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Mediterranean Diet and Mobility Decline in Older Persons

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Abstract

We examined whether adherence to a Mediterranean-style diet has positive effects on mobility assessed over a nine-year follow-up in a representative sample of older adults. This research is part of the InCHIANTI Study, a prospective population-based study of older persons in Tuscany, Italy. The sample for this analysis included 935 women and men aged 65 years and older. Adherence to the Mediterranean diet was assessed at baseline by the standard 10-unit Mediterranean diet score (MDS). Lower extremity function was measured at baseline, and at the 3, 6 and 9-year follow-up visits using the Short Physical Performance Battery (SPPB). At baseline, higher adherence to Mediterranean diet was associated with better lower body performance. Participants with higher adherence experienced less decline in SPPB score, which was of 0.9 points higher ($p < .0001$) at the 3-year-follow, 1.1 points higher ($p = 0.0004$) at the 6-year follow-up and 0.9 points higher ($p = 0.04$) at the 9-year follow-up compared to those with lower adherence. Among participants free of

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mobility disability at baseline, those with higher adherence had a lower risk (HR=0.71, 95% CI=0.51–0.98, $p=0.04$) of developing new mobility disability. High adherence to a Mediterranean-style diet is associated with a slower decline of mobility over time in community dwelling older persons. If replicated, this observation is highly relevant in terms of public health.

Keywords

Mediterranean diet; mobility; SPPB; aging

INTRODUCTION

The traditional diet of populations living in the Mediterranean area is widely considered a model of healthy eating [1,2]. The Mediterranean diet is characterized by high intake of vegetables, legumes, fruits and nuts, cereals and olive oil with low intake of saturated fat, moderately high intake of fish, low-to-moderate intake of dairy products, low intake of meat, and a regular but moderate intake of alcohol primarily in the form of wine during meals [3]. Epidemiological studies conducted in different countries have shown that adherence to a Mediterranean type diet is associated with longer survival, lower risk of cognitive decline, chronic degenerative disease, depression, and reduced cardiovascular and cancer mortality [3–9]. However, whether adherence to a Mediterranean-style diet is associated with less decline of physical function in aging individuals has not been investigated. Testing this hypothesis is important to build the foundation for the development of nutritional interventions aimed at promoting healthy aging. In this study we examined the longitudinal relationship between adherence to a Mediterranean-style diet and lower extremity performance over a nine-year follow-up in a representative sample of community-dwelling older Italians. We hypothesized that higher adherence to Mediterranean diet would be associated with slower decline of lower extremity performance and lower risk of developing mobility disability.

METHODS AND MATERIALS

Study Population

This study is based on data collected in the InCHIANTI (**In**vecchiare in **Chianti**, aging in the Chianti area) study, a prospective population-based study of older persons in Tuscany (Italy) designed to investigate factors contributing to decline of mobility in late life. A description of the study rationale, design and methods is given elsewhere [10]. Briefly, in 1998–1999 a sample was randomly selected from two sites, Greve in Chianti and Bagno a Ripoli, using a multistage stratified sampling method: 1270 persons ≥ 65 years were randomly selected from the population registry of the two sites, another 29 subjects ≥ 90 years were oversampled. Thirty-nine participants were not eligible because they had already died or emigrated. Among those who were eligible, 1155 (91.6%) were enrolled. The participation rate increased with age up to the age of 85 and in each age group was higher in women than in men. However, there was a drop in participation in the oldest-old age group (men: 77.1%; women: 78.4%). Data collection included: 1) a home interview concerning demographics, health-related behaviors, functional status, cognitive function and a food-frequencies questionnaire; 2) a medical examination including several performance-based tests of physical function conducted in the study clinic; 3) 24-h urine collection and blood drawing. Participants were invited again to a three-year follow-up visit (2001–2003), six-year follow-up visit (2004–2006) and nine-year (2007–2009) follow-up visit.

Of the 1155 participants aged ≥ 65 enrolled in the study, we excluded 159 because of missing data on dietary intake or physical performance at baseline. Moreover, 61

participants with dementia were also excluded. In cross-sectional analyses we included all 935 remaining participants. Among these, 705 participants had available data on lower body mobility at 3-year follow-up, 614 at 6-year follow-up and 486 at 9-year follow-up. Over the course of the study, 247 participants died, and 10 were lost to follow-up. Participants who did not take part in any of the follow-ups, as compared to participants who participated in at least at one follow-up, were significantly older, more likely to be disabled, reported more chronic diseases, had poorer cognitive function and lower extremity performance.

All respondents signed informed consent and the Italian National Institute of Research and Care on Aging Ethical Committee approved the study protocol.

Mediterranean Diet Score

Daily dietary intake was assessed at baseline by the food-frequency questionnaire created for the European Prospective Investigation on Cancer and Nutrition (EPIC) study, previously validated in the InCHIANTI population [11]. The Mediterranean Diet Score (MDS) was computed according to the method developed by Trichopoulos et. al [3]. Intake of each of 9 food groups was dichotomized using sex-specific median values as cut-offs. A score of 1 was assigned for above the median level of presumed beneficial foods (vegetables, legumes, fruits, cereal, fish and ratio of monounsaturated fats to saturated fats) and consumptions below the median level of presumed detrimental foods (meat and dairy products). For ethanol, 1 point was assigned to men who consumed between 10 and 50 g per day and to women who consumed between 5 and 25 g per day. Thus, the total MDS ranged from 0 (minimal adherence to the traditional Mediterranean diet) to 9 (maximal adherence). For analytical purposes, we also categorized the MDS into approximate tertiles as follows: low adherence (MDS ≤ 3), medium adherence (MDS 4–5) and high adherence (MDS ≥ 6).

Physical performance

Lower body performance was assessed at baseline and at 3-, 6- and 9-year follow-up with the Short Physical Performance Battery (SPPB) [12], which was derived from three objective tests of physical function: 4-meter walking speed, repeated chair rises and standing balance in progressively more challenging positions. Walking speed was defined as the better performance (time) of 2 walks at usual pace over a 4-meter course. For the chair-stand test, participants were asked to rise 5 times from a seated position as quickly as possible with their hands folded across the chest, and performance was expressed as total time to complete the test. For the standing balance tests, participants were asked to stand in 3 progressively more difficult positions for 10 seconds each: feet in side-by-side, semitandem and full tandem positions. Each test was scored 0 to 4 as per previously determined criteria [13] with a value of 0 indicating the inability to complete the test and 4 the highest level of performance. Scores from the three tests were summed into a composite score ranging 0 to 12, higher scores reflect better physical function. The SPPB has excellent reliability and is a strong predictor of nursing home admission, disability in self-care tasks and mobility, and death among older adults [12,13]. The SPPB is highly sensitive and the loss of 1 point is considered a clinically meaningful change [14]. Previous studies indicated that an SPPB cut point of less than 10 identifies individuals at increased risk of mobility disability [15]. Therefore, the development of “mobility disability” was defined as an SPPB score below 10 points.

Covariates

The following covariates assessed at baseline were used in the analysis: age, gender, education (years), smoking habit (current/former/non-smoker), Mini Mental State Examination (MMSE) score, body mass index (BMI), number of prescribed and non-prescribed drugs. Level of physical activity in the previous 12 months was classified as

sedentary (completely inactive or light physical activity: ie, walking), light (light physical activity for 2 to 4 h/wk), and moderate to intense (light physical activity for more than 4 h/wk or moderate physical activity (ie, swimming etc) [16]. Number of activities of daily living (ADL) (0–6) and instrumental activities of daily living (IADL) (0–8) disabilities was defined as self-report of inability or needing personal help in performing any basic or instrumental activities of daily living [17]. Total number of chronic diseases (heart failure, coronary heart disease including angina and myocardial infarction, stroke, chronic obstructive lung disease, hypertension, diabetes, cancer, Parkinson's disease and hip arthritis) was calculated as a global marker of poor physical health; diseases were ascertained according to standardized, pre-established criteria and algorithms based upon those used in the Women's Health and Aging Study [18] using information on self-reported history, pharmacological treatments, medical exam data and hospital discharge records. Energy intake was collected by the food-frequency EPIC questionnaire [11]. Depressive symptoms were assessed using the Center for Epidemiological Studies-Depression Scale (CES-D) [19]. A score ≥ 20 was operationally defined as clinically relevant "depressed mood" [20]. Knee extension, assessed by using a handheld dynamometer and a standard protocol [21] was considered to indicate lower extremity muscle strength. Previously from the InCHIANTI Study, Lauretani et al. [22] reported that participants with lower plasma carotenoids, a reliable index of fruit and vegetables intake, had higher decline over time of knee extension.

Statistical Analyses

Variables were reported as percentage or means $\pm$ SD as appropriate. Logistic regression analyses were used to measure the association between MDS and mobility disability at baseline, adjusting progressively for all confounders significantly associated with MDS. To examine the longitudinal association of baseline MDS with SPPB scores while accounting for correlation of repeated SPPB measures, regression models were fitted using generalized estimating equations (GEE) with an unstructured covariance [23]. Appropriate MDS-by-time interaction terms were included in the model to compare rates of change in SPPB scores at each follow-up point between participants with different baseline MDS. Covariates were selected that in the literature have been associated with dietary intake and that were significantly associated with MDS at baseline. From the initial fully adjusted models, we derived parsimonious models adjusted for age, sex, energy intake, BMI and confounders that significantly and independently contributed to the model fit. This analysis was repeated using mixed models analyses with an unstructured covariance; all variables were entered in the model as fixed factors, the only random factor entered in the model was the subject. Next, multivariate Cox proportional hazards model were used to compare risk of developing mobility disability over the follow-up period associated with different MDS groups in a subset of participants with no ADL disabilities and SPPB ≥ 10 at enrollment. The proportional hazards assumption was checked by including a time-to-event by MDS interaction term. Those surviving without developing mobility disability were censored at the date of the last follow-up; those dying without their SPPB dropping below 10 points were censored at the time of their death. Hazard Ratios (HRs) and 95% Confidence Intervals (CIs) were used to compare MDS groups. Multivariate models were additionally adjusted for baseline SPPB in order to correct for the "regression to the mean". Finally, analyses were repeated including the adjustment for knee extension. This adjustment was not included in previous analyses in order to avoid overadjustment, defined as the control for an intermediate variable (or a descending proxy for an intermediate variable) on a causal path from exposure to outcome [24]. All analyses were performed using SAS (v. 9.1, SAS Institute, Inc., Cary, NC) with a statistical significance level set at $P < 0.05$.

RESULTS

Participants mean ($\pm$ standard deviation, SD) age at baseline was 74.1 ($\pm$ 6.8) years and 55.6% were women. Figure 1 shows the distributions of 935 participants at enrollment, according to sex and MDS scores. Of these, 27.1% showed low adherence (MDS $\leq$ 3) to the Mediterranean diet, 43.6% medium adherence (MDS 4–5) to this diet and 29.3% high adherence (MDS $\geq$ 6) to this diet. No participants obtained a score of 9, indicating maximal adherence to the Mediterranean diet. Table 1 describes the characteristics of participants for the total baseline sample and according to MDS subgroups: low adherence (MDS $\leq$ 3), medium adherence (MDS 4–5) and high adherence (MDS $\geq$ 6). Participants with low adherence were older, had a higher number of chronic diseases, took more medications, were more likely to be women, disabled, depressed and sedentary, had lower SPPB and MMSE scores, had lower energy dietary intake and knee strength. Adjusted Odds Ratios (OR) for the association between MDS and mobility disability at baseline are shown in Table 2. After adjustment for age, sex, energy intake and BMI, participants with high adherence, as compared to those with low adherence, were less likely to have mobility disability at baseline (OR=0.50, 95%CI=0.30–0.82, $p=0.006$). After full adjustment, participants highly adherent still had a lower probability of having mobility disability, although not significant. Consistent findings were obtained with continuous MDS (Table 2); round number close to the SD (1.6 points) were used as increments in the regression models.

A GEE model adjusted for age, sex, energy intake, BMI, MMSE score, physical activity, ADL and IADL disabilities, depressed mood and number of chronic diseases, was fit in order to compare how SPPB scores changed over time across baseline MDS groups. As shown in Figure 2, participants with higher adherence experienced a significantly smaller decrease in SPPB scores over time. Specifically, participants with MDS score 6–9 had average change in SPPB scores of 0.9 points higher (SE=0.2, $p<.0001$) at 3-year-follow, 1.1 point higher (SE=0.3, $p=0.0002$) at 6-year follow-up and 0.9 points higher (SE=0.4, $p=0.03$) at 9-year follow-up (Table 3) compared to those with MDS score 1–3. Difference in average SPPB scores between participants with medium adherence and those with low adherence was statistically significant only at 3-year follow-up by 0.6 points (SE=0.2, $p=0.01$). These findings were confirmed by mixed models analyses with substantially the same results (data not shown).

Among non-disabled participants with SPPB score ≥ 10 at baseline, higher adherence to Mediterranean diet at baseline was also a significant predictor of lower probability of developing mobility disability over the follow-up (Table 4). Of these 684 highly functioning participants, 272 (39.8%) developed mobility disability over the follow-up period. The proportional hazard assumption was met in all analyses (non significant time-to-event by MDS interaction term). After adjustment for age, sex, baseline SPPB, energy intake, BMI, MMSE score, physical activity, IADL disabilities, depressed mood and number of chronic diseases, participants with high adherence, as compared to those with low adherence, had a lower risk (HR=0.71, 95%CI=0.51–0.98, $p=0.04$) of developing mobility disability. Moreover, a 2-point increase in MDS was associated with a 14% lower risk of mobility disability over time (Table 4). In previous analyses we did not include knee strength because this variable may be considered to be in the causal pathway between poor dietary intake and lower extremity performance [22,24]. However, when knee strength was included in the final model, in addition to the variables in model 2 (Table 4), higher adherence to a Mediterranean-style diet (per 2 MDS points increase) was still associated with a lower risk (HR=0.86, 95%CI=0.74–0.99, $p=0.04$) of developing mobility disability.

DISCUSSION

Using data from a population-based study of older persons in Italy, we found evidence of a prospective association between adherence to a Mediterranean-style diet and mobility. Participants highly adherent to Mediterranean diet had slower decline in lower body physical performance over nine years of follow-up and had lower risk of developing mobility disability.

Previous studies in older persons established a beneficial role for a Mediterranean diet type in preventing cardiovascular diseases, cancer, and neurodegenerative disorders, and promoting quality of life and overall survival [2]. To our knowledge, this is the first study directly examining the relationship between Mediterranean diet and decline of lower body mobility in older adults.

Mediterranean diet could influence physical function decline in several ways. Adherence to a Mediterranean-style diet is associated with adequate intake of certain nutrients, such as vitamins and other antioxidants, which have been related to a reduced risk of physical function impairment in older persons. Previous studies have shown that low levels of intake and low serum concentrations of vitamin E are associated with reduced physical performance, frailty and disability [25–27]. Moreover, lower plasma levels of carotenoids have been shown to be associated with poor skeletal muscle strength [22]. High plasma concentrations of carotenoids have also been found to be protective against decline in walking speed and the development of severe walking disability [28–30]. Antioxidants play an important role in counterbalancing the age-dependent increase in oxidative stress through the quenching of hydroxyl radicals and reduction in lipid peroxidation [31]. If the amount of free radicals generated exceeds the antioxidant potential capacity, this imbalance may cause oxidative damage to DNA, protein, and lipids in skeletal muscle, leading to atrophy and loss of muscle fibers [31]. Moreover, antioxidants such as carotenoids have been shown to modulate activation of nuclear factor κ B (NF- κ B) a major transcriptional factor involved in the up-regulation of interleukin-6 [32]. Therefore, low levels of these nutrients are independent predictors of subsequent increase in the inflammatory response, which, in turn, is associated with an increased risk of reduced physical function [33]. Recent trials showed that nutritional interventions based on Mediterranean diet significantly reduced the levels of inflammatory markers such as interleukin-6 and C reactive protein [34,35].

A major strength of this study is the longitudinal design and the use of a standardized, objective battery of physical performance tests for lower extremity function (SPPB), which is probably less biased by personality, mood and cognition than self-report measures. Moreover, adherence to Mediterranean diet was evaluated by a score which has been widely used and validated [3]. A limitation of this study is the loss of participants to follow-up. Participants who were lost to follow-up were significantly older, more disabled, had more chronic diseases and poorer cognitive function compared to those who participated in at least one follow-up; this could limit the generalization of the findings. However, participants lost to follow-up also had significantly lower physical performance. Therefore, censoring of these participants would likely underestimate the strength of the relationship between adherence to this dietary pattern and lower extremity performance. Moreover, the relationship under study has many potential important confounders: participants with low adherence to a Mediterranean diet had more chronic diseases and disabilities, conditions that could determine a lower adherence to a healthy dietary pattern. However, the association between Mediterranean diet and change in physical function remained significant after the selection of a subset of participants with no disabilities and a SPPB scores ≥ 10 , a measure that identifies healthy and highly functioning persons.

Despite these limitations, the current study provides evidence that a high adherence to a Mediterranean-style diet is associated with a slower decline in lower body mobility over time in older persons living in the community. Confirmation of this finding in other studies and adequately sized clinical trials are needed to definitively determine whether a nutritional intervention that follow a Mediterranean diet can reduce functional decline and the onset of disability in older persons. Dietary interventions may be a cost-effective strategy to promote healthy aging and reduce the burden of age-related disability in the population.

Mediterranean diet is widely considered a model of healthy eating

- Adherence to Mediterranean is associated with lower decline in mobility over time.
- Adherence to Mediterranean is associated with lower risk of mobility disability.

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Figure 1.
MDS score distribution in women (n = 520) and (n = 415) men.

Figure 2. Short Physical Performance Battery (SPPB) scores during 9 years of follow-up by baseline Mediterranean Diet Score groups. Estimated Means and Standard Errors are adjusted for age, sex, energy intake, BMI, MMSE score, physical activity, ADL and IADL disabilities, depressed mood and number of chronic diseases.

Table 1

Characteristics of the study population at baseline according to Mediterranean Diet Score.

Characteristics	Total sample (n=935)	Mediterranean Diet Score			<i>p</i> [*]
		≤ 3 (n=253)	4 – 5 (n=408)	≥ 6 (n=274)	
Age (years)	74.1±6.8	76.3±7.4	73.9±6.8	72.5±5.8	<.0001
Sex (F)	55.6	54.2	60.3	50.0	0.03
Education (years)	5.5±3.3	5.3±3.5	5.4±3.2	5.7±3.2	0.3
Smoking status					0.86
non smoker	58.9	58.5	60.3	57.3	
former smoker	27.2	26.1	26.7	28.8	
current smoker	13.9	15.4	13.0	13.9	
MMSE scores	25.4±3.1	24.9±3.3	25.4±3.1	25.8±2.9	0.002
BMI (Kg/m ²)	27.5±4.1	27.1±4.4	27.5±4.1	27.9±3.8	0.06
Physical activity					<.0001
Low	17.4	26.5	15.4	12.0	
Medium	76.8	70.8	78.2	80.3	
High	5.8	2.8	6.4	7.7	
Depressed mood	20	27.8	19.6	13.6	0.0002
No. of ADL disabilities	0.1±0.6	0.5±1.4	0.2±0.8	0.1±0.6	<.0001
No. of IADL disabilities	0.6±1.6	0.3±0.9	0.1±0.5	0.1±0.4	<.0001
No. of medications	2.2±2.0	2.7±2.2	2.2±1.9	1.9±1.9	<.0001
No. of chronic diseases	1.2±0.9	1.4±1.1	1.2±0.9	1.1±0.8	0.0003
SPPB score	10.1±2.9	9.3±3.5	10.1±2.7	10.8±2.1	<.0001
Energy intake (Kcal/day)	1932.2±560.9	1807.6±579.9	1915.1±559.4	2072.5±514.5	<.0001
Knee strength (Kg)	16.0±6.0	15.1±6.1	15.9±6.0	17.0±5.9	0.001

Variables reported as percentage or means±standard deviation as appropriate

* Based on chi-square or general linear model as appropriate.

MMSE, Mini Mental State Examination; BMI, Body Mass Index; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; SPPB, Short Physical Performance Battery.

Depressed mood: CES-D score ≥ 20 .

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Table 2
Adjusted Odds Ratios of Mobility Disability according to Mediterranean Diet Score baseline.

Mobility Disability									
n = 935	Model 1*			Model 2†			Model 3‡		
	O.R.	95% C.I.	P	O.R.	95% C.I.	P	O.R.	95% C.I.	P
MDS									
Low adherence	Ref			Ref			Ref		
Medium adherence	0.70	(0.47 – 1.05)	0.09	0.73	(0.48 – 1.10)	0.13	0.97	(0.60 – 1.57)	0.9
High adherence	0.47	(0.29 – 0.76)	0.002	0.50	(0.30 – 0.82)	0.006	0.73	(0.41 – 1.28)	0.27
Per 2-point increase	0.75	(0.61 – 0.92)	0.005	0.78	(0.63 – 0.96)	0.02	0.92	(0.73 – 1.17)	0.49

* Adjusted for age and sex
† Adjusted for age, sex, energy intake and BMI.
‡ Adjusted for age, sex, energy intake, BMI, MMSE score, physical activity, ADL and IADL disabilities, depressed mood, number of chronic diseases and medications
O.R. Odds Ratio; C.I., Confidence Interval
MDS, Mediterranean Diet Score: low adherence ≤ 3; medium adherence 4 – 5; high adherence ≥ 6; SD = 1.6 points
Mobility Disability: SPPB ≤ 9.

Table 3

GEE model estimates of lower extremity performance over 9 years follow-up in InCHIANTI participants according to baseline Mediterranean Diet Score.

	Estimate	S.E.	P
Interaction: Diet × Time			
Low adherence × T1	Ref		
Medium adherence × T1	0.59	0.21	0.01
High adherence × T1	0.86	0.21	<.0001
Low adherence × T2	Ref		
Medium adherence × T2	0.37	0.28	0.19
High adherence × T2	1.09	0.29	0.0002
Low adherence × T3	Ref		
Medium adherence × T3	0.57	0.38	0.14
High adherence × T3	0.90	0.41	0.03

Adjusted for age, sex, energy intake, BMI, MMSE score, physical activity, ADL and IADL disabilities, depressed mood and number of chronic diseases.

Mediterranean Diet Score: low adherence ≤ 3; medium adherence 4 – 5; high adherence ≥ 6.

Adjusted Incidence of Mobility Disability according to baseline Mediterranean Diet Score in participants without ADL disabilities and SPBB ≥ 10 .

Table 4

Mobility Disability					
n = 684	Model 1*			Model 2†	
	H.R.	95% C.I.	P	H.R.	95% C.I.
Mediterranean Diet Score					
Low adherence	Ref			Ref	
Medium adherence	0.79	(0.58 – 1.06)	0.11	0.78	(0.58 – 1.07)
High adherence	0.69	(0.50 – 0.96)	0.03	0.71	(0.51 – 0.98)
Per 2 points increase	0.85	(0.74 – 0.98)	0.03	0.86	(0.74 – 0.99)

* Adjusted for age, sex and baseline SPPB.

† Adjusted for age, sex, baseline SPPB, energy intake, BMI, MMSE score, physical activity, IADL disabilities, depressed mood and number of chronic diseases.

H.R. Hazard Ratio; C.I., Confidence Interval.

Mediterranean Diet Score: low adherence ≤ 3 ; medium adherence 4 – 5; high adherence ≥ 6 ; SD = 1.6 points

Mobility Disability: SPPB ≤ 9 .