerides (mg/dL)	56 (32-83)	70..5 (50-108)	104.5 (69-319)	0.000[3]*
Normal	59 (100%)	22 (100%)	71 (82.6%)	
Borderline high	0	0	10 (11.6%)	
High	0	0	5 (5.8%)	
HDL (mg/dL)	61 (35-85)	50 (35-72)	44 (28-70)	0.000[3]*
Low	7 (11.9%)	7 (31.8%)	53 (61.6%)	
Normal	52 (88.1%)	15 (68.2%)	33 (38.4%)	

[1] Chi Square test; [2] One Way Anova test; [3] Kruskal Wallis test; * significant = p<0.05.

(33.8%) (p = 0.0443). Visceral fat showed an increasing trend across AIP categories, reaching a median of 7.5 in the high-risk group (p = 0.0003). Total body water percentage was significantly lower in the high-risk group (45.7%) compared to others (p = 0.0073), and bone mass was significantly higher in this group as well (p = 0.0002).

In laboratory findings, triglyceride levels increased significantly across AIP categories (p = 0.0003), with the high-risk group showing the highest median level (104.5 mg/dL). HDL cholesterol levels showed an inverse trend, with significantly lower median values in the high-risk group (44 mg/dL) compared to the low-risk group (61 mg/dL) (p = 0.0003). Similarly, LDL cholesterol and non-HDL cholesterol were significantly higher in the high-risk group (p = 0.0002), accompanied by a greater proportion of individuals in borderline or high-risk lipid categories. No significant differences were observed in fasting blood glucose, sex distribution, handgrip strength, or physical activity levels across AIP categories (p > 0.05)

Association of Fat Mass Percentage, Muscle Mass Percentage, and Visceral Fat with the Atherogenic Index of Plasma

Figures 1–3 illustrate the associations between selected body composition parameters and the Atherogenic Index of Plasma (AIP), based on Spearman correlation and linear regression analyses. A significant positive correlation was ob-

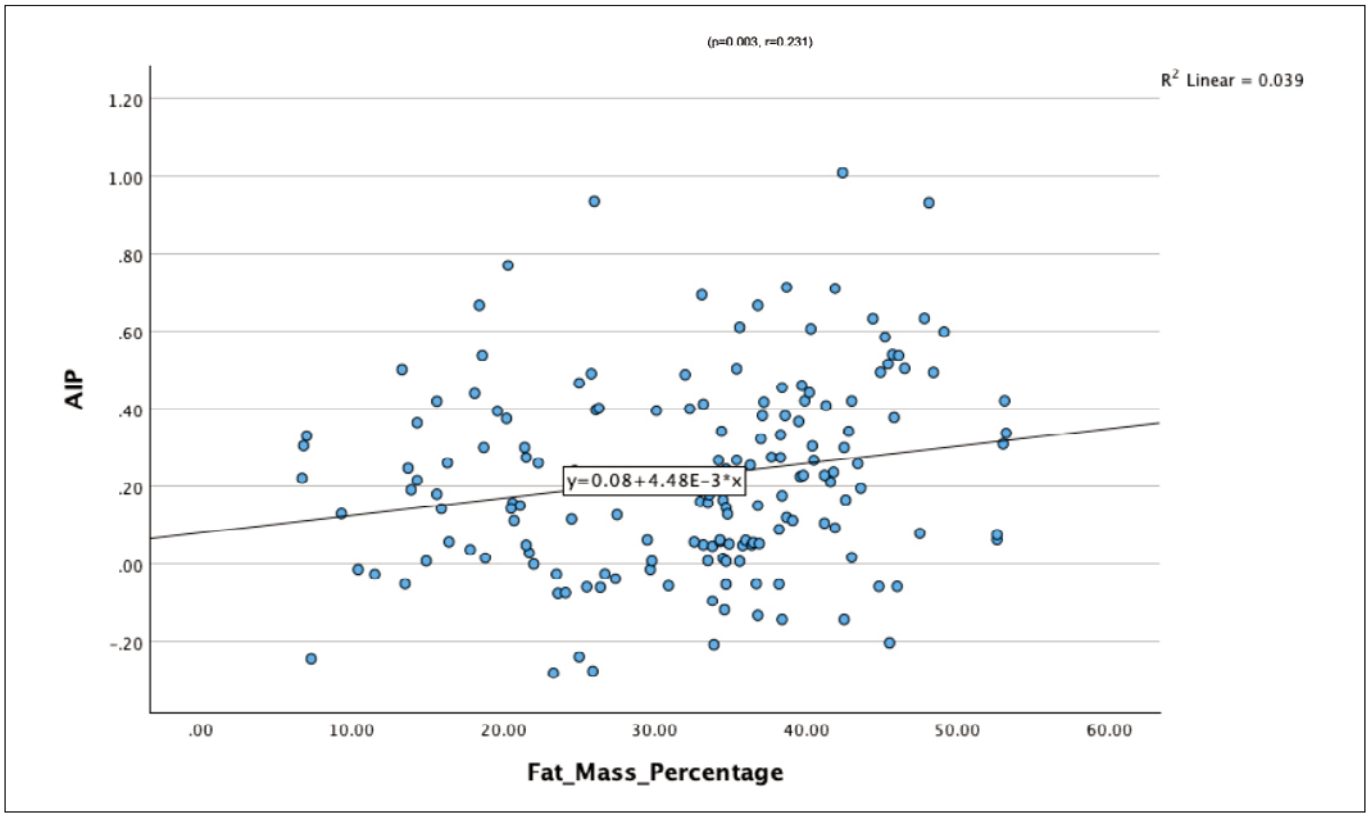


Figure 1. Scatter Diagram between Fat Mass Percentage and Atherogenic Index of Plasma

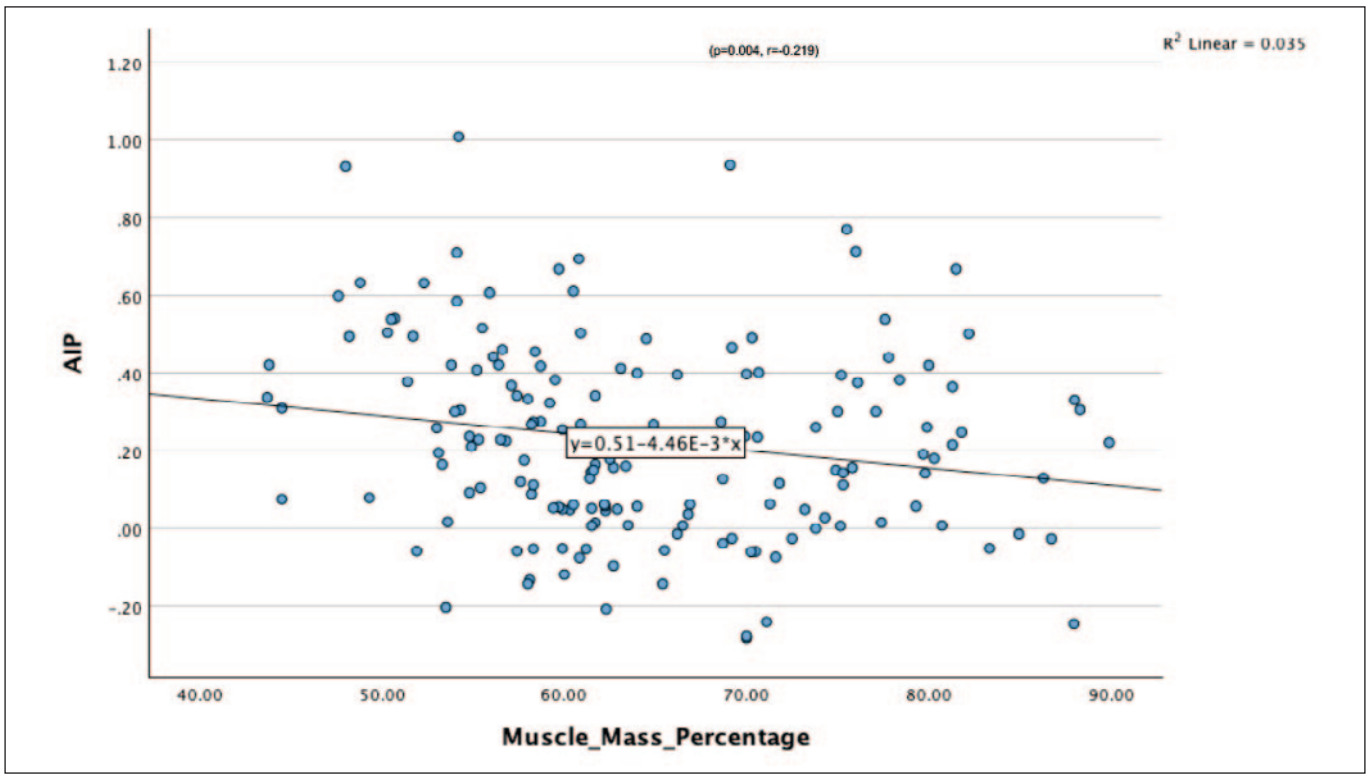


Figure 2. Scatter Diagram between Fat Mass Percentage and Atherogenic Index of Plasma

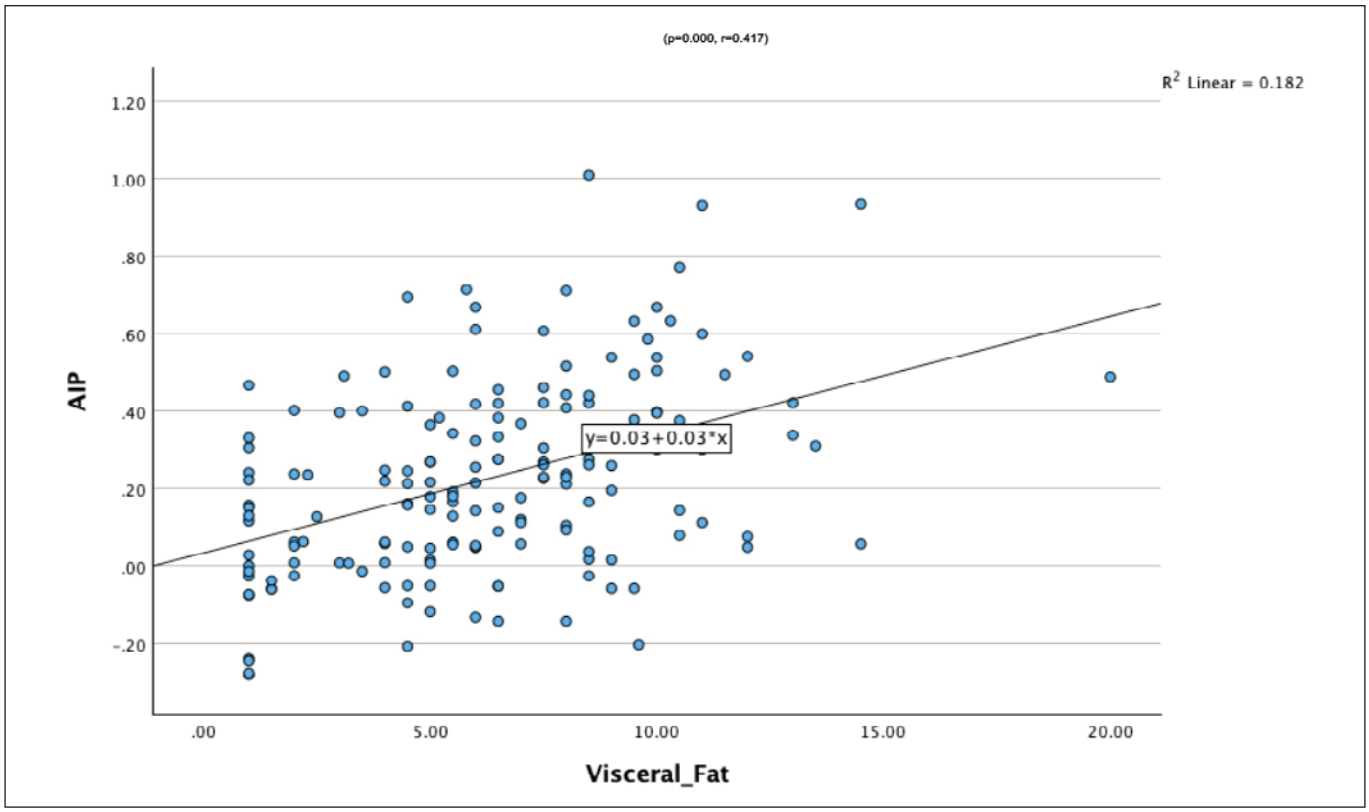


Figure 3. Scatter Diagram between Visceral Fat and Atherogenic Index of Plasma

served between fat mass percentage and AIP (r = 0.231, p = 0.003), as shown in Figure 1. The linear regression model (y = 0.08 + 0.0044x) indicates that an increase in fat mass percentage is associated with an incremental rise in AIP values.

Figure 2 displays the relationship between muscle mass percentage and AIP, demonstrating a significant negative correlation (r = –0.219, p = 0.004). The corresponding regression equation (y = 0.51 – 0.00446x) suggests that higher muscle mass percentage is associated with lower AIP scores.

In Figure 3, visceral fat exhibits a strong positive correlation with AIP (r = 0.417, p < 0.001). The regression model (y = 0.003 + 0.03x) supports a linear trend, indicating that increasing visceral fat levels correspond with elevated AIP values. These findings highlight the relevance of adiposity and muscle composition in modulating atherogenic risk.

Table 5 displays the results of a multiple linear regression analysis using the backward elimination method to identify significant predictors of the Atherogenic Index of Plasma (AIP) based on selected body composition variables.

The initial model (Model 1) included four predictors: bone mass, total body water, waist circumference, and visceral fat. This model explained 19.5% of the variance in AIP (R^2 = 0.195; Adj. R^2 = 0.175), although none of the variables reached statistical significance (p > 0.05). Visceral fat showed the strongest effect among the predictors (β = 0.227, p = 0.124), while total body water had minimal contribution (β = –0.039, p = 0.678).

Following the backward method, total body water was removed in Model 2, resulting in a slightly improved adjusted R^2 of 0.179. Visceral fat remained the most influential predictor (β = 0.253) and approached statistical significance (p = 0.057), whereas bone mass and waist circumference remained non-significant.

In Model 3, bone mass was eliminated. Visceral fat became a statistically significant predictor (p = 0.022), with a standardized beta of 0.289, while waist circumference remained non-significant. The model accounted for 19.0% of the variance (Adj. R^2 = 0.180).

The final model (Model 4) retained only visceral fat, which emerged as a significant independent predictor of AIP (p < 0.001). This model explained 17.7% of the variation in AIP (Adj. R^2 = 0.177), with a standardized beta coefficient of 0.426. The variance inflation factor (VIF) values across all models remained below the multicollinearity threshold.

Table 5. Multiple Linear Regression Analysis

Model	Predictors	R^2	Adj. R^2	B (Unstandardized)	Sig.	Beta (Standardized)	VIF
1	Bone Mass	0.195	0.175	0.048	0.352	0.110	2.778
	Total Body Water			–0.002	0.678	–0.039	1.785
	Waist Circumference			0.003	0.931	0.124	3.587
	Visceral Fat			0.016	0.124	0.227	4.346
2	Bone Mass	0.194	0.179	0.037	0.402	0.086	2.097
	Waist Circumference			0.003	0.295	0.137	3.412
	Visceral Fat			0.018	0.057	0.253	3.531
3	Waist Circumference	0.190	0.180	0.003	0.187	0.166	3.168
	Visceral Fat			0.021	0.022*	0.289	3.168
4	Visceral Fat	0.182	0.177	0.031	0.000*	0.426	1.000

* significance = p<0,05.

DISCUSSION

Sex-Based Differences in Body Composition and Visceral Fat Accumulation: A Comparative Analysis

Sex-based disparities in human body composition have been extensively documented in the literature and are primarily attributed to physiological, hormonal, and evolutionary influences. The present findings, indicating that females exhibit significantly higher fat mass percentages and lower muscle mass compared to males, are consistent with established patterns of sexual dimorphism. These differences are largely driven by the influence of sex hormones, particularly estrogen, which promotes the accumulation of adipose tissue, predominantly in subcutaneous regions. This pattern of fat deposition is considered evolutionarily adaptive, supporting reproductive and metabolic demands associated with pregnancy and lactation. As noted by Wells (2007), the emergence of sex-based differences in fat distribution be-comes especially prominent during puberty, with hormonal shifts playing a pivotal role in determining regional adiposity[19]. The emergence of sex-based differences in fat distribution becomes especially prominent during puberty, driven by hormonal shifts that influence regional adiposity.

In contrast, males tend to possess greater skeletal muscle mass, total body water (TBW), and bone mineral content, differences that can be attributed to the anabolic effects of androgens such as testosterone. Testosterone facilitates protein synthesis and increases lean tissue development, contributing to higher muscle mass and, consequently, elevated TBW due to the water-rich nature of muscle tissue. The study conducted by Janssen et al. (2000) provides robust evidence supporting this observation, demonstrating that males exhibit significantly greater absolute skeletal muscle mass compared to females across a wide age range[20].

Despite well-documented sex-based differences in total body fat, muscle mass, and bone density, evidence suggests that the pathogenic potential of visceral adipose tissue (VAT) may be comparable between men and women. Kuk et al. (2006) demonstrated that visceral fat is an independent predictor of all-cause mortality in men, even after adjusting for subcutaneous fat, liver fat, and waist circumference[21]. This finding underscores the uniquely deleterious role of VAT, which is more metabolically active and pro-inflammatory than subcutaneous fat and is closely linked to insulin resistance, dyslipidemia, and increased cardiometabolic risk.

Complementary findings from Yang et al. (2021) further illuminate the role of regional adiposity in metabolic health across sexes. Using dual-energy X-ray absorptiometry (DXA) in a cohort of overweight and obese Chinese adults, the authors found that although women exhibited higher total body fat and central fat percentages, central fat was significantly associated with clustered cardiometabolic risk in both sexes. Notably, the odds of exhibiting multiple cardiometabolic risk factors associated with a one standard deviation increase in central fat were comparable, or even greater, in men than in women. These associations remained significant after controlling for total body fat and relevant lifestyle factors[22].

Taken together, these findings suggest that while body composition differs between sexes, central fat accumulation confers similar or even heightened cardiometabolic risk in men compared to women. The absence of a significant protective effect in either sex reinforces the notion that both men and women are susceptible to VAT-related metabolic dysfunction under conditions of positive energy balance and obesity.

In conclusion, the observed body composition differences between sexes—namely, higher fat mass in females and greater lean and skeletal mass in males—are consistent with established physiological norms. However, the lack of significant variation in visceral fat distribution highlights a critical area of shared risk between sexes in the context of obesity. These findings underscore the importance of focusing on visceral adiposity as a primary determinant of metabolic health, irrespective of sex, and suggest that both males and females may benefit equally from interventions targeting abdominal obesity.

Atherogenic Risk Profile and Fat Distribution: Insights from the Atherogenic Index of Plasma (AIP)

The Atherogenic Index of Plasma (AIP), calculated as the base-10 logarithm of the ratio between triglycerides (TG) and high-density lipoprotein cholesterol (HDL-C), has emerged as a robust and practical marker in assessing cardiovascular and metabolic risk. More than a reflection of dyslipidemia, AIP captures the atherogenic potential of lipoprotein subtypes and has shown strong associations with central obesity, insulin resistance, and cardiovascular events[23]. A growing body of evidence supports the relationship between elevated AIP and visceral fat accumulation. In a large-scale cross-sectional study, Shen et al. (2018) demonstrated a linear correlation between AIP and waist circumference (WC), where a 1 cm increase in WC corresponded to a 0.0175 rise in AIP. Their findings revealed significantly higher AIP levels among individuals with abdominal obesity compared to those with normal WC, suggesting that AIP effectively reflects visceral fat burden[24]. Hwang et al. (2016) further substantiated this by showing in a five-year longitudinal cohort of Japanese Americans that both baseline visceral adipose tissue (VAT) and its progression were independently associated with future development of atherogenic dyslipidemia, whereas subcutaneous adipose tissue (SAT) showed no such link. These observations underscore the unique metabolic role of VAT in disrupting lipid homeostasis and increasing cardiometabolic risk[5].

The predictive power of AIP extends beyond fat distribution to its association with subclinical atherosclerosis and coronary artery disease (CAD). In an observational study involving over 6,900 subjects, Won et al. (2020) reported that higher AIP quartiles were independently associated with advanced coronary pathology, including elevated coronary artery calcium scores (CACS >100) and obstructive coronary plaques, even after adjusting for age, sex, hypertension, diabetes, and dyslipidemia[23]. Complementing these findings, Cai et al. (2017) confirmed that AIP was the lipid parameter most strongly associated with CAD in a large Chinese Han population, outperforming other traditional lipid markers and ratios. The study also highlighted AIP's inverse correlation with HDL-C and positive correlation with TG, total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-C), further reinforcing its clinical value[7].

AIP also correlates with the presence of small dense LDL (sdLDL) particles, known to be more atherogenic due to their enhanced ability to penetrate arterial walls and undergo oxidation. While direct sdLDL measurement is expensive and technically demanding, AIP serves as a simple and economical proxy, making it highly applicable in routine clinical practice[24]. Moreover, in the context of diabetes, Hulkoti et al. (2022) evaluated the Visceral Adiposity Index (VAI), a composite index based on WC, BMI, TG, and HDL-C that shares conceptual overlap with AIP, and demonstrated that higher VAI levels were significantly associated with microvascular complications such as retinopathy, nephropathy, and neuropathy in patients with type 2 diabetes mellitus (T2DM). AIP showed stronger predictive value for these complications than BMI or WC alone, emphasizing its utility in identifying high-risk diabetic patients[25]. These findings highlight the relevance of AIP in reflecting visceral fat-related risk and suggest that monitoring and managing abdominal obesity could be beneficial across diverse populations.

Predictors of AIP: Visceral Fat as a Key Determinant

In the present study, multiple linear regression analysis using backward elimination identified visceral fat as the sole statistically significant independent predictor of the Atherogenic Index of Plasma (AIP) in the final model. This outcome provides compelling evidence that visceral adiposity plays a central and independent role in modulating lipid-derived cardiovascular risk, beyond the contributions of general obesity or anthropometric surrogates such as waist circumference.

Although waist circumference (WC) is widely used as a proxy for abdominal fat accumulation, it has clear limitations, chiefly, its inability to differentiate between subcutaneous and visceral compartments of abdominal fat. Shen et al. (2018) found that individuals with abdominal obesity had significantly higher AIP levels, and that AIP increased linearly with WC, highlighting a relationship between central adiposity and dyslipidemia[24]. However, they also emphasized that AIP serves as a more specific indicator of visceral obesity than WC alone

Further, Zhou et al. (2018) demonstrated that among various adiposity indices, visceral fat markers—such as the

Visceral Adiposity Index (VAI) and Lipid Accumulation Product (LAP)—were more strongly associated with AIP than BMI or WC, especially in lean hemodialysis patients. These associations remained significant even after adjusting for BMI, suggesting that visceral fat provides unique insight into lipid atherogenicity independent of general adiposity[6]. This finding aligns with Guo et al. (2020), who identified AIP as a powerful independent risk factor for coronary artery disease (CAD) in postmenopausal women, even after adjusting for age, BMI, smoking, hypertension, diabetes, and family history. AIP was significantly correlated with other non-traditional lipid parameters but remained independent of age and BMI, highlighting its relevance as a biomarker in populations at cardiovascular risk[26].

Building upon this evidence, a recent prospective cohort study by Hu et al. (2025) demonstrated that AIP was positively associated with cardiovascular disease (CVD) risk across the spectrum of Cardiovascular–Kidney–Metabolic (CKM) syndrome stages 0–3. Importantly, the authors found that metabolic syndrome partially mediated this relationship, implicating visceral adiposity as a central mechanism linking dyslipidemia to cardiovascular outcomes[27]. These findings emphasize the importance of AIP as a marker of visceral fat-related cardiovascular risk and support the need for targeted strategies to reduce abdominal obesity in both clinical and public health settings.

Muscle Mass and Cardiovascular Risk: An Inverse Relationship with Atherogenic Index of Plasma

The inverse association observed between muscle mass percentage and the Atherogenic Index of Plasma (AIP) suggests that increased skeletal muscle mass may confer a cardioprotective effect, particularly through modulation of lipid metabolism. This finding aligns with growing evidence that skeletal muscle acts as a critical regulator of systemic metabolic health, beyond its mechanical function.

Muscle, particularly skeletal muscle serves as the primary site for insulin-mediated glucose disposal and is increasingly recognized as a secretory organ through the release of myokines, molecules that exert beneficial effects on glucose and lipid metabolism[28]. Sarcopenia, or low muscle mass, has been consistently linked to increased insulin resistance, which in turn is a well-established contributor to atherogenic dyslipidemia, a key component of the metabolic syndrome[28].

Kim and Park (2018) demonstrated that individuals with high muscle and low fat mass exhibited significantly lower insulin resistance compared to those with low muscle/high fat mass, underscoring the metabolic advantages of lean body composition[29]. In a large-scale cross-sectional study of Korean adults, Kim and Park found that the protective effects of high muscle mass were negated when fat mass was concurrently elevated. This interaction highlights the complex interplay between muscle and fat in determining cardiovascular risk. Their analysis revealed that while high muscle mass was associated with reduced insulin resistance ($p < 0.001$), the presence of high fat mass led to a significantly increased incidence rate ratio (IRR) for metabolic syndrome—even in individuals with substantial muscle mass[29].

Similar patterns were observed in the prospective cohort study by Yamada et al. (2022), which followed Japanese women over seven years. This study reported that low relative muscle mass (as measured by ALM/Wt) significantly predicted the development of metabolic syndrome (adjusted hazard ratio = 5.60, 95% CI: 1.04–30.0), whereas absolute muscle mass alone was not predictive once fat mass was accounted for[30]. These results reinforce the importance of evaluating muscle quality in the context of body fat distribution when assessing cardiovascular risk. These findings highlight the relevance of AIP as a marker of lipid-related cardiovascular risk and support the promotion of strategies to enhance muscle mass as a modifiable protective factor in cardiometabolic health.

CONCLUSION

The discussion underscores the clear sex-based differences in body composition—females typically have higher fat mass while males have greater muscle and bone mass—driven largely by hormonal and evolutionary factors. Despite these disparities, visceral adipose tissue (VAT) poses a shared cardiometabolic risk for both sexes, as evidenced by its strong association with the Atherogenic Index of Plasma (AIP), a reliable marker of lipid-related cardiovascular risk. Importantly, VAT's metabolic activity and its influence on dyslipidemia, insulin resistance, and cardiovascular disease highlight its critical role in determining health outcomes, regardless of gender. Additionally, the protective influence of skeletal muscle mass, particularly when not accompanied by excessive fat, reveals the complex interplay between muscle and fat in metabolic regulation.

RECOMMENDATION

In light of the findings, clinical and public health strategies should prioritize the reduction of visceral fat accumulation through targeted interventions such as dietary management, physical activity, and lifestyle modifications that emphasize both fat reduction and muscle preservation. Regular monitoring of AIP can serve as a practical, cost-effective screening tool to identify individuals at elevated cardiometabolic risk, enabling early preventive measures. Moreover, muscle-strengthening exercises should be promoted, not only to build lean mass but also to counteract the adverse metabolic effects of central obesity, especially in populations vulnerable to sarcopenia or metabolic syndrome.

REFERENCES

1. Obesity and overweight [Internet]. [cited 2025 May 15]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
2. Hayat Y, Rasyid H, As'Ad S, Taslim NA, Syauki Y, Bukhari A. The Nusantara Diet of Makassar on the ratio of triglyceride to HDL on the risk of cardiovascular disease in individuals with the risk of metabolic syndrome. Nutricion Clinica y Dietetica Hospitalaria. 2024;44(4):60–4. doi: 10.12873/444hayat
3. Taslim NA, Handayani ND, Arruan W, Aminuddin, Bukhari A, Faradillah A, et al. Dietary Patterns and Ultra-Processed Foods Consumption in Modern and Traditional Populations in South Sulawesi: An Analysis of Nutritional Status and Body Composition. Nutricion Clinica y Dietetica Hospitalaria. 2023;43(1):90–8. doi: 10.12873/431handayani
4. Koceva A, Herman R, Janez A, Rakusa M, Jensterle M. Sex- and Gender-Related Differences in Obesity: From Pathophysiological Mechanisms to Clinical Implications. Vol. 25, International Journal of Molecular Sciences. Multidisciplinary Digital Publishing Institute (MDPI); 2024. doi: 10.3390/ijms25137342
5. Hwang YC, Fujimoto WY, Hayashi T, Kahn SE, Leonetti DL, Boyko EJ. Increased visceral adipose tissue is an independent predictor for future development of atherogenic dyslipidemia. Journal of Clinical Endocrinology and Metabolism. 2016 Feb 1;101(2):678–85. doi: 10.1210/jc.2015-3246
6. Zhou C, Peng H, Yuan J, Lin X, Zha Y, Chen H. Visceral, general, abdominal adiposity and atherogenic index of plasma in relatively lean hemodialysis patients. BMC Nephrol. 2018 Aug 16;19(1). doi: 10.1186/s12882-018-0996-0
7. Cai G, Shi G, Xue S, Lu W. The atherogenic index of plasma is a strong and independent predictor for coronary artery disease in the Chinese Han population. Medicine (United States). 2017 Sep 1; 96(37). doi: 10.1097/MD.0000000000008058
8. Arruan W, Bukhari A, Handayani ND, Taslim NA, Faradilah A, Aminuddin. The relationship of physical activity with nutritional status and body composition in traditional and modern populations in South Sulawesi, Indonesia. Nutricion Clinica y Dietetica Hospitalaria. 2024;44(3):204–11. doi: 10.12873/443arruan
9. Cohn JN, Hoke L, Whitwam W, Sommers PA, Taylor AL, Duprez D, et al. Screening for early detection of cardiovascular disease in asymptomatic individuals. Am Heart J. 2003;146(4):679–85. doi: https://doi.org/10.1016/S0002-8703(03)00499-X
10. Riskesdas Kementrian Kesehatan RI. Laporan Riskesdas 2018 Nasional. Lembaga Penerbit Balitbangkes. 2018.
11. Indonesian Ministry of Health Development Policy Board. Indonesian Health Survey (Survei Kesehatan Indonesia) 2023. Ministry of Health. 2023;1–68.
12. Oktaviani S, Mizutani M, Nishide R, Tanimura S. Spatial Clusters of High Prevalences of Overweight and Obesity Among Children in Indonesia. Cureus. 2024 Apr;16(4):e57370. doi: 10.7759/cureus.57370
13. Amrynia SU, Prameswari GN. Hubungan Pola Makan, Sedentary Lifestyle, dan Durasi Tidur dengan Kejadian Gizi Lebih Pada Remaja (Studi Kasus di SMA Negeri 1 Demak). Indonesian Journal of Public Health and Nutrition. 2022;2(1):112–21. doi: 10.15294/ijphn.v2i1.52044
14. Ofenheimer A, Breyer-Kohansal R, Hartl S, Burghuber OC, Krach F, Franssen FME, et al. Using Body Composition Groups to Identify Children and Adolescents at Risk of Dyslipidemia. Children (Basel). 2021 Nov;8(11). doi: 10.3390/children8111047
15. Niroumand S, Khajedaluee M, Khadem-Rezaiyan M, Abrishami M, Juya M, Khodaee G, et al. Atherogenic Index of Plasma (AIP): A marker of cardiovascular disease. Med J Islam Repub Iran [Internet]. 2015 [cited 2025 May 9];29(1):240. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC4715400/
16. Aschner P, Balkau B, Barter P, Bennet P, Boyko E. The IDF consensus worldwide definition of the METABOLIC SYNDROME. 2006.
17. TANITA Corporation. Body Composition Guide for InnerScan [Internet]. Hong Kong; 2015. Available from: www.tanita.asia.
18. Bo MS, Cheah WL, Lwin S, Moe Nwe T, Win TT, Aung M. Understanding the Relationship between Atherogenic Index of Plasma and Cardiovascular Disease Risk Factors among Staff of an University in Malaysia. J Nutr Metab. 2018;2018(2015). doi: 10.1155/2018/7027624
19. Wells JCK. Sexual dimorphism of body composition. Best Pract Res Clin Endocrinol Metab. 2007;21(3):415–30. doi: https://doi.org/10.1016/j.beem.2007.04.007
20. Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol. 2000 Jul;89(1):81-8. doi: 10.1152/jappl.2000.89.1.81.
21. Kuk JL, Katzmarzyk PT, Nichaman MZ, Church TS, Blair SN, Ross R. Visceral fat is an independent predictor of all-cause mortality in men. Obesity. 2006 Feb;14(2):336–41. doi: 10.1038/oby.2006.43
22. Yang Y, Xie M, Yuan S, Zeng Y, Dong Y, Wang Z, et al. Sex differences in the associations between adiposity distribution and cardiometabolic risk factors in overweight or obese individuals: a cross-sectional study. BMC Public Health. 2021 Jun 26;21(1): 1232. doi: 10.1186/s12889-021-11316-4
23. Won KB, Jang MH, Park EJ, Park HB, Heo R, Han D, et al. Atherogenic index of plasma and the risk of advanced subclinical coronary artery disease beyond traditional risk factors: An observational cohort study. Clin Cardiol. 2020 Dec 1;43(12):1398–404. doi: 10.1002/clc.23450
24. Shen SW, Lu Y, Li F, Yang CJ, Feng YB, Li HW, Yao WF, Shen ZH. Atherogenic index of plasma is an effective index for estimating abdominal obesity. Lipids Health Dis. 2018 Jan 15;17(1):11. doi: 10.1186/s12944-018-0656-1.
25. Hulkoti V, Acharya S, Shukla S, Kumar S, Kabra R, Dubey A, Lahane V, Giri A. Visceral Adiposity Index in Type 2 Diabetes Mellitus (DM) and Its Correlation With Microvascular Complications. Cureus. 2022 Nov 9;14(11):e31279. doi: 10.7759/cureus.31279.
26. Guo Q, Zhou S, Feng X, Yang J, Qiao J, Zhao Y, et al. The sensibility of the new blood lipid indicator-atherogenic index of plasma

(AIP) in menopausal women with coronary artery disease. Lipids Health Dis. 2020 Feb 24;19(1). doi: 10.1186/s12944-020-01208-8

27. Hu Y, Liang Y, Li J, Li X, Yu M, Cui W. Correlation between atherogenic index of plasma and cardiovascular disease risk across Cardiovascular-kidney-metabolic syndrome stages 0-3: a nationwide prospective cohort study. Cardiovasc Diabetol. 2025 Jan 24;24(1):40. doi: 10.1186/s12933-025-02593-z.

28. Kim G, Kim JH. Impact of skeletal muscle mass on metabolic health. Endocrinology and Metabolism. 2020 Mar 1;35(1):1–6. doi: 10.3803/EnM.2020.35.1.1

29. Kim K, Park SM. Association of muscle mass and fat mass with insulin resistance and the prevalence of metabolic syndrome in Korean adults: a cross-sectional study. Sci Rep. 2018 Dec 1;8(1). doi: 10.1038/s41598-018-21168-5

30. Yamada Y, Murakami H, Kawakami R, Gando Y, Nanri H, Nakagata T, Watanabe D, Yoshida T, Hatamoto Y, Yoshimura E, Sanada K, Miyatake N, Miyachi M. Association between skeletal muscle mass or percent body fat and metabolic syndrome development in Japanese women: A 7-year prospective study. PLoS One. 2022 Oct 6;17(10):e0263213. doi: 10.1371/journal.pone.0263213.