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Adherence to a Mediterranean diet and onset of disability in older persons

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Abstract Higher adherence to a Mediterranean-type diet is linked to lower risk of mortality, cardiovascular disease and Alzheimer's disease while its association with disability has never been assessed. The aim of the study was to investigate the relation between adherence to a Mediterranean diet (MeDi) and disability in activities of daily living. The study sample consisted of 1,410 individuals from Bordeaux, France, included in 2001–2002 in the Three-City Study and re-examined at least once over 5 years. Adherence to a MeDi (scored as 0–9) was computed from a food frequency questionnaire and 24H recall. Disability in Basic and Instrumental ADL (B-IADL) was evaluated on the Lawton–Brody and Katz scales. Statistical analyses were stratified by gender and adjusted for potential confounders. No association between MeDi adherence and baseline disability in B-IADL was highlighted in men or in women in multivariate models. Risk of onset of disability in B-IADL over time was not significantly associated with MeDi adherence in men. In women, MeDi adherence was inversely associated with the risk of incident disability in B-IADL (HR = 0.90, 95% Confidence Interval 0.82–0.98 for 1 point of the score). Women with the highest MeDi adherence (score 6–8) had a 50% (22–68%) relative risk reduction of incident disability in B-IADL over time than women in the lowest MeDi category (score 0–3). In addition to its well-documented beneficial effects on health, adherence to a Mediterranean-type diet could contribute to slow down the disablement process in women.

Keywords Mediterranean diet · Disability · Activities of daily living

Introduction

Absence of disability or activity limitation is a major component of successful aging. Disability is defined as difficulty or dependency in carrying out activities necessary for independent living, including roles, tasks needed for self-care and household chores and other activities important for a person's quality of life [1]. The disablement process leads to a poorer quality of life, a rise in morbidity and mortality without predictable pattern [2–4]. Despite a trend to lower disability rates in the last years, the prevalence of disability increases again as a consequence of increasing number of older subjects, surviving to severe disease or with long course poorer health status, such as obesity and overweight [3, 5]. Therefore, strategies to prevent or delay the entry into the disablement process, to slow down its progression and/or to contribute to recover from disability must be developed [6].

Nutrition constitutes an interesting approach against the development and progression of disability, which deserves further investigation [7, 8]. Some epidemiological studies have suggested that specific foods or nutrients (i.e., dairy products, fruits, vegetables, calcium, vitamins D, E, B6, B12, folate and selenium) may have potential protective effects against disability [9–15]. While many components

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of food have been studied in isolation, nutrients are consumed in combination in foods, which are themselves components of various dietary patterns [16]. In this context, the Mediterranean diet (MeDi) combines several foods and nutrients already proposed as potential protective factors against several conditions that may contribute to the disablement process [17–19]. Greater MeDi adherence has already been associated with longer survival, reduced risk for cardiovascular and cancer mortality, lower cancer and Alzheimer's disease incidence and slower cognitive decline [18–23]. To our knowledge, the association between MeDi adherence and disability in older persons has never been assessed.

The purpose of the current study was to investigate the relationship between MeDi adherence and disability in activities of daily living over 5 years among French older community-dwellers from the Three-City Study.

Methods

Participants

The Three-City (3C) study is a prospective cohort study of vascular risk factors of dementia whose methodology has been described elsewhere [24]. The 3C study protocol was approved by the Consultative Committee for the Protection of Persons participating in Biomedical Research at Kremlin-Bicêtre University Hospital (Paris). A sample of 9294 community dwellers aged 65 and over was selected in 1999–2000 from the electoral rolls of three French cities (Bordeaux, Dijon and Montpellier). All participants gave written informed consent. Three follow-up examinations were performed 2 (wave 1, 2001–2002), 4 (wave 2, 2003–2004) and 7 y (wave 3, 2006–2007) after baseline examination. Data collection included socio-demographic information, lifestyle, symptoms and medical complaints, medical history, blood pressure, smoking status, drug use, anthropometric data, neuropsychological testing, and blood sampling. The present study is based on waves 1, 2 and 3 in Bordeaux, the only centre where the standard data collection was completed with a comprehensive dietary survey. The study sample, whose characteristics were detailed previously [22], comprises 1,410 non-demented participants without missing nutritional data and with at least one follow-up re-examination over 5 years. At wave 2, 1,340 subjects (95%) were re-examined and 1,213 (86% of the initial study sample) were re-examined at wave 3. Among the 114 subjects (53 men and 61 women) with nutritional data at wave 1 but without follow up examination over time, 69.8% of men and 57.4% of women were deceased and 42 subjects refused or were lost-to- follow-up between waves 1 and 3. Wave 3 was closed on December 2007 in the Bordeaux Center.

Assessment of disability

Two domains of disability based on the concepts of basic activities of daily living (ADL) and instrumental ADL (IADL) were investigated as outcomes. Based on the Lawton–Brody scale [25], disability in IADL was assessed according to the ability of the participants to use a telephone, manage medication, manage money, use public or private transport, and do shopping, for both genders, and additionally, to do the laundry, do housework and prepare meals for women. Disability in ADL was assessed using five items of the Katz scale [26]: bathing, dressing, toileting, transferring from bed to chair, and eating. Incontinence, which is an impairment rather than a disability [27], was not considered here. At each wave, a subject was considered as disabled if he/she could not perform at least one activity of the domain without a given level of assistance, as defined in the respective instruments [25, 26].

Dietary assessment and MeDi score

At wave 1, participants were visited at home by a specifically trained dietician who administered a food frequency questionnaire (FFQ, not semi-quantitative) and a 24H dietary recall [28, 29]. Data from the 24H recall were only used to estimate total energy intake in kcal/d and to compute the MUFA-to-SFA ratio (ratio of the nutrient intake in g/d). Based on the FFQ, the frequency of consumption of 40 categories of foods and beverages for each of the 3 main meals and 3 between-meals snacks was recorded in 11 classes. The food items were converted into number of servings per week and then aggregated into 20 food and beverage groups as described earlier [29]. We then identified the food groups considered to be part of the MeDi: vegetables, fruits, legumes, cereals (including bread, pasta and rice, without distinction between whole and refined grains), fish, meat and dairy products. The number of servings/week for each food group was determined and the MeDi score was computed as follows: a value of 0 or 1 was assigned to each food group using sex-specific medians of the population as cut-offs, as previously described [30]. Briefly, subjects received one point if their intake was higher than the sex-specific median for a presumed protective component (vegetables, fruits, legumes, cereals, fish and MUFA-to-SFA ratio) and lower than the sex-specific median for a presumed deleterious component (meat and dairy products). For alcohol, one point was given to mild-to-moderate consumers. Cut-offs, chosen to be close to the second quartile of distribution of total alcohol consumption, were defined in men and women separately. One point was attributed for men if consumption was within 7-to-14 glasses per week (10-to-20 g/d) and for women if consumption was within 1-to-4 glasses per week (1.4-to-5.7 g/d). The MeDi score was generated by adding the scores for each food category for each participant. Thus, the MeDi score could range from 0 to 9, with higher scores indicating greater MeDi adherence [22]. Three MeDi categories (Low MeDi adherence, score 0–3; Middle MeDi adherence, score 4–5; or High MeDi adherence, score 6–9) were defined so as to be nutritionally relevant, close to tertiles of the distribution of the MeDi score in our sample and similar to those used in previous studies [21, 22, 30].

Covariates

Socio-demographic information included age, sex, education (in four classes: no education or primary school only, secondary (middle) school, high school, vocational school or university), income (less than 750 euros, 750–1,500 euros, 1,500–2,250 euros, more than 2,250 euros per month and refuse to answer) and marital status (in four classes: married, divorced or separated, widowed, single). Global cognitive functioning was assessed using the Mini-Mental State Examination (MMSE), used as continuous variable [31]. Vascular risk factors included Body Mass Index (BMI in kg/m^2, used as continuous variable), smoking status (in three classes: never, ex- and current smokers), self-reported history of cerebrovascular disease, diabetes, hypercholesterolemia and measured hypertension (blood pressure $\geq$ 140/90 mmHg or treated), all used as dichotomous variable. Moreover, taking five medications/d (median of total medication consumption/d) or more was considered an indicator of comorbidity and used as dichotomous variable [22, 24]. Depressive symptomatology was assessed on the Center for Epidemiological Studies-Depression scale (CES-D), used as continuous variable [32, 33]. Practice and intensity of physical exercise was assessed by two questions: 'Do you practice sports?' and 'Do you perspire when you practice sport?'. A three-level variable (no, moderate and intensive) was computed to describe intensity of physical exercise as earlier described [28].

Statistical analyses

All statistical analyses were performed with SAS Statistical package (Version 9.1 SAS Institute).

Participants were classified according to their disability status at baseline in each domain separately (IADL or ADL) and also according to categories of MeDi adherence (low, middle or high). Baseline disability status and dietary characteristics were compared between men and women using Chi-Square statistics or Student's t test. Baseline demographic, dietary and clinical characteristics were compared, in men and women separately, between subjects with and without disability in IADL or ADL using Chi-Square statistics or Student's t test.

We then explored associations between the presence of disability in IADL or ADL and MeDi adherence at baseline (wave 1) by multi-linear logistic regression. Associations between MeDi adherence and incidence of disability were investigated in subjects without baseline disability by Cox proportional hazards models with delayed entry and taking age as a time scale [34]. Odds ratios (OR), Hazard ratios (HR) and 95% confidence intervals (95% CI) were estimated for the MeDi score considered as a continuous variable (MeDi score from 0 to 9, 1-point increase) or as a categorical variable (low MeDi category, score 0–3 as reference vs. middle, score 4–5 and high, score 6–9, categories respectively).

For logistic regressions and Cox analyses, two models were performed: model 1 was adjusted for (age) education (the first class (no education or primary school only) was chosen as reference), income (reference: less than 750 euros), marital status (reference: married) and total energy intake, used as continuous variable. Then, cardiovascular risk factors (smoking (reference: never), BMI, hypertension (reference: no hypertension) and diabetes (reference: no diabetes), stroke (reference: no history of stroke), taking $\geq$5 medications/d (reference: less than 5 medications/d), MMSE and CES-D scores were entered as additional adjustment variables in model 2. Additional adjustment for physical activity (reference: no practice) was performed in secondary analyses.

Separate analyses were performed for each gender since gender differences in disability have been widely documented [35, 36], three specific items were additionally used when assessing women as in the original IADL scale [25] and the MeDi score was computed according to the sex-specific medians of consumption of food groups.

In sensitivity analyses, we explored the association between MeDi adherence and disability in IADL focusing only on the five items administered for both genders (to use a telephone, manage medication, manage money, use public or private transport, and do shopping) in order to perform similar analyses in women and men.

Results

The study sample consisted of 1,410 non-demented individuals (527 men and 883 women), aged 75.9y on average (range 67.7–94.9), with at least one follow-up re-examination over 5 years. The median follow-up was 4.1y (range 1.6–6.1y). Participants with missing follow-up ($n = 114$) had a non-significant lower mean MeDi score (4.1 vs. 4.4 $P = 0.09$), were significantly more disabled in IADL (29.5% vs. 13.6%, $P < 0.0001$) but not in ADL (2.6% vs. 1.1%, $P = 0.16$) at baseline than those with complete follow-up.

Disability in IADL and ADL was present in 190 (13.6%) and 16 (1.1%) participants at baseline respectively (Table 1). Women were significantly more often disabled in IADL than men at baseline. Because of the small number of ADL disabled subjects at baseline, participants with disability in ADL or IADL were brought together at each wave and termed as subjects with disability in basic or instrumental ADL (B-IADL).

The MeDi score ranged from 0 to 8. The mean (SD) MeDi score was 4.4 (1.7) and was slightly but significantly higher in men (Table 1). As expected, greater MeDi adherence was characterized by higher intake of vegetables, fruits, legumes, cereals and fish and lower intake of meat and dairy products. High MeDi adherence was significantly more frequent in men.

Men with baseline disability in B-IADL were significantly older, had lower income, higher mean CES-D scores and took significantly more medications/d than the control men (Table 2). The mean MeDi score did not differ between men with and without baseline disability in B-IADL (Table 2). Women with baseline disability in B-IADL were significantly older, had lower educational level and income, were more often widowed and had a lower practice of physical exercise than control women. The mean MeDi score was also significantly lower in women with baseline disability in B-IADL than in control women, with a borderline significant trend to a higher frequency of women with low MeDi adherence (Table 2). Women with baseline disability had also a worse health status than control women (Table 2).

The association between baseline disability in B- IADL and MeDi adherence was assessed in multivariate logistic regression models in 513 men and 839 women without missing data on any covariate (Table 3). In men as in women, MeDi score, either as a continuous or categorical variable, was not associated with baseline disability in B-IADL.

Among the 1,212 participants without disability in B-IADL at baseline, incident disability in B-IADL occurred for 284 subjects. The incidence of disability for

Table 1 Prevalence of disability in IADL and basic ADL according to gender, and baseline dietary characteristics, among older persons living in Bordeaux, The Three-City study, 2001–2002 ($N = 1,410$)

	All	Men ($n = 527$)	Women ($n = 883$)	*P*
Disability (n) %				
IADL	(190) 13.6	(48) 9.2	(142) 16.3	0.0002
ADL	(16) 1.1	(6) 1.1	(10) 1.1	0.99
B-IADL	(198) 14.0	(50) 9.5	(148) 16.7	0.0002
Dietary characteristics				
Median of weekly consumption of 8 food components of the MeDi score[a]				
Dairy products	14.2	14.0	15.0	
Red meat	5.0	5.0	4.0	
Vegetables	19.0	19.0	18.7	
Fruits	14.0	14.0	14.0	
Legumes	0.5	0.5	0.5	
Cereal[b]	23.0	23.5	23.0	
Fish	2.5	2.7	2.5	
MUFA-to-SFA ratio, median	0.8	0.8	0.8	
Mild-to-moderate alcohol consumers[c] (%)	28.4	33.0	25.6	
MeDi score, mean (SD)	4.4 (1.7)	4.5 (1.7)	4.2 (1.6)	0.001
MeDi categories				0.01
Low MeDi category (score 0–3), (*n*) %	(423) 30.0	(135) 25.6	(288) 32.6	
Middle MeDi category (score 4–5), (*n*) %	(615) 43.6	(235) 44.6	(380) 43.0	
High MeDi category (score 6–8), (*n*) %	(372) 26.4	(157) 29.8	(215) 24.3	

IADL Instrumental activities of daily living, *ADL* Basic activities of daily living, *MeDi* Mediterranean diet, *MUFA* Monounsaturated fatty acid, *SFA* Saturated fatty acids

P for the Chi-Square test or Student's *t* test (mean MeDi score) between men and women

[a] Median of frequency of consumption (serving/week) for each food group

[b] Cereals included consumption of cereals, bread and pasta (whole and refined grains)

[c] For alcohol intake, we attributed a value of 1 for people whose consumption was mild-to moderate, close to the second quartile of distribution of total alcohol intake. One point was given to men if their consumption was within 7-to-14 glasses per week (10-to-20 g/d) and to women if consumption was within 1-to-4 (1.4-to-5.7 g/d) glasses per week

Table 2 Demographic, dietary and clinical characteristics according to baseline disability in basic or instrumental ADL among older persons living in Bordeaux, The Three-City study, 2001–2002

	Men ($n = 527$)			Women ($n = 883$)		
	Control ($n = 477$)	Disabled ($n = 50$)	*P*	Control ($n = 735$)	Disabled ($n = 148$)	*P*
Demographic characteristics						
Age (y) mean (SD)	75.1 (4.6)	77.8 (4.6)	<0.0001	75.4 (4.6)	79.3 (5.0)	<0.0001
Education (%)			0.17			0.0002
No or primary school	23.7	38.0		33.1	51.4	
Secondary	25.8	22.0		29.4	23.6	
High school	22.4	18.0		24.1	12.5	
University	28.1	22.0		13.4	12.5	
Monthly income (€) (%)			0.003			0.0005
<750	1.5	8.0		9.5	16.4	
750–1,500	22.7	34.0		38.0	50.7	
1,500–2,250	28.4	26.0		23.5	13.7	
>2,250	40.8	32.0		21.9	13.7	
Refused to answer	6.7	0.0		7.1	5.5	
Marital status (%)			0.98			0.008
Married	79.6	82.0		45.0	34.9	
Divorced/separated	4.8	4.0		10.0	7.5	
Widowed	13.5	12.0		35.6	50.7	
Single	2.1	2.0		9.4	6.9	
Practice of physical exercise (%)			0.16			0.0001
No	51.7	62.0		52.7	64.4	
Moderate	16.8	14.0		20.8	6.8	
Intensive	14.7	4.0		4.5	1.4	
No answer	16.8	20.0		22.0	27.4	
Dietary characteristics						
MeDi score, mean (SD)	4.5 (1.7)	4.6 (1.6)	0.79	4.3 (1.6)	3.9 (1.7)	0.003
MeDi categories (%)			0.81			0.06
Low MeDi category (score 0–3)	26.1	22.0		31.0	41.1	
Middle MeDi category (score 4–5)	44.3	48.0		43.1	38.4	
High MeDi category (score 6–8)	29.6	30.0		25.1	20.5	
Total energy intake (kcal/d), mean (SD)	1,876 (513)	1,810 (543)	0.39	1,473 (443)	1,485 (395)	0.77
Clinical characteristics						
BMI (kg/m^2), mean (SD)	27.0 (3.5)	27.1 (3.5)	0.88	26.1 (4.3)	26.9 (5.0)	0.06
CES-D score, mean (SD)	5.2 (5.3)	9.2 (9.1)	0.004	8.2 (7.4)	12.4 (8.8)	<0.0001
MMSE score, mean (SD)	27.8 (1.7)	27.4 (2.2)	0.16	27.7 (2.0)	27.1 (2.1)	0.001
Number of drug/d > 5 (%)	41.0	62.0	0.004	48.5	75.3	<0.0001
Hypertension (%)	80.2	72.0	0.17	71.6	82.9	0.005
Diabetes (%)	13.1	20.0	0.17	5.6	14.4	0.0001
Smoking status (%)			0.21			0.14
Never	61.1	50.0		82.2	88.4	
Ex-smoker	30.7	36.0		14.3	8.2	
Current smoker	8.2	14.0		3.5	3.4	
Stroke (%)	1.9	0.0	0.33	1.1	4.8	0.001

ADL Activities of daily living, *MeDi* Mediterranean diet, *BMI* Body Mass Index, *CES-D* Center for Epidemiological Studies-Depression scale, *MMSE* Mini-Mental State Examination

P-value for the Chi-Square test between subjects with baseline disability in B-IADL and control subjects, except for age, Mediterranean diet score, total energy intake, BMI, CES-D score and MMSE score whose means were compared by Student's *t* test

Table 3 Association between Mediterranean Diet adherence and baseline disability in basic or instrumental ADL stratified by gender and adjusted for potential confounders among older persons, Bordeaux, The Three-City study, 2001–2002

	Men (n = 513)						Women (n = 839)					
	Model 1			Model 2			Model 1			Model 2		
	OR (95% CI)	*P*	Overall	OR (95% CI)	*P*	Overall	OR (95% CI)	*P*	Overall	OR (95% CI)	*P*	Overall
MeDi score (0–8)	0.99 (0.83 to 1.19)	0.98		1.01 (0.83 to 1.22)	0.95		0.89 (0.79 to 1.01)	0.08		0.91 (0.80 to 1.04)	0.18	
Low MeDi category[a] (score 0–3)	1.00			1.00			1.00			1.00		
Middle MeDi category (score 4–5)	1.18 (0.54–2.60)	0.68	0.87	1.29 (0.56–2.97)	0.54	0.82	0.67 (0.43–1.05)	0.08	0.21	0.71 (0.44–1.13)	0.15	0.34
High MeDi category (score 6–8)	1.02 (0.43–2.42)	0.97		1.14 (0.45–2.85)	0.79		0.76 (0.44–1.29)	0.30		0.89 (0.51–1.56)	0.69	

MeDi Mediterranean diet, *ADL* Activities of daily living, *OR* Odds ratio, *CI* Confidence Intervals

[a] The lowest category of MeDi score (0–3) was chosen as referent

Model 1: Model adjusted for (age) education, marital status, income and total energy intake

Model 2: Model 1 + additional adjustment for Body Mass Index, hypertension, diabetes, smoking, stroke, taking ≥5 drugs/d, Mini-Mental State Examination score and Center for Epidemiological Studies-Depression score

B-IADL was higher in women than in men (6.7 for 100 persons-years vs. 4.8 respectively, $P = 0.02$).

Among 470 men without missing data on adjustment variables, there was no association between MeDi score, either as a continuous or categorical variable, and the risk of disability in B-IADL over time (Table 4). In women ($n = 709$ without missing data), each additional unit of MeDi score was associated with a 10% (95% CI 2–18%) reduced risk of incident disability in B-IADL over time (Table 4). When considering the MeDi score as a categorical variable, women in the highest MeDi category (score 6–8) compared with those in the lowest MeDi category (score 0–3) had a 50% (95% CI 22–68%) relative risk reduction of incident disability in B-IADL over time (Table 4). Additional adjustment for physical activity did not modify these associations (data available on request).

In sensitivity analyses, the association between MeDi adherence and incident disability in B-IADL was assessed in women excluding the three women-specific items of the IADL scale. We identified 720 women without baseline disability in the 5-common IADL items and without missing data on adjustment variables. Among them, incident disability in the same items occurred for 185 women. As for the whole study sample of women, each additional unit of MeDi score was associated with a reduced risk of incident disability in the 5-common IADL items over time (HR = 0.90, 95% CI 0.82–0.98, $P = 0.02$). Moreover, a 50% relative risk reduction for incidence of disability in the 5-common IADL items was observed for women in the highest MeDi category (score 6–8) compared with those in the lowest MeDi category (score 0–3) (HR = 0.50, 95% CI 0.32–0.78, $P = 0.002$, P for trend = 0.01).

Discussion

This large population-based prospective study in older persons living in South-western France shows no association between MeDi adherence and the presence of disability in B-IADL in men as in women in fully adjusted models. By contrast, women with higher MeDi adherence were less likely to become disabled in B-IADL over time. Moreover, there was no association between MeDi adherence and incidence of disability in B-IADL in men. These associations were independent of energy intake, depressive symptomatology, cardiovascular risk factors and baseline global cognitive performances.

Few studies have linked dietary factors with disability in B-IADL among older persons and to our knowledge, none concerned the MeDi [8, 37]. Among prospective studies, intake of dairy products, fruits and vegetables were inversely associated with risk of disability in IADL and ADL over time, mainly in women [9, 15]. No association

Table 4 Association between Mediterranean diet adherence and risk for incident disability in basic or instrumental ADL stratified by gender and adjusted for potential confounders among older persons without disability in basic or instrumental ADL at baseline, Bordeaux, The Three-City study, 2001–2007

	Men (n = 470; 90 incident cases)						Women (n = 709; 185 incident cases)					
	Model 1			Model 2			Model 1			Model 2		
	HR (95% CI)	P	Overall	HR (95% CI)	P	Overall	HR (95% CI)	P	Overall	HR (95% CI)	P	Overall
MeDi score (0–8)	1.02 (0.90–1.15)	0.79		1.03 (0.91–1.17)	0.61		0.89 (0.81–0.97)	0.01		0.90 (0.82–0.98)	0.02	
Low MeDi category[a] (score 0–3)	1.00			1.00			1.00			1.00		
Middle MeDi category (score 4–5)	0.78 (0.47–1.32)	0.36	0.61	0.82 (0.48–1.39)	0.45	0.65	0.84 (0.61–1.17)	0.31	0.007	0.89 (0.64–1.23)	0.48	0.009
High MeDi category (score 6–8)	0.94 (0.53–1.66)	0.83		1.00 (0.56–1.81)	0.99		0.49 (0.31–0.76)	0.002		0.50 (0.32–0.78)	0.003	

MeDi Mediterranean diet, *ADL* Activities of Daily Living, *HR* Hazard ratio, *CI* Confidence Intervals

P value for Cox proportional hazard models

[a] The lowest category of MeDi score (0–3) was chosen as referent

Model 1: Model adjusted for (age) education, marital status, income and total energy intake

Model 2: Model 1 + additional adjustment for Body Mass Index, hypertension, diabetes, smoking, stroke, taking $\geq$5 drugs/d, Mini-Mental State Examination score and Center for Epidemiological Studies-Depression score

with other food groups was reported in these analyses. Despite the lack of assessment of disability in IADL and ADL at baseline in these studies, which constituted a major drawback, results are in agreement with a potential benefit role of particular food groups in the disablement process. Concerning dietary micronutrient intake, women of the E3 N study with IADL impairment reported past lower intakes of vitamins B6 and B12 [15]. Biological data confirm these findings since low serum concentration of vitamins B6 and B12, were significant and independent predictors of ADL disability 3 years later in women enrolled in the Women's Health and Aging Study while carotenoids, zinc and folate levels, which are also yet common in the MeDi, were not significant predictors [10].

The biological basis for the apparent health benefits of the MeDi involves a decrease in oxidative stress and inflammation which also participates in the dysregulation of cellular function, muscle damages and the exacerbation of degenerative diseases, such as cognitive decline, sarcopenia, cardiovascular diseases, atherosclerosis, cancer and frailty, leading to B-IADL disability [9, 10, 14, 38–41]. Individuals with higher MeDi adherence have been shown to have higher reduced-to-oxidized glutathione ratio, and lower insulin resistance, oxidized low-density lipoprotein, C-reactive protein and interleukin-18 levels [42–44].

The striking differences of the association between MeDi adherence and incident disability in B-IADL according to gender may be explained by several factors. First of all, some chronic and acute conditions impacting on the disablement process may differ in men and women [4, 35, 36, 45]. For instance, the incidence of cardiovascular disease is higher in men, leading to sudden death without prior disability. The inverse association between adherence to a MeDi and lower risk of cardiovascular mortality has been widely documented [21, 22]. Hence, in men a protective effect of the MeDi may be more easily evidenced on mortality than on disability. However, the mean MeDi score was not significantly different between men with follow-up compared to those who deceased between 2001–2002 and 2006–2007 (data available on request). A second set of explanations for these gender differences may lie in methodological aspects related to the measurement of dietary intake. Firstly, computation of the MeDi score is based on sex-specific medians. In our sample, the medians consumption of most of food groups were very similar in men and women, except for that of dairy products and meat. Second, the FFQ used in the present study assessed number of servings but not portion size. Although our analyses were adjusted for total energy intake, we cannot exclude that the quantity of presumed protective or deleterious nutrients consumed by men and women with a similar MeDi score may differ. This misclassification in the levels of exposure is probably not related to the incidence of disability in B-IADL. Therefore, our results may have been an underestimation of the true associations. This could in part explain the lack of association between MeDi adherence and incidence of disability in B-IADL in men. Finally, the lack of an association between MeDi adherence and disability in B-IADL at baseline may be due to a lack of statistical power, since few men are disabled at baseline.

We found an inverse association between MeDi adherence and risk of disability in B-IADL over time but not at baseline in fully adjusted models. First, it is important to consider that women included in cross-sectional and longitudinal analyses partly differed. Indeed, women with baseline disability in B-IADL are excluded from longitudinal analyses, leading to a sub-sample of women with high baseline MeDi score and better health status for longitudinal analyses. Second, most late-life disability is believed to be the result of an insidious process in which risk factors for disablement accumulate over many years and slowly exert deleterious effects that impair the ability to live independently [46]. The protective association between the MeDi and risk of B-IADL disability is in accordance with previous findings of slower cognitive decline in older persons adhering more closely to a MeDi [23]. Indeed, B-IADL, and more specifically the so-called “Instrumental” activities [25], include complex tasks such as managing finances, medication or means or transportation that require integrity of cognitive functioning [47]. Limitation on these activities is strongly associated with cognitive decline and risk of dementia [48]. Hence, the MeDi could contribute to postpone disability in B-IADL by slowing down cognitive decline in older persons. Indeed, the MeDi provides dietary antioxidants, from fruits and vegetables, B vitamins, from cereals and green leafy vegetables and omega3 fatty acids, from fish, whose protective role against brain aging has been suggested by many observational studies [49–51]. This effect was independent of baseline cognitive performance and cardiovascular risk factors in our study. Nevertheless, this protective association was observed only in women and not explained by the three women-specific items of the IADL scale. Some studies observed a higher incidence of dementia in women [52] which may have increased the power of the study to detect a protective effect against functional decline associated with neurodegenerative disease in women.

Our results should be interpreted with caution because of some methodological limitations. First, the overall good health of participants is highlighted by the low prevalence of baseline disability in subjects enrolled in the current study compared with those who were not included in these analyses. This may in part explain the low incidence of disability in IADL and ADL observed and may have decreased our chance to evidence additional or stronger associations. In a sub-sample of the French PAQUID study, we already observed similar incidence of disability in IADL and ADL [53, 54]. Usually, women experience longer disability before death than men [35]. Hence, more new “cases” of disability may have been missed in men who may have died in a disabled state between two waves of follow-up, and thus never detected. Second, the MeDi score is based on a traditional Mediterranean reference pattern defined a priori which does not consider the overall correlation between all foods [16]. The use of sex-specific cut-off points does not measure adherence to a universal traditional MeDi pattern but rather to a specific pattern, which precludes generalising results of the present study to other populations who have on the whole different food intake and MeDi adherence [55]. However, advantage of the MeDi score is the potential to consider additional, synergistic or opposite effects of 9 food groups and therefore to minimize confounding and modification effects among nutritional variables. In the same way, we adjusted our analyses for energy intake, to achieve of an isocaloric diet and to reduce measurement error in the score [56, 57]. Finally, we cannot rule out the possibility of residual confounding by other unknown risk or protective factors such as a general healthier lifestyle of MeDi adherents.

Despite these limitations, the strengths of the present study are its size, the population-based design, and control for several potential confounders. In particular, we controlled for depressive symptomatology since links between poor performance in IADL and depression are well documented [58, 59]. We also controlled our analysis for BMI, cardiovascular risk factors and cognitive performances, which reinforced our results [5, 21, 22]. Although physical activity would most likely impact the association between dietary intake and physical functioning and disability, additional adjustment for this variable did not modify the result of the analyses. We did not adjust our main analyses for physical activity because we hypothesized that it might lie in the causal pathway, and thus was not a confounder [60].

In conclusion, this cohort study conducted in French elderly community dwellers showed an inverse association between adherence to a Mediterranean type diet and risk of B-IADL disability in women. No association was evidenced in men. The Mediterranean-style diet pattern probably does not fully explain the better health of persons who adhere to it but it likely contributes directly. The possible beneficial effect of the MeDi identified in the current study on the onset of disability, at least in older women, could be added to its widely acknowledged health benefits.

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