ORIGINAL ARTICLE

Mediterranean Diet and Changes in Sleep Duration and Indicators of Sleep Quality in Older Adults

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Study Objective: To examine the association between adherence to a Mediterranean diet (MD) and changes in sleep duration and sleep quality in older adults.
Methods: We used data from 1596 participants in the Seniors-ENRICA cohort aged ≥ 60 years. MD was evaluated in 2012 with the Mediterranean Diet Adherence Screener (MEDAS) score. Sleep duration (h) and indicators of poor sleep quality were assessed both in 2012 and 2015. Analyses were adjusted for sociodemographic, lifestyle and morbidity variables, and for sleep duration and the number of poor sleep indicators at baseline.
Results: Over a median follow-up of 2.8 years, 12.2% of individuals increased and 8.8% decreased their sleep duration by ≥2 h/night. Compared with those in the lowest tertile of adherence to the MD in 2012, those in the highest tertile showed both a lower risk of a ≥2 h/night increase in sleep duration (odds ratio [OR]: 0.54, 95% confidence interval [CI] 0.34–0.85, *p*-trend = .01) and of a ≥2 h/night decrease (OR: 0.58, 95% CI 0.35–0.95, *p*-trend = 0.02) from 2012 to 2015. Being in the highest tertile of MD in 2012 was also associated with lower risk of poor sleep quality at follow-up, the OR (95% CI) for having 2–3 indicators of poor sleep was 0.70 (0.51–0.97) and for ≥4 indicators was 0.68 (0.47–0.99, *p*-trend = .04). High adherence to the MD was also associated with 56% lower odds of having large changes in sleep duration and ≥2 indicators of poor sleep quality simultaneously (OR: 0.44, 95% CI 0.29–0.68, *p* trend < .001).
Conclusions: Adherence to a MD pattern was associated with lower risk of changes in sleep duration and with better sleep quality in older adults.
Keywords: change in sleep duration; elderly; Epworth Sleepiness Scale; Mediterranean diet; MEDAS; sleep duration; sleep quality.

Statement of significance
Diet may provide many health benefits, but its influence on sleep patterns is uncertain. We found that adherence to the Mediterranean diet was associated with lower risk of substantial changes in sleep duration over time, as well as with better sleep quality, in older adults. Our results suggest that the Mediterranean diet, as a healthy eating pattern, may contribute to better sleep quality and to stability of sleep duration over time. Future studies should investigate the mechanisms of this association.

INTRODUCTION

Both short and long sleep duration have been associated with several adverse health outcomes in older adults, including the metabolic syndrome[1] and diabetes.[2] Moreover, changes in sleep duration over time (both increased and decreased) have also been related to higher inflammatory levels,[3] lower cognitive function[4] and higher risk of diabetes,[5,6] and overall mortality.[7] In addition, poor quality of sleep has been related to higher frequency of impaired cognition,[8] the metabolic syndrome,[9] and frailty[10] in older adults.

Several factors, including individual dietary factors and nutrients, have been found to modulate sleep duration and quality. Specifically, sleeping 7–8 hours has been associated with better diet quality,[11] higher intake of protein,[11,12] vegetables and fruits,[13] and lower total fat.[13,14] Poor sleep quality has been associated with inadequate eating behaviors, such as low intake of vegetables, high intake of confectionary products,[15] and an unhealthy pattern of fat intake.[14,16] These results could be explained by the fact that nutrients promote the release of gastrointestinal hormones, stimulate the synthesis of serotonin and melatonin, and act on serotonergic and GABAergic neurons, which affect sleep.[17] However, the direction of the relationship between diet and sleep duration and quality remains unclear, mainly because previous studies were predominantly cross-sectional,[13] which limits causal inference. In addition, these studies focused on individual nutrients and foods, so they could not assess their synergistic effects.

A recent review has highlighted the importance to investigate the effects of dietary patterns and specific nutrients on sleep.[18] The Mediterranean diet (MD) is a healthy eating pattern which has been linked to lower mortality,[19] reduced risk of cardiovascular diseases,[20] and lower frailty risk in older adults.[21] To our knowledge, only one study has focused on the association between the MD and sleep quality, and it found an inverse cross-sectional relationship between higher adherence to this eating pattern and the frequency of insomnia symptoms.[22] Therefore, the objective of this study was to examine the prospective association between adherence to a MD pattern and changes in sleep duration and nine indicators of sleep quality in older adults in Spain. Our hypothesis was that a higher adherence to the MD, which represents a healthy dietary pattern, is associated with lower variability in sleep duration and better sleep quality over time.

METHODS

Study Design and Participants

Data were taken from the Seniors-ENRICA cohort, whose methods have been reported elsewhere.[23,24] This cohort was established in 2008–2010 with individuals aged 60 years and older; for this analysis, we used information from 2519 individuals participating in wave 2 (2012), and who were followed through wave 3 (2015). In waves 2 and 3, data on sociodemographic variables, lifestyle, and health status were collected by telephone interview. In addition, trained research staff collected diet information and conducted a physical exam to measure anthropometric variables and assess physical function. From wave 2 through wave 3, a total of 82 individuals died and 616 were lost to follow-up. Individuals lost were less educated and reported a higher prevalence of diagnosed chronic diseases than individuals without missing values. Among the remaining 1821 study participants, we excluded the following subjects: 193 without data on diet or sleep duration, 9 participants with implausibly high or low sleep duration (outside the range of 3–12 h/night), and 23 with missing data on sleep quality. Thus, the analyses were conducted on 1596 individuals. Exception was made for the Epworth Sleepiness Scale, which had 263 missing cases due to failure to complete the instrument; thus, analyses were conducted with 1333 individuals for this variable.

Study participants gave written informed consent. The study was approved by the Clinical Research Ethics Committee of the *La Paz* University Hospital in Madrid.

Diet

In 2012, data were collected on the consumption of 880 foods in the preceding year through a validated computer-assisted face-to-face diet history, which was developed from that used in the EPIC cohort study in Spain.[25] This instrument includes a set of 127 photographs to help estimate the amount of intake. Adherence to the MD was evaluated with the Mediterranean Diet Adherence Screener (MEDAS),[26] which consists of 12 items with targets for food consumption and another 2 items with targets for food intake habits characteristic of this diet in Spain. The total MEDAS score ranges from 0 to 14, with a higher score indicating better MD adherence. One point is given for each of the following components: using olive oil as the principal source of fat for cooking; preferring white meat over red meat; ≥4 tablespoons of olive oil/d; ≥2 servings of vegetables/d; ≥3 pieces of fruit/d; <1 serving of red meat, a hamburger, or sausage/d; <1 serving of butter, margarine or cream/d; <1 sugar-sweetened or carbonated beverage/d; ≥1 servings of red wine/d; ≥3 servings of legumes/wk; ≥ 3 servings of fish or seafood/wk; <2 commercial baked goods/wk; ≥ 3 servings of nuts/wk; and ≥2 servings/wk of a dish with a traditional sauce of tomatoes, garlic, onion, or leeks sautéed in olive oil (“sofrito”). We considered that a MEDAS score ≥9 (highest tertile) represented high adherence to the MD, and a score of 8 (mid-tertile) represented moderate adherence.[21]

Sleep Duration

In 2012 and 2015, sleep duration was obtained with the question: “Approximately, for how long do you usually sleep per night?” Sleep duration was categorized as short sleep (≤6 h), normal sleep (7–8 h), and long sleep (≥9 h).[27] Change in sleep duration was calculated by subtracting the number of h/night slept in 2015 from those slept in 2012. Changes in sleep duration were categorized as no change (changes < 30 min), slight increase (increase ≥30 min and <2 h), large increase (increase ≥2 h),[5,6] slight decrease (decrease ≥30 min and <2 h), and large decrease (decrease ≥2 h). We additionally dichotomized change in sleep duration as “slight change” (increase or decrease of ≥30 min and <2 h) and “large change” (increase or decrease of ≥2 h).

Sleep Quality

In 2012 and 2015, participants were asked to self-report their general quality of sleep as “very poor”, “poor”, “regular”(categorized as poor sleep), “good”, or “very good” (categorized as good sleep). In addition, we recorded four indicators of poor nighttime sleep quality (difficulty falling asleep, awakening during the night, early awakening with difficulty of getting back to sleep, and use of sleeping medications) and two specific indicators of daytime sleep (being so sleepy at daytime as to need a nap, and not feeling rested in the morning) were recorded. For analyses, an indicator of poor sleep was considered absent when rated as “rarely or never”, and was deemed to be present when it was reported to occur “sometimes” or “almost always”. Participants were also asked if they snored (yes/no). Finally, general sleepiness was evaluated with the Epworth Sleepiness Scale (ESS), a four-grade scale (0, no napping; 3, high likelihood of napping), with eight questions, with a maximum of 24 points[28]; a score >10 was considered to be excessive sleepiness. With the above outcomes, we calculated the total number of indicators of sleep quality that affected each participant.

Other Variables

In 2012, a standardized health interview collected sociodemographic and lifestyle variables. Educational level was classified into primary, secondary, and university studies. Smoking status was categorized as never smoker, former smoker, and current smoker. Weight and height were measured in standardized conditions,[29] and body mass index (BMI) was calculated as weight in kg divided by square of height in m and classified as <25, ≥25–29.9, and ≥30 kg/m^2. Physical activity during leisure time (metabolic equivalent h/wk) was ascertained with the EPIC-cohort questionnaire, validated in Spain.[30] Total energy intake (kcal/d) and caffeine (mg/d) were estimated from standard composition tables of foods in Spain.[25] Finally, participants also reported, both at baseline and follow-up, the following physician-diagnosed diseases: cardiovascular disease (ischemic heart disease, stroke, and heart failure), diabetes, cancer, depression requiring treatment, and Parkinson’s disease.

Statistical Analysis

Differences in sociodemographic, lifestyle, morbidity, and sleep variables across the MEDAS tertiles were assessed using ANOVA for continuous variables and Pearson’s chi square for categorical variables. Multinomial logistic models were used to examine the association between adherence to the MEDAS score in 2012 (independent variable) and categories of sleep duration change from 2012 to 2015 (dependent variable), using no change as the reference. Multinomial logistic models were also used to examine the association between the MEDAS and sleep quality. To allow for a sufficient number of individuals in each category, the number of indicators of sleep quality was grouped into three categories: ≤1, 2–3, and ≥4; the reference group included persons with ≤1 indicator. Analyses were repeated for each of the nine sleep indicators independently, using logistic regression models. Study associations were summarized with odds ratios (OR) and their 95% confidence interval (CI).

We investigated the linear dose–response associations by using the tertiles of the MEDAS score as a continuous variable in all the above models. In addition, we calculated the risk of sleep outcomes associated with a two-point increase in the MEDAS score (corresponding to approximately one standard deviation difference). All models were initially adjusted for age, sex, and educational level. Further adjustments were made for BMI and lifestyle variables and morbidity (prevalent and incident diseases), along with the appropriate sleep variable at baseline (sleep duration [≤6, 7–8, ≥ 9 h] or number of poor sleep indicators in 2012).

To examine the simultaneous effect of the MD pattern on both endpoints (change in sleep duration and number of indicators of poor sleep quality), participants were also classified in combined categories of change in sleep duration (change <2 h and change ≥2 h) and number of indicators of poor sleep (≤1 and ≥2). ORs (95% CI) were calculated for having 1 and 2 endpoints at follow-up. For these analyses, model 2 was adjusted both for sleep duration and number of indicators of poor sleep in 2012.

Differences between men and women in the study associations were tested with likelihood-ratio tests, which compared models with and without cross-product interaction terms. As no interactions were detected between sex and the MEDAS score in relation to sleep change (p = .44) and to sleep quality (p = .47), results are presented for women and men combined. Similarly, since no significant interactions were found for strata of BMI, physical activity, tobacco consumption and baseline sleep duration, and the MEDAS in relation to the sleep endpoints, we are not presenting stratified analyses for these variables. Significance level was set at $p < .05$. The statistical analysis was performed using Stata software (version 13.0).

RESULTS

The mean (*SD*) MEDAS score at baseline was 7.55 (± 1.65). Compared with those with the lowest adherence to the MEDAS, those with the highest adherence were less frequently women and smokers, and reported higher total energy intake and more physical activity during leisure time; they also had lower frequency of depression and Parkinson's disease (Table 1). Mean (*SD*) sleep duration in the study participants was 6.88 (1.34) h/night in 2012 and 7.02 (1.36) h/night in 2015. Approximately half of participants reported normative durations (7–8 h/night) in 2012 and in 2015.

Over a mean follow-up of 2.8 years, 614 (38.5%) persons increased their sleep duration at least 30 min/night; of these, 194 (31.6%) had an increase ≥ 2 h/night. A total of 453 (28.4%) persons reported a decrease of at least 30 min/night in sleep duration, of whom 141 (31.1%) had a decrease of ≥2 h/night. Compared to individuals in the lowest tertile of the MEDAS score, those in the highest tertile showed a lower risk of large changes in sleep duration (≥ 2 h), both for increase (OR: 0.54, 95% CI 0.34–0.85, p-trend = .01) and decrease (OR: 0.58, 95% CI 0.35–0.95, p-trend = .02), in the fully-adjusted analyses (Table 2). A two-point increment in the MEDAS score was associated with lower risk for large change in sleep duration (0.82, 95% CI 0.69–0.97).

Overall, 79.8% of the study subjects reported at least two of the nine indicators of poor sleep quality, 55.9% reported at least three indicators, and 36.9%, between 4 and 9. The most frequent (>35%) indicators were difficulty falling asleep, awakening during the night, early awakening and snoring; of note, 26% of participants reported three of them. We found an association between the highest tertile of MEDAS score and lower risk of reporting 2–3 indicators of sleep quality (OR: 0.70, 95% CI 0.51–0.97, p-trend = .04) and of reporting ≥4 indicators of quality (OR: 0.68, 95% CI 0.47–0.99, p-trend= .04), in the fully adjusted model (Table 3). A two-point increment in the MEDAS score was marginally associated with lower risk of ≥2 indicators of poor sleep (OR: 0.88, 95% CI 0.75–1.03). As regards individual indicators of poor sleep, a higher adherence to the MD was associated with lower risk of early awakening (OR: 0.68, 95% CI 0.47–1.00, p-trend = 0.05), using sleeping pills (OR: 0.60, 95% CI 0.37–0.96, p-trend = .03), and of poor general sleep quality (OR: 0.68, 95% CI 0.45–1.03, p-trend = .07) (Table 4).

In the combined endpoints analysis, we estimated that participants with the highest MD adherence had 32% lower odds of having one of the sleep endpoints (OR: 0.68, 95% CI 0.49–0.94, p trend = .01) and 56% lower odds of having both sleep endpoints (OR: 0.44, 95% CI 0.29–0.68, p trend < .001) at follow-up (Table 5), after adjustment for sociodemographic, lifestyle, morbidity, sleep duration, and number of poor sleep indicators at baseline. A two-point increment in the MEDAS score was associated with lower risk for both 1 endpoint (OR: 0.73, 95% CI 0.55–0.97) and 2 endpoints (OR: 0.78, 95% CI 0.63–0.96).

We conducted sensitivity analyses by replicating models excluding those participants with depression or Parkinson's disease at baseline, because these diseases may alter sleep patterns, and with diabetes, cancer, or cardiovascular disease, diseases which are strongly associated with both diet quality and sleep conditions, and also excluding persons who reported using sleep medication, which is a marker of conditions that affect sleep. These analyses showed similar results, with the exception of the loss of statistical significance for the association between high adherence to the MD and large decrease of sleep, which could be due to the exclusion of many participants from the analyses (see Supplementary Tables 1 and 2).

Finally, we performed analyses with individual components of MEDAS score and all the sleep endpoints studied. Most of the results were non-significant (Supplementary Tables 3–5), although it was possible to observe a beneficial association for higher consumption of olive oil and vegetables. Surprisingly, sugar-sweetened beverages consumption also showed a beneficial association with some indicators of poor sleep quality, possibly for the presence of stimulating substances on a large proportion of these beverages.

DISCUSSION

In this study among older adults, a higher adherence to the MD was associated with a lower risk of large changes in sleep duration and with better sleep quality. Since the relationship between sleep quantity and quality and adverse health outcomes in older people has been extensively shown,[10,31] it is of great relevance to understand the determinants of changes in sleep duration and quality. To our knowledge, this is the first population study to prospectively investigate the association between MD adherence and the characteristics of sleep.

Information about the association of dietary habits with sleep duration has been obtained mostly from cross-sectional studies. Diet quality[11,13] and food intake, including low consumption

Table 1—Characteristics of the Study Participants by Tertiles of Adherence to the Mediterranean Diet (n = 1596).

	Mediterranean Diet Adherence Screener (MEDAS)			*p*
	Low adherence (score 2–7)	**Moderate adherence (score 8)**	**High adherence (score 9–12)**	
Number of participants	777	366	453	
MEDAS score	6.17 (0.92)	8.00 (0.00)	9.58 (0.76)	<.001
Female, %	57.4	48.09	43.71	<.001
Age, y	71.6 (6.3)	71.2 (5.8)	70.9 (5.6)	.09
Educational level, %				.09
≤ Primary	52.0	50.8	47.2	
Secondary	25.9	29.0	25.2	
University	22.1	20.2	27.6	
Current smokers, %	10.7	8.5	7.3	.12
Energy intake, kcal/d	2000 (457)	2005 (439)	2093 (491)	.002
BMI, kg/m^2	28.6 (4.3)	28.3 (4.1)	28.1 (4.2)	.12
Caffeine consumption, mg/d	88.1 (147)	93.2 (160)	86.8 (146)	.81
Physical activity, METs*h/wk	20.4 (14.4)	24.1 (15.9)	24.5 (15.0)	<.001
Comorbidities, %				
Cardiovascular disease[a]	5.9	6.0	5.7	.99
Diabetes	20.0	20.0	20.8	.94
Cancer	2.2	3.0	3.1	.56
Depression	9.4	8.7	6.0	.10
Parkinson's disease	0.4	1.4	0.2	.06
Sleep duration in 2012, h	6.86 (1.38)	6.95 (1.34)	6.87 (1.28)	.53
Sleep duration in 2015, h	7.04 (1.38)	7.06 (1.35)	6.96 (1.34)	.49
Sleep duration in 2012, %				.78
≤6 h	39.3	37.7	36.9	
7–8 h	52.6	53.0	55.6	
≥9 h	8.1	9.3	7.5	
Sleep duration in 2015, %				.68
≤6 h	35.4	33.6	35.3	
7–8 h	53.8	55.2	56.1	
≥9 h	10.8	11.2	8.6	
Changes in sleep duration				
No change in sleep duration,[b] %	32.0	29.8	37.2	
Increase in sleep duration, h	1.43 (0.94)	1.32 (0.71)	1.24 (0.75)	.07
Decrease in sleep duration, h	1.43 (0.88)	1.29 (0.85)	1.27 (0.82)	.18
Number of indicators of poor sleep quality in 2012[c]	2.9 (1.6)	2.8 (1.6)	2.6 (1.6)	.02
Number of indicators of poor sleep quality in 2015[c]	2.9 (1.5)	2.7 (1.5)	2.7 (1.6)	.08
≥1 indicator of poor sleep quality in 2012,[c] %	79.5	77.05	73.7	.06
≥1 indicator of poor sleep quality in 2015,[c] %	82.4	80.6	74.8	.006

For continuous variables, means (standard deviations) are reported. Values of sociodemographic, lifestyle, and morbidity variables are from 2012.
[a]Ischemic heart disease, stroke, and heart failure.
[b]Less than 30 min of change in sleep duration.
[c]Indicators of poor sleep quality are: poor general sleep quality, difficulty falling asleep, awakening during the night, early awakening with difficulty of getting back to sleep, need to sleep at daytime, not feeling rested in the morning, use of sleeping medication, snoring and daytime sleepiness (Epworth Sleepiness Scale > 10).

Table 2—Odds Ratios (95% Confidence Interval) for the Association Between Tertiles of Adherence to the Mediterranean Diet and Change in Sleep Duration During a 2.8 Years Follow-up of Older Adults (*n* = 1596).

	Mediterranean Diet Adherence Screener (MEDAS)				Continuous per two-point increment in the MEDAS score
	Low adherence	Moderate adherence	High adherence	*p* for trend	
	(*n* = 777)	(*n* = 366)	(*n* = 453)		
No change[a]	251	109	169		
Reference category	1.00	1.00	1.00		
Increase ≥30 min to <2 h	204	94	122		
Model 1	1.00	1.08 (0.77; 1.51)	0.90 (0.66; 1.21)	.52	0.89 (0.76; 1.03)
Model 2	1.00	1.08 (0.76; 1.51)	0.89 (0.65; 1.21)	.50	0.87 (0.74; 1.01)
Increase ≥2 h	108	48	38		
Model 1	1.00	1.05 (0.70; 1.59)	0.55 (0.36; 0.84)	.01	0.80 (0.66; 0.98)
Model 2	1.00	1.00 (0.64; 1.58)	0.56 (0.35; 0.87)	.02	0.78 (0.63; 0.97)
Decrease ≥30 min to <2 h	132	86	94		
Model 1	1.00	1.56 (1.09; 2.22)	1.08 (0.77; 1.50)	.51	0.97 (0.83; 1.15)
Model 2	1.00	1.56 (1.09; 2.25)	1.04 (0.74; 1.46)	.65	0.97 (0.82; 1.15)
Decrease ≥2 h	82	29	30		
Model 1	1.00	0.84 (0.51; 1.36)	0.58 (0.36; 0.92)	.02	0.82 (0.65; 1.02)
Model 2	1.00	0.76 (0.45; 1.29)	0.58 (0.35; 0.95)	.03	0.85 (0.67; 1.07)
Slight change[b] (<2 h)	336	180	216		
Model 1	1.00	1.27 (0.95; 1.70)	0.97 (0.74; 1.26)	.94	0.92 (0.81; 1.05)
Model 2	1.00	1.27 (0.94; 1.71)	0.95 (0.73; 1.24)	.003	0.91 (0.80; 1.04)
Large change[b] (≥2 h)	190	77	68		
Model 1	1.00	0.96 (0.67; 1.36)	0.56 (0.40; 0.79)	.002	0.81 (0.69; 0.95)
Model 2	1.00	0.94 (0.65; 1.36)	0.57 (0.40; 0.82)	.85	0.81 (0.69; 0.97)

Model 1: multinomial logistic regression model adjusted for age, sex, and educational level (≤primary, secondary, university). Model 2: multinomial logistic regression model adjusted as in model 1 and for BMI (<25, ≥25–29.9, ≥30 kg/m^2), energy intake (kcal/d, tertiles), physical activity (METs*h/wk, tertiles), tobacco (never smoker, former smoker, current smoker), caffeine (mg/d, tertiles), baseline and incident cardiovascular diseases, diabetes, cancer, depression and Parkinson's disease, and sleep duration (≤6, 7–8, ≥9 h) in 2012.
[a]Less than 30 min of change in sleep duration.
[b]Increase or decrease.

of protein,[11–14] fiber,[12] fruits,[11] and vegetables,[13,32] snacking,[32,33] excessive seasoning, irregular eating,[32] skipping breakfast,[33] and high intake of empty calories[11] have been associated with shorter or longer sleep duration. However, eating is a complex habit, and the assessment of the potential synergistic effects of foods on health outcomes requires the evaluation of dietary patterns rather than specific foods or nutrients. Specifically, we found an inverse dose-response association between the MEDAS score and large changes in sleep duration, which suggests a protective role of the MD on preventing changes in sleep duration over time in older adults, regardless of baseline duration.

Previous cross-sectional studies have also examined some dietary habits in relation to sleep quality, finding that low protein,[16,34] fiber,[16] and energy intake,[34] as well as being on a low fat/cholesterol diet[16] were associated with higher frequency of indicators of poor sleep. Among a French community-dwelling older population, the MD was a protective factor for one, two, or three insomnia factors.[22] Similarly, in our study we found a tendency to an inverse association between the MEDAS score and difficulty falling asleep. In addition, results from the National Health and Nutrition Examination Survey (NHANES) 2007–2008, showed that difficulty falling asleep was associated with decreased protein and fiber intake, in addition to less intake of alpha carotene, selenium, dodecanoic acid (a monounsaturated fat) and calcium, and more hexadecanoic acid (saturated fat).[16] Several studies have also shown that persons with poor sleep quality consume less protein,[35,36] low amounts of vegetables and fish, and high amounts of confectionary and noodles,[15] besides having unhealthy eating behaviors such as skipping breakfast and eating irregularly.[15] Our findings of an association between higher adherence to the MD and better sleep quality are in line with all the above literature. On the other hand, Cheng *et al*.[37] conducted a longitudinal study to investigate the association in

Table 3—Odds Ratios (95% Confidence Interval) for the Association Between Tertiles of Adherence to the Mediterranean Diet and Number of Indicators of Poor Sleep Quality During a 2.8-Year Follow-up of Older Adults (*n* = 1596).

	Mediterranean Diet Adherence Screener (MEDAS)				**Continuous per two-point increment in the MEDAS score**
	Low adherence	**Moderate adherence**	**High adherence**	***p* for trend**	
	(*n* = 777)	**(*n* = 366)**	**(*n* = 453)**		
≤1 Indicator of poor sleep quality[a]	137	71	114		
Reference category	1.00	1.00	1.00		
2–3 Indicators of poor sleep quality	333	165	187		
Model 1	1.00	0.96 (0.68; 1.35)	0.67 (0.49; 0.92)	.02	0.85 (0.73; 1.00)
Model 2	1.00	0.98 (0.68; 1.41)	0.70 (0.50; 0.97)	.04	0.88 (0.75; 1.04)
≥4 Indicators of poor sleep quality	307	130	152		
Model 1	1.00	0.86 (0.60; 1.24)	0.65 (0.47; 0.90)	.01	0.85 (0.72; 1.00)
Model 2	1.00	0.86 (0.57; 1.30)	0.68 (0.47; 0.99)	.04	0.88 (0.73; 1.06)
≥2 Indicators of poor sleep quality[b]	640	295	339		
Model 1	1.00	0.91 (0.66; 1.26)	0.66 (0.50; 0.88)	.01	0.85 (0.74; 0.99)
Model 2	1.00	0.94 (0.66; 1.33)	0.69 (0.51; 0.95)	.03	0.88 (0.75; 1.03)

Model 1: multinomial logistic regression model adjusted for age, sex and educational level (≤primary, secondary, university). Model 2: multinomial logistic regression model adjusted as in model 1 and for BMI (<25, ≥25–29.9, ≥30 kg/m^2), energy intake (kcal/d, tertiles), physical activity (METs*h/wk, tertiles), tobacco (never smoker, former smoker, current smoker), caffeine (mg/d, tertiles), baseline and incident cardiovascular diseases, diabetes, cancer, depression and Parkinson's disease, and number of indicators of poor sleep quality (0–9) in 2012.
[a]Indicators of poor sleep quality include: poor general sleep quality, difficulty falling asleep, awakening during the night, early awakening with difficulty of getting back to sleep, need to sleep at daytime, not feeling rested in the morning, use of sleeping medication, snoring and daytime sleepiness (Epworth Sleepiness Scale >10).
[b]Logistic regression models.

the opposite direction, which showed that insomnia symptoms were related to higher energy intake and lower scores for diet quality in healthy men.

Intervention studies corroborate the importance of some diet habits on sleep quality, such as adequate amount of carbohydrate, high fiber and low saturated fat consumption.[18] However, there is the potential for reverse causation since other experimental studies have shown that sleep deprivation increased appetite for food with elevated levels of carbohydrates, fats,[38] and caloric intake.[39,40]

Given that different sleep symptoms may occur simultaneously,[22,35] we performed a comprehensive analysis of indicators of poor sleep quality in older adults. When evaluating the nine indicators together, we found a protective effect of a higher MEDAS score on having 2–3 and ≥4 indicators, regardless of the number of indicators at baseline. Therefore, it is possible that interventions addressing several indicators of poor sleep may be more efficient than those directed at individual indicators.

We found no association between the MEDAS score and general daytime sleepiness measured by the Epworth Sleepiness Scale. Several factors could account for this lack of association. First, an interviewer administered the questionnaire, which may have resulted in underestimation of sleepiness, possibly caused by social desirability bias and lack of anonymity during the interview.[41] Second, older adults might find it difficult to answer all of the questions in this scale,[42] which may explain the elevated number of missing data for this variable. Finally, this scale might not adequately represent poor sleep quality in Spain, because the cultural habit of the "siesta" linked to a Mediterranean lifestyle, is common in older adults.[43] When we assessed the relation of diet with both endpoints combined, we found that a high adherence to the MD was associated with the two endpoints simultaneously. In fact, the association between sleeping difficulties and sleep duration, both short and long, has already been demonstrated.[27,44] Our findings reinforce the importance of measuring both duration and quality of sleep in epidemiological studies.

The MD pattern has a healthy profile of fat, protein and fiber intake,[45,46] which results from moderate, or even high, consumption of fish, olive oil, fruits and vegetables. Thus, some mechanisms associated with these foods might explain the association between the MD and sleep over time. For example, there seems to be a bidirectional relationship between sleep disorders and proinflammatory markers, like IL-6, C-reactive protein (RCP) and soluble intercellular adhesion molecule (sICAM).[3,47] Because the MD is rich in antioxidant compounds,[48] such as monounsaturated and n-3 polyunsaturated fatty acids,[45] resveratrol, and polyphenols,[49] it is possible that anti-inflammatory and antioxidant pathways link the MD to a healthy sleep.[50] In addition, habitual foods in the MD like olives and grapes are rich in melatonin,[49] which is an endogenous compound involved in the regulation of the circadian

Table 4—Odds Ratios (95% confidence interval) for the Association Between Tertiles of Adherence to the Mediterranean Diet and the Incidence of Each Indicator of Poor Sleep Quality During a 2.8-Year Follow-up of Older Adults.

	Mediterranean Diet Adherence Screener (MEDAS)			
	Low adherence	Moderate adherence	High adherence	*p* for trend
Difficulty falling asleep, *N*/*n* cases	486/112	216/29	314/61	
Model 1	1.00	0.55 (0.35; 0.86)	0.86 (0.60; 1.23)	.27
Model 2	1.00	0.55 (0.35; 0.87)	0.82 (0.57; 1.18)	.19
Awakening during the night, *N*/*n* cases	254/153	127/72	165/106	
Model 1	1.00	0.86 (0.56; 1.34)	1.21 (0.80; 1.83)	.43
Model 2	1.00	0.88 (0.56; 1.39)	1.26 (0.82; 1.94)	.36
Early awakening, *N*/*n* cases	396/117	212/58	251/56	
Model 1	1.00	0.90 (0.62; 1.31)	0.70 (0.48; 1.01)	.06
Model 2	1.00	0.85 (0.58; 1.25)	0.68 (0.47; 1.00)	.05
Need to sleep at daytime, *N*/*n* cases	652/75	304/33	383/46	
Model 1	1.00	0.96 (0.62; 1.49)	1.07 (0.72; 1.60)	.76
Model 2	1.00	0.97 (0.62; 1.51)	1.12 (0.75; 1.68)	.61
Not feeling rested in the morning, *N*/*n* cases	585/74	287/36	354/38	
Model 1	1.00	1.07 (0.69; 1.65)	0.94 (0.61; 1.43)	.82
Model 2	1.00	1.07 (0.69; 1.67)	1.00 (0.65; 1.55)	.95
Use of sleeping medications, *N*/*n* cases	606/77	283/31	373/30	
Model 1	1.00	0.89 (0.57; 1.39)	0.64 (0.41; 1.01)	.06
Model 2	1.00	0.78 (0.48; 1.25)	0.60 (0.37; 0.96)	.03
Snoring, *N*/*n* cases	271/71	150/44	178/41	
Model 1	1.00	1.14 (0.73; 1.79)	0.81 (0.52; 1.27)	.42
Model 2	1.00	1.02 (0.64; 1.64)	0.81 (0.51; 1.29)	.41
Poor general sleep quality, *N*/*n* cases	540/92	254/38	336/39	
Model 1	1.00	0.86 (0.57; 1.31)	0.68 (0.45; 1.02)	.06
Model 2	1.00	0.86 (0.56; 1.32)	0.68 (0.45; 1.03)	.07
Daytime sleepiness[a], *N*/*n* cases	585/27	291/16	355/20	
Model 1	1.00	1.19 (0.63; 2.25)	1.27 (0.69; 2.30)	.43
Model 2	1.00	1.26 (0.66; 2.42)	1.25 (0.68; 2.31)	.45

Model 1: logistic regression model adjusted for age, sex and educational level (≤primary, secondary, university). Model 2: logistic regression model adjusted as in model 1 and for BMI (<25, ≥25–29.9, ≥30 kg/m^2), physical activity (METs*h/wk, tertiles), tobacco (never smoker, former smoker, current smoker), energy intake (kcal/d, tertiles) and caffeine (mg/d, tertiles) in 2012, and baseline and incident cardiovascular diseases, diabetes, cancer, depression and Parkinson's disease.
[a]More than 10 points in the Epworth Sleepiness Scale. Analyses based on 1333 participants who completed the questionnaire.

cycle and is used in the management sleep disorders.[51] Finally, Yannakoulia *et al*.[52] have emphasized that the MD is part of a lifestyle pattern including food sharing, cooking raw products, and long meals, which could be associated with regular sleep patterns and a less stressful life.

Strengths of this study are its prospective design and the measurement of habitual diet with a validated diet history. Furthermore, we examined changes in sleep duration over time and performed a comprehensive assessment of sleep quality using many indicators. Results were also robust after adjustment for many potential confounders and in sensitivity analyses.

Some limitations should also be acknowledged. First, we used self-reported sleep duration and quality, which may be affected by recall and social desirability biases. However, it should be noted that previous studies using self-reports were able to find associations of sleep with health outcomes.[4,8] In addition, although objective measures are more robust,[53] information related to personal perception of sleep can only be achieved with self-reported data.[54] Second, although we adjusted the models for baseline values of the outcomes examined, reverse causation cannot be completely ruled out. Lastly, the relatively small sample size may have resulted in limited statistical power

Table 5—Odds Ratios (95% confidence interval) for the Association Between Adherence to the Mediterranean Diet and Both Change in Sleep Duration and Number of Indicators of Poor Sleep Quality During a 2.8-Year Follow-up of Older Adults (n = 1596).

	Mediterranean diet adherence screener (MEDAS)				**Continuous per two-point increment in the MEDAS score**
	Low adherence	**Moderate adherence**	**High adherence**	***p* for trend**	
	(*n* = 777)	**(*n* = 366)**	**(*n* = 453)**		
0 endpoint[a]	115	59	107		
Reference category	1.00	1.00	1.00		
One endpoint	494	242	285		
Model 1	1.00	0.99 (0.69; 1.40)	0.65 (0.48; 0.88)	.006	0.80 (0.68; 0.93)
Model 2	1.00	1.01 (0.69; 1.49)	0.65 (0.47; 0.92)	.02	0.82 (0.69; 0.97)
Two endpoints	168	65	61		
Model 1	1.00	0.78 (0.50; 1.20)	0.42 (0.28; 0.63)	<.001	0.74 (0.61; 0.90)
Model 2	1.00	0.77 (0.48; 1.23)	0.43 (0.28; 0.67)	<.001	0.76 (0.62; 0.95)

Model 1: multinomial logistic regression model adjusted for age, sex and educational level (≤primary, secondary, university). Model 2: multinomial logistic regression model adjusted as in model 1 and for BMI (<25, ≥25–29.9, ≥30 kg/m^2), physical activity (METs*h/wk, tertiles), tobacco (never smoker, former smoker, current smoker), energy intake (kcal/d, tertiles), caffeine (mg/d, tertiles), baseline and incident cardiovascular diseases, diabetes, cancer, depression, and Parkinson's disease, sleep duration (≤6, 7–8, ≥9 h), and number of indicators of poor sleep quality (0–9) in 2012.
[a]Endpoints are: large changes (increase or decrease) in sleep duration (≥2 h) and ≥2 indicators of poor sleep quality.

to detect an association between MD and some individual poor sleep indicators, and to examine the association between this diet and patterns of changes in sleep quality.

In conclusion, we found that lower risk of large changes in sleep duration and lower risk of having two or more indicators of poor sleep quality were associated with higher adherence to a MD pattern. Our results suggest that the MD plays a role in preventing changes in sleep duration and poor sleep quality in older adults. Clinical trials with interventions designed to increase adherence to a MD should assess its potential benefit in sleep duration and quality.

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