

ORIGINAL RESEARCH ARTICLE

Association between adherence to the Mediterranean diet and sarcopenia among US adults: A cross-sectional study

Dichun Lv^{1,2†}, Jialan Chen^{1†}, Yuanyuan Wang³, Gaochenzi Tao⁴, Zikun Xie¹, Chengkai Wu^{5,6}, Tao Li¹, Jia Li¹, Donghong Guo^{1*}, and Jian Wang^{1*}

¹Division of Orthopaedic Surgery, Department of Orthopedics, Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong, China

²The Second School of Clinical Medicine, Southern Medical University, Guangzhou, Guangdong, China

³Department of Health Management, Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong, China

⁴Department of Gynecology, Guangzhou Haizhu District Changgang Street Community Service Center, Guangzhou, Guangdong, China

⁵School of Public Health, Southern Medical University, Guangzhou, China

⁶School of Health Management, Southern Medical University, Guangzhou, China

[†]These authors contributed equally to this work.

*Corresponding authors:

Donghong Guo
(511021271@qq.com)
Jian Wang
(digitalphoto@163.com)

Citation: Lv D, Chen J, Wang Y, et al. Association between adherence to the Mediterranean diet and sarcopenia among US adults: A cross-sectional study. *Orthop Tissue Eng.* 2026;1(2):025330010. doi: 10.36922/OTE025330010

Received: August 15, 2025

Revised: November 19, 2025

Accepted: November 20, 2025

Published online: December 12, 2025

Copyright: © 2025 Author(s). This is an Open-Access article distributed under the terms of the Creative Commons Attribution License, permitting distribution, and reproduction in any medium, provided the original work is properly cited.

Publisher's Note: AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract

Sarcopenia, a progressive loss of muscle mass and function associated with aging, has become an increasingly important public health concern worldwide. Research has demonstrated that the relationship between adherence to the Mediterranean diet and muscle mass is generally positive; however, findings regarding its association with sarcopenia have been inconsistent. To investigate whether adherence to the Mediterranean diet is associated with sarcopenia prevalence, we analyzed data from adults aged 20 years and older in the National Health and Nutrition Examination Survey from 2011 to 2018, with a sample size of 17,110 adults. Multivariable-adjusted logistic regression analysis was employed. The robustness of our results was assessed using several methods, including subgroup analysis, weighted quantile sum (WQS) regression, and sensitivity analysis. Results revealed that participants with higher adherence to the Mediterranean diet were less likely to have sarcopenia. In the adjusted model, the protective effect remained significant ($p=0.006$). Subgroup analysis indicated that this protective effect might be more pronounced among individuals aged 45 years and older, and independent of body mass index. We used WQS regression and logistic regression to assess individual components of the Mediterranean diet and found that fish and nuts had the highest weights and showed significant associations. Sensitivity analysis confirmed the robustness of the results. In conclusion, higher adherence to the Mediterranean diet is associated with a lower prevalence of sarcopenia. In the absence of effective pharmacological treatments, it may serve as a promising nutritional intervention for preventing and managing sarcopenia. Further validation through prospective studies is needed.

Keywords: Mediterranean diet; Sarcopenia; Cross-sectional research; National health and nutrition examination survey

1. Introduction

Known as a progressive musculoskeletal disorder, sarcopenia is marked by the accelerated decline in skeletal muscle mass, strength, and function.¹ This deterioration substantially contributes to impaired mobility and a higher risk of falls and fractures, ultimately diminishing the quality of life in aging populations. As an etiologically complex condition, sarcopenia is caused by multiple factors, including aging, disease, inactivity, and malnutrition.² Nutritional issues are widely prevalent globally.³ Nutrients, such as protein and vitamin D, have been proven to be effective in preventing sarcopenia.⁴ During the past decade, there has been a substantial increase in evidence regarding the positive relationship between healthier dietary patterns and musculoskeletal health.⁵ Nutritional intervention, therefore, emerges as a promising approach for both preventive strategies and therapeutic management of sarcopenia.⁴

The Mediterranean diet is a plant-based dietary pattern prevalent in Mediterranean regions, emphasizing a high intake of vegetables, cereals, nuts, fruits, legumes/beans, e/virgin olive oil, and dairy products; moderate intake of fish and red wine; and limited consumption of eggs and sweets.⁶ It contains an abundance of fibers, polyphenols, high-quality proteins, and ω -3 fatty acids, contributing to healthy metabolism and exerting anti-inflammatory and antioxidant effects.^{7,8} Recognized as one of the healthiest recommended dietary patterns,⁹ the Mediterranean diet significantly reduces the risk of developing major chronic diseases, particularly cardiovascular disease, Type 2 diabetes, and various cancer types.¹⁰

Over the past decades, the Mediterranean diet has also gained attention for its beneficial effects on muscle quality and physical performance, with burgeoning evidence suggesting its potential role in preventing sarcopenia progression.¹¹ However, significant knowledge gaps persist. Previous studies have investigated the relationship between adherence to the Mediterranean diet and several common muscle-related outcomes, such as grip strength, appendicular muscle mass, walking speed, and the ability to rise from a chair; generally finding positive correlations.¹¹ Rodacki *et al.*¹² found that fish oil supplements (rich in ω -3 fatty acids) resulted in higher leg muscle strength. The Mediterranean diet is known for its anti-inflammatory and antioxidant effects, which are suggested to have a significant effect on muscle function.^{13,14} Researchers have also concentrated on its relationship with sarcopenia, but have drawn inconsistent conclusions. For example, association was statistically evident in the PREDIMED-Plus study,¹⁵ while no significance was found in the Lookup 7+ database.¹⁶ However, some shortcomings limit

those studies from drawing a consistent conclusion: few studies have used sarcopenia as an outcome, and there are significant population differences in current research.^{11,17}

In summary, studies investigating the relationship between adherence to the Mediterranean diet and sarcopenia remain limited, and the conclusions have been inconsistent. Therefore, we designed a large-scale cross-sectional study to explore this relationship, providing more evidence for its effectiveness.

2. Data and methods

2.1. Study participants

The National Health and Nutrition Examination Survey (NHANES) is conducted in the United States (US), aiming to assess the health and nutrition status of adults and children. By performing physical examinations, interviews, and laboratory tests on diverse populations, NHANES collects data to support public health policies and research. NHANES is conducted in line with the Declaration of Helsinki and is approved by the National Center for Health Statistics Ethics Review Board. NHANES is conducted under federal privacy regulations and adheres to strict data-protection standards.

We analyzed data in NHANES from 2011 to 2018, focusing on adults aged 20 and over. Participants with missing data on dual-energy X-ray absorptiometry (DXA), hand grip strength, and nutrient intakes were excluded from our analyses. The final analytic sample included 17,110 adults. These participants were then divided into two groups: One with complete DXA data and the other with complete grip-strength data. A flow diagram of the study population is shown in Figure S1.

2.2. Assessment of the alternate Mediterranean diet (aMED) score

The aMED score assessment comprises nine components, including fruits, vegetables, nuts, legumes, whole grains, fish, red and processed meat, the ratio of monounsaturated fat to saturated fat, and alcohol intake. All these components were obtained through a 24-h dietary recall over 2 days during the examination in Mobile Examination Center. To minimize recall bias, the first dietary recall interview was conducted in person in an examination center, while the second interview was conducted over the phone 3–10 days after the first interview. We used the R package “dietaryindex” for aMED calculation. “Dietaryindex” was created and validated by Zhan *et al.*,¹⁸ and its results have been proven to be consistent.¹⁹ Red and processed meat consumption below the median received 1 point. Alcohol intake between 5 and 15 g/d received 1 point; otherwise, 0 points. For other components, participants with intake

above the median intake received 1 point. The possible score range for aMED was 0 to 9, and a higher score represented closer adherence to the Mediterranean diet.

2.3. Assessment of sarcopenia and its components

Sarcopenia was the primary outcome variable in this study, indicating a condition of low muscle mass. NHANES obtained appendicular lean mass through the DXA method. Staff used Hologic Discovery model A densitometers (Hologic, Inc., US) with Apex 3.2 software to complete the whole body scans. Before being released publicly, its data was analyzed using APEX v4.0 (Hologic), and its quality was inspected by a technologist. Participants with a height of over 192.5 cm, a weight of more than 136.4 kg, or a status of pregnancy were unqualified for the DXA examination. Sarcopenia was defined based on an objective index, calculated as the total mass of appendicular skeletal muscle (kg) divided by body mass index (BMI; kg/m²). According to the guidelines from the Foundation for the National Institutes of Health, the index had different cutoff points for men (0.789) and women (0.512).²¹ Participants with an index lower than the cutoff points were diagnosed with sarcopenia.

Muscle mass and grip strength are also crucial indicators in other diagnostic guidelines for sarcopenia.²⁰ These indicators were investigated as secondary outcome variables. Grip strength measurements were conducted during the 2011–2014 NHANES. According to the survey protocol, participants alternately squeezed a dynamometer with maximum effort 3 times for each hand, totaling six attempts. The maximum value of all measurements was calculated as the result of the grip strength test, commonly referred to as the dominant grip strength.

2.4. Assessment of the covariates

In this study, covariates included age, data release cycle, gender, ethnicity, education level, marital status, the ratio of family income to the federal poverty threshold (PIR), smoking status, physical activity, hypertension, diabetes, and BMI. These covariates were included if commonly used in prior research or were considered as potential confounders that might be associated with sarcopenia.^{22,23} Data release cycle was categorized as “2011–2012,” “2013–2014,” “2015–2016,” and “2017–2018.” Ethnicity was categorized as Hispanic, non-Hispanic White, non-Hispanic Black, Mexican American, and others. Education level was categorized as less than high school, more than high school, high school, and general educational development. Marital status was categorized as never married, married/living with partner, and separated/divorced/widowed. Smoking status was dichotomized as “No” (never smokers) and “Yes” (former or current

smokers). Physical activity was categorized as less than moderate, moderate, and vigorous according to the questionnaire in NHANES. Hypertension and diabetes were also self-reported through questionnaires. Since alcohol was a part of the Mediterranean diet, it was not treated as a covariate in this study.

2.5. Statistical analysis

The NHANES samples are not simple random samples; they use a multistage sampling design that includes primary sampling units, strata, and sample weights. Accordingly, we incorporated the sampling weights recommended in NHANES guidelines. The characteristics of participants were presented as means with SD for continuous variables or percentages for categorical variables. Statistical characteristics were based on the sarcopenia status. In our analysis, continuous variables were assessed using survey-weighted analysis of variance, while categorical variables were evaluated by using chi-square tests to examine the significance of differences between different sarcopenia statuses.

Weighted multivariate logistic regression analysis was conducted to assess the association between adherence to the Mediterranean diet, as well as its components, and sarcopenia, by calculating odds ratios (ORs) and 95% confidence intervals. The aMED score was divided into tertiles, with T1 serving as the reference to investigate any linear trends. Three models were created to control for the effects of confounding factors. Model 1 was a crude model. Model 2 was adjusted for age, data release cycle, gender, ethnicity, education level, marital status, and PIR. Model 3 was adjusted for the covariates in Model 2, as well as smoking status, physical activity, hypertension, diabetes, and BMI.

According to Model 3, we performed subgroup analysis to examine the correlation between the Mediterranean diet and sarcopenia across different subgroups. Stratified variables included age (<45 and ≥45), BMI (<25 and ≥25), gender (male and female), race (Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, and other), and PIR (<1.3, 1.3–3.5, and >3.5). The results of the subgroup analysis are shown in the form of a forest plot.

Furthermore, we investigated the correlation between individual food components of the Mediterranean diet and sarcopenia. First, we conducted weighted quantile sum (WQS) regression to assess the importance of individual food components by calculating their weights. WQS regression is a statistical model for multivariate regression, commonly used in high-dimensional datasets such as environmental exposure studies. This is a machine learning model, constructing a weighted index in a supervised

manner to assess the overall effect and the contribution of each component. In our model, we set the training set ratio to 70%, the number of resampling's to 100, and assumed a normal distribution for the data. Alcohol components were excluded from the WQS model because of their unidirectionality. Second, we repeated weighted multivariate logistic regression on each food component to determine the correlation. Finally, we performed a series of sensitivity analyses to ensure the stability of our results. We excluded participants who were overweight (BMI >50 kg/m²) or underweight (BMI <15 kg/m²).

All analyses were performed using RStudio (version 4.3.1, Posit, US). A $p < 0.05$ was considered statistically significant.

3. Results

3.1. Participant characteristics

The characteristics of individuals based on sarcopenia status are shown in Table 1. The p -values were calculated as weighted means for continuous variables and as weighted percentages for categorical variables. This study included 17,110 participants, comprising 8,149 (47.6%) males and 8,961 (52.4%) females. Among the participants with complete DXA data (8,849), 773 participants were diagnosed with sarcopenia. Participants with higher aMED scores tended to be older, of non-Hispanic White ethnicity, with a lower BMI, higher education level, higher income, and engaged in more physical activity. We also found that females showed greater adherence to the Mediterranean diet ($p < 0.001$), and observed a small but statistically significant difference between survey cycles ($p = 0.046$). The prevalence of sarcopenia declined with increasing tertiles of Mediterranean diet adherence scores. In the highest tertile, the prevalence of sarcopenia was 6.8%.

3.2. Mediterranean diet and sarcopenia

The results of the three weighted logistic regression models are shown in Tables 2 and 3. When aMED scores were treated as a categorical variable, compared with the lowest tertile of the aMED score, the highest tertile was significantly associated with a lower risk of sarcopenia (OR = 0.52 [0.39–0.69]). When aMED scores were treated as a continuous variable, a noticeable trend was observed between them and sarcopenia ($p < 0.001$). In adjusted models, almost all of the aMED score tertiles were significantly associated with sarcopenia, and the trend test remained significant ($p = 0.010$). For the components of sarcopenia, there were no significant differences in the unadjusted model. However, we detected a significant association between aMED and the sarcopenia components relevant to muscle mass after adjusting for covariates (Model 2: Appendicular

muscle mass, $p < 0.001$; total muscle mass, $p < 0.001$; hand grip strength, $p < 0.001$; Model 3: Appendicular muscle mass, $p < 0.001$; total muscle mass, $p = 0.002$; hand grip strength, $p = 0.410$).

3.3. Subgroup analysis

To investigate the consistency of our results, we conducted subgroup analysis stratified by age, gender, BMI, race, and PIR (Figure 1). For individuals over 45 years of age, the indicator showed a significant protective effect (OR = 0.60 [0.47, 0.76]), whereas those under 45 years of age did not exhibit a significant effect (OR = 1.06 [0.85, 1.33]). Regardless of obesity status, the Mediterranean diet had a protective effect against sarcopenia, with a more pronounced effect in individuals with a BMI below 25 (OR = 0.30 [0.11, 0.83]). The protective effects were prominent in both male (OR = 0.77 [0.59, 1.00]) and female (OR = 0.73 [0.56, 0.95]). For PIR, we observed a significant effect for values between 1.3 and 3.5, and a minor effect for values <1.3. No interaction effect was found in gender and the PIR subgroup.

3.4. Individual components of the Mediterranean diet and sarcopenia

The results of the association between individual components of the Mediterranean diet and sarcopenia are presented in Table 4 and Figure 2. We applied two approaches to assess the weight and reliability of individual components. In WQS regression, we hypothesized that all components of the Mediterranean diet have protective effects against sarcopenia based on the positive results from aMED analysis. According to WQS regression, fish and nuts were among the highest weights (fish: 0.47, nuts: 0.26), followed by legumes and vegetables (legumes: 0.14, vegetables: 0.05). These components accounted for over 95% of the total weight. In the regression of individual components, significant trends were observed in vegetables ($p = 0.006$), nuts ($p = 0.034$), and fish ($p = 0.048$), while a subtle trend was found in legumes ($p = 0.061$). In contrast, whole grains, alcohol, fruits, red/processed meats, and the ratio of monounsaturated to saturated fatty acids were not significantly associated with sarcopenia prevalence. The results of WQS regression might vary across different sampling methods. Therefore, we could only infer that the results of the two methods were consistent in fish and nuts.

3.5. Sensitivity analysis

We excluded BMI outliers to minimize the influence of individuals who might be in a disease state. The results remained significant in the adjusted model (OR = 0.45 [0.28, 0.91], $p = 0.005$; Table S1). The sensitivity analysis showed the robustness and consistency of the results.

Table 1. Characteristics of study participants by aMED score tertiles (n=17,110)

Parameters	aMED scores			p-value
	Tertile 1 (n=7,931)	Tertile 2 (n=4,365)	Tertile 3 (n=4,814)	
Age (year; mean±SD)	47.27 (17.54)	51.63 (17.33)	52.91 (16.99)	<0.001
Survey cycle (n [%])				
2011–2012	1,988 (25.1)	1,068 (24.5)	1,246 (25.9)	0.046
2013–2014	2,051 (25.9)	1,102 (25.2)	1,319 (27.4)	
2015–2016	1,956 (24.7)	1,112 (25.5)	1,132 (23.5)	
2017–2018	1,936 (24.4)	1,083 (24.8)	1,117 (23.2)	
Gender (n [%])				
Male	4,040 (50.9)	2,062 (47.2)	2,047 (42.5)	<0.001
Female	3,891 (49.1)	2,303 (52.8)	2,767 (57.5)	
Race (n [%])				
Mexican American	940 (11.9)	661 (15.1)	604 (12.5)	<0.001
Other Hispanic	797 (10.0)	457 (10.5)	466 (9.7)	
Non-Hispanic White	3,181 (40.1)	1,708 (39.1)	1,801 (37.4)	
Non-Hispanic Black	2,213 (27.9)	961 (22.0)	793 (16.5)	
Others	800 (10.1)	578 (13.2)	1,150 (23.9)	
Education level (n [%])				
<High school	1,842 (23.2)	872 (20.0)	680 (14.1)	<0.001
>High school	3,940 (49.7)	2,533 (58.1)	3,410 (70.9)	
High school	2,144 (27.1)	954 (21.9)	722 (15.0)	
Marital status (n [%])				
Married/living with partner	4,299 (54.2)	2,655 (60.8)	3,197 (66.4)	<0.001
Never married	1,837 (23.2)	690 (15.8)	677 (14.1)	
Separated/divorced/widowed	1,795 (22.6)	1,020 (23.4)	940 (19.5)	
PIR (n [%])				
<1.3	2,857 (39.3)	1,132 (28.5)	915 (20.8)	<0.001
≥3.5	1,616 (22.2)	1,249 (31.5)	1,966 (44.6)	
1.3–3.5	2,791 (38.4)	1,585 (40.0)	1,524 (34.6)	
Smoke status (n [%])				
No	1,765 (45.1)	1,131 (63.6)	1,235 (76.1)	<0.001
Yes	2,151 (54.9)	647 (36.4)	388 (23.9)	
Activity (n [%])				
0	2,800 (35.3)	1,435 (32.9)	1,238 (25.7)	<0.001
1	2,248 (28.3)	1,361 (31.2)	1,655 (34.4)	
2	2,883 (36.4)	1,569 (35.9)	1,921 (39.9)	
BMI (kg/m ²) (mean±SD)	30.36 (7.64)	29.73 (7.07)	28.05 (6.30)	<0.001
Diabate (n [%])				
No	6,837 (86.3)	3,667 (84.0)	4,175 (86.7)	<0.001
Yes	1,089 (13.7)	696 (16.0)	638 (13.3)	
Hypertension (n [%])				
No	4,967 (62.7)	2,607 (59.8)	3,062 (63.6)	<0.001
Yes	2,953 (37.3)	1,754 (40.2)	1,749 (36.4)	
Appendicular muscle mass (mean±SD)	0.80 (0.21)	0.80 (0.20)	0.80 (0.20)	0.142
Total muscle mass (mean±SD)	1.82 (0.39)	1.81 (0.38)	1.81 (0.37)	0.278
Grip strength (mean±SD)	0.89 (0.28)	0.88 (0.27)	0.90 (0.25)	0.161
Sarcopenia (n [%])				
No	3,994 (90.1)	1,944 (91.6)	2,165 (93.2)	<0.001
Yes	437 (9.9)	178 (8.4)	159 (6.8)	

Abbreviations: aMED: Alternate Mediterranean diet; BMI: Body mass index; PIR: Ratio of family income to poverty; SD: Standard deviation.

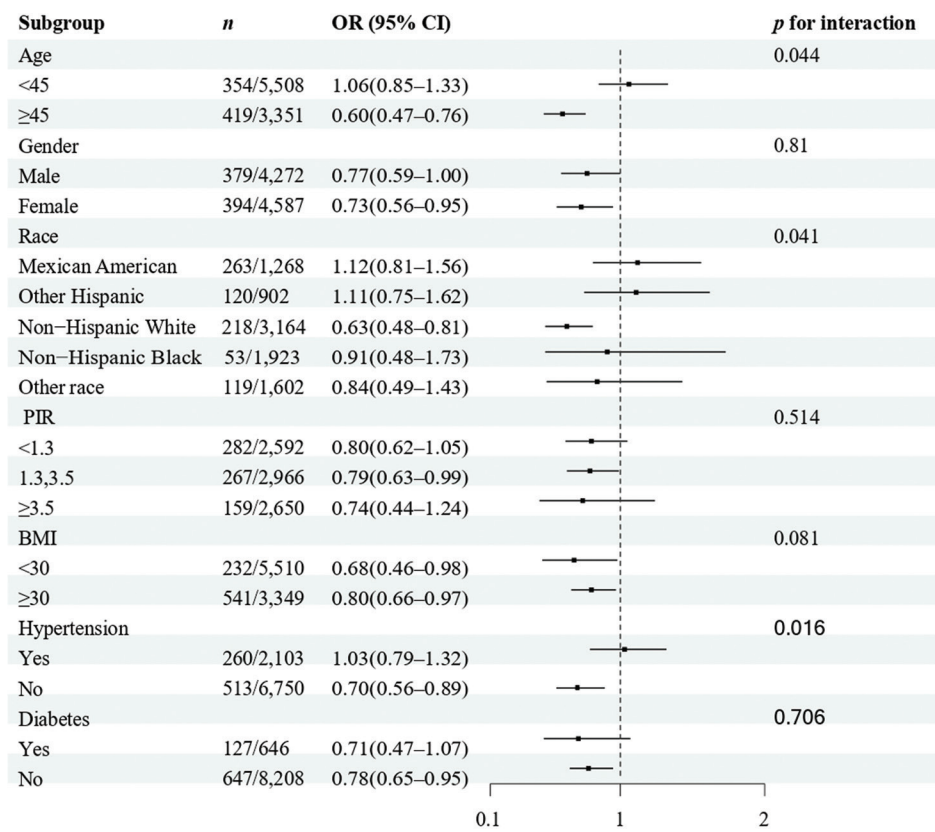


Figure 1. Subgroup analysis for the association between Mediterranean diet and sarcopenia

Notes: An interaction term was added to test the heterogeneity of associations between subgroups; $p < 0.05$ was considered statistically significant. Abbreviations: BMI: Body mass index; OR: Odds ratio; PIR: Ratio of family income to poverty.

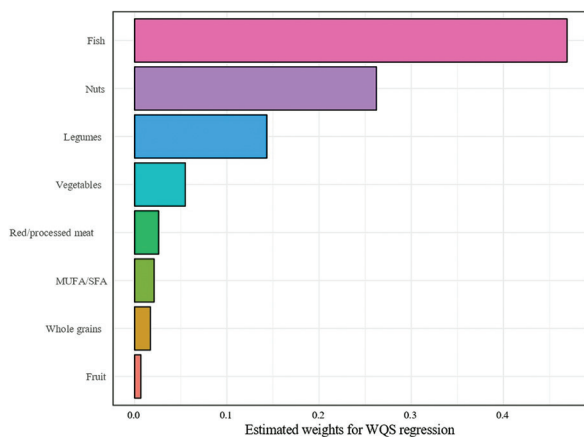


Figure 2. Weight quantile sum (WQS) model regression index weights for individual food components of the Mediterranean diet

Note: Alcohol components were excluded from the WQS model due to their unidirectionality.

Abbreviations: MUFA: Monounsaturated fatty acids; SFA: Saturated fatty acids.

4. Discussion

By analyzing NHANES data from 2011 to 2018, our study found that the Mediterranean diet was significantly

Table 2. Association between the aMED score tertiles and sarcopenia among NHANES 2011–2018 participants: Sample-weighted multivariate logistic analysis

Model	OR (95% CI)			p for trend
	Tertile 1	Tertile 2	Tertile 3	
1	Ref.	0.76 (0.60–0.96)	0.52 (0.39–0.69)	<0.001
2	Ref.	0.76 (0.60–0.96)	0.52 (0.39–0.69)	<0.001
3	Ref.	0.76 (0.53–1.10)	0.47 (0.25–0.94)	0.010

Notes: Model 1 was unadjusted. Model 2 was adjusted for age, data release cycle, gender, ethnicity, education, marital status, and PIR. Model 3 was adjusted for the covariates in Model 2 in addition to smoking status, physical activity, hypertension, diabetes, and BMI. Abbreviations: aMED: Alternate Mediterranean diet; BMI: Body mass index; OR: Odds ratio; PIR: Ratio of family income to poverty; Ref.: Reference; CI: Confidence interval.

associated with a reduction in the risk of sarcopenia. We compared to the lowest tertile, the odds of sarcopenia in the highest tertile were decreased by 53%. The relationship between the Mediterranean diet and sarcopenia components, especially muscle mass, was consistent. In addition, subgroup analysis revealed two phenomena:

Table 3. Relationship between aMED score tertiles and sarcopenia components

Components	β (95% CI)			p for trend
	Tertile 1	Tertile 2	Tertile 3	
Model 1				
Appendicular muscle mass	Ref.	0.004 (−0.010–0.018)	0.008 (−0.006–0.023)	0.512
Total muscle mass	Ref.	0.007 (−0.020–0.034)	0.021 (−0.007–0.049)	0.281
Hand grip strength	Ref.	0.004 (−0.010–0.018)	0.008 (−0.006–0.023)	0.384
Model 2				
Appendicular muscle mass	Ref.	0.017 (0.005–0.028)	0.032 (0.022–0.041)	<0.001
Total muscle mass	Ref.	0.035 (0.021–0.050)	0.088 (0.073–0.104)	<0.001
Hand grip strength	Ref.	0.023 (0.008–0.038)	0.062 (0.050–0.075)	<0.001
Model 3				
Appendicular muscle mass	Ref.	0.024 (0.009–0.039)	0.030 (0.010–0.052)	<0.001
Total muscle mass	Ref.	0.020 (0.001–0.038)	0.031 (0.006–0.057)	0.002
Hand grip strength	Ref.	0.006 (−0.015–0.026)	−0.002 (−0.021–0.016)	0.410

Notes: Model 1 was unadjusted. Model 2 was adjusted for age, data release cycle, gender, ethnicity, education, marital status, and PIR. Model 3 was adjusted for the covariates in Model 2 in addition to smoking status, physical activity, hypertension, diabetes, and BMI.

Abbreviations: aMED: Alternate Mediterranean diet; BMI: Body mass index; PIR: Ratio of family income to poverty; Ref.: Reference; CI: Confidence interval.

Table 4. Associations between the individual food components in the Mediterranean diet and the prevalence of sarcopenia in NHANES participants

Component	OR (95% CI)	<i>p</i> -value
Vegetables	0.43 (0.24–0.77)	0.006
Nuts	0.53 (0.29–0.95)	0.034
Fish	0.53 (0.28–0.99)	0.048
Legumes	0.55 (0.30–1.03)	0.061
Whole grains	0.83 (0.47–1.46)	0.505
Alcohol	0.78 (0.27–2.27)	0.643
Fruit	0.88 (0.50–1.57)	0.664
Red/processed meat	0.95 (0.61–1.50)	0.827
MUFA/SFA	1.00 (0.63–1.59)	0.989

Notes: Mediterranean diet adherence scores are derived by assigning a value of “0” and “1” across nine food components. Covariates were adjusted in the same way as in Model 3.

Abbreviations: MUFA: Monounsaturated fatty acids; NHANES: National Health and Nutrition Examination Survey; SFA: Saturated fatty acids; OR: Odds ratio; CI: Confidence interval.

the protective effect of the Mediterranean diet was more pronounced in the elderly population, and the protective effect could be detected in both obese and non-obese individuals. In summary, our results support an inverse association between Mediterranean diet adherence and sarcopenia.

The Mediterranean diet may influence muscle function by a variety of mechanisms. Biochemical processes, such as inflammation and oxidation, are vital pathways through

which the Mediterranean diet exerts its protective effects against sarcopenia. The occurrence of many diseases is inflammation-mediated: inflammatory cells facilitate tumor growth by releasing growth and survival factors²⁴; recent research links inflammation to cardiovascular diseases.^{25,26} Musculoskeletal disease is not an exception. Cross-sectional and cohort studies revealed that increasing inflammatory markers are associated with muscle dysfunction and sarcopenia.^{27,28} This indicates that the Mediterranean diet may reduce the risk of sarcopenia by inhibiting inflammation. The anti-oxidative effect of the Mediterranean diet also plays a protective role. From a macroscopic perspective, individuals with lower oxidative balance scores are less likely to have sarcopenia.²⁹ At the cellular level, skeletal muscle can produce reactive oxygen species, which can activate the mitochondrial apoptosis pathway.³⁰ In short, the role of inflammation and oxidative processes in the development of sarcopenia has become relatively clear,^{31,32} and it is an essential mechanism that has gained widespread attention. Another trending topic regarding its potential mechanism is the intestinal microbe. A review summarized that the Mediterranean diet was likely associated with increased representation of bacterial taxa that promoted metabolic function.³³ Meanwhile, the depletion of bacterial taxa, especially those capable of synthesizing short-chain fatty acids, is a major symbol of frailty and sarcopenia.^{34,35}

In this study, we focused on sarcopenia and its relevant indicators, and drew a consistent conclusion that the Mediterranean diet has a significant protective

effect in almost all models. Existing research has shown mixed results. Although the majority of studies supported the association between the Mediterranean diet and sarcopenia, consensus has not been reached.²⁰ The lack of agreement on the definition of sarcopenia might be a critical factor. As previously stated, some studies used indicators relevant to sarcopenia without diagnosing sarcopenia itself; some studies did not make a confirmed diagnosis. For example, Huang *et al.*³⁶ found no association between hand grip strength, gait speed, and other parameters of sarcopenia. As is known, low muscle mass is a key criterion for the confirmed diagnosis of sarcopenia.² A cross-sectional study, estimating muscle mass using an approximate equation rather than an accurate measurement, reached the conclusion that the Mediterranean diet had no protective effect.¹⁶ Over the past 5 years, several studies have measured muscle mass using DXA and obtained encouraging results,^{37,38} indicating that accurately measuring muscle mass and confirming the diagnosis of sarcopenia are substantial methodologies for reliable results. Therefore, our study analyzed the NHANES database, which adopted DXA to assess muscle mass, and reached a consistent conclusion as expected. It also provided a reasonable explanation that the result of hand grip strength indirectly showed a protective effect. It is noteworthy that low muscle strength is used to diagnose potential sarcopenia.² These findings suggest that the definition of sarcopenia still has much room for improvement. Fortunately, the Global Leadership Initiative in Sarcopenia has been established to reach a consensus on the definition of sarcopenia, serving as a gold standard for diagnosis.³⁹ It will bring hope for reaching an objective agreement on this topic.

There are two other intriguing discoveries. That is, the protective effects were found to vary across the age subgroup, but were consistent across BMI status in the subgroup analysis. For the age subgroup, we used age 45 as the cutoff point for grouping in the subgroup analysis. In fact, the period from the age of 70–80 is when muscle mass begins to decline rapidly.⁴⁰ Hence, enormous research has focused on the elderly population.^{37,38,41} Nonetheless, muscle mass begins to be lost at 45 years old, and a life course framework has been established to encourage intervention at earlier life stages.^{1,2,42,43} Overall, the combination of the above conclusion and our outcomes, which showed a significant protective effect in the population aged 45 and above, demonstrates the rationality and necessity of early intervention. Meanwhile, the subgroup analysis regarding BMI brought up the topic of sarcopenic obesity. Sarcopenic obesity is a type of sarcopenia that is increasingly garnering attention.^{44,45}

Current management strategies are exercise and nutrition interventions.⁴⁵ The current definition of sarcopenic obesity is the co-existence of sarcopenia and obesity. However, establishing a universally accepted cutoff point for sarcopenic obesity remains challenging. We tentatively used BMI ≥ 30 as the cutoff point of obesity, as suggested by the American Association of Clinical Endocrinologists. We can infer from the similar results that the Mediterranean diet might be beneficial for sarcopenia patients with different weight conditions.

We also assessed the associations between individual food components of the Mediterranean diet and the prevalence of sarcopenia, as these relationships may offer insights into the underlying mechanisms of sarcopenia development. In the weighted multivariate logistic regression, significant differences were found in four components: Vegetables, nuts, fish, and legumes. These components contain an abundance of anti-inflammatory and antioxidant substances, thus fighting against sarcopenia through the mechanisms mentioned above. Similar effects were found in another research, which specifically focuses on vegetables and fruits.⁴⁶ However, only nuts and fish had the major weights in the prevention of sarcopenia in the WQS regression. This finding indicates that although a significant relationship was observed between these components and sarcopenia, the strength of this relationship is insufficient to produce a practical impact. This can be potentially explained by two reasons. First, the effectiveness of protein in combating sarcopenia is related to its source. Due to differences in bioavailability, animal proteins, such as fish and dairy, are considered high-quality proteins.⁴⁷ However, there is also evidence indicating that consuming adequate protein can offset the influence of protein sources.⁴⁸ Anyway, our results showed that compared with plant proteins and other animal proteins, fish may have a stronger protective effect against sarcopenia. On the other hand, the positive results of nuts correspond with studies from different regions.^{49,50}

The most significant contribution of our study is that it examined a large sample size from a wide-ranging database and utilized the most accurate definition of sarcopenia currently available. There is also an innovative aspect in our study. To the best of our knowledge, few studies have focused on the impact of individual components of the Mediterranean diet on sarcopenia,³⁸ and those efforts are meaningful. Current studies have shown notable ethnic disparities in the protective effects of the Mediterranean diet, which may be attributable to varying perceptions of the same food components among different populations.^{17,38,51} At the same time, differences among populations and

factors such as psychosocial stressors also pose difficulties in adhering to the Mediterranean diet.^{52,53} Summarizing the components of the Mediterranean diet may hold considerable importance for its widespread promotion and longitudinal adherence.

The limitations of this study are primarily reflected in the following aspects. Firstly, the cross-sectional study design makes it challenging to establish causality between the Mediterranean diet and sarcopenia. Secondly, NHANES only measured the DXA of participants aged 8–59 years for safety reasons. Lastly, dietary data were obtained from recall questionnaires, which may be subject to recall bias and changes in eating habits.

5. Conclusion

Better adherence to the Mediterranean diet is associated with a lower prevalence of sarcopenia, regardless of weight status, and this association is significant in both males and females. Among the nine components of the Mediterranean diet, fish and nuts are potentially more impactful than other components, as supported by WQS regression and weighted multivariate logistic regression. These findings highlight the importance of early dietary intervention in managing sarcopenia. More studies, especially clinical trials, should be conducted to definitively evaluate the relationship between the Mediterranean diet and sarcopenia.

Acknowledgments

The authors wish to thank all the staff and participants of the NHANES study for their valuable contributions in data support.

Funding

None.

Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Jian Wang, Donghong Guo

Formal analysis: Dichun Lv, Jialan Chen

Investigation: Yuanyuan Wang, Gaochenzi Tao, Zikun Xie

Methodology: Chengkai Wu, Tao Li

Writing–original draft: Dichun Lv

Writing–review & editing: Jia Li, Jialan Chen

Ethics approval and consent to participate

The studies involving human participants were reviewed and approved by the NCHS Research Ethics Review

Board (ERB). Since the data released by the NCHS are anonymized and de-identified during analysis, further ethical approval or informed consent is not required for secondary analysis.

Consent for publication

Not applicable.

Availability of data

All datasets were publicly available from NHANES: <https://www.cdc.gov/nchs/nhanes/index.htm>.

References

1. Sayer AA, Cooper R, Arai H, *et al.* Sarcopenia. *Nat Rev Dis Primers.* 2024;10(1):68.
doi: 10.1038/s41572-024-00550-w
2. Cruz-Jentoft AJ, Bahat G, Bauer J, *et al.* Sarcopenia: Revised European consensus on definition and diagnosis. *Age Ageing.* 2019;48(1):16–31.
doi: 10.1093/ageing/afy169
3. *The State of Food Security and Nutrition in the World 2024.* Rome: FAO, IFAD, UNICEF, WFP, WHO; 2024.
doi: 10.4060/cd1254en
4. Robinson SM, Reginster JY, Rizzoli R, *et al.* Does nutrition play a role in the prevention and management of sarcopenia? *Clin Nutr.* 2018;37(4):1121–1132.
doi: 10.1016/j.clnu.2017.08.016
5. Welch AA, Scott J, Cameron D, Yates M. Are dietary patterns relevant for reducing the risk of fractures and sarcopenia? *Curr Osteoporos Rep.* 2025;23(1):7.
doi: 10.1007/s11914-024-00899-7
6. Davis C, Bryan J, Hodgson J, Murphy K. Definition of the mediterranean diet; a literature review. *Nutrients.* 2015;7(11):9139–9153.
doi: 10.3390/nu7115459
7. Lees M, Carson B. The potential role of fish-derived protein hydrolysates on metabolic health, skeletal muscle mass and function in ageing. *Nutrients.* 2020;12(8):2434.
doi: 10.3390/nu12082434
8. Barber TM, Kabisch S, Pfeiffer AFH, Weickert MO. The effects of the mediterranean diet on health and gut microbiota. *Nutrients.* 2023;15(9):2150.
doi: 10.3390/nu15092150
9. Tagtow A, Rahavi E, Bard S, Stoody EE, Casavale K, Mosher A. Coming together to communicate the 2015–2020 dietary guidelines for Americans. *J Acad Nutr Diet.* 2016;116(2):209–212.

- doi: 10.1016/j.jand.2015.12.010
10. Sofi F, Cesari F, Abbate R, Gensini GF, Casini A. Adherence to Mediterranean diet and health status: Meta-analysis. *BMJ*. 2008;337:a1344.
doi: 10.1136/bmj.a1344
11. Granic A, Sayer AA, Robinson SM. Dietary patterns, skeletal muscle health, and sarcopenia in older adults. *Nutrients*. 2019;11(4):745.
doi: 10.3390/nu11040745
12. Rodacki CL, Rodacki AL, Pereira G, et al. Fish-oil supplementation enhances the effects of strength training in elderly women. *Am J Clin Nutr*. 2012;95(2):428-436.
doi: 10.3945/ajcn.111.021915
13. Itsiopoulos C, Mayr HL, Thomas CJ. The anti-inflammatory effects of a Mediterranean diet: A review. *Curr Opin Clin Nutr Metab Care*. 2022;25(6):415-422.
doi: 10.1097/MCO.0000000000000872
14. Haß U, Herpich C, Kochlik B, Weber D, Grune T, Norman K. Dietary inflammatory index and cross-sectional associations with inflammation, muscle mass and function in healthy old adults. *J Nutr Health Aging*. 2022;26(4):346-351.
doi: 10.1007/s12603-022-1753-4
15. Abete I, Konieczna J, Zulet MA, et al. Association of lifestyle factors and inflammation with sarcopenic obesity: Data from the PREDIMED-Plus trial. *J Cachexia Sarcopenia Muscle*. 2019;10(5):974-984.
doi: 10.1002/jcsm.12442
16. Coelho-Júnior HJ, Calvani R, Picca A, et al. Combined aerobic training and mediterranean diet is not associated with a lower prevalence of sarcopenia in Italian older adults. *Nutrients*. 2023;15(13):2963.
doi: 10.3390/nu15132963
17. Ganapathy A, Nieves JW. Nutrition and sarcopenia-what do we know? *Nutrients*. 2020;12(6):1755.
doi: 10.3390/nu12061755
18. Zhan JJ, Hodge RA, Dunlop AL, et al. Dietaryindex: A user-friendly and versatile R package for standardizing dietary pattern analysis in epidemiological and clinical studies. *Am J Clin Nutr*. 2024;120(5):1165-1174.
doi: 10.1016/j.ajcnut.2024.08.021
19. Fung TT, Rexrode KM, Mantzoros CS, Manson JE, Willett WC, Hu FB. Mediterranean diet and incidence of and mortality from coronary heart disease and stroke in women. *Circulation*. 2009;119(8):1093-1100.
doi: 10.1161/CIRCULATIONAHA.108.816736
20. Dominguez LJ, Veronese N, Smith L, et al. Associations between adherence to the mediterranean diet and incident sarcopenia in prospective cohort studies. *Nutrients*. 2025;17(2):313.
doi: 10.3390/nu17020313
21. Studenski SA, Peters KW, Alley DE, et al. The FNIH sarcopenia project: Rationale, study description, conference recommendations, and final estimates. *J Gerontol A Biol Sci Med Sci*. 2014;69(5):547-558.
doi: 10.1093/gerona/glu010
22. Liccini AP, Malmstrom TK. Frailty and sarcopenia as predictors of adverse health outcomes in persons with diabetes mellitus. *J Am Med Dir Assoc*. 2016;17(9):846-851.
doi: 10.1016/j.jamda.2016.07.007
23. Han P, Yu H, Ma Y, et al. The increased risk of sarcopenia in patients with cardiovascular risk factors in Suburb-Dwelling older Chinese using the AWGS definition. *Sci Rep*. 2017;7(1):9592.
doi: 10.1038/s41598-017-08488-8
24. Coussens LM, Werb Z. Inflammation and cancer. *Nature*. 2002;420(6917):860-867.
doi: 10.1038/nature01322
25. Aboukhater D, Morad B, Nasrallah N, et al. Inflammation and hypertension: Underlying mechanisms and emerging understandings. *J Cell Physiol*. 2023;238(6):1148-1159.
doi: 10.1002/jcp.31019
26. Libby P, Nahrendorf M, Swirski FK. Leukocytes link local and systemic inflammation in ischemic cardiovascular disease. *J Am Coll Cardiol*. 2016;67(9):1091-1103.
doi: 10.1016/j.jacc.2015.12.048
27. Schaap LA, Pluijm SMF, Deeg DJH, et al. Higher inflammatory marker levels in older persons: Associations with 5-year change in muscle mass and muscle strength. *J Gerontol A Biol Sci Med Sci*. 2009;64A(11):1183-1189.
doi: 10.1093/gerona/glp097
28. Guo B, Liu X, Si Q, et al. Associations of CBC-Derived inflammatory indicators with sarcopenia and mortality in adults: Evidence from Nhanes 1999~2006. *BMC Geriatr*. 2024;24(1):432.
doi: 10.1186/s12877-024-05012-2
29. Xu W, Mu D, Wang Y, Wang Y, Wang C, Zhang X. Association between oxidative balance score and sarcopenia in US adults: NHANES 2011–2018. *Front Nutr*. 2024;11:1342113.
doi: 10.3389/fnut.2024.1342113
30. Jackson MJ, Pye D, Palomero J. The production of reactive oxygen and nitrogen species by skeletal muscle. *J Appl Physiol*. 2007;102(4):1664-1670.
doi: 10.1152/japplphysiol.01102.2006
31. Liu D, Wang S, Liu S, Wang Q, Che X, Wu G. Frontiers in sarcopenia: Advancements in diagnostics, molecular

- mechanisms, and therapeutic strategies. *Mol Aspects Med.* 2024;97:101270.
doi: 10.1016/j.mam.2024.101270
32. Livshits G, Kalinkovich A. A cross-talk between sestrins, chronic inflammation and cellular senescence governs the development of age-associated sarcopenia and obesity. *Ageing Res Rev.* 2023;86:101852.
doi: 10.1016/j.arr.2023.101852
 33. Ticinesi A, Nouvenne A, Cerundolo N, Parise A, Mena P, Meschi T. The interaction between Mediterranean diet and intestinal microbiome: Relevance for preventive strategies against frailty in older individuals. *Aging Clin Exp Res.* 2024;36(1):58.
doi: 10.1007/s40520-024-02707-9
 34. Lv W, Lin X, Shen H, *et al.* Human gut microbiome impacts skeletal muscle mass via gut microbial synthesis of the short-chain fatty acid butyrate among healthy menopausal women. *J Cachexia Sarcopenia Muscle.* 2021;12(6):1860-1870.
doi: 10.1002/jcsm.12788
 35. Ticinesi A, Mancabelli L, Tagliaferri S, *et al.* The gut-muscle axis in older subjects with low muscle mass and performance: A proof of concept study exploring fecal microbiota composition and function with shotgun metagenomics sequencing. *Int J Mol Sci.* 2020;21(23):8946.
doi: 10.3390/ijms21238946
 36. Huang CH, Okada K, Matsushita E, *et al.* Dietary patterns and muscle mass, muscle strength, and physical performance in the elderly: A 3-year cohort study. *J Nutr Health Aging.* 2021;25(1):108-115.
doi: 10.1007/s12603-020-1437-x
 37. Karlsson M, Becker W, Michaëlsson K, Cederholm T, Sjögren P. Associations between dietary patterns at age 71 and the prevalence of sarcopenia 16 years later. *Clin Nutr.* 2020;39(4):1077-1084.
doi: 10.1016/j.clnu.2019.04.009
 38. Cervo MMC, Scott D, Seibel MJ, *et al.* Adherence to Mediterranean diet and its associations with circulating cytokines, musculoskeletal health and incident falls in community-dwelling older men: The Concord Health and Ageing in Men Project. *Clin Nutr.* 2021;40(12):5753-5763.
doi: 10.1016/j.clnu.2021.10.010
 39. Kirk B, Cawthon PM, Arai H, *et al.* The conceptual definition of sarcopenia: Delphi consensus from the global leadership initiative in sarcopenia (GLIS). *Age Ageing.* 2024;53(3):afae052.
doi: 10.1093/ageing/afae052
 40. Wilkinson DJ, Piasecki M, Atherton PJ. The age-related loss of skeletal muscle mass and function: Measurement and physiology of muscle fibre atrophy and muscle fibre loss in humans. *Ageing Res Rev.* 2018;47:123-132.
doi: 10.1016/j.arr.2018.07.005
 41. Cacciatore S, Calvani R, Marzetti E, *et al.* Low adherence to mediterranean diet is associated with probable sarcopenia in community-dwelling older adults: Results from the longevity check-up (Lookup) 7+ project. *Nutrients.* 2023;15(4):1026.
doi: 10.3390/nu15041026
 42. Cho MR, Lee S, Song SK. A review of sarcopenia pathophysiology, diagnosis, treatment and future direction. *J Korean Med Sci.* 2022;37(18):e146.
doi: 10.3346/jkms.2022.37.e146
 43. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. *Lancet.* 2019;393(10191):2636-2646.
doi: 10.1016/S0140-6736(19)31138-9
 44. Batsis JA, Villareal DT. Sarcopenic obesity in older adults: Aetiology, epidemiology and treatment strategies. *Nat Rev Endocrinol.* 2018;14(9):513-537.
doi: 10.1038/s41574-018-0062-9
 45. Prado CM, Batsis JA, Donini LM, Gonzalez MC, Siervo M. Sarcopenic obesity in older adults: A clinical overview. *Nat Rev Endocrinol.* 2024;20(5):261-277.
doi: 10.1038/s41574-023-00943-z
 46. Kim J, Lee Y, Kye S, Chung YS, Kim KM. Association of vegetables and fruits consumption with sarcopenia in older adults: The Fourth Korea National Health and Nutrition Examination Survey. *Age Ageing.* 2015;44(1):96-102.
doi: 10.1093/ageing/afu028
 47. Reid-McCann RJ, Brennan SF, McKinley MC, McEvoy CT. The effect of animal versus plant protein on muscle mass, muscle strength, physical performance and sarcopenia in adults: Protocol for a systematic review. *Syst Rev.* 2022;11(1):64.
doi: 10.1186/s13643-022-01951-2
 48. Putra C, Konow N, Gage M, York C, Mangano K. Protein source and muscle health in older adults: A literature review. *Nutrients.* 2021;13(3):743.
doi: 10.3390/nu13030743
 49. Feyesa I, George ES, Scott D, *et al.* Nut intake, functional limitations, and quality of life in older adults: Findings from NHANES 2003–2012. *J Cachexia Sarcopenia Muscle.* 2025;16(4):e70022.
doi: 10.1002/jcsm.70022
 50. Du Q, Lu Y, Hu F, *et al.* Dietary diversity and possible sarcopenia among older people in China: A nationwide population-based study. *Front Nutr.* 2023;10:1218453.
doi: 10.3389/fnut.2023.1218453
 51. Martínez-González MÁ, Hernández Hernández A. Effect

of the Mediterranean diet in cardiovascular prevention. *Rev Esp Cardiol (Engl Ed)*. 2024;77(7):574-582.

doi: 10.1016/j.rec.2024.01.006

52. Georgoulis M, Georgousopoulou EN, Chrysohoou C, Pitsavos C, Panagiotakos DB. Longitudinal trends, determinants, and cardiometabolic impact of adherence to the mediterranean diet among greek adults. *Foods*. 2022;11(16):2389.
doi: 10.3390/foods11162389
53. Mazza E, Ferro Y, Pujia R, *et al*. Mediterranean diet in healthy aging. *J Nutr Health Aging*. 2021;25(9):1076-1083.
doi: 10.1007/s12603-021-1675-6