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Original Study

Dietary Patterns and 12-Year Risk of Frailty: Results From the Three-City Bordeaux Study

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A B S T R A C T

Objective: To analyze the association between dietary patterns and the 12-year risk of frailty and its components in community-dwelling elderly French adults.
Design: A prospective cohort study.
Setting: The Bordeaux sample of the Three-City Study.
Participants: A total of 972 initially nonfrail nondemented participants (336 men and 636 women) aged 73 years on average, re-examined at least once over 12 years.
Measurements: Five sex-specific dietary clusters were previously derived at baseline. Frailty incident to the baseline visit was defined as having at least three out of the following 5 criteria: unintentional weight loss, exhaustion, low energy expenditure, slowness, and muscle weakness. Multivariate Cox proportional hazard models were used to assess the association between dietary clusters and the risk of frailty and its components.
Results: In total, 78 men for 3719 person-years and 221 women for 7027 person-years became frail over the follow-up. In multivariate analyses, men in the "pasta" pattern and women in the "biscuits and snacking" pattern had a significantly higher risk of frailty compared with those in the "healthy" pattern [hazard ratio (HR) 2.2; 95% confidence interval (CI) 1.1–4.4 and HR 1.8; 95% CI 1.2–2.8, respectively; $P = .09$ and $P = .13$ for the global test of significance of risk difference across clusters, respectively]. In men, "biscuits and snacking" and "pasta" patterns were significantly associated with higher risk for muscle weakness (HR 3.3; 95% CI 1.6–7.0 and HR 2.1; 95% CI 1.2–3.7, respectively; $P = .003$ for global test).
Conclusions: This 12-year prospective population-based study suggests that some particular unhealthy dietary patterns may increase the risk of frailty in older adults.

In aging societies, the frailty of elderly people has emerged as a major concept because it has been associated with higher risk of dependence, institutionalization, morbidity, and mortality.[1] There is no consensus to date to define frailty, although most researchers have used the frailty phenotype proposed by Fried et al to operationalize this concept.[2,3] The frailty phenotype was mainly defined as "a biologic syndrome of decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiologic systems, and causing vulnerability to adverse outcomes."[1] Using Fried's definition, a systematic review reported a prevalence of 10% for frailty in community-dwelling adults aged 65 years and older, although higher/lower prevalence has also been reported.[4]

As part of modifiable lifestyle, nutrition may play an essential role in the etiology of frailty and of its components.[5] Most of evidence about the role of nutrition on frailty has been provided by the study of single nutrients or specific foods.[5–7] Deficiencies in vitamin D, in antioxidant vitamins (E, C, and carotenoids), and lower intake

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of protein were associated with higher risk of frailty[6] whereas a higher consumption of fruits and vegetables was associated with a reduced risk of frailty in a dose-response manner.[7] However, people do not eat single nutrients, or foods and nutrients may have additive, opposite, or synergistic effects, which encourages study in combination.[8] Hence, dietary patterns that represent a combination of foods may be better associated with disease risk than single foods.[9,10]

However, few epidemiologic reports have investigated the association between dietary patterns and frailty to date.[5] Most of them were interested in dietary patterns based on a priori hypotheses, such as the Mediterranean diet, and reported a significant reduced risk of frailty among elderly people with greater Mediterranean diet adherence.[11–13] Unlike a priori patterns, a posteriori dietary patterns are derived independently of any prior hypotheses on beneficial or harmful effects of diet on health and reflect actual dietary intakes observed in a given population.[14] Studies on the relationship between a posteriori dietary patterns and frailty in older adults are still few.[15–17] To our knowledge, only two prospective studies examined this relationship to date.[15,16] In the Seniors-Study on Nutrition and Cardiovascular Risk in Spain cohort, a higher adherence to a "prudent" pattern, characterized by high intake of olive oil and vegetables, was associated with a reduced risk of frailty after 3.5 years of follow-up.[15] In a Chinese cohort, no association was found between dietary patterns and 4-year incident frailty.[16] These two studies analyzed the risk of frailty over a relatively short follow-up period, whereas the possible (deleterious or beneficial) effect of dietary habits on frailty could be a long-term effect.

We propose to investigate the relationship between a posteriori dietary patterns that were previously derived by hybrid clustering method[18] and the risk for frailty and its components over a long follow-up period (ie, 12 years), in older adults aged 65 years and over from the Bordeaux sample of the Three-City (3C) Study.

Methods

Study Population

The study was conducted in the Bordeaux sample of the 3C Study, a prospective cohort study of vascular risk factors for dementia that included 2104 community-dwelling people in Bordeaux, France, at baseline in 1999–2000. Individuals aged 65 years and over and not institutionalized were eligible for recruitment. The protocol of the 3C Study and baseline characteristics have been detailed previously.[19] This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human individuals were approved by the Consultative Committee for the Protection of Persons participating in Biomedical Research of the Kremlin-Bicêtre University Hospital (Paris). Written informed consent was obtained from all participants.

At baseline, the standard data collection performed by trained psychologists included sociodemographic and lifestyle characteristics, medical history, neuropsychological testing, a physical examination, and blood sampling. Five follow-up examinations were performed, 2 years (wave 1, 2001–2002), 4 years (wave 2, 2003–2004), 7 years (wave 3, 2006–2007), 10 years (wave 4, 2009–2010), and 12 years (wave 5, 2011–2012) after baseline examination. At wave 1, in addition to the usual follow-up, participants answered a comprehensive dietary survey, including a 24-hour dietary recall and a detailed food frequency questionnaire, performed by trained dieticians. Frailty status was available only at baseline, waves 4 and 5, which limited the present analysis on data from baseline to wave 4 and wave 5.

Among the 2104 participants from Bordeaux included at baseline, 1474 were nonfrail and had available data for diet. We excluded 17 participants with prevalent dementia (as they were at higher risk of frailty, and they may have modified their diet because of their disease). Thus, the initial study sample was constituted of 1457 participants. Among them, 293 deceased between baseline and wave 4. After exclusion of 181 participants with missing data about frailty in waves 4 and 5, and 11 participants with incomplete data for covariates, 972 participants (336 men and 636 women) were included in the present analyses.

Frailty

According to definition of Fried et al,[1] participants were classified as frail if they met three or more criteria among the following: (1) unintentional weight loss; (2) exhaustion; (3) low energy expenditure; (4) slowness; and (5) weakness.

Weight loss was defined in our study as the self-reported unintentional loss of 3 kg or more recently. In case of missing data, this criteria was considered as fulfilled if body mass index (BMI) was <21 kg/m^2. Exhaustion was defined using two items of the Center for Epidemiologic Studies Depression scale.[20] Respondents were considered as exhausted if they answered "yes" to at least one of the two following items: During the past week, "I felt that everything I did was an effort" and "I could not get going." Low energy expenditure was defined as reporting no engagement in physical activities (strenuous leisure activities or sport). Slowness was ascertained using the Rosow-Breslau Health scale.[21] Respondents were considered as slow if they answered "no" to the 2 last Rosow-Breslau Health scale items: "walking between 1.6 and 3.3 feet" and "going up and down a flight of stairs." This proxy has been shown to be strongly associated with walking ability.[22] Finally, weakness was defined using the chair stand test at baseline and wave 5 and by the weakest quartile stratified by BMI and sex of the handgrip strength ascertained by dynamometer at wave 4. The chair stand test was shown to be a good proxy for handgrip strength.[23,24] Respondents unable to complete the respective physical performance tests were included as slow and as weak.

Dietary Clusters

Among participants from the 3C Bordeaux cohort who answered the dietary interview at wave 1, we previously characterized five sex-specific dietary clusters by hybrid clustering method.[18] The clusters have been described in details in a previous publication from our group.[18] Briefly, among both men and women, the most frequent cluster, labeled "small eaters" (31.4% in men and 31.0% in women), was characterized by a lower intake of all food groups and lower daily energy intake. The second most frequent cluster, labeled "healthy" (24.3% in men and 24.8% in women), was characterized by higher fish intake in men and higher fruits and vegetables intake in women. Moreover, we identified a "biscuits and snacking" cluster in both sexes (8.8% in men and 15.0% in women), which grouped individuals having frequent snacks, biscuits, and cakes, and a slightly higher energy intake. The fourth cluster was a "charcuterie, meat, and alcohol" cluster in men (14.5%) and a "charcuterie, starchy food, and alcohol" cluster in women (24.7%). Finally, a fifth cluster included frequent "pasta" eaters in men (21.0%) and "pizza, sandwich" eaters in women (4.5%).

Other Data

Baseline sociodemographic information included age, sex, education (in four classes: no or primary school, secondary school, high school, and university), monthly income (in four classes: refused to answer, $<$€1500, €1500–€2250, and $\geq$€2250), and marital status (in two classes: married and divorced/separated/widowed/single). Participants underwent an extensive neurologic testing for dementia and an independent committee of neurologists made dementia

diagnoses using the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition criteria. Height and weight were measured and BMI was computed as the weight/height squared ratio and expressed in kg/m^2. Multimorbidity was defined as combining at least two self-reported chronic diseases among: hypertension, diabetes, hypercholesterolemia, angina, cardiac rhythm disorders, cardiac failure, arteritis, myocardial infarction, asthma, Parkinson disease, dyspnea, osteoporosis, and thyroid diseases. Global cognitive performance was assessed using the Mini-Mental State Examination (MMSE).[25] Depressive symptomatology was defined as a Center for Epidemiologic Studies Depression score ≥23 for women and ≥17 for men (maximum score is 60).[20,26]

Statistical Analyses

All analyses were performed separately in men and women as dietary clusters were sex-specific.

We described the five dietary clusters based on baseline sample characteristics and compared clusters using *t*-test or analysis of variance for continuous variables and χ^2 test or Fisher exact test for categorical variables when appropriate.

Cox proportional hazard models were used to assess the association between a posteriori dietary clusters and the risk of frailty with age as the underlying time scale and delayed entry. As our data were interval-censored, the age at frailty onset was imputed using the age at midpoint of the interval between the diagnosis visit and the previous one. Participants who were never considered as frail were censored at their last follow-up visit. The "healthy" cluster, which we hypothesized to be associated with the lowest risk of frailty, was chosen as the reference category. In multivariate analyses, sociodemographic variables (marital status, education level, and income) were entered first (model 1), then health-related covariates (multimorbidity, BMI, depressive symptomatology, MMSE) were added to models (model 2). BMI was categorized into sex-specific tertiles to verify log-linearity assumption. In women, Cox models were stratified on marital status as the proportional hazard assumption was not verified for this variable.

Finally, we reran fully-adjusted Cox proportional hazard models with each frailty component as outcome in participants who did not fulfill the studied frailty component at baseline.

The level of significance was fixed at $\alpha = 0.05$ for all analyses. Statistical analyses were performed with SAS Statistical package release 9.3 (SAS institute Inc, Cary, NC).

Results

Sample Characteristics

The study sample was constituted of 972 nonfrail nondemented participants at baseline, including 336 men and 636 women. Their age at baseline was 73.2 (standard deviation 4.6) years, and the length of follow-up was 11.7 (standard deviation 0.6) years, on average. Over the follow-up, 78 (2.2%) men and 221 (3.6%) women became frail.

Among men, 30.1% were classified in the "small eaters" cluster, 6.0% in the "biscuits and snacking" cluster, 26.8% in the "healthy" cluster, 14.3% in the "charcuterie, meat, and alcohol" cluster and 22.9% in the "pasta" cluster (Table 1). Dietary clusters were significantly associated with marital status, BMI and multimorbidity at baseline ($P = .001$, $P < .001$ and $P = .04$, respectively).

Among women, 32.1% were in the "small eaters" cluster, 12.3% in the "biscuits and snacking" cluster, 26.3% in the "healthy" cluster, 25.3% in the "charcuterie, starchy, foods" cluster, and 4.1% in the "pizza, sandwich" cluster (Table 2). Dietary clusters were significantly associated with marital status and income at baseline ($P = .02$ and $P = .03$, respectively).

Table 1
Baseline Sociodemographic and Health Characteristics of Elderly Men Living in Bordeaux (France) Based on Dietary Clusters, the Bordeaux Sample of the 3C Study 1999–2000 (N = 336)

	Overall	Dietary Clusters					*P* Value
		Small Eaters	Biscuits and Snacking	Healthy	Charcuterie, Meat, Alcohol	Pasta	
Sample, n (%)	336	101 (30.1)	20 (6.0)	90 (26.8)	48 (14.3)	77 (22.9)	
Sociodemographic characteristics							
Age (years), mean (SD)	72.6 (4.4)	72.9 (4.4)	72.9 (4.4)	73.1 (4.2)	72.2 (4.2)	72.1 (4.6)	.19
Marital status, n (%)							**10^{-3}**
Married	275 (81.9)	82 (81.2)	11 (55.0)	78 (86.7)	34 (70.8)	70 (90.9)	
Single, divorced, separated, widower	61 (18.2)	19 (18.8)	9 (45.0)	12 (13.3)	14 (29.2)	7 (9.1)	
Education level, n (%)							.22
No or primary school	77 (22.9)	27 (26.7)	3 (15.0)	19 (21.1)	11 (22.9)	17 (22.1)	
Secondary	80 (23.8)	26 (25.7)	5 (25.0)	22 (24.4)	10 (20.8)	17 (22.1)	
High school	75 (22.3)	24 (23.8)	6 (30.0)	17 (18.9)	12 (25.0)	16 (20.8)	
University	104 (31.0)	24 (23.8)	6 (30.0)	32 (35.6)	15 (31.3)	27 (35.1)	
Income, €, n (%)							.06*
<€1500	74 (22.0)	30 (29.7)	5 (25.0)	13 (14.4)	11 (22.9)	15 (19.5)	
€1500–€2250	96 (28.6)	22 (21.8)	7 (35.0)	22 (24.4)	17 (35.4)	28 (36.4)	
≥€2250	145 (43.2)	44 (43.6)	7 (35.0)	50 (55.6)	18 (37.5)	26 (33.8)	
Don't want to answer	21 (6.3)	5 (5.0)	1 (5.0)	5 (5.6)	2 (4.2)	8 (10.4)	
Health characteristics							
BMI (kg/m^2), n (%)							**$<10^{-3}$**
18.83–25.46	111 (33.0)	33 (32.7)	8 (40.0)	25 (27.8)	12 (25.0)	33 (42.9)	
25.46–28.04	111 (33.0)	26 (25.7)	6 (30.0)	48 (53.3)	15 (31.3)	16 (20.8)	
28.04–40.86	114 (33.9)	42 (41.6)	6 (30.0)	17 (18.9)	21 (48.8)	28 (36.4)	
MMSE, mean (SD)	27.9 (1.7)	27.6 (1.8)	28.2 (2.3)	28.0 (1.8)	27.9 (1.6)	28.1 (1.4)	.20
Multimorbidity, n (%)	149 (44.4)	48 (47.5)	8 (40.0)	50 (55.6)	16 (33.3)	27 (35.1)	**4.10^{-2}**
Depressive symptomatology, n (%)	36 (10.7)	10 (9.9)	4 (20.0)	10 (11.1)	3 (6.3)	9 (11.7)	.56

Note. Bold values are statistically significant $P < 05$. CES-D, Center for Epidemiologic Studies - Depression Scale; SD, standard deviation.
Multimorbidity ≥2 chronic diseases among hypertension, diabetes, hypercholesterolemia, angina, cardiac rhythm disorders, cardiac failure, arteritis, myocardial infarction, asthma, Parkinson disease, dyspnea, osteoporosis, and thyroid diseases; depressive symptomatology defined as a CES-D score ≥23 for women and ≥17 for men.
*"<€1500" and "€1500–2250" categories were grouped together and "Don't want to answer" was not considered for χ^2 test.

Table 2
Baseline Sociodemographic and Health Characteristics of Elderly Women Living in Bordeaux (France) Based on Dietary Clusters, the Bordeaux Sample of the 3C Study 1999–2000 (N = 636)

	Overall	Dietary Clusters					*P* Value
		Small Eaters	Biscuits and Snacking	Healthy	Charcuterie, Starchy Foods	Pizza, Sandwich	
Sample, n (%)	636	204 (32.1)	78 (12.3)	167 (26.3)	161 (25.3)	26 (4.1)	
Sociodemographic characteristics							
Age (years), mean (SD)	73.6 (4.6)	73.5 (4.5)	74.1 (5.1)	74 (4.7)	72.6 (4.2)	75.3 (5.3)	.50
Marital status, n (%)							**2.10^{-2}**
Married	279 (43.9)	81 (39.7)	29 (37.2)	68 (40.7)	89 (55.3)	12 (46.2)	
Single, divorced, separated, widower	357 (56.1)	123 (60.3)	49 (62.8)	99 (59.3)	72 (44.7)	14 (53.9)	
Education level, n (%)							.22
No or primary school	218 (34.3)	75 (36.8)	31 (39.7)	55 (32.9)	48 (29.8)	9 (34.6)	
Secondary school	194 (30.5)	60 (29.4)	26 (33.3)	58 (34.7)	44 (27.3)	6 (23.1)	
High school	135 (21.2)	47 (23.0)	11 (14.1)	34 (20.4)	39 (24.2)	4 (15.4)	
University	89 (14.0)	22 (10.8)	10 (12.8)	20 (12.0)	30 (18.6)	7 (26.9)	
Income, €, n (%)							**3.10^{-2}***
<€1500	308 (48.4)	98 (48.0)	47 (60.3)	89 (53.3)	62 (38.5)	12 (46.2)	
€1500–€2250	146 (23.0)	49 (24.0)	19 (24.4)	33 (19.8)	37 (23.0)	8 (30.8)	
≥€2250	143 (22.5)	37 (18.1)	11 (14.1)	38 (22.8)	51 (31.7)	6 (23.1)	
Don't want to answer	39 (6.1)	20 (9.8)	1 (1.3)	7 (4.2)	11 (6.8)	0 (0.0)	
Health characteristics							
BMI (kg/m^2), n (%)							.15
13.59–23.62	210 (33.0)	61 (29.9)	23 (29.5)	54 (32.3)	63 (39.1)	9 (34.6)	
23.62–27.23	208 (32.7)	68 (33.3)	29 (37.2)	45 (26.9)	58 (36.0)	8 (30.8)	
27.23–43.29	218 (34.3)	75 (36.8)	26 (33.3)	68 (40.7)	40 (24.8)	9 (34.6)	
MMSE, mean (SD)	27.7 (1.9)	27.5 (2.0)	27.6 (1.8)	27.8 (1.9)	27.8 (1.9)	27.5 (1.6)	.20
Multimorbidity, n (%)	317 (49.8)	97 (47.6)	37 (47.4)	93 (55.7)	78 (48.5)	12 (46.2)	.53
Depressive symptomatology, n (%)	142 (22.3)	42 (20.6)	24 (30.8)	32 (19.2)	38 (23.6)	6 (23.1)	.32

Note. Bold values are statistically significant $P < 05$. CES-D, Center for Epidemiologic Studies - Depression Scale; SD, standard deviation.
Multimorbidity ≥2 chronic diseases among hypertension, diabetes, hypercholesterolemia, angina, cardiac rhythm disorders, cardiac failure, arteritis, myocardial infarction, asthma, Parkinson disease, dyspnea, osteoporosis, and thyroid diseases; depressive symptomatology defined as a CES-D score ≥23 for women and ≥17 for men.
*"Don't want to answer" category was not considered when carried out χ^2 test.

Dietary Clusters and 12-Year Risk of Frailty

In men, compared with the "healthy" cluster, the "pasta" cluster was significantly associated with a higher risk of frailty in multivariate analyses [hazard ratio (HR) 2.2; 95% confidence interval (CI) 1.1–4.4 in the model adjusted for marital status, education level, income, multimorbidity, BMI, depressive symptomatology, and MMSE; Table 3]. In contrast, the "biscuits and snacking," "charcuterie, meat and alcohol," and "small eaters" clusters were not significantly associated with the risk of frailty. Furthermore, the global test for risk difference across all clusters was not statistically significant at the α-risk of 5% ($P = .09$ in the fully adjusted model).

In women, the "biscuits and snacking" cluster was significantly associated with a higher risk of frailty compared with the "healthy" cluster (HR 1.8; 95% CI 1.2–2.8 in the fully adjusted model). Other clusters were not significantly associated with the risk of frailty. As with men, the global test was not statistically significant ($P = .13$ in model 2).

Dietary Clusters and Risk of Each Frailty Component

In a secondary analysis, we examined the risk of each frailty component based on dietary cluster. In men, 43 (1.2%), 67 (2.3%), 117 (3.8%), 76 (2.5%), and 148 (7.6%) new cases of weight loss, exhaustion, weakness, slowness, and low energy expenditure, respectively, were observed. In women, these are 60 (0.9%), 171 (3.2%), 285 (4.9%), 218 (4.0%), and 325 (11.0%) new cases, respectively.

Table 3
Multivariate Associations Between Dietary Clusters and the 12-Year Risk of Frailty in the Bordeaux Sample of the 3C Study

	Number of Incident Cases of Frailty	Model 1		Model 2	
		HR (95% CI)	*P*	HR (95% CI)	*P*
Men (N = 336)	78		.13		.09
Dietary clusters					
Healthy	19	1		1	
Small eaters	27	1.65 (0.88–3.09)		1.46 (0.77–2.78)	
Biscuits and snacking	4	1.44 (0.47–4.45)		1.35 (0.43–4.24)	
Charcuterie, meat, alcohol	6	0.78 (0.30–2.02)		0.73 (0.28–1.91)	
Pasta	22	1.95 (1.01–3.75)		2.21 (1.11–4.40)	
Women (N = 636)	221				
Dietary clusters			.19		.13
Healthy	53	1		1	
Small eaters	75	1.27 (0.89–1.81)		1.30 (0.91–1.86)	
Biscuits and snacking	35	1.72 (1.11–2.64)		1.81 (1.17–2.81)	
Charcuterie, starchy foods	46	1.20 (0.80–1.80)		1.28 (0.85–1.92)	
Pizza, sandwich	12	1.42 (0.74–2.70)		1.45 (0.75–2.80)	

Model 1: model adjusted for marital status, education level, and income.
Model 2: model 1 further adjusted for multimorbidity, BMI, depressive symptomatology, and MMSE.

When examining each frailty component separately, dietary clusters were significantly associated with the risk of muscle weakness in men ($P = .003$; Table 4). Men in "biscuits and snacking" and "pasta" clusters were at higher risk of muscle weakness compared with men in the "healthy" cluster (HR 3.3; 95% CI 1.6–7.0 and HR 2.1; 95% CI 1.2–3.7, respectively). Men in the "biscuits and snacking" cluster were also at higher risk for low energy expenditure compared with men in "healthy" cluster (HR 2.3; 95% CI 1.2–4.6) while the global test was not statistically significant ($P = .13$). In contrast, no association between all dietary clusters and each frailty component were observed in women.

Discussion

Our findings indicated that compared with participants in the "healthy" cluster characterized by higher consumption of fish in men and fruits and vegetables in women, men in the "pasta" cluster characterized by frequent consumption of starchy food (pasta, rice, potatoes, bread) and women in the "biscuits and snacking" cluster characterized by frequent consumption of biscuits and cakes (rich in mono-and disaccharides) and low intakes of fruits, vegetables and fish were at higher risk of frailty over the 12-year follow-up.

To our knowledge, only two population-based studies have been conducted to examine the relationships between a posteriori dietary patterns and frailty so far. Among 1872 noninstitutionalized Spanish older adults aged 60 years and over, León-Muñoz et al[15] identified a "prudent" pattern, characterized by high intake of olive oil and vegetables, and a "Westernized" pattern, characterized by high consumption of refined bread, whole dairy products, and red and processed meat, as well as a low intake of whole grains, fruit, low-fat dairy, and vegetables. They found an inverse dose-response relationship between higher adherence to the "prudent" pattern and a frailty risk after 3.5 years of follow-up; whereas the "Westernized" pattern was not associated with incident frailty. However, the "Westernized" pattern was associated with an increased risk of slow walking speed and weight loss whereas the "prudent pattern" was not associated with frailty criteria. In a 4-year study including 2724 Chinese community-dwelling volunteers aged ≥65 years, Chan et al[16] identified three dietary patterns, namely "vegetables-fruits," "snacks-drinks-milk products," and "meat-fish," using factor analysis but they failed to show an association with incident frailty. These previous studies used factor analysis whereas our research was based on cluster analysis; furthermore, a posteriori statistical methods derive dietary patterns that are specific to populations and thus, comparison of our findings with these studies is difficult.

Compared with the "healthy" cluster, men in the "pasta" cluster had higher risk for frailty and for muscle weakness in our secondary analyses. This frailty component may explain by itself a large part of the association observed with risk of frailty in men. These findings are consistent with our previous cross-sectional results, in which men in the "pasta" cluster had poorer self-rated health and higher depressive symptoms,[18] which are strong risk factors for frailty[27,28] and particularly for muscle weakness.[29,30] These factors could also lead to a potential reverse causality bias even though we excluded participants frail at baseline. No evident mechanistic hypothesis could be formulated to explain this relationship.

Women in the "biscuits and snacking" cluster were at higher risk of frailty and men in this cluster had higher risk of isolated frailty components (ie, weakness and low energy expenditure). One study showed that products rich in simple carbohydrates were correlated with inflammatory biomarkers.[31] Epidemiologic studies reported significant associations between inflammation biomarkers and loss of muscle mass and strength, poor physical performance, and frailty.[32–34] Both leukocyte migration and inflammation cascade activation and monocyte/macrophage-mediated immune-inflammation would contribute to frailty.[35] Fruits and vegetables are rich in carotenoids, protective against proinflammatory mechanisms implicated in sarcopenia.[6] Literature also reports that low levels of carotenoids were related to poor muscle strength and performance.[36–38] An analysis of three prospective cohorts of community-dwelling older European adults, including the 3C cohort, has shown that consumption of fruits and vegetables was associated with lower short-term risk of frailty in a dose-response manner, and the strongest association was obtained with 3 portions of fruits/day and 2 portions of vegetables/day.[7]

Our findings suggest that physical decline assessed by frailty as a whole is summarized by the co-occurrence of different frailty criteria in women and is not imputable to an isolated marker of frailty. An absence of association of dietary patterns with any single frailty criteria but a relationship with the global frailty score strongly supports the relevance of a global approach of frailty using a single end

Table 4
Multivariate Associations* Between a Posteriori Dietary Clusters and the Risk of Each Frailty Component in the Bordeaux Sample of the 3C Study

	Weight Loss		Exhaustion†		Weakness		Slowness		Low Energy	
	HR (95% CI)	*P*	HR (95% CI)	*P*	HR (95% CI)	*P*	HR (95% CI)	*P*	HR (95% CI)	*P*
Men (n/N)	43/350‡		67/291§		117/321		76/296‡		148/236	
Dietary patterns		0.38		0.82		**3.10^{-3}**		0.38		0.13
Healthy	1		1		1		1		1	
Small eaters	1.71 (0.81–4.51)		1.11 (0.56–2.19)		1.43 (0.83–2.45)		1.13 (0.64–2.70)		1.09 (0.70–1.72)	
Biscuits and snacking	2.53 (0.73–8.72)		1.34 (0.47–3.87)		3.34 (1.59–7.00)		1.84 (0.70–4.82)		2.34 (1.20–4.55)	
Charcuterie, meat, alcohol	0.89 (0.26–2.98)		0.98 (0.40–2.42)		0.83 (0.39–1.80)		1.00 (0.88–3.90)		0.91 (0.50–1.68)	
Pasta	1.37 (0.51–3.68)		1.51 (0.73–3.15)		2.07 (1.16–3.71)		1.85 (0.88–3.90)		0.88 (0.53–1.48)	
Women (n/N)	60/622		171/537		285/628		218/574‖		325/424	
Dietary patterns		0.74		0.90		0.30		0.19		0.35
Healthy	1		1		1		1		1	
Small eaters	1.31 (0.68–2.51)		1.00 (0.67–1.50)		1.35 (0.99–1.86)		1.20 (0.84–1.70)		1.24 (0.92–1.67)	
Biscuits and snacking	0.76 (0.27–2.10)		1.05 (0.59–1.85)		1.38 (0.93–2.05)		1.39 (0.90–2.13)		1.40 (0.95–2.06)	
Charcuterie, starchy foods	1.04 (0.49–2.20)		1.21 (0.80–1.83)		1.36 (0.96–1.91)		0.82 (0.54–1.24)		1.29 (0.94–1.76)	
Pizza, sandwich	1.58 (0.45–5.55)		0.98 (0.41–2.32)		1.26 (0.71–2.26)		1.15 (0.57–2.35)		1.06 (0.58–1.92)	

Note. Bold values are statistically significant $P < 05$. n, number of incident cases; N, sample size.
*Adjusted for marital status, education level, income, multimorbidity, BMI, depressive symptomatology, and MMSE.
†Model not adjusted for depressive symptomatology.
‡Model stratified on BMI.
§Model stratified on income.
‖Model stratified on depressive symptomatology.

point. This is in line with our previous findings about the association between Mediterranean diet adherence and the risk of disability (ie, consequence of frailty),[39] where we evidenced a protective role of the Mediterranean diet against the risk of disability among women. The reasons for a different pattern of associations in men remain unclear. It is possible that diet is more strongly associated with muscle weakness among men than women because men have a higher muscle mass and, thus, more variability in muscle strength than women (potentially leading to more statistical power to evidence associations in men).

The present study has some limitations. The incidence of frailty may seem low. However, low conversion rates were expected in our sample, which included participants in generally good health at baseline. Indeed, to avoid reverse causality (that may have occurred if frail individuals modified their diets), we excluded participants at higher risk of frailty at baseline (ie, individuals with dementia). In both men and women, nonfrail nondemented participants were younger and more likely to be married; they have higher education level and income, reported more likely 2 or more chronic diseases, and have better cognitive performance than other participants. Furthermore, 748 nonfrail nondemented participants at baseline were excluded because of a lack of follow-up data. Participants included in the analysis were younger, more educated, had higher income, and had better cognitive performance than those with no data for frailty at follow-up visits. Dietary clusters were built based on intake frequencies of major food groups that may not accurately reflect portion size and is subject to a desirability bias. However, there is acceptable correlation with data from 24-hour recall in the same subsample.[40] Diet assessment was done at a single time point, and we cannot preclude that participants may have changed their dietary habits during the follow-up. However, we have found a good stability of general dietary habits (eg, intake of fruits, vegetables, fish, meats) over the cohort follow-up (ie, 10 years) in the 3C Bordeaux Study.[41] Moreover, several frailty criteria were self-reported, which might have led to underestimation of the number of incident cases of frailty. Because of lack of measure of walking speed at each wave, we defined slowness using the Rosow-Breslau scale that has been shown to be strongly associated with walking[22] to reduce the risk of a misclassification bias. Furthermore, we were unable to use the same measure of weakness in wave 4 (based on handgrip strength) than in waves 0 and 5 (based on chair stand test). However, chair stand test was shown to be a good proxy for handgrip strength.[23,24] We, however, cannot preclude a persisting misclassification bias that may lead to an under- or overestimation of frailty incidence. The competing risk with mortality may have led to the underestimation of frailty incidence because our data are interval-censored.[42] Nevertheless, dietary clusters were not associated with high mortality risk in this sample suggesting that the competing risk with mortality was limited in this analysis (data not shown). Low sample size in men may limit the power of statistical test. Finally, adjustment for potential confounding factors does not preclude for residual confounding, although we adjusted the present analyses for global cognitive performances and depressive symptomatology, both being associated with a higher risk of frailty.[28,43]

The main strengths of our study are the length of the follow-up (up to 12 years) compared with the two available prospective studies to date; the community-dwelling population-based design of our sample; the use of an innovative approach with a mixed clustering strategy to identify dietary clusters; and comprehensive adjustment for several confounders, especially cognitive performance and depressive symptomatology.

Conclusions

Among community-dwelling older French adults, some particular sex-specific unhealthy dietary patterns appeared associated with a higher long-term risk of frailty. The present study provided additional evidence that attention should be paid to nutritional habits of elderly people to help them maintain optimal health and foster successful aging. Focused nutritional preventive programs, combined with strategies against poor health characteristics, may delay the onset of frailty and of its severe consequences.

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