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Mediterranean Diet Adherence and Non-Alcoholic Fatty Liver Disease Risk in Turkish Adults: a case-control study

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Abbreviations:

NAFLD: Non-alcoholic fatty liver disease; MASLD: Metabolic dysfunction-associated steatotic liver disease; MetS: Metabolic syndrome; IR: Insulin resistance; T2DM: Type 2 diabetes mellitus; BMI: Body mass index; IPAQ: International Physical Activity Questionnaire; MET: Metabolic equivalent of task; MEDAS: Mediterranean Diet Adherence Screener; MUFAs: Monounsaturated fatty acids; LDL: Low-density lipoprotein

Abstract

The Mediterranean diet has emerged as a promising dietary pattern for preventing non-alcoholic fatty liver disease (NAFLD). This study aimed to examine the role of the Mediterranean diet on the risk of NAFLD in Turkish adults. A total of 252 individuals (126 NAFLD and 126 age- and sex-matched controls) participated in this case-control study. Dietary intake was assessed with a 24-h recall, and adherence to the Mediterranean diet was evaluated using the Mediterranean Diet Adherence Screener (MEDAS). Logistic regression models were applied to estimate odds ratios (ORs). The prevalence of NAFLD was higher in the lowest tertile (64.6%) and lower in the highest tertile (30.5%; $p<0.001$). Moderate adherence to the Mediterranean diet was associated with a 57.0% lower risk of NAFLD after adjusting for age, sex, BMI, and energy intake. High adherence conferred an 86.0% reduction after adjusting for age, sex, BMI, energy intake, and comorbidities. Frequent consumption of butter, margarine, cream, (OR=2.75; 95% CI: 1.72–6.43) and sugar-sweetened beverages (OR=2.87; 95% CI: 1.20–6.87) significantly increased the risk. However, consuming nuts three or more servings per week was protective (OR=0.46; 95% CI: 0.21–0.99). In individuals who did not consume ≥3 servings of fruit daily, the risk of NAFLD was significantly reduced (OR=0.28; 95% CI: 0.16–0.69). Adherence to the Mediterranean diet was strongly associated with a reduced risk of NAFLD, highlighting the importance of limiting saturated fats and sugar-sweetened beverages while promoting nuts as practical strategies for prevention.

Keywords: Mediterranean diet; non-alcoholic fatty liver disease; dietary pattern; nutrition

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Introduction

Non-alcoholic fatty liver disease (NAFLD) is a multisystem disease that presents as the hepatic manifestation of metabolic syndrome (MetS) [1]. There has been a growing consensus to replace the term NAFLD with Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD) in recent years. This name change has been proposed to more accurately reflect the disease's strong association with metabolic disorder and to reduce the stigma associated with the term 'fatty'. However, descriptions of NAFLD and MASLD differ, as NAFLD specifically excludes excessive alcohol consumption and other hepatic disorders [2]. In the most recent systematic review and meta-analysis, the global prevalence of NAFLD increased from 25.3% in 1990–2006 to 38.0% in 2016–2019, reflecting an increase of approximately 50% [3]. In a multicenter study examining data from 113,239 individuals in Türkiye between 2007 and 2016, the overall prevalence of NAFLD was determined to be 48.3%, with a 22% increase reported during this period. This increase is consistent with the prevalence of obesity [4]. As a result, liver disease has become the second leading cause of mortality among individuals aged 35 to 49 [5]. The ongoing rise in the prevalence of diabetes and obesity has become a major driver of the increasing global burden of liver diseases [6].

The liver is particularly susceptible to damage from factors such as excessive exposure to toxins and unhealthy dietary habits due to its central role in metabolism and detoxification [7]. Physical activity and healthy habits are among the key lifestyle factors associated with NAFLD [8,9]. Accordingly, lifestyle modification represents the cornerstone of both primary prevention and treatment in NAFLD. Effective management strategies focus on weight reduction and the control of key comorbidities, including insulin resistance (IR), dyslipidemia, and type 2 diabetes mellitus (T2DM). These interventions are essential to slow disease progression, improve metabolic parameters, and reduce associated morbidity and mortality [10].

Dietary management of NAFLD typically involves adherence to diets low in processed foods, such as the Mediterranean diet, combined with energy restriction [11]. While the Mediterranean diet is influenced by environmental factors, cultural practices, and various socio-economic determinants, it is primarily characterized by a dietary pattern rich in fresh fruits and vegetables, extra virgin olive oil, whole grains, and nuts. It includes moderate consumption of wine (typically red, during meals), fish, poultry, and legumes, and is limited in red and processed meats as well as foods high in added sugars [12]. A randomized

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controlled trial reported that a six-month Mediterranean diet intervention could improve anthropometric parameters and lipid profile and contribute to the reduction of hepatic fat accumulation and liver stiffness [13]. An observational study reported that adherence to the Mediterranean diet was associated with reduced insulin resistance and hepatic fat content in patients with NAFLD [14]. In another study, higher adherence to the Mediterranean diet was significantly associated with a lower prevalence of ultrasound-diagnosed hepatic steatosis [15]. The findings collectively underscore the possible preventive effect of the Mediterranean diet against the development of NAFLD; nevertheless, additional research is necessary to investigate this association across other populations. This study aims to assess the role of the Mediterranean diet and its components in reducing the risk of developing NAFLD in Turkish adults.

Materials and Methods

Study design and participants

This case-control study was conducted with 252 adults (63.9% women; mean age 50.4±11.52 years) at the Gastroenterology Outpatient Clinic, Faculty of Medicine, Ondokuz Mayıs University, Samsun/Türkiye. A post-hoc power analysis was conducted using G*Power software. Based on a total sample of 252 participants distributed across tertiles (T1:99, T2:94, T3:59) and a medium effect size (w=0.27), the estimated power was 0.98 at an alpha level of 0.05, suggesting that the sample size was adequate for detecting group differences.

The study consisted of two groups: the first group consisted of those diagnosed with NAFLD (n=126) by a physician based on liver enzyme tests and/or abdominal ultrasonography, and the second group consisted of age- and sex- matched controls (n=126). The inclusion criteria required that participants be diagnosed with NAFLD by a physician and not following any diet. Exclusion criteria were alcohol consumption (≥30 g/day for men and ≥20 g/day for women), presence of HBsAg or anti-HCV antibodies, pregnancy and breastfeeding, hereditary hemochromatosis, history of jejunoileal bypass surgery or gastroplasty, taking hepatotoxic drugs such as calcium channel blockers and high doses of synthetic estrogen, having a history of hypothyroidism, Cushing's syndrome, renal failure, and kidney stones. The control group was matched with those who applied to the Gastroenterology Outpatient Clinic, who were not diagnosed with NAFLD and met the same

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exclusion criteria. Controls were matched to NAFLD cases by age (±5 years) and sex using a frequency matching approach.

Ethical permission was obtained from the Ondokuz Mayıs University Clinical Research Ethics Committee (date: 14.02.2023 and decision number: 2022/581). Written information was provided, and consent was obtained for their volunteer participation. The study was conducted in accordance with the Declaration of Helsinki and, reported in accordance with the STROBE guidelines for observational studies.

Data acquisition and tools

Data were collected using a questionnaire. Descriptive and health data were taken, including sex, age, education level, income, marital status, smoking status, and comorbidities. Physical activity level, Mediterranean diet adherence, and food consumption were assessed for each participant.

Anthropometric measurements

Body weight (kg) and height (cm) were measured using standard measurement protocols. Height was measured with a stadiometer while the participants were in a Frankfort plane. The body weight was obtained using a bioelectrical impedance analyzer (BC 730, Tanita, Tokyo, Japan). Body mass index (BMI) was calculated by dividing body weight (kg) with height (m) squared.

Physical activity levels

Physical activity levels were assessed using the 7-item short form of the International Physical Activity Questionnaire (IPAQ) developed by Craig et al. [16] and validated by Sağlam et al. [17]. A MET value of 3.3 was used for walking, 4.0 for moderate activity, and 8.0 for vigorous activity. Scores are obtained as MET-min/week using MET values of each activity, activity duration (min), and number of days of activity (per week). The physical activity levels of the individuals were grouped as low (<600 MET-min/week), moderate (600-3000 MET-min/week), and high (>3000 MET-min/week).

Food consumption records

The food consumption of the participants was examined in face-to-face interviews using the 24-h dietary recall method by researchers. Portion sizes were collected using food

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photographs to improve recall accuracy. The dietary energy intakes were calculated using a nutrition information system [18]. This system has a database contains Turkish food compositions [18].

Mediterranean diet adherence

Mediterranean Diet Adherence Screener (MEDAS) was used to assess the participants' Mediterranean diet adherence. The tool was administered through face-to-face interviews conducted by trained researchers. The validation of the Turkish language version of the tool was performed by Özkan Pehlivanoğlu et al. [19] and Bekar and Göktaş [20]. The tool consists of 14 items and a two-point scoring system (0-1). The highest score is 14, and increasing scores reflect higher adherence to the Mediterranean diet.

Statistical analysis

Analyses were performed using SPSS version 21 statistical package program. Normality was checked with the Kolmogorov-Smirnov test. Quantitative data were given as mean ± standard deviation, and qualitative data as number (n) and frequency (%). Binary logistic regression models (crude and adjusted) were performed to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for NAFLD (+/-) according to tertiles of Mediterranean diet adherence (T1-T3), with the lowest tertile (T1) used as the reference category. ORs for Mediterranean diet components in relation to NAFLD were estimated using binary logistic regression model, compared participants responding “no” versus “yes” (reference) for each component. Adjusted models included age, sex, BMI, energy intake, physical activity level, and comorbidities as potential confounders. Visualization was performed using R software (R version 4.5.0 (2025-04-11), R Foundation for Statistical Computing, Vienna, Austria). The significance value was taken as $p<0.05$.

Results

Characteristics of participants according to the Mediterranean diet adherence are shown in Table 1. The mean age of the participants was 50.4±11.52 years, and age tended to increase as the level of adherence to the Mediterranean diet increased ($p=0.008$). The body mass index was significantly lower in the highest adherence group ($p=0.012$). The MEDAS score showed a significant difference between compliance groups ($p<0.001$). The prevalence of NAFLD was higher in the lowest tertile (64.6%) and lower in the highest tertile (30.5%; $p<0.001$). No significant difference was observed between the tertiles in terms of other

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variables (gender, education level, marital status, income, smoking and physical activity) ($p>0.05$).

Increased adherence to the Mediterranean diet was associated with a significant reduction in the risk of NAFLD (Table 2). With reference to individuals with low dietary adherence, the risk of NAFLD was reduced by 52% in the group with moderate adherence according to the crude model (OR=0.48; 95% CI: 0.27-0.86). This reduction reached 53% after adjusting for age, sex, and BMI (Model 1) (OR=0.47; 95% CI: 0.24-0.89), and when energy intake was included in the model (Model 2), the risk was 57% lower (OR=0.43; 95% CI: 0.20-0.95). The reduction in NAFLD risk was much more pronounced in individuals with a high level of adherence to the Mediterranean diet. In the crude model, the risk of the disease was 76% lower (OR=0.24; 95% CI: 0.12-0.48). In Model 1 and Model 2, this reduction was 72% (OR=0.28; 95% CI: 0.13-0.62) and 75% (OR=0.25; 95% CI: 0.10-0.65), respectively, while in Model 3, which controlled for all variables, the risk was reduced by 86% (OR=0.14; 95% CI: 0.04-0.50).

In Figure 1, some components of the Mediterranean diet were found to significantly affect the risk of NAFLD. In individuals who did not consume ≥3 servings of fruit daily, the risk of NAFLD was significantly reduced (OR=0.28; 95% CI: 0.16-0.69; $p<0.05$). Daily consumption of >1 serving of butter, margarine or cream (OR=2.75; 95% CI: 1.72-6.43) and >1 unit of sweet or carbonated drinks (OR=2.87; 95% CI: 1.20-6.87) increased the risk of NAFLD by 2.75 and 2.87 times, respectively. A significantly increased risk was also observed in individuals who did not consume ≥3 servings of nuts and peanuts weekly (OR=2.17; 95% CI: 1.01-4.65). No statistically significant association was found between other dietary components (olive oil consumption, vegetable consumption, fish consumption, etc.) and NAFLD.

Discussion

In the present study, greater adherence to the Mediterranean diet was associated with a reduced risk of NAFLD. This was reflected by the substantially lower prevalence observed in the high adherence group (30.5%) compared with the low adherence group (64.6%). Regression analyses further revealed that the risk of NAFLD was reduced by 57.0-86.0% lower in the moderate and high adherence groups after adjusting for potential confounding variables such as age, sex, BMI, and energy intake.

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Previous studies examining the relationship between adherence to the Mediterranean diet and NAFLD consistently support the protective effects of this dietary model. In a study conducted by Trovato et al., in 532 NAFLD patients and 667 control individuals, the Mediterranean diet adherence score was identified as a strong and independent predictor of the severity of fatty liver disease [21]. Similarly, a cross-sectional study reported a significant and inverse relationship between the Mediterranean diet score and the risk of NAFLD in adjusted models [22]. Consistent with these findings, a recent meta-analysis also revealed that adherence to the Mediterranean diet reduced the risk of NAFLD by 23% [23]. The Mediterranean lifestyle is an effective non-pharmacological strategy for improving liver health and preventing liver-related complications in patients with MASLD [24]. Although some literature refers to MASLD terminology, the present findings are discussed within the NAFLD to maintain consistency with the study design and diagnostic criteria. Collectively, these findings suggest that the Mediterranean diet may be an effective nutritional strategy in the prevention and management of NAFLD.

The beneficial effects of the Mediterranean diet on NAFLD are likely explained by synergistic interactions among its characteristic food components. Saturated fatty acids have been shown to increase cellular dysfunction by activating endoplasmic reticulum stress pathways, negatively affect NAFLD-related metabolic pathways, and increase systemic and hepatic insulin resistance. Monounsaturated fatty acids (MUFAs) represent the main source of fatty acids in the Mediterranean diet. Olive oil is the main source of MUFAs in the Mediterranean diet, which may partially explain some of the findings [25]. Numerous studies have reported positive effects of olive oil on reducing cardiovascular risk, improving lipid metabolism (especially preventing the oxidation of LDL cholesterol, thereby reducing the atherogenicity of LDL), and balancing glycemic levels [26,27]. The Mediterranean diet may also lower plasma cholesterol levels, particularly through water-soluble fibers in beans, vegetables, fruits, and whole grains [25].

An unexpected observation was that participants consuming fewer than three servings of fruit on a daily basis had a lower likelihood of NAFLD. In line with our findings, a study demonstrated that consuming more than four servings of fruit per day worsened steatosis, dyslipidemia, and glycemic control in patients with NAFLD [28]. A case-control study found that a fruit-rich dietary pattern (more than 2–3 servings/day of fruits and >20 g/day of fructose) was associated with a fourfold increased likelihood of developing NAFLD. The mechanism behind this may be related to the intake of large amounts of sugars, such as

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fructose [29]. Decreased fatty acid oxidation in skeletal muscle results in free fatty acids being directed to the liver, which increases hepatic fat accumulation. Fructose can also increase liver fat through de novo lipogenesis. After absorption, glucose is primarily metabolized by peripheral tissues, while fructose is directly transported to the liver. Due to the lack of feedback control, fructose is metabolized more rapidly than glucose and enters the lipogenesis pathway [28]. However, prospective cohort study involving 52,280 Korean adults found that higher consumption of fruits, vegetables, and total fruit/vegetable intake is associated with a significantly reduced risk of NAFLD [30] (Kim & Shin, 2020). Furthermore, a meta-analysis of 11 observational studies (including 493,682 participants) concluded that increased consumption of vegetables and fruits is generally correlated with a lower likelihood of developing NAFLD [31] (Wang et al., 2024). Therefore, the present finding should be interpreted with caution. The result does not imply a protective effect of low fruit intake per se and may reflect reverse causation, whereby individuals with fatty liver modify their dietary habits. It has been reported that people with fatty liver are more likely to consume fruits and confectionery containing simple carbohydrates compared to people with diabetes [32].

In the present study, high intake of saturated fat-rich butter, margarine, and cream products, as well as sweetened and carbonated beverages, was positively associated with NAFLD, supporting evidence on the adverse metabolic effects of saturated fats and added sugars [33-36]. Furthermore, the observed increased risk among individuals consuming fewer than three servings of nuts per week highlights the protective role of nuts (attributed to their healthy fatty acid profile and antioxidant content), in maintaining liver health [37].

Strengths of this study include the use of the validated MEDAS tool and adjustment for key confounders. Nevertheless, the case-control design limits causal inference, and dietary intake relied on self-report, including a single 24-hour recall, which may not reflect habitual intake. As Mediterranean diet adherence was assessed using the MEDAS screening tool and energy intake was included only as a covariate, participants were not excluded based on potential under- or over-reporting of energy intake. Fatty liver disease was defined according to NAFLD criteria, as data were collected prior to the introduction of MAFLD/MASLD terminology. Given the differences in diagnostic frameworks, direct reclassification was not feasible and may limit comparability. Although an a priori sample size calculation was performed for the parent thesis (see acknowledgements), the current analysis relied on post-hoc power estimation, which should be interpreted cautiously. The inverse association observed for fruit consumption should be interpreted with caution and does not indicate that

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lower fruit intake is protective against NAFLD. Future prospective and intervention-based studies are recommended to further investigate the mechanistic effects of the Mediterranean diet on NAFLD.

In conclusion, the findings suggest that adherence to the Mediterranean diet is associated with reduced NAFLD risk. Limiting the intake of saturated fats and sugar-sweetened beverages while prioritizing nutrient-dense foods may represent a relevant dietary strategy.

Declarations

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Authors' contributions: RKF: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft, EA: Investigation, Formal analysis, Writing - original draft, YEÖ: Conceptualization, Methodology, Writing - review & editing, Supervision

Ethics approval and consent to participate: Ethics Committee Approval dated 14.02.2023 and numbered 2022/581 was obtained from Ondokuz Mayıs University Clinical Research Ethics Committee.

Consent for publication: The voluntary consent form was signed by the participants.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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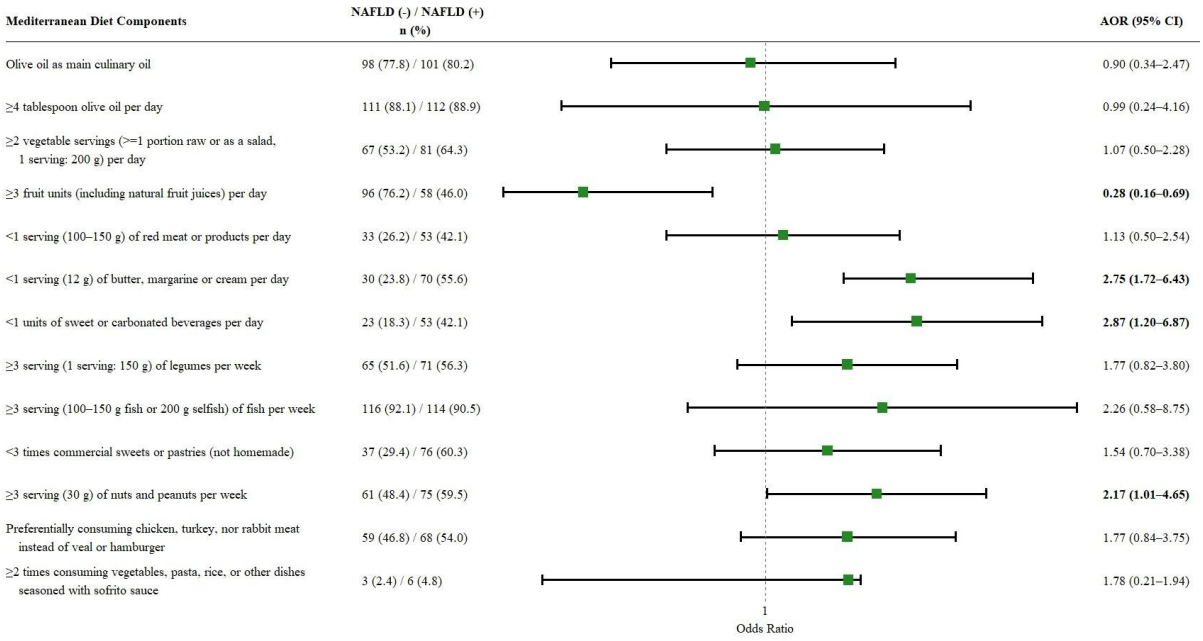


Figure 1. Odds ratios for Mediterranean diet components according to NAFLD. n(%) indicates the number and percentage of participants responding "no" for each component. Odds ratios represent the odds of NAFLD for "no" versus "yes" responses (reference). AOR: Adjusted for age, sex, BMI, energy intake, comorbidities (other). NAFLD: Non-Alcoholic Fatty Liver Disease. Statistically significant ($p<0.05$) data were shown in bold. None of the participants consume ≥7 glasses of wine per week

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Table 1. Characteristics of participants according to the Mediterranean diet adherence

Parameters	Total (n=252)	Adherence Tertiles			p
		T1 (n=99)	T2 (n=94)	T3 (n=59)	
Age (years)	50.4±11.52	48.4±11.16	50.2±12.06	54.2±10.44	**0.008**
Cases (n, %)					
NAFLD (+)	126 (50.0)	64 (64.6)	44 (46.8)	18 (30.5)	**<0.001**
NAFLD (-)	126 (50.0)	35 (35.4)	50 (53.2)	41 (69.5)	
Sex (n, %)					
Women	161 (63.9)	68 (68.7)	59 (62.8)	34 (57.6)	0.360
Men	91 (36.1)	31 (31.3)	35 (37.2)	25 (42.4)	
BMI (kg/m^2)	30.1±5.70	31.2±6.35	30.1±5.23	28.4±4.87	**0.012**
Education level (n, %)					
Middle school or below	136 (54.0)	55 (55.6)	46 (48.9)	35 (59.3)	
High school	50 (19.8)	20 (20.2)	23 (24.5)	7 (11.9)	0.404
University or above	66 (26.2)	24 (24.2)	25 (26.6)	17 (28.8)	
Marital status (n, %)					
Married	203 (80.6)	77 (77.8)	79 (84.0)	47 (79.7)	0.536
Single or divorced	49 (19.4)	22 (22.2)	15 (16.0)	12 (20.3)	
Income level (n, %)					
<10.000 TL	84 (33.3)	34 (34.3)	28 (29.8)	22 (37.3)	
10.000-20.000 TL	91 (36.1)	36 (36.4)	35 (37.2)	20 (33.9)	0.899
≥20.000 TL	77 (30.6)	29 (29.3)	31 (33.0)	17 (28.8)	
Smoking status (n, %)					
Yes	73 (29.0)	33 (33.3)	28 (29.8)	12 (20.3)	0.214
No	179 (71.0)	66 (66.7)	66 (70.2)	47 (79.7)	
Physical activity level (n, %)					
Low	176 (69.8)	72 (72.7)	62 (66.0)	42 (71.2)	
Moderate	53 (21.0)	17 (17.2)	23 (24.5)	13 (22.0)	0.722
High	23 (9.1)	10 (10.1)	9 (9.6)	4 (6.8)	
Energy intake (kcal)	1722.4± 1000.30	1895.9± 1243.42	1672.6± 805.33	1510.6± 759.51	**0.053**
Comorbidities (n, %)					
Diabetes	49 (29.9)	19 (29.2)	17 (28.3)	13 (33.3)	0.859
Other endocrine disorders	9 (5.5)	5 (7.7)	4 (6.7)	-	0.219
Hypertension	69 (42.1)	30 (46.2)	23 (38.3)	16 (41.0)	0.668
Cardiovascular diseases	12 (7.3)	3 (4.6)	7 (11.7)	2 (5.1)	0.266
Gastrointestinal diseases	71 (43.3)	24 (36.9)	27 (45.0)	20 (51.3)	0.340
Other*	25 (15.2)	8 (12.3)	15 (25.0)	2 (5.1)	**0.019**
MEDAS score	6.1±1.91	4.2±1.01	6.4±0.05	8.7±0.85	**<0.001**

NAFLD: Non-Alcoholic Fatty Liver Disease, BMI: Body mass index, TL: Turkish liras, MEDAS: Mediterranean diet adherence screener

Statistically significant ($p<0.05$) data was shown in bold

* Depression, anxiety, autoimmune diseases, cancer, neurological diseases

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Table 2. Binary logistic regression analysis of NAFLD risk according to Mediterranean diet adherence tertiles (n=252)

	Adherence Tertiles		
	T1 (n=99)	**T2 (n=94)**	**T3 (n=59)**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Crude	1.00 (Reference)	**0.48 (0.27-0.86)**	**0.24 (0.12-0.48)**
Model 1[a]	1.00 (Reference)	**0.47 (0.24-0.89)**	**0.28 (0.13-0.62)**
Model 2[b]	1.00 (Reference)	**0.43 (0.20-0.95)**	**0.25 (0.10-0.65)**
Model 3[c]	1.00 (Reference)	0.69 (0.25-1.89)	**0.14 (0.04-0.50)**

Statistically significant ($p<0.05$) data was shown in bold

[a]adjusted for age, sex, BMI

[b]adjusted for age, sex, BMI, energy intake

[c]adjusted for age, sex, BMI, energy intake, comorbidities (other)

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