Current Research

Dietary Patterns Derived by Hybrid Clustering Method in Older People: Association with Cognition, Mood, and Self-Rated Health

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ABSTRACT

Background Several nutritional factors, including dietary fatty acids, antioxidants, and folates, have been related to pathological brain aging. Dietary patterns that represent a combination of foods may better predict disease risk than single foods or nutrients.

Objective To identify dietary patterns by a mixed clustering method and to analyze their relationship with cognitive function, depressive symptoms, and self-rated health in older people.

Design Cross-sectional population-based study.

Subjects/setting Subjects included 1,724 elderly community dwellers living in Bordeaux, France from 2001 to 2002.

Statistical analysis Cluster analysis, combining hybrid clustering, and research for stable groups during the k-means step on mean number of weekly servings of 20 predetermined food groups, separately in men and women.

Results Five dietary clusters were identified in each sex. A "healthy" cluster characterized by higher consumption of fish in men (n=157; 24.3%) and fruits and vegetables in women (n=267; 24.8%) had significantly lower mean number of errors to Mini Mental State score after adjustment for socio-demographic variables ($\beta=-0.11$; 95% confidence interval [CI], -0.22 to -0.004 in men; $\beta=-0.13$; 95% CI, -0.22 to -0.04 in women). The same cluster was associated with borderline significance with lower depressive symptoms in women ($\beta=-0.16$; 95% CI, -0.33 to 0.007). Men in the "pasta eaters" cluster (n=136; 21%) had higher depressive symptoms ($\beta=0.26$; 95% CI, 0.06 to 0.46) and higher risk to report poor health (polytomous regression, odds ratio [OR]=1.91; 95% CI, 1.21 to 3.01) than the "healthy" cluster. Women in the "biscuits and snacking" cluster (n=162; 15%) had greater risk of poor perceived health (OR=1.69; 95% CI, 1.15 to 2.48) compared to "healthy" eaters. Additional adjustment for body mass index and medication use strengthened these associations.

Conclusions Sex-specific dietary patterns derived by hybrid clustering method are associated with fewer cognitive and depressive symptoms and better perceived health in older people.

J Am Diet Assoc. 2008;108:1461-1471.

The role of nutritional factors in brain aging is a new area of research. The potential protective effects of polyunsaturated fatty acids, antioxidant micronutrients, and folates against age-associated cognitive and mood disorders arouse increasing interest (1,2). However, these nutrients are consumed in combination in the diet and they may have synergistic effects that make their isolated study very difficult (3). Dietary patterns that represent a combination of foods may be better associated to disease risk than single foods or nutrients (4-8).

Paradoxically, dietary patterns were seldom investigated in elderly populations (9-12). Very few studies aimed at relating food patterns to cognitive (13,14) or mood disorders (15,16). In addition, self-rated health is a widely used health indicator that is strongly associated with mood and functional ability in older people (17). Fruit and vegetable intake was related to better self-rated health in adults (18,19). Both unhealthy dietary patterns and poor self-rated health are independent predictors of mortality (20). However, we are aware of no study investigating the relationship between empirically derived dietary patterns and self-rated health in older people.

To derive dietary patterns, exploratory multidimensional techniques have recently emerged. Among these, cluster analysis divides the subjects into homogeneous nonoverlapping subgroups with a similar pattern of mean food intake. The two most important clustering methods are partitioning methods (including k-means) and hierarchical classification methods (21,22). Because of their easy use in large samples with high computational effi-

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Manuscript accepted: March 25, 2008.

0002-8223/08/10809-0005$34.00/0
doi: 10.1016/j.jada.2008.06.437

ciency, the first methods were preferred to derive dietary patterns (8). However, two major limitations of partitioning methods must be stressed. First, the number of clusters must be fixed a priori. Second, the final clustering solution depends on the first observations chosen to start the algorithm. Therefore, the partition may differ according to the order of classification of subjects in the dataset. On the other hand, hierarchical classification methods are limited by the dependence on the partition obtained at the precedent level. To approach an optimal clustering solution, a hybrid clustering method combining k-means and hierarchical classification has been developed (23) but rarely used to derive dietary patterns (24,25). Moreover, to deal with the problem of dependence of results on the set of initial observations in the k-means method, it was proposed (26) to look for "stable groups" in order to increase stability of the final clustering solution (21).

The objective of this study was to derive food patterns in a sample of French elderly community dwellers and to investigate the relationship between these dietary patterns and three aspects of brain aging: cognitive function, mood, and self-rated health. We propose to perform a mixed clustering strategy that develops hybrid clustering on weekly mean number of food servings, looking for stable groups in a first step.

METHODS

Participants

The study was conducted among participants in the Three-City study, a large ongoing prospective cohort study of vascular risk factors for dementia that included 9,294 community dwellers in Bordeaux (n=2,104), Dijon (n=4,931), and Montpellier (n=2,259), France, at baseline in 1999 to 2000. To be eligible for recruitment into the Three-City study, individuals had to be living in one of these three French cities, aged 65 years or older, and not institutionalized. Methods of the study and baseline characteristics are described elsewhere (27). The protocol of the Three-City study has been approved by the Consultative Committee for the Protection of Persons participating in Biomedical Research of the Kremlin-Bicêtre University Hospital (Paris, France). All participants signed an informed consent. Baseline data collection included sociodemographic and lifestyle characteristics, symptoms and complaints, main chronic conditions, neuropsychological testing, a physical examination, and blood sampling. The present study is based on the first follow-up conducted in 2001 to 2002 in Bordeaux, which placed a particular emphasis on nutritional data.

Dietary Data

Among the 1,811 participants enrolled at baseline who accepted to participate in the first follow-up in Bordeaux, 1,796 subjects completed the dietary assessment. A food frequency questionnaire (FFQ) was administered by registered dietitians who received collective training and monitoring. A 24-hour dietary recall was performed during the same interview (28). Concordance between responses to the FFQ and the 24-hour dietary recall was assessed for fatty acids. There were acceptable correlations between number of weekly servings of foods obtained from the FFQ and the corresponding fatty acid intakes obtained from the dietary recall (28). Data from the same FFQ were also compared to information from a 24-hour dietary recall in an independent subsample (n=105) of the Three-City study (29). Significant correlations ranging from 0.20 to 0.43 were observed between number of weekly servings of foods obtained from the FFQ and the corresponding nutrient intakes obtained from the dietary recall. Strong correlations between the two enquiries were observed for alcohol (r=0.73). Detailed results of both studies are available from authors upon request.

Frequency of consumption of 40 categories of foods and nonalcoholic beverages for each of the three main meals and three between-meals snacks was recorded in 11 classes. Reported frequencies were then transformed into discrete variables as follows: 0 for never or less than once a week, 0.25 for once a month, 0.5 for twice a month, 0.75 for three times a month, 1 for once a week, and from 2 for twice a week to 7 for seven times a week. This coding was used to estimate the number of usual weekly servings of each of the 148 food items, ranging as a result from 0 to 42 (with a maximum of six meals a day). The number of glasses of alcohol per week was also recorded. The food items were then aggregated into 20 food and beverage groups: fresh fruits, compotes and fruit juices; all kinds of meat, excluding poultry; fish and seafood; pizzas, sandwiches, quiches, and salted pies; biscuits, cakes, cookies, and Viennese pastries; all kinds of sweet products, including sodas; all kinds of dairy products; cereals and bread. All other food groups included a single item (see Tables 1 and 2).

Other Variables

Sociodemographic information included age, sex, marital status, living arrangement, educational level (in four classes, see Table 3) and income (in four predetermined classes expressed in euros, see Table 3). Body mass index (BMI) was computed as kg/m^2. Medical history was recorded, including actual or past cardiovascular and cerebrovascular diseases, diabetes, hypercholesterolemia, and cancer. All drugs consumed at least once a week during the last month were recorded. Neuropsychological examination was performed by trained psychologists. Overall cognitive function was assessed by the Mini Mental State (MMS) examination (30). Depressive symptoms were assessed using the Center for Epidemiologic Studies-Depression (CESD) scale (31). Participants were asked to rate their present health status as very good, good, fair, bad, or very bad.

Statistical Analyses

Missing data were treated as follows. The 66 participants (3.7%) who presented two missing values or more among the dietary items were excluded. To minimize loss of power and selection bias, the 202 participants (11.2%) who presented only one missing data were kept and their missing values were imputed function of sex and age by Multivariate Imputation by Chained Equations technique available on R software (32).

Table 1. Number of servings per week by dietary pattern among elderly men living in Bordeaux, France, the Three-City Study, 2001 to 2002

	Overall	By Dietary Pattern: Small eaters	Biscuits and snacking	Healthy	Charcuterie, meat, alcohol	Pasta eaters
		n (%)				
	647	203 (31.4)	58 (8.8)	157 (24.3)	95 (14.5)	136 (21.0)
Food groups intake/week	*mean (standard deviation)*					
Raw vegetables and salad	9.3 (4.96)	6.8 (3.75)	6.7[ab] (4.95)	11.3 (4.69)	9.5 (4.57)	11.7 (4.90)
Cooked vegetables	10.1 (4.72)	8.9 (4.41)	8.1 (4.83)	11.2 (3.95)	9.6 (4.51)	12.0 (5.17)
Pasta	2.3 (1.61)	1.8 (1.20)	2.8 (1.88)	1.5[ab] (0.90)	2.6 (1.35)	3.7[ac] (1.79)
Rice	1.4 (1.25)	1.1 (0.94)	2.3[ac] (1.68)	1.0 (0.76)	1.2 (1.09)	2.3 (1.38)
Potatoes	2.9 (1.68)	2.3 (1.36)	2.5 (1.60)	2.3 (1.33)	3.4 (1.57)	4.2 (1.77)
Pulses	0.7 (0.81)	0.5 (0.50)	0.6 (0.66)	0.6 (0.56)	1.5[ac] (1.34)	0.7 (0.70)
Fruits	13.1 (6.90)	10.5 (5.72)	13.3 (9.41)	16.5 (6.75)	11.2 (5.48)	14.4 (6.41)
Eggs	1.5 (1.15)	1.1 (0.77)	1.4 (1.01)	1.5 (1.06)	1.8 (1.22)	1.9 (1.47)
Poultry	1.8 (1.35)	1.5 (1.03)	1.5 (1.31)	1.5 (0.93)	1.7 (1.11)	2.9 (1.72)
Meat	5.2 (2.62)	5.3 (2.53)	4.6 (2.40)	4.7 (2.22)	7.4[ac] (2.86)	4.5 (2.29)
Fish and seafood	2.9 (1.77)	2.1 (1.12)	2.8 (2.23)	3.8[ac] (1.80)	2.5 (1.43)	3.5 (1.84)
Pizza, sandwich, salted pie	0.5 (0.75)	0.4 (0.78)	0.4 (0.58)	0.4 (0.59)	0.5 (0.76)	0.6 (0.88)
Charcuterie	2.2 (2.62)	1.6 (1.84)	1.8 (1.96)	1.3 (1.34)	6.2[ad] (3.43)	1.7 (1.84)
Biscuits, cakes	2.3 (3.75)	1.0 (2.03)	9.8[ad] (5.48)	1.8 (2.74)	2.4 (3.31)	1.3 (2.29)
Sweets, chocolate, soda	8.6 (6.70)	6.8 (5.52)	10.5 (7.73)	10.1 (7.24)	10.1 (6.91)	7.7 (6.27)
Dairy products	15.8 (7.46)	12.8 (6.96)	21.3[ac] (8.28)	17.1 (6.60)	14.7 (7.34)	17.2 (6.82)
Cereals, bread	19.3 (4.63)	18.2 (4.72)	16.3[ab] (5.88)	20.0 (4.26)	19.3 (3.98)	21.3 (3.57)
Alcohol	16.6 (14.02)	14.7 (12.91)	14.8 (13.98)	19.5 (14.14)	25.3[ac] (16.70)	10.6 (9.05)
Coffee	6.1 (5.21)	5.8 (5.17)	6.1 (5.91)	7.0 (4.76)	4.2 (4.42)	6.6 (5.65)
Tea	1.7 (3.59)	0.8 (2.28)	2.3 (5.07)	2.9 (4.23)	1.6 (3.34)	1.5 (3.45)
Energy intake (kcal/day)	2,003 (532.5)	1,822 (509.4)	2,124 (593.6)	2,024 (512.6)	2,210 (521.5)	2,051 (494.0)

[a]SDU=standard deviation unit=(group mean−overall mean)/overall standard deviation.
[b]−1 to −0.5 SDU.
[c]+0.5 to 1 SDU.
[d]+1 to 2 SDU.

We derived clusters on the basis of average number of weekly servings. To ensure that clusters would not be influenced by food categories with larger ranges, the 20 predetermined food groups were standardized by transformation into z scores. Then, cluster analysis was performed using a mixed method combining hybrid clustering (23) and research for stable groups (26,33) during the k-means step on the mean number of weekly servings of these 20 food groups. Separate analyses were run for men and women because we expected some differences in dietary habits across sexes (34-36).

The first step of hybrid clustering is a k-means clustering procedure that groups subjects into exclusive clusters based on Euclidian distance of observations from the cluster centroid in an iterative process (23). The k number of clusters to analyze must be fixed a priori and k initial observations are randomized to start the algorithm. The research for stable groups during the k-means step allows us to focus on high-density clusters to perform the hierarchical algorithm in a second step. Indeed, when several k-means partitions are performed, initialized by a random set of observations, stable groups are made by the individuals who are always sent to the same class. We performed two successive k-means partitions with k=8 initial clusters for men and k=10 for women. The two partitions were crossed to obtain a product-partition of, respectively, 8^2 and 10^2 groups that was able to represent about 10% of each sample. Each stable group is a set of observations the weight of which is proportional to the number of individuals it contains.

The second step is a Ward's hierarchical clustering procedure performed on stable groups (21). This step aggregates consecutively the closest elements by maximizing inter-class variance using Ward's criterion. This process leads to the construction of a tree and defines increasing level indexes. To obtain the final partition, tree cut is made at a level corresponding to an index jump. Considering these rules, the number of five final clusters was chosen for both men and women. Finally, a third consolidation step involved a last k-means partition. Centers of the classes obtained by tree cut were used to initiate the reallocation procedure that necessary leads to increase overall inertia.

Mean number of servings per week was computed per cluster and then standardized to compare the weights of each food group between clusters (37). Finally, we described the mean daily energy intake obtained from the 24-hour dietary recall across clusters.

Analysis of variance was used to compare continuous sociodemographic and health variables across clusters. χ^2

Table 2. Number of servings per week by dietary pattern among elderly women living in Bordeaux, France, the Three-City Study, 2001-2002						
		By Dietary Pattern				
	Overall	Small eaters	Biscuits and snacking	Healthy	Charcuterie, starchy foods	Pizza, sandwich
	←		n (%)			→
	1077	334 (31.0)	162 (15.0)	267 (24.8)	266 (24.7)	48 (4.5)
Food groups intake/week	←		mean (standard deviation)			→
Raw vegetables and salad	8.8 (5.46)	6.3 (4.12)	6.7 (4.40)	12.7[ab] (5.25)	9.3 (5.32)	9.7 (5.57)
Cooked vegetables	10.2 (4.24)	8.7 (3.55)	9.4 (4.20)	12.5[ab] (4.12)	10.2 (4.10)	9.5 (4.57)
Pasta	1.9 (1.43)	1.5 (1.19)	1.6 (1.12)	1.6 (1.15)	3.1[ab] (1.53)	2.0 (1.36)
Rice	1.2 (1.23)	0.8 (0.81)	1.0 (1.07)	1.0 (0.92)	2.0[ab] (1.62)	1.3 (1.16)
Potatoes	2.5 (1.71)	1.8 (1.29)	2.4 (1.67)	2.1 (1.46)	3.7[ab] (1.82)	2.5 (1.57)
Pulses	0.5 (0.55)	0.4 (0.40)	0.5 (0.46)	0.5 (0.46)	0.9[ab] (0.70)	0.3[ac] (0.33)
Fruits	13.7 (7.03)	11.1 (5.75)	14.1 (7.08)	17.8[ab] (7.40)	12.5 (6.15)	13.4 (6.80)
Eggs	1.5 (1.09)	1.2 (0.91)	1.4 (1.00)	1.5 (1.00)	1.9 (1.25)	1.5 (1.21)
Poultry	1.8 (1.31)	1.5 (1.07)	1.5 (1.08)	1.9 (1.25)	2.2 (1.36)	2.5[ab] (2.27)
Meat	4.6 (2.33)	4.3 (2.39)	4.3 (2.15)	4.4 (2.37)	5.2 (2.23)	4.7 (2.26)
Fish and seafood	2.8 (1.81)	1.9 (1.19)	2.4 (1.49)	3.5 (1.73)	3.5 (2.05)	2.8 (2.32)
Pizza, sandwich, salted pie	0.4 (0.79)	0.2 (0.36)	0.3 (0.47)	0.2 (0.35)	0.4 (0.53)	3.2[ad] (1.49)
Charcuterie	1.3 (1.88)	0.9 (1.36)	1.0 (1.40)	0.9 (1.35)	2.4[ab] (2.59)	1.3 (1.77)
Biscuits, cakes	2.2 (3.44)	0.6 (1.24)	8.3[ae] (3.38)	0.9 (1.77)	1.6 (2.52)	2.7 (2.90)
Sweets, chocolate, soda	9.0 (7.10)	6.9 (5.74)	12.1 (8.74)	7.7 (6.22)	10.7 (7.35)	10.6 (6.49)
Dairy products	16.3 (7.09)	15.6 (6.85)	16.7 (7.83)	16.3 (6.56)	16.5 (7.18)	18.6 (8.04)
Cereals, bread	18.1 (5.76)	16.6 (6.10)	15.4 (6.14)	18.8 (5.59)	20.5 (3.94)	19.6 (4.78)
Alcohol	6.0 (6.94)	5.9 (6.95)	4.1 (4.35)	4.4 (5.13)	9.4 (8.69)	3.3 (4.18)
Coffee	5.4 (5.17)	5.4 (5.2)	4.8 (4.96)	5.4 (5.00)	5.3 (5.15)	7.2 (6.10)
Tea	3.3 (4.88)	1.8 (3.44)	4.2 (5.89)	5.2 (5.67)	2.6 (3.94)	3.7 (5.59)
Energy intake (kcal/day)	1,517 (457.7)	1,374 (444.7)	1,514 (420.9)	1,509 (434.9)	1,687 (459.7)	1,629 (453.8)

[a]SDU=standard deviation unit=(group mean−overall mean)/overall standard deviation.
[b]+0.5 to 1 SDU.
[c]−1 to −0.5 SDU.
[d]>+2 SDU.
[e]+1 to 2 SDU.

tests were performed on categorical variables. We hypothesized that some particular clusters may be associated with better cognitive function (lower number of errors to MMS score), fewer depressive symptoms (lower CESD score) and better self-rated health. CESD and MMS scores presented skewed distributions. In order to choose the best transformation for the CESD score, the square root transformation ($\sqrt{\text{CESD}}$) and the log transformation ($\log_{\text{CESD}}$) were tested. The normality of distributions was better for $\sqrt{\text{CESD}}$ than for $\log_{\text{CESD}}$. Normality plots of residuals also revealed acceptable normality after square root transformation. Thus, $\sqrt{\text{CESD}}$ was preferred to $\log_{\text{CESD}}$. Moreover, the square root transformation applied to the number of errors to MMS score ($\sqrt{30-\text{MMS}}$) was previously shown to be the best way to ensure the conditions of validity in linear models, ie, normality and homoscedasticity of residuals (38,39). In the present study, regression diagnosis confirmed that $\sqrt{30-\text{MMS}}$ led to acceptable normalization of residuals. Linear regression was therefore carried with $\sqrt{30-\text{MMS}}$ and $\sqrt{\text{CESD}}$ as dependent variables, and the clusters as explanatory variables, adjusting for sociodemographic characteristics. All the sociodemographic variables—except living arrangements, which were not associated with health status in univariate analysis and were expected to be multicollinear with marital status—were used as adjustment covariates in the regressions of the clusters on $\sqrt{30-\text{MMS}}$ and $\sqrt{\text{CESD}}$. Additional models were performed with further adjustment on BMI and medication use (number of drugs, five or more vs less than five per day, which was the median in this sample). Finally, homoscedasticity and independence of residuals were checked. In all linear regressions, the clusters were coded as using sum-to-zero contrasts (40) so that each β-coefficient compared the level of the factor (ie, cluster) to the average of all the levels.

Polytomous logistic regression by Proportional Odds model (41) was used to model self-rated health as a five-level−ordered dependent variable function of the clusters adjusting for sociodemographic covariates. Further adjustment on prevalent and past comorbidities was performed.

Analyses were performed using SAS software (9.1 release, 2002-2003; SAS Institute, Cary, NC), R software (2.4.1 release, 2006, http://www.r-project.org/), and SPAD software (5.5 release, 2003, Decisia, Paris, France) for cluster analysis.

Table 3. Sociodemographic and health characteristics of elderly men living in Bordeaux (France) according to their dietary pattern, the Three-City Study, 2001 to 2002

	Overall	Small eaters	Biscuits and snacking	Healthy	Charcuterie, meat, alcohol	Pasta eaters	*P* value
		By Dietary Pattern					
	← *n (%)* →						
	647	203 (31.4)	58 (8.8)	157 (24.3)	95 (14.5)	136 (21.0)	
	← *mean (standard deviation)* →						
Age	76.0 (4.97)	75.8 (4.97)	76.9 (5.52)	76.3 (4.71)	75.7 (4.90)	75.5 (5.05)	0.39[a]
BMI[b]	26.9 (3.59)	27.4 (3.35)	26.3 (4.29)	26.6 (3.23)	26.9 (3.15)	26.9 (4.21)	0.17[a]
Education	← % →						
No or Primary	26.9	33.7	17.5	21.8	31.9	23.0	0.05[c]
Secondary	26.2	27.7	24.6	25.0	23.4	28.2	
High school	21.1	18.8	28.1	19.9	25.5	20.0	
University	25.8	19.8	29.8	33.3	19.2	28.8	
Monthly income							
<750€	2.9	3.5	5.2	2.6	3.2	1.5	0.03[d]
750-1500€	24.4	29.1	19.3	15.3	29.8	26.4	
1,500-2,250€	29.4	25.1	31.6	24.8	37.2	34.6	
>2,250€	36.9	37.4	35.1	50.3	23.4	30.9	
Refused to answer	6.3	4.9	8.8	7.0	6.4	6.6	
Marital status							
Married	78.9	77.1	71.9	84.1	68.1	86.0	0.004[d]
Divorced, separated or single	7.0	8.0	3.5	7.0	6.4	7.4	
Widowed	14.1	14.9	24.6	8.9	25.5	6.6	
Living arrangements							
Alone	18.4	17.7	26.3	14.7	28.7	13.2	0.01[d]
With spouse	78.8	78.3	73.7	83.4	66.0	85.3	
With other(s)	2.9	3.9	0	1.9	5.3	1.5	
No. of drugs ≥5	46.1	48.3	45.6	47.1	37.6	47.8	0.51[c]
	← *mean (standard deviation)* →						
MMS[e] **score**	27.4 (2.59)	27.1 (2.76)	26.9 (3.53)	27.8 (1.88)	27.2 (2.42)	27.4 (2.66)	0.06[a]
CESD[f] **score**	6.0 (6.41)	5.7 (6.90)	6.5 (7.25)	5.0 (4.49)	6.5 (6.92)	7.2 (6.68)	0.04[a]
Self-rated health	← % →						
Very good	9.2	5.5	16.1	10.8	10.8	8.8	0.04[g]
Good	59.2	65.4	55.4	62.4	59.1	47.8	
Fair	25.5	23.8	19.6	22.3	23.7	35.3	
Bad	5.4	5.5	8.9	3.2	6.5	5.9	
Very bad	0.8	0	0	1.3	0	2.2	

[a]Analysis of variance.
[b]BMI=body mass index (calculated as kg/m^2).
[c]χ^2 test.
[d]χ^2 test on binary variables: monthly income (<1,500€ vs ≥1,500€), marital status (married vs others), living arrangements (alone vs others).
[e]MMS=Mini Mental State.
[f]CESD=Center for Epidemiologic Studies-Depression.
[g]Polytomous logistic regression with self-rated health as dependent variable.

RESULTS

Dietary Clusters

After exclusion of 66 individuals with at least two missing dietary data and six with missing sociodemographic information, the sample consisted of 1,724 participants (647 men and 1,077 women). Five dietary clusters in men (Table 1) and five in women (Table 2) were identified.

Among both men and women, the first cluster labeled "small eaters" (31% of participants) did not represent a particular food group. It was characterized by a slightly lower mean number of servings per week than the overall population for all food groups and the lowest mean daily energy intake. The second cluster included individuals having frequent snacks (58% of both men and women in this cluster had frequent snacks compared to 36% in overall male and 41% in overall female samples), a frequent consumption of biscuits and cakes, and a quite high energy intake in both sexes. The third cluster labeled "healthy cluster" differed between men and women for its major food components: fish eaters in men vs fruit and vegetable consumers in women. The fourth cluster was characterized by frequent consumption of "charcuterie, meat, and alcohol" in men and "charcuterie and starchy foods" in women, with the highest daily energy intake in both sexes. The fifth cluster included frequent "pasta eaters" in men and "pizza, sandwich" eaters in women.

Dietary Clusters and Sociodemographic Characteristics

In men, mean age, BMI, and medication use did not differ significantly across clusters (Table 3). "Small eaters" had a lower educational level and income. "Biscuits and snacking" eaters had the highest educational level, but not income, and they were often widowed and living alone. "Healthy" eaters included individuals with both a high education and income, living with a spouse. Men in the "Charcuterie, meat, and alcohol" cluster were similar to "small eaters" regarding their education and income, but they were more often widowed and living alone. Sociodemographic characteristics of "pasta eaters" were very similar to those of "healthy" eaters except for income.

In women, there was no significant difference in education and medication use across clusters, whereas age and BMI did differ (Table 4). Sociodemographic characteristics of "small eaters" were very similar to those of the whole sample except for the higher frequency of women living alone. Conversely to men, women in the "biscuits and snacking" cluster had a lower education and income, they were older, but as men they were more often widowed and living alone. "Healthy" eaters had the highest education and a fairly high income. Women in the "Charcuterie and starchy foods" cluster had high educations and incomes, and were more often married. The "pizza and sandwich" cluster would correspond to a rather disadvantaged group with fairly low education and income, often widowed and living alone.

Dietary Clusters and Health Status

Mean MMS score was higher in the "healthy" cluster and lower in the "biscuits and snacking" cluster in both sexes (Tables 3 and 4). CESD score was significantly lower in the "healthy" cluster and higher in the "pasta eaters" cluster in men (Table 3). In women, CESD score was lower in the "healthy" and "charcuterie and starchy foods" clusters and higher in the "biscuits and snacking" and "pizza and sandwich" clusters (Table 4). Health was more often perceived as good to very good in "healthy" eaters in both sexes. It was more often fair to very bad in "pasta eaters" in men and "biscuits and snacking" eaters in women.

The relationship between $\sqrt{30-\text{MMS}}$, $\sqrt{\text{CESD}}$, self-rated health and dietary clusters was explored in univariate and multivariate models in men and women (Table 5).

Men and women in the "healthy" cluster had a significantly lower mean number of errors to MMS score in univariate and sociodemographic adjusted models. In men, depressive symptoms were significantly higher in the "pasta-eaters" cluster in univariate and multivariate models. In women, depressive symptoms were significantly lower in the "healthy" and "charcuterie and starchy foods" clusters and higher in the "biscuits and snacking" cluster in univariate analysis. After adjustment on sociodemographic variables, only the negative association between the "healthy" and "charcuterie and starchy foods" clusters and CESD score remained of borderline significance in women.

In polytomous regressions, the best self-rated health class (Very Good Health) was chosen as reference category for the dependent variable. The "healthy" cluster was chosen in both sexes as reference category to investigate whether one particular dietary pattern was associated with an increased risk of perception of impaired health compared to this food pattern. Men in the "pasta eaters" cluster had about twice more risk to report impaired health than the "healthy" eaters. Women in the "biscuits and snacking" cluster had a significantly greater risk of perception of impaired health compared to the "healthy" eaters in multivariate analysis. In polytomous regressions on self-rated health, further adjustment on prevalent and past comorbidities did not change the results (results not shown).

These results were mostly unchanged after additional adjustment for BMI and medication use. However, this further adjustment reinforced or suggested some novel associations in women. A significant association between the "charcuterie and starchy foods" cluster and poorer self-rated health was observed (odds ratio=1.42; 95% confidence interval, 1.00 to 2.00; P=0.05), whereas the association between the "healthy"cluster and lower depressive symptoms became significant (β=−0.19; 95% confidence interval, −0.35 to −0.03; P=0.02). The relationship between "biscuits and snacking" and impaired self-rated health was also reinforced (odds ratio=1.82; 95% confidence interval, 1.23 to 2.70; P=0.003).

DISCUSSION

Using an innovative approach with a mixed clustering strategy, we identified five dietary patterns that differed between older men and women. A "healthy" dietary pattern characterized by higher consumption of fish in men and fruits and vegetables in women was related to better cognitive performance and self-rated health in both sexes, and less depressive symptoms in women.

Nutritional data are difficult to cluster into stable nonoverlapping groups because of small food consumption differences between individuals. There is no consensus on which clustering method is preferable for use with dietary variables (8).The first k-means partition allowed to reduce the dimension of observations to classify by making a first grouping. Crossing two k-means focused on the most-dense zone of observations to start the hierarchical algorithm. The last k-means consolidation step increased homogeneity of the final clusters. Clusters derived from number of food servings were recently shown to be more sensitive to fruit and vegetable intake than clusters derived from percent energy contribution in older people (9). Because fruits and vegetables contain high amounts of micronutrients, which might be related to cognitive and mood disorders (2,18), our patterns based on number of servings could more accurately reflect the relationship between dietary habits and these conditions.

Table 4. Sociodemographic and health characteristics of elderly women living in Bordeaux (France) according to their dietary pattern, the Three-City Study, 2001 to 2002

		By Dietary Pattern					
	Overall	Small eaters	Biscuits and snacking	Healthy	Charcuterie, starchy foods	Pizza, sandwich	*P* value
		← *n (%)* →					
	1077	334 (31.0)	162 (15.0)	267 (24.8)	266 (24.7)	48 (4.5)	
	← *mean (standard deviation)* →						
Age	76.8 (5.10)	76.5 (4.91)	78.5 (5.77)	76.6 (4.91)	76.2 (4.85)	77.3 (5.26)	<0.001[a]
BMI[b]	26.1 (4.56)	26.6 (4.92)	25.7 (4.20)	26.6 (4.92)	25.5 (3.94)	25.3 (3.63)	0.008[a]
Education	← % →						
No or Primary	39.1	43.8	42.9	33.7	35.7	41.7	0.15[c]
Secondary	27.5	27.0	28.0	31.5	24.8	22.9	
High school	20.4	19.2	18.6	21.4	22.6	16.7	
University	13.0	9.9	10.6	13.5	16.9	18.8	
Monthly income							
<750€	11.9	12.9	13.6	7.9	14.3	8.3	0.03[d]
750-1,500€	41.0	42.5	46.3	46.1	31.6	37.5	
1500-2,250€	19.9	19.8	19.8	18.4	20.7	25.0	
>2,250€	19.9	15.6	15.4	22.1	25.6	20.8	
Refused to answer	7.3	9.3	4.9	5.6	7.9	8.3	
Marital status							
Married	41.4	36.0	36.0	42.3	51.0	39.6	<0.001[d]
Divorced, separated, or single	19.1	20.1	14.9	18.5	21.7	14.6	
Widowed	39.5	43.8	49.1	39.3	27.4	45.8	
Living arrangements							
Alone	52.3	58.7	58.0	52.1	40.2	56.3	<0.001[d]
With spouse	41.9	36.2	36.4	42.7	51.9	39.6	
With other(s)	5.9	5.1	5.6	5.2	7.9	4.2	
No. of drugs ≥5	55.4	58.1	58.6	58.4	48.5	47.9	0.06[c]
	← *mean (standard deviation)* →						
MMS[e] **score**	27.2 (2.58)	27.1 (2.59)	26.6 (3.24)	27.6 (2.43)	27.4 (2.18)	26.8 (2.52)	0.002[a]
CESD[f] **score**	9.2 (8.15)	9.3 (8.17)	10.8 (8.64)	8.6 (8.19)	8.5 (7.42)	10.7 (9.36)	0.03[a]
Self-rated health	← % →						
Very good	7.0	8.3	4.3	7.9	6.8	4.3	0.007[g]
Good	51.7	53.8	42.0	56.2	50.4	53.2	
Fair	35.2	31.2	46.9	30.9	37.2	34.0	
Bad	5.6	6.7	6.2	3.8	5.3	8.5	
Very bad	0.5	0	0.6	1.1	0.4	0	

[a]Analysis of variance.
[b]BMI=body mass index (calculated as kg/m^2).
[c]χ^2 test.
[d]χ^2 test on binary variables: monthly income (<1,500€ vs ≥1,500€), marital status (married vs others), living arrangements (alone vs others).
[e]MMS=Mini Mental State.
[f]CESD=Center for Epidemiologic Studies-Depression.
[g]Polytomous logistic regression with self-rated health as dependent variable.

Some potential limitations to our findings must, however, be stressed. Although our clusters are consistent with similar patterns that have shown reproducibility across populations, further research will be necessary to describe the nutrient profiles of each cluster and ascertain their internal validity. This analysis was based on intake frequency that may not accurately reflect portion size. Moreover, no causal link can be inferred from this cross-sectional study. In particular, depressed or slightly cognitively impaired subjects may have changed their diet in reaction to their disease. Finally, adjustment for potential confounding factors does not eliminate the possibility of residual confounding (3).

Despite these potential limitations, our findings are consistent with previous studies on elderly populations. Indeed, a "healthy" or "prudent" pattern is frequently described (9-11,42-44) in opposition to a "traditional" or "Western" pattern (12) and a "sweet-gourmand" pattern (10,37,45-47). Our results confirm a previous report (13) that associated a higher score on the "healthy diet indi-

Table 5. Association between square root of number of errors to Mini Mental State (MMS) score, square root of Center for Epidemiologic Studies-Depression (CESD) score, self-rated health, and dietary clusters in older persons of the Three-City Study, Bordeaux, France, 2001 to 2002[de]

	$\sqrt{30-\mathrm{MMS}}$[a]					
	Univariate			Multivariate[b]		
Dietary pattern	β	(95% CI[c])	*P* value	β	(95% CI)	*P* value
Male (n=647)						
Small eaters	0.08	(−0.03 to 0.19)	0.15	0.04	(−0.06 to −0.14)	0.38
Biscuits and snacking	0.06	(−0.11 to 0.23)	0.45	0.06	(−0.10 to 0.22)	0.48
Healthy	0.15	(−0.26 to −0.04)	0.01	−0.11	(−0.22 to −0.004)	0.04
Charcuterie, meat, alcohol	0.06	(−0.08 to 0.20)	0.40	0.04	(−0.09 to 0.17)	0.50
Pasta eaters	−0.06	(−0.18 to 0.06)	0.37	−0.03	(−0.14 to 0.08)	0.56
Female (n=1,077)						
Small eaters	−0.01	(−0.10 to 0.08)	0.79	−0.02	(−0.10 to 0.06)	0.60
Biscuits and snacking	0.13	(0.01 to 0.25)	0.03	0.04	(−0.07 to 0.15)	0.47
Healthy	−0.17	(−0.27 to −0.07)	<0.001	−0.13	(−0.22 to −0.04)	0.004
Charcuterie, starchy foods	−0.05	(−0.15 to 0.05)	0.34	0.002	(−0.09 to 0.09)	0.96
Pizza, sandwich	0.11	(−0.21 to 0.43)	0.28	0.11	(−0.06 to 0.28)	0.21
	$\sqrt{\mathrm{CESD}}$[a]					
Male (n=647)						
Small eaters	−0.11	(−0.29 to 0.07)	0.21	−0.11	(−0.29 to 0.07)	0.24
Biscuits and snacking	−0.01	(−0.30 to 0.28)	0.92	−0.06	(−0.35 to 0.23)	0.70
Healthy	−0.13	(−0.32 to 0.06)	0.18	−0.12	(−0.31 to 0.07)	0.21
Charcuterie, meat, alcohol	0.04	(−0.19 to 0.27)	0.75	0.03	(−0.20 to 0.26)	0.83
Pasta eaters	0.22	(0.02 to 0.42)	0.03	0.26	(0.06 to 0.46)	0.01
Female (n=1,077)						
Small eaters	−0.03	(−0.19 to 0.13)	0.73	−0.03	(−0.19 to 0.13)	0.71
Biscuits and snacking	0.21	(0.01 to 0.41)	0.04	0.13	(−0.07 to 0.33)	0.19
Healthy	−0.18	(−0.35 to −0.01)	0.03	−0.16	(−.33 to 0.007)	0.06
Charcuterie, starchy foods	−0.19	(−0.36 to −0.02)	0.02	−0.15	(−0.32 to 0.02)	0.07
Pizza, sandwich	0.19	(−0.13 to 0.51)	0.23	0.21	(−0.11 to 0.53)	0.19
	Self-Rated Health[d]					
Male (n=647)	OR[e]	(95% CI)	*P* value	OR	(95% CI)	*P* value
Small eaters	1.27	(0.84 to 1.92)	0.27	1.23	(0.81 to 1.88)	0.34
Biscuits and snacking	0.95	(0.51 to 1.75)	0.87	0.96	(0.51 to 1.77)	0.88
Healthy	1	—	—	1	—	—
Charcuterie, meat, alcohol	1.14	(0.69 to 1.91)	0.61	1.17	(0.70 to 1.97)	0.55
Pasta eaters	1.91	(1.22 to 3.01)	0.005	1.91	(1.21 to 3.01)	0.006
Female (n=1,077)						
Small eaters	1.09	(0.79 to 1.49)	0.60	1.05	(0.77 to 1.45)	0.76
Biscuits and snacking	1.94	(1.33 to 2.82)	<0.001	1.69	(1.15 to 2.48)	0.007
Healthy	1	—	—	1	—	—
Charcuterie, starchy foods	1.30	(0.94 to 1.80)	0.12	1.29	(0.92 to 1.80)	0.14
Pizza, sandwich	1.41	(0.78 to 2.56)	0.25	1.42	(0.78 to 2.59)	0.25

[a]Linear regression models with respectively $\sqrt{30-\mathrm{MMS}}$ and $\sqrt{\mathrm{CESD}}$ as dependent variables. The reference for the variable cluster is the average of cluster levels.
[b]Adjusted for age, education, income, and marital status.
[c]CI=confidence interval.
[d]Polytomous logistic regression with self-rated health as five-level ordered dependent variable (1=very good, 2=good, 3=fair, 4=bad, 5=very bad).
[e]OR=odds ratio.

cator" to better cognitive function in a male European population. Frequent fish consumption (48,49) as well as higher consumption of vegetables (50) have been found to be associated with better cognitive performance in older people. To our knowledge, this is the first analysis of the relationships between multidimensionally derived food patterns and cognition. Our findings are also consistent with a recent study (15) reporting more vascular nutritional risk factors in depressive elderly subjects. Several previous reports suggest beneficial effects of Mediterranean-type diet, including fish and vegetable consumption, on mood regulation (16). Contrary to our findings, two previous studies failed to identify any association between overall diet and health perception (51,52). The relationship between a healthful dietary pattern derived by factor analysis and better self-rated health disappeared after adjustment in another study (20). By contrast, higher consumption of fruits and vegetables was found to be related to better perceived health (18,19).

About 30% of our sample were "small eaters." Protein-energy undernutrition is frequent in older people (53). Although probably underestimated from a single 24-hour dietary recall, mean daily energy intake was lower in the "small eaters" cluster than in other patterns. Moreover, in women it just equaled the estimated value of energy expenditure at rest in the 60- to 75-year-old female population (54). Therefore, the "small eaters" pattern may neither cover the energy requirement of active subjects nor provide adequate nutrient intake in these older people who mostly belong to disadvantaged social classes. On the other hand, the "small eaters" had higher BMI than others. We thus cannot exclude that some of these subjects may have underreported their daily intake.

Inadequate nutrient intake was previously observed in older and single women with low education or income in the same sample (28). These sociodemographic factors are similar to the characteristics of both the "pizza, sandwich" and the "biscuits and snacking" female clusters and in accordance with the "sweet and fat" pattern of a European older population (10). These clusters may, therefore, represent a group at risk for malnutrition in women, with the "biscuits and snacking" cluster being related with a twofold higher risk of poor perceived health than the "healthy" cluster.

In men, the cross-sectional relationship between the "pasta-eaters" pattern and both poorer self-rated health and higher depressive symptoms suggests that this pattern could rather be a consequence of poor health. Indeed, depressive older people may modify their dietary behavior in an unfavorable way. In women, the charcuterie and alcohol-based pattern, similar to the widely described "traditional pattern," was associated with higher risk of impaired perceived health in fully adjusted models. This result may be explained by the negative effects of alcohol and saturated fats contained in charcuterie.

The "healthy" cluster seemed to be the most adequately balanced pattern in both sexes, as confirmed by its protective association with cognitive function, mood, and self-rated health. Several physiological explanations to our findings may be proposed. Indeed, fruits and vegetables are good sources of carotenoids and flavonoids, which are powerful antioxidants. Dietary antioxidants could contribute to slow down age-associated cognitive disorders (55). In addition, green leafy vegetables provide folates that might exert protective effects against cognitive decline (1,2,56), but also mood disorders (57). Moreover, fish contains high levels of long-chain n-3 polyunsaturated fatty acids, in particular eicosapentaenoic acid and docosahexaenoic acid. In the same sample, we found an inverse association between eicosapentaenoic acid plasma levels and depressive symptomatology (58). n-3 polyunsaturated fatty acids are major components of neurone membranes and have vascular and anti-inflammatory properties that could explain their protective effect against Alzheimer's disease, cognitive decline, and depression (59). A combination of regular consumption of fruits, vegetables, and fish was associated with a decreased risk of incident dementia in the whole Three-City cohort (60).

Dietary patterns, which summarize an eating style, increase the effectiveness of nutrition education in promoting sensible food choices (61). Because multidimensionally derived dietary patterns had not yet been related to cognitive function, mood disorders, and self-rated health in older people, our study offers original results that should be considered in nutritional prevention policies. Our findings reinforce the importance of a healthful dietary pattern including regular consumption of fish, fruits, and vegetables, in accordance with the Department of Health and Human Services' 2005 *Dietary Guidelines for Americans* (62).

C. Samieri benefits from a research grant from the Association Internationale pour la Recherche sur la Maladie d'Alzheimer.

The Three-City (Three-City) Study is conducted under a partnership agreement between the Institut National de la Santé et de la Recherche Médicale (INSERM), the Institut de Santé Publique et Développement of the Victor Segalen Bordeaux 2 University, and Sanofi-Aventis. The Fondation pour la Recherche Médicale funded the preparation and initiation of the study. The Three-City Study is also supported by the Caisse Nationale Maladie des Travailleurs Salariés, Direction Générale de la Santé, Mutuelle Générale de l'Education Nationale, Institut de la Longévité, Regional Councils of Aquitaine and Bourgogne, Fondation de France, and Ministry of Research-INSERM Programme "Cohortes et collections de données biologiques." The nutritional part of the Three-City study is included in the COGINUT (COGnition, anti-oxidants, fatty acids: an interdisciplinary approach of the role of NUTrition in brain aging) research program. This work was carried out with the financial support of the Agence Nationale de la Recherche, The French National Research Agency under the Programme National de Recherche en Alimentation et nutrition humaine, project ANR-06-PNRA-005.

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