GAS Journal of Clinical Medicine and Medical Research (GASJCMMR)

Volume 3 | Issue 11, 2026 Homepage: https://gaspublishers.com/gasjcmmr/ ISSN: 3049-1568

Atherogenic Index of Plasma and Its Relationship with Blood Pressure Control among Adults in Irrua, Nigeria: A Cross-Sectional Study

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Received: *12.10.2026* | ***Accepted:*** *26.10.2026* | ***Published:*** *03.11.2026*

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DOI: *10.5281/zenodo.23911024*

Abstract **Original Research Article**

The atherogenic index of plasma (AIP), calculated as log10 [triglyceride/high-density lipoprotein cholesterol (HDL-C)], is a sensitive marker of atherogenic dyslipideamia, small dense low-density lipoprotein particle size, and residual cardiovascular risk beyond individual lipid parameters. Its role in hypertensive patients in Irrua remains underexplored.

Objective: To determine the distribution of AIP and its relationship with blood pressure (BP) control among hypertensive patients in Irrua, Southern Nigeria.

Method: This was a hospital-based, cross-sectional study of 300 adult hypertensive patients (299 with complete lipid data for AIP calculation) attending the Cardiology clinic of Irrua Specialist Teaching Hospital, Edo State, Nigeria. Fasting lipid profile was measured and AIP calculated as log10 (TG/HDL-C). AIP was categorized as low-risk (<0.11), intermediate-risk (0.11-0.21), high-risk (>0.21). BP control was defined as <140/90 mmHg in accordance with the European Society of Cardiology/European Society of Hypertension guidelines.

Results: The mean AIP was -0.04 + 0.26. A low-risk AIP was found in 75.3% of the patients, intermediate risk in 15.1% and high risk in 9.7%. Blood pressure control was poor and not significantly associated with AIP category.

Conclusion: AIP was low in most hypertensives in Irrua, and was not a strong discriminator of BP control. Routine lipid screening remains important, but AIP alone should not guide BP management.

Keywords: Atherogenic Index of Plasma; Blood Pressure Control; Hypertension; Dyslipideamia; Irrua; Nigeria

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Citation: Onuoha, A. C., Onuoha-Ojeamiren, G. O., Adunbiola, P. O., Abdullazeez, M. I., Iweka, F. K., Dada, F. L., Uwuigbe, C. O., Jimmy, R. E., & Emordi, J. E. (2026). Atherogenic index of plasma and its relationship with blood pressure control among adults in Irrua, Nigeria: A cross-sectional study. *GAS Journal of Clinical Medicine and Medical Research (GASJCMMR), 3*(11), 1-10.

INTRODUCTION

Hypertension is the leading modifiable risk factor for cardiovascular disease (CVD), contributing to over 10.8 million deaths annually worldwide (World Health Organization, 2023). In Nigeria, systematic reviews report adult prevalence of 28.9% to 44.9%, with control rates below 35% in most community and hospital-based studies (Adeloye et al., 2021; Wahab et al., 2024). Poorly controlled hypertension amplifies risk of stroke, heart failure and chronic kidney disease (World Health Organization, 2023; Mancia et al., 2023).

Dyslipidaemia frequently coexists with hypertension and synergistically worsens CVD risk (Onyegbutulem et al., 2021; Idemudia, 2014). AIP, defined by Dobiasova and Frohlich as $\log_{10}$[TG/HDL-C], is inversely related to LDL particle diameter (Dobiasova & Frohlich, 2001). AIP predicts coronary artery disease (CAD) better than isolated lipids (Dobiasova, 2004; Onat et al., 2010). This was confirmed by recent systematic review and meta-analysis of 51 observational studies with >80,000 participants, where higher AIP was associated with increased odds of CAD (OR 2.79, 95% CI 1.75-4.45), coronary calcification (aOR 2.28), multivessel disease (aOR 2.04) and major adverse cardiovascular events (MACE) (HR 1.28) (Assempoor et al., 2025).

Recent studies have linked elevated AIP to hypertension. In the China Health and Retirement Longitudinal Study (CHARLS) including 12,376 middle-aged and elderly participants, each unit increment in AIP was associated with 109.0% increased prevalence of hypertension (aOR 2.09, 95% CI 1.78-2.46) and 57.7% increase in incidence over 7 years (aOR 1.58, 95% CI 1.28-1.94) (Chen et al., 2025). Similarly, Zhang et al. (2025) in a Chinese population aged ≥45 years (n = 10,201) found AIP associated with hypertension, with BMI mediating 55.6% of the association.

In Africa, Lokpo et al. (2017) in a Ghanaian hospital-based case-control study at Battor Catholic Hospital, involving 125 patients with hypertension, type 2 diabetes, or both, and 62 age-matched healthy controls, found that anthropometric and atherogenic dyslipeademic indices were significantly higher in the patients than in the controls. Among the patients, 39.2% had a high 10-year risk and 32.8% a moderate 10-year risk of coronary heart disease, compared with 11.3% moderate risk and no high risk among the controls. The odds of developing coronary heart disease within ten years were 4.5 times higher in the patient's group, with a higher female preponderance. Asamoah-Boakye et al. (2017) among 152 type 2 diabetic outpatients in Ghana reported prevalence of single dyslipidaemia 63.8%, combined 15.8%, mixed 1.3%, high coronary risk 35.3% and high atherosclerosis risk 5.3%, with coronary risk strongly associated with total cholesterol (r = 0.690) and LDL-C (r = 0.783) and atherosclerosis risk with TG (r = 0.817). Atherogenic dyslipideamia is common in South-South Nigeria (Akpa et al., 2017), but data from Edo Central Senatorial District are scarce.

Irrua, the administrative headquarters of Esan Central Local Government Area in Edo State, South-South Nigeria, hosts the Irrua Specialist Teaching Hospital (ISTH), a center of excellence for Lassa fever management. Despite a high burden of hypertension in the catchment area, routine lipid assessment is not universally performed for hypertensive patients in this setting due to out-of-pocket health financing, high patient load, intermittent reagent availability for HDL-cholesterol assay, and the need for fasting samples, which poses logistic challenges for patients traveling long distance. Consequently, atherogenic dyslipidaemia and residual cardiovascular risk may be underestimated. Evaluating the distribution of AIP may therefore help identify high-risk individuals with atherogenic dyslipidaemia who would benefit from intensive statin therapy in accordance with the 2019 European Society of Cardiology/European Atherosclerosis Society (ESC/EAS) dyslipidaemia guidelines (Mach et al., 2020).

OBJECTIVES

Primary: To determine AIP and its relationship with

blood pressure control among adults in Irrua, Nigeria. Secondary: (1) To determine AIP distribution, (2) To determine BP control rate, (3) To assess association between AIP and BP control, (4) To determine independent predictors of uncontrolled BP.

METHODS

Study Design and Setting: This was a hospital-based cross-sectional study conducted at the Irrua Specialist Teaching Hospital (ISTH), Irrua, Edo State, South-South Nigeria, between January 2nd and 20th of December 2022. The study was conducted in compliance with the Declaration of Helsinki.

Study Population: Three hundred (300) consecutive consenting adults aged ≥18 years attending the General Out-Patient Department (GOPD) and Medical Out-Patient Department (MOPD) were recruited. Inclusion criteria were adults with a diagnosis of hypertension defined as systolic BP >140 mmHg and/or diastolic BP >90 mmHg or current use of antihypertensive medications. Exclusion criteria were secondary hypertension, pregnancy, current use of lipid-lowering therapy, chronic kidney disease, and diabetes mellitus.

Sample Size Determination: The minimum sample size was calculated using Cochran's formula $N = Z^2pq/d^2$, where Z = 1.96 at 95% CI, p = 0.33 (prevalence of dyslipidaemia among hypertensives from previous Nigerian studies) (Onyegbutulem et al., 2021; Idemudia, 2014), q = (1-p), and d = 0.05 margin of error. With an additional 10% non-response rate, the minimum required sample size was 300. A total of 308 participants were recruited, the first 300 consecutive rows were analyzed, of which 299 had complete data for AIP calculation.

Ethical Considerations: Ethical approval was obtained from the Health Research Ethics Committee (HREC) of Irrua Specialist Teaching Hospital, Irrua, with approval number ISTH/HREC/20201112/136. Written informed consent was obtained from all participants. Confidentiality was maintained by use of anonymized codes, and participants were free to withdraw at any point without affecting their care. No additional risk was posed beyond routine venipuncture.

Clinical Measurements: Data on alcohol use and smoking history were obtained using a structured interviewer-administered questionnaire. Body mass index (BMI) was calculated as weight (kg) divided by height (m^2). Waist-hip ratio was measured using a non-stretchable tape. BP was measured twice in the sitting position after 5 minutes rest using a validated mercury sphygmomanometer, and the average was used for analysis. Controlled BP was defined as systolic BP <140 mmHg and diastolic BP <90 mmHg according to the 2018 ESC/ESH guidelines and the Eighth Joint National Committee (JNC 8) report (Williams et al., 2018; James et al., 2014).

Laboratory Procedures: After an 8-12 hour overnight fast, venous blood samples were collected for fasting plasma glucose (FPG), serum creatinine, urea, total cholesterol (TC), triglycerides (TG), high-density lipoprotein-cholesterol (HDL-C) by enzymatic colorimetric auto-analyzer (Onyegbutulem et al., 2021; Idemudia, 2014), and low-density lipoprotein-cholesterol (LDL-C) calculated using Friedewald's equation. The AIP was calculated as $\log_{10}$[TG/HDL-C mmol/L], with both TG and HDL-C expressed in mmol/L. AIP was categorized as low-risk (<0.11), intermediate-risk (0.11-0.21), and high-risk (>0.21) according to Dobiasova et al. (Dobiasova & Frohlich, 2001; Dobiasova, 2004). High-risk AIP ≥0.24 as per the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria (National Cholesterol Education Program, 2002).

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26.0 (IBM Corp, Armonk, NY) and Python 3.9. Continuous variables were expressed as mean ± standard deviation (SD), or median and interquartile range (IQR) where skewed. Categorical variables were presented as frequencies and percentages (%). Independent Student t-test was used to compare mean AIP between controlled and uncontrolled BP groups. Chi-square test was used to assess

association between AIP categories and BP control. Pearson correlation coefficient (r) was used to assess correlation between AIP and SBP, DBP and BMI. Multivariate binary logistic regression was performed to determine predictors of uncontrolled BP, including AIP, age, BMI, gender, and alcohol use. Odds ratio (OR) with 95% confidence interval (CI) was reported. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 300 participants were recruited, of whom 299 had complete lipid data and were included in the analysis. The general characteristics of the participants are summarized in Table 1.

The mean age was 56.6 ± 12.5 years, with a slight male predominance (52.5%). The mean body mass index (BMI) was 28.3 ± 5.2 kg/m², and the mean waist-hip ratio was 0.86 ± 0.11. The mean AIP was -0.04 ± 0.26 (median -0.04, range -0.62 to 1.80). The mean SBP 140.3 ± 27.6 mmHg and the mean DBP 91.9 ± 16.9 mmHg (Table 1).

Blood pressure control, defined as <140/90 mmHg, was achieved in 49.5% (n = 148; mean 122.4 ± 10.2/78.6 ± 8.4 mmHg) of the participants, while 50.5% (n = 151; mean 158.0 ± 26.1/105.0 ± 14.2 mmHg) remained uncontrolled (Table 2).

The distribution of AIP is shown in Table 3. Most participants were in low-risk category (75.3%, n = 225), followed by the intermediate-risk category (15.1%, n = 45), and the high-risk category (9.7%, n = 29).

There was no significant association between AIP category and blood pressure control ($\chi^2 = 2.78$, df = 2, p = 0.249) (Table 4).

Pearson correlation analysis showed no significant association between AIP and SBP (r = 0.065, p = 0.27), DBP (r = 0.040, p = 0.49) or BMI (r = 0.020, p = 0.71), indicating no correlation (Table 5).

Multivariate logistic regression was used to identify independent predictors of blood pressure control (N = 299) (Table 6). None of the variables independently predicted blood pressure control. AIP was not associated with control (aOR 1.16, 95% CI 0.45-2.98, p = 0.75). Similarly, age (aOR 1.02, p = 0.22), BMI (aOR 1.04, p = 0.21), and alcohol use (aOR 0.76, p = 0.39) were not significant predictors. There was also no gender difference, with males having comparable odds of control to females (aOR 1.36, 95% CI 0.84-2.20, p = 0.21).

TABLES

Table 1: General Characteristics (N=300, AIP N=299)

Variable	Mean ± SD or n (%)	Range
Age (years)	56.6 ± 12.5	24-92
Male gender	157 (52.5%)	-
Female gender	142 (47.5%)	-
BMI (kg/m2)	28.3 ± 5.2	17-42
Waist-hip ratio	0.86 ± 0.11	0.65-1.12
Fasting glucose (mmol/L)	4.55 ± 0.55	3.2-6.8
Total cholesterol (mmol/L)	4.91 ± 1.38	2.1-8.5
Triglyceride (mmol/L)	1.28 ± 0.60	0.4-3.8
HDL-C (mmol/L)	1.37 ± 0.38	0.6-2.4

LDL-C (mmol/L)	2.95 ± 1.13	1.0-5.8
AIP	-0.04 ± 0.26, median -0.04, IQR -0.205 to 0.10	-0.62 to 1.80
SBP (mmHg)	140.3 ± 27.6	90-230
DBP (mmHg)	91.9 ± 16.9	60-150

Table 2: Blood Pressure Control Rate

BP Control	**n (%)**	**Mean SBP/DBP**
Controlled (<140/90)	148 (49.5%)	122.4 ± 10.2 / 78.6 ± 8.4
Uncontrolled (≥140/90)	151 (50.5%)	158.0 ± 26.1 / 105.0 ± 14.2

Table 3: AIP distribution (N=299)

AIP Category	**Cut-off**	**n (%)**
Low risk	<0.11	225 (75.3%)
Intermediate risk	0.11-0.21	45 (15.1%)
High risk	>0.21	29 (9.7%)

Table 4: AIP category by blood pressure control

AIP Category	**Uncontrolled n=150 (%)**	**Controlled n=149 (%)**	**Total N=299**
Low <0.11	113 (75.3%)	112 (75.2%)	225 (75.3%)
Intermediate 0.11-0.21	26 (17.3%)	19 (12.8%)	45 (15.1%)
High >0.21	11 (7.3%)	18 (12.1%)	29 (9.7%)

Table 5: Pearson Correlation AIP and BP/BMI (N=299)

Variable	**r value**	**p-value**	**Interpretation**
AIP vs SBP	0.065	0.27	No correlation
AIP vs DBP	0.040	0.49	No correlation
AIP vs BMI	0.020	0.71	No correlation

Table 6: Multivariate Logistic Regression Analysis of Predictors of Uncontrolled BP (N=295)

Variable	Adjusted Odds Ratio (aOR)	95% CI	p-value
AIP (per 1 unit)	1.16	0.45-2.98	0.75
Age (per year)	1.02	0.99-1.05	0.22
BMI (per kg/m2)	1.04	0.98-1.11	0.21
Male vs Female	1.36	0.84-2.20	0.21
Alcohol Yes vs No	0.76	0.41-1.42	0.39

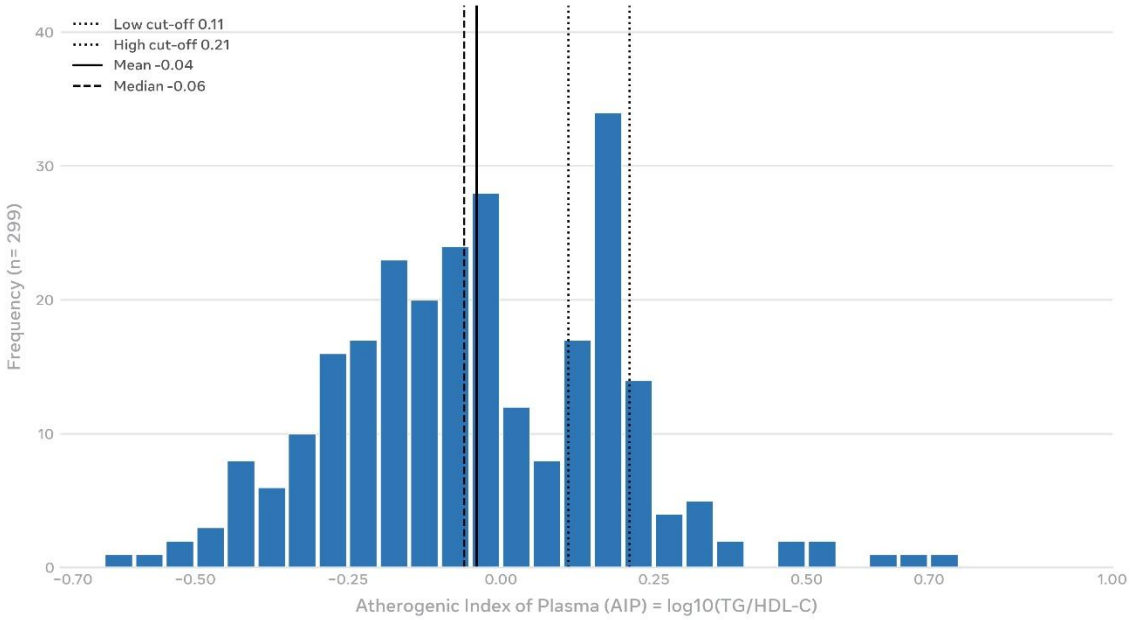


Figure 1: Histogram Showing Atherogenic Index of Plasma (AIP) distribution among 299 adults in Irrua.

Mean -0.04 ± 0.26 median -0.04 IQR -0.205 to 0.10 range -0.62 to 1.80. Low risk (<0.11) 75.3%, Intermediate (0.11-0.21) 15.1%, High (>0.21) 9.7%.

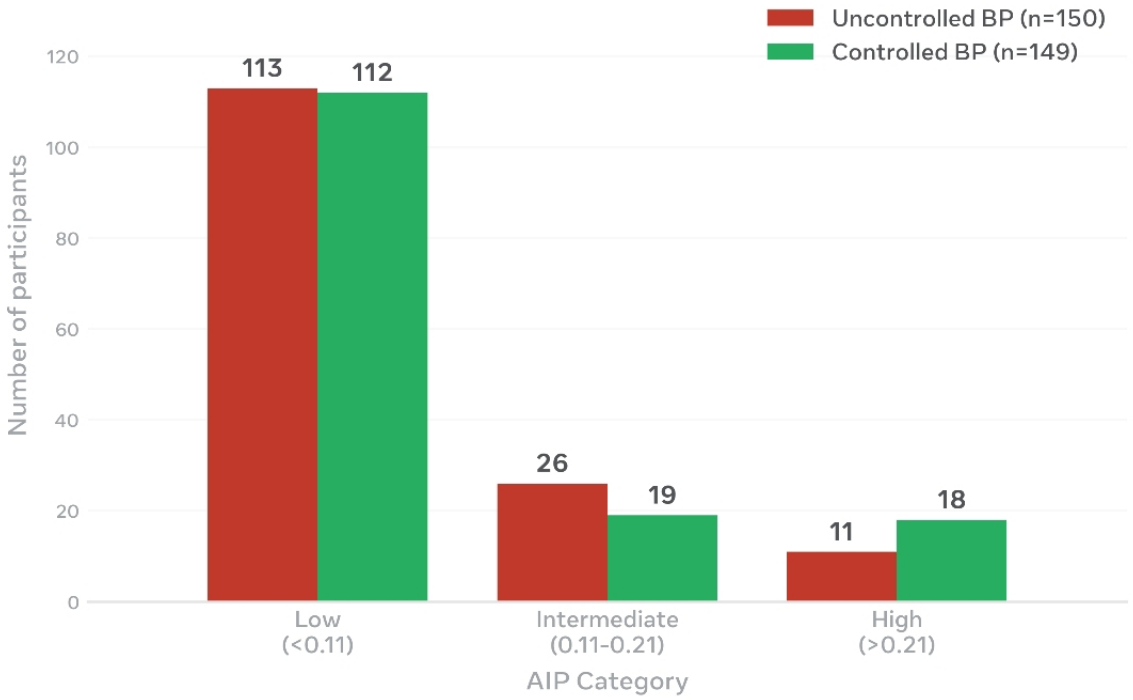


Figure 2: Clustered Bar Chart of AIP Category by Blood Pressure Control Status (N = 299).

$\chi^2 = 2.78$, df = 2, p = 0.249, no significant association. Uncontrolled BP (n = 150): Low 75.3% (113), Intermediate 17.3% (26), High 7.3% (11). Controlled BP (n = 149): Low 75.2% (112), Intermediate 12.8% (19), High 12.1% (18).

DISCUSSION

In this Irrua cohort of 299 adults attending ISTH clinics, we found a predominantly low atherogenic risk profile with mean AIP -0.04 ± 0.26 and 75.3% low-risk. Only 9.7% had high AIP >0.21 despite 50.3% uncontrolled BP. The distribution was bell-shaped, slightly left-skewed, ranging from -0.62 to 1.80 with an IQR of -0.205 to 0.10.

This low-risk profile contrasts sharply with international data. Assempoor et al. (2025) in meta-analysis of 51 studies reported that higher AIP strongly predicted coronary artery disease (OR 2.79). Similarly, among untreated hypertensives in Southern Nigeria, Akpa and Unamba (2017) found lipid disorders were common, with reduced HDL-C in 37.3% and elevated LDL-C in 30.3% of the patients, and AIP was abnormal in 12.1%. Among patients with type 2 diabetes in Ghana, Asamoah-Boakye et al., (2017) reported 63.8% dyslipideamia and 35.3% high coronary risk by AIP. Our findings may be explained by a more favorable lipid phenotype in this semi-urban Edo community: with lower mean TG 1.28 mmol/L and higher HDL-C 1.37 mmol/L, higher than values reported in urban Ghanaian cohorts. This likely reflects dietary patterns characterized by unprocessed carbohydrates, high fiber, moderation of palm oil reuse, higher physical activity related to farming, and lower consumption of ultra-processed foods and sugar-sweetened beverages, all of which help maintain higher HDL-C (Onyegbutulem et al., 2021; Idemudia, 2014). The low AIP is also consistent with Nigerian data from Port Harcourt, where AIP was abnormal in only 12.1% of untreated hypertensives (Akpa & Unamba, 2017).

Contrary to our hypothesis and to findings from the China Health and Retirement Longitudinal Study

(CHARLS) where each unit increase in AIP increased hypertension prevalence by 109% (OR 2.09) and incidence by 57.7% (OR 1.58) (Chen et al., 2025), we found no relationship between AIP and blood pressure control. Mean AIP did not differ significantly between controlled (-0.048) and uncontrolled (-0.037) groups (p = 0.69). There was no association between AIP categories and control status (χ^2 = 2.78, p = 0.25, Figure 2) and no meaningful correlation SBP (r = 0.065) or DBP (r = 0.040).

This negative finding is consistent with the Nigerian evidence that determinants of blood pressure control are sociodemographic and lifestyle factors rather than lipid indices alone (Okwuonu et al., 2021). Zhang et al. (2025) demonstrated that BMI mediated 55.6% of the AIP-hypertension association.

Reasons for the negative finding are multi-factorial: (1) Low TG variance reduces the discriminatory power of AIP, which is log-transformed TG/HDL-C ratio. With 75% of participants in low-risk categories, the index has limited spread to differentiate controlled from uncontrolled. (2) AIP reflects small dense LDL, which drives atherosclerosis over years, whereas blood pressure control is an acute haemodynamic outcome influenced by drug adherence, salt intake, and sympathetic tone. (3) Cross-sectional design cannot capture longitudinal effects of chronic atherogenic exposure on vascular stiffness.

Clinical and Public Health Implications: Despite poor BP control, our population has low short-term atherogenic risk, which is reassuring. However, the 9.7% with high AIP >0.21 still represent a high-risk group that needs intensive lifestyle intervention. AIP remains a cheap, readily available tool from routine lipids in Irrua where advanced assays are unavailable. Its utility may be more in long-term cardiovascular risk stratification rather than predicting BP control.

Strengths and Limitations: Strengths include a well-characterized cohort from a tertiary center serving rural Edo, use of standardized BP measurement, and 99.7% complete lipid data (299 of 300). Limitations: Single-center, cross-sectional design precludes causality; we did not adjust for antihypertensive drug classes (e.g., thiazides raise TG), statin use, diet scores, or physical activity indices; and the outlier AIP of 1.80 suggests severe hypertriglycerideamia needing exclusion sensitivity analysis.

CONCLUSION

Irrua adults show low AIP despite high rates of uncontrolled hypertension, and AIP category is not associated with BP control. Control strategies in this setting should prioritize adherence, weight reduction, and salt restriction, while using AIP to identify the minority at high atherogenic risk for targeted dyslipideamia management.

Conflict of Interest

The authors have no conflicts of interest to declare.

Funding

None

Data Availability

All data generated or analyzed during this study are included in this article, and additional details or raw data are available from the corresponding author upon request.

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