

ORIGINAL ARTICLE

Dietary patterns associated with vitamin/mineral supplement use and smoking among women of the E3N–EPIC cohort

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Background/Objectives: An understanding of the relationships between dietary habits and supplement use or smoking is useful for aetiological studies and surveillance purposes. The objective of this study is to describe dietary patterns associated with vitamin/mineral supplement use and smoking habits in French women.

Methods: Scores for dietary patterns were obtained by factor analysis in 64 252 women from the French E3N–EPIC cohort. The association with supplement and tobacco use was investigated by logistic regression analysis.

Results: We identified three dietary patterns: ‘processed meat/starchy foods’ (fast foods, processed meat, rice/pasta/semolina and cakes and few vegetables); ‘fruit/vegetables’ (fruits, vegetables, seafood, vegetable oils and yoghurt); and ‘alcohol/meat products’ (alcohol, meat and meat products, and coffee, and few fruits and soup). Supplement use was positively associated with the fruit/vegetables pattern (multivariate OR for quartile 4 versus 1 (OR₄) = 1.55, 95% confidence interval: 1.47–1.63), and inversely associated with the processed meat/starchy foods (OR₄ = 0.84; 0.80–0.89) and alcohol/meat products (OR₄ = 0.69; 0.66–0.73) patterns (*P* trend for all associations < 0.0001). As compared with never smoking, current smoking was inversely associated with the fruit/vegetables pattern (OR₄ = 0.85; 0.78–0.92), while former smoking was positively associated with the fruit/vegetables pattern (OR₄ = 1.32; 1.25–1.40); both current and former smoking were inversely associated with the processed meat/starchy foods pattern (OR₄ = 0.57; 0.53–0.62 and 0.64; 0.60–0.67, respectively); whereas current and former smoking were both strongly positively associated with the alcohol/meat products pattern (OR₄ = 5.78; 5.26–6.36 and 2.03; 1.91–2.15, respectively); *P* trend for all associations was < 0.001.

Conclusions: Supplement use and smoking are strongly associated with dietary patterns.

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Contributors: MT designed the study, analysed and interpreted the data and wrote the manuscript. MN was in charge of collection and validation of dietary data. J-LV, LL and SL contributed in interpreting results and editing the manuscript. FC designed and coordinated the study cohort and supervised the study. MCBR supervised the design, analysis and interpretation of the data, as well as writing of the manuscript. All authors reviewed the manuscript. None of the authors had a conflict of interest.

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Introduction

Dietary patterns, smoking status and supplement use, more specifically antioxidant supplements such as β -carotene, vitamin C and vitamin E, have been suggested to modulate the risk of several conditions including cancer and cardiovascular disease (Patterson *et al.*, 1997; Nissen *et al.*, 2003; Bjelakovic *et al.*, 2004; Edwards, 2004; Kesse *et al.*, 2006; Riccioni *et al.*, 2007). Underlying mechanisms are complex and may involve interactions between several of these factors as suggested for smoking and β -carotene (Touvier *et al.*, 2005). Elucidating associations between dietary patterns, supplement use and smoking status will help understand complex behaviours and mechanisms, as well

as enable proper control for potential confounding in studies that investigate the relationship between one of these factors and a chronic disease. Several studies have suggested associations between diet, supplement use and smoking (Schulze *et al.*, 2001; Kerver *et al.*, 2003; Beitz *et al.*, 2004; Bamia *et al.*, 2005; Engeset *et al.*, 2005). Supplement use is often associated with a healthy diet (Kerver *et al.*, 2003; Beitz *et al.*, 2004; McNaughton *et al.*, 2007), although a positive association between alcohol consumption and supplement use was once described (Schulze *et al.*, 2001). Current smoking is generally inversely related to a healthy diet (Zondervan *et al.*, 1996; Pryer *et al.*, 2001; Schulze *et al.*, 2001; McNaughton *et al.*, 2007), and positively related to alcohol consumption (Schulze *et al.*, 2001; Engeset *et al.*, 2005), but few studies have investigated associations with former smoking (Bamia *et al.*, 2005; McNaughton *et al.*, 2007). Moreover, although a few studies have investigated diet in association with tobacco or dietary supplements in France (Beer-Borst *et al.*, 2000; Marques-Vidal *et al.*, 2000; Scali *et al.*, 2001; Perrin *et al.*, 2005; Touvier *et al.*, 2006), they have mainly focused on the associations with individual foods or nutrients rather than with an overall pattern, and to our knowledge, none has simultaneously studied dietary patterns, smoking and supplements.

Our objective was to establish dietary patterns in the E3N-EPIC cohort, a large cohort of French women, and to determine whether these patterns differ between dietary supplement users and non-users (investigating overall supplement use as well as the specific antioxidant supplements of β -carotene, vitamin C and vitamin E), and between never, former and current smokers.

Subjects and methods

Subjects

The E3N (Etude Epidémiologique de Femmes de la Mutuelle Générale de l'Education Nationale, MGEN) prospective cohort was initiated in France in 1990 to investigate factors associated with the most frequent sites of cancer in women (Clavel-Chapelon *et al.*, 1997). The cohort consists of 98 995 women living in France, aged 40–65 years at baseline and covered by the MGEN, the National Health Insurance Plan for teachers and co-workers. All study subjects signed an informed consent form, in compliance with the rules of the French National Commission for Computed Data and Individual Freedom (Commission Nationale Informatique et Libertés) from which we obtained approval. Among the 73 034 women of the cohort with valid dietary data (as detailed below), the 64 252 women with available data for both supplement use and smoking status were considered in the analysis.

Data collection

Dietary data. Dietary data were collected between June 1993 and July 1995 using a two-part self-administered questionnaire. The first part contained questions on the quantity and

frequency of consumption of food groups, while the second consisted of qualitative questions, enabling the food groups to be broken down into individual food items. The questionnaire, accompanied by a booklet of photographs for the estimation of portion sizes, assessed dietary consumption of 208 food items, beverages and recipes. Both the questionnaire and the booklet were validated, and the reproducibility of the questionnaire was tested after 1 year (Lucas *et al.*, 1995; van Liere *et al.*, 1997). The percentage of subjects classified in the same or the adjacent quintile by questionnaire as well as by 24-h recall (standard method) was on average 76% for foods and 72% for nutrients.

The dietary questionnaire was sent to the 95 644 women, who had responded to the 1992 previous questionnaire, with two reminders to non-responders. In all, 77 613 questionnaires (81.1%) were returned. After exclusion of 985 questionnaires due to absence of consent for external health follow-up by the health insurer in the case of dropout, 2050 questionnaires due to miscoded answers, 8 blank questionnaires, 46 duplicate questionnaires and 1490 questionnaires with extreme values (in the bottom 1% or top 1%) for the ratio between energy intake and required energy (required energy = $1.55 \times$ basal metabolic rate, the latter calculated from weight, height and age; FAO/WHO/UNO, 1986), 73 034 questionnaires were available for analysis. Daily dietary intakes of macro- and micronutrients (especially total energy intake in kcal day^{-1} , β -carotene, and vitamins C and E in mg day^{-1}) were estimated using a food composition table derived from the French National database (Favier *et al.*, 1995). As the dietary questionnaire recorded food intake separately for each meal or snack, we were able to calculate the proportion of energy intake from each meal (energy from the meal divided by total daily energy intake). Women were asked if they were undergoing one of the following specific diets: diabetic, cholesterol-lowering or weight loss diets. Responders to the dietary questionnaire represent the French part of the European Prospective Investigation on Cancer (EPIC; Riboli, 1992).

Smoking status. Smoking status was assessed in the same questionnaire as diet. Subjects were classified as never, former or current smokers. Past or current smokers of less than one cigarette per day (occasional smokers) were considered non-smokers.

Dietary supplement use. In the questionnaire mailed in 1994, study participants were asked if they took a supplement for the following nutrients: β -carotene, calcium, retinol, vitamins C, E, D, B-group, and other vitamins and minerals, at least three times a week. About 97% of the questionnaires were returned by December 1996.

Statistical analysis

Derivation of dietary patterns by principal component analysis (PCA). First, we assigned the 208 food items into 46 predefined food groups (Appendix). Dietary patterns were

produced from a factor analysis, based on the predefined food groups, using the procedure factor (principal component method). The Scree plot method (Cattell, 1966) was used to determine the number of factors to retain. Besides, the first three patterns were easily interpretable, whereas the interpretation of the fourth one was less clear, which strengthened our decision to retain the first three patterns. PCA reduces the data by forming linear combinations of the original observed variables, thereby grouping together correlated variables which in turn identifies any underlying dimension in the data. The coefficients defining these linear combinations are called 'factor loadings' and represent the correlations of each food item with that component. A negative (respectively positive) factor loading means that the food group or item is inversely (respectively positively) correlated with the factor. For interpreting the data, we considered food groups or items most strongly related to the factor, that is those for which the loading coefficient was higher than 0.2 or lower than -0.2. Labels were chosen according to the most significant foods associated with the patterns. Factors were rotated by an orthogonal transformation, using the SAS 'Varimax' option, to obtain a simpler structure to make interpretation easier (Terry *et al.*, 2001; Newby *et al.*, 2006). For each subject, the factor score for each pattern was calculated by summing up the observed consumption of food groups weighted by the factor loadings. The factor score of subjects measures the adequacy of their diet to the given pattern (a higher score meaning a better adequacy).

Main statistical analysis: association between dietary patterns and supplement use or smoking. We used logistic regression analysis to estimate odds ratios (ORs) and 95% confidence intervals (95% CIs) in order to compare dietary patterns according to supplement use and smoking status. In multivariate models, control for confounders was ensured by adjustment for age, physical activity (estimated by multiplying the metabolic equivalent cost, MET (Ainsworth *et al.*, 2000) of activities by their duration and frequency), body mass index in kg m^{-2} (continuous variables, assessed in the same questionnaire as diet), education level (< or ≥ 12 years of schooling, collected in the baseline self-administered questionnaire in 1990) and smoking status (never/former/current smoker) or supplement use (yes/no), depending on the studied parameter, as well as mutual adjustment for dietary patterns (quartiles). Analyses were performed using SAS software, version 8.2.

Results

Characteristics of the dietary patterns

We identified three main dietary patterns. Table 1 presents the factor-loading matrix between food items or food groups, and the patterns. Pattern 1 was characterized by high

consumption of biscuits, bread, butter/cream, cakes, French fries, marmalade/honey, pulses, pizza/pies, potatoes, processed meat, rice/pasta/semolina, sandwiches, dairy-based sweet puddings, sugar/confectionary and by low consumption of vegetables; this pattern was named 'processed meat/starchy foods'. Pattern 2 was positively correlated with consumption of breakfast cereals, eggs, fruits, ham, pulses, offal, olive oil, seafood, vegetable oil, vegetables, yoghurt/cottage cheese and was named 'fruit/vegetables'. Pattern 3 was associated with high consumption of high- and low-alcohol beverages, wine, meat, offal, poultry/rabbit, processed meat, appetizers, artificial sweeteners, coffee and French fries, as well as with low consumption of fruits, soup and marmalade/honey. It was named 'alcohol/meat

Table 1 Factor loadings^a for the three rotated factors ($n = 64\,252$)

Food group	Processed meat/ starchy foods	Fruit/ vegetables	Alcohol/meat products
Appetizers			0.47
Artificial sweeteners			0.22
Biscuits	0.27		
Bread	0.39		
Breakfast cereals		0.20	
Butter, cream	0.35		
Cakes	0.44		
Coffee			0.36
Dairy-based sweet puddings	0.31		
Egg		0.36	
French fries	0.40		0.35
Fruit		0.39	-0.30
Ham		0.28	
High-alcohol beverages			0.59
Low-alcohol beverages			0.33
Marmalade, honey	0.27		-0.29
Meat			0.21
Offal		0.25	0.22
Olive oil		0.34	
Pizza, pies	0.40		
Potatoes	0.46		
Poultry and rabbit			0.21
Processed meat ^b	0.43		0.39
Pulses	0.35	0.31	
Rice, pasta, semolina	0.50		
Sandwiches	0.30		
Seafood		0.53	
Soup			-0.37
Sugar and confectionary	0.38		
Vegetable oil ^c		0.49	
Vegetables	-0.22	0.74	
Wine			0.50
Yoghurt, cottage cheese		0.43	

^aFactor loadings of less than ± 0.20 were omitted for simplicity (crisp bread, cheese, chicory, chocolate beverages, juices, milk, margarine, other fats, diet soft drinks, regular soft drinks, tea, bottled and tap water).

^bExcept ham.

^cExcept olive oil.

products'. Characteristics of subjects according to their factor score for each pattern are presented in Table 2.

Association between dietary patterns and supplement use

In the study population, 26.9% of women took dietary supplements at least three times a week. The prevalence was 6.0% for vitamin C, 5.6% for vitamin E and 2.3% for β -carotene. Overall dietary supplement use was inversely associated with the processed meat/starchy foods pattern, as well as with the alcohol/meat products pattern. In contrast, overall supplement use was positively associated with the

fruit/vegetables pattern. For each pattern, associations with use of β -carotene, vitamins C and E supplements were similar to those with overall supplement use (Table 3).

Association between dietary patterns and smoking status

In the study population, 8.7% of the women were current smokers and 20.8% were former smokers. As compared with never smoking, current and former smoking were inversely associated with the processed meat/starchy foods pattern and positively associated with the alcohol/meat products pattern. Current smoking was inversely associated with the

Table 2 Characteristics of the women ($n = 64\,252$) by mean (s.d.) or percentage, according to quartiles of factor scores for each pattern

	Quartile 1	Quartile 2	Quartile 3	Quartile 4	P for trend ^a
<i>Processed meat/starchy foods pattern</i>					
Age (years)	54.5 (6.8)	53.6 (6.8)	52.6 (6.6)	51.1 (6.2)	<0.0001
Body mass index (kg m^{-2})	23.2 (3.3)	22.9 (3.2)	22.8 (3.1)	22.9 (3.4)	<0.0001
<12 years of schooling (%)	11.7	10.9	10.6	11.2	0.08
Physical activity (MET h week^{-1})	48.6 (33.9)	48.1 (31.9)	47.7 (30.9)	46.6 (31.1)	<0.0001
Energy intake (kcal day^{-1})	1699.5 (417.8)	1982.7 (384.9)	2254.6 (390.4)	2747.9 (488.3)	<0.0001
Proportion of energy intake—breakfast (%)	17.3 (8.7)	17.7 (8.1)	17.6 (7.7)	16.8 (7.3)	<0.0001
Proportion of energy intake—lunch (%)	41.9 (10.1)	41.5 (8.8)	40.7 (7.8)	39.6 (7.3)	<0.0001
Proportion of energy intake—dinner (%)	35.0 (10.1)	34.4 (8.7)	34.4 (7.8)	34.5 (7.3)	<0.0001
Proportion of energy intake—snacking (%)	5.8 (6.0)	6.4 (6.0)	7.3 (6.2)	9.1 (7.0)	<0.0001
Diabetic/cholesterol—lowering/weight loss diets (%)	2.2/9.7/13.5	1.2/7.7/6.2	0.9/6.2/4.2	0.6/4.4/3.7	<0.0001 ^b
β -Carotene dietary intake (mg day^{-1})	4.4 (2.1)	3.9 (1.7)	3.8 (1.6)	3.8 (1.5)	<0.0001
Vitamin C dietary intake (mg day^{-1})	145.4 (66.7)	138.1 (60.4)	137.7 (59.0)	141.8 (61.2)	<0.0001
Vitamin E dietary intake (mg day^{-1})	13.4 (6.2)	13.4 (5.6)	14.2 (5.6)	15.9 (5.9)	<0.0001
<i>Fruit/vegetables pattern</i>					
Age (years)	53.0 (6.9)	53.0 (6.8)	52.9 (6.6)	52.9 (6.5)	0.02
Body mass index (kg m^{-2})	22.3 (3.0)	22.7 (3.1)	23.1 (3.2)	23.8 (3.6)	<0.0001
<12 years of schooling (%)	12.0	11.0	10.1	11.4	0.01
Physical activity (MET h week^{-1})	45.1 (32.2)	47.8 (31.9)	48.4 (30.7)	49.8 (32.9)	<0.0001
Energy intake (kcal day^{-1})	1878.0 (497.1)	2077.8 (496.0)	2238.5 (524.2)	2490.2 (585.1)	<0.0001
Proportion of energy intake—breakfast (%)	19.0 (8.9)	17.7 (7.8)	16.9 (7.4)	15.8 (7.2)	<0.0001
Proportion of energy intake—lunch (%)	40.0 (9.9)	41.2 (8.5)	41.2 (8.0)	41.3 (7.8)	<0.0001
Proportion of energy intake—dinner (%)	33.6 (9.9)	34.2 (8.3)	34.8 (8.0)	35.6 (7.6)	<0.0001
Proportion of energy intake—snacking (%)	7.4 (7.1)	6.9 (6.2)	7.1 (6.2)	7.3 (6.2)	0.6
Diabetic/cholesterol—lowering/weight loss diets (%)	0.8/5.5/2.9	0.9/6.5/4.1	1.3/7.4/6.6	1.9/8.6/14.0	<0.0001 ^b
β -Carotene dietary intake (mg day^{-1})	2.6 (1.0)	3.5 (1.1)	4.2 (1.3)	5.6 (1.9)	<0.0001
Vitamin C dietary intake (mg day^{-1})	94.5 (37.5)	125.0 (41.2)	149.2 (48.3)	194.2 (67.9)	<0.0001
Vitamin E dietary intake (mg day^{-1})	9.7 (3.3)	12.7 (3.9)	15.1 (4.6)	19.4 (6.5)	<0.0001
<i>Alcohol/meat products pattern</i>					
Age (years)	54.4 (7.0)	53.3 (6.8)	52.5 (6.5)	51.6 (6.2)	<0.0001
Body mass index (kg m^{-2})	22.2 (2.9)	22.8 (3.1)	23.2 (3.3)	23.6 (3.5)	<0.0001
<12 years of schooling (%)	10.3	11.5	11.6	11.0	0.05
Physical activity (MET h week^{-1})	51.3 (32.9)	47.6 (32.0)	46.5 (31.7)	45.7 (30.9)	<0.0001
Energy intake (kcal day^{-1})	2187.4 (552.5)	2066.8 (546.1)	2097.3 (547.0)	2333.2 (604.8)	<0.0001
Proportion of energy intake—breakfast (%)	20.8 (8.2)	18.3 (7.8)	16.5 (7.3)	13.9 (6.8)	<0.0001
Proportion of energy intake—lunch (%)	39.0 (8.2)	41.0 (8.6)	41.7 (8.6)	41.9 (8.8)	<0.0001
Proportion of energy intake—dinner (%)	31.5 (7.7)	33.3 (7.9)	35.1 (8.2)	38.3 (8.7)	<0.0001
Proportion of energy intake—snacking (%)	8.7 (7.2)	7.4 (6.6)	6.7 (6.0)	5.9 (5.6)	<0.0001
Diabetic/cholesterol—lowering/weight loss diets (%)	1.0/9.6/4.1	1.1/7.3/6.0	1.4/6.1/7.9	1.4/5.0/9.6	<0.0001 ^b
β -Carotene dietary intake (mg day^{-1})	4.5 (1.9)	4.0 (1.7)	3.8 (1.7)	3.6 (1.7)	<0.0001
Vitamin C dietary intake (mg day^{-1})	157.4 (66.1)	139.5 (58.1)	133.9 (57.1)	132.1 (62.8)	<0.0001
Vitamin E dietary intake (mg day^{-1})	14.2 (5.8)	13.8 (5.7)	14.0 (5.7)	14.9 (6.3)	<0.0001

Abbreviation: MET, metabolic equivalent cost.

^aLogistic regression for qualitative variables and linear regression for continuous variables.

^bFor each of the three types of restrictive diet.

Table 3 Dietary patterns of the women (*n* = 64 252) according to dietary supplement use, by logistic regression analysis

	OR (95% CI)				P for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
<i>Processed meat/starchy foods pattern</i>					
Overall dietary supplement use ^a	29.2	26.8	26.5	25.2	
Unadjusted model	1	0.89 (0.85–0.93)	0.87 (0.83–0.92)	0.82 (0.78–0.86)	<0.0001
Multivariate model ^b	1	0.90 (0.85–0.94)	0.89 (0.84–0.93)	0.84 (0.80–0.89)	<0.0001
β-Carotene dietary supplement use ^a	3.1	2.1	2.0	2.0	
Unadjusted model	1	0.68 (0.59–0.79)	0.66 (0.57–0.76)	0.63 (0.55–0.73)	<0.0001
Multivariate model	1	0.69 (0.60–0.80)	0.65 (0.56–0.75)	0.60 (0.52–0.70)	<0.0001
Vitamin C dietary supplement use ^a	7.2	6.1	5.5	5.4	
Unadjusted model	1	0.84 (0.77–0.91)	0.75 (0.68–0.82)	0.74 (0.68–0.81)	<0.0001
Multivariate model	1	0.85 (0.78–0.93)	0.74 (0.68–0.81)	0.72 (0.65–0.79)	<0.0001
Vitamin E dietary supplement use ^a	7.1	5.7	5.1	4.4	
Unadjusted model	1	0.80 (0.73–0.87)	0.71 (0.64–0.77)	0.61 (0.55–0.67)	<0.0001
Multivariate model	1	0.81 (0.74–0.88)	0.71 (0.65–0.78)	0.60 (0.55–0.66)	<0.0001
<i>Fruit/vegetables pattern</i>					
Overall dietary supplement use	23.7	26.4	26.9	30.6	
Unadjusted model	1	1.15 (1.09–1.21)	1.18 (1.12–1.24)	1.42 (1.35–1.49)	<0.0001
Multivariate model	1	1.17 (1.11–1.23)	1.23 (1.17–1.30)	1.55 (1.47–1.63)	<0.0001
β-Carotene dietary supplement use	1.7	1.9	2.5	3.0	
Unadjusted model	1	1.12 (0.95–1.32)	1.47 (1.26–1.72)	1.79 (1.54–2.08)	<0.0001
Multivariate model	1	1.16 (0.99–1.37)	1.55 (1.33–1.82)	1.95 (1.68–2.28)	<0.0001
Vitamin C dietary supplement use	4.9	5.5	6.0	7.7	
Unadjusted model	1	1.14 (1.03–1.25)	1.25 (1.13–1.38)	1.63 (1.49–1.79)	<0.0001
Multivariate model	1	1.17 (1.06–1.29)	1.31 (1.19–1.45)	1.79 (1.62–1.96)	<0.0001
Vitamin E dietary supplement use	4.4	5.1	5.6	7.2	
Unadjusted model	1	1.17 (1.06–1.30)	1.31 (1.19–1.45)	1.71 (1.55–1.88)	<0.0001
Multivariate model	1	1.22 (1.10–1.35)	1.40 (1.27–1.55)	1.91 (1.73–2.11)	<0.0001
<i>Alcohol/meat products pattern</i>					
Overall dietary supplement use	32.5	27.7	24.9	22.5	
Unadjusted model	1	0.80 (0.76–0.83)	0.69 (0.65–0.72)	0.60 (0.57–0.63)	<0.0001
Multivariate model	1	0.85 (0.81–0.89)	0.76 (0.72–0.80)	0.69 (0.66–0.73)	<0.0001
β-Carotene dietary supplement use	2.7	2.2	2.2	2.0	
Unadjusted model	1	0.81 (0.70–0.93)	0.79 (0.69–0.91)	0.74 (0.64–0.85)	<0.0001
Multivariate model	1	0.85 (0.73–0.98)	0.85 (0.73–0.98)	0.80 (0.69–0.93)	0.008
Vitamin C dietary supplement use	7.0	6.1	5.6	5.5	
Unadjusted model	1	0.85 (0.78–0.93)	0.78 (0.71–0.86)	0.76 (0.70–0.84)	<0.0001
Multivariate model	1	0.89 (0.81–0.97)	0.83 (0.75–0.91)	0.80 (0.73–0.89)	<0.0001
Vitamin E dietary supplement use	7.0	5.7	5.0	4.6	
Unadjusted model	1	0.80 (0.73–0.87)	0.70 (0.64–0.77)	0.64 (0.58–0.70)	<0.0001
Multivariate model	1	0.84 (0.77–0.93)	0.78 (0.70–0.85)	0.72 (0.65–0.80)	<0.0001

Abbreviation: CI, confidence interval.

^aProportion of users (%).

^bAll multivariate models were adjusted for age, body mass index, physical activity, education level and smoking status, and mutually adjusted for all dietary patterns.

fruit/vegetables pattern, while former smoking was positively associated with this pattern (Table 4).

Discussion

Our study provides original data on the relationships between dietary patterns, supplement use and smoking in French middle-aged women. We identified a pattern globally associated with recommendations for a healthy diet, and two ‘unhealthy’ patterns which differed in terms of risk factors: a processed meat/starchy foods pattern, typical western pattern (Slattery *et al.*, 1998; Bamia *et al.*, 2005; Newby *et al.*, 2006; McNaughton *et al.*, 2007) and an alcohol/meat products pattern, sharing only some of the characteristics

of a western diet, but associated with additional risk factors such as alcohol and tobacco. Patterns similar to some of ours have been described in a representative sample of the French population (the ASPCC study; Martin *et al.*, 2001), and in other countries (Terry *et al.*, 2001; Bamia *et al.*, 2005; Crozier *et al.*, 2006; McNaughton *et al.*, 2007), adding to the consistency of our findings.

While diet has traditionally been investigated through the analysis of selected nutrients or foods, a more global approach of dietary pattern assessment is emerging (Hu, 2002). Subjects are classified according to global food consumption behaviour, while the nutrient-food approach is more appropriate to interpret and understand mechanisms involved (Jacobs and Steffen, 2003). The identification of dietary patterns by factor analysis has some limitations

Table 4 Dietary patterns of the women (*n* = 64 252) according to smoking status, by logistic regression analysis

	Proportion of current or former smokers (%)				P for trend
	OR (95% CI)				
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
<i>Processed meat/starchy foods pattern</i>					
Current smokers vs never smokers ^a	10.4	8.8	7.7	7.9	
Unadjusted model	1	0.79 (0.73–0.85)	0.68 (0.63–0.73)	0.69 (0.64–0.75)	<0.0001
Multivariate model ^b	1	0.78 (0.72–0.84)	0.63 (0.58–0.69)	0.57 (0.53–0.62)	<0.0001
Former smokers vs never smokers ^c	23.8	20.6	19.8	19.0	
Unadjusted model	1	0.81 (0.77–0.85)	0.76 (0.72–0.80)	0.72 (0.68–0.76)	<0.0001
Multivariate model	1	0.82 (0.77–0.86)	0.74 (0.70–0.78)	0.64 (0.60–0.67)	<0.0001
<i>Fruit/vegetables pattern</i>					
Current smokers vs never smokers	10.4	8.4	8.1	7.9	
Unadjusted model	1	0.81 (0.75–0.87)	0.79 (0.73–0.86)	0.79 (0.73–0.86)	<0.0001
Multivariate model	1	0.87 (0.80–0.94)	0.85 (0.78–0.92)	0.85 (0.78–0.92)	0.0002
Former smokers vs never smokers	18.3	19.8	21.5	23.7	
Unadjusted model	1	1.08 (1.02–1.14)	1.19 (1.13–1.26)	1.35 (1.28–1.43)	<0.0001
Multivariate model	1	1.10 (1.04–1.16)	1.19 (1.13–1.26)	1.32 (1.25–1.40)	<0.0001
<i>Alcohol/meat products pattern</i>					
Current smokers vs never smokers	3.7	5.8	9.4	15.8	
Unadjusted model	1	1.67 (1.50–1.85)	2.95 (2.67–3.25)	5.81 (5.30–6.38)	<0.0001
Multivariate model	1	1.61 (1.45–1.79)	2.87 (2.60–3.17)	5.78 (5.26–6.36)	<0.0001
Former smokers vs never smokers	16.2	19.3	22.0	25.7	
Unadjusted model	1	1.27 (1.20–1.35)	1.58 (1.49–1.67)	2.16 (2.05–2.29)	<0.0001
Multivariate model	1	1.23 (1.16–1.30)	1.50 (1.41–1.59)	2.03 (1.91–2.15)	<0.0001

Abbreviation: CI, confidence interval.

^aProportion of current smokers (%).

^bAll multivariate models were adjusted for age, body mass index, physical activity, education level and dietary supplement use, and mutually adjusted for all dietary patterns.

^cProportion of former smokers (%).

(Jacques and Tucker, 2001; Hu, 2002), including subjective decisions about the choice and definition of food groups included in the factor analysis step, the number of components to extract and the labelling of the identified patterns (Martinez *et al.*, 1998). Dietary patterns derived from factor analysis have been found to be stable over time, as well as reproducible across populations (Newby *et al.*, 2006; Borland *et al.*, 2007).

It may be expected that a healthy pattern is characterized by a lower energy intake. However, the fact that energy intake is increasing with increasing factor score in each pattern is expected and regularly described in similar studies (Terry *et al.*, 2001; Bamia *et al.*, 2005; Kesse *et al.*, 2006), as by definition, the factor score is a linear combination of intake of each food group in g day⁻¹. Therefore, the subjects who consume the largest amounts of the foods characteristic of the pattern are grouped in the highest quartile of each pattern. Although the fruit/vegetables pattern follows this trend, it is less marked than for the processed meat/starchy foods pattern because the latter foods are more energy-dense than fruits and vegetables.

The proportion of vitamin/mineral supplement users in our study (26.9%) was lower than in the United States, where 52% of adults declared supplement use over the past month in 1999–2000, with 35% of multivitamin/mineral users (Radimer *et al.*, 2004). However, our proportion of supple-

ment users was higher than the one observed in a 2002 study based on a representative sample of French adults that reported approximately 10% of vitamin/mineral supplement users in the 2 weeks before the interview (Guilbert and Perrin-Escalon, 2004). This higher proportion can be mostly explained by the fact that our study was restricted to women, middle-aged and mostly teachers, that is, with a higher level of education and a healthier lifestyle (e.g. lower rate of smoking and lower BMI) than the general female population of the same age, characteristics that are strong predictors of supplement use (Lyle *et al.*, 1998; Knudsen *et al.*, 2002). Due to these specificities, caution is needed in extrapolating our results to the general population.

A potential limitation of our study is the assessment of dietary supplement use through a unique question. However, several cross-sectional studies on characteristics of supplement users relied on a similar definition (Patterson *et al.*, 1998; Neuhaus *et al.*, 2001), and more generally, the high education level and strong involvement of the participants of the E3N cohort, as highlighted by a 85% response rate after 10 years of follow-up, accounted for the overall good quality of our data.

The fact that supplement use was positively associated with the fruit/vegetables pattern and inversely associated with both western-style patterns is consistent with previous studies, which observed that supplement users tended to

have a healthier lifestyle and diet than non-users (Lyle *et al.*, 1998; Messerer *et al.*, 2001; Harrison *et al.*, 2004; Radimer *et al.*, 2004; Touvier *et al.*, 2006; McNaughton *et al.*, 2007; Rock, 2007).

In our study, the alcohol/meat products pattern was strongly associated with past and current smoking. Associations between alcohol and meat consumption, on the one hand (Hebert and Kabat, 1991; Kesse *et al.*, 2001), and between alcohol and tobacco use, on the other hand (Schulze *et al.*, 2001; Engeset *et al.*, 2005), have been described elsewhere. The latter association has usually been described for heavy drinkers and smokers; thus, it is of interest to observe this relationship between alcohol and tobacco in our population of well-educated women with low-to-moderate alcohol and tobacco consumption. We also observed an inverse association between current smoking and a healthy diet, as described elsewhere (Zondervan *et al.*, 1996; Beer-Borst *et al.*, 2000; Scali *et al.*, 2001; Schulze *et al.*, 2001; Perrin *et al.*, 2005; McNaughton *et al.*, 2007), while former smokers tended to have a healthy diet. We can hypothesize that this healthy eating behaviour of former smokers could be a part of an attempt to achieve an overall healthier lifestyle. This is consistent with the fact that former smokers were more likely to take supplements than current smokers in our study ($P < 0.0001$), as reported elsewhere (Knudsen *et al.*, 2002). However, former smoking was also significantly associated with the alcohol/meat products pattern. It can thus be hypothesized that when smokers stop smoking, some adopt a healthier lifestyle and convert to a healthy diet and/or take dietary supplements, while others maintain an unhealthy diet. In terms of public health, people who stop smoking should be encouraged to adopt a healthier diet, but non-supervised intake of dietary supplements may represent an unsuspected hazard (Touvier *et al.*, 2005).

It is also interesting in terms of public health and nutritional epidemiology to disentangle the group of subjects with a so-called healthy diet. While this group is partly composed of subjects who have always had a healthy way of life, it also includes a significant proportion of subjects who were on a diet (that is, subjects who were recommended a healthier diet because of overweight or medical conditions) and of former smokers who may have had a less healthy lifestyle when currently smoking. While our cross-sectional assessment did not allow us to demonstrate them, such hypothesized changes in dietary habits need to be confirmed in longitudinal studies. In that case, they may greatly reduce the ability to demonstrate a beneficial impact of a healthy diet, especially for diet-related diseases with a long latency period. Therefore, for investigating these diseases, systematic adjustment for former smoking is highly recommended, as well as adjustment for duration of tobacco use and/or age at stopping tobacco intake, although regularly updated longitudinal assessment of diet would be the best method.

Another issue is surveillance of excessive cumulative micronutrient intake from different sources. In this respect,

of concern is our finding that supplement use was associated with a healthy dietary pattern, which already provided high nutrient density.

Supplement use and smoking are often associated with cancer risk, and will therefore act as confounders in analyses of the relationship between diet and cancer. Our results demonstrate that to avoid major confounding, it is therefore essential that studies investigating the association between chronic disease and environmental factors, including diet, supplement use or smoking, take into account the relationships between these three factors. Conversely, we suggest that patterns could be used instead of single foods or nutrients when adjusting for diet in studies that will investigate an association between diseases and either smoking or supplement use. Beyond the confounding issue, these three types of exposure may be involved in complex mechanisms that play a role in the aetiology of several pathologies, and potential interactions should therefore be investigated in future epidemiological studies.

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Appendix

Food groups and food items introduced in the factor analysis

<i>Food groups</i>	<i>Details</i>
Appetizers	Savoury biscuits, olives and nuts
Artificial sweeteners	Added by the women to hot drinks, yoghurts, and so on (mostly aspartame)
Biscuits	Sweet biscuits such as digestive biscuits, chocolate-coated biscuits.
Bottled water	Mineral water, spring water (plain or sparkling)
Bread	Bread of any kind, including white bread, whole meal bread, toast
Breakfast cereals	Sweetened and unsweetened
Butter, cream ^a	Salted and plain butter, clotted cream
Cakes	Cakes, sweet pies, pastries (homemade or commercial)
Cheese	All sorts except cottage cheese and yoghurt
Chicory	As hot drink (substitute for coffee)
Chocolate beverages	Mostly milk plus sweetened cocoa powder
Coffee	Espresso, instant, from coffee machine, etc.
Crisp bread	Manufactured rusks
Dairy-based sweet puddings	Cream or milk desserts, rice or semolina puddings, ice cream
Egg	Hard-boiled, omelette, and so on
French fries	Homemade, deep-frozen, fast food
Fruit	All fresh and preserved fruits except nuts, olives and juices
Ham ^b	Cured and cooked ham
High-alcohol beverages	Spirits, vodka, gin, whisky, aniseed beverages and cocktails
Juices	Home-made or commercial pure fruit juice
Low-alcohol beverages	Beer and cider
Margarine ^a	For spread and home cooking
Marmalade, honey	Honey; home-made and commercial jam and marmalade
Meat	Pork, beef, veal, mutton, lamb
Milk	Half-fat, full-fat and semi-skimmed milk
Offal	Liver, kidney, tongue, and so on
Olive oil ^a	Added for cooking and dressings
Other fats ^a	Goose, duck fat
Pizza, pies	Pizza, savoury tarts and pies
Potatoes	Potatoes, except French fries
Poultry and rabbit	Chicken, turkey, duck, goose and rabbit
Processed meat ^b	All except ham (sausages, pâté, and so on)
Pulses	Dried peas, lentils
Rice, pasta, semolina	Rice, pasta, wheat or corn semolina
Sandwiches	Including hamburgers
Seafood	Fish, molluscs and crustaceans
Soup	Soups and broths (homemade or commercial)
Sugar and confectionary	Including chocolate
Soft drinks—diet	Soda and fruit beverages (except pure fruit juice) with artificial sweeteners
Soft drinks—regular	Soda and fruit beverages (except pure fruit juice)
Tap water	Tap water
Tea	As a hot drink
Vegetable oil ^a	Added for cooking and dressing, except olive oil
Vegetables	Raw and cooked vegetables
Wine	Wine, champagne
Yoghurt, cottage cheese	Full-fat and low-fat yoghurt and cottage cheese

^aTypes of seasoning and cooking fats studied separately because of large regional differences as well as differences in perception as healthy or unhealthy.

^bHam studied separately from other processed meats as it is often part of a low-energy diet, unlike other processed meats such as sausage or pâté.