

# EPIC–Oxford: lifestyle characteristics and nutrient intakes in a cohort of 33 883 meat-eaters and 31 546 non meat-eaters in the UK

Gwyneth K Davey<sup>1,2,\*</sup>, Elizabeth A Spencer<sup>1</sup>, Paul N Appleby<sup>1</sup>, Naomi E Allen<sup>1</sup>, Katherine H Knox<sup>1</sup> and Timothy J Key<sup>1</sup>

<sup>1</sup>Cancer Research UK Epidemiology Unit, University of Oxford, Gibson Building, Radcliffe Infirmary, Oxford OX2 6HE, UK; <sup>2</sup>Present address: Unit of Nutrition and Cancer, International Agency for Research on Cancer, 150 cours Albert Thomas, 69372 Lyon Cedex 08, France

Submitted 5 June 2002; Accepted 10 October 2002

## Abstract

*Objective:* To describe the lifestyle characteristics and nutrient intakes of the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC).

*Design:* Cohort of men and women recruited through general practices or by post to include a high proportion of non meat-eaters. Dietary, anthropometric and lifestyle data were collected at baseline and four diet groups were defined.

*Setting:* United Kingdom.

*Participants:* In total, 65 429 men and women aged 20 to 97 years, comprising 33 883 meat-eaters, 10 110 fish-eaters, 18 840 lacto-ovo vegetarians and 2596 vegans.

*Results:* Nutrient intakes and lifestyle factors differed across the diet groups, with striking differences between meat-eaters and vegans, and fish-eaters and vegetarians usually having intermediate values. Mean fat intake in each diet group was below the UK dietary reference value of 33% of total energy intake. The mean intake of saturated fatty acids in vegans was approximately 5% of energy, less than half the mean intake among meat-eaters (10–11%). Vegans had the highest intakes of fibre, vitamin B<sub>1</sub>, folate, vitamin C, vitamin E, magnesium and iron, and the lowest intakes of retinol, vitamin B<sub>12</sub>, vitamin D, calcium and zinc.

*Conclusions:* The EPIC–Oxford cohort includes 31 546 non meat-eaters and is one of the largest studies of vegetarians in the world. The average nutrient intakes in the whole cohort are close to those currently recommended for good health. Comparisons of the diet groups show wide ranges in the intakes of major nutrients such as saturated fat and dietary fibre. Such variation should increase the ability of the study to detect associations of diet with major cancers and causes of death.

**Keywords**  
Diet  
Vegetarian  
Vegan  
Prospective study

This paper describes the baseline characteristics of the participants in the EPIC–Oxford cohort, focusing on the dietary and lifestyle characteristics of four diet groups: meat-eaters, fish-eaters, vegetarians and vegans. The EPIC–Oxford cohort is part of the European Prospective Investigation into Cancer and Nutrition (EPIC), a cohort of over 500 000 men and women recruited in 10 European countries during the 1990s<sup>1</sup>. EPIC–Oxford is one of two UK EPIC cohorts, the other being EPIC–Norfolk<sup>2</sup>. The strategy for establishing the EPIC–Oxford cohort was to recruit participants with a wide range of diets by targeting vegetarians as well as the general UK population.

## Methods

### Recruitment

Two methods of recruitment were used: general practice (GP) recruitment and postal recruitment. The protocol was approved by the Royal College of General Practitioners' Clinical Research Ethics Committee, the Central Oxford Research Ethics Committee and local research ethics committees. Recruitment from the general population through GPs was carried out by EPIC nurses working in general practice surgeries in Oxfordshire, Buckinghamshire and Greater Manchester. All men and women aged 35 to 69 years on each collaborating GP's list were invited

\*Corresponding author. Email davey@iarc.fr

to participate. Questionnaires were mailed to consenting participants and appointments were made to attend the GP's surgery for an interview with the nurse. The nurse took anthropometric and blood pressure measurements and a 30 ml blood sample, and checked the completed questionnaire. In addition, a pilot recruitment phase was conducted by collaborating GPs in Scotland who recruited 900 women aged 40 to 59 years from those attending the surgery for other reasons. The GP method recruited 7379 participants, comprising 21.2% of the meat-eaters, 1.2% of the fish-eaters, 0.4% of the vegetarians and no vegans.

Postal recruitment, aimed at those aged 20 years and over, was designed to recruit as many vegetarians and vegans as possible. The main questionnaire was mailed directly to all members of The Vegetarian Society of the UK and all surviving participants in the Oxford Vegetarian Study<sup>3</sup>. Respondents were invited to give names and addresses of relatives and friends who might also be interested in receiving a questionnaire. In addition, a short questionnaire (or insert) was distributed to all members of The Vegan Society, enclosed in health/diet-interest magazines and displayed on counters in health-food shops. This was contained on a single A4 sheet, which could be folded and sealed for pre-paid return mailing to the study office. Questions on this insert were limited to four dietary categorisation questions, date and place of birth, sex, height, weight, age left school, smoking history, alcohol consumption and brief medical history. The main questionnaire was then mailed to all those who returned an insert indicating an interest in receiving this. Participants recruited by these postal methods and who completed the main questionnaire were asked if they would be willing to provide a blood sample. The participant's GP was then approached to take a blood sample on behalf of EPIC-Oxford. These two postal methods recruited 58 050 participants, comprising 78.8% of the meat-eaters, 98.8% of the fish-eaters, 99.6% of the vegetarians and all of the vegans.

### **Anthropometry**

Self-reported height and weight were recorded in the main questionnaire, except for the first 2215 participants recruited by a GP or nurse for whom only height and weight measured by the nurse were recorded. For the remaining 5208 participants recruited by nurses we recorded both measured and self-reported height and weight. Self-reported height and weight were used to calculate body mass index (BMI; weight in kilograms divided by the square of height in metres) as reported here. Participants with reported values of height less than 100 cm (men and women), height more than 213 cm in men and height more than 198 cm in women, weight less than 30 kg in men and weight less than 20 kg in women, and BMI less than  $15 \text{ kg m}^{-2}$  or greater than  $60 \text{ kg m}^{-2}$ , were excluded from the data presented. BMI was available for 13 982 men and for 48 749 women.

### **Diet group, food and nutrient intakes**

Participants were categorised into one of four diet groups according to their replies to four questions:

1. 'Do you eat any meat (including bacon, ham, poultry, game, meat pies, sausages)?'
2. 'Do you eat any fish?'
3. 'Do you eat any dairy products (including milk, cheese, butter, yoghurt)?'
4. 'Do you eat any eggs (including eggs in cakes and other baked foods)?'

These questions were designed to clarify dietary habit and to avoid misclassification, which can occur because of the differing diets perceived as 'vegetarian'. From these four questions, four diet groups were established: meat-eaters (those who eat meat), fish-eaters (those who do not eat meat but do eat fish), vegetarians (those who do not eat meat or fish but do eat dairy products and/or eggs) and vegans (those who eat no animal products). For the women recruited in the pilot phase of the study, and the first 1300 men and women recruited by EPIC nurses, these four dietary categorisation questions were not asked and diet group was assigned according to responses provided in the food-frequency questionnaire (FFQ; see below). For 60 participants (five men and 55 women) who failed to complete the four questions and the FFQ adequately it was not possible to assign a diet group; these participants were therefore excluded from the analyses described here.

The FFQ was based on the questionnaire developed for the US Nurses' Health Study<sup>4</sup>. Validation of this FFQ in the UK<sup>5-7</sup> showed that it provided reasonable estimates of usual intakes of important nutrients, whereby Spearman correlation coefficients between individual results from weighed records and the FFQ were: energy 0.52, % energy from carbohydrate 0.69, % energy from protein 0.70, % energy from fat 0.64, alcohol 0.90, non-starch polysaccharides (NSP) 0.57, retinol 0.55, vitamin C 0.54, calcium 0.50 and iron 0.43<sup>7</sup>. The participants in EPIC-Oxford estimated their average frequency of intake of each of 130 foods over the previous 12 months as: never or less than once a month, 1-3 times monthly, once a week, 2-4 times weekly, 5-6 times weekly, once a day, 2-3 times daily, 4-5 times daily and 6+ times daily. Daily mean nutrient intakes were estimated using standard portion sizes, derived largely from the Ministry of Agriculture, Fisheries and Food<sup>8</sup>, and nutrient contents from the fifth edition of *McCance & Widdowson's The Composition of Foods*<sup>9</sup> and its supplements<sup>10-18</sup>. Seventeen of the 130 questions, grouped on the first page of the FFQ, concerned the consumption of meat and fish. If the answer to 'Do you eat any meat or fish?' was 'No', participants were asked to move directly to the next page. Therefore, the 17 meat and fish questions were not completed by vegetarians and vegans. Fifty-two participants failed to complete 70% or more of the relevant food frequency questions and were excluded. Women with estimated daily energy intake of

less than 2.1 MJ (500 kcal) or more than 14.7 MJ (3500 kcal) (620 participants), and men with estimated daily energy intake of less than 3.3 MJ (800 kcal) or more than 16.7 MJ (4000 kcal) (227 participants), were also excluded from the nutrient analyses. Apparently valid nutrient estimates were available for 12 969 men and 43 582 women.

**Lifestyle characteristics**

Smoking habit was categorised as current smoker, ex-smoker or never smoker. Participants also reported smoking duration and amount smoked. Physical activity at work was defined according to the type of current or most recent job, whether a sedentary occupation (e.g. office work), a standing occupation (e.g. shop assistant) or a manual/heavy manual occupation (e.g. construction worker). Education level was assessed according to age at leaving school and qualifications obtained. Marital status was defined as married or living as married; separated or divorced; widowed; or single.

**Medical conditions**

Participants were asked to report if they had been diagnosed with any of the following conditions: myocardial infarction (or heart attack or coronary thrombosis), angina, stroke, hypertension, hyperlipidaemia, diabetes, gallstones, polyps in the large intestine, cancer or any other illness or operations. They were also asked to give details of prescribed medication for any condition.

**Food diary**

A 7-day food diary, chosen for use as a dietary assessment method in conjunction with the FFQ<sup>1</sup>, was distributed to each participant, either at the nurse recruitment interview or, for those who joined the study by post, a few months after the completion of the main questionnaire. A total of

31 088 diaries were completed and returned. The data in the food diaries will be reported in future publications.

**Results**

**Participants**

The main questionnaire was completed by 57 450 participants and data from the insert alone were available for an additional 7979 participants. Participants were recruited from throughout the United Kingdom, with 85% from England, 10% from Scotland, 4% from Wales and 1% from Northern Ireland.

Table 1 shows the age and sex distribution of the cohort, according to diet group. The total cohort comprised 65 429 participants of whom 14 606 (22%) were men and 50 823 (78%) were women. Age ranged from 20 to 97 years. Median age differed between the diet groups, being highest in the meat-eaters and lowest in the vegans. Overall, the median age was 46 years for men and 43 years for women. Median ages for men were 51, 42, 39 and 35 years and for women 48, 39, 35 and 32 years for meat-eaters, fish-eaters, vegetarians and vegans, respectively. Forty-seven per cent of men and 49% of women were non meat-eaters.

The median duration of diet of each of the non-meat-eating groups was 10, 10 and 5 years in men and 9, 8 and 4 years in women for fish-eaters, vegetarians and vegans, respectively. In men, 78% of fish-eaters, 76% of vegetarians and 55% of vegans reported following the diet for 5 years or more. In women, 76% of fish-eaters, 75% of vegetarians and 43% of vegans reported following the diet for 5 years or more.

**Lifestyle characteristics**

Table 2 describes smoking status, physical activity at work, school-leaving age, educational qualifications and marital

**Table 1** Age and sex distribution of the cohort by diet group

Age (years)	Meat-eaters		Fish-eaters		Vegetarians		Vegans		Total	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
<i>Men</i>										
20–	542	30	213	12	781	44	254	14	1790	12
30–	1079	34	492	15	1348	42	307	10	3226	22
40–	1869	52	495	14	1066	29	198	6	3628	25
50–	1832	70	239	9	459	18	76	3	2606	18
60–	1670	77	183	8	258	12	60	3	2171	15
70–	620	68	88	10	179	20	26	3	913	6
80–	155	57	21	8	80	29	16	6	272	2
Total	7767	53	1731	12	4171	28	937	6	14 606	22
<i>Women</i>										
20–	2400	25	1808	19	4778	50	658	7	9644	19
30–	4292	37	2453	21	4383	38	459	4	11 587	23
40–	7410	58	2072	16	3098	24	264	2	12 844	25
50–	6669	72	1144	12	1347	15	127	1	9287	18
60–	3776	74	592	12	614	12	97	2	5079	10
70–	1327	68	249	13	326	17	38	2	1940	4
80–	242	55	61	14	123	28	16	4	442	1
Total	26 116	51	8379	17	14 669	29	1659	3	50 823	78
Total	33 883	52	10 110	15	18 840	29	2596	4	65 429	100

**Table 2** Characteristics of the cohort (percentage in each diet group\*)

	Men					Women				
	Meat-eaters	Fish-eaters	Vegetarians	Vegans	All	Meat-eaters	Fish-eaters	Vegetarians	Vegans	All
Smoking status	(n = 7394)	(n = 1622)	(n = 4002)	(n = 874)	(n = 13 892)	(n = 24 914)	(n = 7801)	(n = 13 858)	(n = 1522)	(n = 48 095)
Never smoked	51	59	61	66	56	63	64	69	67	65
Ex-smoker	39	31	30	27	35	26	27	23	23	25
Current smoker	10	10	9	8	9	11	8	8	10	10
Physical activity at work	(n = 6959)	(n = 1511)	(n = 3754)	(n = 769)	(n = 12 993)	(n = 20 653)	(n = 6786)	(n = 12 108)	(n = 1294)	(n = 40 841)
Sitting	58	57	59	51	58	51	54	53	48	52
Standing	24	27	25	27	25	41	37	37	40	39
Manual	18	16	16	23	17	8	9	10	13	9
Age left school (years)	(n = 7443)	(n = 1675)	(n = 4021)	(n = 901)	(n = 14 040)	(n = 25 222)	(n = 8098)	(n = 14 147)	(n = 1583)	(n = 49 050)
< 16	25	13	13	16	20	24	13	11	13	18
16–17	40	40	43	42	41	44	43	46	47	44
18+	35	46	44	42	39	32	44	43	40	37
Highest qualification	(n = 5230)	(n = 1335)	(n = 3314)	(n = 664)	(n = 10 543)	(n = 16 698)	(n = 5967)	(n = 10 889)	(n = 1148)	(n = 34 702)
CSE or 'O' level	23	16	21	24	21	35	26	27	26	31
'A' level† or HNC	27	23	24	27	26	30	27	29	29	29
Degree	50	61	55	49	53	35	47	44	45	40
Marital status	(n = 7 060)	(n = 1 527)	(n = 3 800)	(n = 792)	(n = 16 179)	(n = 23 346)	(n = 7 002)	(n = 12 459)	(n = 1 344)	(n = 44 151)
Single	13	22	25	41	19	12	22	27	36	18
Married or living as married	77	69	66	50	71	71	63	61	51	67
Separated or divorced	7	8	7	8	7	10	12	9	11	10
Widowed	3	2	2	1	2	7	4	3	2	5

\* Because of rounding the percentages do not always sum to 100.

† Including Scottish Highers.

status, by diet group. Data for activity at work, marital status and qualifications were available only for those participants who completed the main questionnaire. Fifty-six per cent of men and 65% of women had never smoked, indicating a generally health-conscious cohort. In each diet group, 11% or less of men and women currently smoked and differences in the prevalence of smoking between the diet groups were small. More than half the cohort reported having sedentary occupations. Vegans reported the highest levels of manual work, among both men and women. Overall, school-leaving age was similar for men and women with over 80% having left school at age 16 or older. However, approximately 25% of meat-eating men and women left school before age 16, whereas less than 17% of non-meat-eating men and women left school before age 16. Fifty-three per cent of men and 40%

of women were university graduates, indicating a well educated cohort, although this distribution varied by diet group with a higher proportion of both men and women fish-eaters having degrees than the other diet groups. The distribution of married, single, separated or divorced and widowed participants partly reflects the age distributions of the different diet groups: vegans were more likely to be single and meat-eaters more likely to be married.

### **Reproductive factors in women**

Overall, 20% of women aged 40 and above had had no children, ranging from 16% of meat-eaters to 38% of vegans (Table 3). Among parous women, 36% of meat-eaters and vegans and 31% of fish-eaters and vegetarians reported having three or more children. Almost three-quarters of women had used the oral contraceptive pill at

**Table 3** Distribution of reproductive factors in women (percentage in each diet group\*)

	Meat-eaters	Fish-eaters	Vegetarians	Vegans	All
Parity (aged 40+)	(n = 17 687)	(n = 3548)	(n = 4923)	(n = 466)	(n = 26 624)
0	16	25	29	38	20
1	12	13	15	14	13
2	42	38	35	26	40
3+	30	24	21	23	28
Contraceptive pill use (all ages)	(n = 23 051)	(n = 6976)	(n = 12 403)	(n = 1340)	(n = 43 770)
Ever used	70	79	79	70	74
Hormone replacement therapy use (aged 50+)	(n = 10 784)	(n = 1767)	(n = 2152)	(n = 228)	(n = 14 931)
Ever used	43	35	30	19	40
Hysterectomy (aged 50+)	(n = 10 850)	(n = 1778)	(n = 2173)	(n = 233)	(n = 15 034)
Undergone hysterectomy	25	21	18	19	24

\* Because of rounding the percentages do not always sum to 100.

some time, although 10% fewer meat-eaters and vegans had used the oral contraceptive pill than fish-eaters and vegetarians. Forty per cent of those aged 50 and over had used hormone replacement therapy (HRT), with more than twice as much use in meat-eaters compared with vegans. About 24% of those aged 50 and over reported having had a hysterectomy; the proportion of women reporting hysterectomy was higher among meat-eaters than among the other diet groups.

**Body mass index**

Among men, the mean BMIs in the four diet groups were 24.9, 23.6, 23.5 and 22.5 kg m<sup>-2</sup> for meat-eaters, fish-eaters, vegetarians and vegans, respectively, and 24.2 kg m<sup>-2</sup> overall. Among women, the mean BMIs in the four diet groups were 24.3, 22.9, 22.7 and 21.9 kg m<sup>-2</sup> for meat-eaters, fish-eaters, vegetarians and vegans, respectively, and 23.5 kg m<sup>-2</sup> overall.

Figure 1 shows the mean BMI by diet group and 10-year age group. Meat-eaters had the highest mean BMI and vegans had the lowest mean BMI across all age groups for both men and women. The mean BMIs of fish-eaters and vegetarians were very similar to each other and were intermediate between those of meat-eaters and vegans. Overall, 5.1% of men and 6.8% of women were obese (BMI > 30 kg m<sup>-2</sup>). In men aged 20 to 65 years, 7.1% of meat-eaters, 3.0% of fish-eaters, 3.5% of vegetarians and 1.6% of vegans were obese. In women aged 20 to 65 years, 9.3% of meat-eaters, 4.4% of fish-eaters, 4.5% of vegetarians and 2.5% of vegans were obese.

**Nutrient intakes**

Table 4 shows energy and nutrient intakes by sex and diet group. Striking differences in nutrient intakes between meat-eaters and vegans were found, with fish-eaters and vegetarians usually having intermediate values. These patterns were similar for men and women.

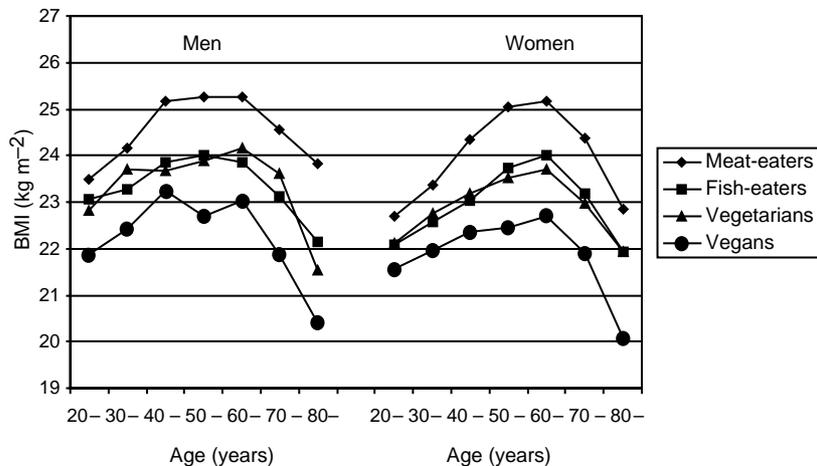
Overall, mean energy intakes were 8.96 MJ and 7.82 MJ in men and women, respectively; mean energy intake for

vegans was approximately 14% lower than that for meat-eaters in both men and women. Carbohydrate provided approximately 50% of energy in both men and women, and mean intakes were highest in the vegans and lowest in the meat-eaters. Mean protein intakes provided 14.7% and 15.8% of energy for men and women, respectively, and were highest in meat-eaters and lowest in vegans. Mean total fat intakes were 31% of energy for both men and women, and were highest in the meat-eaters and lowest in vegans, although this difference was relatively small. The percentage of energy from saturated fat was strikingly different across the four diet groups, with vegans having less than half the mean intake of meat-eaters. Conversely, the percentage of energy from polyunsaturated fat was substantially higher in vegans than in the other diet groups, with a trend of increasing intake from meat-eaters to vegans. Mean alcohol intake was low, providing 4.99% and 2.97% of energy in men and women, respectively; among both men and women the lowest alcohol intake was in the vegans and the highest intake was in the fish-eaters.

Mean fibre intakes, estimated as NSP, were 20.8 and 20.4 g day<sup>-1</sup> in men and women, respectively. Fibre intake was 41% higher in vegan men than in meat-eating men and 36% higher in vegan women than in meat-eating women; mean fibre intakes for fish-eaters and vegetarians were intermediate and similar.

For vitamins, vegans had the highest intakes of vitamin B<sub>1</sub>, folate, vitamin C and vitamin E, and by far the lowest intakes of retinol, vitamin B<sub>12</sub> and vitamin D. Differences between diet groups in the intakes of vitamin B<sub>2</sub>, niacin and vitamin B<sub>6</sub> were small (<10% difference between meat-eaters and vegans). For minerals, vegans had the highest intakes of magnesium and iron, and the lowest intakes of calcium and zinc; differences in potassium intake between diet groups were small (≤5%).

Figure 2 shows the distribution of intakes of saturated fatty acids (percentage of energy), NSP and calcium in women in each of the diet groups. The distributions for



**Fig. 1** Mean body mass index (BMI) by diet group and 10-year age group

**Table 4** Mean daily nutrient intakes by sex and diet group

	Meat-eaters		Fish-eaters		Vegetarians		Vegans		All	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
<i>Men*</i>										
Energy (MJ)	9.18	(2.46)	8.90	(2.43)	8.78	(2.39)	8.01	(2.50)	8.96	(2.46)
% Energy from carbohydrate	46.9	(6.50)	49.8	(6.65)	51.2	(6.77)	54.9	(7.74)	49.0	(7.10)
% Energy from protein	16.0	(2.78)	13.9	(2.23)	13.1	(1.98)	12.9	(2.16)	14.7	(2.84)
% Energy from total fat	31.9	(5.81)	31.1	(6.15)	31.1	(6.26)	28.2	(7.14)	31.4	(6.13)
% Energy from SFA	10.7	(3.29)	9.36	(3.27)	9.37	(3.37)	4.99	(1.85)	9.80	(3.52)
% Energy from PUFA	5.21	(1.89)	5.64	(2.21)	5.67	(2.35)	7.53	(2.91)	5.53	(2.21)
P:S ratio	0.54	(0.25)	0.67	(0.34)	0.68	(0.36)	1.57	(0.45)	0.66	(0.39)
% Energy from alcohol	5.20	(5.73)	5.23	(5.56)	4.69	(5.70)	4.02	(5.78)	4.99	(5.71)
NSP (g)	18.7	(7.13)	22.1	(7.92)	22.7	(7.87)	27.7	(9.38)	20.8	(8.00)
Retinol ( $\mu$ g)	740	(782)	337	(238)	306	(195)	74.2	(94.7)	529	(633)
Vitamin B <sub>1</sub> (mg)	1.69	(0.51)	1.80	(0.58)	1.90	(0.61)	2.29	(0.82)	1.80	(0.59)
Vitamin B <sub>2</sub> (mg)	2.30	(0.75)	2.20	(0.79)	2.23	(0.85)	2.26	(1.21)	2.27	(0.82)
Niacin (mg)	24.7	(7.22)	21.7	(7.19)	20.8	(7.00)	23.9	(9.52)	23.2	(7.53)
Vitamin B <sub>6</sub> (mg)	2.26	(0.62)	2.07	(0.62)	2.03	(0.60)	2.23	(0.74)	2.17	(0.63)
Vitamin B <sub>12</sub> ( $\mu$ g)	7.25	(3.78)	5.01	(2.86)	2.57	(1.42)	0.41	(0.60)	5.23	(3.85)
Folate ( $\mu$ g)	329	(102)	358	(117)	367	(120)	431	(162)	350	(117)
Vitamin C (mg)	119	(56.6)	130	(64.0)	123	(63.2)	155	(86.0)	125	(62.2)
Vitamin D ( $\mu$ g)	3.39	(2.00)	2.90	(2.15)	1.56	(1.20)	0.88	(1.07)	2.66	(2.00)
Vitamin E (mg)	11.8	(6.24)	13.0	(6.63)	13.7	(6.91)	16.1	(8.42)	12.8	(6.74)
Calcium (mg)	1057	(332)	1081	(368)	1087	(408)	610	(241)	1042	(372)
Magnesium (mg)	366	(98.9)	396	(110)	396	(111)	440	(141)	382	(109)
Potassium (mg)	3965	(960)	3940	(1036)	3867	(1042)	4029	(1265)	3937	(1015)
Iron (mg)	13.4	(4.09)	14.0	(4.34)	13.9	(4.34)	15.3	(4.98)	13.8	(4.28)
Zinc (mg)	9.78	(2.74)	8.59	(2.48)	8.44	(2.50)	7.99	(2.68)	9.15	(2.73)
<i>Women†</i>										
Energy (MJ)	8.02	(2.11)	7.75	(2.11)	7.60	(2.10)	6.97	(2.18)	7.82	(2.12)
% Energy from carbohydrate	48.3	(6.14)	51.2	(6.47)	52.9	(6.50)	56.1	(7.77)	50.0	(6.75)
% Energy from protein	17.3	(3.01)	14.9	(2.36)	13.8	(2.14)	13.5	(2.30)	15.8	(3.13)
% Energy from total fat	31.5	(5.93)	30.7	(6.39)	30.4	(6.57)	27.8	(7.40)	31.0	(6.28)
% Energy from SFA	10.4	(3.27)	9.33	(3.31)	9.33	(3.40)	5.11	(2.03)	9.75	(3.42)
% Energy from PUFA	5.19	(1.88)	5.43	(2.12)	5.29	(2.23)	7.20	(2.79)	5.32	(2.08)
P:S ratio	0.54	(0.25)	0.65	(0.32)	0.63	(0.33)	1.49	(0.45)	0.61	(0.33)
% Energy from alcohol	2.89	(3.57)	3.26	(3.80)	3.01	(3.78)	2.63	(3.88)	2.97	(3.68)
NSP (g)	18.9	(6.95)	21.6	(7.81)	21.8	(8.10)	26.4	(9.77)	20.4	(7.73)
Retinol ( $\mu$ g)	654	(617)	308	(253)	277	(180)	76.6	(92.6)	474	(507)
Vitamin B <sub>1</sub> (mg)	1.62	(0.47)	1.72	(0.55)	1.77	(0.59)	2.14	(0.78)	1.69	(0.54)
Vitamin B <sub>2</sub> (mg)	2.19	(0.71)	2.11	(0.76)	2.10	(0.80)	2.13	(1.10)	2.15	(0.76)
Niacin (mg)	23.2	(6.85)	19.5	(6.40)	18.3	(6.40)	21.1	(8.32)	21.1	(7.06)
Vitamin B <sub>6</sub> (mg)	2.17	(0.59)	1.99	(0.58)	1.91	(0.58)	2.08	(0.72)	2.06	(0.60)
Vitamin B <sub>12</sub> ( $\mu$ g)	6.98	(3.29)	4.93	(2.76)	2.51	(1.34)	0.49	(0.70)	5.18	(3.44)
Folate ( $\mu$ g)	321	(100)	346	(113)	350	(121)	412	(158)	336	(112)
Vitamin C (mg)	138	(65.3)	147	(71.1)	147	(74.0)	169	(96.6)	143	(70.2)
Vitamin D ( $\mu$ g)	3.32	(1.91)	2.78	(1.95)	1.51	(1.15)	0.88	(1.00)	2.64	(1.91)
Vitamin E (mg)	10.7	(5.30)	11.4	(5.60)	11.6	(5.85)	14.0	(7.19)	11.2	(5.61)
Calcium (mg)	989	(308)	1021	(344)	1012	(356)	582	(242)	988	(334)
Magnesium (mg)	341	(90.6)	358	(100)	352	(103)	391	(129)	349	(97.6)
Potassium (mg)	3839	(960)	3759	(1032)	3656	(1044)	3817	(1280)	3773	(1010)
Iron (mg)	12.6	(4.13)	12.8	(4.30)	12.6	(4.29)	14.1	(4.81)	12.7	(4.24)
Zinc (mg)	9.16	(2.55)	7.94	(2.31)	7.67	(2.31)	7.22	(2.42)	8.49	(2.55)

SD – standard deviation; SFA – saturated fatty acids; PUFA – polyunsaturated fatty acids; P:S ratio – polyunsaturated fat (g)/saturated fat (g); NSP – non-starch polysaccharides.

\*  $n = 12\,969$ : 6951 meat-eaters; 1500 fish-eaters; 3748 vegetarians; 770 vegans.

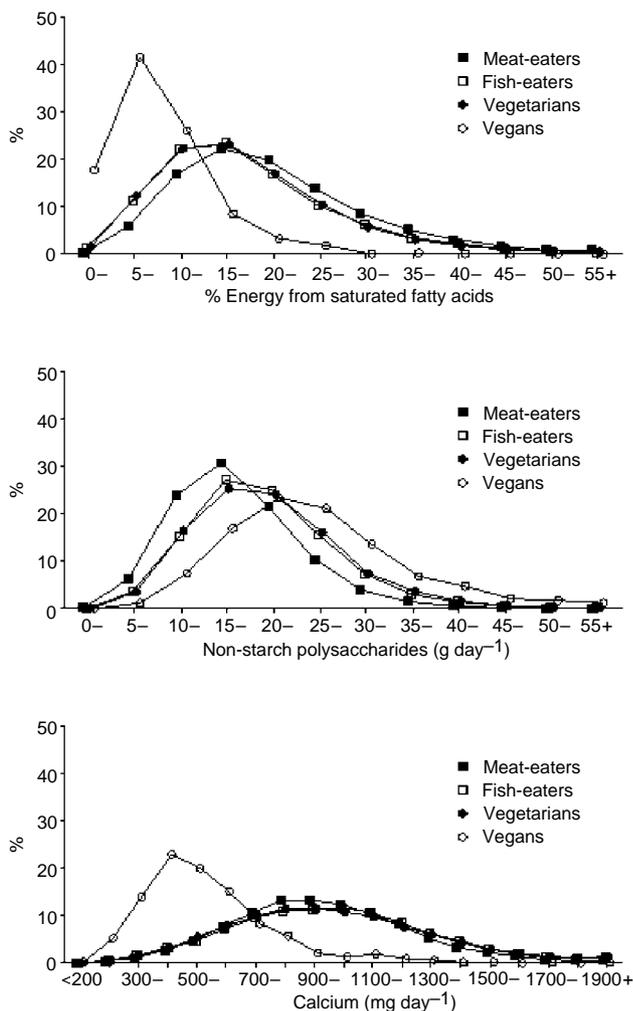
†  $n = 43\,582$ : 22 962 meat-eaters; 6931 fish-eaters; 12 347 vegetarians; 1342 vegans.

men were very similar (data not shown). The distributions of saturated fatty acids intake in fish-eaters and vegetarians were almost identical; for meat-eaters, the distribution was similar to that for fish-eaters and vegetarians but around a slightly higher mean. For vegans, however, the distribution of saturated fatty acids intake was much narrower around a much lower mean. There was a wide range of NSP intake in each diet group, with a higher mean intake in vegans than in the other diet groups. Again, the

distributions for fish-eaters and vegetarians were very similar. Calcium intake in vegans was much lower, with a narrower distribution, compared with the other diet groups.

### Medical conditions

Among men, 3% reported myocardial infarction, heart attack or coronary thrombosis, 4% reported angina, 1% reported stroke, 12% reported hypertension, 8% reported



**Fig. 2** Distribution of intakes of saturated fatty acids (percentage of energy), non-starch polysaccharides and calcium in women, by diet group

hyperlipidaemia, 2% reported diabetes, 2% reported gallstones, 0.8% reported polyps in the large intestine and 3% reported cancer. Among the women, 1% reported myocardial infarction, heart attack or coronary thrombosis, 1% reported angina, 0.5% reported stroke, 12% reported hypertension, 5% reported hyperlipidaemia, 1% reported diabetes, 4% reported gallstones, 0.6% reported polyps in the large intestine and 5% reported cancer. The prevalence of these conditions was different between the diet groups but this was strongly affected by differences in age, and is not reported here.

**Discussion**

Recruitment of participants into EPIC–Oxford was successful in establishing a large cohort of people with a wide range of dietary intakes. About 50% of participants reported that they did not eat meat and the EPIC–Oxford cohort currently includes the largest number of vegetarians of any comparable study in the world. In a pooled

analysis of mortality rates in vegetarians in five prospective studies for which data were available in the mid-1990s, the total number of vegetarians in the five cohorts was 27 808, with the largest single study including about 10 000 vegetarians<sup>19</sup>. By comparison, EPIC–Oxford includes 21 436 vegetarians and vegans, of whom 18 207 provided complete dietary data. None of the other cohorts contributing to the whole EPIC collaboration across Europe has recruited a large proportion of vegetarians, but another cohort in the UK has been established with targeted recruitment of vegetarians which includes 33 971 women of whom 9793 described themselves as vegetarian<sup>20</sup>.

Age differed substantially between the diet groups in both men and women, with median age at recruitment decreasing progressively from meat-eaters to fish-eaters, vegetarians and vegans. This probably explains some of the differences in lifestyle and dietary choices observed between the diet groups. Overall, in this cohort, 56% of men and 65% of women have never smoked. This is a larger proportion than the 40% of men and 52% of women in England in 1996<sup>21</sup> who had never smoked and current smoking levels were far lower in this cohort than in the general population of England. In men, the prevalence of smoking was lowest in the vegan group, whereas, among women, prevalence of smoking was lowest among fish-eaters and vegetarians.

Manual work, which included employment in horticultural and other environmental occupations together with factory and building site occupations, was most prevalent in vegans among both men and women.

The age distribution of the cohort may explain the differences in education levels observed between the diet groups. Meat-eaters, being older, would have had more opportunity to leave school before the age of 16, whereas younger non meat-eaters would have had greater opportunity to complete further and higher education. Legislation in the UK raised the minimum school-leaving age at various times over the latter half of the last century and it is currently set at 16 years. More recent developments in education have considerably broadened the accessibility of higher education. However, this does not explain why the proportion of vegan men with degrees was slightly less than the proportions in the other diet groups. Overall, this is a predominantly well educated cohort.

For women aged 40 and over, notable differences in parity were reported. The observation that 38% of vegan women in this age category were nulliparous compared with 16% of meat-eaters might indicate a preference for vegan women to choose not to have children. However, among parous women aged 40 and over, the proportions with larger families (i.e. three or more children) were highest for vegans (38%) and meat-eaters (36%) and somewhat lower for fish-eaters and vegetarians (31%).

Use of the oral contraceptive pill did not differ greatly between diet groups. In women aged 50 and over,

however, the percentage of women who had ever used HRT was over twice as high in meat-eaters as in vegans and the percentage of women who had had a hysterectomy was substantially lower among vegetarians and vegans than among meat-eaters.

In this study, mean BMI for those aged 20 to 64 years was  $24.2 \text{ kg m}^{-2}$  for men and  $23.5 \text{ kg m}^{-2}$  for women; 8.6% of men and 9.7% of women were classified as obese. In England in 1995, mean BMI at ages 16 to 64 years was reported as  $26.0 \text{ kg m}^{-2}$  for men and  $25.6 \text{ kg m}^{-2}$  for women, with 15.0% of men and 16.5% of women being obese<sup>22</sup>. We have previously shown that self-reported height and weight data in this cohort are valid but do lead to a small, systematic, underestimation of BMI<sup>23</sup>. On average, the underestimation was  $0.96$  (95% confidence interval (CI)  $0.90\text{--}1.01$ )  $\text{kg m}^{-2}$  in men and  $0.72$  (95% CI  $0.67\text{--}0.77$ )  $\text{kg m}^{-2}$  in women, indicating that the true mean BMI of the men and women in EPIC-Oxford is probably about  $1 \text{ kg m}^{-2}$  lower than the national average. Within the study, there were substantial differences in mean BMI between the four diet groups, with fish-eaters and vegetarians having a mean BMI about  $1 \text{ kg m}^{-2}$  lower than meat-eaters, and vegans having a mean BMI about  $2 \text{ kg m}^{-2}$  lower than meat-eaters. The determinants of these differences in BMI between diet groups are difficult to identify, although it appears that the composition of the diet may be of considerable importance<sup>24</sup>.

Estimated mean energy intakes were 15% below the average requirements in men and 3% below the average requirements in women. The mean energy intakes for meat-eaters reported here are very similar to those reported from EPIC-Norfolk<sup>25</sup> using the same FFQ. Uniform portion sizes were assigned for men and women and it is possible that this resulted in underestimation of energy intake particularly for men. This may also partly explain the lower energy intakes reported by vegetarians and vegans, since these individuals may eat larger portions of staple foods such as bread and potatoes. Seven-day food diaries were completed by 31 000 participants and these will provide further information on energy intake. Preliminary analysis of a sample of 150 food diaries indicates that the FFQ does indeed underestimate intakes of energy, and therefore of most nutrients, among vegans (unpublished data).

Overall, this cohort reported macronutrient intakes close to the guidelines for a healthy diet as recommended by the Department of Health<sup>22</sup> in 1995, and which differed in some respects from intakes reported for the UK general population in the Dietary and Nutritional Survey of British Adults<sup>26</sup> in 1990, supporting the description of this cohort as 'health-conscious'. Percentage energy from carbohydrate slightly exceeded the Dietary Reference Value (DRV) of 47%<sup>27</sup>, and was highest among the vegans. Overall, the percentage energy from protein was very similar to that reported in the national nutritional survey<sup>26</sup> although it was substantially higher among the meat-eaters

than among the other dietary groups, and the lowest protein intake was among the vegans. The mean percentage energy from total fat was slightly below the DRV of 33% in all four diet groups. The percentage energy from saturated fat was on average below the DRV of 10% although the mean intake among meat-eaters slightly exceeded this. However, even the meat-eaters had a much lower percentage energy from saturated fat intake than that reported for UK adult men (15.4%) and women (16.5%)<sup>26</sup>. The percentage energy from polyunsaturated fatty acids (DRV 6%) averaged between 5% and 6% in all diet groups except vegans, among whom the mean intake was above 7%.

Micronutrient intakes also differed markedly between the dietary groups. In comparison with the other diet groups, vegans had the highest intakes of fibre, vitamin B<sub>1</sub>, folate, vitamin C, vitamin E, magnesium and iron, and the lowest intakes of retinol, vitamin B<sub>12</sub>, vitamin D, calcium and zinc. Differences between diet groups in the intakes of vitamin B<sub>2</sub>, niacin, vitamin B<sub>6</sub> and potassium were small.

Mean micronutrient intakes in all four dietary groups were generally well above the Reference Nutrient Intakes (RNI) for the UK, with the following exceptions. Mean dietary vitamin B<sub>12</sub> intake among vegans was  $0.41 \mu\text{g day}^{-1}$  in men and  $0.49 \mu\text{g day}^{-1}$  in women, well below the RNI of  $1.5 \mu\text{g day}^{-1}$ . The actual intakes of vitamin B<sub>12</sub> might be greater than this, because the number of foods fortified with this vitamin has increased in recent years and this may not be fully reflected by current food tables. Furthermore, the estimates reported here also do not include vitamin B<sub>12</sub> in nutritional supplements. Mean calcium intake in vegans ( $610 \text{ mg day}^{-1}$  in men,  $582 \text{ mg day}^{-1}$  in women) was also below the RNI of  $700 \text{ mg day}^{-1}$ , but again the actual intakes may be higher than this because of increasing fortification of foods, such as soy products, and because the FFQ may cause some overall underestimation of nutrient intakes in vegans. For iron, women in all four dietary groups had mean intakes below the RNI for premenopausal women of  $14.8 \text{ mg day}^{-1}$ ; the estimated iron intake was highest in the vegan women, but the bioavailability of this iron would be expected to be lower than in the meat- and fish-eaters because of the absence of haem iron in vegan diets. Mean zinc intakes among men were below the RNI of  $9.5 \text{ mg day}^{-1}$  in fish-eaters, vegetarians and vegans, but just above this value in meat-eaters ( $9.78 \text{ mg day}^{-1}$ ).

Data on the use of supplements are available for coding from the FFQ and will be used in future analyses. Forty-five per cent of men and 61% of women reported taking nutritional supplements. Additionally, the possible underestimation of nutrient intakes, especially for vegan men, caused by the FFQ will be addressed in future analyses using additional information from the questionnaire, whereby participants were asked to give details of foods usually eaten that were not contained in the FFQ.

Mean values for both macro- and micronutrients reported here for meat-eaters are very similar to those reported in EPIC–Norfolk<sup>25</sup>, except that alcohol intake was slightly higher in EPIC–Oxford. With the inclusion of 50% of non meat-eaters in the Oxford cohort there is a wide distribution of nutrient intakes which should facilitate the identification of associations between dietary factors and the incidence of major cancers and causes of death. Analyses will be conducted both within the EPIC–Oxford cohort itself and in combination with data from the other EPIC–Europe cohorts, as appropriate. Analyses to date have concentrated on examining the possible associations of diet with levels of hormones that are associated with the development of some types of cancer. These analyses have shown that levels of androgens and oestrogens do not vary with diet group in men<sup>28</sup> or women<sup>29</sup> and that consumption of soy products in this cohort is not associated with sex hormone levels in men<sup>30</sup> or women<sup>31</sup>. In contrast, levels of insulin-like growth factor-I were found to differ significantly by diet group; levels were lower in vegans (but not in vegetarians) than in meat-eaters<sup>28,32</sup>. Preliminary analyses of mortality rates, after the first 5 years of follow-up, have shown that the mortality rates in the cohort overall are much lower than the national average<sup>33</sup>. We intend to follow the long-term health of the participants in EPIC–Oxford over the next 10 years to identify any associations with dietary factors, with particular emphasis on cancer incidence and mortality rates.

### Acknowledgements

We thank all of the participants in this study; the GPs and practice staff who have generously assisted in the recruitment of participants; the EPIC staff at the Cancer Research UK Epidemiology Unit, University of Oxford; and Dr Clifford Kay, Professor Philip Hannaford and Professor David Forman, who worked on the first phase of the study. EPIC–Oxford is supported by Cancer Research UK, the Medical Research Council, and the European Commission under the Europe Against Cancer Programme.

### References

- Riboli E. Nutrition and cancer: background and rationale of the European Prospective Investigation into Cancer and Nutrition (EPIC). *Ann. Oncol.* 1992; **3**: 783–91.
- Day N, Oakes S, Luben R, Khaw K-T, Bingham S, Welch A, *et al.* EPIC–Norfolk: study design and characteristics of the cohort. *Br. J. Cancer* 1999; **80**(Suppl. 1): 95–103.
- Appleby PN, Thorogood M, Mann JI, Key TJ. The Oxford Vegetarian Study: an overview. *Am. J. Clin. Nutr.* 1999; **70**(Suppl): 525S–31S.
- Willett WC, Sampson L, Browne ML, Stampfer MJ, Rosner B, Hennekens CH, *et al.* The use of a self-administered questionnaire to assess diet four years in the past. *Am. J. Epidemiol.* 1988; **127**: 188–99.
- Bingham SA, Gill C, Welch A, Day K, Cassidy A, Khaw KT, *et al.* Comparison of dietary assessment methods in nutritional epidemiology: weighed records *v.* 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br. J. Nutr.* 1994; **72**: 619–43.
- Bingham SA, Cassidy A, Cole TJ, Welch A, Runswick SA, Black AE, *et al.* Validation of weighed records and other methods of dietary assessment using the 24 h urine nitrogen technique and other biological markers. *Br. J. Nutr.* 1995; **73**: 531–50.
- Bingham SA, Gill C, Welch A, Cassidy A, Runswick SA, Oakes S, *et al.* Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. *Int. J. Epidemiol.* 1997; **26**(Suppl. 1): S137–51.
- Ministry of Agriculture, Fisheries and Food. *Food Portion Sizes*, 2nd ed. London: HMSO, 1993.
- Holland B, Welch AA, Unwin ID, Buss DH, Paul AA, Southgate DAT. *McCance & Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1991.
- Holland B, Unwin ID, Buss DH. *Vegetables, Herbs and Spices. Fifth Supplement to McCance & Widdowson's The Composition of Foods*. Cambridge: Royal Society of Chemistry, 1991.
- Holland B, Unwin ID, Buss DH. *Fruit and Nuts. First Supplement to McCance & Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1992.
- Holland B, Welch AA, Buss DH. *Vegetable Dishes. Second Supplement to McCance & Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1992.
- Holland B, Brown J, Buss DH. *Fish and Fish Products. Third Supplement to McCance & Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1993.
- Chan W, Brown J, Buss DH. *Miscellaneous Foods. Fourth Supplement to McCance and Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1994.
- Chan W, Brown J, Lee SM, Buss DH. *Meat, Poultry and Game. Fifth Supplement to McCance & Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1995.
- Chan W, Brown J, Church SM, Buss DH. *Meat Products and Dishes. Sixth Supplement to McCance & Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry, 1996.
- Holland B, Unwin ID, Buss DH. *Cereals and Cereal Products. Third Supplement to McCance & Widdowson's The Composition of Foods*, 4th ed. Cambridge: Royal Society of Chemistry, 1988.
- Holland B, Unwin ID, Buss DH. *Milk Products and Eggs. Fourth Supplement to McCance & Widdowson's The Composition of Foods*, 4th ed. Cambridge: Royal Society of Chemistry, 1989.
- Key TJ, Fraser GE, Thorogood M, Appleby PN, Beral V, Reeves G, *et al.* Mortality in vegetarians and non-vegetarians: a collaborative analysis of 8300 deaths among 76 000 men and women in five prospective studies. *Public Health Nutr.* 1998; **1**: 33–41.
- Greenwood DC, Cade JE, Draper A, Barrett JH, Calvert C, Greenhalgh A. Seven unique food consumption patterns identified among women in the UK Women's Cohort Study. *Eur. J. Clin. Nutr.* 2000; **54**: 314–20.
- Department of Health. *Health Survey for England: Trend Data for Adults 1993–1999*, Table 9 [online]. Available at [www.doh.gov.uk/stats/trends1.htm](http://www.doh.gov.uk/stats/trends1.htm). Accessed 2 May 2002.

- 22 Department of Health. Prescott-Clarke P, Primatesta P, eds. *Health Survey for England 1995. Vol. 1. Findings*. London: The Stationery Office, 1997.
- 23 Spencer EA, Appleby PN, Davey GK, Key TJ. Validity of self-reported height and weight in 4808 EPIC–Oxford participants. *Public Health Nutr.* 2002; **5**: 561–65.
- 24 Spencer EA, Appleby PN, Davey GK, Key TJ. Diet and body mass index in 38,000 EPIC–Oxford meat-eaters, fish-eaters, vegetarians and vegans. *Int. J. Obes.* 2002; in press.
- 25 Bingham SA, Welch AA, McTaggart A, Mulligan AA, Runswick SA, Luben R, *et al.* Nutritional methods in the European Prospective Investigation of Cancer in Norfolk. *Public Health Nutr.* 2001; **4**: 847–58.
- 26 Gregory J, Foster K, Tyler H, Wiseman H. *The Dietary and Nutritional Survey of British Adults*. London: HMSO, 1990.
- 27 Department of Health. *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*. Report of the Panel on Dietary Reference Values. Report on Health and Social Subjects No 41. London: HMSO, 1991.
- 28 Allen NE, Appleby PN, Davey GK, Key TJ. Hormones and diet: low insulin-like growth factor-I but normal bioavailable androgens in vegan men. *Br. J. Cancer* 2000; **83**: 95–7.
- 29 Thomas HV, Davey GK, Key TJ. Oestradiol and sex hormone-binding globulin in premenopausal and post-menopausal meat-eaters, vegetarians and vegans. *Br. J. Cancer* 1999; **80**: 1470–5.
- 30 Allen NE, Appleby PN, Davey GK, Key TJ. Soya milk intake in relation to serum sex hormone levels in British men. *Nutr. Cancer* 2001; **41**: 41–6.
- 31 Verkasalo PK, Appleby PN, Davey GK, Key TJ. Soy milk intake and plasma sex hormones: a cross-sectional study in pre- and postmenopausal women (EPIC–Oxford). *Nutr. Cancer* 2001; **40**: 79–86.
- 32 Allen NE, Appleby PN, Davey GK, Kaaks R, Rinaldi S, Key TJ. Circulating total and bioavailable insulin-like growth factor-I is lower among vegan women compared with vegetarians and meat-eaters. *Cancer Epidemiol. Biomark. Prev.* 2002; **11**: 1441–8.
- 33 Key TJ, Appleby PN, Davey GK, Allen NE, Spencer EA, Travis RC. Mortality in British vegetarians: review and preliminary results from EPIC–Oxford. *Am. J. Clin. Nutr.* 2002; in press.