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Article

Relationship Between Dietary Inflammatory Index With Biochemical Markers and Atherogenic Risk in Patients With Atherosclerotic Heart Disease

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Abstract

Aims/Background: The relationship between cardiovascular disease and the inflammatory potential of diet has been recently reported. This study aimed to investigate the relationship between a pro-inflammatory diet, as assessed by the dietary inflammatory index (DII), and the atherogenic index of plasma (AIP) and biochemical markers in patients with atherosclerotic heart disease. **Methods:** This study was conducted with 100 patients with atherosclerotic heart disease who were admitted or hospitalised at the Department of Cardiology, Erciyes University Faculty of Medicine between March and September 2024. Participants' sociodemographic variables, anthropometric measurements, and biochemical markers were recorded. Their AIP and DII values were calculated. The 14-item Mediterranean Diet Adherence Tool and the Global Physical Activity Questionnaire were administered to them. **Results:** In our study, DII scores ranged from (–0.50) to (+12.20). Patients were divided into three groups based on their DII scores; T1 and T3 represented lower and higher DII scores, respectively. There were no significant differences in AIP values among the groups ($p > 0.05$). There were also no differences among the groups in serum Na, K, Ca, fasting blood glucose (FBG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglyceride (TG), and C-reactive protein (CRP) values ($p > 0.05$ for all); only Hemoglobin (Hb) value was higher in the T1 group compared to the other groups ($p = 0.014$). Participants in the T1 group had higher intakes of energy, total fat, carbohydrates, protein, monounsaturated fat, polyunsaturated fat, fiber; beta-carotene, thiamine, riboflavin, niacin, folic acid, and vitamins A, E, C, and B6; and iron and zinc ($p < 0.001$ for all). Significant differences were observed among the groups in the intake of saturated fat ($p = 0.020$), vitamin B12 ($p = 0.030$), magnesium ($p < 0.001$), garlic ($p = 0.004$), onion ($p < 0.001$), and pepper ($p < 0.001$), whereas no significant differences were found for cholesterol, vitamin D, selenium, and tea consumption ($p > 0.05$). No associations were observed between DII and HDL-C, LDL-C, TG, TC, CRP, AIP, Global Physical Activity Questionnaire (GPAQ) score, or the 14-item Mediterranean Diet Adherence score after adjustment for confounders in the whole cohort ($p > 0.05$ for all). **Conclusion:** This study demonstrates that patients with atherosclerotic heart disease tend to have more pro-inflammatory dietary habits, which are significantly correlated with energy intake and various macronutrient and micronutrient levels. Although there is no direct association between DII and AIP or key biochemical markers, continued pro-inflammatory dietary habits in patients may increase inflammation, potentially affecting the development and progression of atherosclerosis. Accordingly, reducing the inflammatory load of the diet may be a beneficial strategy for preventing and managing atherosclerosis and related cardiovascular diseases.

Keywords: anti-inflammatory diet; pro-inflammatory diet; atherosclerosis; dietary inflammatory index; inflammation

1. Introduction

Atherosclerosis, one of the mechanisms thought to cause cardiovascular diseases (CVD), is a chronic inflammatory disease in which atheroma or plaques block arteries [1]. Inflammation-induced endothelial dysfunction causes increased permeability to lipoproteins, their subendothelial accumulation, attraction of leukocytes, and activation of platelets. Monocytes are transformed into macrophages, which develop pro- or anti-inflammatory properties depending on their microenvironment [2]. Progressive lesions may narrow the lumen and cause a 50% decrease in blood flow and, consequently, angina. Moreover, because of their fatty and inflammatory nature, these lesions may also rupture over time [3]. In addition to traditional cardiovascular risk factors, exposure to acute and chronic psychological stress and inflammation, resulting in increased sympathetic outflow and release of inflammatory cytokines, may increase the cardiovascular disease risk [2].

Factors such as age, gender, smoking, physical activity, and drug use affect inflammation. In recent years, nutrition has also been recognised as one of the most important determinants of inflammation. It is accepted that consuming vegetables, fruits, olive oil, whole grains, and nuts in a Mediterranean-style diet, which has been accepted as an ideal diet for cardiovascular diseases especially, has anti-inflammatory effects and prevents inflammation, whereas the Western-style diet, which is rich in simple carbohydrates, red meat, trans fatty acids, saturated fatty acids,

and processed foods, has pro-inflammatory effects and triggers inflammation. For this reason, it is known that anti-inflammatory dietary components are significantly effective in preventing many chronic and systemic diseases, especially atherosclerotic heart diseases [4].

The dietary inflammatory index (DII) is an index developed to evaluate the diet of individuals by classifying their diets from anti-inflammatory to pro-inflammatory [5]. Many studies have proven the importance of this index, which was developed to evaluate the diet's inflammatory potential and thus enable the association of dietary content with inflammation [6,7]. To date, DII has been associated with many systemic diseases and inflammatory markers and has also been used in studies investigating the relationship between diet and heart disease risk [8,9].

Atherosclerotic heart disease is a major burden on health worldwide, significantly affecting quality and duration of life. The impact of dietary inflammatory burden on these diseases' development has not been fully elucidated in the current literature. In this context, understanding DII's effects on atherosclerotic heart disease is an important research area for preventing and managing cardiovascular diseases. Therefore, this cross-sectional study aimed to evaluate the association between dietary inflammatory index (DII) and atherogenic index of plasma (AIP), as well as key biochemical indicators, in a cohort of patients with atherosclerotic heart disease in Turkey. Thus, we hope to provide a better understanding of the association of high DII scores with the development and outcomes of cardiovascular disease in individuals with atherosclerosis and to provide a basis for further research specifically about the potential benefits of reducing the inflammatory burden of diet in managing or ameliorating atherosclerosis.

2. Methods

2.1 Study Plan

This cross-sectional study was conducted between March and September 2024 and aimed to evaluate the association between DII and atherosclerotic heart disease. A total of 100 atherosclerotic heart disease patients (n = 100) who were admitted or hospitalised at the cardiology clinic of Erciyes University Faculty of Medicine voluntarily participated. After the purpose of study was explained to them, their verbal and written informed consent was obtained. Furthermore, the author obtained the approval of the Nuh Naci Yazgan University Scientific Research and Publication Ethics Committee (approval number: 2023/010-006) on 7 December 2023, and the Academic Committee of Department of Cardiology, Erciyes University Faculty of Medicine. The author also obtained the required permissions for the use of the 14-item Mediterranean Diet Adherence Tool.

2.2 Study Population

Sample size was calculated using the TURCOSA Statistical System based on a one-way analysis of variance (ANOVA). Based on Zhang et al. (2023) [9], assuming an effect size of 0.75, a statistical power of 90%, and a significance level (α) of 0.05, the minimum required sample size was determined. Accordingly, 100 participants aged 20–65 years who were admitted to or hospitalised in the university hospital's cardiology clinic and diagnosed with atherosclerotic heart disease were included in the study. Cardiology specialists made the atherosclerotic heart disease diagnosis in accordance with the European Society of Cardiology (ESC) 2019 guidelines [10]. The diagnostic process involved evaluating patients' clinical symptoms, medical history, and cardiovascular risk factors. Basic clinical examinations such as biochemical tests, resting electrocardiography, and echocardiography were used. Depending on clinical necessity, the diagnosis was confirmed using coronary computed tomography (CT) angiography, functional imaging techniques, or invasive coronary angiography. Individuals with a body mass index (BMI) >40 kg/m^2; individuals with physician-diagnosed diabetes; pregnant or breastfeeding individuals; those who had in the past six months, consumed high amounts of alcohol or tobacco; those using nutritional supplements that may affect inflammation; and those with a daily energy intake of less than 500 kcal or more than 4200 kcal were excluded from the study.

Cardiology specialists evaluated and managed the diagnosis of atherosclerotic heart disease and the medical treatment processes of patients in accordance with ESC 2019 guidelines on chronic coronary syndromes. The treatment approach was individualised according to patients' clinical characteristics, including anti-ischemic drugs (e.g., beta-blockers, calcium channel blockers, nitrates) and therapies that improve prognosis (e.g., antiplatelet agents, statins, angiotensin-converting enzyme [ACE] inhibitors/angiotensin II receptor blockers [ARBs]). During the study period, outpatients continued their routine clinical treatments, and no systematic changes to their existing medications were reported; inpatients' treatments were managed and adjusted by their physicians according to clinical necessity during hospitalisation.

2.3 Data Collection

Participants' sociodemographic information was collected through face-to-face interviews using a questionnaire. Anthropometric measurements and biochemical data were taken during hospital admission or hospitalisation. Single retrospective 24-hour dietary recall records were collected, and DII scores were calculated based on pre-hospital admission dietary habits. Additionally, participants completed the 14-item Mediterranean Diet Compliance Test and the Global Physical Activity Questionnaire (GPAQ).

2.3.1 Anthropometric Measurements

Participants' body weight and height were measured SECA 213 portable stadiometer (seca GmbH & Co. KG, Hamburg, Germany) at the beginning of the study. Measurements were taken in the morning on an empty stomach after defecation and urination, taking care to remove excess clothing. BMI was calculated by the following formula: [weight (kg)/height $(m)^2$].

2.3.2 Biochemical Analyses

Biochemical parameters were obtained from fasting blood samples collected at hospital admission. Hemoglobin (Hb) and fasting blood glucose (FBG), sodium (Na), potassium (K), calcium (Ca), total cholesterol (TC), LDL-C, HDL-C, triglycerides (TG), and C-reactive protein (CRP) levels were recorded.

2.3.3 Dietary Assessment

Individuals were given single retrospective 24-hour dietary recalls the day before their hospital admission or hospitalisation. Additionally, the amount of food consumption defined using the 'Food and Nutrition Photograph' catalog was supported with additional questions such as 'What was the portion of the food/drink you consumed? How much of it did you eat/drink? What was in it?' [11].

2.3.4 Global Physical Activity Questionnaire (GPAQ)

Participants' physical activity status was assessed using GPAQ, which Adıgüzel et al. [12] validated and verified for Turkey. According to the results, the total number of metabolic equivalent of task minutes (MET-minutes) of physical activity in a week was calculated [12,13]. For GPAQ scoring, moderate activity was assigned a MET coefficient of 4, and vigorous activity a coefficient of 8. After determining the number of days and minutes per day of the relevant activity, the METs value of each section was calculated by using the relevant coefficients multiplied by the result obtained from the multiplication weekly values below 600 MET-min/week indicated that the participant was physically inactive, weekly values of 600–2999 MET-min/week indicated that the participant was moderately active, and weekly values of ≥3000 MET-min/week indicated that the participant was highly active [13].

2.3.5 The 14-Item Mediterranean Diet Adherence Tool

The 14-item Mediterranean Diet Adherence Tool, developed by Martínez-González et al. (2012) [14] and validated and verified in Turkey, was used to evaluate participants' adherence to a Mediterranean diet [15]. The tool provided scoring between 0 and 14 points and evaluated their daily consumption of olive oil, vegetables, fruits, red meat, white meat, butter, sugar, wine, dried legumes, seafood, pastries, and nuts. Fourteen questions were asked; a score of <7 indicated a low level of adherence to a Mediterranean diet, a score of 7–9 indicated a moderate level of adherence, and a score of ≥10 indicated a high level of adherence to a Mediterranean diet. No participants reported alcohol consumption; therefore, the wine component did not contribute to the total score.

2.3.6 Atherogenic Index of Plasma (AIP)

The AIP was used for predicting cardiovascular disease risk. The index, calculated using plasma TG and HDL-C values, represented the relationship between atherogenic and protective lipoproteins [16]. To calculate the index value, TG (mg/dL÷88.57) and HDL-C (mg/dL÷38.67) values were converted to mmol/L using the relevant formulas. Then, the ratio of TG to HDL-C (TG/HDL-C) was calculated by logarithmic conversion to base 10. The received AIP values were respectively defined as low-grade risk (<0.11), moderate risk (0.11–0.21), and high-grade risk (>0.21) [16]. Increased AIP value was associated with increased atherosclerosis and coronary heart disease [17].

2.3.7 Dietary Inflammatory Index (DII)

This method, about which Shivappa et al. [5] reported, was used to determine the DII values of participants' diets. Shivappa et al. [5] identified 45 food components affecting the concentration of inflammatory or anti-inflammatory biomarkers. In this study, DII scores were calculated on the basis of 28 food components (instead of 45) because of the lack of some nutrients in the nutrient database of the Electronic Nutrition Information System (eBeBiS), Version 8.2 (BeBiS Software, Istanbul, Turkey) (2020): energy values, protein, total fat, saturated fat, monounsaturated fat acid (MUFA), polyunsaturated fat acid (PUFA), cholesterol, carbohydrate, fiber, vitamin A, beta-carotene, vitamin D, vitamin E, thiamine, riboflavin, niacin, vitamin B6, folic acid, vitamin B12, vitamin C, iron, magnesium, zinc, selenium, onion, garlic, pepper, and tea. No participants reported alcohol consumption; therefore, the wine component of the DII did not contribute to the total score. To calculate DII for the participants, dietary data were linked to the standard global mean as a z-score. All the food-parameter-specific DII scores were then summed to obtain the overall DII score for every participant. According to this score, patients were classified into three groups (tertiles: T1, T2, T3). The groups represent increasing levels of dietary inflammatory potential from T1 to T3.

2.4 Statistical Analysis

Histogram and q-q plots were examined, and Shapiro-Wilk's test was conducted to assess data normality. Levene's test was used to test variance homogeneity. Continuous variables following a normal distribution were presented as mean ± standard deviation (SD), analyzed using ANOVA, and post hoc comparisons were performed using Tukey's test. Continuous variables not following a normal distribution were presented as median (interquartile range, IQR), analyzed using the Kruskal–Wallis test, and post hoc

comparisons were performed using Dunn's test. Categorical variables were presented as n (%), and analyzed using Pearson's χ^2 or Fisher's exact test. Spearman's rank correlation analysis was used to evaluate the correlations between DII, AIP, lipid parameters, CRP, Mediterranean Diet Adherence score, and GPAQ score. To evaluate the association between DII scores and cardiometabolic variables, multiple linear regression analysis was performed. Independent variables were entered into the models simultaneously using the Enter method. Both crude and adjusted regression models were estimated; the crude model included only the DII score, whereas the adjusted model additionally included potential confounding variables, namely age, gender, education level, marital status, employment status, and body mass index (BMI). Prior to the regression analyses, key model assumptions were assessed. The linearity assumption between dependent and independent variables was evaluated using residual plots and scatter plots. Multicollinearity among independent variables was assessed using variance inflation factor (VIF) and tolerance values. VIF values <10 and tolerance values >0.1 were considered indicative of acceptable levels of multicollinearity [18]. No significant multicollinearity was found among the variables in this study. Additionally, the independence and homoscedasticity of residuals were evaluated using standardized residuals and graphical methods. Regression coefficients (β), 95% confidence intervals, coefficient of determination (R^2), and *p*-values were reported. Analyses were conducted using R version 4.5.1 (https://www.r-project.org). A two-sided *p*-value < 0.05 was considered statistically significant.

3. Results

3.1 General Information of Patients

The median DII scores were 4.6 (2.7–5.2), 7.1 (6.7–7.5), and 9.4 (8.4–9.9) for T1, T2, and T3, respectively, with an overall range of −0.5 to 12.2. A total of 100 participants were included in the analysis and categorised into tertiles according to their DII scores. There was no difference between tertiles on sociodemographic values, BMI, AIP scores, GPAQ scores, and 14-Item Mediterranean Diet Adherence Tool scores ($p > 0.05$) (Table 1).

3.2 Biochemical Parameters and Dietary Intake Across DII Tertiles

Serum Na, K, Ca, FBG, TC, HDL-C, LDL-C, TG, and CRP levels did not differ significantly across DII tertiles ($p > 0.05$). Hemoglobin levels were significantly higher in the T1 group compared with the T2 and T3 groups ($p = 0.014$). Energy, total fat, fiber and protein intake were higher in T1 and T2 than in T3 ($p < 0.001$). Carbohydrate intake was higher in T1 than in T2 and T3 ($p < 0.001$). MUFA intake was higher in T1 and T2 than in T3, whereas PUFA and fiber intake differed significantly across tertiles, with the highest values observed in T1 ($p < 0.001$). Intakes of vitamin A, vitamin E, vitamin C, vitamin B6, and magnesium were higher in T1 than in T2 and T3 ($p < 0.001$), whereas intakes of beta-carotene, thiamine, riboflavin, niacin, folic acid, iron, and zinc were higher in T1 and T2 than in T3 ($p < 0.001$). Vitamin D, cholesterol and selenium intake did not differ across tertiles ($p > 0.05$). Saturated fat, vitamin B12, garlic, onion, and pepper consumption differed significantly across tertiles ($p < 0.05$), whereas tea consumption was similar between groups ($p > 0.05$) (Table 2).

3.3 Correlation Between AIP, DII, Lipid Profile, Mediterranean Diet Adherence and Physical Activity

According to Spearman's correlation analysis, AIP score was strongly negatively correlated with HDL-C levels ($r = -0.715$, $p < 0.001$); positively correlated with TC ($r = 0.227$, $p < 0.05$) and TG levels ($r = 0.937$, $p < 0.001$). A strong positive correlation was observed between LDL-C and TC ($r = 0.851$, $p < 0.001$). TG levels were negatively correlated with HDL-C ($r = -0.466$, $p < 0.001$); positively correlated with TC ($r = 0.374$, $p < 0.001$) and LDL-C ($r = 0.214$, $p < 0.05$). The Mediterranean Diet Adherence Score showed a weak positive correlation with HDL-C ($r = 0.228$, $p < 0.05$). No significant correlations were found between DII score and AIP, CRP, or lipid parameters ($p > 0.05$) (Fig. 1). In addition, GPAQ score showed no significant correlation with AIP, lipid parameters, CRP, DII score, or Mediterranean Diet Adherence ($p > 0.05$).

3.4 Crude and Adjusted Linear Regression Models for the Association of DII Score With Selected Study Variables

Multiple linear regression analysis showed that DII scores were not significantly associated with HDL-C, LDL-C, TC, TG, CRP, AIP scores; 14-Item Mediterranean Diet Adherence Tool scores; or GPAQ scores in the crude model ($p > 0.05$). After adjustment for age, sex, education level, marital status, employment status, and BMI, no significant associations were observed between DII scores and the examined biochemical, dietary, or other variables (Table 3).

4. Discussion

This study examined the relationship between DII scores and adherence to the Mediterranean diet, and macro- and micro-nutrient intake in patients diagnosed with atherosclerosis. According to the research findings, patients with atherosclerosis tended to consume foods with higher inflammatory potential. Specifically, those with higher DII scores showed lower intake of vitamins and minerals that suppress inflammation and exhibit antioxidant properties, consistent with lower adherence to the Mediterranean diet. This may reflect a dietary pattern characterized by lower consumption of plant-based foods and foods rich in antioxidant compounds. These dietary components are known to play a regulatory role in inflammatory processes and oxidative stress, which are key mechanisms involved in the development and progression of atheroscle-

Table 1. Comparison of selected characteristics of participants across tertiles of the DII.

Variables	DII tertiles			*p*	*Test value*
	T1 (*n* = 34)	T2 (*n* = 32)	T3 (*n* = 34)		
DII score	4.6 (2.7–5.2)	7.1 (6.7–7.5)	9.4 (8.4–9.9)	<0.001	183.851†
Age (Years)	54.29 ± 7.30	54.78 ± 7.44	56.91 ± 8.81	0.353	1.053*
Weight (kg)	80.97 ± 15.11	83.91 ± 14.35	85.59 ± 14.71	0.429	0.854*
BMI (kg/m^2)	29.23 ± 5.30	29.39 ± 4.58	29.56 ± 4.53	0.961	0.040*
BMI classification					
Normal (18.5–24.9 kg/m^2)	8 (23.5)	5 (15.6)	4 (11.8)	2.201	0.699***
Overweight (25.0–29.9 kg/m^2)	13 (38.2)	12 (37.5)	16 (47.1)		
Obese (≥30 kg/m^2)	13 (38.2)	15 (46.9)	14 (41.2)		
Working status					
Working	18 (52.9)	16 (50.0)	12 (35.3)	0.296	2.434***
Non-working	16 (47.1)	16 (50.0)	22 (64.7)		
Education level					
High school and before	26 (76.5)	29 (90.6)	32 (94.1)	0.111**	-
College graduate and above	8 (23.5)	3 (9.4)	2 (5.9)		
Marital status					
Single	2 (5.9)	4 (12.5)	2 (5.9)	0.587**	-
Married	32 (94.1)	28 (87.5)	32 (94.1)		
Gender					
Male	21 (61.8)	22 (68.8)	22 (64.7)	0.837	0.356***
Female	13 (38.2)	10 (31.3)	12 (35.3)		
Global Physical Activity Questionnaire (GPAQ), MET-min/week	3090.0 (1530.0–5250.0)	1740.0 (840.0–3950.0)	1810.0 (960.0–4950.0)	0.476	1.484†
GPAQ Classification					
Physically inactive	3 (8.8)	5 (15.6)	6 (17.6)		
Moderately active	14 (41.2)	14 (43.8)	13 (38.2)	0.833**	-
Highly active	17 (50.0)	13 (40.6)	15 (44.1)		
14-Item Mediterranean Diet Adherence Tool score (median (IQR))	7.0 (6.0–9.0)	7.0 (5.3–8.0)	7.0 (5.8–8.0)	0.534	1.255†
14-Item Mediterranean Diet Adherence Tool classification					
Low	12 (35.3)	15 (46.9)	13 (38.2)		
Medium	18 (52.9)	14 (43.8)	20 (58.8)	0.542**	-
High	4 (11.8)	3 (9.4)	1 (2.9)		
Atherogenic index of plasma (AIP)	0.2 (–0.4–0.5)	0.2 (–0.3–0.7)	0.3 (–0.3–0.8)	0.417	1.750†
AIP classification					
Low	4 (11.8)	2 (6.3)	2 (5.9)		
Medium	2 (5.9)	0 (0.0)	1 (2.9)	0.617**	-
High	28 (82.4)	30 (93.8)	31 (91.2)		

Mean ± standard deviation, median (1st–3rd quartile), and n (%). †: Kruskal-Wallis analysis. *One-way ANOVA. **Fisher-Freeman-Halton exact test. ***Pearson chi-square analysis.

Abbreviations: DII, dietary inflammatory index; GPAQ, Global Physical Activity Questionnaire; BMI, body mass index; IQR, interquartile range; ANOVA, analysis of variance.

rosis [19]. Although no statistically significant association was observed between the DII score and clinical biomarkers in the present study, the observed dietary pattern suggests that the inflammatory potential of the diet may still influence nutrient intake and overall dietary quality relevant to cardiovascular health.

Atherosclerotic plaques are structures formed as a result of lipid accumulation, inflammation, and fibrosis in the arterial walls, playing a crucial role in cardiovascular disease development [1]. The AIP is a quantitative measure used to assess lipid-related atherogenic risk in the development of cardiovascular disease [16]. A high AIP indicates an increased risk of CVD, such as myocardial infarction, stroke, and peripheral artery disease. A study conducted with the National Health and Nutrition Examination Survey (NHANES) (2005–2018) population showed that AIP

Table 2. Comparison of biochemical parameters and dietary intake across tertiles of DII.

Variables	DII tertiles			*p*	*Test value*
	T1 (*n* = 34)	T2 (*n* = 32)	T3 (*n* = 34)		
Na (mmol/L)	139.36 ± 2.09	139.76 ± 3.61	139.01 ± 4.44	0.694	0.367*
K (mmol/L)	4.33 ± 0.57	4.38 ± 0.62	4.48 ± 0.81	0.676	0.393*
Ca (mg/dL)	9.4 (9.3–9.7)	9.3 (9.0–9.6)	9.4 (9.1–9.6)	0.382	1.923†
Hb (g/dL)	15.16 ± 2.27[a]	14.02 ± 1.49[b]	13.88 ± 1.90[b]	0.014	4.480*
FBG (mg/dL)	101.85 ± 17.62	110.28 ± 21.51	110.0 ± 21.34	0.157	1.886*
TC (mg/dL)	185.81 ± 38.58	166.70 ± 35.99	181.36 ± 52.14	0.175	1.772*
HDL-C (mg/dL)	38.0 (32.9–49.6)	38.5 (32.0–43.0)	36.4 (32.6–41.3)	0.491	1.423†
LDL-C (mg/dL)	110.6 (93.0–138.3)	105.8 (60.6–118.8)	101.0 (73.5–135.0)	0.246	2.806†
TG (mg/dL)	143.0 (88.5–205.0)	134.5 (98.3–196.0)	166.5 (109.5–243.5)	0.481	1.464†
CRP (mg/L)	2.5 (1.3–4.7)	3.0 (1.7–4.5)	3.0 (1.8–4.7)	0.883	0.249†
Energy (kcal)	1400.5 (1229.5–1670.0)[a]	1230.5 (1046.3–1601.3)[a]	902.5 (733.0–1371.8)[b]	<0.001	21.798†
Total fat (g)	57.9 (47.2–66.2)[a]	55.8 (43.4–74.3)[a]	38.3 (31.1–51.2)[b]	<0.001	13.854†
Carbohydrate (g)	176.7 (139.8–202.4)[a]	132.4 (90.8–202.1)[b]	102.1 (79.3–164.0)[b]	<0.001	20.077†
Protein (g)	58.5 (44.7–69.7)[a]	52.6 (40.0–65.2)[a]	36.4 (26.7–52.3)[b]	<0.001	18.183†
Cholesterol (mg)	201.5 (124.5–417.8)	241.5 (161.3–359.8)	200.0 (116.5–317.5)	0.408	1.795†
Saturated fat (g)	27.7 (20.8–30.7)[ab]	28.1 (22.5–35.4)[a]	21.1 (14.6–27.0)[b]	0.020	7.804†
MUFA (g)	18.1 (13.9–21.5)[a]	16.9 (13.1–23.4)[a]	11.3 (8.7–16.8)[b]	<0.001	14.919†
PUFA (g)	8.6 (6.4–9.7)[a]	6.0 (4.4–8.4)[b]	3.3 (2.6–5.5)[c]	<0.001	38.146†
Fiber (g)	13.5 (11.3–17.2)[a]	10.4 (7.9–12.8)[b]	6.3 (3.8–7.8)[c]	<0.001	58.556†
Vitamin A (mcg RAE)	788.5 (485.3–1158.5)[a]	492.5 (363.8–595.3)[b]	370.5 (298.0–463.3)[c]	<0.001	28.543†
Beta carotene (mcg)	992.0 (511.0–3001.8)[a]	536.0 (249.8–827.8)[a]	305.0 (158.0–408.0)[b]	<0.001	23.153†
Vitamin D (mcg)	1.0 (0.7–2.0)	1.0 (0.7–2.0)	0.9 (0.6–1.7)	0.281	2.540†
Vitamin E (mg α-TE)	6.8 (4.9–9.5)[a]	4.7 (3.0–6.9)[b]	2.6 (2.0–3.6)[c]	<0.001	38.487†
Vitamin C (mg)	70.1 (46.5–135.2)[a]	39.7 (27.2–62.1)[b]	15.5 (4.0–30.8)[c]	<0.001	44.060†
Thiamine (mg)	0.7 (0.6–0.8)[a]	0.5 (0.4–0.7)[a]	0.4 (0.3–0.5)[b]	<0.001	36.902†
Riboflavin (mg)	1.3 (1.1–1.6)[a]	1.2 (1.0–1.5)[a]	0.9 (0.7–1.2)[b]	<0.001	19.383†
Niacin (mg)	20.4 (15.0–26.0)[a]	17.9 (11.6–26.6)[a]	11.2 (6.8–18.3)[b]	<0.001	14.943†
Vitamin B6 (mg)	1.1 (0.8–1.3)[a]	0.7 (0.6–0.9)[b]	0.4 (0.3–0.7)[c]	<0.001	35.990†
Folic acid (mcg)	259.5 (197.3–283.3)[a]	190.0 (160.5–244.0)[a]	120.0 (89.0–145.0)[b]	<0.001	48.977†
Vitamin B12 (mcg)	3.0 (2.4–4.2)[a]	2.9 (2.0–3.6)ab	2.1 (1.6–3.0)[b]	0.030	6.922†
Magnesium (mg)	225.0 (179.5–241.0)[a]	165.5 (134.5–193.0)[b]	108.0 (87.0–145.0)[c]	<0.001	40.691†
Iron (mg)	6.8 (5.2–7.9)[a]	5.6 (4.4–6.5)[a]	3.3 (2.6–4.6)[b]	<0.001	38.391†
Zinc (mg)	7.1 (6.0–8.9)[a]	6.9 (5.0–8.0)[a]	4.4 (3.5–7.2)[b]	<0.001	16.040†
Selenium (mcg)	57.1 (14.8–94.6)	59.5 (19.8–93.6)	32.1 (2.6–78.6)	0.327	2.234†
Garlic (g)	0.0 (0.0–3.0)[a]	0.0 (0.0–0.0)[ab]	0.0 (0.0–0.0)[b]	0.004	11.107†
Onion (g)	30.0 (18.8–41.3)[a]	15.0 (10.0–25.0)[b]	10.0 (0.0–15.0)[c]	<0.001	30.058†
Pepper (g)	23.5 (14.0–32.0)[a]	13.0 (11.0–22.5)[b]	6.5 (0.0–14.0)[c]	<0.001	30.394†
Tea (g)	4.2 (1.8–5.5)	3.5 (1.1–5.0)	4.0 (2.2–4.8)	0.463	1.539†

Mean ± standard deviation, and median (1st–3rd quartile). †: Kruskal-Wallis analysis, *One-way ANOVA.

The same superscript letter in the same row indicates no statistically significant difference between groups, while different letters indicate significant differences between groups ($p < 0.05$).

Abbreviations: FBG, fasting blood glucose; Na, sodium; K, potassium; Ca, calcium; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; Hb, Hemoglobin; CRP, C-reactive protein; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

can be an effective tool for predicting the risk of cardiovascular disease-related mortality, especially in individuals between the ages of 40 and 60 [20]. Results from the National Diabetes Survey of Pakistan (2016–2017) indicated that AIP had a high correlation with lipid parameters and atherosclerosis indices and can be a good predictor of CVD [21]. Therefore, AIP was assessed as a useful tool for individualised risk management in primary and secondary prevention strategies [21,22]. Although a positive trend was observed between AIP and DII scores in our study, this association did not reach statistical significance (Table 3). Several factors may explain this finding. First,

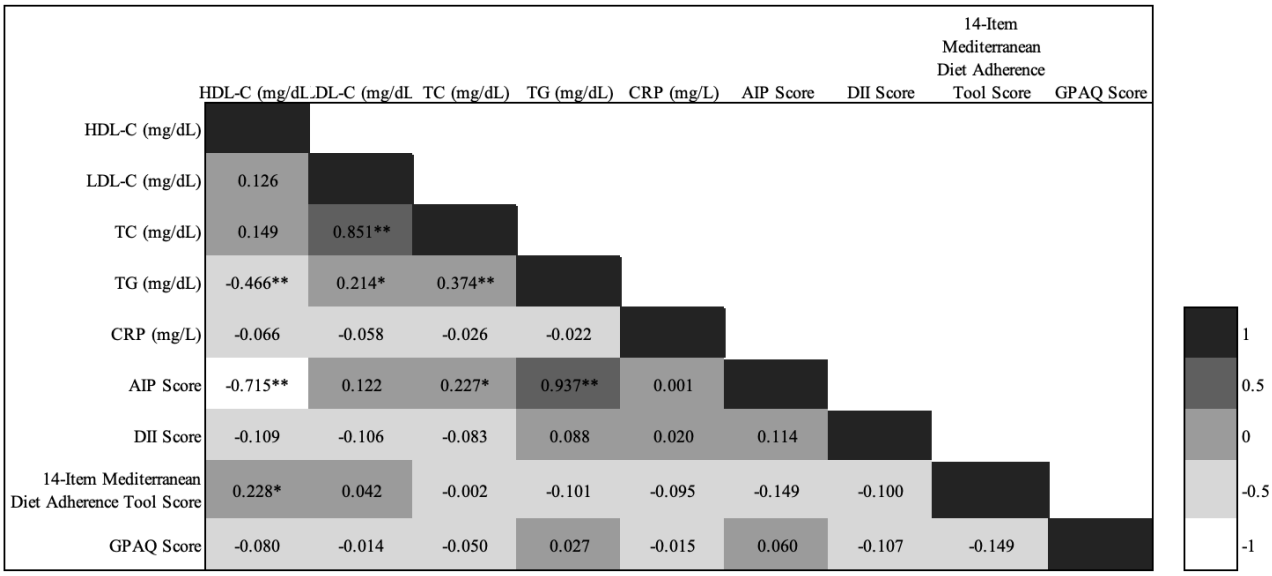

Fig. 1. Correlation matrix illustrating the relationships between HDL-C, LDL-C, TC, TG, CRP, AIP score, DII score, 14-Item Mediterranean Diet Adherence Tool score and GPAQ score among adults with atherosclerotic heart disease. Correlation coefficients are presented using Spearman correlation analysis r; $p < 0.05$ (*) and $p < 0.001$ (**). Darker shades represent stronger positive correlations, while lighter shades indicate negative associations. Abbreviations: HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; CRP, C-reactive protein; AIP, atherogenic index of plasma; DII, dietary inflammatory index; GPAQ, Global Physical Activity Questionnaire.

Table 3. Crude and adjusted multiple linear regression models evaluating the association between the DII score and study variables.

Parameters		DII score				
		95% confidence interval				
		Coefficient (β)	Lower	Upper	R^2	*p*
HDL-C	Crude model	–0.486	–1.327	0.356	0.013	0.255
	Adjusted model*	–0.461	–1.335	0.413	0.034	0.298
LDL-C	Crude model	–1.730	–4.598	1.138	0.014	0.234
	Adjusted model*	–1.690	–4.602	1.222	0.077	0.252
TC	Crude model	–1.033	–4.326	2.259	0.004	0.535
	Adjusted model*	–0.839	–4.232	2.554	0.039	0.625
TG	Crude model	3.731	–2.893	10.355	0.013	0.266
	Adjusted model*	4.422	–2.250	11.093	0.090	0.191
CRP	Crude model	0.114	–0.222	0.451	0.005	0.502
	Adjusted model*	0.108	–0.241	0.456	0.031	0.540
AIP	Crude model	0.015	–0.007	0.037	0.018	0.186
	Adjusted model*	0.017	–0.006	0.039	0.066	0.150
14-Item Mediterranean Diet Adherence Tool score	Crude model	–0.066	–0.197	0.065	0.010	0.322
	Adjusted model*	–0.072	–0.198	0.055	0.168	0.262
GPAQ score	Crude model	–69.824	–282.396	142.749	0.004	0.516
	Adjusted model*	–46.963	–258.790	164.863	0.101	0.661

The $p < 0.05$ was considered significant. Multiple linear regression analysis. *Adjusted model: Adjustment for age, gender, education level, marital status, employment status and BMI. Abbreviations: DII, dietary inflammatory index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG,triglyceride; CRP, C-reactive protein; AIP, atherogenic index of plasma.

atherosclerosis is a multifactorial condition that develops through the interaction of genetic predisposition, metabolic status, medication use, and lifestyle factors, rather than being solely determined by the inflammatory potential of the diet [2,4]. Therefore, the DII score, which reflects the inflammatory load of the diet, may not necessarily show a strong direct association with AIP, a lipid-based index. In addition, while AIP primarily reflects lipid metabolism, the DII evaluates the inflammatory properties of the overall diet; thus, these two indicators represent different biological processes, which may partly account for the weak association observed. Furthermore, the relatively limited sample size of the present study may have reduced the statistical power to detect a significant relationship. Indeed, studies conducted with larger populations have reported clearer associations between AIP and cardiometabolic risk indicators [20,21]. Therefore, future studies with larger sample sizes and prospective designs are warranted to better clarify the relationship between the inflammatory potential of the diet and atherogenic lipid profiles.

The DII was developed based on a strong evidence base that includes data from different human populations and data from animal and cell culture experiments. A report based on NHANES-III data showed that a pro-inflammatory diet is also associated with an increased mortality risk from cardiovascular disease [23]. Until the DII was developed, the Healthy Eating Index-2010 (HEI-2010), Alternative Healthy Eating Index (AHEI), and Dietary Approaches to Stop Hypertension (DASH) were used. Further, all dietary indices based on a specific culinary culture or dietary pattern, such as the Mediterranean Diet Index, were examined in relation to CVD incidence and mortality. A meta-analysis conducted in 2015 examined the results of 15 prospective studies and showed that healthy diets with high HEI, AHEI, and DASH scores significantly reduced the risk of CVD incidence or mortality. However, each of these indices contains methodological differences and limitations, such as limited exposure diversity, and none of them assesses the diet's inflammatory potential [21]. In a cross-sectional study of US adults, a non-linear relationship was observed between DII and atherosclerotic cardiovascular disease (ASCVD), with a sudden increase in ASCVD risk when DII scores exceeded 3. Additionally, the association between DII and ASCVD was found to have a stronger effect in women than in men [9]. Although no significant relationship was found between DII score and AIP (Fig. 1), patients generally had high DII scores (range: −0.5 to 12.2), indicating a pro-inflammatory dietary pattern, and most were classified as high-risk according to AIP. This may also be related to methodological aspects of dietary assessment, as the 24-hour dietary recall method used to calculate DII relies on participants' memory and may introduce recall bias, potentially affecting the accurate estimation of dietary inflammatory potential.

However, no significant relationship was detected between patients' DII and Mediterranean Diet Adherence scores and classic cardiometabolic risk markers such as LDL cholesterol and the inflammation marker CRP levels (Fig. 1). This supported the clinical importance of evaluating atherosclerosis through biochemical parameters and direct vascular imaging methods [24,25]. Additionally, when individuals were grouped into tertiles based on the DII, the absence of statistically significant differences in blood parameters such as LDL and CRP between tertiles (Table 2) suggested that the relationship between dietary inflammatory potential and subclinical inflammation may not always be reflected in biomarker levels and that diets with high inflammatory potential may increase systemic inflammation over time. However, this effect may be slow to reflect in acute phase reactants such as CRP [26]. Next, the absence of a significant relationship among DII and HDL-C, LDL-C, TG, TC, and AIP in the model adjusted for demographic variables and BMI further supported these findings (Table 3). Furthermore, the lack of detailed information on medication use among participants should also be considered as a limitation. Certain medications commonly used in the management of cardiovascular diseases may influence lipid profiles and inflammatory markers, which could potentially confound the relationship between the inflammatory potential of the diet and cardiometabolic indicators. Therefore, future studies with larger sample sizes and prospective designs are warranted to better elucidate the relationship between dietary inflammatory potential and cardiovascular risk markers.

Obesity is a significant metabolic disorder that triggers systemic inflammation, particularly with an increase in abdominal fat, and that plays a crucial role in atherosclerosis development. It has been reported that diets with high DII scores, which have high inflammatory potential, are associated with increased levels of inflammatory markers such as CRP, interleukin-6 (IL-6), and tumour necrosis factor-alpha (TNF-α), and that exacerbates metabolic disorders related to obesity [27]. In the literature, individuals with normal BMI but pro-inflammatory dietary habits are defined as metabolically high-risk individuals because of visceral fat accumulation and low physical activity levels [28,29]. In our study, 42% of the participants were classified as obese, which represents a notable prevalence of obesity within the study population. In addition, the relatively high DII scores observed in the study group indicate that a considerable proportion of patients followed a pro-inflammatory dietary pattern. The coexistence of a high prevalence of obesity and a pro-inflammatory diet may be particularly important, as these factors may synergistically contribute to increased systemic inflammation and the progression of atherosclerotic processes. Furthermore, the high DII scores observed in our patients suggest that, even in individuals with normal BMI values, diets with a high inflammatory potential may still be associated with increased systemic inflamma-

tion and potentially accelerated atherosclerotic processes [5]. This finding may partly be explained by the limitations of BMI as an indicator of body composition, since BMI does not account for parameters such as fat mass distribution or muscle mass. Therefore, evaluating cardiometabolic risk solely on the basis of BMI may be insufficient, and assessment of dietary inflammatory load together with additional anthropometric and metabolic indicators may provide a more comprehensive understanding of atherosclerosis risk.

The Mediterranean diet is commonly recognised for its anti-inflammatory effects because of its high content of olive oil, vegetables, fruit, whole grains, legumes and fish. In the Coronary Diet Intervention With Olive Oil and Cardiovascular Prevention (CORDIOPREV) study, a long-term secondary prevention study involving Mediterranean or low-fat diet interventions, it was reported that the Mediterranean diet is effective in delaying the progression of atherosclerosis [19]. In the current study, there was no significant relationship between the DII score and the Mediterranean Diet Adherence score. The low rate of individuals with high adherence to the Mediterranean diet in our study may explain why this relationship could not be statistically significant. Although no significant relationship between the Mediterranean Diet Adherence score and biochemical parameters was found, the overall low level of adherence indicates the need for more effective interventions. Further, high DII scores were found to be associated with low vitamin and mineral intake (Table 2) and with insufficient consumption of anti-inflammatory foods, such as fruits, vegetables, and whole grains, which paralleled the low Mediterranean Diet Adherence score. These food groups contain biologically active compounds such as polyphenols, carotenoids, fiber, and antioxidant vitamins, which play an important role in the regulation of the inflammatory response. Therefore, low consumption of these foods may increase the inflammatory potential of the diet and contribute to higher DII scores.

Garlic inhibits the nuclear factor kappa-B (NF-κB) signalling pathway of inflammatory cytokines and may reduce Reactive oxygen species (ROS) release. Similarly, onion inhibits NF-κB, the release of cytokines such as IL-1α, IL-4 and TNF-α, and pepper inhibits pro-inflammatory markers such as interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF-α), prostaglandin E2 (PGE2), and nitric oxide (NO). Peppers, rich in carotenoids, also help reduce oxidative stress [30]. In our study, the group with higher DII scores consumed smaller amounts of anti-inflammatory components such as onions, peppers, and garlic (Table 2). This finding is consistent with studies demonstrating the regulatory role of plant-based foods in dietary inflammation [31,32]. These mechanisms suggest that specific dietary components and overall diet quality may play a crucial role in regulating inflammatory processes.

The T1 group appears to be mostly active in terms of physical activity. This level of physical activity, which seems higher than expected for our study group, can be explained by the rural lifestyle and socio-geographic characteristics of our participants. Individuals in this region engage in intensive occupational physical activity such as agricultural activities as part of their daily routines and predominantly prefer walking for transportation. A follow-up study by Mahe et al. [33] (2025) examined the differential effects of occupational and leisure-time activities on mortality rates. The study revealed that only non-occupational activity or a combination of both activities was associated with lower cardiovascular mortality [33]. Another study examining the effect of physical activity habits on AIP compared individuals who exercise only on weekends with those who exercise regularly throughout the week [34]. The study showed that individuals who exercise regularly were more successful in improving their AIP levels [34]. In our study, despite this high level of activity, the median AIP score of 0.2 indicates that patients are close to the high-risk threshold (Table 1). This situation suggests that despite the protective effect of physical activity, the influence of other risk factors such as genetic predisposition or dietary habits may persist; however, the relationship between CVD and physical activity paradox, which is a controversial topic in the literature, may also be taken into consideration [35,36]. However, as noted, the use of AIP alone, a lipid-based indicator, to assess cardiovascular risk represents a limitation of our study; the inclusion of other cardiovascular risk assessment methods, such as advanced imaging techniques, could have contributed to a more comprehensive evaluation of atherogenic risk.

The association between DII and cardiovascular disease risk has been widely investigated in the literature. However, most of these studies have been conducted in the general population, in individuals with various chronic diseases, or in populations with cardiometabolic risk factors. In contrast, studies specifically evaluating the inflammatory potential of diet in patients with established atherosclerotic heart disease remain limited. In particular, investigations assessing the relationship between DII, biochemical parameters, and the atherogenic index of plasma (AIP) directly in patients with atherosclerotic heart disease are scarce. Furthermore, to the best of our knowledge, no study conducted in Turkey has examined the relationship between DII, biochemical parameters, and AIP in individuals with atherosclerotic heart disease. Therefore, the present study provides additional evidence by evaluating the inflammatory potential of diet and its relationship with cardiometabolic indicators in patients with atherosclerotic heart disease.

This study has several limitations. First, the relatively small sample size may limit the generalizability of the findings. Additionally, since the study population consisted of adults residing in Turkey, the results may not be generaliz-

able to populations with different cultural or geographical backgrounds. The use of a single retrospective 24-hour dietary recall may be subject to recall bias and may not accurately reflect habitual dietary intake, potentially leading to misclassification of the DII. Moreover, calculating the DII score only once may not capture possible changes in dietary habits over time. Another limitation relates to the evaluation of pharmacological treatments. Because participants were receiving largely similar treatments within standard clinical management protocols, medication use was not considered a confounding factor in the analyses. However, more detailed information on the type, dosage, and duration of medications could have allowed a more comprehensive assessment of their potential effects on the studied parameters. In addition, we recognize that excluding individuals with diabetes may limit the generalizability of our findings. Given the high prevalence of diabetes among patients with atherosclerotic heart disease, future studies including diabetic populations are warranted to better reflect real-world clinical settings.

5. Conclusion

This study showed that diets with high inflammatory properties may be associated with atherosclerosis. It also highlighted the importance of following plant-based, antioxidant-rich, Mediterranean-style diets that reduce the diet's inflammatory load. Therefore, people at risk of atherosclerosis should be offered dietary counselling aimed at reducing the inflammatory load, and individualised dietary plans should be created that promote plant-based, antioxidant-rich, and Mediterranean-style diets. Public health programmes should be developed to encourage anti-inflammatory diets at the community level.

Key Points

A total of 100 patients with atherosclerotic heart disease were included in this study and were divided into three groups according to their dietary inflammatory index (DII) scores.

• No significant association was observed between the dietary inflammatory index (DII) score and lipid parameters, CRP, AIP, Mediterranean Diet Adherence, or physical activity levels in patients with atherosclerotic heart disease.

• Higher DII scores were associated with lower intake of antioxidant vitamins, minerals, and plant-based foods with anti-inflammatory properties.

• Diets with higher inflammatory potential may contribute to the development of atherosclerosis, but further prospective studies are needed to confirm this relationship.

Availability of Data and Materials

All data included in this study are available from the corresponding author upon reasonable request.

Author Contributions

Conceptualization: HNY, AO, and AGÇ; Methodology: HNY and AGÇ; Data curation: HNY; Formal analysis: AGÇ; Investigation: HNY and AO; Writing—original draft: HNY and AGÇ; Writing—review and editing: AO and AGÇ; Supervision: AO and AGÇ. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional or national research committee and with the Declaration of Helsinki. The study was reviewed and approved by the Nuh Naci Yazgan University Scientific Research and Publication Ethics Committee (approval number: 2023/010-006). In addition, institutional permission to conduct the study in the hospital setting was obtained from the Academic Committee of the Department of Cardiology, Erciyes University Faculty of Medicine (permission number: E-44008645-010.99-612400). Written informed consent was obtained from all participants.

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Conflicts of Interest

The authors declare no conflicts of interest.

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