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Energy intake and sources of energy intake in the European Prospective Investigation into Cancer and Nutrition

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Objectives: To describe energy intake and its macronutrient and food sources among 27 regions in 10 countries participating in the European Prospective Investigation into Cancer and Nutrition (EPIC) study.
Methods: Between 1995 and 2000, 36 034 subjects aged 35–74 years were administered a standardized 24-h dietary recall. Intakes of macronutrients (g/day) and energy (kcal/day) were estimated using standardized national nutrient databases. Mean

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Contributors: MO carried out statistical analysis, prepared tables and figures and wrote the paper, taking into account comments from all co-authors. NS was the overall coordinator of this project and of the EPIC nutritional databases (ENDB) project. MO, NS, NL, SG, SB, PF, SS, VB, JL and EW were members of the writing group and gave input on statistical analysis, drafting of the paper and interpretation of results. The other co-authors were local EPIC collaborators involved in the collection of data, and in documenting, compiling and evaluating the subset of their national nutrient databases used in the ENDB. ER is the overall coordinator of the EPIC study.

intakes were weighted by season and day of the week and were adjusted for age, height and weight, after stratification by gender. Extreme low- and high-energy reporters were identified using Goldberg's cutoff points (ratio of energy intake and estimated basal metabolic rate <0.88 or >2.72), and their effects on macronutrient and energy intakes were studied.
Results: Low-energy reporting was more prevalent in women than in men. The exclusion of extreme-energy reporters substantially lowered the EPIC-wide range in mean energy intake from 2196–2877 to 2309–2866 kcal among men. For women, these ranges were 1659–2070 and 1873–2108 kcal. There was no north–south gradient in energy intake or in the prevalence of low-energy reporting. In most centres, cereals and cereal products were the largest contributors to energy intake. The food groups meat, dairy products and fats and oils were also important energy sources. In many centres, the highest mean energy intakes were observed on Saturdays.
Conclusions: These data highlight and quantify the variations and similarities in energy intake and sources of energy intake among 10 European countries. The prevalence of low-energy reporting indicates that the study of energy intake is hampered by the problem of underreporting.

Introduction

Nowadays, in Europe, an enormously rich variety of foods is available on the market, and this very abundance, especially of energy-dense foods and drinks, is considered to be one of the factors leading to energy intakes higher than individual biological and physiological requirements (Swinburn *et al.*, 2004). People whose energy intake is high in comparison with their energy expenditure gain weight and ultimately develop overweight or even obesity. Thus, together with a low level of physical activity, dietary energy intake is of major importance in the aetiology of obesity (Swinburn *et al.*, 2004; Branca *et al.*, 2007).

Dietary monitoring in Europe is organized at the national level and is not standardized across countries (Brussaard *et al.*, 2002; Elmadfa and Weichselbaum, 2005). For this reason, there are no comparable data on energy intakes across Europe, apart from some studies on specific populations (de Groot *et al.*, 1999). Moreover, energy intake is difficult to measure. The doubly-labelled water method, the only golden standard method, cannot be applied to large-scale studies because of its high cost and sophisticated laboratory requirements (Livingstone and Black, 2003). Other methods that rely on self-reporting of food consumption may suffer from systematic underreporting (Kipnis *et al.*, 2003).

In the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study, highly standardized 24-h dietary recalls (24-HDR) were collected from almost 37 000 participants randomly selected from among 27 regions in 10 European countries (Slimani *et al.*, 2002). In addition, a harmonized nutrient database was compiled (Slimani *et al.*, 2007), which allows a reliable comparison of energy intakes between these countries. To provide advice to policy makers and evaluate dietary policies with regard to overweight and obesity, it is important that nationally representative and comparable data on energy intake (and expenditure) of good quality become available for all European countries. Although the study populations of the EPIC cohort study are not nationally representative samples of the European general populations, results from the EPIC calibration study may identify important differences in energy intakes and profiles across Europe.

In this descriptive paper, we examine variations in energy intake among 27 regions, in different population subgroups and by day of the week. In addition, the relative contributions of macronutrients and various food groups to energy intake are presented.

Materials and methods

Study population

The EPIC calibration study was nested within the European Prospective Investigation into Cancer and Nutrition, a multicentre cohort study aimed at investigating the association between diet, cancer and other chronic diseases across 10 European countries: Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Spain, Sweden and the United Kingdom (Riboli *et al.*, 2002; Slimani *et al.*, 2002). EPIC participants were mostly recruited from the general population residing within defined geographical areas, with some exceptions: women members of a health insurance for school employees (France); women attending breast cancer screening (Utrecht, the Netherlands); blood donors (some centres in Italy and Spain) and a cohort consisting predominantly of vegetarians ('health-conscious' cohort in Oxford, UK). In Norway, participants from the entire country were included (Slimani *et al.*, 2002). The original 23 administrative EPIC centres were reclassified into 27 regions according to a geographical south–north gradient. Nineteen of the 27 EPIC regions had both female and male participants, and eight recruited only women: regions belonging to France, Norway, Utrecht (the Netherlands) and Naples (Italy). Individual habitual dietary intake was assessed using different questionnaires in each country (Riboli *et al.*, 2002). The calibration study was undertaken between 1995 and 2000 to express individual dietary intakes according to the same reference scale and to partially correct diet–disease associations for attenuation due to measurement errors (Ferrari *et al.*, 2004). The calibration population sample consisted of 36 994 participants, that is, an ~8% stratified random sample of the total EPIC cohort.

A total of 36 034 subjects with 24-HDR data were included in this analysis, after exclusion of 960 subjects aged under 35 or over 74 years because of low participation in these age categories. Approval for the study was obtained from the ethical review boards of the International Agency for Research on Cancer (Lyon, France) and from all local recruiting institutes. All participants provided written informed consent.

Measurements of diet and other lifestyle factors

Previous publications outline in detail the rationale, methodology and population characteristics of the 24-HDR calibration study (Kaaks *et al.*, 1994, 1995; Slimani *et al.*, 2002; Ferrari *et al.*, 2008). In brief, each participant provided a single 24-HDR in a face-to-face interview, except in Norway, where it was obtained by telephone interview (Brustad *et al.*, 2003). A computerized interview programme, named EPIC-SOFT, was developed to conduct highly standardized 24-HDR interviews (Slimani *et al.*, 1999, 2000). The interviews were distributed over various seasons and over different days of the week. In most countries, for logistical constraint reasons, interviews with regard to diet on Saturday were conducted on Monday, whereas for all other days of the week, the interview was conducted the following day. The classification of the EPIC-SOFT food (sub-) groups used in the calibration study is derived from a system described in detail elsewhere (Slimani *et al.*, 2002).

Energy intakes (kcal/day) and contributions of total carbohydrates, fat, protein and alcohol were estimated from the 24-HDR using country-specific food composition tables that were standardized across countries to allow comparisons at the nutrient level. The EPIC Nutrient Database (ENDB) project outlines in detail the methods used to standardize the national nutrient databases across the 10 countries, including matching of EPIC foods to the national databases, deriving nutrient values of unavailable foods and imputing missing values (Slimani *et al.*, 2007). The energy content of a food was calculated as the sum of the factored contributions from standardized protein, carbohydrates, fat and alcohol using the Atwater factors in kJ 17, 17, 37 and 29 (in kcal 4, 4, 9 and 7) per gram of protein, carbohydrate, fat and alcohol, respectively.

The ratio of reported energy intake (EI) to estimated basal metabolic rate (BMR) based on Schofield equations (Schofield, 1985) was used to ascertain the magnitude of misreporting. Goldberg's cutoff points for a single day in populations with a sedentary lifestyle, physical activity level (PAL) of 1.55 (Goldberg *et al.*, 1991), were used to identify participants with a physiologically extreme-energy intake (low-energy reporter = EI/BMR < 0.88 and high-energy reporter = EI/BMR > 2.72) as outlined previously (Ferrari *et al.*, 2002).

Data on other lifestyle factors, including education level, total physical activity and smoking history, considered in this analysis were collected at baseline through standardized questionnaires and clinical examinations, and have been described for the calibration sample elsewhere (Haftenberger *et al.*, 2002; Riboli *et al.*, 2002; Slimani *et al.*, 2002). Data on age as well as body weight and height were self-reported by participants during the 24-HDR interview. The mean time interval between these baseline questionnaire measures and the 24-HDR interview varied by country, from 1 day to 3 years later (Slimani *et al.*, 2002).

Statistical methods

Data are presented as mean intakes and s.e., stratified by study centre and gender. Mean energy intakes were adjusted for age (except when stratified by age), height and weight and were weighted by season and day of the week of recall using generalized linear models to control for different distributions of 24-HDR interviews across seasons and days of the week. We examined the effect of exclusion of extreme-energy reporters and of not adjusting for height and weight on mean energy intakes and centre rankings.

The contribution of macronutrients and food groups to total energy intakes was calculated and expressed as energy percent (E%). For food subgroups, the contribution of energy intake from the subgroup to energy intake from the main food group was calculated. These analyses were adjusted for age but not for height and weight because we wanted to describe the actual composition of the diet in European populations. The effects of exclusion of extreme-energy intake were examined because misreporting may be more pronounced for certain macronutrients (Livingstone and Black, 2003).

We also performed stratified analyses to determine differences in energy intake according to age (10-year age groups), body mass index (BMI) category (<25; 25–30; >30 kg/m^2), smoking status (never; ex; current), education level (none or primary school; technical/professional/secondary school; university), category of physical activity (inactive; moderately inactive; moderately active; active), season (quarters of the year) and day of the week. Stratification for physical activity could not be performed for Umeå and for the Norwegian cohorts, because their data were not comparable. In stratified analyses, we retained age, weight and height in the models in addition to weighting by season and day of the week. The stratified analyses were performed by country rather than by centre to prevent many cells with small numbers. As the health-conscious cohort in the United Kingdom is so different from the general population cohort, these two groups were kept separate.

Analyses were performed using SAS (version 9.1, SAS Institute, Cary, NC, USA).

Results

Mean intakes of energy

After adjustment for age, height and weight and weighting by season and day of 24-HDR, centre-specific mean reported energy intakes ranged from 2196 to 2877 kcal/day among men and from 1659 to 2070 kcal/day among women (Table 1). There was no north–south gradient in energy intake. In about one in four male cohorts and one in seven female cohorts, energy intake decreased with age, whereas in Varese (Italy), an increase with age was observed among men. Without adjustment for weight and height, mean energy intakes in the southern European centres were about 20–100 kcal (that is, 1–6%) lower, whereas in most other centres, mean intakes were higher (up to 70 kcal; that is, 0–3%) (Table A1 in Appendix). Additional adjustment for physical activity (not possible for Norway and for Umeå, Sweden) had a minor impact on centre-specific mean energy intakes: the changes ranged from a decrease of 18 kcal to an increase of 30 kcal/day, which is about 1% of total mean energy intake (data not shown).

Low-energy reporting was more prevalent in women than in men (Table 2). Among male participants, the percentage of low-energy reporters (EI/BMR ratio <0.88) ranged from 4% in San Sebastian (Spain) to 18% in Greece. Among women, low-energy reporting ranged from 6% in northwest France to 32% in Greece. Low-energy reporting was more prevalent among the 6835 participants who were following a special diet (19% of the study population). In subjects not on a special diet, low-energy reporting ranged from 0 to 16% in men and from 4 to 29% in women (data not shown). The percentage of high-energy reporters (EI/BMR >2.72) was low in both genders, with the highest percentages (4–5%) observed in Ragusa (Italy). There was no north–south gradient in extreme-energy reporting. After exclusion of the 5211 extreme-energy reporters (14.5%), age-, height- and weight-adjusted mean energy intakes changed considerably for some centres (Table 2 vs Table 1). With some exceptions among men, mean energy intake generally increased, illustrating the significantly larger proportion of low-energy reporters compared with high-energy reporters. For men, the average change was an increase of 3% in centre-specific energy intakes and the largest impact of about 170 kcal ($\sim$7%) was seen in Malmö and Greece. For men, after exclusion of extreme-energy reporters, the lowest mean daily energy intake of 2309 kcal was still observed in the UK health-conscious cohort and the highest still in San Sebastian (2866 kcal/day). For women, exclusion of extreme-energy reporters resulted in an average increase of 5% in centre-specific mean energy intakes. France was the only country in which the increase in all centres was less than 5%. In contrast, the largest change of about 215 kcal (13%) was observed in Greek women. As a consequence, the mean daily energy intake among Greek women became similar to the energy intake among women in Granada (Spain) and in the UK general population cohort. For women, the range in energy intake became 1873–2108 after exclusion of extreme-energy reporters. After exclusion of extreme-energy reporters, the maximum difference in mean adjusted energy intake across centres decreased from about 680 to 560 kcal in men, and from 410 to 240 kcal in women (Table 2 vs Table 1).

Contributions of macronutrient intake to total energy intake

Table 3 presents the age-adjusted mean contributions of macronutrient intake to total energy intake on the basis of the whole study population. The highest mean proportions of fat intake were observed in the Greek cohort (men 40.7 E%, women 42.2 E%). The lowest proportions of fat were observed in Italy; for men it was <30 E% in all Italian centres and for women it was <33 E% in three of the Italian centres, and also in the UK general population cohort. Centres with a high mean contribution of energy from fat generally had a low contribution from carbohydrates and vice versa (correlation coefficient −0.8). The range in the mean contribution of carbohydrate intake to total energy intake was 35–50 E%. In the UK health-conscious cohort, the highest mean E% of carbohydrates ($\sim$50 E%) and the lowest E% of protein ($\sim$13 E%) were observed in both men and women. In other centres, the mean protein intake ranged between 14 and 21 E%. In men, there seemed to be a north–south gradient; the mean contribution of protein to energy intake was $\geqslant$16 E% in centres in Mediterranean countries, but it was lower in other centres. Such a gradient was less clear in women. The mean contribution of alcohol to energy intake was highest in Copenhagen (men 9.2 E%, women 6.9 E%). The lowest contribution of alcohol was observed in Umeå for men (2.5 E%) and in Granada for women (1.1 E%). In all centres, the average contribution of alcohol to energy intake was higher in men than in women.

Exclusion of extreme-energy reporters gave slightly different results (Data not shown but available on the EPIC website (http://epic.iarc.fr)). The mean contributions of fat and alcohol increased slightly (average increase in fat of 0.2 E% for men and 0.5 E% for women over centres, and an average increase in alcohol of 0.1 E% for both genders), whereas the contributions of carbohydrates and protein decreased slightly (average changes in carbohydrates over centres: men −0.2 E%, women −0.3 E%; average changes for protein over centres: men −0.2 E%, women −0.4 E%).

Contributions of food groups to total energy intake

The age-adjusted proportions of total energy intake contributed by the EPIC-SOFT food groups stratified by gender are shown in Figures 1a and b. The tables related to these figures are given on the EPIC website (http://epic.iarc.fr). The distribution of energy intake within subgroups of the main EPIC-SOFT food groups is described in the text, where relevant.

In almost all centres, cereals and cereal products made the largest contribution to energy intake, but the proportion varied considerably, ranging from 14.7 to 34.3 E% in men and from 14.0 to 30.4 E% in women (Figure 1). In all Italian centres, cereals contributed to more than one-quarter of energy intake. This was also the case for men in the Greek and UK health-conscious cohorts. Of all the energy provided by the cereal group, bread contributed 75% in Greece and $\sim$50–60% in Italy and in the UK health-conscious group;

Table 1 Fully adjusted[a] mean daily intakes of total energy in kcal by centre ordered from south to north, gender, and age group

Country and centre	*Men*												*Women*											
	N	*All*		*35–44 years*		*45–54 years*		*55–64 years*		*65–74 years*		P_{trend}	N	*All*		*35–44 years*		*45–54 years*		*55–64 years*		*65–74 years*		P_{trend}
		M	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*			*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	
Greece	1311	2260	24	2431	70	2381	48	2193	43	2127	38	0.03	1373	1659	18	1622	46	1722	30	1638	31	1611	35	0.70
Spain																								
Granada	214	2585	57	—	—	2639	119	2601	77	2468	128	0.70	300	1777	36	1794	93	1922	61	1672	57	1734	116	0.48
Murcia	243	2715	53	2945	165	2809	95	2666	74	2598	185	0.01	304	1998	36	2016	72	2024	61	2011	60	—	—	0.20
Navarra	444	2703	40	3153	171	2935	66	2593	56	2277	121	0.00	271	1912	38	1892	100	1919	62	1913	58	—	—	0.15
San Sebastian	490	2877	38	2975	89	3000	52	2832	71	2675	189	0.08	244	1973	40	2085	86	2119	65	1793	68	—	—	0.35
Asturias	386	2722	42	2776	159	2753	71	2693	63	2787	115	0.92	324	1898	35	1973	84	1908	57	1898	56	1810	128	0.04
Italy																								
Ragusa	168	2657	64	—	—	2731	95	2594	100	—	—	0.01	138	1946	53	2179	89	1712	99	2053	95	—	—	0.26
Naples													403	1906	31	2073	101	1900	50	1837	48	2125	101	0.91
Florence	271	2615	50	2958	159	2594	86	2699	72	—	—	0.12	784	1832	22	1891	75	1832	39	1821	31	1857	87	0.53
Turin	676	2582	32	2667	103	2649	53	2570	46	2564	122	0.06	392	1833	32	1926	100	1847	53	1818	44	—	—	0.05
Varese	327	2806	46	—	—	2712	102	2807	55	2968	154	0.02	794	1884	22	1917	72	1896	37	1880	34	1842	67	0.02
France																								
South coast													620	1991	25			1971	41	2009	39	1946	53	0.74
South													1425	1946	17			1932	26	1962	26	1913	37	0.75
North-East													2059	2018	14			2044	22	2008	22	1942	32	0.11
North-West													631	1974	25			1991	40	1950	38	1955	60	0.40
Germany																								
Heidelberg	1034	2463	26	2572	69	2526	41	2443	38	—	—	0.51	1087	1859	19	1926	33	1914	35	1808	32	—	—	0.76
Potsdam	1233	2555	24	2806	68	2549	48	2532	31	2538	92	0.21	1061	1832	19	1809	38	1891	37	1838	28	1876	121	0.48
The Netherlands																								
Bilthoven	1024	2579	27	2748	51	2666	40	2572	45	—	—	0.11	1086	1878	19	1982	34	1905	30	1812	37	—	—	0.08
Utrecht													1870	1920	15			1902	25	1938	22	1853	29	0.61
United Kingdom																								
General population	402	2349	41	2593	136	2433	74	2267	75	2230	75	0.03	570	1748	26	1823	79	1838	43	1688	47	1631	56	0.08
Health-conscious	114	2196	78	—	—	2044	127	2218	120	—	—	0.81	197	1875	45	1806	141	1831	73	1928	70	1904	123	0.13
Denmark																								
Copenhagen	1356	2590	23			2542	37	2620	29	2528	113	0.91	1484	1893	16			1892	27	1891	21	1759	77	0.33
Aarhus	567	2707	35			2723	49	2725	50	—	—	0.34	510	2070	28			2117	39	2022	40	—	—	0.16
Sweden																								
Malmö	1421	2326	23			2417	66	2253	35	2207	31	0.20	1711	1799	16			1836	31	1755	25	1756	24	0.34
Umeå	1344	2479	23	2813	77	2477	42	2418	31	2391	67	0.12	1574	1844	16	1883	38	1860	28	1814	24	1838	51	0.21
Norway																								
South and East													1004	1786	20	1859	48	1806	24	1765	49			0.05
North and West													793	1769	23	1905	51	1771	27	1752	58			0.26

Abbreviations: M, mean; s.e., standard error; '—' If a group comprised fewer than 20 persons, mean intake is not presented.
[a]Adjusted for age (when not stratified for age), weight, and height and weighted by season and day of recall.

Table 2 Percentage of extreme-energy reporters[a], low-energy reporters[b] and high-energy reporters[c] and adjusted[d] mean energy intakes in kcal after exclusion of extreme-energy reporters by gender and centre ordered from south to north

Country and centre	*Men*							*Women*						
	N	*Extreme-energy reporter (%)*	*Low-energy reporter (%)*	*High-energy reporter (%)*	*Energy intake*			N	*Extreme-energy reporter (%)*	*Low-energy reporter (%)*	*High-energy reporter (%)*	*Energy intake*		
					N	*Mean*	*s.e.*					N	*Mean*	*s.e.*
Greece	1311	19.9	18.3	1.6	1050	2430	21	1373	32.3	31.8	0.6	929	1873	17
Spain														
Granada	214	9.8	7.9	1.9	193	2625	48	300	23.0	22.3	0.7	231	1879	33
Murcia	243	12.3	8.6	3.7	213	2754	46	304	17.1	14.5	2.6	252	2056	32
Navarra	444	6.1	5.4	0.7	417	2744	33	271	13.3	12.2	1.1	235	1968	33
San Sebastian	490	7.1	4.1	3.1	455	2866	32	244	11.5	10.7	0.8	216	2048	34
Asturias	386	10.4	6.0	4.4	346	2709	36	324	18.2	17.3	0.9	265	2011	31
Italy														
Ragusa	168	14.9	9.5	5.4	143	2592	56	138	23.2	18.8	4.3	106	2005	49
Naples								403	20.3	19.4	1.0	321	2021	28
Florence	271	7.4	5.5	1.8	251	2628	42	784	18.2	17.2	1.0	641	1970	20
Turin	676	9.9	8.1	1.8	609	2654	27	392	19.4	19.1	0.3	316	2005	28
Varese	327	8.0	5.2	2.8	301	2838	39	794	13.6	13.0	0.6	686	1990	19
France														
South coast								620	9.8	7.7	2.1	559	2055	21
South								1425	10.7	8.6	2.1	1272	2020	14
North-East								2059	9.5	7.2	2.2	1864	2067	12
North-West								631	7.3	5.9	1.4	585	2031	21
Germany														
Heidelberg	1034	16.5	15.2	1.4	863	2586	23	1087	16.9	16.1	0.8	903	1971	17
Potsdam	1233	11.0	10.1	1.0	1097	2627	20	1061	17.0	16.3	0.7	881	1937	17
The Netherlands														
Bilthoven	1024	12.0	9.4	2.6	901	2607	23	1086	16.6	15.6	1.0	906	1993	17
Utrecht								1870	12.9	12.0	0.9	1629	2016	13
United Kingdom														
General population	402	11.4	10.7	0.7	356	2467	35	570	18.1	17.5	0.5	467	1875	23
Health-conscious	114	15.8	13.2	2.6	96	2309	69	197	12.7	10.7	2.0	172	1952	38
Denmark														
Copenhagen	1356	11.1	10.0	1.1	1205	2668	19	1484	16.1	15.1	1.0	1245	1988	14
Aarhus	567	7.9	7.2	0.7	522	2792	29	510	12.9	11.0	2.0	444	2108	24
Sweden														
Malmö	1421	15.7	14.7	1.0	1198	2497	21	1711	16.8	16.0	0.8	1424	1921	14
Umeå	1344	10.8	9.0	1.8	1199	2538	20	1574	13.7	13.1	0.6	1359	1948	14
Norway														
South and East								1004	16.5	15.5	1.0	838	1936	18
North and West								793	16.5	15.3	1.3	662	1890	20

Abbreviations: BMR, basal metabolic rate; EI, energy intake; s.e., standard error.

[a]EI/BMR <0.88 or >2.72.

[b]EI/BMR <0.88.

[c]EI/BMR >2.72; Age- and gender-specific BMR was estimated, taking weight and height into account according to Schofield (1985).

[d]Adjusted for age, height and weight and weighted by season and day of recall.

Table 3 Minimally adjusted[a] mean daily intakes of total fat, total carbohydrates, protein and alcohol as a percentage of total daily energy intake by gender and centre ordered from south to north

Country and centre	*Men*									*Women*								
	N	*Fat*		*Carbohydrates*		*Protein*		*Alcohol*		N	*Fat*		*Carbohydrates*		*Protein*		*Alcohol*	
		M	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*		*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*
Greece	1311	40.7	0.2	36.7	0.3	16.3	0.1	6.3	0.2	1373	42.2	0.2	40.2	0.3	16.2	0.1	1.5	0.1
Spain																		
Granada	214	38.5	0.6	37.5	0.6	18.1	0.3	5.9	0.5	300	37.6	0.5	42.9	0.6	18.3	0.3	1.1	0.3
Murcia	243	36.6	0.6	40.0	0.6	16.5	0.3	6.8	0.5	304	38.1	0.5	42.0	0.6	17.3	0.3	2.5	0.3
Navarra	444	37.9	0.4	35.1	0.4	18.6	0.2	8.3	0.4	271	40.9	0.5	38.5	0.6	19.3	0.3	1.4	0.3
San Sebastian	490	36.5	0.4	35.0	0.4	20.6	0.2	7.9	0.3	244	36.9	0.6	40.8	0.6	20.1	0.3	2.2	0.4
Asturias	386	33.7	0.4	38.6	0.5	20.2	0.2	7.5	0.4	324	34.5	0.5	43.0	0.5	20.8	0.3	1.8	0.3
Italy																		
Ragusa	168	29.3	0.7	49.1	0.7	17.5	0.3	4.0	0.6	138	35.3	0.7	46.5	0.8	16.7	0.4	1.5	0.5
Naples										403	33.3	0.4	47.2	0.5	16.6	0.2	3.0	0.3
Florence	271	29.9	0.5	47.5	0.6	16.8	0.3	5.9	0.5	784	32.2	0.3	47.6	0.3	17.3	0.2	2.9	0.2
Turin	676	28.2	0.3	47.5	0.4	16.1	0.2	8.3	0.3	392	31.3	0.4	47.6	0.5	17.1	0.2	4.1	0.3
Varese	327	29.6	0.5	46.2	0.5	16.2	0.2	8.1	0.4	794	31.8	0.3	49.1	0.3	16.5	0.2	2.7	0.2
France																		
South coast										620	38.8	0.3	39.7	0.4	17.5	0.2	3.9	0.2
South										1425	36.5	0.2	42.4	0.3	17.3	0.1	3.7	0.1
North-East										2059	37.6	0.2	41.0	0.2	17.2	0.1	4.0	0.1
North-West										631	36.4	0.3	41.5	0.4	17.7	0.2	4.3	0.2
Germany																		
Heidelberg	1034	36.2	0.3	40.3	0.3	15.2	0.1	8.4	0.2	1087	36.6	0.3	43.8	0.3	14.9	0.1	4.7	0.2
Potsdam	1233	39.3	0.2	40.2	0.3	14.3	0.1	6.3	0.2	1061	36.2	0.3	46.4	0.3	14.1	0.1	3.2	0.2
The Netherlands																		
Bilthoven	1024	35.1	0.3	42.7	0.3	16.0	0.1	6.2	0.2	1086	34.4	0.3	45.6	0.3	16.3	0.1	3.8	0.2
Utrecht										1870	33.9	0.2			17.0	0.1	4.1	0.1
United Kingdom																		
General population	402	32.9	0.4	45.4	0.5	15.8	0.2	5.8	0.4	570	31.4	0.4	47.0	0.4	16.8	0.2	4.6	0.2
Health-conscious	114	32.7	0.8	50.0	0.9	12.7	0.4	4.6	0.7	197	33.9	0.6	49.8	0.7	13.0	0.3	3.2	0.4
Denmark																		
Copenhagen	1356	36.3	0.2	39.6	0.3	14.8	0.1	9.2	0.2	1484	34.3	0.2	43.3	0.2	15.5	0.1	6.9	0.1
Aarhus	567	37.0	0.4	40.1	0.4	14.7	0.2	8.1	0.3	510	35.1	0.4	44.3	0.4	15.2	0.2	5.4	0.2
Sweden																		
Malmö	1421	37.3	0.2	42.4	0.3	16.0	0.1	4.3	0.2	1711	37.0	0.2	44.1	0.2	16.0	0.1	2.8	0.1
Umeå	1344	37.3	0.2	44.8	0.3	15.3	0.1	2.5	0.2	1574	35.0	0.2	47.3	0.2	15.9	0.1	1.8	0.1
Norway																		
South and East										1004	34.4	0.3	46.0	0.3	16.9	0.1	2.7	0.2
North and West										793	34.3	0.3	46.5	0.3	17.0	0.2	2.2	0.2

Abbreviations: M, mean; s.e., standard error.
[a]Adjusted for age and weighted by season and day of recall.

pasta and rice contributed ~30–45% in the Italian centres and ~15% in the Greek and health-conscious cohorts; and breakfast cereals contributed ~20% in the health-conscious cohort and a negligible proportion in Greece and Italy (data not shown). The lowest proportions of cereals were observed in some of the Spanish centres (Figure 1).

The proportion of total energy intake from dairy products was smallest in the UK health-conscious cohort (men 6.2 E%, women 8.9 E%), whereas the highest contributions were observed in men in Umeå (14.4 E%) and in women in Utrecht (17.5 E%) (Figure 1). Among women, dairy products contributed more than 15% to total energy intake in French and Norwegian cohorts, in Asturias and Granada (Spain), and in Utrecht (the Netherlands) and Umeå (Sweden). In all centres, the percentages of energy intake from dairy products were higher in women than in men.

The proportion of energy intake from meat in the UK health-conscience cohort (<2 E%) was much lower than

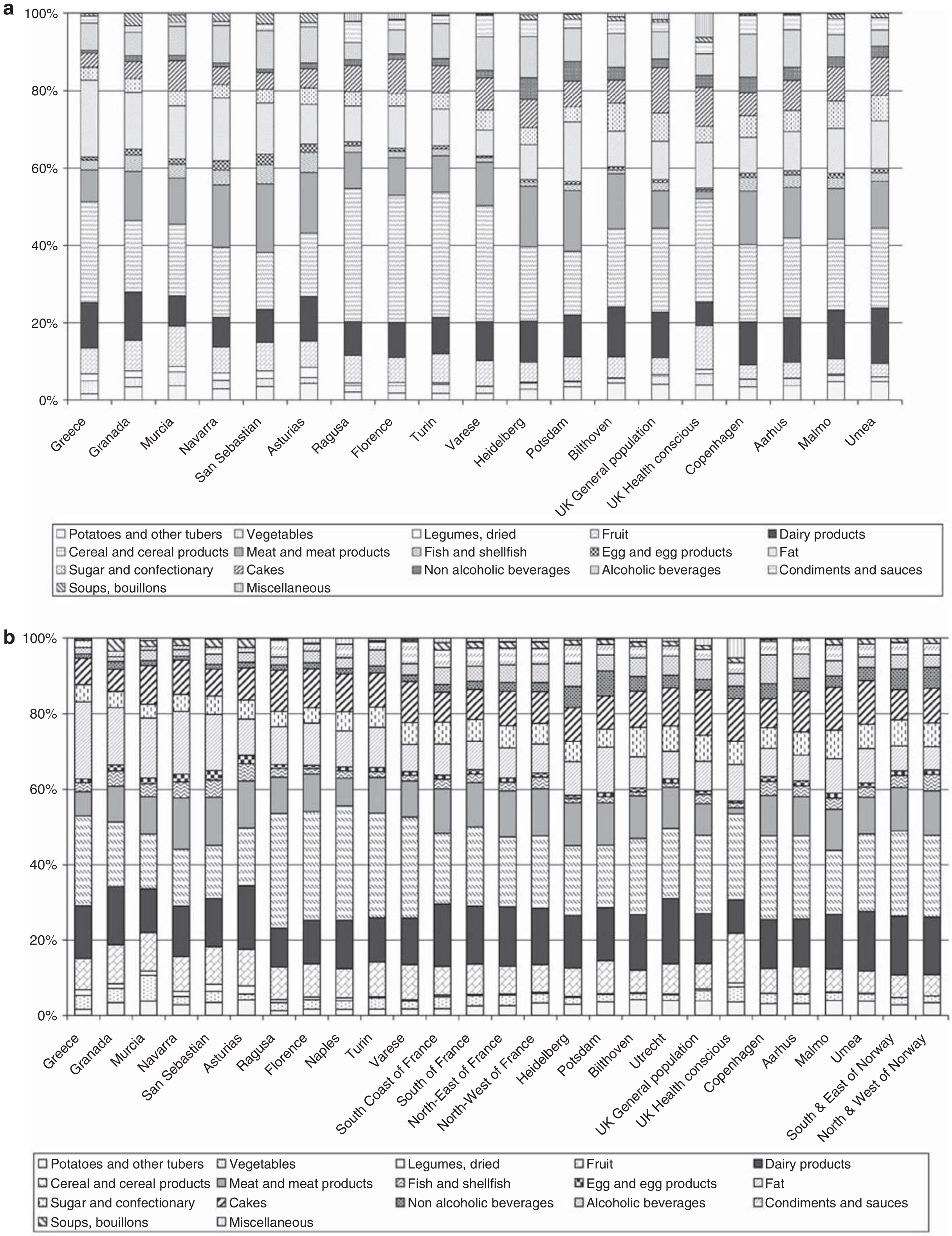

Figure 1 Sources of energy intake (E%) in (**a**) men and (**b**) women, adjusted for age and weighted for day of 24-h recall and season, by centre ordered from south to north.

that in other EPIC centres because of the high proportion of vegans, ovo-lacto vegetarians and fish eaters (Figure 1). In other cohorts, the proportion of energy from meat varied from 6.5% in Greek women to 17.5% in San Sebastian men (Spain). In three Spanish cohorts, San Sebastian, Asturias and Navarra and in both German cohorts, meat contributed ⩾15% to men's total energy intake. In most cohorts, the contribution of meat to energy intake was lower for women than for men.

In Greek men and women, the food group fats and oils contributed one-fifth to total energy intake, which is higher than in any other centre (Figure 1). In some Spanish centres, the proportion was >15 E% (both genders in Navarra, women in Granada and Murcia). This was also the case for men in Potsdam, where the proportion of energy from the food group fats and oils (15.4 E%) was considerably higher than that in the other German cohort in Heidelberg (9.0 E%). In the southern European centres with a high-energy contribution from fats and oils, this was mainly derived from vegetable oils, whereas in Potsdam, butter and margarine contributed the most. In contrast, the lowest percentage of energy intake from the food group fats and oils was observed in Varese (6.8 E%) among men, and in Norway and Aarhus (6–7 E%) among women (Figure 1).

In all cohorts, the contribution of cakes to energy intake was higher in women than in men (Figure 1). Cakes contributed >10% to total energy intake in both genders in the UK cohorts, and in women in Murcia, Utrecht, Sweden, Aarhus and in the Italian centres except Turin. The lowest proportion of energy intake from cakes was observed in Greek men.

Furthermore, for fruit, the contribution to energy intake was greater in women than in men. Contributions <5% were observed only among men in cohorts of the UK general population, Sweden and Denmark. Contributions >10 E% were observed in the UK health-conscious cohort, in Murcia and, among women only, in Granada. In contrast to Murcia and Granada, energy provided by the food group 'fruit' in the UK health-conscious cohort included more energy from nuts (spreads) and seeds (38%) (data not shown).

Men had, however, a higher contribution to energy intake from alcoholic beverages than did women (Figure 1). For men in Copenhagen and Heidelberg, the proportion was ~11 E%. Among women, the highest contributions from alcoholic beverages were also observed in these centres, together with Aarhus, but in the range of 6–8 E%.

Stratified analyses

Total mean energy intakes by country, for men and women, stratified by day of the week, are presented in Table 4. These data are adjusted for age, height and weight and weighted by season. In most but not all countries, mean energy intake was highest on Saturday, followed by Friday or Sunday. Even when alcohol was excluded, the highest mean energy intakes were observed on Saturdays in most countries (data not shown).

For stratifications by level of physical activity, no significant increases in adjusted mean energy intake with higher

Table 4 Fully adjusted[a] mean daily energy intakes (s.e.) in kcal by country and gender, according to day of the week

Country	N	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*	*Sunday*
Men								
Greece	1311	2381 (59)	2269 (57)	2346 (53)	2142 (60)	2241 (61)	2253 (77)	2224 (63)
Spain	1777	2663 (48)	2668 (48)	2714 (49)	2666 (56)	2787 (51)	2965 (66)	2789 (53)
Italy	1442	2507 (56)	2564 (50)	2666 (51)	2517 (52)	2589 (57)	2866 (81)	2864 (59)
France								
Germany	2267	2370 (36)	2377 (35)	2369 (38)	2393 (44)	2542 (80)	2799 (58)	2619 (54)
The Netherlands	1024	2546 (66)	2574 (64)	2411 (63)	2513 (65)	2568 (74)	2781 (82)	2615 (72)
UK general population	402	2166 (97)	2308 (106)	2374 (102)	2367 (100)	2457 (105)	2465 (145)	2414 (102)
UK health-conscious	114	2186 (142)	2140 (184)	2405 (177)	2065 (189)	2256 (280)	2165 (274)	2200 (284)
Denmark	1923	2568 (42)	2378 (38)	2534 (44)	2549 (46)	2767 (60)	3073 (74)	2638 (58)
Sweden	2765	2242 (42)	2306 (40)	2288 (40)	2370 (38)	2567 (47)	2697 (51)	2331 (45)
Norway								
Women								
Greece	1373	1545 (43)	1634 (40)	1669 (39)	1625 (44)	1606 (53)	1708 (55)	1757 (46)
Spain	1443	1844 (37)	1905 (37)	1814 (38)	1922 (45)	1905 (55)	2006 (47)	1956 (50)
Italy	2511	1834 (29)	1816 (29)	1786 (29)	1816 (31)	1800 (40)	1891 (41)	2024 (34)
France	4735	1924 (20)	1886 (20)	1951 (21)	1929 (23)	1881 (31)	2128 (30)	2168 (29)
Germany	2148	1743 (30)	1753 (27)	1746 (32)	1828 (38)	1777 (45)	1983 (45)	1959 (40)
The Netherlands	2956	1809 (28)	1840 (27)	1892 (28)	1880 (31)	1926 (30)	2026 (34)	1956 (32)
UK general population	570	1675 (61)	1677 (66)	1738 (61)	1674 (65)	1776 (69)	1828 (76)	1819 (74)
UK health-conscious	197	1682 (88)	1900 (87)	1771 (97)	1961 (128)	1989 (189)	2001 (155)	1772 (146)
Denmark	1994	1803 (29)	1805 (28)	1942 (33)	1730 (37)	2005 (44)	2245 (52)	2060 (43)
Sweden	3285	1738 (27)	1733 (26)	1761 (27)	1687 (29)	1920 (29)	2042 (31)	1846 (31)
Norway	1797	1695 (35)	1656 (34)	1725 (35)	1797 (40)	1903 (54)	2046 (49)	1733 (39)

Abbreviation: s.e., standard error.
[a]Adjusted for age, height and weight and weighted by season.

level of physical activity were observed across the cohorts. Similarly, no consistent trends in adjusted mean energy intakes were observed across levels of education, BMI category, smoking status and season (data not shown).

Discussion

In this study, a wide range of mean energy intakes was observed between the centres of the EPIC study, with higher average values for men than for women. After correction for differences in age, height and weight between the study populations and standardization for differences in distribution of interviews over days of the week and seasons, the maximum difference between centre mean energy intakes amounted to almost 700 kcal/day for men and to more than 400 kcal/day for women. However, a substantial part of this variation was due to differences in low-energy reporting. The prevalence of low-energy reporting was larger for women than for men.

Underreporting of energy intake is a phenomenon frequently observed in Western adult populations. It occurs in all kinds of studies that use dietary assessment methods that rely on self-reported dietary intake (Livingstone and Black, 2003). We evaluated underreporting at the individual level against presumed energy requirements, assuming a PAL of 1.55 appropriate for moderately active populations (Haftenberger *et al.*, 2002), taking into account the uncertainty of recalling a single day's diet. This approach has several limitations. First, a PAL of 1.55 is a conservative value and may therefore underestimate the number of underreporters. Second, the cutoff identifies low-energy reporters, and has low sensitivity and poor specificity for identifying true underreporters. Persons who underreport from a higher intake in such a way that EI/BMR does not fall below the cutoff for PAL of 1.55*BMR are not identified (Livingstone and Black, 2003). Moreover, some of the low-energy reporters may truly be consuming a very low-energy diet. In this study, this seems more likely for participants following a special diet.

The observed low-energy reporting confirms previously published results using energy contents of foods from country-specific food composition tables rather than the ENDB (Ferrari *et al.*, 2002). Many studies applying presumed energy requirements to identify underreporters observed more prevalent low-energy reporting among women than among men. It is unclear, however, whether underreporting is also more prevalent among women or whether this is because of the application of a single cutoff for EI/BMR. Doubly-labelled water studies suggest that men have a higher physical activity level and thus higher energy intake. A single cutoff would then identify fewer men as underreporters (Livingstone and Black, 2003).

A previous analysis of the EPIC calibration dataset showed that persons on a special diet and overweight people were significantly more likely to be low-energy reporters than were normal weight subjects and those not on a special diet (Ferrari *et al.*, 2002). A higher prevalence of low-energy reporters among people with a higher BMI has been observed in many studies (Heitmann and Lissner, 1995; Braam *et al.*, 1998; Livingstone and Black, 2003). In addition, low-energy reporting might be related to age, as well as to socioeconomic, psychosocial and behavioural characteristics (Livingstone and Black, 2003; Maurer *et al.*, 2006).

The aim of the EPIC calibration study is to express dietary measurements, obtained using country- and centre-specific dietary assessment methods, on a common scale and to correct for bias because of measurement errors in dietary assessment. It is assumed that the 24-HDRs used are unbiased or have equal bias across centres. This study confirms the previous observation (Ferrari *et al.*, 2002) that underreporting differs between centres, with the highest level in the Greek cohort (men 18%, women 32% versus 4–15% for men and 6–22% for women in other centres). This provides evidence regarding the limitations of the use of 24-HDRs as reference measurements in the calibration study (Ferrari *et al.*, 2008). Ferrari *et al.* showed that, after exclusion of extreme-energy reporters, the EI/BMR ratio was fairly constant. The question is whether a solution would be found to exclude the 24-HDRs of low-energy reporters when calibrating dietary intake in the EPIC study. This might also introduce unknown biases in the dataset.

The problem of underreporting is also relevant when nutrients are the topic of interest, as underreporting of energy intake is associated with underreporting of nutrient intake. It is known that the degree of underreporting differs by nutrients (Livingstone and Black, 2003). The data of this study also suggest that underreporting was larger for fat and alcohol than for protein and carbohydrate intake. With regard to potassium and nitrogen, measurement errors in the EPIC calibration study have been investigated using urinary excretion data. The results suggested that 24-HDRs can be used as reference measurements at individual and aggregate levels for potassium intake. For nitrogen intake, performance was good for between–centre calibration (Slimani *et al.*, 2003), but some limitations were apparent at the individual level (Ferrari *et al.*, 2009). Adjustment for energy intake seems to solve a major part of the impact of measurement error in nutrient intake (Kipnis *et al.*, 2003). However, because low-energy reporting is also related to personal characteristics (for example, BMI) that may determine disease outcome, exclusion of low-energy reporters and adjustment for energy intake in the case of nutrients do not solve the whole problem. More complex measurement error models are needed that will account for systematic bias (for example, depending on BMI) as well as random errors.

Regional differences in sources of energy intake were more pronounced than were variations in energy intake. This was expected, as physiological variations in energy intakes should be relatively modest after adjustment for age, gender, physical activity and anthropometry (Black and Cole, 2000). Greater variations in energy intake were observed in men than in women.

As expected, the UK health-conscious cohort showed a very specific pattern of energy sources. In comparison with other centres, meat and dairy products contributed only small proportions to total energy intake, whereas the food groups 'fruits' (which includes nuts and seeds) and 'miscellaneous' (which includes soy products) contributed relatively large proportions. As in the Italian and Greek cohorts, cereals contributed to more than a quarter of total daily energy intake in the UK health-conscious cohort.

The highest contributions of meat were observed in the Spanish and German cohorts, and some of the lowest were observed in Italy. Dairy products made relatively large contributions to energy intake in the Dutch, French, Swedish and Norwegian cohorts and also in some of the Spanish centres. The highest contributions from the food group fats and oils were observed in the Greek and Spanish cohorts and in Potsdam, Germany. The type of fat differed between these Mediterranean countries and Potsdam, as has been described in more detail by Linseisen *et al.* (2009).

The contributions of macronutrients to energy intake also varied considerably across the European centres. There was a difference of $\sim$10 E% in mean fat intake between the Greek and Italian centres. Only among Italian men was the average fat intake in accordance with the international recommendation of $<$30 E% (WHO/FAO, 2003). The range in the mean contribution of carbohydrates to total energy intake was 35–50 E%. Centres with a high mean contribution of energy from fat in general had a low contribution from carbohydrates and vice versa. The mean protein intake ranged between 13 and 21 E%. In men, the mean contribution of protein to energy intake was higher in the Mediterranean centres than in the more northern centres. The mean contribution of alcohol to energy intake was highest in Copenhagen (men 9.2 E%, women 6.9 E%). In all centres, men had a higher average contribution of alcohol to energy intake than did women. In general, these results are in line with the results from national food consumption surveys such as those summarized in the European Nutrition and Health Report 2004 (Elmadfa and Weichselbaum, 2005). A detailed comparison of our results and those of the European Nutrition and Health Report would be inappropriate because of differences in dietary assessment methods and populations. Further details regarding energy intake from fat, including various types of fatty acids, carbohydrates, protein and alcohol are described elsewhere in this Supplement (Cust *et al.*, 2009; Halkjær *et al.*, 2009; Linseisen *et al.*, 2009; Sieri *et al.*, 2009). These papers also present results on absolute intakes of macronutrients, their determinants and food sources.

In most of the EPIC cohorts, highest mean energy intakes were observed on and around Saturdays, even when the energy contribution of alcohol intake was excluded. Although expected, little evidence of this weekday variation exists in literature. In addition, in some of the cohorts, an inverse association between energy intake and age was observed. For other sociodemographic and lifestyle variables, including physical activity level and season, no consistent associations were present in the data. For physical activity, this is surprising, as higher physical activity should be accompanied by higher energy intake to maintain energy balance. In a previous multivariate analysis of covariance within the EPIC calibration study, physical activity at work and during leisure time was a predictor of EI/BMR (Ferrari *et al.*, 2002).

This is the largest study to date describing intake of energy and its sources across several European countries. One of the strengths of this descriptive paper is the use of a standardized dietary assessment methodology (EPIC-SOFT programme) as well as a standardized food composition table, the ENDB (Slimani *et al.*, 2007), making it possible to compare intake of energy and macronutrients across 10 countries and 27 regions. Comparable and detailed information on energy intake and sources of energy intake across countries is useful for conducting and interpreting the results of large multicentre dietary studies. Furthermore, the large geographical span makes it possible to study the manner in which different food patterns across Europe contribute to energy intake.

However, as not all EPIC cohorts are population based, the results cannot be extrapolated to the general population of each region. Another limitation is that each participant provided only one 24-HDR. Intake can therefore be evaluated only for group means rather than at the individual level. This makes it impossible to estimate the percentage of the population that adheres to dietary recommendations for the contribution of various macronutrients to energy intake.

In conclusion, we measured diet in a highly standardized manner across 10 European countries. Our findings highlight and quantify the variations and similarities in energy intake and its sources between these countries. This information is important for future aetiological analyses on how energy intake and different types of macronutrients are related to health outcomes. Moreover, the presence of underreporting of energy and nutrient intake in the reported diets should be taken into account in analyses on diet in relation to health and disease.

Conflict of interest

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Appendix

Table A1 Minimally adjusted[a] mean daily intakes of total energy (kcal) by centre ordered from south to north, gender and age group

Country and centre	*Men*												*Women*											
	N	*All*		*35–44 years*		*45–54 years*		*55–64 years*		*65–74 years*		P_{trend}	N	*All*		*35–44 years*		*45–54 years*		*55–64 years*		*65–74 years*		P_{trend}
		M	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*			*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	*M*	*s.e.*	
Greece	1311	2190	23	2430	70	2326	48	2112	43	2010	37	0.01	1373	1560	17	1591	46	1651	30	1513	31	1452	35	0.2
Spain																								
Granada	214	2509	57	—	—	2562	120	2510	77	2392	129	0.72	300	1687	36	1725	94	1851	61	1567	57	1629	118	0.4
Murcia	243	2629	53	2879	166	2732	96	2582	75	2453	186	0.00	304	1923	36	1993	73	1964	61	1923	60	—	—	0.1
Navarra	444	2626	39	3123	172	2877	66	2504	56	2154	121	0.00	271	1848	38	1893	101	1867	63	1829	59	—	—	0.6
San Sebastian	490	2825	38	2951	90	2962	52	2790	72	2620	190	0.07	244	1935	40	2090	86	2096	66	1743	68	—	—	0.3
Asturias	386	2656	42	2727	160	2699	71	2628	63	2669	115	0.26	324	1834	35	1930	85	1855	57	1826	56	1762	129	0.0
Italy																								
Ragusa	168	2576	64	—	—	2667	96	2497	100	—	—	0.01	138	1852	54	2112	89	1626	100	1972	96	—	—	0.2
Naples													403	1817	31	2059	102	1820	50	1740	48	1962	102	0.7
Florence	271	2596	50	3018	160	2602	87	2663	72	—	—	0.09	784	1802	22	1921	76	1813	39	1777	31	1791	88	0.2
Turin	676	2546	32	2697	104	2620	54	2527	46	2507	123	0.03	392	1795	32	1890	101	1818	53	1779	44	—	—	0.0
Varese	327	2776	46	—	—	2691	103	2767	55	2908	155	0.03	794	1830	22	1925	72	1853	37	1817	34	1737	68	0.0
France																								
South coast													620	2008	25			1995	42	2023	40	1921	53	0.5
South													1425	1964	17			1961	26	1967	27	1902	38	0.4
North-East													2059	2035	14			2071	22	2013	22	1933	32	0.1
North-West													631	1987	25			2019	40	1944	38	1944	60	0.3
Germany																								
Heidelberg	1034	2477	26	2628	69	2573	41	2445	38	—	—	0.98	1087	1872	19	1992	33	1938	35	1807	32	—	—	0.9
Potsdam	1233	2556	24	2860	68	2565	48	2524	31	2520	93	0.16	1061	1812	19	1850	38	1884	38	1802	28	1810	122	0.3
The Netherlands																								
Bilthoven	1024	2607	27	2838	51	2720	40	2587	46	—	—	0.08	1086	1890	19	2047	34	1932	30	1807	37	—	—	0.2
Utrecht													1870	1949	15			1940	25	1959	22	1847	30	0.4
United Kingdom																								
Gen. population	402	2373	41	2649	137	2463	74	2292	76	2227	75	0.02	570	1743	26	1841	80	1844	43	1685	48	1584	57	0.1
Health conscious	114	2267	78	—	—	2124	127	2297	120	—	—	0.69	197	1911	45	1847	142	1860	74	1981	71	1915	124	0.3
Denmark																								
Copenhagen	1356	2633	23			2603	37	2653	29	2555	114	0.67	1484	1922	16			1936	27	1905	21	1771	78	0.2
Aarhus	567	2739	35			2773	49	2749	50	—	—	0.29	510	2096	28			2153	39	2038	40	—	—	0.2
Sweden																								
Malmö	1421	2379	23			2476	66	2293	35	2227	31	0.17	1711	1823	16			1869	31	1769	25	1742	24	0.2
Umeå	1344	2525	23	2897	77	2549	42	2447	31	2409	68	0.09	1574	1858	16	1922	39	1892	28	1813	24	1821	51	0.1
Norway																								
South & East													1004	1847	20	1946	48	1889	24	1825	49			0.0
North & West													793	1813	23	1987	51	1833	27	1793	59			0.2

Abbreviations: M, mean; s.e., standard error; '—' If a group comprised fewer than 20 persons, mean intake is not presented.
[a]Adjusted for age (when not stratified for age) and weighted by season and day of recall.