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Non-linear relationship between atherogenic index of plasma and fat-to-muscle mass ratio: a cross-sectional study

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Research Article

Keywords: Fat-to-muscle mass ratio, Atherogenic index of plasma, Waist-to-hip ratio, Appendicular skeletal muscle mass, Cardiovascular disease

Posted Date: May 21st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9389951/v1

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Additional Declarations: No competing interests reported.

Abstract

Background Although there is numerous studies have suggested an association between lipid metabolism and body composition, the precise relationship between the atherogenic index of plasma (AIP) and the fat-to-muscle mass ratio (F/M) remains unclear. Therefore, we aimed to elucidate the non-linear relationship between AIP and F/M.

Methods This cross-sectional study was conducted among the health examination population at Hefei First People's Hospital between May and November 2023. A total of 1082 participants were included in this study. Body composition was assessed using bioelectrical impedance analysis (BIA) to calculate the F/M. Biochemical indexes including blood glucose, blood lipids, liver and kidney functions. The AIP was calculated as log10 (triglycerides / high-density lipoprotein cholesterol). The one-way ANOVA with Bonferroni correction, smoothing functions, threshold effect analyses, log-likelihood ratio tests, trend tests, interaction tests, and subgroup analyses were used to assess the association between F/M and AIP.

Results A significant increasing trend in the AIP was observed across ascending F/M quartiles. After adjustment for confounding factors, a positive association was observed between F/M and AIP before the inflection point (F/M = 0.47) (β = 0.68, *P* < 0.0001), whereas a negative association was identified beyond this threshold (β = -0.37, *P* = 0.009). Trend tests revealed a statistically significant increasing trend in AIP across ascending F/M quartiles in the subgroup with F/M < 0.47 (*P* < 0.0001); however, the decreasing trend was not statistically significant in the subgroup with F/M ≥ 0.47 (*P*= 0.4119). Interaction tests further revealed waist-to-hip ratio (WHR) and the appendicular skeletal muscle mass-to-body mass index ratio (ASM/BMI) as significant effect modifiers in the F/M < 0.47 (*P* = 0.0049) and F/M ≥ 0.47 (*P* = 0.0214) subgroups, respectively.

Conclusions In the health examination population, the relationship between F/M and AIP exhibited a threshold-saturation effect, characterized by a positive correlation below the inflection point (F/M = 0.47) and no correlation beyond it. For individuals with F/M < 0.47, central obesity is a primary driver of atherogenic risk, underscoring the benefit of weight loss. Conversely, in those with F/M ≥ 0.47, increasing appendicular skeletal muscle mass mitigates cardiovascular risk, calling for a focus on muscle-building training beyond weight management.

Introduction

The atherogenic index of plasma (AIP), defined as the base-10 logarithm of the ratio of triglycerides (TG) to high-density lipoprotein cholesterol (HDL-C) [1], is a strong predictor of cardiovascular disease (CVD) risk and a biomarker of plasma atherogenicity. A cohort study demonstrated that AIP is an independent predictor of cardiovascular events and related mortality after adjusting for traditional risk factors [2]. A prospective community-based cohort study demonstrated that cumulative AIP served as an independent predictor of major adverse cardiovascular events (MACE), stroke, and myocardial infarction, with the

most pronounced association observed for stroke in the elderly population [3].Furthermore, AIP is an independent predictive marker for rapid plaque progression beyond traditional risk factors [4]. In summary, AIP is a powerful biomarker for predicting CVD.

Obesity is a well-established risk factor for the development and mortality of CVD [5]. Although body mass index (BMI) is widely used to define obesity, it has a crucial limitation in that it cannot differentiate between adipose tissue and muscle mass [6]. Even individuals with similar BMI levels may have different body fat and muscle mass. Some scholars propose that body fat mass represents metabolic load, while muscle mass represents metabolic capacity, and their interaction determines metabolic risk [7–9]. Numerous studies underscore the critical role of body composition in cardiometabolic risk assessment [10–12]. Specifically, skeletal muscle mass demonstrates a protective role, exhibiting an inverse association with cardiometabolic risk factors [13]. In contrast, elevated fat mass is strongly positively correlated with these risks [14]. Consequently, cardiovascular risk is determined by the interaction between these two compartments rather than their isolated effects. This interplay is captured by the fat-to-muscle mass ratio (F/M), a composite body composition metric that integrates their opposing influences. While previous studies have established an association between the F/M and diseases such as diabetes and hypertension [15, 16], there is limited evidence regarding its relationship with cardiovascular diseases. Therefore, we conducted a cross-sectional study within a physical examination cohort to investigate the association between the F/M and AIP.

Methods

Data source and study sample

Participants: A total of 1333 adults who underwent a health check-up with bioelectrical impedance analysis at the Physical Examination Center of Hefei First People's Hospital (May-November 2023) were initially screened. After applying the inclusion and exclusion criteria, 1082 participants were ultimately enrolled in this cross-sectional study.

Inclusion criteria comprised individuals aged 18 to 90 years.

Exclusion criteria: 1. A history of active malignancy or current acute infection; 2. Severe hepatic or renal dysfunction; 3. Pregnancy or lactation; 4. Participants who were taking lipid-lowering agents during the study, including statins, fibrates, niacin, cholesterol absorption inhibitors, etc.; 5. Individuals with missing data (Fig. 1).

Data collection: Basic clinical information, including sex, age, and history of chronic diseases (e.g., diabetes and hypertension), was collected. Height, body weight, systolic blood pressure (SBP), and diastolic blood pressure (DBP) were measured in the morning under fasting and resting conditions.

Laboratory Tests

Venous blood was drawn in the morning after at least 8 hours of fasting. Biochemical analyses were performed on a Siemens Aptio automation system with reagents from a single batch to ensure consistency. The measured parameters included fasting blood glucose (FBG), triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), alanine aminotransferase (ALT), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), total bilirubin (TBIL), direct bilirubin (DBIL), indirect bilirubin (IBIL), albumin (ALB), serum creatinine (SCr), and serum uric acid (SUA). Body composition indicators were determined using a bioelectrical impedance analyzer (BIA; DONGHUAYUAN MEDICAL, Beijing, China).

Atherogenic index of plasma was calculated: $AIP = \log_{10}(TG / HDL\text{-}C)$

Diagnostic Criteria

Definition of hypertension [17]: 1. History of hypertension; 2. Systolic blood pressure ≥ 140mmHg; 3. Diastolic blood pressure ≥ 90mmHg, meet any of the diagnostic criteria.

Definitions of diabetes [18]: 1. a history of diabetes; 2. Fasting blood glucose ≥ 7.0mmol/l; 3. Hemoglobin A1C ≥ 6.5%, meet any of the diagnostic criteria.

Statistical Analysis

Data analysis was performed using GraphPad Prism version 10.0.3, Empower(R) (www.empowerstats.com, X&Y Solutions, Inc., Boston, MA), and R software (http://www.R-project.org). The normality of data distribution was assessed using the Shapiro-Wilk test and Q-Q plots. Continuous variables following a normal distribution are presented as mean ± standard deviation ($\bar{x} \pm s$), while skewed variables are presented as median and interquartile range [M (P25, P75)]. One-Way Analysis of Variance (ANOVA) was used to compare differences in continuous variables among F/M quartile groups, with Bonferroni correction for multiple comparisons. Smooth curve fitting and threshold effect analysis were used to determine the relationship between F/M and AIP. A log-likelihood ratio test was used to compare the one-line linear regression model and the two-piecewise linear regression model. Further trend tests across multiple regression models were conducted. Interaction tests were used to analyze potential interactive factors in the F/M-AIP relationship, along with stratified analyses. A two-sided $P < 0.05$ was considered statistically significant.

Results

Analysis of AIP across F/M Quartile Groups using One-Way ANOVA

Participants were stratified into four groups based on F/M quartiles: Q1 (0.0563–0.3145), Q2 (0.3147–0.4124), Q3 (0.4127–0.5086), and Q4 (0.5097–1.0815). AIP showed a significant increasing trend with rising F/M ($P < 0.001$, Table 1, Fig. 2).

Table 1 Baseline characteristics of the study participants stratified by F/M quartiles

Characteristics	F/M				*P value*
	Q1 (0.0563-0.3145)	**Q2 (0.3147-0.4124)**	**Q3 (0.4127-0.5086)**	**Q4 (0.5097-1.0815)**	
Age (years)	46.80 ± 15.35	46.74 ± 13.38	45.06 ± 12.73	49.43 ± 11.42	0.002
Sex					<0.001
female	27 (9.96%)	77 (28.52%)	125 (46.30%)	51 (18.82%)	
male	244 (90.04%)	193 (71.48%)	145 (53.70%)	220 (81.18%)	
Muscle mass (kg)	49.89 ± 7.48	47.27 ± 8.65	44.50 ± 9.02	39.58 ± 7.47	<0.001
Fat mass (Kg)	11.69 ± 3.49	17.45 ± 3.47	20.27 ± 4.29	24.04 ± 5.45	<0.001
BMI (kg/m2)	22.45 ± 2.43	24.09 ± 2.85	24.90 ± 3.17	26.29 ± 3.14	<0.001
SBP (mmHg)	121.70 ± 16.29	123.45 ± 16.37	123.34 ± 16.70	124.03 ± 17.89	0.404
DBP (mmHg)	74.52 ± 10.62	76.12 ± 10.58	75.46 ± 10.64	74.56 ± 10.93	0.152
HbA1c (%)	5.71 ± 0.62	5.73 ± 0.79	5.71 ± 0.70	5.84 ± 0.95	0.038
FBG (mmol/l)	5.29 ± 0.99	5.45 ± 1.38	5.38 ± 1.25	5.52 ± 1.50	0.009
ALT (U/L)	20.83 ± 10.22	23.24 ± 14.54	24.93 ± 15.57	23.58 ± 15.63	0.163
AST (U/L)	22.93 ± 6.04	23.24 ± 6.51	23.91 ± 8.53	24.12 ± 8.30	0.939
GGT (U/L)	25.41 ± 16.29	30.98 ± 23.13	29.90 ± 20.01	29.94 ± 22.17	0.176
ALB (g/L)	47.49 ± 2.52	47.18 ± 2.39	47.61 ± 2.19	46.54 ± 2.21	<0.001
eGFR (ml/min.1.73m^2)	101.07 ± 14.67	103.74 ± 15.43	105.96 ± 14.30	105.67 ± 14.69	<0.001
TG (mmol/l)	1.43 ± 1.45	1.67 ± 1.46	1.97 ± 2.16	1.69 ± 0.94	<0.001
HDL-C (mmol/l)	1.41 ± 0.38	1.32 ± 0.35	1.27 ± 0.32	1.37 ± 0.32	<0.001
LDL-C (mmol/l)	3.00 ± 0.89	3.01 ± 0.81	2.96 ± 0.73	3.17 ± 0.80	0.009
TC (mmol/l)	4.76 ± 0.96	4.76 ± 0.91	4.76 ± 0.85	4.99 ± 0.92	0.003
AIP	-0.06 ± 0.31	0.02 ± 0.36	0.10 ± 0.35	0.05 ± 0.29	<0.001

Data is presented with number of participants (percentage) or mean (SD)

P < 0.05 indicate significant difference between or across groups

Abbreviations: F/M, fat to muscle mass ratio; BMI, body mass index; SBP, systolic blood pressure; DBP,

diastolic blood pressure; HbA1c, hemoglobin A1c; FBG, fasting blood-glucose; ALT, alanine aminotransferase; AST, aspartate Aminotransferase; GGT, gamma-glutamyl transferase; ALB, albumin; eGFR, estimated glomerular filtration rate; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; AIP, atherogenic index of plasma

Smooth Curve Fitting and Threshold Effect Analysis of the Relationship between F/M and AIP

After adjusting for confounders including gender, age, BMI, blood pressure, blood glucose, blood lipids, hepatic and renal function, a curvilinear relationship was observed between F/M and AIP. A two-piecewise linear regression model identified an inflection point at F/M = 0.47. Below this threshold, each unit increase in F/M was associated with a 0.68-unit increase in AIP (β = 0.68, 95% CI: 0.44, 0.92, *P* < 0.0001). Conversely, above this point, each unit increase in F/M was associated with a 0.37-unit decrease in AIP (β = -0.37, 95% CI: -0.64, -0.09, *P* = 0.009) (Table 2, Fig. 3).

Table 2 Threshold effect analysis of the association between F/M and AIP

	AIP
Exposure: F/M	**Outcome: β (95% CI) *P*-value**
model 1	
One-line effect	0.23 (0.05, 0.42) 0.0143
model 2	
inflection point (k)	0.47
<K segment effect 1	0.68 (0.44, 0.92) <0.0001
>K segment effect 2	-0.37 (-0.64, -0.09) 0.0090
Effect difference	-1.05 (-1.40, -0.69) <0.0001
The predicted value of the equation at the inflection point	0.11 (0.08, 0.14)
Log-likelihood ratio test	<0.001

Data is presented with number of participants (percentage) or mean (SD)

P < 0.05 indicate significant difference between or across groups

Model 1 was a crude model

Model 2 adjusted for age, sex, BMI, SBP, DBP, FBG, HbA1c, ALT, AST, LDL-C, TC, and eGFR

Abbreviations: F/M, fat to muscle mass ratio; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; FBG, fasting blood-glucose; ALT, alanine

aminotransferase; AST, aspartate Aminotransferase; eGFR, estimated glomerular filtration rate; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; AIP, atherogenic index of plasma

Trend Tests across Multiple Regression Models for the F/M-AIP Relationship

Below the inflection point (F/M < 0.47), in the fully adjusted multivariate linear regression models, the associations between F/M and AIP (β = 0.61, 95% CI: 0.33, 0.89) were significantly positive (*P* < 0.0001). The trend remained to be of statistical significance among the F/M quartile groups, with participants in the second, third, and fourth quartiles of F/M having progressively higher levels of AIP compared to the lowest quartile (*P* for Trend < 0.0001). Above the inflection point (F/M ≥ 0.47), no statistically significant discernible trend in AIP was observed across F/M quartiles in the fully adjusted model (*P* for trend = 0.4119) (Table 3, Table 4).

Interaction Tests for the F/M-AIP Relationship

In the F/M < 0.47 subgroup, WHR was a significant interactive factor for the F/M-AIP relationship (*P* = 0.0049). In the stratified analysis by WHR median, among individuals with low WHR, for each standard deviation increase in F/M, AIP increased by 1.21 (β = 1.21, 95% CI: 0.79, 1.62, *P* < 0.0001), whereas no significant correlation was observed in the high WHR group (β = 0.34, 95% CI: -0.13, 0.80, *P* = 0.1543). In the F/M ≥ 0.47 subgroup, ASM/BMI was a significant interactive factor for the F/M-AIP relationship (*P* = 0.0214). In the stratified analysis by ASM/BMI median, no significant correlation was observed in the low ASM/BMI group (β = -0.01, 95% CI: -0.43, 0.40, *P* = 0.9489), whereas in the high ASM/BMI group, for each standard deviation increase in F/M, AIP decreased by 0.78 (β = -0.78, 95% CI: -1.31, -0.25, *P* = 0.0039) (Fig. 4, Fig. 5).

Table 3 Trend tests for the association between F/M and the AIP in the low F/M subgroup (F/M < 0.47)

Outcome: AIP	Model 1	*P*-value	Model 2	*P*-value	Model 3	*P*-value
	β （95%CI）		β （95%CI）		β （95%CI）	
F/M (Per 1-SD increase)	0.82（0.56，1.08）	＜0.0001	0.56（0.27，0.86）	0.0002	0.61 （0.33，0.89）	＜0.0001
F/M Quartiles						
Q1 (Reference)	Reference		Reference		Reference	
Q2	0.11（0.04，0.18）	0.0017	0.07（0.01，0.14）	0.0238	0.08（0.02，0.14）	0.0083
Q3	0.14（0.08，0.21）	＜0.0001	0.08（0.01，0.15）	0.0346	0.09（0.03，0.16）	0.0062
Q4	0.21（0.14，0.28）	＜0.0001	0.15（0.08，0.23）	＜0.0001	0.16（0.09，0.23）	＜0.0001
F/M (Continuous, per quartile)	0.07（0.05，0.09）	＜0.0001	0.05（0.02，0.07）	0.0002	0.05（0.02，0.07）	＜0.0001
P for trend		＜0.0001		0.0002		＜0.0001

Data is presented with number of participants (percentage) or mean (SD)

P < 0.05 indicate significant difference between or across groups

Model 1 was a crude model

Model 2 adjusted for age, sex, BMI

Model 3 adjusted for age, sex, BMI, SBP, DBP, FBG, HbA1c, ALT, AST, LDL-C, TC, and eGFR

Abbreviations: F/M, fat to muscle mass ratio; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; FBG, fasting blood-glucose; ALT, alanine aminotransferase; AST, aspartate Aminotransferase; eGFR, estimated glomerular filtration rate; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; AIP, atherogenic index of plasma

Table 4 Trend tests for the association between F/M and the AIP in the high F/M subgroup (F/M ≥ 0.47)

Outcome: AIP	Model 1	*P*-value	Model 2	*P*-value	Model 3	*P*-value
	β （95%CI）		β （95%CI）		β （95%CI）	
F/M (Per 1-SD increase)	-0.33(-0.66，0.00)	0.0536	-0.34(-0.72，0.03)	0.0746	-0.36(-0.70，-0.02)	0.040
F/M Quartiles						
Q1 (Reference)	0		0		0	
Q2	-0.04（-0.13，0.05）	0.4175	0.01（-0.08，0.09）	0.8928	0.02（-0.05，0.10）	0.5512
Q3	-0.04（-0.14，0.05）	0.3324	0.01(-0.09，0.10）	0.9103	0.03（-0.06，0.11）	0.5181
Q4	-0.03（-0.12，0.06）	0.5678	0.03（-0.08，0.13）	0.5933	0.04（-0.05，0.14）	0.4006
F/M (Continuous, per quartile)	-0.01（-0.04，0.02）	0.5552	0.01（-0.03，0.04）	0.6373	0.01（-0.02，0.04）	0.4119
P for trend		0.5552		0.6373		0.4119

Data is presented with number of participants (percentage) or mean (SD)

P < 0.05 indicate significant difference between or across groups

Model 1 was a crude model

Model 2 adjusted for age, sex, BMI

Model 3 adjusted for age, sex, BMI, SBP, DBP, FBG, HbA1c, ALT, AST, LDL-C, TC, and eGFR

Abbreviations: F/M, fat to muscle mass ratio; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; FBG, fasting blood-glucose; ALT, alanine aminotransferase; AST, aspartate Aminotransferase; eGFR, estimated glomerular filtration rate; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; AIP, atherogenic index of plasma

Discussion

In this cross-sectional study, we investigated a promising and convenient body composition indicator—the fat-to-muscle mass ratio (F/M), that exhibits a significant and non-linear association with the atherogenic index of plasma (AIP) in a general health check-up population. AIP, as a reliable indicator for assessing atherosclerosis risk, has been confirmed by multiple studies to be closely associated with

cardiovascular events, its logarithmic transformation more accurately reflects the predictive power of the lipid ratio for cardiovascular risk [19-22]. Our findings demonstrate that the metabolic interplay between adipose and muscle tissue exerts a differential impact on AIP across distinct body composition phenotypes, though longitudinal studies are required to confirm these observations. This provides a theoretical foundation for developing personalized body composition management strategies aimed at mitigating cardiovascular risk.

F/M, a composite indicator reflecting the relative balance between adipose and muscle tissue, has gained increasing attention in metabolic research. F/M, a composite indicator reflecting the relative balance between adipose and muscle tissue, has gained increasing attention in metabolic research. Previous studies have established associations between F/M and glucose metabolic disorders [23-25], as well as between individual body composition components (fat mass or muscle mass) and cardiovascular risk [26, 27]. However, these studies only considered the separate effects of fat mass and muscle mass on CVD risk. Our study reveals a more complex, nonlinear relationship between the F/M and AIP—a established biomarker for CVD. Specifically, we identified a distinct threshold effect, with an inflection point at F/M = 0.47. Investigating the association between F/M and AIP is clinically important because this composite body composition metric may capture the metabolic interplay between adipose and muscle tissue more effectively than isolated components. In this study, we observed a non-linear relationship between F/M and AIP, characterized by a distinct threshold effect at F/M = 0.47, suggesting that the influence of body composition on atherogenic lipid profiles may vary across different F/M ranges.

In the subgroup with F/M < 0.47, we observed a significant positive association between F/M and AIP. This finding corroborates earlier reports [26-28]. Notably, waist-to-hip ratio (WHR) emerged as a significant effect modifier in this subgroup, suggesting that the prominent contribution of central obesity to atherogenic lipid profiles, even during the early stages of fat accumulation. This aligns with the well-established role of visceral fat as a key driver of cardiometabolic risk factors [29, 30], potentially operating through mechanisms involving free fatty acid release and pro-inflammatory signaling [31]. Our stratified analysis revealed a stronger F/M-AIP association in the low WHR subgroup, raising the possibility that relative increases in total body fat mass may warrant attention even in individuals without pronounced central obesity. From a clinical perspective, these findings suggest that individuals with elevated F/M ratios should be monitored for adiposity-related metabolic alterations even in the absence of pronounced central obesity, and may benefit from targeted lifestyle interventions aimed at reducing body fat.

In the subgroup with F/M ≥ 0.47, no significant association was observed between F/M and AIP. Notably, appendicular skeletal muscle mass adjusted for BMI (ASM/BMI)—an established indicator of muscle health recommended by the Asian Working Group for Sarcopenia [32, 33]—emerged as a significant interactive factor, underscoring the critical moderating role of muscle mass in obesity-related cardiovascular risk. Our stratified analysis indicated that among individuals with high F/M, those with

higher ASM/BMI exhibited a significant negative correlation between F/M and AIP, suggesting that relatively abundant skeletal muscle mass may mitigate the atherogenic risk driven by obesity, even in the context of a high baseline fat load. The underlying mechanism may involve skeletal muscle, as an important metabolic organ, where increased mass can enhance glucose uptake and disposal [34], improve intramyocellular lipid metabolism [35], and secrete beneficial myokines [36], thereby improving whole-body insulin sensitivity [37], ameliorating the atherogenic lipid profile, and ultimately reducing AIP levels. These findings suggest that such individuals with high F/M but preserved muscle mass may represent a "metabolically healthy obesity" phenotype [38], highlighting the importance of combined fat reduction and muscle gain as a precision strategy for cardiovascular protection in this population.

Meanwhile, this study has several limitations. First, the cross-sectional design cannot infer causality. Second, the study participants were from a single health check-up center, potentially introducing selection bias. Additionally, although BIA is practical for large-scale assessments, its accuracy is inferior to that of more advanced techniques. Future prospective cohort studies employing more precise body composition measurements, such as dual-energy X-ray absorptiometry (DEXA), are needed to validate our findings.

Conclusion

In summary, our findings highlight potential implications for personalized body composition assessment based on F/M categories. For individuals with F/M < 0.47, particularly those with elevated WHR, monitoring and addressing adiposity may be warranted. Even in patients without significant central obesity, attention should be paid to relative increases in body fat mass. Conversely, for individuals with F/M ≥ 0.47, maintaining or increasing appendicular skeletal muscle mass—through resistance training or other appropriate interventions—may be considered alongside general weight management. These observations require validation in prospective studies before definitive clinical recommendations can be established.

Abbreviations

AIP	Atherogenic index of plasma
F/M	Fat-to-muscle mass ratio
WHR	Waist-to-hip ratio
ASM/BMI	Appendicular skeletal muscle mass-to-body mass index ratio
TG	Triglycerides
CVD	Cardiovascular disease
MACE	Major adverse cardiovascular events
BMI	Body mass index
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
FBG	Fasting blood glucose
TC	Total cholesterol
HDL-C	High-density lipoprotein cholesterol
LDL-C	Low-density lipoprotein cholesterol
ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
GGT	Gamma-glutamyl transferase
TBIL	Total bilirubin
DBIL	Direct bilirubin
IBIL	Indirect bilirubin
ALB	Albumin
SCr	Serum creatinine
SUA	Serum uric acid
BIA	Bioelectrical impedance analyzer
HbA1c	Hemoglobin A1c
eGFR	Estimated glomerular filtration rate
T2DM	Type 2 diabetes
DEXA	Dual-energy X-ray absorptiometry

Declarations

Author contributions

QZ contributed to the conception of the work, QZ, Ying Li and YG contributed to the design of the work, QZ and ZZ contributed to data analysis, Yan Liu, LC and QY contributed to data interpretation, and QZ, GW and HP managed the presentation of the manuscript. MC was responsible for supervision and revision of the work. All authors have approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Funding

No specific funding was obtained from any bodies in the public, commercial or not-for-profit sectors to carry out the work described in this article.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to privacy/ethical restrictions but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study involved anonymized patient data and, due to its retrospective nature, was exempt from the requirement for informed consent. This study was approved by the Ethics Committee of Hefei First People's Hospital (2025-251-01), in compliance with the Declaration of Helsinki.

Consent for publication

All authors have consented to the publication of this manuscript.approved by the Ethics Committee of Hefei First People's Hospital (2025-251-01), in compliance with the Declaration of Helsinki.

Clinical trial number

Not applicable

Competing interests

The authors declare no competing interests.

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Figures

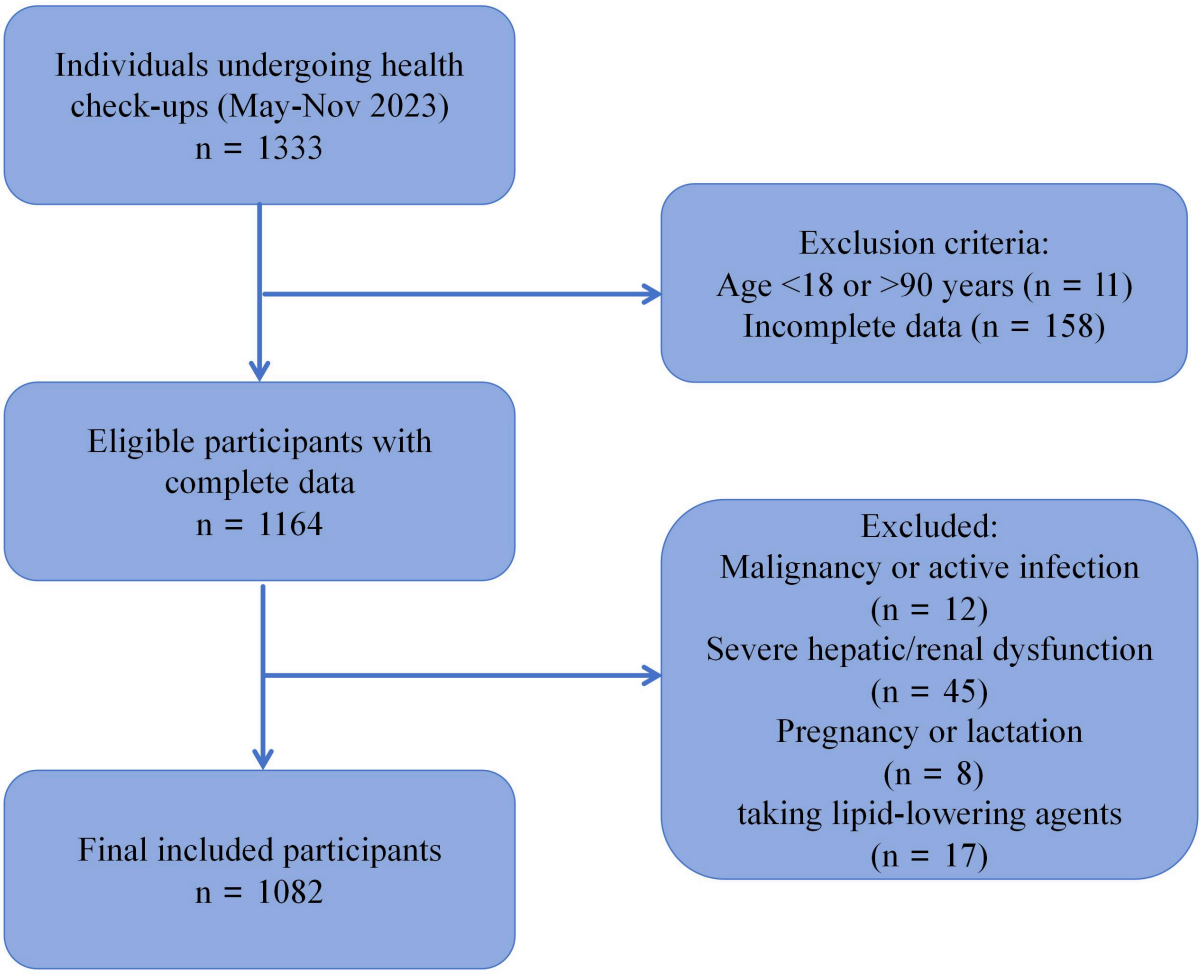


Figure 1

Flowchart of study participant selection

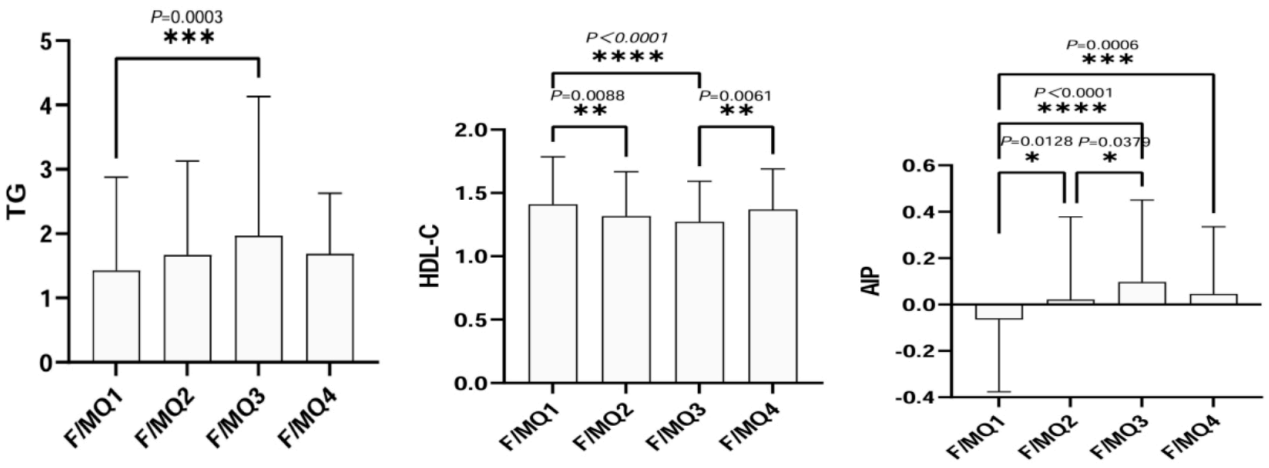


Figure 2

The comparisons of TG, HDL-C, and AIP among four groups divided by F/M using inter-quartile range

Abbreviations: F/M, fat to muscle mass ratio; TG, triglyceride; HDL-C, high density lipoprotein cholesterol; AIP, atherogenic index of plasma

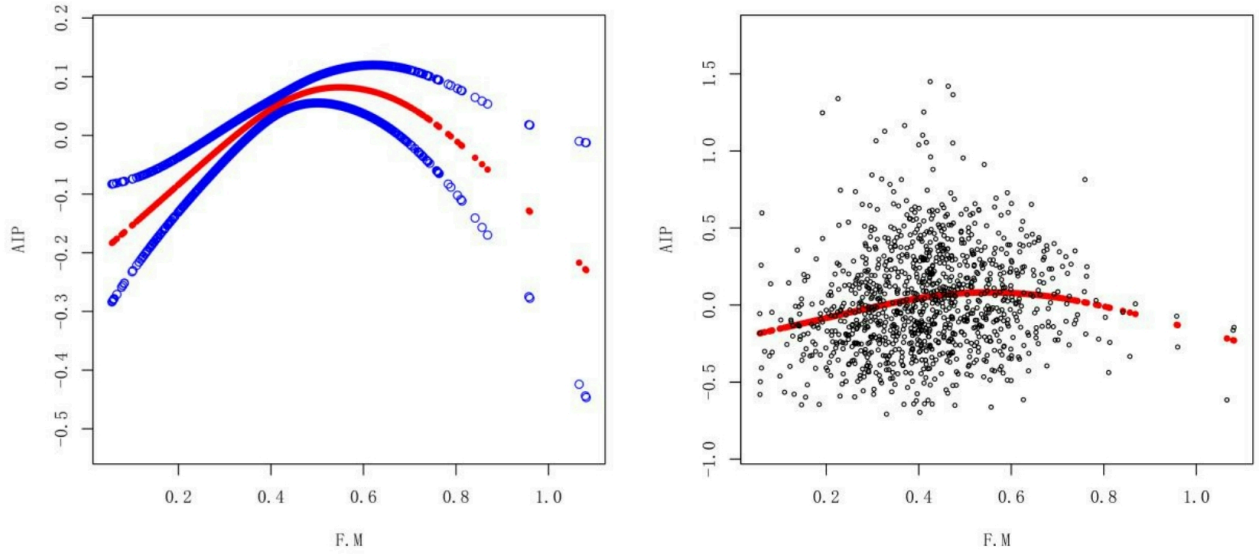


Figure 3

Smooth curve fitting diagrams of the relationships between F/M and AIP

Abbreviations: F/M, fat to muscle mass ratio; AIP, atherogenic index of plasma

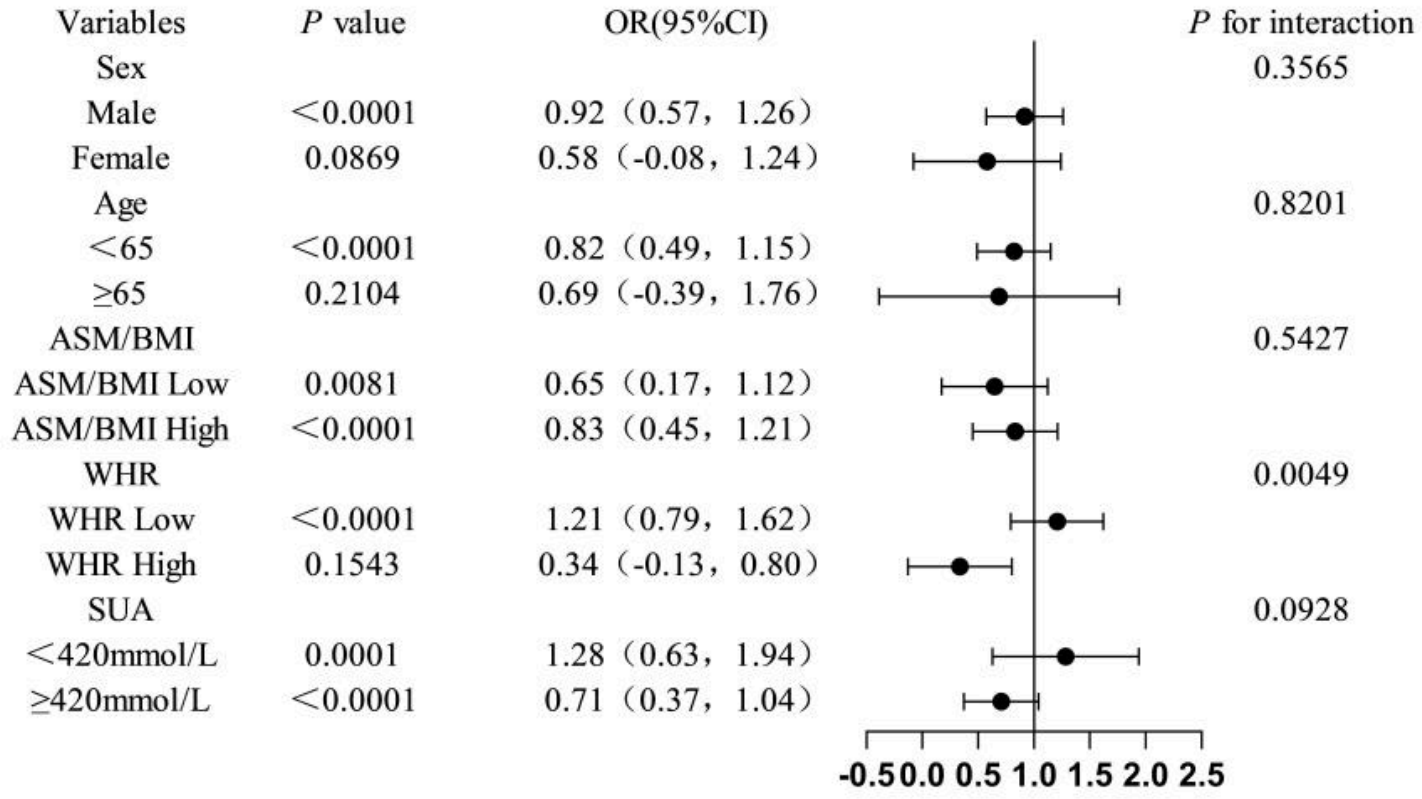


Figure 4

Interaction test for the relationship between F/M and AIP in the F/M < 0.47 subgroup

Subgroup analyses were stratified by age, sex, WHR, ASM/BMI, and SUA

Models were not separately adjusted for the stratification variables within each subgroup

P < 0.05 indicate significant difference

Abbreviations: F/M, fat to muscle mass ratio; AIP, atherogenic index of plasma; ASM/BMI, appendicular skeletal muscle mass-to-body mass index ratio; WHR, waist-to-hip ratio; SUA, serum uric acid

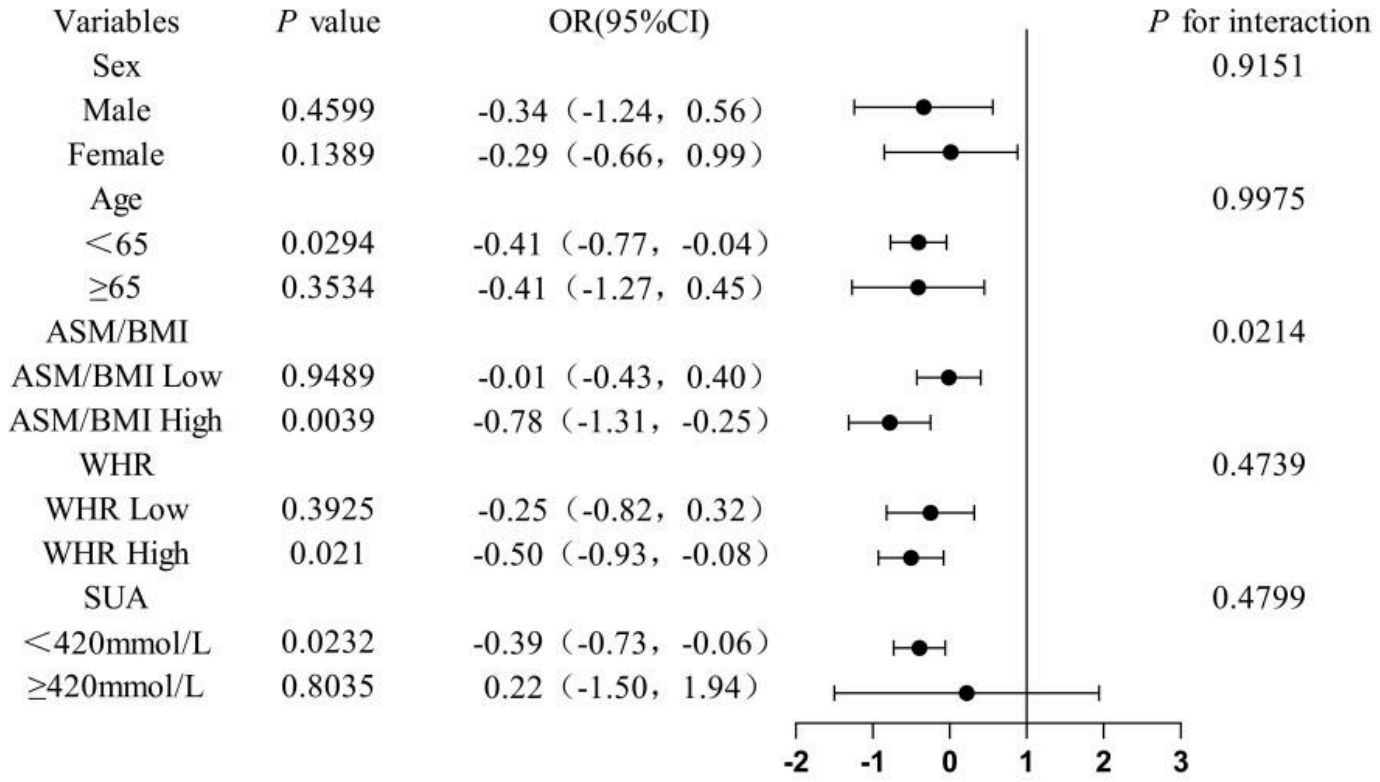


Figure 5

Interaction test for the relationship between F/M and AIP in the F/M ≥ 0.47 subgroup. Subgroup analyses were stratified by age, sex, WHR, ASM/BMI, and SUA

Models were not separately adjusted for the stratification variables within each subgroup

P < 0.05 indicate significant difference

Abbreviations: F/M, fat to muscle mass ratio; AIP, atherogenic index of plasma; ASM/BMI, appendicular skeletal muscle mass-to-body mass index ratio; WHR, waist-to-hip ratio; SUA, serum uric acid