Public Health Nutrition: 4(3), 787–795 DOI: 10.1079/PHN200098

Identification of groups who report similar patterns of diet among a representative national sample of British adults aged 65 years of age or more

Jane A Pryer[1,*], Adrian Cook[2] and Prakash Shetty[3]

[1]Department of Primary Care and Population Sciences, Royal Free and University College Medical School, Royal Free Campus, Rowland Hill Street, London NW3 2PF, UK: [2]Department of Primary Care and General Practice, Imperial College School of Medicine, Norfolk Place, London W2 1PG, UK: [3]Public Health Nutrition Unit, London School of Hygiene and Tropical Medicine, 49–51 Bedford Square, London WC1B 3DP, UK

Submitted 13 March 2000: Accepted 27 September 2000

Abstract

Objectives: Using a national representative sample to identify groups within the UK male and female population over 65 years who report similar patterns of diet.
Design: National representative dietary survey, using 4-day weighed dietary records of men and women aged over 65 years old and living in private households in Great Britain in 1994–1995. Cluster analysis was used to aggregate individuals into diet groups.
Setting: United Kingdom.
Subjects: 558 women and 539 men.
Main outcome measures: Consumption of predefined food groups, nutrient intakes, socio-economic, demographic and behavioural characteristics.
Results: Three large clusters comprising 86% of the male population and three large clusters comprising 83% of the female population were identified. Among men, the most prevalent cluster was a 'mixed diet' with elements from a traditional diet and some elements from a healthy diet (48% of the male population); the second was a 'healthy diet' (21% of the male population); and the third was a 'traditional diet high in alcohol' (17% of the male population). Among women, the most prevalent diet was a 'sweet traditional diet' (33% of the female population); the second was a 'healthy diet' (32% of the female population); and the last was a 'mixed diet' with elements of the traditional diet and the healthy diet (18% of the female population). There were important differences in average nutrient intakes, socio-demographic and behavioural characteristics across these diet clusters.
Conclusions: Cluster analysis identified three diet groups among men and three among women. These differed not only in terms of reported dietary intake, but also with respect to their nutrient content, social and behavioural profile. The groups identified could provide a useful basis for health promotion based upon the diet clusters.

Keywords
Diet
Cluster analysis
Dietary patterns
Nutrients
Social profile

There has been increasing interest in the identification of patterns of diet consumed by age-stratified segments of the UK population. Such an approach may be of particular relevance to policy makers as it is the combination of foods that groups of individuals eat which comprise the overall diet, rather than the presence or absence of specific food items, that is ultimately of importance to nutritional health status. It is also this aspect that is most amenable to change by intervention[1]. The elderly are an increasingly important demographic constituent of the population and, for a number of reasons, are vulnerable to poor nutritional health[1].

The National Diet and Nutrition Survey (NDNS) of people aged 65 years and over provides detailed information on the food intake of a national sample of elderly people living in Britain together with important socio-economic and lifestyle characteristics. This paper reports an analysis of the National Diet and Nutrition Survey of people aged 65 years and over in which we used the multivariate statistical technique of cluster analysis to identify groups within this population who report similar patterns of diet. The food types that characterise the groups, together with the nutrient intakes, socio-demographic and lifestyle characteristics of the groups are presented in this paper.

*Corresponding author: Email j.pryer@ucl.ac.uk

Methods

The database was the National Diet and Nutritional Survey of people aged 65 years and over. The survey was commissioned by the Ministry of Agriculture, Fisheries and Food and the Department of Health, and undertaken by Social and Community Planning Research (SCPR), University College London Department of Epidemiology and Public Health and the Dunn Nutrition Unit, Cambridge. Fieldwork was carried out from October 1994 to September 1995. The sample was recruited using a multi-stage random probability design. Postal sectors were selected as primary units. All postal sectors in Wales, England and mainland Scotland were stratified according to region and 1991 census data on social class. Eighty postal sectors were selected as first-stage units, with the chance of selection being proportional to size[2].

Free-living study participants were issued with calibrated food-weighing scales and asked to keep a weighed record for all food consumed during the 4-day period. This is the most precise method available for assessing intake, but it has disadvantages. For example, validation studies of the weighed intake method using doubly labelled water or urinary nitrogen indicate that under-reporting bias is common in particular groups[3,10]. The response rate for the 4-day intake was 59%. Body weight, height, and blood and urine samples were collected. Information was also collected using an interviewer-administered questionnaire including: age, sex, social class, income, pensions, benefits, geographical area of residence, cigarette smoking, and household composition. This analysis uses only the free-living sample. Three-hundred-and-fifty-seven participants in this group did not keep 4-day diaries and a further 78 did not have their body weights recorded, thereby preventing calculation of basal metabolic rate (BMR). Thus 1097 participants remained for this analysis, 558 women and 539 men[2].

BMR was calculated for each participant from his or her body weight, age and sex using the Schofield equations[4]. Separate age- and gender-based equations were used for those aged below and over 75 years of age. The within-subject coefficient of variation of daily reported energy intake was 17.5%, giving a 'cut-off 2' value of 1.1 using the Goldberg formula[5]. Low energy reporters (LERs) were thus defined as those participants reporting an average daily energy intake over four days below 1.1 times BMR.

The clustering technique used was a hierarchical agglomerative (or stepwise) technique available on SPSS for Windows. Ward's method was used, based on squared Euclidean distances[6]. In Monte Carlo studies, Ward's method has been found to be the most robust clustering method using a similarity matrix based upon squared Euclidean distances[7,8].

Analyses were conducted for men and women separately. Twenty-seven food/drink groups were used in the analysis. Continuous food and beverage group values (all estimated in g per week) were standardised by converting to the standard normal deviate. This is to ensure that clusters are not influenced by food categories with high specific gravity such as beverages. A matrix of distances based upon squared Euclidean distance was computed followed by stepwise fusion of cases. The clustering coefficient was then used to indicate the stage on the agglomeration schedule where large changes between fusions were evident, as compared with immediately preceding stages[6].

As possible instability of the results could be one of the limitations of a cluster analysis, we tested the stability of the cluster solution. Two methods were used: (i) discriminant analysis to test the degree of association between group membership assigned by cluster analysis using 27 food/beverage groups, and (ii) by randomly splitting the data into two, clustering separately in each subset and comparing cluster membership in each split sample.

Statistical comparisons were made across the clusters in terms of reported food-group consumption, intakes of macronutrients and micronutrients, LERs[3], and selected socio-economic, demographic and behavioural variables. Non-parametric Kruskal–Wallis one-way analysis of variance (ANOVA) was used to test for differences between clusters in the consumption of each food group and of alcohol. Parametric one-way ANOVA was used to test for between-group differences in frequency distribution of nutrients and biochemical variables. Chi-square was used for categorical variables. Statistical analyses were performed using the SPSS for Windows and SAS statistical packages.

Results

Identification of clusters

Among men, three large clusters were identified comprising 86% of the male sample, and three small clusters comprising the remaining 14%. Among women, three large clusters were identified comprising 83% of the female sample, and three small clusters comprising the remaining 17%. In order to test the stability of the solution obtained, a discriminant analysis was undertaken to test the degree of association between group membership assigned by cluster analysis using 27 food/beverage group variables. The level of agreement between group membership identified by cluster and predicted group membership using discriminant analysis was 83% among men and 81% among women. We also did a split sample to test whether the results were different in each split sample. The results show that the split samples were the same, identifying six large clusters and six small clusters. These results indicate relatively good overall agreement between actual and predicted group membership using cluster and discriminant analysis, and using the split samples.

Table 1 Consumption of 27 food groups by sex and dietary cluster (g daily and relative level*)

	Men ($n = 539$)					Women ($n = 558$)				
Food group	Population median	MC1 'mixed' ($n = 273$)	MC2 'healthy' ($n = 122$)	MC3 'traditional' ($n = 97$)	P	Population median	FC1 'traditional' ($n = 192$)	FC2 'healthy' ($n = 185$)	FC3 'mixed' ($n = 102$)	P
Rice, pasta	0	0	0	0	<0.01	0	0	0	0	<0.01
White bread, refined cereals	281	347 MH	38 L	342 MH	<0.01	180	167 ML	97 ML	316 H	<0.01
Brown bread, wholemeal cereals	236	122 ML	504 H	215 ML	<0.01	185	216 MH	288 H	62 L	<0.01
Biscuits, cakes, pastries	320	330 MH	382 MH	329 MH	<0.33	232	356 H	198 ML	176 ML	<0.01
Whole milk	160	360 H	35 L	640 H	<0.01	248	764 H	25 L	112 L	<0.01
Low-fat milk	173	0 L	780 H	0 L	<0.01	0	0	701	196	<0.01
Ice cream, yoghurt	0	0	46	0	<0.04	0	0	84	0	<0.01
Cheese	36	32 ML	45 MH	56 H	<0.01	20	16 ML	32 H	0 L	<0.01
Eggs	57	58 MH	52 ML	58 MH	<0.59	40	44 MH	22 ML	0 L	<0.63
Butter	0	0	0	71	<0.01	0	35	0	0	<0.01
Low-fat spreads	37	59 H	56 H	0 L	<0.01	16	0 L	44 H	23 MH	<0.01
Other spreads	0	0	0	0	<0.65	0	0	0	0	<0.9
Bacon, ham	46	50 MH	38 ML	50 MH	<0.52	29	25 ML	26 ML	40 MH	<0.05
Beef, pork, lamb	144	153 MH	86 ML	160 MH	<0.01	108	88 ML	115 MH	117 MH	<0.84
Chicken, turkey	0	0	125	0	<0.01	0	0	45	30	<0.01
Meat products	130	138 MH	130 M	115 ML	<0.51	71	100 MH	44 ML	88 MH	<0.01
Fish	118	128 MH	135 MH	123 MH	<0.96	100	86 ML	101 MH	130 MH	<0.01
Potatoes	424	439 MH	449 MH	430 MH	<0.01	326	330 MH	335 MH	386 MH	<0.01
Vegetables	426	439 MH	570 MH	435 MH	<0.01	370	375 MH	488 MH	296 ML	<0.01
Fruit	282	210 ML	605 H	302 MH	<0.01	312	325 MH	467 MH	165 ML	<0.01
Sugar, preserves	112	139 MH	96 ML	107 ML	<0.01	54	104 H	35 ML	56 MH	<0.01
Fruit juice	0	0	0	0	<0.03	0	0	0	0	<0.01
Soft drinks	0	0	0	0	<0.54	0	0	0	0	<0.01
Alcohol	18	0 L	100 H	86 H	<0.05	0	0	0	0	<0.04
Tea, coffee	3226	3372 MH	3349 MH	3230 M	<0.4	2774	2754 ML	2748 ML	3040 MH	<0.31
Soup	0	0	0	0	<0.22	0	0	0	0	<0.24
Sauces, pickles	50	45 ML	82 H	47 ML	<0.01	41	31 ML	58 MH	40 ML	<0.01

* L = low (<50%); ML = moderate–low (50–100%); MH = moderate–high (100–150%); H = high (>50%); statistical test = Kruskal–Wallis ANOVA (non-parametric).

Reported food and drink consumption

Table 1 presents for men and women the total sample median food/drink group intake by clusters. For the purposes of data summary, cluster median food/drink intakes below 50% of the respective sample intake were considered 'low'. Cluster median intakes between 50% and 99% and between 100% and 149% of the respective total sample median were considered 'moderate–low' and 'moderate–high', respectively. Cluster median food/drink group intakes above 150% of the respective total sample median intake were considered as 'high'.

Male dietary clusters

The most prevalent male dietary group was cluster 1 (MC1; $n = 273$; 48% of the male sample) who reported median food/drink groups in the 'high' category (i.e. >150% of the median of the total male sample) such as whole milk and cream and low-fat spreads. This cluster also had a 'moderate–high' (100–149%) consumption of refined cereals including white bread, biscuits, cakes and pastries, eggs, bacon and ham, beef, veal, lamb, pork, liver and meat products, fish, potatoes, vegetables, sugar and tea/coffee. They also had a 'moderate–low' consumption of brown bread, cheese, fruit, sauces and pickles. This dietary pattern is interesting in that it has elements of the traditional diet, and also has some elements of a healthy diet. This pattern is hence designated a 'mixed diet'.

Male cluster 2 (MC2; $n = 122$; i.e. 21% of the male sample) reported food/drink groups in the 'high' category for brown bread, low-fat spreads, fruit and alcohol, and 'moderate–high' for biscuits, cakes and pastries, cheese, liver and meat products, fish, potatoes, vegetables, tea/coffee, sauces and pickles. This cluster also demonstrated 'moderate–low' values for whole milk and cream, eggs, bacon and ham, beef, veal, pork, sugar and preserves, with 'low' consumption of food items such as refined cereals including white bread, rice and pasta, yoghurt and ice cream, butter, margarine, chicken and turkey, fruit juice, soft drinks, soup and pickles. This dietary pattern could be considered a 'healthy diet'. However, this diet was also high in alcohol, which has generally not hitherto been considered an attribute of a 'healthy' diet.

Male cluster 3 (MC3; $n = 97$; i.e. 17% of the male sample) had median intakes in the 'high' category for whole milk and cream, cheese and alcohol; and in the 'moderate–high category' for refined cereals including white bread, biscuits, cakes and pastries, eggs, meat products, fish, fruit, tea/coffee, potatoes, vegetables and fruit. This third male cluster also showed a 'moderate–low' category for brown bread, butter, margarine, bacon and ham, beef, veal, pork, sugar and preserves, sauces

Table 2 Mean macronutrient density (% energy or g per 1000 kcal) and relative level* in the sample population by sex and dietary cluster

	Men ($n = 539$)								Women ($n = 558$)							
		'Mixed' ($n = 273$)		'Healthy' ($n = 122$)		'Traditional' ($n = 97$)				'Traditional' ($n = 192$)		'Healthy' ($n = 185$)		'Mixed' ($n = 102$)		
Nutrient	Population mean	Mean	Level	Mean	Level	Mean	Level	*P*	Population mean	Mean	Level	Mean	Level	Mean	Level	*P*
% Energy																
Protein	15.1	14.9	ML	15.8	MH	14.9	ML	<0.01	15.9	14.4	ML	16.9	MH	16.8	MH	<0.01
Carbohydrate	46.1	47.0	MH	47.1	MH	44.7	ML	<0.01	46.5	46.1	LM	47.7	MH	46.7	MH	<0.02
Alcohol	3.70	2.18	ML	2.88	ML	3.17	ML	<0.06	1.12	0.50	L	0.95	ML	0.37	L	<0.01
Fat	35.1	35.9	MH	34.2	ML	37.3	MH	<0.01	36.5	39.0	MH	34.5	ML	36.1	ML	<0.01
Saturated fat	14.6	14.7	MH	13.6	ML	17.5	MH	<0.01	15.7	18.2	MH	14.0	ML	14.9	ML	<0.01
Trans saturated fat	1.52	1.62	MH	1.40	ML	1.53	MH	<0.01	1.61	1.83	MH	1.45	ML	1.50	ML	<0.01
Monounsaturated fat	10.9	11.1	MH	10.5	ML	11.0	MH	<0.02	11.0	11.4	MH	10.3	ML	11.2	MH	<0.01
n3 polyunsaturated	0.77	0.77	ML	0.84	MH	0.70	ML	<0.01	0.81	0.70	ML	0.86	MH	0.81	MH	<0.01
n6 polyunsaturated	4.83	5.10	MH	5.34	MH	3.79	ML	<0.01	4.77	4.06	ML	5.43	MH	5.16	MH	<0.01
Polyunsaturated	5.62	5.89	MH	6.23	MH	4.52	ML	<0.01	5.63	4.79	ML	6.41	MH	5.99	MH	<0.01
g per 1000 kcal																
Sugar	54.9	56.0	MH	55.8	MH	51.1	ML	<0.04	55.7	56.1	MH	58.2	MH	49.8	ML	<0.01
Starch	68.0	69.3	MH	69.8	MH	68.0	MH	<0.60	68.3	66.8	ML	69.1	MH	74.7	MH	<0.01
Fibre	10.3	9.5	ML	13.4	MH	9.5	ML	<0.01	11.2	10.0	ML	13.4	MH	10.1	ML	<0.01

* L = low; ML = moderate–low; MH = moderate–high; H = high; statistical test = ANOVA.

and pickles, as well as a 'low' category for food items such as pasta and rice, low-fat milk, yoghurt and ice cream, chicken and turkey, fruit juice, soft drinks, and soups and pickles. This dietary pattern may be considered a 'traditional diet high in alcohol'.

Female dietary clusters

The most prevalent female dietary group was cluster 1 (FC1; $n = 192$; 33% of the female sample) with reported food/drink groups in the 'high' category that included biscuits, cakes and pastries, whole milk and cream, sugar and preserves; and in the 'moderate–high' category for brown bread, eggs, meat products, potatoes, vegetables and fruit. This female group also demonstrated a 'moderate–low' for white bread, cheese, bacon and ham, beef, veal, pork, fish, tea/coffee, sauces and pickles, and a 'low' for butter. This diet was a 'sweet, traditional diet'.

Female cluster 2 (FC2; $n = 185$; 32% of female sample) had reported median food/drink groups in the 'high' categories including brown bread and whole grain cereals, low-fat milk, yoghurt, cheese, low-fat spread, chicken and turkey, and fruit. This cluster had a 'moderate–high' for beef, veal, pork, fish, potatoes, vegetables, sauces and pickles; and a 'moderate–low' for white bread, biscuits, cakes and pastries, eggs, bacon and ham, meat products, sugar and preserves, and tea/coffee. Cluster FC2 also showed a 'low' for whole milk and cream. This diet could be considered a 'healthy diet'.

Female cluster 3 (FC3; $n = 102$; 18% of the female sample) was found to have reported food/drink groups in the 'high' category for white bread and low-fat milk; and 'moderate–high' for low-fat spread, bacon and ham, beef, veal, pork, chicken, meat products, fish, sugars and preserves, tea/coffee, and potatoes. FC3 also had a 'moderate–low' for brown bread, biscuits, cakes and pastries, vegetables, fruit, sauces and pickles; and a 'low' for whole milk and cream. This diet is interesting as it has elements from a healthy diet – low-fat milk and spread, brown bread, low in biscuits, cakes and pastries, high in white meats and fish – along with elements from a traditional diet, i.e. white bread, potatoes, red meat and meat products, low vegetables and fruit, and high sugars and preserves. This dietary pattern could be called a 'mixed diet'.

Macronutrient density

Table 2 presents data on macronutrient densities for the three large clusters for men and three clusters for women. Of the three large men and women clusters, the 'healthy' diets (MC2; FC2) had the lowest mean densities for total fatty acids, saturated fatty acids and *trans* fatty acids, the highest for carbohydrate, starch and n6 polyunsaturated fatty acids, and the highest for fibre. In men (MC2) total sugar density was close to the sample mean, but in women (FC2) total sugar density was the highest of all the diets. Conversely, the 'traditional' diet (MC3; FC1) had the highest mean densities for total fatty acids and saturated fatty acids, and had the lowest mean density for fibre. Compared with the 'traditional diet' (FC1), the FC3 and MC1 diet, which has elements of traditional and healthy diets, had higher mean densities for carbohydrate, protein, n6 polyunsaturated fatty acids, n3 polyunsaturated fatty acids, polyunsaturated fatty acids and starch, and lower mean densities for total fatty acids and saturated fat. Compared with the 'traditional diet' (MC1), the male 'traditional diet high in alcohol' (MC3) had lower mean densities of carbohydrates, *trans* fatty acids, n6 unsaturated fatty acids, n3 unsaturated fatty acids, total sugars and starch, and higher mean densities of alcohol, total fatty acids and saturated fatty acids.

Table 3 Mean micronutrient density (% energy or mg or μg per 1000 kcal) and relative level* in the sample population by sex and dietary cluster

	Men ($n = 539$)								Women ($n = 558$)							
		'Mixed' ($n = 273$)		'Healthy' ($n = 122$)		'Traditional' ($n = 97$)				'Traditional' ($n = 192$)		'Healthy' ($n = 185$)		'Mixed' ($n = 102$)		
Nutrient	Population mean	Mean	Level	Mean	Level	Mean	Level	*P*	Population mean	Mean	Level	Mean	Level	Mean	Level	*P*
Iron	5.87	5.60	ML	6.87	MH	5.61	ML	<0.01	6.13	5.71	ML	6.85	MH	5.80	ML	<0.01
Calcium	4435	441	ML	477	MH	453	MH	<0.01	488	470	ML	549	MH	438	ML	<0.01
Potassium	1418	1342	ML	1623	MH	1357	ML	<0.01	1562	1349	ML	1777	MH	1529	ML	<0.01
Magnesium	133	122	ML	161	MH	124	ML	<0.01	139	126	ML	162	MH	124	ML	<0.01
Phosphorus	653	633	ML	733	MH	631	ML	<0.01	700	652	ML	782	MH	658	ML	<0.01
Copper	0.58	0.54	ML	0.71	MH	0.58	MH	<0.01	0.61	0.58	ML	0.68	MH	0.58	ML	<0.04
Zinc	4.66	4.58	ML	5.06	MH	4.57	ML	<0.01	4.90	4.61	ML	5.31	MH	4.80	ML	<0.01
Iodine	99.6	98.3	ML	93.2	ML	102	MH	<0.14	105	106	MH	106	MH	105	ML	<0.94
Vitamin A	606	559	ML	823	MH	643	MH	<0.05	678	716	MH	709	MH	599	ML	<0.63
Vitamin D	2.10	2.28	MH	2.18	MH	1.71	ML	<0.01	2.02	1.68	ML	2.20	MH	2.14	MH	<0.01
Vitamin E	4.61	4.89	MH	5.21	MH	3.44	ML	<0.01	4.68	3.80	ML	5.61	MH	4.93	MH	<0.01
Vitamin C	33.9	29.0	ML	43.6	MH	28.1	ML	<0.01	42.0	29.5	ML	54.4	MH	36.5	ML	<0.01
Thiamin	0.79	0.78	ML	0.88	MH	0.74	ML	<0.01	0.85	0.75	ML	0.95	MH	0.88	MH	<0.01
Riboflavin	0.93	0.90	ML	1.04	MH	0.88	ML	<0.01	1.01	0.95	ML	1.14	MH	0.96	ML	<0.01
Niacin	16.9	16.1	ML	18.7	MH	16.3	ML	<0.01	17.7	15.4	ML	19.4	MH	18.3	MH	<0.01
Vitamin B_6	1.11	1.04	ML	1.18	MH	1.03	ML	<0.01	1.15	0.97	ML	1.29	MH	1.16	MH	<0.01
Vitamin B_{12}	3.12	3.02	ML	3.56	MH	3.10	ML	<0.37	3.05	2.76	ML	3.25	MH	2.86	ML	<0.21
Folate	141	129	ML	162	MH	129	ML	<0.01	147	126	ML	170	MH	146	ML	<0.01
Biotin	17.0	15.6	ML	20.2	MH	16.0	ML	<0.01	17.6	16.3	ML	19.6	MH	14.4	ML	<0.01
Pantothenic acid	2.62	2.52	ML	2.96	MH	2.39	ML	<0.01	2.78	2.44	ML	3.09	MH	2.81	MH	<0.01

* ML = moderate–low, MH = moderate–high; statistical test = ANOVA.

Micronutrient densities

Table 3 presents data on mean densities for 20 vitamins and minerals for the three large men and women clusters. The 'healthy' diet clusters (MC2; FC2) had the highest mean densities for 18 of 20 mineral and vitamins. The traditional diet, MC3, had the lowest mean micronutrient densities for 16 of 20 micronutrients, and FC1 had the lowest mean micronutrient densities for 15 of 20 micronutrients (Table 3). Interestingly, FC3 and MC1 – which both had elements from a traditional diet and a healthy diet – had mean micronutrient densities higher than the traditional diet (FC1) for 14 of 20 micronutrient densities and (MC1) for 12 of 20 micronutrient densities (Table 3). Lastly, compared with the male 'traditional diet' (MC1), MC3 – 'traditional diet high in alcohol' – had mean densities of micronutrients lower for seven nutrients including: phosphorus, copper, vitamin D, vitamin E, vitamin C, thiamine and pantothenic acid, and higher for nine nutrients including: calcium, potassium, magnesium, iodine, vitamin A, niacin, vitamin B_{12}, folate and biotin.

Biochemical measurements

Table 4 presents data on the mean biochemical measurements by sex and cluster. The 'healthy diet' (MC2; FC2) had the highest mean biochemical indices for nine of the 15 measurements for men, and 12 of 15 measurements for women (see Table 4). The 'traditional diet' clusters (MC3 and FC1) had the highest levels for three of the 15 including serum folate, red-cell folate and plasma retinol. Of the 'mixed diet' clusters, the men (MC1) had the highest levels of serum ferritin, serum vitamin E, serum zinc and EGRAC (erythrocyte glutathione reducase activators coefficient) (high levels of EGRAC are indicative of low vitamin B_2 status). The 'mixed diet' cluster for women (FC1) showed the highest levels of serum vitamin E and EGRAC (i.e. poor B_2 status). For many biochemical measurements, levels differed significantly between clusters, but in other cases differences may have arisen by chance.

Energy, body mass index (BMI) and LERs

Table 5 presents data on mean energy intake, BMI and proportions of LERs for the three large male and female clusters. Only among women are the cluster differences in energy intake, the percentage LERs and BMIs statistically significant. Among the females, the 'healthy diet' cluster (FC2) and the 'traditional and healthy diet' cluster (FC3) had the lowest mean energy intakes. Among women, the proportion of LERs was higher in the 'mixed diet' (59%) followed by the 'healthy diet' (52%) clusters, while the 'traditional diet' cluster had the lowest proportion of LERs (34%). Among the males, the 'healthy diet' cluster (MC2) had the highest mean energy intake and the 'mixed diet' cluster (MC1) the lowest mean energy intake. Among the male clusters, the lowest proportion of LERs was in the 'healthy diet' cluster (MC2) followed by the 'traditional diet' group (MC3), with the highest proportion of LERs in the 'mixed diet' cluster.

Socio-demographic and behavioural profiles

Selected socio-demographic and behavioural characteristics for the three large male and three large female

Table 4 Summary of the blood biochemistry of the sample population by sex and dietary cluster

	Men ($n = 539$)				Women ($n = 558$)			
	MC1 'mixed' ($n = 273$)	MC2 'healthy' ($n = 122$)	MC3 'traditional' ($n = 97$)	*P*	FC1 'traditional' ($n = 192$)	FC2 'healthy' ($n = 185$)	FC3 'mixed' ($n = 102$)	*P*
Serum haemoglobin (g dl^{-1})	14.5	14.5	14.3	<0.4	13.4	13.6	13.3	<0.16
Serum ferritin ($\mu g\ l^{-1}$)	133	112	125	<0.56	65.2	89.2	86.0	<0.03
Serum folate (nM)	14.3	16.2	16.6	<0.11	15.4	19.7	16.1	<0.01
Red-cell folate (nM)	456	509	562	<0.01	454	562	504	<0.01
Plasma α-carotene (μM)	0.06	0.08	0.06	<0.01	0.08	0.09	0.06	<0.03
Plasma β-carotene (μM)	0.33	0.40	0.30	<0.04	0.41	0.47	0.32	<0.01
Serum cryptoxanthin (μM)	0.11	0.17	0.13	<0.01	0.14	0.21	0.14	<0.01
Serum vitamin C (μM)	35.2	47.4	38.6	<0.01	36.0	57.7	37.0	<0.01
Plasma vitamin A (μM)	2.28	2.17	2.31	<0.25	2.20	2.17	2.19	<0.94
Plasma 25-hydroxy D (nM)	58.0	63.3	57.2	<0.23	44.9	54.6	51.5	<0.01
Serum vitamin B_{12} (pM)	216	241	228	<0.11	223	254	237	<0.14
Plasma vitamin E (μM)	36.2	35.8	33.3	<0.14	37.9	42.0	39.0	<0.04
Plasma zinc (μM)	14.4	14.2	14.1	<0.54	14.4	14.4	14.2	<0.88
EGRAC*	1.31	1.28	1.29	<0.25	1.29	1.27	1.35	<0.01

* EGRAC = erythrocyte glutathione reductase activator coefficient; statistical tests = ANOVA.

Table 5 Body mass index, low energy reporters, and reported energy intake by sex and dietary cluster

	Men ($n = 539$)				Women ($n = 558$)			
	'Mixed' ($n = 273$)	'Healthy' ($n = 122$)	'Traditional' ($n = 97$)	*P*	'Traditional' ($n = 192$)	'Healthy' ($n = 185$)	'Mixed' ($n = 102$)	*P*
Energy intake, mean daily (kcal)	1855	1956	1924	<0.11	1523	1400	1299	<0.01
BMI, mean (kg m^{-2})	26.2	26.0	26.6	<0.5	25.7	27.0	27.2	<0.02
LER (%)	32	21	28	<0.1	34	52	59	<0.01

Table 6 Socio-economic, behavioural and demographic characteristics* of the sample population by sex and dietary cluster

	Men ($n = 539$)				Women ($n = 558$)			
	MC1 'mixed' ($n = 273$)	MC2 'healthy' ($n = 122$)	MC3 'traditional' ($n = 97$)	*P*	FC1 'traditional' ($n = 192$)	FC2 'healthy' ($n = 185$)	FC3 'mixed' ($n = 102$)	*P*
Age in years, mean (se)	76.5 (0.4)	74.8 (0.6)	77.3 (0.8)	0.03	80 (0.6)	75.6 (0.6)	77.9 (0.8)	<0.01
Behavioural characteristics								
% Current smoker (*n*)	24 (63)	14 (16)	30 (28)	0.02	13 (21)	8 (13)	22 (21)	<0.01
% Living alone (*n*)	22 (59)	20 (25)	25 (24)	0.7	63 (120)	57 (105)	54 (55)	<0.3
Socio-economic characteristics								
% Manual social class (*n*)	62 (167)	34 (41)	57 (51)	<0.01	52 (84)	43 (69)	56 (49)	<0.08
% Income >£6000 p.a. (*n*)	62 (138)	78 (81)	70 (57)	0.01	32 (46)	42 (59)	30 (25)	<0.13
% In receipt of benefits (*n*)	40 (104)	25 (28)	35 (32)	0.01	52 (96)	49 (86)	57 (54)	<0.43
% Educated beyond 14 years (*n*)	25 (69)	52 (64)	33 (32)	<0.01	30 (58)	35 (64)	17 (17)	<0.01
Area of residence								
% North (*n*)	23 (64)	22 (27)	24 (23)	0.49	32 (62)	21 (38)	26 (27)	<0.03
% Midlands (*n*)	26 (71)	25 (30)	22 (21)		19 (36)	24 (45)	25 (26)	
% South (*n*)	33 (90)	42 (51)	41 (40)		28 (54)	42 (78)	29 (30)	
% Scotland (*n*)	10 (28)	4 (5)	8 (8)		13 (24)	6 (12)	11 (11)	
% Wales (*n*)	7 (20)	7 (9)	5 (5)		8 (16)	6 (12)	8 (8)	

* Statistical tests: ANOVA for age; then Chi-square for the rest of the table.

clusters are presented in Table 6. Males and females in the 'traditional diet' and the 'mixed diet' groups were more likely to be smokers and to come from manual social classes. They were more likely to be in receipt of state benefits and to be on lower incomes than those in the 'healthy diet' group. Among men, those adopting the 'healthy diet' had in general more years of education than those in the 'traditional diet' and 'mixed diet' groups, but this was not so amongst women. Women in the 'healthy' and 'mixed diet' groups were more likely to report having consciously changed their diet in the past. There was an age effect in both men and women, with higher proportions of younger individuals in the 'healthy diet' group, and the more elderly individuals in the 'traditional' and 'mixed diet' groups.

Discussion

In this paper we report results of an investigation which uses cluster analysis to identify groups of individuals over 65 years of age with similar patterns of dietary behaviour within the UK population. As compared with a more traditional approach of *a priori* classification of individuals (e.g. by social class) followed by analysis of variance, cluster analysis adopts a more dynamic approach to exploring patterns of food intake by grouping participants with comparable combinations of food types.

We characterised the sample using 27 food groups and then used cluster analysis to identify similar eating patterns[9]. In this study, three large clusters comprising 86% of the male sample and three large clusters comprising 83% of the female sample were identified. The mixed diet was consumed by 48% of men and 18% of women, the healthy diet was consumed by 21% of men and 32% of women, and the traditional diet was consumed by 17% of men and 33% of women.

Current smokers, manual social class and education were least in the healthy diet and most in the traditional diet. Among men, LERs were most in the mixed diet and least in the healthy diet. Among women, LERs were least in the traditional diet and most in the mixed diet. Among men, red-cell folate was highest in the traditional diet, and serum vitamin C, plasma 25 hydroxy D and plasma α-carotene were highest in the healthy diet cluster. Among women, red-cell folate, plasma α-carotene, plasma β-carotene, serum cryptoxanthin, serum vitamin C, plasma vitamin A and plasma vitamin E were highest in the healthy diet cluster.

A priori classification by social class, age and gender did show some differences in dietary intake, but these were small[2]. In this study differences in mean levels among clusters were larger and combinations of undesirable/desirable dietary and other factors were observed. For example, the 'traditional diet' included high fat/high alcohol consumption and low micronutrient intake, and the group had a higher prevalence of smokers than the overall population. On the other hand, the 'healthy diet' group had a low mean fat intake, higher micronutrient intake and had fewer smokers. Other studies have shown that a more health-conscious behaviour is often associated with a higher social class[11], with a more favourable biochemical profile of cardiovascular risk factors[12].

Cluster analysis has not been widely used in nutritional analysis relevant to public health. Huijbregts *et al.*[13] identified four dietary groups using cluster analysis on the elderly population in Zutphen. The first dietary group was high in alcohol, meat, fish, eggs and cheese, and below average in bread, cereals, vegetables and fruit, milk and sugars. This cluster is similar to our male 'traditional cluster high in alcohol'. The second dietary group identified in the Zutphen study was a healthy cluster high in bread, potatoes, vegetables and fruit, and below average in meat, fish, eggs, edible fats, sugars. This is similar to the 'healthy diet' cluster in this study. The third cluster was a sweet cluster high in milk, sugars and pastries, and below average for bread, meat, eggs, cheese and alcohol. This is similar to the female 'sweet traditional' diet cluster of this study. Tucker *et al.*[14] identified four clusters in an elderly sample from Boston: an alcohol cluster; a milk, cereal, fruit cluster; a bread, poultry cluster; and a meat and potatoes cluster were identified. Socio-demographic characteristics and nutrient intake differentiated clusters. Using data on adults aged 65–74 years from the US Nationwide Food Consumption Survey, Akin *et al.*[15] identified eight clusters which differed in terms of nutrient intake and socio-economic characteristics. Hulshof *et al.*[16] used the cluster analysis technique to analyse data from the Dutch Nutritional Surveillance System (17–85 years). Eight clusters were identified on the basis of macronutrient intake that differed not only in terms of nutrient intake, but also in terms of diet and lifestyle characteristics.

Our work identified six large groups among UK men and women aged 65 years and over which differed not only in terms of reported dietary intakes, but also with respect to their nutritional status, social status and behavioural profile. Further research is needed on mortality and morbidity by clusters. Nevertheless, these results should be of relevance to the development, monitoring and targeting of public health nutrition policy in the UK. In particular, they could be used to develop a tailored health promotion programme based on diet clusters, by positively reinforcing the healthy diet, pointing out deficiencies in the mixed diet and targeting the traditional diet for significant improvements.

Acknowledgements

This work was sponsored by the Ministry of Agriculture, Fisheries and Food, UK.

References

1 Ebrahim S, Davey-Smith G. *Health Promotion in Older People for the Prevention of Coronary Heart Disease and Stroke*. London: Health Education Authority, 1996.
2 Finch S, Doyle W, Lowe C, Bates CJ, Prentice A, Smithers G, Clarke PC. *National Diet and Nutrition Survey: People Aged 65 Years and Over, Vol. 1: Report of the Diet and Nutrition Survey*. London: HMSO, 1998.
3 Pryer JA, Vrijheid M, Nichols R, Kiggins M, Elliott P. Who are 'low energy reporters' in the Dietary and Nutritional Survey of British Adults. *Int. J. Epidemiol.* 1997; **26**: 146–54.
4 Department of Health. *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*. Report of the Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Policy. London: HMSO, 1991.
5 Goldberg GA, Black AE, Jebb SA, Cole TJ, Murgatroyd PA, Coward WA, Prentice AM. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1.

Derivation of cut-off limits to identify under-recording. *Eur. J. Clin. Nutr.* 1991; **45**: 569–81.
6 Everitt B. *Cluster Analysis*. London: Heineman Educational Books, 1980.
7 Blashfield RK. Mixture model tests of cluster analysis: accuracy of four agglomerative hierarchical methods. *Psychol. Bull.* 1976; **83**: 377–88.
8 Edelbrock C. Mixture model tests of hierarchical clustering algorithms: the problem of classifying everybody. *Multivar. Behav. Res.* 1979; **14**: 367–84.
9 Pryer JA, Nichols R, Elliott P, Thakrar B, Brunner E, Marmot M. Identification of groups who report similar patterns of diet among a national random sample of British adults. *J. Epidemiol. Community Health* 2001; **55**: 29–37.
10 Cook A, Pryer JA, Shetty P. Low energy reporters in the Dietary and Nutritional Survey of people over 65 years. *J. Epidemiol. Community Health* 2001; **54**: 611–6.
11 Marmot M, Elliott P. (eds). *Coronary Heart Disease Epidemiology: From Aetiology to Public Health*. Oxford: Oxford University Press, 1992.
12 Nicklas TA, Webber LS, Thompson B, Bereson GS. A multivariate model for assessing eating patterns and their relation to cardiovascular risk factors: The Bogalusa Heart Study. *Am. J. Clin. Nutr.* 1989; **49**: 1320–7.
13 Huijbregts PPC, Feskens EJM, Kromhout D. Dietary patterns and cardiovascular risk factors in elderly men: The Zutphen Elderly Study. *Int. J. Epidemiol.* 1995; **24**: 313–20.
14 Tucker KL, Dallal GE, Rush D. Dietary patterns of elderly Boston area residents defined by cluster analysis. *J. Am. Dietetic Assoc.* 1992; **92**: 1487–91.
15 Akin JS, Guilkey DK, Popkin BM, Fanelli MT. Cluster analysis of food consumption patterns of older Americans. *J. Am. Dietetic Assoc.* 1996; **86**: 616–24.
16 Hulshof KFAM, Wedel M, Lewik MRH, Kok FJ, Kistemaker C, Hermus RSS, ten Hoor F, Ockhuizen TH. Clustering of dietary variables and other lifestyle factors (Dutch Nutritional Surveillance System). *J. Epidemiol. Community Health* 1992; **46**: 417–24.

Appendix: food groups

1. **Rice and pasta.** Rice includes fried, boiled, savoury rice, egg fried rice, rice flakes and rice flour; all types of pasta including dried, fresh and canned (including egg noodles, macaroni cheese, ravioli, canned spaghetti bolognaise).
2. **White bread and refined cereals.** White bread: sliced and unsliced, toasted, fried, French stick, milk loaf, slimmer's bread, pita bread, rolls, chapattis, soda bread; cereals: Corn Flakes, Coco Pops, Sugar Puffs and Pop Tarts.
3. **Brown bread, wholemeal cereals.** Brown bread: sliced, unsliced, toasted, fried, chapattis, pita bread, rolls, hi-bran bread, wholemeal soda bread; cereals: All-Bran, muesli, Shredded Wheat, porridge and Ready Brek.
4. **Biscuits, cakes and pastries.** Biscuits: sweet and savoury, cream crackers, flapjacks, bread sticks, crispbread, cereal crunchy bars, ice-cream cornet; cakes and pastries: Danish pastries, currant buns, doughnuts, Eccles cakes, Bakewell tarts, jam tarts, scones, sponge cakes, fruit cake, eclairs, currant bread, malt loaf, gateaux, pastry, mince pies, sponge fingers, scotch pancakes, croissants, custard tart, lemon meringue pie.
5. **Whole milk.** Pasteurised, UHT, sterilised, and Channel Islands' milk.
6. **Low-fat milk.** Semi-skimmed and skimmed milk: pasteurised, UHT, sterilised, canned milk with added vitamins, and (additionally for skimmed milk) Vital and Calcia.
7. **Ice cream and yoghurt**. Ice cream: non-dairy, choc ices, ice-cream desserts, lollies containing ice cream, low-fat/low-calorie ice cream; yoghurts: all types including soya, goat's, sheep yoghurt mousse, yoghurt drink, frozen yoghurt, custard-style yoghurt, Greek yoghurt.
8. **Cheese**. Includes cottage cheese, hard, soft, cream cheese, processed, reduced-fat cheeses, vegetarian cheese, cheese spread.
9. **Eggs**. Includes boiled, fried, scrambled, poached, dried, omelettes, and egg dishes: quiches, flans, soufflés, scotch eggs, eggy bread, sorbet, apple snow, meringue, pavlova, curried eggs.
10. **Butter**. Salted and unsalted, butter ghee, spreadable butter.
11. **Low-fat spreads**. Low-fat spreads including those high in polysaturated fat, and includes spreads made with olive oil and rapeseed oil.
12. **Other spreads**. Includes block margarine, soft margarine claimed to be high in polyunsaturated fat, and polyunsaturated magarines.
13. **Bacon and ham**. Includes bacon and gammon joints, steaks, chops and rashers; all types of ham, pork shoulder, bacon and cheese grills.
14. **Beef, pork and lamb**. Beef includes beef joints, steaks, minced beef, stewing steak, beef casseroles, meat balls, lasagne, chilli con carne, beef curry, bolognaise sauce, shepherd's pie, canned beef. Pork includes joints, chops, steaks, belly rashers, pork stews and casseroles, sweet and sour pork, spare ribs, roast roll. Lamb includes lamb joints, chops, cutlets, fillets, lamb curries, Irish stew, lamb casseroles and stews.
15. **Chicken and turkey**. Includes roast chicken and turkey, barbecued, fried, curries, stews, casseroles, chow mein, tandori, in spread or sauce, and chicken/turkey roll.
16. **Meat products**. Burgers includes beef burgers, ham burgers, cheese burgers, doner/shish/kote kebabs; sausages include: beef, pork turkey, polony, saveloy, frankfurters, sausages dishes; meat pies and pastries: chicken/turkey pies, steak and kidney pies and puddings, beef pies, pork pies, veal and ham pie, pasties, sausage rolls, meat samosas, pancake rolls.
17. **Fish**. White fish includes cod, haddock, plaice, etc., poached, steamed, baked, grilled, smoked and dried; includes curried fish, fish in sauce, fish pie, kedgeree. Shellfish includes mussels, prawns, crab and shellfish dishes. Oily fish includes herrings, kippers, mackerel, sprats, eels, herring roe, salmon, tuna, sardines, trout, taramasalata, mackerel paté, fish paste and fish dishes.
18. **Potatoes**. Includes boiled, mashed, baked, canned, potato salads, instant potato, potato-based curries, cheese and potato pie; chips fresh or frozen including oven and microwave chips, French fries, roast potatoes, fried croquettes, fried waffles, fritters and hash browns.

19. **Vegetables**. Including salad vegetables: raw carrots and tomatoes, salad and other types of raw vegetable, coleslaw. Vegetables not raw includes peas, green beans, baked beans, leafy greens, carrots, tomatoes, mushrooms, onion, aubergine, parsnips, sweetcorn, peppers, leeks, courgettes, cauliflower, mixed vegetables, TVP/soya, quorn, tofu. Vegetable dishes: curries, pulse dishes, casseroles, and stews, pies, vegetable lasagne, cauliflower cheese, vegiburgers, vegetable samosas, ratatouille.
20. **Fruit**. Apples, pears, citrus fruit (oranges, grapefruit, lemons and limes, tangerines, ortananiques), bananas (including baked bananas and banana chips), canned fruit in juice, canned in syrup, other fruit (plums, grapes, apricots), fruit pie fillings, dried fruit, fruit salad.
21. **Sugar and preserves**. Sugar: all types including golden syrup, fructose; preserves: jam, fruit spreads, marmalade, honey, lemon curd.
22. **Fruit juice**. Includes 100% single or mixed fruit juices, canned, bottled, cartons, carbonated, still, freshly squeezed, vegetable juice.
23. **Soft drinks**. Carbonates, concentrated squashes and cordials, ready-to-drink fruit drinks, tonic water; diet/low-calorie soft drinks: carbonates, concentrated squashes and cordials, ready-to-drink fruit drinks, slimline tonics, sugar-free/no added sugar products.
24. **Alcohol**. Liqueurs, spirits, wine, fortified wine, low-calorie and alcohol-free drinks, beer and lager including low-alcohol or free-alcohol lager and beers, cider and perry.
25. **Tea and coffee**. Coffee includes instant and bean coffee, decaffeinated, vending machines with whitener, coffee essence; tea: infusion, instant, decaffeinated, vending machine with whitener, herbal tea.
26. **Soup**. Home-made, dried, condensed, canned.
27. **Sauces and pickles**. White sauces, cook-in sauces, sauce mixes, tomato ketchup, pickles, chutney, gravy, mayonnaise, salad cream, dried herbs, spices.