British Journal of Nutrition (2005), **94**, 100–113 DOI: 10.1079/BJN20051456

Dietary patterns among older Europeans: the EPIC-Elderly study

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(Received 31 August 2004 – Revised 8 December 2004 – Accepted 31 January 2005)

Overall dietary patterns have been associated with health and longevity. We used principal component (PC) and cluster analyses to identify the prevailing dietary patterns of 99 744 participants, aged 60 years or older, living in nine European countries and participating in the European Prospective Investigation into Cancer and Nutrition (EPIC-Elderly cohort) and to examine their socio-demographic and lifestyle correlates. Two PC were identified: PC1 reflects a 'vegetable-based' diet with an emphasis on foods of plant origin, rice, pasta and other grain rather than on margarine, potatoes and non-alcoholic beverages. PC2 indicates a 'sweet- and fat-dominated' diet with a preference for sweets, added fat and dairy products but not meat, alcohol, bread and eggs. PC1 was

Abbreviations: EPIC, European Prospective Investigation into Cancer and Nutrition; PC, principal component.

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associated with a younger age, a higher level of education, physical activity, a higher BMI, a lower waist:hip ratio and never and past smoking. PC2 was associated with older age, less education, never having smoked, a lower BMI and waist:hip ratio and lower levels of physical activity. Elderly individuals in southern Europe scored positively on PC1 and about zero on PC2, whereas the elderly in northern Europe scored negatively on PC1 and variably on PC2. The results of cluster analysis were compatible with the indicated dietary patterns. 'Vegetable-based' and a 'sweet- and fat-dominated' diets are prevalent among the elderly across Europe, and there is a north–south gradient regarding their dietary choices. Our study contributes to the identification of groups of elderly who are likely to have different prospects for long-term disease occurrence and survival.

Dietary patterns: Elderly: Cohort study

There is extensive scientific literature on the relation between specific foods, food groups, nutrients and other food components on the one hand, and the incidence of or mortality from several chronic diseases on the other (Hu & Willett, 2002; Mann, 2002; Key *et al.* 2004; Srinath Reddy & Katan, 2004). In addition to single dietary components or nutrients, several studies have focused on the role of the effects of overall dietary patterns on health status and longevity (Trichopoulou *et al.* 1995, 2003; Slattery *et al.* 1998; Kumagai *et al.* 1999; Hu *et al.* 2000; Kant *et al.* 2000; Fung *et al.* 2001*a*,*b*; Osler *et al.* 2001; Terry *et al.* 2001; Martinez-Gonzalez *et al.* 2002; Sieri *et al.* 2004). Interest in dietary patterns has been dictated by the ability of the latter to integrate the complex or subtle interactive effects of many dietary exposures, to accommodate the intercorrelation of nutrients within a diet and to bypass problems created by multiple testing.

Two general approaches have been used for the development of an overall descriptor of a dietary pattern (Trichopoulos & Lagiou, 2001): The *a priori* approach builds on previous knowledge concerning the favourable or adverse health effects of various dietary constituents and operates through the calculation of a graded score that identifies groups with 'better' or 'worse' nutritional intakes (Patterson *et al.* 1994; Kennedy *et al.* 1995; Trichopoulou *et al.* 1995, 2003; Huijbregts *et al.* 1997; Haines *et al.* 1999; McCullough *et al.* 2002). The second approach uses the observed dietary data in order to extract, by means of appropriate exploratory statistical methodology, *a posteriori* dietary patterns.

The *a posteriori* approach has been used in nutritional studies and has been shown to be a useful tool for identifying groups with different dietary habits (Prevost *et al.* 1997; McCann *et al.* 2001; Schulze *et al.* 2001; Balder *et al.* 2003; Costacou *et al.* 2003). The main techniques used for the *a posteriori* approach are principal component (PC) analysis, related factor analysis and cluster analysis. The common objective of the first two techniques is to reduce the dimensionality of the data, by transforming the original large set of correlated dietary variables into a new, smaller set of uncorrelated variables, which are called principal components or factors. In contrast, the aim of cluster analysis is to classify persons into naturally existing, mutually exclusive groups on the basis of a similarity in food intake.

Concerning the elderly, studies assessing past and current overall dietary patterns are limited, although this group of people has attracted special attention over the past decade. Focusing on the elderly has been motivated by both a genuine interest in this important age group, which is increasing in most countries, and by methodological considerations (the cumulative effects of diet over an extended period and an inherently high frequency of undesirable outcomes). In Europe, studies that have aimed to describe the diet of the elderly by means of overall dietary patterns are either based on the Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA) investigation (Euronut–SENECA, 1991; Schroll *et al.* 1996; Haveman-Nies *et al.* 1998, 2001), a multicentre survey of modest sample size (1282 individuals), or have relied on smaller sample sizes of particular elderly populations (Huijbregts *et al.* 1995). In the USA, studies on the diet of the elderly have focused on small samples of either residents of Boston (Tucker *et al.* 1992) or Hispanic elders (Lin *et al.* 2003). In these studies, cluster analysis was the statistical tool used for the *a posteriori* identification of dietary patterns.

We have used the *a posteriori* approach by means of PC and cluster analyses to assess the dietary patterns in a large sample of older Europeans, living in nine different European countries and participating in the prospective, multicentre study European Prospective Investigation into Cancer and Nutrition (EPIC) (Riboli *et al.* 2002; Slimani *et al.* 2002*a*). Moreover, we have evaluated, through multiple regression techniques, the dependence of these dietary patterns on socio-demographic and lifestyle variables. Participants were aged 60 years or older at enrolment (EPIC-Elderly project).

Materials and methods

Recruitment

A total of 100 059 individuals from nine European countries who were aged 60 years or older at recruitment, and who participated in the EPIC study, were included in the EPIC-Elderly project. EPIC is a multicentre cohort study examining the role of diet on the aetiology of cancer and other chronic diseases, under the coordination of the International Agency for Research on Cancer. Details of the design and methods of the EPIC study have been described in detail elsewhere (Riboli *et al.* 2002; Slimani *et al.* 2002*a*).

In brief, 519 978 apparently healthy volunteers were recruited into EPIC from ten European countries (Denmark, France, Germany, Greece, Italy, The Netherlands, Norway, Spain, Sweden and the UK), in twenty-two centres, between 1992 and 2000. Study subjects were either recruited from the general population (Greece, Florence, Varese and Naples in Italy, Germany, Bilthoven in The Netherlands, Denmark, Sweden and Norway), or were teachers and school workers (France), patients of general practitioners (Cambridge in the UK), participants in breast cancer screening (Utrecht in The Netherlands), blood donors (included in the cohorts of Granada, Murcia, Navarra, San Sebastian and Asturius in Spain) and their partners (included in the cohorts of Ragusa and Turin in Italy), or health-conscious subjects, many of them with vegetarian eating habits (the majority of individuals in the Oxford cohort). In France, Norway, Utrecht (The Netherlands) and Naples (Italy), only women were enrolled. The study protocol was approved by ethical committees at both the International Agency for Research on Cancer and the participating centres. All participants signed an informed consent form before enrolment. All procedures were in line with the Helsinki declaration for human rights.

The objectives of the EPIC-Elderly project were to investigate the prevailing dietary patterns among the European elders (aged 60 years or older at enrolment) and to study the role of these patterns on their health and longevity. Participants from all countries are included in the EPIC-Elderly database, with the exception of Norway, whose cohort is relatively young (all of the Norwegians in the EPIC cohort still being younger than 60 years).

Dietary intakes

Information on foods and beverages consumed during the year preceding enrolment was collected with the use of instruments that had been developed and validated within each centre. The assessment tools consisted of self- or interviewer-administered quantitative or food-frequency questionnaires.

The results presented in this paper are based on dietary intakes obtained from these food-frequency questionnaires. Standard portion sizes in each country were used for the estimation of consumed quantities, and methods of quantification were standardised between countries by using photographs, household measures depicted in pictures and standardised units. The intake of each food in g/d was calculated taking into account standard recipes and edible fractions. Alcohol consumption was expressed in grams of ethanol per day. Total energy intake (in kJ/d) for each participant was also estimated.

Foods were classified according to a common classification into seventeen main groups and 124 subgroups (Slimani *et al.* 2002*b*). This classification groups foods that could be described and quantified according to common rules across countries. All the main groups of this classification were considered in the present analysis except 'miscellaneous' (Table 1). In addition, 'soya' ('soya' and 'soya products') was considered. Some food groups were, however, broken down: 'cereals and cereal products' into 'pasta, rice and other grain', 'bread' and 'other cereals'; 'added fats' into 'vegetable oils', 'margarine' and 'butter'; and 'alcoholic beverages' into 'wine' and 'other alcoholic beverages'. The classification processes relied on suggestions from the participating centres, submitted before the collaborative analysis was undertaken.

Lifestyle, anthropometric and medical variables

Data on a number of lifestyle and health variables were also recorded with the use of a core lifestyle questionnaire, which contained a common set of questions and possible answers for all participating centres. For centres in which lifestyle and health variables had been collected prior to EPIC initiation, standardisation procedures were developed to ensure the comparability of these variables with those derived from the core EPIC lifestyle questionnaire (Riboli *et al.* 2002).

Table 1. Food groups and food items included in the analysis of the EPIC-Elderly cohort (From The EPIC-Elderly study)

Food group	Definition and content
Vegetables	Leafy, fruiting, root, grain, pod and stalk vegetables, mushrooms, alliums, cruciferous, sprouts and mixed salad/vegetables
Fruits	Fresh fruits, nuts, seeds, stewed fruit, mixed fruits and olives
Potatoes	Potatoes and potato products, except potato crisps
Legumes	Dried peas, lentils and beans, except soya
Cereals and cereal products	
Pasta, rice and other grain	Pasta, rice, other grain
Bread	Bread, crisp bread, rusks
Other cereals	Flour, flakes, starches, breakfast cereals, salty and aperitif biscuits, dough and pastry (puff, short-crust, pizza)
Cakes	Cakes, pies, pastries puddings (non-milk-based), dry cakes, biscuits
Sugar and confectionery	Sugar, jam, marmalade, honey, chocolate and products, candy bars, confetti/flakes, drops, boiled sweets, chewing gum, nougat, cereal bars, marzipan, syrup, water ice
Added fats	
Vegetable oils	Vegetable oils
Margarine	Margarines, mixed dairy margarines, baking fat
Butter	Butter, herbal butter, butter concentrate
Dairy products	Liquid milk (e.g. cow's, goat's), processed milk (condensed, dried), whey, milk beverages, yoghurt, cheeses, cream desserts, puddings (milk-based), dairy creams, ice cream
Meat and products	Beef, veal, pork, lamb/mutton, horse, goat, poultry, game and offal, processed meat from red meat or poultry (e.g. ham, bacon, sausages, pâtés, etc.)
Eggs	Eggs (e.g. chicken, turkey, duck, goose, quail) and egg products, except if used for bread and bakery products
Fish and shellfish	Fish and fish products, crustaceans and molluscs
Non-alcoholic beverages	Tea (with and without caffeine); iced tea: infusion, powder, instant beverage; coffee (with and without caffeine): infusion, powder, instant beverage. Carbonated/soft/isotonic drinks, diluted syrups. Fruit and/or vegetable juices and nectars, freshly squeezed juices: pure or diluted with water
Alcoholic beverages	Expressed as ethanol
Wine	
Other alcoholic beverages	Fortified wine, beer, cider, spirits, brandy, aniseed drinks, liqueurs, cocktails
Condiments and sauces	Sauces (tomato sauces, dressing sauces, mayonnaises and similar), yeast, spices, herbs, flavourings, condiments
Soups	Soups, bouillon
Soya	Soya and products

The lifestyle questionnaire included questions on educational achievement, history of previous illnesses, history of smoking and physical activity (occupational and during leisure). For leisure, the time spent on each of a number of activities (in hours per week) was multiplied by an energy cost coefficient to convert hours per week to kJ; all the products were then summed to produce a score of daily physical activity at leisure. To account for possible effects of gender and for the different assessment tools used within centres, gender- and centre-specific tertiles of the estimated physical activity level at leisure were used.

Anthropometric measurements (height, weight, waist and hip circumference) were taken in all EPIC centres using similar, standardised procedures, except for France, Oxford and Norway. In the latter centres, self-reported values for height and weight were recorded instead, with actual measurements being obtained for a fraction of the participants. BMI was calculated as the ratio of weight in kilograms divided by the square of the height in metres. For participants with self-reported weight and height, these values were used in the respective calculations.

Statistical analysis

PC analysis and cluster analyses were applied to the total EPIC-Elderly cohort as well as separately to males and females. From the initial 100 059 Europeans of 60 years or older at recruitment, males from Bilthoven (315) were administratively excluded. The original twenty-two dietary variables (indicated in Table 1) were considered as residuals from linear regressions of each of these on total energy intake over all the centres to control for the role of energy intake on the reported individual food intake (Willett, 1998). In this way, the correlations between foods would be based on dietary choices rather than reflecting between-person variation in overall quantities of intake. We did not include ‘centre’ in the respective regressions because our objective was to ascertain patterns across Europe rather than within study centres.

PC analysis. Dietary patterns were identified by means of PC extracted from PC analysis (Chatfield & Collins, 1995). PC were extracted using the correlation matrix in order to adjust for unequal variances of the original variables. To identify the number of PC to be retained, we used the following three commonly used criteria: the criterion of eigenvalues exceeding 1 (the interpretation of this criterion being that each component should explain a larger amount of variance than a single standardised variable in order to be retained), the scree plot (which is a plot of the total variance associated with each component) and the interpretability of each component. Food groups (residuals) with absolute scoring coefficients $>0{\cdot}2$ were considered to be important contributors to a component (pattern); scoring coefficients indicate the degree of correlation between the original variables (residuals of food group intakes) and the PC extracted. A positive scoring coefficient indicates that the original dietary variable is positively associated with the respective PC, whereas a negative scoring coefficient implies an inverse association. Dietary patterns were expressed as the scores of each PC retained; these were calculated by summing the standardised values of the food groups (residuals) weighted by their scoring coefficients. Thus, each individual received a score for each identified pattern. We labelled patterns on the basis of those food groups, the consumption of which is reflected by high, positive scores in the respective component.

Multiple regression models were fitted for each of the dietary pattern scores on socio-demographic and lifestyle characteristics: gender (‘males’, ‘females’; by category), age (‘60–64 years’, ‘65–69 years’ and ‘ ≥ 70 years’; by category), BMI (in 3 kg/m^2 increments; continuous), waist:hip ratio (in 0·5 unit increments; continuous), total energy intake (in 1257 kJ (300 kcal) increments; continuous), physical activity at work (‘unemployed’, ‘sedentary occupation’, ‘standing occupation’, ‘manual work’, ‘heavy manual work’; by category), physical activity at leisure time, in centre- and sex-specific tertiles (ordered; continuous), smoking status (‘never’, ‘past’, ‘current smoker’; by category), educational achievement (‘none/primary school completed’, ‘technical/vocational school completed’, ‘secondary school completed’, ‘higher degree’; by category) and centre (by category).

For the purpose of this analysis, the EPIC centres within a country were further aggregated in order to reflect geographical regions that are presumed to share common diets. The five Spanish centres were aggregated into two geographical regions: Northern Spain (San Sebastian, Pamplona, Oviedo) and Southern Spain (Granada, Murcia). The two Danish centres were combined into one, as were the two centres in The Netherlands. In contrast, the UK Oxford centre participants were divided into two, for general population and health-conscious participants (Slimani *et al.* 2002*b*). In all models, France was chosen as the reference category as the dietary habits of French are considered to be somewhere between the diets evident in northern Europe and diets that are typical of people living in southern Europe.

Cluster analysis. Ward’s agglomerative method of the minimum variance (Chatfield & Collins, 1995) was used to cluster individuals into a smaller number of mutually exclusive groups according to their reported daily dietary intake (g/d) of the same list of twenty-two food groups (as residuals). Cluster analysis is sensitive to outliers so clusters with fewer than ten observations were excluded. The sufficient number of clusters to be retained was assessed by pseudo F, pseudo t^2 and cubic clustering criterion, as well as by tree diagrams.

The SAS (SAS Institute Inc., 1999) and STATA (Stata Corporation, 1999) statistical software packages were used.

Results

Among Europeans aged 60 years or older, the mean energy intake ranged from 8134·6 kJ/d in Umeå to 10 820 kJ/d in Denmark for males, and from 5945·5 kJ/d to 9439 kJ/d for females at Umiå and Naples respectively. Among men, overall, energy intake was derived as 45 % from carbohydrates, 15 % from protein, 13 % from saturated lipids, 13 % from monounsaturated lipids, 6 % from polyunsaturated lipids and 5 % from ethanol. The contributions of the same macronutrients to total energy intake among women were 46, 16, 13, 13, 6 and 3 %, respectively.

Table 2 shows the within-centre average daily intake of each of the twenty-two food groups (original values), as a percentage of the corresponding EPIC-Elderly overall mean for the 99 744 elders (34 086 men and 65 658 women), by gender. There was a high variation between centres in the daily consumption of the indicated food groups, whereas the within-centre respective differences between genders was relatively small.

This table suggests two major dietary profiles among European elders. The first is a northern profile characterised by low consumptions of fruit and pasta/rice/other grain (very low in Germany), vegetables, bread and wine (very low in Sweden), fish (very low

Table 2. Percentage of the within-centre mean daily intakes of the indicated food groups relative to the respective EPIC-Elderly overall mean intakes, by gender (M, male; F, female) (From The EPIC-Elderly study)

		Potatoes	Vegetables	Legumes	Fruit	Dairy	Cereals and cereal products: Pasta, rice, other grain	Cereals and cereal products: Bread	Cereals and cereal products: Other cereals*	Meat	Fish	Eggs
Italy												
Florence	M	27	77	83	141	63	422	145	42	100	81	87
	F	29	69	89	114	74	256	134	59	110	84	92
Varese	M	22	72	49	138	73	433	106	42	99	69	84
	F	25	64	53	115	77	268	86	57	101	71	77
Ragusa	M	18	61	32	209	40	357	206	41	68	56	78
	F	23	60	23	183	42	199	176	54	73	54	73
Turin	M	23	88	50	150	63	367	103	51	89	75	88
	F	24	81	55	132	75	205	87	73	94	84	95
Naples	M	–	–	–	–	–	–	–	–	–	–	–
	F	29	94	172	147	55	334	164	60	90	146	73
Spain												
North Spain	M	75	121	520	140	81	115	123	15	124	199	172
	F	76	92	351	131	103	94	102	37	121	176	132
South Spain	M	74	133	444	163	81	148	130	19	99	162	111
	F	70	99	333	122	92	118	115	19	89	134	88
France	M	–	–	–	–	–	–	–	–	–	–	–
	F	73	123	133	107	90	129	116	43	108	112	145
Greece	M	43	215	158	213	58	175	85	45	72	56	68
	F	52	174	142	166	54	158	83	60	76	58	56
UK												
Oxford health-conscious	M	83	139	166	117	115	103	75	193	49	83	74
	F	108	141	171	111	117	115	76	235	65	109	76
Oxford general population	M	88	115	112	92	127	79	66	158	88	96	82
	F	117	120	111	95	127	92	77	206	110	126	73
Cambridge	M	97	117	114	86	127	53	68	151	85	89	77
	F	129	119	107	92	123	62	74	197	108	111	70
The Netherlands	M	–	–	–	–	–	–	–	–	–	–	–
	F	103	60	79	88	131	49	103	35	98	31	93
Germany												
Heidelberg	M	82	61	56	52	57	72	118	32	95	55	77
	F	102	60	38	49	65	60	123	37	92	55	67
Potsdam	M	100	63	78	67	68	40	144	23	111	71	93
	F	120	63	49	67	77	40	139	33	106	66	78
Sweden												
Malmö	M	118	64	41	79	124	51	98	169	105	122	122
	F	115	65	28	77	115	47	75	192	100	127	114
Umeå	M	151	32	36	60	135	71	33	288	66	48	13
	F	173	45	26	71	108	66	44	294	64	55	10
Denmark	M	147	77	5	71	108	89	124	51	143	138	145
	F	160	79	9	80	109	66	123	63	127	146	133

Table 2. *Continued*

		Added fat						Alcoholic beverages				
		Vegetable oils	Butter	Margarine	Sugar	Cakes	Non-alcoholic beverages	Wine	Other alcoholic beverages	Condiments, sauces	Soups	Soya
Italy												
Florence	M	301	44	3	95	76	17	269	14	97	255	0
	F	318	42	4	99	81	17	158	31	55	136	0
Varese	M	261	50	5	100	73	23	319	17	90	324	0
	F	293	39	5	107	91	20	161	16	46	173	0
Ragusa	M	299	23	3	83	49	14	156	13	87	268	0
	F	358	16	4	94	59	14	77	17	78	145	0
Turin	M	305	39	5	78	44	17	303	15	80	278	0
	F	337	26	5	86	60	17	162	23	41	132	0
Naples	M	–	–	–	–	–	–	–	–	–	–	–
	F	93	15	74	72	109	7	134	48	119	7	0
Spain												
North Spain	M	324	3	7	44	44	14	336	23	50	223	2
	F	288	11	19	59	81	18	78	16	47	95	3
South Spain	M	244	6	8	45	68	15	178	37	26	161	3
	F	236	7	26	43	82	12	32	43	23	84	2
France	M	–	–	–	–	–	–	–	–	–	–	–
	F	68	163	33	101	84	114	173	69	111	229	0
Greece	M	458	11	15	47	34	27	102	43	58	77	0
	F	497	10	23	49	42	20	39	28	54	45	0
UK												
Oxford health-conscious	M	29	156	113	114	144	91	66	49	145	126	1319
	F	30	158	145	109	148	87	73	58	171	83	952
Oxford general population	M	37	178	118	128	155	108	78	71	148	107	105
	F	36	153	149	118	147	100	87	72	174	76	130
Cambridge	M	41	172	127	144	167	111	48	58	136	94	40
	F	40	150	171	142	163	102	58	55	160	62	65
The Netherlands	M	–	–	–	–	–	–	–	–	–	–	–
	F	31	123	154	100	90	122	60	73	48	109	78
Germany												
Heidelberg	M	54	278	39	90	135	131	172	162	78	128	0
	F	69	258	47	99	138	135	156	139	78	61	0
Potsdam	M	32	290	119	91	143	122	55	168	78	89	0
	F	47	209	141	99	155	127	87	103	73	46	0
Sweden												
Malmö	M	10	69	309	126	115	111	36	114	195	150	4
	F	9	39	317	120	130	119	49	231	184	92	7
Umeå	M	19	153	241	98	117	61	13	53	26	49	0
	F	14	74	211	52	95	54	14	70	20	22	0
Denmark	M	0	0	0	94	48	162	108	180	58	0	10
	F	0	0	0	108	49	173	143	240	63	0	6

* Flour, flakes, starches, breakfast cereals, salty and aperitif biscuits, dough and pastry (puff, short crust, pizza).

in the Netherlands), legumes and vegetable oils (very low in Denmark), and high consumptions of butter (very high in Germany), potatoes, dairy products and other cereals, such as flour, pastry and breakfast cereals (very high in Sweden), meat, non-alcoholic and alcoholic beverages except for wine (very high in Denmark), and sugar and cakes (very high in Cambridge). The second is a southern profile characterised by a high consumption of vegetables, fruits and vegetable oils (very high in Greece), bread, pasta/rice/other grain and soups (very high in Italy), legumes, fish and wine (very high in Spain), and low consumption of dairy products, non- and other alcoholic beverages (very low in Italy), sugar (very low in Spain) and cakes (very low in Greece).

Table 2 also shows the unique characteristics of diets followed in particular countries that may belong to the same general group. For example, the Italian diet is dominated by pasta, cereals and cereal products, and the Greek diet is characterised by vegetable oils (essentially olive oil), fruit and vegetables, whereas the Spanish diet is characterised by both plant foods and animal food groups (particularly fish and eggs). The mean consumption of soya reaches its highest value in the Oxford health-conscious subjects.

PC and cluster analyses revealed almost identical results for male and female participants of the EPIC-Elderly cohort, hence only findings referring to the total sample are reported. PC analysis identified seven dietary patterns on the basis of the eigenvalue >1 criterion. These PC explained approximately 52 % of the total variation in daily food intake. However, the plot of the total variance associated with each PC (scree test), as well as the lack of any meaningful interpretability of some of these components, indicated that the first two PC, explaining approximately 25 % of the total variation, could be used to adequately describe the prevailing dietary patterns among the EPIC-Elderly participants.

Table 3 shows the main constituents of each of the two dominant dietary components, adjusted for total energy intake, in rank order of the absolute value of the positive and negative scoring coefficients. Large coefficients indicate strong associations between the food groups and the corresponding pattern. The food groups contributed to only one specific pattern, with the exception of margarine, which loaded on both of the emerging patterns but with opposite signs. PC1 reflects a ‘vegetable-based’ diet characterised by a contrast between plant food groups (positive scoring coefficients) and potatoes, margarine and non-alcoholic beverages (negative scoring coefficients). Thus, high positive scores of this component indicate a high consumption of vegetable oils, fruit, pasta, rice and other grain, vegetables and legumes, *and* a low consumption of non-alcoholic beverages, potatoes and margarine. Evidently, negative scores on PC1 imply the opposite pattern of consumption.

The second PC (PC2) reflects a ‘sweet- and fat-dominated’ diet with the consumption of sweets and cereals such as flour and savoury snacks, added fat and dairy products (positive values) contrasting with the consumption of bread, meat and eggs, and alcoholic beverages (negative values). Therefore, individuals with high scores on PC2 follow diets with an emphasis on dairy products, cakes, sugar and confectionery, other cereals (flour, pastry, breakfast cereals and similar), margarine, condiments and sauces, whereas they consume small quantities of bread, meat, eggs and alcoholic beverages.

Table 4 shows multiple regression-derived, mutually adjusted partial regression coefficients and their corresponding standard errors, and two-tailed *P* values of PC1 and PC2 regressed on lifestyle, demographic and anthropometric variables. Partial regression coefficients can be interpreted better than partial correlation coefficients because they have natural dimensions and units, in addition to pointing to the direction of the associations. Only 89 560 subjects with complete information on all predictor variables were included in this analysis. The ‘vegetable-based’ PC1 was positively associated with female gender, higher educational level, total energy intake, physical activity, higher BMI and never and past smoking (as opposed to current smoking). PC1 was inversely associated with age (within the elderly group) and waist:hip ratio. Regarding place of residence, EPIC-Elderly participants living in south Europe had the highest overall scores for PC1, whereas values for this score decrease as we move to countries in the north. An exception to this is the Oxford health-conscious cohort, whose score was slightly lower than the score of France for PC1.

Individuals scoring high on PC2 were more likely to be female, older, less well educated and never smokers, with a lower BMI and waist:hip ratio. Similarly to PC1, PC2 was also positively associated with energy intake but, contrary to the ‘vegetable-based diet’, PC2 was inversely associated with physical activity level at work. Elders living in south Europe had coefficients for PC2 around zero, i.e. noticeably smaller in absolute value than those corresponding to PC1 for the same centres. Northern European centres differed with respect to scores on PC2: whereas UK and Sweden had the highest scores on PC2, Germany

Table 3. Principal components and corresponding scoring coefficients for dietary variables in the EPIC-Elderly population (From The EPIC-Elderly study)

Principal components	Positive scoring coefficients	Negative scoring coefficients	Variance explained (%)
Principal component 1 (PC1)			14·6
‘Vegetable-based’ diet	Vegetable oils (0·46)	Non alcoholic beverages (−0·31)	
	Fruits (0·34)	Potatoes (−0·27)	
	Pasta, rice and other grain (0·34)	Margarine (−0·24)	
	Vegetables (0·33)		
	Legumes (0·25)		
Principal component 2 (PC2)			9·7
‘Sweet- and fat-dominated’ diet	Other cereals (0·33)	Meat (−0·36)	
	Cakes (0·32)	Bread (−0·28)	
	Condiments & sauces (0·29)	Other alcoholic beverages (−0·26)	
	Margarine (0·28)	Wine (−0·25)	
	Sugar and confectionery (0·22)	Eggs (−0·20)	
	Dairy products (0·20)		

Table 4. Multiple, regression-derived coefficients (β) and standard errors (SE) of specified predictors for the two principal components, PC1 and PC2* (From The EPIC-Elderly study)

	PC1: 'Vegetable-based' diet			PC2: 'Sweet- and fat-dominated' diet		
Characteristics	β	SE	Two-sided *P* value	β	SE	Two-sided *P* value
Gender						
Males	Baseline			Baseline		
Females	0·12	0·01	$<10^{-3}$	0·35	0·01	$<10^{-3}$
Age (years)						
60–64	Baseline			Baseline		
65–69	−0·04	0·01	$<10^{-3}$	0·04	0·01	$<10^{-3}$
70+	−0·09	0·01	$<10^{-3}$	0·10	0·01	$<10^{-3}$
Educational achievement						
None/primary school completed	Baseline			Baseline		
Technical/vocational school completed	0·13	0·01	$<10^{-3}$	0·02	0·02	0·063
Secondary school completed	0·20	0·01	$<10^{-3}$	0·04	0·02	0·001
Higher degree	0·26	0·01	$<10^{-3}$	−0·03	0·02	0·015
BMI (per 3 kg/m^2 increment)	0·01	0·003	$<10^{-3}$	−0·04	0·003	$<10^{-3}$
Waist:hip ratio† (per 0·5 units increment)	−0·10	0·03	$<10^{-3}$	−0·58	0·03	$<10^{-3}$
Energy intake (per 1257 kJ increment)	0·08	0·002	$<10^{-3}$	0·10	0·002	$<10^{-3}$
Physical activity at work						
Unemployed	Baseline			Baseline		
Sedentary occupation	0·14	0·01	$<10^{-3}$	−0·03	0·01	0·023
Standing occupation	0·01	0·01	0·195	0·003	0·01	0·813
Manual work	0·10	0·01	$<10^{-3}$	−0·08	0·02	$<10^{-3}$
Heavy manual work	0·04	0·03	0·180	−0·22	0·03	$<10^{-3}$
Physical activity at leisure time						
1st tertile	Baseline			Baseline		
2nd tertile	0·06	0·01	$<10^{-3}$	−0·01	0·01	0·525
3rd tertile	0·11	0·01	$<10^{-3}$	0·02	0·01	0·043
Smoking status						
Never smoked	Baseline			Baseline		
Past smoker	0·08	0·01	$<10^{-3}$	−0·13	0·01	$<10^{-3}$
Current smoker	−0·08	0·01	$<10^{-3}$	−0·32	0·01	$<10^{-3}$
Participating centre						
France (overall)	Baseline			Baseline		
Florence (Italy)	1·70	0·02	$<10^{-3}$	0·004	0·03	0·873
Varese (Italy)	1·63	0·02	$<10^{-3}$	0·28	0·03	$<10^{-3}$
Ragusa (Italy)	2·28	0·05	$<10^{-3}$	0·18	0·05	$<10^{-3}$
Turin (Italy)	2·03	0·03	$<10^{-3}$	0·19	0·03	$<10^{-3}$
Naples (Italy)	1·50	0·04	$<10^{-3}$	0·37	0·04	$<10^{-3}$
North Spain (Oviedo, Pamplona, San Sebastian)	1·96	0·02	$<10^{-3}$	−0·26	0·02	$<10^{-3}$
South Spain (Granada, Murcia)	1·64	0·03	$<10^{-3}$	0·25	0·03	$<10^{-3}$
Cambridge (UK)	−1·41	0·02	$<10^{-3}$	1·59	0·02	$<10^{-3}$
Oxford (health-conscious; UK)	−0·62	0·02	$<10^{-3}$	1·94	0·02	$<10^{-3}$
Oxford (general population; UK)	−1·20	0·04	$<10^{-3}$	1·40	0·04	$<10^{-3}$
The Netherlands (overall)	−1·33	0·02	$<10^{-3}$	0·32	0·02	$<10^{-3}$
Greece (overall)	2·79	0·02	$<10^{-3}$	0·90	0·02	$<10^{-3}$
Heidelberg (Germany)	−1·30	0·02	$<10^{-3}$	−0·23	0·02	$<10^{-3}$
Potsdam (Germany)	−1·65	0·02	$<10^{-3}$	−0·14	0·02	$<10^{-3}$
Malmö (Sweden)	−2·19	0·01	$<10^{-3}$	1·21	0·02	$<10^{-3}$
Umeå (Sweden)	−1·98	0·02	$<10^{-3}$	1·64	0·02	$<10^{-3}$
Denmark (overall)	−1·69	0·01	$<10^{-3}$	−1·25	0·02	$<10^{-3}$

* From the initial 99 744, 10 184 individuals were excluded owing to missing values for the variables of educational level, physical activity at work and at leisure, and smoking status.
† For some individuals, values for waist:hip ratio were imputed from a linear regression model with age, weight and height as independent variables and waist:hip ratio as the dependent variable.

(Heidelberg and Potsdam) and The Netherlands scored about the same as France in this component, and Denmark was characterised by the largest, in absolute value, negative scoring coefficient on PC2 (i.e. the elderly in Denmark consume high quantities of alcoholic beverages, meat, bread and eggs).

To examine further the adherence of the elders of each participating country to the dietary patterns implicit in PC1 and PC2, the graph of the respective mean scores (plotted one against the other) is shown in Fig. 1. Centre-specific mean scores are denoted by circles whose area is proportional to the size of the respective cohort. Centres in southern Europe are concentrated in the far right part of the graph, identified by high positive scores on PC1, and scores on PC2 that range from small positive (Greece) to around zero (Naples and Varese) and small negative (Southern Spain, Florence, Turin, Ragusa and Northern Spain). France is low but positive on PC1 and about zero on PC2.

The left-hand side of the graph depicts all northern European centres (apart from the Oxford health-conscious group).

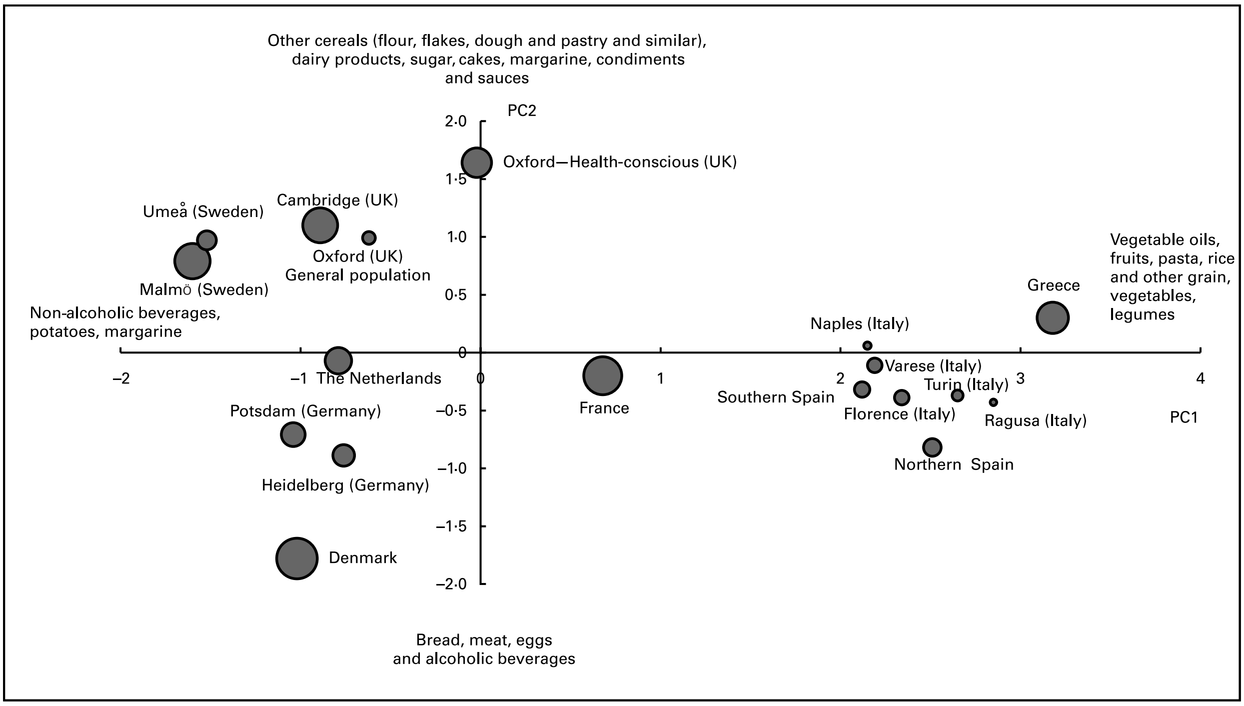

Fig. 1. Mean score of principal component 1 (PC1) and principal component 2 (PC2) by participating centre. (●) denote centre-specific mean scores, the size of the circles being proportional to the size of the respective cohort (From The EPIC-Elderly study).

The common element in this set of centres is that the respective populations of elders score negatively on PC1, i.e. they tend to consume margarine, potatoes and non-alcoholic beverages, *and* tend not to consume vegetable oils and foods of plant origin (apart from potatoes). The Oxford health-conscious cohort has a zero score on PC1, indicating a dietary pattern with no particular emphasis on any of the foods that define the positive or negative 'vegetable-based' scores. With respect to PC2, northern centres are spread across the PC2 axis, indicating that different northern countries 'belong' to different centiles of the distribution of this score. Thus, elders in Sweden and the UK prefer sweets, dairy products, condiments and margarine but not meat, bread, alcohol and eggs, whereas those in Denmark, and to a lesser degree Germany, follow the opposite pattern of consumption. Finally, The Netherlands is not characterised by any of the foods that are responsible for the extreme values (positive and negative) on PC2. Countries in southern Europe have in general small (mainly negative) or zero PC2 scores which vary, Northern Spain having the highest negative value in this component among the European southern countries.

Three major clusters emerged from cluster analyses using the criteria described in the Materials and Methods section, and are depicted in Fig. 2. Cluster A was characterised by a high consumption of vegetables, legumes, fruit, pasta, rice and other grain, vegetable oils and wine, and a low consumption of potatoes, butter, margarine, dairy products, meat, sugar, cakes, non-alcoholic beverages and alcoholic beverages except for wine. In contrast, cluster B was characterised by a high consumption of potatoes, other cereals (flour, pastry, breakfast cereals and similar), butter, margarine, sugar and cakes, and a low consumption of vegetables, legumes, pasta, rice and other grains, fruit, and vegetable oils. Cluster C was characterised by a fairly similar pattern of dietary intake to that of cluster B. What distinguished clusters B and C was the consumption of other cereals (flour, breakfast cereals, pastry and similar), butter, margarine, sugar and cakes, which was lower in cluster C than in cluster B, and the consumption of eggs, non-alcoholic beverages and alcoholic beverages except for wine, which was higher in cluster C than in cluster B. The number of elders in clusters A, B and C was 18 562, 41 912 and 39 270, respectively.

Fig. 3 shows the mean scores of PC1 and PC2 for elders grouped into clusters A, B and C. There were remarkable differences with respect to the means of PC1 between clusters A and B, and A and C, whereas differences in mean PC2 between the three clusters were less striking. Thus, the odds of an individual belonging to the highest (compared with the lowest) quintile of PC1 were more than 100-fold if the individual was classified into cluster A compared with either cluster B or C, whereas the corresponding odds for PC2 were 1·8 and 4·2 times higher for elders allocated to cluster B than cluster A or C, respectively.

Expanding on the relations between PC and clusters, a much higher mean score for the first PC occurred in cluster A compared with the other two clusters. This, together with the practically zero mean score for PC2 estimated in this cluster, indicates that elders of cluster A tend overwhelmingly to follow the 'vegetable-based' diet. Regarding cluster B, the negative mean value for PC1 and the positive mean value for PC2 denote that the 'sweet- and fat-dominated' rather than the 'vegetable-based' is the diet of choice for elders belonging to this cluster. The negative value for PC1 in this cluster reflects the additional consumption of food groups such as potatoes, which characterise this cluster and have negative scoring coefficients in the definition of PC1. Finally, both PC1 and PC2 have negative mean values for cluster C. Thus, the diet of this cluster of elders is neither

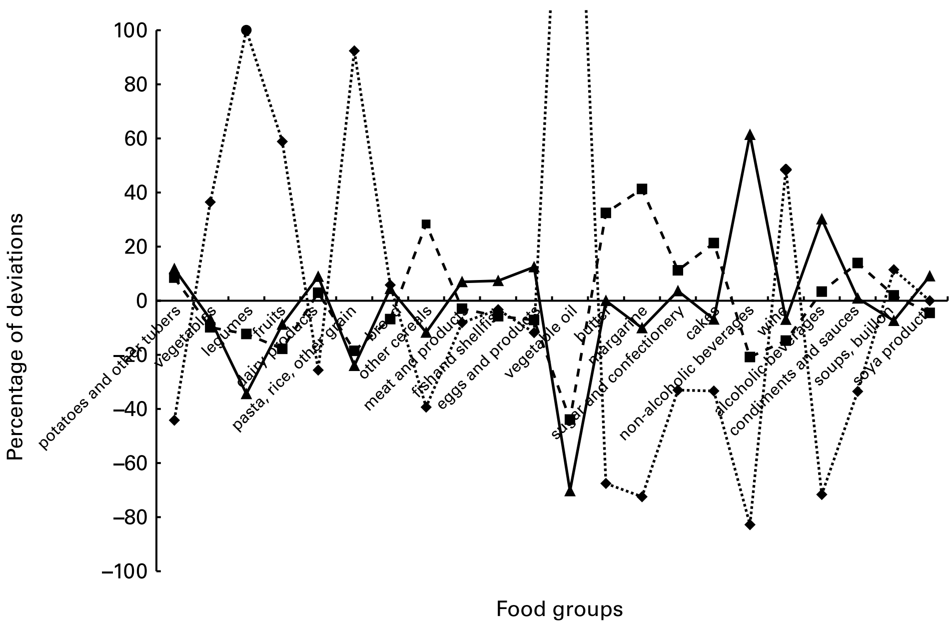

Fig. 2. Three clusters of the study participants on the basis of their dietary intakes of twenty-two food groups. The vertical axis indicates percentage deviations of the within-cluster mean dietary intakes of each food group from the corresponding overall mean intakes (From The EPIC-Elderly study ··· Cluster A (18562 subjects), --- Cluster B (41912 subjects), — Cluster C (39270 subjects)).

'vegetable-based' nor 'sweet- and fat-dominated' but emerges from food groups with negative scoring coefficients on both PC1 and PC2, i.e. potatoes, margarine, non-alcoholic beverages and alcoholic beverages (except for wine), meat and eggs.

Fig. 4 presents the distribution of elders of each participating centre to the three identified clusters. EPIC-Elderly participants of centres in Italy, Spain and Greece belonged almost entirely to cluster A, i.e. they appeared to have an overwhelming preference for the 'vegetable-based' diet. The rest of the EPIC-Elderly population was divided between clusters B and C (but not A). Elders who lived in France and in northern Europe were grouped into clusters B and C in fairly similar proportions, with the exception of Umeå (Sweden) and Denmark, whose elderly populations belonged almost entirely to clusters B and C, respectively. There were no major differences between centres within a country, except for Sweden.

Discussion

We have explored energy-adjusted dietary patterns in a large European population sample, aged 60 years or more at recruitment, and we have investigated their relation to socio-demographic and lifestyle characteristics. We have identified two major PC that express contrasts between certain food groups: a 'vegetable-based' dietary pattern with an emphasis on foods of plant origin rather than on margarine, potatoes and non-alcoholic beverages, and a 'sweet- and fat-dominated' diet with a preference for sweets and dairy products but not meat, alcohol, bread and eggs. Thus, although two PC have been extracted from our data, the diets of elderly Europeans can be classified into more than two dietary patterns based on the combination of their scores for PC1 and PC2.

The 'vegetable-based' diet was preferred by younger, female, non-smoking subjects with a higher educational level, higher

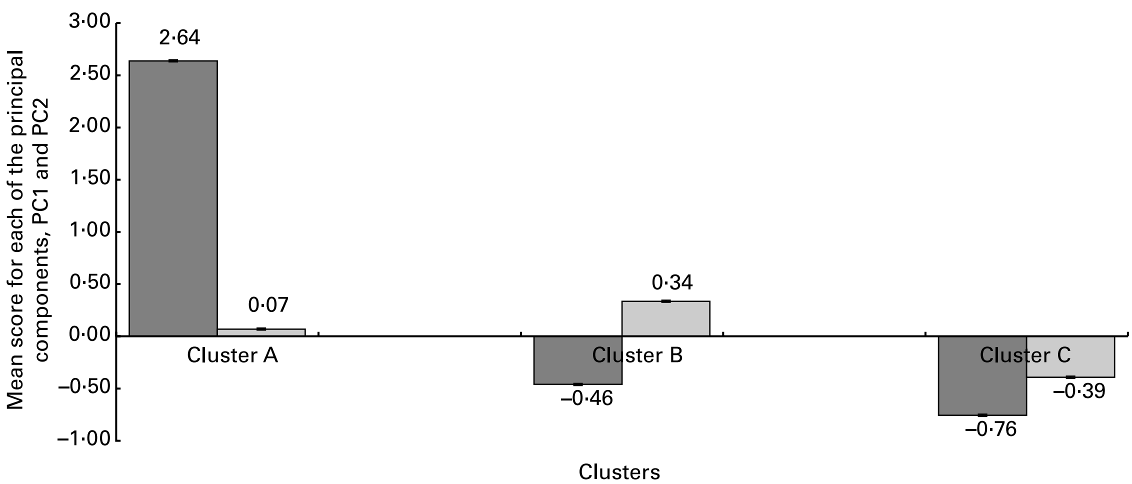

Fig. 3. Mean scores of the two principal components PC1 (■) and PC2 (■) in clusters of individuals with similar dietary intakes in the EPIC-Elderly population (cluster A *v.* cluster B *v.* cluster C) (From The EPIC Elderly study).

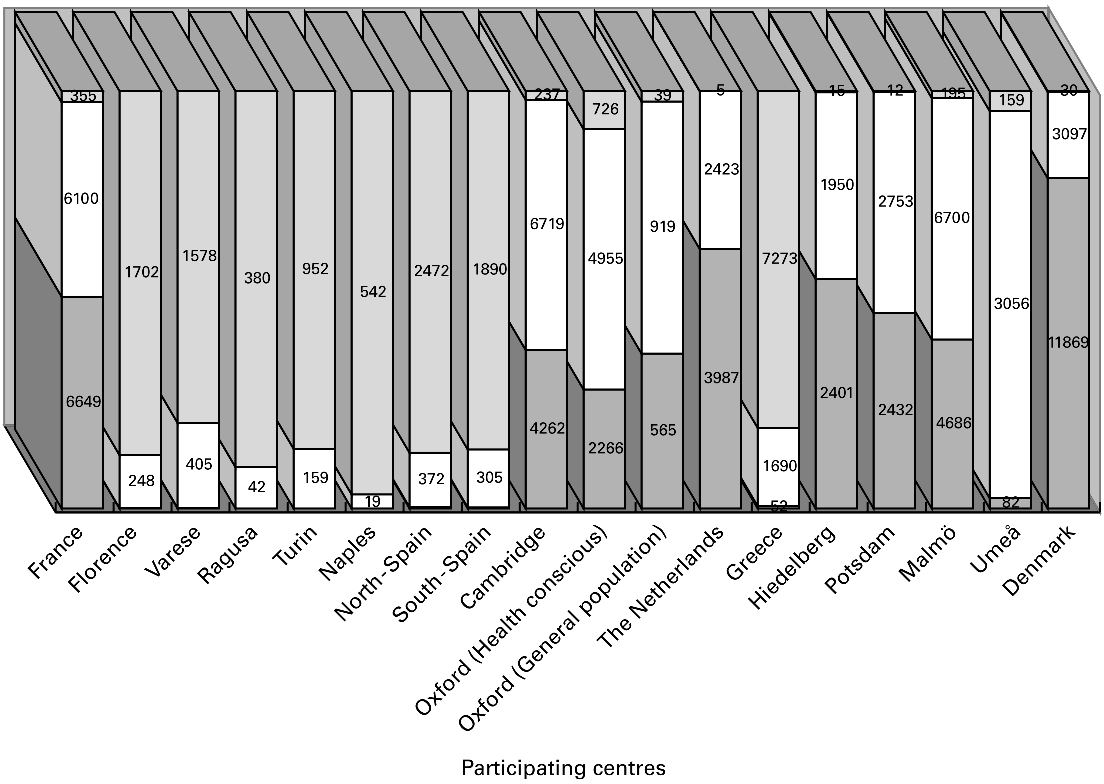

Fig. 4. Distribution of the EPIC-Elderly population by participating centre and identified cluster ■ Cluster A (18562 subjects), □ Cluster B (41912 subjects), ▧ Cluster C (39270 subjects) (From The EPIC Elderly study).

BMI but lower waist:hip ratio and higher physical activity. It seems that this diet represents the choice of the educated and health-conscious elderly Europeans. A south–north gradient was also fully identifiable by PC1. High positive scores of this component denote a high consumption of food groups that are part of the traditional Mediterranean diet. Thus, countries of southern Europe, notably Spain, Italy and Greece, received the highest overall scores for this dietary pattern. France was less ‘vegetable-based’ than the rest of the Mediterranean counties. The dietary choices of the health-conscious elderly from Oxford were neutral with respect to this dietary pattern (score on PC1 about zero); in contrast, negative scores on PC1 were evident in the rest of the northern European centres, indicating that older individuals in these countries consume potatoes, non-alcoholic beverages and margarine, and fewer vegetable oils or foods of plant origin. Thus, the ‘vegetable-based’ diet varies with geography, as well as with education and socio-cultural factors (de Groot *et al.* 1996).

The ‘sweet- and fat-dominated’ diet reflected the dietary choice of older female elders with a low educational achievement, who had never been smokers and who had a low BMI but also a low level of physical activity. Scores on PC2 discriminate between participants from northern and from southern Europe. Thus, elderly from the UK and Sweden receive high PC2 scores because they follow diets rich in dairy products, sweets, savoury snacks and margarine, whereas they refrain from consuming bread, meat, eggs and alcohol. The opposite pattern of consumption, which closely resembles what has been labelled as the ‘Western diet’ in previous studies (Slattery *et al.*1998; Hu *et al.* 1999; Fung *et al.* 2001*a*,*b*; Osler *et al.* 2001; Terry *et al.* 2001; Costacou *et al.* 2003), is evident in Germany and Denmark. Elderly individuals from The Netherlands score zero on PC2, indicating that they do not have any particular preference for foods deemed important for this component. In southern Europe, PC2 scores are small in absolute value, are mostly negative and vary between centres. Thus, the consumption of meat, bread, alcohol and eggs is low among the Mediterranean elderly but varies, with Northern Spain having a relatively high consumption of some of these foods, particularly eggs, meat and meat products. The distribution of PC2 scores among the Mediterranean countries can thus be seen as an indicator of the degree of evolution in the traditional diets of these countries towards a more Western-type diet.

We have also identified clusters of elderly who share similar dietary behaviour and who are identifiable by the mean scores of the extracted PC. Elders in cluster A are distinct from individuals outside this cluster in terms of their preference for the ‘vegetable-based’ pattern and their relative antipathy towards foods that characterise PC2. In contrast, elders in clusters B and C share some dietary choices, as indicated by the negative mean value of PC1 in both clusters, and they differ only with respect to those food components which are responsible for the extreme scores on the ‘sweet- and fat-dominated’ diet: individuals in cluster B consume high quantities of other cereals (flour, breakfast cereals, pastry and similar), margarine, sugar, cakes and condiments and sauces (positive scores on PC2), whereas elderly in cluster C consume meat and products, eggs and alcoholic beverages (negative scores on PC2). Regarding the distribution of centres into the three clusters, Mediterranean countries were segregated into cluster A. Northern Europeans belong exclusively to clusters B and C, but both clusters are represented in almost all northern centres.

Several attempts have been made to classify dietary choices and consumptions into dietary patterns with *a posteriori* approaches. PC analysis and the closely related factor analysis have previously been used in nutritional research carried out in Europe (Prevost *et al.* 1997; Schulze *et al.* 2001; Balder *et al.* 2003; Costacou *et al.* 2003) and in the USA (Hu *et al.* 1999; McCann *et al.* 2001). In contrast, previous studies that focused on the diet of the elderly have used almost exclusively cluster analysis (Tucker *et al.* 1992; Huijbregts *et al.* 1995; Schroll *et al.* 1996; Havemann-Nies *et al.* 1998, 2001; Lin *et al.* 2003). Since no optimal method exists to classify dietary patterns, we have used both analytical approaches. Our results from PC and cluster analyses converge on the same conclusions; however, the classification of countries into different patterns was clearer using PC analysis. Nevertheless, cluster analysis in combination with PC analysis allowed us to evaluate how consistent a particular type of diet was within geographical regions. The resulting dietary choices of elderly Europeans, as defined by PC analysis, are compatible with those reported for a random sample of participants aged 34–75 years from the total EPIC cohort, whose dietary intakes were assessed by 24 h dietary recall interviews (Slimani *et al.* 2002*b*).

Whereas an *a posteriori* approach may seem an objective way to investigate dietary patterns, its use in nutritional epidemiology has raised certain concerns (Martinez *et al.* 1998). In PC analyses, essential decisions include the initial selection of dietary variables, the decision to standardise the dietary variables and the number of components to be retained. Moreover, the amount of total variance that is usually explained by the extracted PC or factors is very small (up to 30 %). Cluster analysis, in addition, is strongly dependent on the clustering method. Nevertheless, the north–south gradient that we observed in our data, as well as the identified clusters, were comparable to the results previously reported for the elderly. Cluster A was similar to the 'healthy diet' cluster identified by Huijbregts *et al.* (1995), whereas a 'sugar- and fat-dominated' cluster approximating our cluster B was evident in studies by Schroll *et al.* (1996), Haveman-Nies *et al.* (2001) and Huijbregts *et al.* (1995). Tucker *et al.* (1992) and Lin *et al.* (2003) did not identify clusters similar to ours in analyses of a US population of elderly, possibly owing to different diets in Europe and the USA.

Regarding the extracted PC, our findings are compatible with results from PC analyses of centre-specific EPIC cohorts: Costacou *et al.* (2003) also identified a 'Mediterranean' and a very similar 'vegetarian' diet, as well as a 'sweet-based' dietary pattern in the Greek population of EPIC participants. The PC identified by Schulze *et al.* (2001) for the EPIC-Potsdam study were not identical to ours, but they were based on forty-nine original food items selected on the basis of culinary usage. The same holds for Balder *et al.* (2003), who analysed four European cohorts and used food items very different from ours. Dietary components named 'prudent' or 'healthy', which are similar to our 'vegetable-based' diet, have been identified by many studies in Europe (Osler *et al.* 2001 in Denmark, Sieri *et al.* 2004 in Italy, Terry *et al.* 2001 in Sweden) and the USA (Slattery *et al.* 1998; Hu *et al.* 1999; Fung *et al.* 2001*a,b*). A 'sweet-' and a 'fat-' dominated diet were also evident in the study by Slattery *et al.* (1998), whereas the 'Western' diet that was discernible in our study (Fig. 1) was also evident in most of the above studies.

Along the same lines, the positive associations between the 'vegetable-based' diet and educational achievement and physical activity, and the inverse association of this diet with current smoking, have also been reported from studies that have focused on 'healthy' or 'prudent' dietary patterns. The inverse associations of the 'sweet- and fat-dominated' diet with physical activity, smoking and BMI have all been reported by Costacou *et al.* (2003), whereas Slattery *et al.* (1998) also found an inverse association between their 'high-fat/sugar dairy' pattern and BMI. As indicated, it is not easy to compare dietary patterns resulting from *a posteriori* analytical approaches across studies because of the different food groups that were originally selected, the different assessment and analytical tools used in the respective countries and different decision criteria for the extracted clusters, or components.

Our study has described the dietary patterns of Europeans of 60 years of age or older who live in nine different European countries. These patterns can be used as covariates when examining a specific nutrient in order to explore whether the nutrient-related effect is independent of the overall dietary patterns (Hu *et al.* 1999). Whether *a posteriori* patterns can be used as a standard approach in order to describe disease associations is, however, questionable (McCann *et al.* 2001; Martinez *et al.* 1998).

Among the advantages of the present study are its large size, its reliance on a sample from European populations of nine countries with considerable variability on several characteristics, the use of within-country validated food-frequency questionnaires, and the standardised measurement of all examined variables across participating centres. Disadvantages of the study are the inherent problems in dietary assessment, the lack of representativeness of some cohorts, the questionable robustness of cluster analysis, and the generic problems underlying the *a posteriori* approach.

In conclusion, we have identified in a large sample of elderly Europeans 'vegetable-based' and 'sweet- and fat-dominated' PC. We have classified the dietary habits of European elders based on combinations of scores of these components, and we have determined their lifestyle and socio-demographic predictors. We have also identified three clusters of individuals whose dietary behaviour is fairly similar within clusters and fairly different between clusters, and we have found that the three clusters are identifiable by the respective PC. Our study thus highlights the dietary patterns prevailing among the elderly across Europe and contributes to the identification of groups that are likely to have different prospects for long-term disease occurrence and survival.

Acknowledgements

This study was supported by the Quality of Life and Management of Living Resources Programme of the European Commission (DG Research, contract No QLK6-CT-2001-00 241) for the project EPIC-Elderly, coordinated by the Department of Hygiene and Epidemiology, University of Athens Medical School; the Europe against Cancer Programme of the European Commission, (DG SANCO) for the project EPIC coordinated by the International Agency for Research on Cancer (WHO); the Greek Ministry of Health and the Greek Ministry of Education (Greece); a fellowship honouring Vasilios and Nafsika Tricha (Greece); The Danish Cancer Society (Denmark); Ligue contre le Cancer (France); Société 3M (France); Mutuelle Générale de l'Education Nationale (France); Institut National de la Santé et de la Recherche Médicale (INSERM) (France); Gustave Roussy Institute and several General Councils in France (France); German Cancer Aid (Germany); German Cancer Research Center (Germany); German Federal Ministry of Education and Research (Germany); Associazione Italiana per la Ricerca contro il Cancro (AIRC) Milan (Italy); Compagnia di San Paolo (Italy); Regione Sicilia and Avis-Ragusa (Italy); the Dutch Ministry of Public Health, Welfare and Sports (the Netherlands); the Health Research Fund (FIS) of the Spanish Ministry of Health (Spain); the Spanish Regional Governments of Andalucia, Asturias, Basque Country, Murcia and Navarra (Spain); the ISCIII Network Red de Centros RCESP (C03/09; Spain); the Swedish Cancer Society (Sweden); the Swedish Scientific Council, City of Malmö, (Sweden); the Regional Government of Skåne, (Sweden); Cancer Research, UK (UK); and the Medical Research Council (UK). The author(s) is (are) solely responsible for the publication, and the publication does not represent the opinion of the community. The community is not responsible for any use that might be made of data appearing in this work.

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