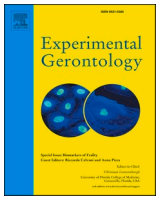
Experimental Gerontology 175 (2023) 112143

Contents lists available at ScienceDirect

Experimental Gerontology

journal homepage: www.elsevier.com/locate/expgero



Mediterranean diet, mental health, cognitive status, quality of life, and successful aging in southern Italian older adults

Justyna Godos [a], Giuseppe Grosso [a,b,*], Raffaele Ferri [c], Filippo Caraci [d,e], Giuseppe Lanza [f,g], Wahidah H. Al-Qahtani [h], Giuseppe Caruso [d,e], Sabrina Castellano [i]

[a] Department of Biomedical and Biotechnological Sciences, University of Catania, Catania, Italy
[b] Center for Human Nutrition and Mediterranean Foods (NUTREA), University of Catania, Catania, Italy
[c] Sleep Research Centre, Department of Neurology IC, Oasi Research Institute-IRCCS, Troina, Italy
[d] Neuropharmacology and Translational Neurosciences Research Unit, Oasi Research Institute-IRCCS, Troina, Italy
[e] Department of Drug and Health Sciences, University of Catania, Catania, Italy
[f] Clinical Neurophysiology Research Unit, Oasi Research Institute-IRCCS, Troina, Italy
[g] Department of Surgery and Medical-Surgical Specialties, University of Catania, Catania, Italy
[h] Department of Food Sciences & Nutrition, College of Food & Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia
[i] Department of Educational Sciences, University of Catania, Catania, Italy

ARTICLE INFO

Keywords:
Successful aging
Mediterranean diet
Cognitive status
Depressive symptoms
Sleep quality
Quality of life

ABSTRACT

Healthy successful aging with preserved mental and cognitive health is expected to be one of the most important challenges of the growing old population globally. Studies investigating these multi-dimensional aspects of senescence are important to identify potential targets for early prevention. The aim of this study was to investigate the relation between adherence to the Mediterranean diet and mental and cognitive health, quality of life, and successful aging in middle-age and older adults living in Sicily, southern Italy. Data from a sample of 883 individuals was collected including information on food intake (through a 110-item food frequency questionnaire), sleep quality (through the Pittsburgh sleep quality index) depressive symptoms (through the Center for the Epidemiological Studies of Depression Short Form), quality of life (through the Manchester Short Assessment of Quality of Life), cognitive status (through the Short Portable Mental Status Questionnaire), and overall successful aging (through the Successful Aging Index). Multivariate logistic regression analyses were conducted to assess the association between adherence to the Mediterranean diet and the outcomes investigated. After adjustment for potential confounding factors, individuals in the highest quartile of adherence to the Mediterranean diet were less likely to have cognitive impairment (OR = 0.19, 95 % CI: 0.04, 0.86), depressive symptoms (OR = 0.19, 95 % CI: 0.08, 0.46) and more likely to have good quality of life (OR = 14.04, 95 % CI: 6.81, 28.93); significant results were also found for individuals in the third quartile of Mediterranean diet adherence and good sleep quality (OR = 1.65, 95 % CI: 1.03, 2.64). Moreover, individuals in the highest quartile of adherence were more likely to have a successful aging (OR = 1.65, 95 % CI: 1.01, 2.68). In conclusion, this study supports the hypothesis that adherence to the Mediterranean diet provides a positive trajectory toward a healthy successful aging, with major potential benefits toward mental and cognitive health.

1. Introduction

The global trends in aging population have been estimated to deeply affect the growing incidence of age-related non-communicable diseases. By 2030, people aged over 60 years will rise from 1 billion (in 2020) to 1.4 billion, to finally double by 2050 (World Health Organization, n.d.). Common non-communicable diseases, such as cardiometabolic disorders and cancer, will only partially contribute to the years lived with disability, which will be growly accompanied by mental and cognitive disorders. The latest report of the global burden of disease has estimated that about 55 million individuals are affected by dementia, with growing trends up to 150 million cases estimated by 2050 (GBD 2019 Dementia Forecasting Collaborators, 2022). Accompanying these estimates there is a prevalence of about 300 million people living with

* Corresponding author at: Department of Biomedical and Biotechnological Sciences, University of Catania, Via Santa Sofia 97, 95123 Catania, Italy.
E-mail address: giuseppe.grosso@unict.it (G. Grosso).

https://doi.org/10.1016/j.exger.2023.112143
Received 31 December 2022; Received in revised form 6 March 2023; Accepted 9 March 2023
Available online 16 March 2023

depression and >260 million people suffering from anxiety disorders worldwide (Friedrich, 2017). Albeit these conditions may be unrelated, there is evidence that sleep and depressive disorders may also represent prodromic symptoms of early onset cognitive impairment (Wennberg et al., 2017). In fact, chronic depressive and sleep disorders may affect central nervous system structural plasticity in older individuals, by reducing the spine density and attenuating the synaptic efficacy in the hippocampus (Raven et al., 2018). Overall, mental and cognitive disorders will represent a public health issue due to their global impact and their effects on quality of life and healthy aging in elderly individuals.

Para-physiological mechanisms related to aging associated with changing lifestyle behaviors of modern societies, including dietary habits, have been considered to play a determinant role in anxiety and depression, sleep and cognitive disorders in elderly individuals (Almeida, 2014; Tsolaki et al., 2009; Yaremchuk, 2018). Although dietary factors have been estimated to be responsible in 2017, globally, for 11 million deaths and 255 million disability-adjusted life-years, with cardiovascular disease being the leading cause of diet-related deaths (GBD 2017 Diet Collaborators, 2019), these figures probably underestimate the burden of dietary risks toward other health conditions, including mental and cognitive disorders indeed. Diet plays an important role in the growing older population, being one of the most important factors to preserve health and lead to a healthy aging. The concept of inflammaging, considered as a progressive cellular senescence mimicking low-grade chronic inflammation associated with growing age, provides the rationale for the role of nutrition in affecting pro-inflammatory stimuli and lowering the exposure to an activated immune system (Di Giosia et al., 2022). Such a process is also affecting the brain health, which in time may lead to disruption of autophagy pathway, impaired neurogenesis and decreased synaptic plasticity, mitochondrial dysfunction due to oxidative stress, and alteration of the cerebral blood flow, all processes related to neurodegeneration and neurodegenerative conditions (Caruso et al., 2022).

Among the dietary patterns potentially associated with healthy aging, the Mediterranean diet is certainly among the most successfully investigated (Capurso et al., 2020). Such a dietary pattern refers to a variety of dietary features characteristic of individuals living in the Mediterranean area when studied in the '60s by American physiologist Ancel Keys (Martini and Bes-Restrollo, 2020). The defining concepts of the Mediterranean diet have then evolved over the following decades, and despite there are no univocal dietary habits across population living in the Mediterranean area, there are though some common aspects broadly accepted as the main characteristics of the Mediterranean diet: consumption of (whole) grains, fruit and vegetable occurs on daily basis and represent major sources of fiber, vitamins and minerals together with legumes, seeds and nuts, which are frequently consumed as well; olive oil represents the main dressing and source of fats; fish, dairy products, and eggs are preferred over meats as dietary sources of proteins and healthy fats; processed meats and sweets are rather limited; finally, moderate alcohol consumption (mainly from wine) during meals also characterized such dietary pattern in the southern European region (Sotos-Prieto et al., 2022). Other aspects have also been taken into account when describing the Mediterranean diet, such as promotion of conviviality, family values, and social integration (Sotos-Prieto et al., 2022). Taking all these features together, higher adherence to the Mediterranean diet has been associated with successful aging, prolonged lifespan, and better mental health in older individuals worldwide.

Comprehensive reviews of the scientific literature show consistent evidence that healthy dietary patterns characterized by plant-based natural foods (i.e., the Mediterranean diet) may lead to a better cognitive status and mental health among older individuals (Chen et al., 2019; Gauci et al., 2022). Dietary factors have also been associated with overall quality of life and healthy aging (Dominguez et al., 2021). However, only a relatively limited number of studies have been conducted in people actually living in the Mediterranean area where adherence to the Mediterranean diet is still relatively preserved (Grosso et al., 2014a). The aim of this study was to assess the association between adherence to the Mediterranean diet and various age-related health outcomes, with focus on mental status and cognitive health, in older Italian adults living in a Mediterranean island.

2. Materials and methods

2.1. Study population

The Mediterranean healthy Eating, Aging, and Lifestyle (MEAL) study is an observational study investigating the association between Mediterranean dietary and lifestyle habits and chronic diseases. A detailed protocol of this study is published elsewhere (Grosso et al., 2017). In brief, a sample of 2044 men and women aged 18 or more years old was randomly selected and enrolled between 2014 and 2015 in the main districts of Catania, a city of southern Italy. The sampling was performed by using the list of registered records of local general practitioners. Data were stratified by 10-year age groups and sex. In order to provide a specific relative precision of 5 % (Type I error, 0.05; Type II error, 0.10), considering an anticipated 70 % participation rate, the theoretical sample size was estimated to 1500 individuals. In detail, 2405 subjects were invited to participate in the study, 2044 participants accepted (response rate of 85 %), while 361 individuals refused. The aims of the study were explained in detail to all participants, who gave their written informed consent. All the procedures were performed in agreement with the Declaration of Helsinki (1989) of the World Medical Association. The study protocol has been revised and authorized by the concerning ethical committee.

2.2. Data collection

Face-to-face personal interviews were conducted and an electronic data collection was implemented with the use of tablet computers. All participants were provided with a paper copy of the questionnaire to better visualize the response options, but the final answers were registered by the interviewer personally. The following background data were collected: sex, age at recruitment, highest degree of education, current occupation (or longest occupation during life if retired), physical activity level, and smoking status. Educational status was categorized as (i) low (primary/secondary), (ii) medium (high school), and (iii) high (university). Occupational status was categorized as (i) unemployed, (i) low, (ii) medium, and (high). International Physical Activity Questionnaires (IPAQ) was used to estimate the physical activity level (Craig et al., 2003). According to IPAQ, physical activity was categorized as (i) low, (ii) moderate, and (iii) high. Smoking status was classified as being a (i) non, (ii) former-, or (iii) current smoker.

2.3. Dietary assessment

The dietary intake was assessed using two versions of food frequency questionnaires (FFQs), a long and a short version (Buscemi et al., 2015; Marventano et al., 2016), previously validated in the Sicilian population. The consumption of seasonal foods refers to the intake during the period in which the food was available and then adjusted by its proportional intake in one year. Employing the determination of the food intake, the energy content as well as the macro- and micro-nutrients intake was calculated through a comparison with food composition tables of Council for Research in Agriculture and Analysis of Agricultural Economy (CREA) (*Tabelle Composizione Degli Alimenti CREA*, n.d.). Phenol-Explorer database was used to estimate (poly)phenol intake, as previously reported in detail (Godos et al., 2017a). Specifically, the individual food consumption (in ml or g) was obtained for each participant of the study by following the standard portion sizes converted to 24 h intake; next, the databases were searched to obtain average values for the energy content, macro-, micronutrients and (poly)phenols contained in the foods (per 100 ml or g). Finally, the energy, nutrient and (poly)

phenol intake from each food was calculated by multiplying the content of each variable by the daily consumption of each food (Godos et al., 2017b). FFQs with lacking data or unreliable intakes (<1000 or >6000 kcal/day) were excluded from the analyses (n = 198) leaving a total of 1846 individuals. The variables of interest were intake of tea, coffee (espresso/stovetop), red and white wine, beer, and fruit juice (fresh citrus juice). Consumption of each beverage was finally classified to three levels: (i) no consumption, (ii) up to 1 cup/day, and (iii) >1 cup/day.

2.4. Adherence to the Mediterranean diet

Adherence to the Mediterranean diet was assessed using a literature-based score (Marventano et al., 2018). The score was built by assigning two points for the highest category, one point for the middle category, and 0 point for the lowest category of consumption of food groups being representative for the Mediterranean diet, such as fruit, vegetables, legumes, cereals, fish, and olive oil, and two points were given for the lowest category, one point for the middle category, and 0 point for the highest category of consumption of food groups not representing it, such as meat and dairy products; moderate alcohol intake was deemed as optimal for higher adherence. The final score comprises nine food categories with a score ranging from 0 point (lowest adherence) to 18 points (highest adherence). Individuals were categorized in the following tertiles: (i) low, (ii) medium, and (iii) high adherence to the Mediterranean diet.

2.5. Mental health status assessment

Participants' sleep quality was evaluated using the Pittsburgh sleep quality index (PSQI) (Buysse et al., 1989). The questionnaire consists of 19 items classified on a four-point scale (0–3) and clustered into seven domains (sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medications, and daytime dysfunction). The item scores in each component were summed and converted into domain scores ranging from 0 (better) to 3 (worse) based on guidelines. The total PSQI score was obtained by calculating the sum of the seven domain scores. The global PSQI score ranges from 0 to 21 points, with a higher score indicating worse sleep quality. A result of <5 on global PSQI score is indicative of adequate sleep quality.

In order to evaluate depressive symptoms, the Center for the Epidemiological Studies of Depression Short Form (CES-D-20) was used (Radloff, 1991). Briefly, CES-D consists of 20 items commonly used to screen for depressive symptoms in the general population. Each item of the scale rates the frequency of each mood or symptom 'during the past week' on a 4-point scale ranging from 0 (rarely or none of the time [<1 day]) to 3 (most or all of the time [5–7 days]). A score is assigned by totaling all items (after reversing the positive mood items); total scores can range from 0 to 30, with higher scores suggesting greater severity of symptoms, and a score ≥ 16 indicating as having depressive symptoms (Kozela et al., 2016; Lewinsohn et al., 1997). Eventually with exclusion of individuals who do not fall within the considered criteria about the mental and sleep health assessment, a total sample of 1572 was included in the final analysis.

2.6. Cognitive status assessment

Cognitive health was evaluated using the Short Portable Mental Status Questionnaire (SPMSQ), a 10-item tool administered by the clinician in the office or in a hospital (Pfeiffer, 1975). The pre-defined categories for interpretation of the screening tool were (i) intact status, <3 errors; (ii) mild impaired, 3 to 4 errors; (iii) moderate impaired, 5 to 7 errors, and (iv) severe impaired status, 8 or more errors. For this study, we considered severe impaired status as cut off point for impaired cognitive health.

2.7. Quality of life assessment

The Manchester Short Assessment of Quality of Life (MANSA) (Priebe et al., 1999), an instrument that consists of 12 subjective items with a seven-point Likert scale (from "could not be worse" to "could not be better") and four yes/no questions related to objective aspects of social life, assessed quality of life. The instrument assesses satisfaction with life as a whole and across several specific domains (including employment, financial situation, friendships, leisure activities, accommodation, personal safety, people living in household/living alone, sex life, relationship with family, and physical and mental health). An overall satisfaction with overall quality of life was arbitrarily defined as being in the highest quartile of the MANSA score (>70 points).

2.8. Successful aging assessment

Successful aging is a multifactorial condition with no univocal definition, however comprising biomedical, social functioning, psychological and subjective dimensions. Based on this multi-dimensional approach, a previously developed and validated successful aging index (SAI) was used to assess successful aging (Tyrovolas et al., 2014). Briefly, SAI includes health-related, social-, lifestyle- and clinical factors, including education, financial status, physical activity, BMI, depressive symptoms, engagement in social activities with friends and family, number of yearly excursions, total number of clinical cardiovascular risk factors (i.e., history of hypertension, diabetes, hypercholesterolemia and obesity) and level of adherence to the Mediterranean diet. For the purposes of the present work, adherence to the Mediterranean diet was excluded from the calculation of SAI since it represents our variable of exposure and thus used as an independent factor in the analyses. Moreover, "number of yearly excursions" was a rather specific question that was generalized as "number of highly intense out-of-home sport activities". Each domain provided a variety of responses categorized as in the original study (Tyrovolas et al., 2014) ranging from 0 to 1. The final SAI could range from 0 to 9, with a score higher than 4.5 considered as successful aging.

2.9. Statistical analysis

The sample was categorized in quartiles of Mediterranean diet adherence score. Categorical variables are presented as absolute numbers and relative frequencies (%), continuous variables are reported as means and standard deviations. Differences between groups of categorical and continuous variables were tested by Chi-square and ANOVA tests (or Kruskal–Wallis test for variables not normally distributed), respectively. Logistic regression analyses were conducted to calculate the odds ratios (ORs) and 95 % confidence intervals (CIs) for the association between adherence to the Mediterranean diet and the variety of outcomes investigated. The associations with depressive symptoms, sleep quality, cognitive status, and quality of life were calculated based on fitted unadjusted (Model 1) and multivariate logistic regression models, including sex, age, educational status, occupational status, smoking status, physical activity level (Model 2) and breakfast skipping, snacking habits, dinner skipping, and marital status (Model 3). A final age- and sex-adjusted logistic regression model was fit to predict the association between adherence to the Mediterranean diet and SAI (the analysis was not adjusted for the other variables because in large part already included in the score). The significance level was set at 0.05 and all reported P-values were based on two-sided tests. Analyses were performed using the SPSS version 27 (SPSS Inc., Chicago, IL, USA).

3. Results

The background characteristics of the study sample by quartiles of adherence to the Mediterranean diet are presented in Table 1. There was a significantly higher proportion of married participants, never smokers,

Table 1
Baseline characteristics of the study sample of Italian older adults (n = 883) according to quartiles of adherence to the Mediterranean diet.

	Mediterranean diet adherence				P-value
	Q1	Q2	Q3	Q4	
Age, mean (SD)	65.4 (10.5)	65.8 (10.0)	63.8 (8.6)	65.3 (9.5)	0.056
Sex, n (%)					0.223
Men	68 (40.5)	104 (40.5)	155 (47.8)	55 (41.0)	
Women	100 (59.5)	153 (59.5)	169 (52.2)	79 (59.0)	
Marital status, n (%)					0.040
Unmarried/ widowed	55 (32.7)	89 (34.6)	81 (25.0)	47 (35.1)	
Married	113 (67.3)	168 (65.4)	243 (75.0)	87 (64.9)	
Smoking status, n (%)					0.003
Never	86 (51.2)	158 (61.5)	181 (55.9)	72 (53.7)	
Current	39 (23.2)	47 (18.3)	58 (17.9)	43 (32.1)	
Former	43 (25.6)	52 (20.2)	85 (26.2)	19 (14.2)	
Educational level, n (%)					0.118
Low	82 (48.8)	140 (54.5)	170 (52.5)	59 (44.0)	
Medium	50 (29.8)	82 (31.9)	98 (30.2)	55 (41.0)	
High	36 (21.4)	35 (13.6)	56 (17.3)	20 (14.9)	
Occupational level, n (%)					0.617
Unemployed	36 (23.2)	66 (30.7)	69 (24.6)	32 (26.0)	
Low	29 (18.7)	31 (14.4)	48 (17.1)	27 (22.0)	
Medium	50 (32.3)	66 (30.7)	82 (29.3)	36 (29.3)	
High	40 (25.8)	52 (24.2)	81 (28.9)	28 (22.8)	
Physical activity level, n (%)					<0.001
Low	41 (27.5)	68 (31.5)	67 (23.3)	20 (20.6)	
Medium	89 (59.7)	103 (47.7)	135 (47.0)	43 (44.3)	
High	19 (12.8)	45 (20.8)	85 (29.6)	34 (35.1)	
Eating habits, n (%)					
Skipping breakfast	145 (86.3)	213 (82.9)	259 (79.9)	85 (63.4)	<0.001
Daily snaking	57 (33.9)	88 (34.2)	118 (36.4)	60 (44.8)	0.172
Skipping dinner	165 (98.2)	250 (97.3)	318 (98.1)	126 (94.0)	0.077

with medium physical activity level among individuals with the highest adherence to the Mediterranean diet; moreover, breakfast skippers were more frequent among participants with the lowest adherence.

Concerning the intake of micro-, macronutrients and major food groups in the study sample, individuals in the highest quartile of adherence to the Mediterranean diet reported having significantly higher energy intake and of carbohydrates, fiber, protein, total PUFA (and specifically omega-3 fatty acids), vitamin A, C, E, sodium and potassium, and consuming more cereals, fruits, vegetables, legumes, olive oil, and less meat and dairy products (Table 2). Also intake of total and major classes of (poly)phenols (including flavonoids, stilbenes, and lignans) was higher among individuals in the highest quartiles of Mediterranean diet adherence (Table 2).

Fig. 1 shows the distribution of the PSQI, CES-D, SPSMQ, and MANSA scores by quartiles of Mediterranean diet adherence score. A significant different distribution was found for CES-D scores (Q1 = 14.9

Table 2
Mean (and standard deviation) consumption of micro-, macro-nutrients and major food groups intake according to quartiles adherence to the Mediterranean diet.

	Mediterranean diet adherence				P-value
	Q1	Q2	Q3	Q4	
	Mean (SD)				
Energy intake (kcal/day)	1824.6 (551.4)	1971.8 (779.0)	2105.0 (598.8)	2334.4 (481.5)	<0.001
Energy intake (kJ/day)	7303.7 (2226.0)	7967.3 (3186.9)	8550.3 (2458.6)	9559.5 (1999.1)	<0.001
Macronutrients					
Carbohydrates (g/day)	248.4 (89.4)	287.7 (119.8)	310.3 (102.5)	368.4 (91.0)	<0.001
Fiber (g/day)	22.5 (11.5)	30.2 (13.2)	36.3 (13.4)	41.5 (9.1)	<0.001
Protein (g/day)	77.0 (31.1)	81.8 (32.7)	87 (26.2)	94.9 (18.3)	<0.001
Fat (g/day)	58.5 (21.1)	58.0 (27.5)	60.5 (19.4)	60.8 (16.6)	0.457
Cholesterol (mg/day)	203.3 (107.5)	184.4 (92.2)	184.7 (76.8)	186.3 (65.9)	0.102
SFA (%)	23.8 (9.5)	22.9 (11.1)	23.7 (8.7)	23.9 (7.6)	0.675
MUFA (%)	24.3 (8.3)	24.7 (11.5)	25.7 (7.4)	27.0 (6.0)	0.027
PUFA (%)	9.9 (4.0)	10.8 (5.4)	11.2 (4.0)	12.2 (3.3)	<0.001
Omega-3 PUFA (%)	1.6 (1.0)	1.7 (0.9)	1.8 (0.7)	2.0 (0.7)	<0.001
Micronutrients					
Vitamin A (Retinol)	672.7 (387.7)	841.7 (448.4)	920.9 (392.4)	1053.2 (386.0)	<0.001
Vitamin C (mg/day)	106.0 (73.0)	150.2 (95.3)	174.5 (103.5)	207.8 (73.3)	<0.001
Vitamin E (mg/day)	7.3 (3.1)	8.3 (3.8)	9.1 (2.8)	10.0 (2.4)	<0.001
Vitamin B12	6.7 (5.4)	6.1 (4.8)	6.0 (3.8)	5.9 (2.4)	0.248
Vitamin D	5.6 (6.8)	5.6 (6.0)	5.6 (4.8)	6.1 (4.3)	0.830
Sodium (mg/day)	2553.2 (992.5)	2703.9 (1221.4)	2766.9 (1030.1)	3112.4 (979.9)	<0.001
Potassium (mg/day)	2978.7 (1261.4)	3564.0 (1428.7)	3932.5 (1351.4)	4219.1 (787.8)	<0.001
(Poly)phenols					
Total (poly) phenols (mg/day)	542.1 (480.8)	630.0 (509.4)	675.6 (382.7)	658.9 (371.6)	0.014
Flavonoids (mg/day)	206.1 (157.8)	229.1 (188.2)	267.4 (187.5)	286.1 (138.4)	<0.001
Phenolic acids (mg/day)	308.8 (430.2)	361.7 (421.6)	362.5 (263.5)	326.6 (315.8)	0.334
Stilbenes (mg/day)	2.95 (4.58)	2.11 (3.96)	2.47 (3.88)	1.50 (2.90)	0.010
Lignans (mg/day)	1.83 (2.09)	2.65 (2.79)	3.23 (2.51)	3.67 (2.26)	<0.001
Foods					
Cereals (g/day)	169.6 (115.8)	211.8 (133.2)	231.6 (114.7)	321.0 (136.6)	<0.001
Vegetables (g/day)	184.8 (147.7)	250.3 (127.1)	284.3 (145.9)	323.0 (128.5)	<0.001
Fruit (g/day)	223.8 (192.9)	381.5 (334.7)	477.7 (340.8)	520.1 (227.9)	<0.001
Legumes (g/day)	23.3 (35.5)	31.3 (28.2)	46.3 (40.2)	46.5 (30.9)	<0.001
Nuts (total, g/day)	20.5 (39.7)	22.4 (38.1)	20.7 (22.8)	17.4 (26.9)	0.532
Fish (g/day)	60.3 (80.7)	61.6 (64.5)	66.0 (54.8)	77.9 (47.5)	0.058
Eggs (g/day)	2.7 (4.7)	2.9 (5.4)	2.5 (4.8)	2.7 (5.1)	0.862
Meat (total, g/day)	80.0 (39.9)	70.9 (43.5)	67.1 (36.3)	56.8 (33.0)	<0.001
Red meat (g/day)	36.9 (25.9)	34.6 (29.6)	32.0 (24.8)	28.0 (21.5)	0.019
Processed meat (g/day)	15.9 (18.3)	13.5 (20.2)	12.7 (14.9)	12.3 (11.9)	0.189
					<0.001

(continued on next page)

Table 2 (*continued*)

	Mediterranean diet adherence				P-value
	Q1	Q2	Q3	Q4	
	Mean (SD)				
Dairy products (g/day)	246.4 (202.0)	223.3 (200.4)	170.5 (139.8)	107.3 (82.7)	
Alcohol (total, g/day)	10.5 (14.7)	7.9 (13.0)	8.8 (12.2)	5.0 (9.6)	0.002
Olive oil (ml/day)	5.9 (3.6)	6.8 (3.1)	7.7 (2.8)	9.3 (1.7)	<0.001

± 8.8 vs. Q4 = 11.4 ± 6.7, P = 0.001), SPSMQ scores (Q1 = 7.8 ± 2.0 vs. Q4 = 8.6 ± 1.5, P < 0.001), and MANSA scores (Q1 = 57.7 ± 8.4 vs. Q4 = 62.5 ± 16.2, P < 0.001). No significant differences in PSQI scores were observed.

The association between adherence to the Mediterranean diet and the outcomes investigated is presented in Table 3. After adjustment for potential confounding factors, individuals in the highest quartile of adherence to the Mediterranean diet were less likely to have cognitive impairment (OR = 0.19, 95 % CI: 0.04, 0.86), depressive symptoms (OR = 0.19, 95 % CI: 0.08, 0.46) and more likely to have good quality of life (OR = 14.04, 95 % CI: 6.81, 28.93); significant results were also found for individuals in the third quartile of Mediterranean diet adherence and good sleep quality (OR = 1.65, 95 % CI: 1.03, 2.64). When considering the Mediterranean diet adherence score as a continuous variable, 1-point increase was significantly associated with 11 % reduction and 53 % increase likelihood of cognitive impairment and good quality of life, respectively (OR = 0.89, 95 % CI: 0.80, 0.99 and OR = 1.53, 95 % CI: 1.37, 1.71, respectively). Significant associations were also found for the association between adherence to the Mediterranean diet and likelihood of having depressive symptoms and good sleep quality in less adjusted model models (Table 3).

The age- and sex-adjusted association between adherence to the Mediterranean diet and SAI by quartiles is presented in Fig. 2: individuals in the highest quartile of adherence were more likely to have a successful aging (OR = 1.65, 95 % CI: 1.01, 2.68). When considering adherence to the Mediterranean diet as a continuous variable, 1-point increase in the Mediterranean diet adherence score was associated with 10 % higher likelihood of successful aging (OR = 1.10, 95 % CI: 1.03, 1.17). A sensitivity analysis conducted by excluding one component of the score at a time showed no substantial differences from the main analysis except for exclusion of moderate alcohol component (leading to null results) (Supplementary Table 1). When exploring the association of the individual components of the score with SAI, some components (including vegetable, moderate alcohol, legumes, and limited meat) were independently associated with successful aging (Supplementary Table 1).

4. Discussion

The present study investigated the relation between adherence to the Mediterranean diet and a variety of outcomes related to mental and cognitive health, as well as overall quality of life in older Italian individuals. The findings showed a consistent association with better cognition, lower depressive symptoms, and improved overall quality of life in individuals reporting higher adherence to the Mediterranean diet compared to those less adherent; a significant association was found for sleep quality, although not showing a linear trend. The results are in line with previous data from the scientific literature reporting a positive relation between adherence to the Mediterranean diet and older adults' global cognition (Loughrey et al., 2017) and better self-rated health and quality of life (Govindaraju et al., 2018; Godos et al., 2019). Other summary of evidence emphasized a more holistic evaluation of older people's health, yet showing a relation between higher adherence to the Mediterranean diet and greater likelihood of successful aging (Critselis and Panagiotakos, 2020). Individual studies conducted in the Mediterranean area are relatively scarce, though. Reports from the ATTICA (n =

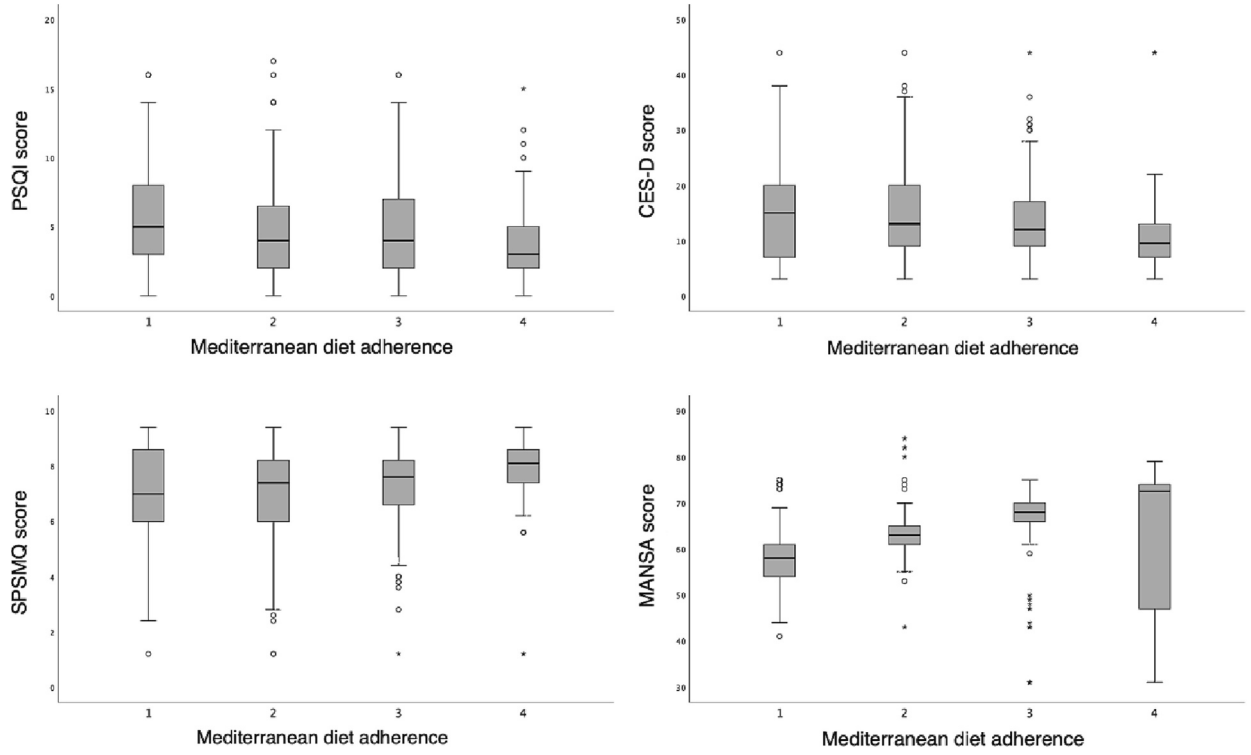


Fig. 1. Mean differences of Pittsburgh sleep quality index (PSQI) (P = 0.248), Center for the Epidemiological Studies of Depression Short Form (CES-D-20) (P = 0.001), the Short Portable Mental Status Questionnaire (SPMSQ) (P < 0.001), and Manchester Short Assessment of Quality of Life (MANSA) (P < 0.001) scores by quartiles of Mediterranean diet adherence scores.

Table 3
Association between adherence to the Mediterranean diet, mental and cognitive health, and quality of life in the study sample.

	OR (95 % CI)				1-point increase
	Q1	Q2	Q3	Q4	
Cognitive impairment					
Model 1	1	0.91 (0.51, 1.63)	0.55 (0.30, 1.02)	0.20 (0.07, 0.61)	0.84 (0.77, 0.92)
Model 2	1	1.04 (0.53, 2.07)	0.70 (0.35, 1.40)	0.17 (0.04, 0.77)	0.87 (0.78, 0.97)
Model 3	1	1.09 (0.54, 2.21)	0.81 (0.40, 1.65)	0.19 (0.04, 0.86)	0.89 (0.80, 0.99)
Depressive symptoms					
Model 1	1	0.95 (0.63, 1.46)	0.61 (0.40, 0.94)	0.24 (0.12, 0.46)	0.91 (0.85, 0.97)
Model 2	1	1.62 (0.71, 1.89)	0.71 (0.44, 1.14)	0.18 (0.08, 0.41)	0.92 (0.85, 0.99)
Model 3	1	1.17 (0.71, 1.93)	0.77 (0.47, 1.26)	0.19 (0.08, 0.46)	0.94 (0.87, 1.02)
Sleep quality (good)					
Model 1	1	1.10 (0.74, 1.66)	1.47 (0.99, 2.19)	1.53 (0.94, 2.51)	1.06 (1.00, 1.13)
Model 2	1	1.01 (0.62, 1.62)	1.63 (1.02, 2.59)	1.83 (0.98, 3.41)	1.08 (1.01, 1.16)
Model 3	1	0.99 (0.61, 1.60)	1.65 (1.03, 2.64)	1.72 (0.90, 3.27)	1.08 (0.99, 1.16)
Quality of life (good)					
Model 1	1	0.44 (0.21, 0.93)	3.94 (2.29, 6.77)	13.56 (7.44, 24.72)	1.62 (1.47, 1.78)
Model 2	1	0.27 (0.10, 0.71)	3.77 (2.08, 6.83)	13.25 (6.55, 26.78)	1.52 (1.37, 1.70)
Model 3	1	0.27 (0.10, 0.72)	3.80 (2.09, 6.92)	14.04 (6.81, 28.93)	1.53 (1.37, 1.71)

Model 1: unadjusted.
Model 2: adjusted for sex, age, educational status, occupational status, smoking status, physical activity level.
Model 3: adjusted as model 2 plus breakfast skipping, snacking habits, dinner skipping, and marital status.

1128) and MEDIS (MEDiterranean Islands Study, n = 2221) epidemiological studies (including participants >50 years) showed that higher adherence to the Mediterranean diet was positively associated with successful aging (beta = 0.107, 95 % CI: 0.079, 0.135 linear association per 1-point increase) (Foscolou et al., 2020), although the association was more consistent when considering individuals living in the Mediterranean islands compared to those living abroad (Papadimitriou et al., 2021). Another report from the Israeli National Health and Nutrition Survey of Older Adults (1770 individuals aged >65 years) reported that better diet quality (assessed through the Healthy Eating Index) was positively associated with successful aging (OR = 1.73, 95 % CI, 1.10, 2.72 for the upper vs. the lowest tertile) (Goshen et al., 2022). Finally, a study from the SU.VI.MAX. cohort (conducted on 3012 individuals aged 45–60 years living in France) evaluating a variety of dimensions fulfilling a definition of healthy aging showed that higher adherence to the Mediterranean diet was associated with higher odds of healthy aging (OR = 1.36, 95 % CI: 1.12, 1.65 or the upper vs. the lowest tertile) (Assmann et al., 2018).

With major reference to mental and cognitive health, there is growing and consistent evidence that dietary factors may play an important role on brain health (McGrattan et al., 2019). Nutrients may exert a variety of pro- or anti-inflammatory actions (Grosso et al., 2022) as well as specific function in the central nervous system (Bourre, 2006a, 2006b), which may provide a rationale for the mechanisms behind the relation between diet and mental health (Siervo et al., 2021). The Mediterranean diet is a largely plant-based dietary pattern, supposedly rich in fruits, vegetables, whole-grain products, and legumes; these foods are all characterized by a high content in fibers, which exert a variety of beneficial effects on metabolic health and, lately, also discovered to potentially affect the central nervous system through the so-called gut-brain axis (Berding et al., 2021). Specifically, fiber is an undigested carbohydrate that modify the gut microbiota profile toward more beneficial patterns of microbial families; such dietary component leads to higher production of butyrate, a short-chain fatty acid (SCFA) able to reduce the inflammatory response to lipopolysaccharides, a pro-inflammatory bacterial factor that may pass through the intestinal mucosa and induce a local and systemic inflammatory response (Grosso et al., 2022).

Richness in plant-derived foods may also lead to higher intake of minerals, vitamins, and (poly)phenols that play a role in brain health.

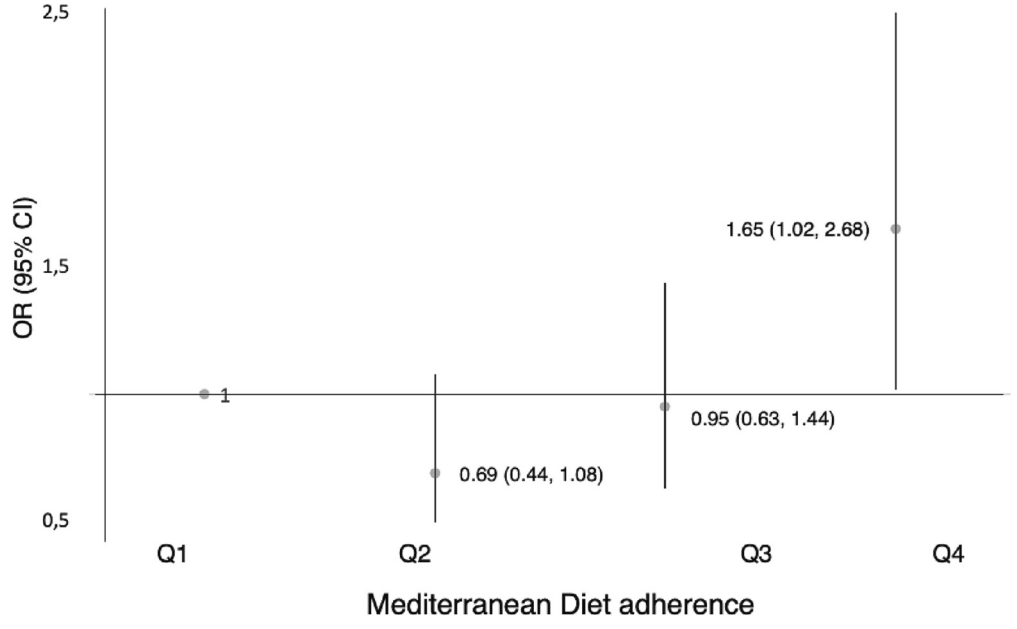


Fig. 2. Age- and sex-adjusted association between adherence to the Mediterranean diet and successful aging index (SAI). OR, odds ratio; CI, confidence interval.

Among vitamins, group B vitamins, antioxidant vitamins (such as vitamin C and vitamin E), vitamin D and vitamin K are involved in nervous tissue biochemistry (Bourre, 2006a). Minerals, such as magnesium, zinc, and selenium play a role in antioxidant cellular defenses that may also help with brain functioning (Tardy et al., 2020). (Poly)phenols, a group of compounds derived from plants and widely represented in common diets, have been reported to exert neuroprotection through a combination of antioxidant, anti-inflammatory, anti-apoptotic, and anti-aggregation activities (Caruso et al., 2022).

Healthy fats typically characterized in the Mediterranean diet, such as mono- and poly-unsaturated fatty acids (MUFA and PUFA, respectively) contained in olive oil, fish, seeds and nuts, have been shown to exert active functions in brain cells (Grosso et al., 2014b). Omega-3 PUFA docosahexanoic acid (DHA) and eicosapentaenoic acid (EPA) are important to preserve the integrity, fluidity, and functioning of the neuronal cellular membrane, as well as to counteract neuro-inflammatory processes (Custers et al., 2022). MUFA highly represented in olive oil, such as oleic acid, have also demonstrated to exert anti-inflammatory properties (Custers et al., 2022). In contrast, higher adherence to the Mediterranean diet is associated with lower intake of refined sugars and trans-fats (and moderate consumption of saturated fats, preferably from dairy products) (Real et al., 2020). These dietary components may promote pro-inflammatory processes across systems, also impacting the brain and establishing a substrate to develop consequent pathological conditions, neurodegeneration, and impaired cognition (Capucho et al., 2022; Yeomans, 2017). Moreover, unhealthy fats have also been demonstrated to alter the vascular components of the brain, such as impairment of blood-brain barrier integrity and reduced cerebral blood flow (Sharma, 2021).

Recently, also non-nutritional dimensions of diet, such as level of food processing and content in additives, have been investigated in relation to adherence to the Mediterranean diet, showing that higher adherence is generally related to lower consumption of ultra-processed foods (UPFs) (Godos et al., 2022). Asides from their widely demonstrated poor nutritional content (Martini et al., 2021), UPFs may contain additives containing nanoparticles that may accumulate in certain brain areas, such as hippocampus, and alter neurotransmitters functioning and cerebral functions, such as learning, memory, and spatial recognition (Mantovani et al., 2022). Moreover, some compounds providing organoleptic, consistence, and flavor features to UPFs have been shown to promote oxidative stress and pro-inflammatory cellular pathways (Lau et al., 2006). A recent study demonstrated that excess consumption of UPFs of the diet predict shorter lifespan irrespectively of its nutritional quality, suggesting that both dimensions are important for a healthy aging and longevity (Bonaccio et al., 2022). As UPFs are generally less consumed among older individuals, it may be important to promote the maintenance of traditional dietary patterns in order to avoid the shift toward use of unhealthy UPFs among future generations of older people.

The results reported in this study should be interpreted in light of the following limitations. As most of the previous published studies, the findings refer to cross-sectional analyses, which do not allow to assess causality but only relations between exposure and outcomes. Moreover, although various factors have been considered as potential confounders, we cannot rule out the possibility that other unmeasured variables may play a role in composite outcomes, such as healthy successful aging. Among other limitations related to the methodology, the dietary assessment may suffer from recall and social desirability bias, leading to under- or overestimation of dietary intakes. Finally, the instrument used to assess successful aging was not validated for the Italian population; although generally used in various countries, as it refers to biological variables rather than factors affected by nationality, its application may not be necessarily optimal due to unmeasured issues.

In conclusion, this study supports the hypothesis that adherence to the Mediterranean diet provides a positive trajectory toward a healthy successful aging, with major potential benefits toward mental and cognitive health. Future studies should better elucidate which dimensions would better describe a healthy successful aging in order to develop more accurate measurements methods. Besides the role of the Mediterranean diet, also studies on healthy eating conducted in older populations outside the Mediterranean area should be further developed.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2023.112143.

Financial support

This work was supported by the Distinguished Scientist Fellowship Program (DSFP) at King Saud University, Riyadh, Saudi Arabia. J.G. was supported by the co-financing of the European Union—FSE-REACT-EU, PON Research and Innovation 2014–2020 DM1062/2021; CUP: E65F21002560001.

Declaration of competing interest

Authors declare no conflict of interest.

References

Almeida, O.P., 2014. Prevention of depression in older age. Maturitas 79 (2), 136–141. https://doi.org/10.1016/j.maturitas.2014.03.005.

Assmann, K.E., Adjibade, M., Andreeva, V.A., Hercberg, S., Galan, P., Kesse-Guyot, E., 2018. Association between adherence to the mediterranean diet at midlife and healthy aging in a cohort of french adults. J. Gerontol. A Biol. Sci. Med. Sci. 73 (3), 347–354. https://doi.org/10.1093/gerona/glx066.

Berding, K., Carbia, C., Cryan, J.F., 2021. Going with the grain: fiber, cognition, and the microbiota-gut-brain-axis. Exp. Biol. Med. 246 (7), 796–811. https://doi.org/10.1177/1535370221995785.

Bonaccio, M., Di Castelnuovo, A., Ruggiero, E., Costanzo, S., Grosso, G., De Curtis, A., Cerletti, C., Donati, M.B., de Gaetano, G., Iacoviello, L., Moli-sani Study Investigators, 2022. Joint association of food nutritional profile by Nutri-Score front-of-pack label and ultra-processed food intake with mortality: Moli-sani prospective cohort study. BMJ (Clinical Research Ed.) 378, e070688. https://doi.org/10.1136/bmj-2022-070688.

Bourre, J.M., 2006a. Effects of nutrients (in food) on the structure and function of the nervous system: update on dietary requirements for brain. Part 1: micronutrients. J. Nutr. Health Aging 10 (5), 377–385.

Bourre, J.M., 2006b. Effects of nutrients (in food) on the structure and function of the nervous system: update on dietary requirements for brain. Part 2: macronutrients. J. Nutr. Health Aging 10 (5), 386–399.

Buscemi, S., Rosafio, G., Vasto, S., Massenti, F.M., Grosso, G., Galvano, F., Rini, N., Barile, A.M., Maniaci, V., Cosentino, L., Verga, S., 2015. Validation of a food frequency questionnaire for use in Italian adults living in Sicily. Int. J. Food Sci. Nutr. 66 (4), 426–438. https://doi.org/10.3109/09637486.2015.1025718.

Buysse, D.J., Reynolds, C.F., Monk, T.H., Berman, S.R., Kupfer, D.J., 1989. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiatry Res. 28 (2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4.

Capucho, A.M., Chegão, A., Martins, F.O., Vicente Miranda, H., Conde, S.V., 2022. Dysmetabolism and neurodegeneration: trick or treat? Nutrients 14 (7). https://doi.org/10.3390/nu14071425.

Capurso, A., Crepaldi, G., Capurso, C., 2020. The Mediterranean diet: a pathway to successful aging. Aging Clin. Exp. Res. 32 (6), 1187–1188. https://doi.org/10.1007/s40520-019-01160-3.

Caruso, G., Torrisi, S.A., Mogavero, M.P., Currenti, W., Castellano, S., Godos, J., Ferri, R., Galvano, F., Leggio, G.M., Grosso, G., Caraci, F., 2022. Polyphenols and neuroprotection: therapeutic implications for cognitive decline. Pharmacol. Ther. 232, 108013 https://doi.org/10.1016/j.pharmthera.2021.108013.

Chen, X., Maguire, B., Brodaty, H., O'Leary, F., 2019. Dietary patterns and cognitive health in older adults: a systematic review. J. Alzheimers Dis. 67 (2), 583–619. https://doi.org/10.3233/JAD-180468.

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., Oja, P., 2003. International physical activity questionnaire: 12-country reliability and validity. Med. Sci. Sports Exerc. 35 (8), 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB.

Critselis, E., Panagiotakos, D., 2020. Adherence to the Mediterranean diet and healthy ageing: current evidence, biological pathways, and future directions. Crit. Rev. Food Sci. Nutr. 60 (13), 2148–2157. https://doi.org/10.1080/10408398.2019.1631752.

Custers, Emma, E.M., Kiliaan, Amanda, J., 2022. Dietary lipids from body to brain. Progress in Lipid Research 85, 101144. https://doi.org/10.1016/j.plipres.2021.101144.

Di Giosia, P., Stamerra, C.A., Giorgini, P., Jamialahamdi, T., Butler, A.E., Sahebkar, A., 2022. The role of nutrition in inflammaging. Ageing Res. Rev. 77, 101596 https://doi.org/10.1016/j.arr.2022.101596.

Dominguez, L.J., Di Bella, G., Veronese, N., Barbagallo, M., 2021. Impact of Mediterranean diet on chronic non-communicable diseases and longevity. Nutrients 13 (6). https://doi.org/10.3390/nu13062028.

Foscolou, A., D'Cunha, N.M., Naumovski, N., Tyrovolas, S., Chrysohoou, C., Rallidis, L., Polychronopoulos, E., Matalas, A.-L., Sidossis, L.S., Panagiotakos, D., 2020. The association between the level of adherence to the Mediterranean diet and successful aging: an analysis of the ATTICA and MEDIS (MEDiterranean Islands Study) epidemiological studies. Arch. Gerontol. Geriatr. 89, 104044 https://doi.org/10.1016/j.archger.2020.104044.

Friedrich, M.J., 2017. Depression is the leading cause of disability around the world. J. Am. Med. Assoc. 317 (15), 1517. https://doi.org/10.1001/jama.2017.3826.

Gauci, S., Young, L.M., Arnoldy, L., Lassemillante, A.-C., Scholey, A., Pipingas, A., 2022. Dietary patterns in middle age: effects on concurrent neurocognition and risk of age-related cognitive decline. Nutr. Rev. 80 (5), 1129–1159. https://doi.org/10.1093/nutrit/nuab047.

GBD 2017 Diet Collaborators, 2019. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet 393 (10184), 1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8.

GBD 2019 Dementia Forecasting Collaborators, 2022. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. The Lancet. Public Health 7 (2), e105–e125. https://doi.org/10.1016/S2468-2667(21)00249-8.

Godos, J., Castellano, S., Marranzano, M., 2019. Adherence to a Mediterranean dietary pattern is associated with higher quality of life in a cohort of Italian adults. Nutrients 11 (5). https://doi.org/10.3390/nu11050981.

Godos, J., Giampieri, F., Al-Qahtani, W.H., Scazzina, F., Bonaccio, M., Grosso, G., 2022. Ultra-processed food consumption and relation with diet quality and Mediterranean diet in southern Italy. Int. J. Environ. Res. Public Health 19 (18). https://doi.org/10.3390/ijerph191811360.

Godos, J., Marventano, S., Mistretta, A., Galvano, F., Grosso, G., 2017. Dietary sources of polyphenols in the Mediterranean healthy eating, aging and lifestyle (MEAL) study cohort. Int. J. Food Sci. Nutr. 68 (6), 750–756. https://doi.org/10.1080/09637486.2017.1285870.

Godos, J., Rapisarda, G., Marventano, S., Galvano, F., Mistretta, A., Grosso, G., 2017. Association between polyphenol intake and adherence to the Mediterranean diet in Sicily, southern Italy. NFS J. 8, 1–7. https://doi.org/10.1016/j.nfs.2017.06.001.

Goshen, A., Goldbourt, U., Benyamini, Y., Shimony, T., Keinan-Boker, L., Gerber, Y., 2022. Association of diet quality with longevity and successful aging in israeli adults 65 years or older. JAMA Netw. Open 5 (6), e2214916. https://doi.org/10.1001/jamanetworkopen.2022.14916.

Govindaraju, T., Sahle, B.W., McCaffrey, T.A., McNeil, J.J., Owen, A.J., 2018. Dietary patterns and quality of life in older adults: a systematic review. Nutrients 10 (8). https://doi.org/10.3390/nu10080971.

Grosso, G., Galvano, F., Marventano, S., Malaguarnera, M., Bucolo, C., Drago, F., Caraci, F., 2014. Omega-3 fatty acids and depression: scientific evidence and biological mechanisms. Oxidative Med. Cell. Longev. 2014, 313570 https://doi.org/10.1155/2014/313570.

Grosso, G., Laudisio, D., Frias-Toral, E., Barrea, L., Muscogiuri, G., Savastano, S., Colao, A., 2022. Anti-inflammatory nutrients and obesity-associated metabolic-inflammation: state of the art and future direction. Nutrients 14 (6). https://doi.org/10.3390/nu14061137.

Grosso, G., Marventano, S., D'Urso, M., Mistretta, A., Galvano, F., 2017. The Mediterranean healthy eating, ageing, and lifestyle (MEAL) study: rationale and study design. Int. J. Food Sci. Nutr. 68 (5), 577–586. https://doi.org/10.1080/09637486.2016.1262335.

Grosso, G., Marventano, S., Giorgianni, G., Raciti, T., Galvano, F., Mistretta, A., 2014. Mediterranean diet adherence rates in Sicily, southern Italy. Public Health Nutr. 17 (9), 2001–2009. https://doi.org/10.1017/S1368980013002188.

Kozela, M., Bobak, M., Besala, A., Micek, A., Kubinova, R., Malyutina, S., Denisova, D., Richards, M., Pikhart, H., Peasey, A., Marmot, M., Pająk, A., 2016. The association of depressive symptoms with cardiovascular and all-cause mortality in central and Eastern Europe: prospective results of the HAPIEE study. Eur. J. Prev. Cardiol. 23 (17), 1839–1847. https://doi.org/10.1177/2047487316649493.

Lau, K., McLean, W.G., Williams, D.P., Howard, C.V., 2006. Synergistic interactions between commonly used food additives in a developmental neurotoxicity test. Toxicol. Sci. 90 (1), 178–187. https://doi.org/10.1093/toxsci/kfj073.

Lewinsohn, P.M., Seeley, J.R., Roberts, R.E., Allen, N.B., 1997. Center for Epidemiologic Studies Depression Scale (CES-D) as a screening instrument for depression among community-residing older adults. Psychol. Aging 12 (2), 277–287. https://doi.org/10.1037//0882-7974.12.2.277.

Loughrey, D.G., Lavecchia, S., Brennan, S., Lawlor, B.A., Kelly, M.E., 2017. The impact of the Mediterranean diet on the cognitive functioning of healthy older adults: a systematic review and meta-analysis. Advances in Nutrition (BethesdaMd.) 8 (4), 571–586. https://doi.org/10.3945/an.117.015495.

Mantovani, A., Aquilina, G., Cubadda, F., Marcon, F., 2022. Risk-benefit assessment of feed additives in the one health perspective. Front. Nutr. 9, 843124 https://doi.org/10.3389/fnut.2022.843124.

Martini, D., Bes-Restrollo, M., 2020. Is Mediterranean diet still a common dietary pattern in the Mediterranean area? Int. J. Food Sci. Nutr. 71 (4), 395–396. https://doi.org/10.1080/09637486.2020.1763264.

Martini, D., Godos, J., Bonaccio, M., Vitaglione, P., Grosso, G., 2021. Ultra-processed foods and nutritional dietary profile: a meta-analysis of nationally representative samples. Nutrients 13 (10). https://doi.org/10.3390/nu13103390.

Marventano, S., Godos, J., Platania, A., Galvano, F., Mistretta, A., Grosso, G., 2018. Mediterranean diet adherence in the Mediterranean healthy eating, aging and lifestyle (MEAL) study cohort. Int. J. Food Sci. Nutr. 69 (1), 100–107. https://doi.org/10.1080/09637486.2017.1332170.

Marventano, S., Mistretta, A., Platania, A., Galvano, F., Grosso, G., 2016. Reliability and relative validity of a food frequency questionnaire for italian adults living in Sicily, southern Italy. Int. J. Food Sci. Nutr. 67 (7), 857–864. https://doi.org/10.1080/09637486.2016.1198893.

McGrattan, A.M., McGuinness, B., McKinley, M.C., Kee, F., Passmore, P., Woodside, J.V., McEvoy, C.T., 2019. Diet and inflammation in cognitive ageing and alzheimer's disease. Curr. Nutr. Rep. 8 (2), 53–65. https://doi.org/10.1007/s13668-019-0271-4.

Papadimitriou, A., Foscolou, A., Itsiopoulos, C., Thodis, A., Kouris-Blazos, A., Brazionis, L., Sidossis, A.C., Polychronopoulos, E.A., Kokkinos, P., Panagiotakos, D., Sidossis, L.S., 2021. Successful aging and lifestyle comparison of Greeks living in Greece and abroad: the epidemiological Mediterranean Islands study (MEDIS). Arch. Gerontol. Geriatr. 97, 104523 https://doi.org/10.1016/j.archger.2021.104523.

Pfeiffer, E., 1975. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. J. Am. Geriatr. Soc. 23 (10), 433–441. https://doi.org/10.1111/j.1532-5415.1975.tb00927.x.

Priebe, S., Huxley, P., Knight, S., Evans, S., 1999. Application and results of the Manchester short assessment of quality of life (MANSA). Int. J. Soc. Psychiatry 45 (1), 7–12. https://doi.org/10.1177/002076409904500102.

Radloff, L.S., 1991. The use of the Center for Epidemiologic Studies Depression Scale in adolescents and young adults. J. Youth Adolesc. 20 (2), 149–166. https://doi.org/10.1007/BF01537606.

Raven, F., Van der Zee, E.A., Meerlo, P., Havekes, R., 2018. The role of sleep in regulating structural plasticity and synaptic strength: implications for memory and cognitive function. Sleep Med. Rev. 39, 3–11. https://doi.org/10.1016/j.smrv.2017.05.002.

Real, H., Queiroz, J., Graça, P., 2020. Mediterranean food pattern vs. Mediterranean diet: a necessary approach? Int. J. Food Sci. Nutr. 71 (1), 1–12. https://doi.org/10.1080/09637486.2019.1617838.

Sharma, S., 2021. High fat diet and its effects on cognitive health: alterations of neuronal and vascular components of brain. Physiol. Behav. 240, 113528 https://doi.org/10.1016/j.physbeh.2021.113528.

Siervo, M., Shannon, O.M., Llewellyn, D.J., Stephan, B.C., Fontana, L., 2021. Mediterranean diet and cognitive function: from methodology to mechanisms of action. Free Radic. Biol. Med. 176, 105–117. https://doi.org/10.1016/j.freeradbiomed.2021.09.018.

Sotos-Prieto, M., Del Rio, D., Drescher, G., Estruch, R., Hanson, C., Harlan, T., Hu, F.B., Loi, M., McClung, J.P., Mojica, A., Puglielli, D., Toong, K., Yangarber, F., Kales, S.N., 2022. Mediterranean diet - promotion and dissemination of healthy eating: proceedings of an exploratory seminar at the Radcliffe institute for advanced study. Int. J. Food Sci. Nutr. 73 (2), 158–171. https://doi.org/10.1080/09637486.2021.1941804.

Tabelle Composizione Degli Alimenti CREA, n.d.Tabelle Composizione Degli Alimenti CREA . (n.d.). Retrieved May 12, 2021, from https://www.crea.gov.it/-/tabella-di-composizione-degli-alimenti.

Tardy, A.-L., Pouteau, E., Marquez, D., Yilmaz, C., Scholey, A., 2020. Vitamins and minerals for energy, fatigue and cognition: a narrative review of the biochemical and clinical evidence. Nutrients 12 (1). https://doi.org/10.3390/nu12010228.

Tsolaki, M., Kounti, F., Karamavrou, S., 2009. Severe psychological stress in elderly individuals: a proposed model of neurodegeneration and its implications. Am. J. Alzheimers Dis. Other Dement. 24 (2), 85–94. https://doi.org/10.1177/1533317508329813.

Tyrovolas, S., Haro, J.M., Mariolis, A., Piscopo, S., Valacchi, G., Tsakountakis, N., Zeimbekis, A., Tyrovola, D., Bountziouka, V., Gotsis, E., Metallinos, G., Tur, J.-A., Matalas, A.-L., Lionis, C., Polychronopoulos, E., Panagiotakos, D., 2014. Successful aging, dietary habits and health status of elderly individuals: a k-dimensional approach within the multi-national MEDIS study. Exp. Gerontol. 60, 57–63. https://doi.org/10.1016/j.exger.2014.09.010.

Wennberg, A.M.V., Wu, M.N., Rosenberg, P.B., Spira, A.P., 2017. Sleep disturbance, cognitive decline, and dementia: a review. Semin. Neurol. 37 (4), 395–406. https://doi.org/10.1055/s-0037-1604351.

World Health Organization, n.d.World Health Organization. (n.d.). Retrieved December 30, 2022, from https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.

Yaremchuk, K., 2018. Sleep disorders in the elderly. Clin. Geriatr. Med. 34 (2), 205–216. https://doi.org/10.1016/j.cger.2018.01.008.

Yeomans, M.R., 2017. Adverse effects of consuming high fat-sugar diets on cognition: implications for understanding obesity. Proc. Nutr. Soc. 76 (4), 455–465. https://doi.org/10.1017/S0029665117000805.