

ORIGINAL COMMUNICATION

Cooking of meat and fish in Europe — results from the European Prospective Investigation into Cancer and Nutrition (EPIC)

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Objectives: There is epidemiologic evidence that the consumption of fried, grilled or barbecued meat and fish that are well-done or browned may be associated with an increased cancer risk. These high-temperature cooking methods are thought to be surrogates for mutagens and carcinogens produced in meat and fish, eg heterocyclic amines or polycyclic hydrocarbons. Since data on food cooking methods are scarce, the aim of this study was to describe the variation in meat and fish cooking methods in different parts of Europe.

Design: Using a standardized 24 h recall from a sub-sample of the EPIC cohort (35 644 persons, 35–75 y old), mean daily intake of meat and fish prepared by different cooking methods and the relative contribution of the cooking methods to the overall cooking of meat and fish was calculated.

Results: Whereas frying was more often noted in northern Europe, roasting and stir frying were more often used in the south. Concerning high-temperature cooking methods, their frequency of application varies between 15% in the EPIC cohort of North-Italy and 49% in the cohort of The Netherlands. Average consumption of fried, grilled and barbecued meat and fish ranges from a low of 12 g/day in the centres in southern Spain to a high of 91 g/day in northern Spain.

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manuscript. JL contributed to data evaluation, statistical analyses, the concept, and writing of the paper. NB, TN, RS and NS contributed to the concept and writing of the paper. NS initiated the general concept and design of EPIC-SOFT and co-ordinated the international calibration study. The other authors were responsible for the field work and data collection and contributed to writing the paper. Received 3 September 2001; revised 20 March 2002; accepted 22 March 2002

Conclusion: High variation in both the kind of meat/fish consumed as well as its cooking methods is observed within EPIC. In order to use this variation for the evaluation of the impact of cooking methods on cancer risk, a questionnaire on meat and fish cooking methods is being developed and could be applied in the whole EPIC cohort.

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Introduction

During recent decades, a possible relationship between the methods of meat and fish preparation and the risk of cancer development of different sites has been observed in epidemiological studies (Sinha *et al*, 1998,1999,2000a,b,2001; Deitz *et al*, 2000; Norris *et al*, 1999; Zheng *et al*, 1999; De Stefani *et al*, 1997a,b,1998a,b; Probst-Hensch *et al*, 1997; Ward *et al*, 1997; Schiffman & Felton, 1990; Steineck *et al*, 1990). It has been suggested that heterocyclic amines (HCA) may explain at least some of the observed effect. HCA are formed during high temperature cooking of meat and fish from creatinine, amino acids, and sugar (Skog *et al*, 1998). These compounds can react together during cooking at high temperatures in Maillard reactions (Jägerstad *et al*, 1983). The carcinogenicity of different members of the HCA family has been proven in animal models (Adamson *et al*, 1990; Shirai *et al*, 1995). However, recent epidemiological studies concerning HCA intake gave conflicting results. While case-control studies conducted in Uruguay and in the USA showed positive correlations between the intake of HCA and the risk of breast (Sinha *et al*, 2000a; De Stefani *et al*, 1997b), colon (Sinha *et al*, 2001; De Stefani *et al*, 1997a), lung (Sinha *et al*, 2000b), and gastric cancer (De Stefani *et al*, 1998a), other groups were not able to detect any association between the intake of HCA and the cancer risk of different sites (Norris *et al*, 1999; Augustsson *et al*, 1999b; Lyon & Mahoney, 1988).

Polycyclic aromatic hydrocarbons (PAH) have also been found in barbecued meat and fish in variable amounts, depending on the type of heat source used. Highest amounts arise when foods were barbecued over wood or cones, but lower when barbecued over charcoal (Larsson *et al*, 1983). An association between barbecued, but not fried, meat and stomach cancer suggests that dietary exposure to PAH may be involved in gastric carcinogenesis (World Cancer Research Fund, 1997). Since PAH are ubiquitous environmental contaminants and a variety of foods, including oils, grains and vegetables, contribute to PAH intake, it is not easy to calculate their intake nor to estimate the relative contribution of food cooking methods applied to meat and fish (Guillén *et al*, 1997; Rothman *et al*, 1993).

At present, assessing the use of cooking methods might be a more appropriate method in epidemiological research than estimating the intake of single carcinogens like HCA or PAH, since reliable estimation of HCA or PAH is a difficult task. The main reason is that no standardized databases that

include a large number of different foods analysed for their HCA or PAH concentration exist which could be used for the calculation of the intake. Several studies have focussed on meat and fish cooking methods. High-temperature cooking techniques, such as grilling, frying and barbecuing, are more likely to be associated with carcinogen production (Skog *et al*, 1998). Several reports, focussing on meat preparation by these high-temperature cooking methods, were able to show an increased risk of lung cancer (Sinha *et al*, 1998; Doneo-Pellegrini *et al*, 1996), breast cancer (Sinha *et al*, 2001; Zheng *et al*, 1998), prostate cancer (Norris *et al*, 1999), colorectal tumors (Sinha *et al*, 1999; Probst-Hensch *et al*, 1997; Ward *et al*, 1997; Gerhardsson de Verdier *et al*, 1991). Apart from the cooking methods, cancer risk was shown to be influenced by the degree of browning of the cooked meat or fish item (Sinha *et al*, 1999; Zheng *et al*, 1999; Probst-Hensch *et al*, 1997; Ward *et al*, 1997). For example, Sinha *et al* (1999) computed a higher risk for colorectal adenomas when red meat was consumed well-done or very well-done in contrast to medium or rare red meat, but in two earlier studies no association between cancer risk and cooking method was observed (Muscat & Wynder, 1994; Lyon & Mahoney, 1988).

A systematic analysis of differences in meat and fish preparation methods used within Europe has not been reported so far. In this report, we describe the differences in meat and fish cooking techniques in different countries and regions in the European Prospective Investigation into Cancer and Nutrition (EPIC), obtained by means of 24 h recalls where detailed information on cooking methods was available.

Material and methods

EPIC is a multi-centre study conducted in 10 European countries with 27 study centres and about half a million participants. It focuses on the relation between diet, nutritional and metabolic characteristics, various lifestyle factors and the risk of cancer (Riboli & Kaaks, 1997). The recruited study participants were not a representative sample of the participating countries. Furthermore, no strict criteria of selection were used. For example, in Greece or Germany, participants were recruited from the general population, whereas in France only female teachers were included in the cohort. During the recruitment phase of EPIC, information about individual usual food habits and lifestyle was

obtained from each participant (Riboli, 1992). Individual long-term dietary intakes were obtained using a country-specific validated dietary assessment instrument. In order to calibrate individual estimates obtained with these country-specific methods, a single 24 h recall was obtained in a representative subgroup of about 10% of all EPIC cohorts.

A computer program, EPIC-SOFT, was developed to ensure that 24 h recalls were conducted in a standardized manner in each country (Slimani *et al*, 1999). The 24 h recall obtained information about type and quantity of foods consumed as well as details on cooking methods. Details on portion sizes were assessed using different methods such as household measurements, standard units and a picture book. In order to standardize information on the consumed food items across countries, systematic questions used for describing a given food were asked, eg cooking method, brand name or fat content. These characteristics of foods were described by so-called 'facets' (Slimani *et al*, 2000). For each facet a set of 'descriptors' was defined, allowing specifying the facet more precisely. The facet 'cooking method' was used to assess *the preparation of meat and fish items just before consumption*. In the case of 'cooking method' 29 common possible answers (descriptors) were foreseen to cover the wide within- and between-centre variations in food cooking methods (Table 1). When a person reported eating a special meat or fish item, questions (facets) on cooking methods were automatically prompted on the screen with several possible pre-defined

answers (descriptors). If a person was not able to answer the question precisely, 'not specific' cooking methods could be chosen (Slimani *et al*, 2000). The cooking method 'fried' was used as a generic descriptor in EPIC-SOFT. In its original meaning it describes foods cooked in hot fat until done, and other descriptors were used to describe foods that were deep fried or stir fried. Although a certain degree of misclassification cannot be excluded, we believe that this kind of misclassification is small and frying is used in most cases in its original meaning since well-trained staff performed all interviews.

Meat and fish data were analysed by country or, as for France, Italy and Spain, by region. We decided to divide these countries into regions because of varying meat and fish cooking habits. Italy and Spain have up to five study centres, located in different regions (Riboli & Kaaks, 1997). For Italy three regions were defined: northern Italy (Florence, Varese, Turin), Naples and Ragusa. Spain was divided into southern Spain (Granada, Murcia) and northern Spain (Oviedo, Pamplona, San Sebastian). France, Norway and Greece recruited participants from all regions of these countries. For statistical analysis in this paper, we included French participants on basis of two regions: southern France and northern France. Norwegian participants were originally assigned to the centres northwest and southeast, but they were analysed by country in this study. Greek data were analysed by country too. The British participants were divided into two groups,

Table 1 Definition of cooking methods in EPIC

Cooking method ^a	Definition
Baked	Cooked by dry heat in an oven, covered or uncovered, no additional fat used for cooking
Barbecued	Cooked on grill bars over burning charcoal or wood
Battered and baked	Covered by batter (flour, milk, and egg mixture) and baked
Battered and fried	Covered by batter (flour, milk, and egg mixture) and fried
Boiled	Cooked in boiling liquid
Breaded and baked	Covered by an outer layer of breadcrumbs and baked
Breaded and fried	Covered by an outer layer of breadcrumbs and fried
Breaded and griddled	Covered by an outer layer of breadcrumbs and griddled
Coated and fried	Covered by an outer layer and fried: includes battered and fried, breaded and fried, in flour and fried
Deep fried	Cooked in a hot fat or oil by immersing the food entirely
Fried	Generic descriptor for cooked in heated fat, usually over a direct source of heat
Griddled	Cooked on a heated flat metal surface over a source of direct heat; a little fat or oil may be used to grease the metal surface
Grilled	Cooked rapidly without moisture, on grill bars under or over intense direct heat, no fat used
In flour and fried	Covered by an outer layer of flour and fried
Microwaved	Cooked or reheated in a microwave oven; no fat used
Poached	Cooked by dropping in boiling liquid
Reheated	Made hot; no liquid nor fat is added
Roasted	Cooked by dry heat in an oven or over a fire
Shallow fried	Cooked in a shallow layer of heated fat
Steamed	Cooked by steam, in pressure cooker or cooked suspended above boiling water
Stewed	Cooked by boiling or simmering in liquid contained in an enclosed vessel; the food is cooked over a low heat for a long period of time
Stir fried/sauteed	Cooked by frying food over high heat, by stirring constantly to avoid sticking
Toasted	Cooked with direct heat until the surface of the food is browned
Cooked NS (not specified)	Generic descriptor, used in the case the subject does not know the answer
Cooking method not applicable ^b	Generic descriptor for food on which no cooking method can be applied
Raw ^b	Generic descriptor for food on which no cooking method was applied

^aCooking method is defined as the preparation of meat and fish items just before consumption.

^bThese descriptors do not exclude cooking outside house or preparation in another way.

the general population and health-conscious persons. The group of UK health-conscious persons ($n = 311$) was excluded from the present analysis because of their low meat consumption.

The present report deals with data concerning the consumption of prepared meat and fish (which means meat and fish with information on cooking method). In total, 60850 consumption events with information on meat and fish cooking methods from 35644 participants were used. Food items mentioned in these data sets were divided into several food classes as already defined by EPIC-SOFT.

A general view is given for the frequency of the most important cooking methods per region and, in a second step, all cooking methods per food group were analysed by region. Furthermore, mean daily intake of meat and fish prepared by different cooking methods was calculated. Mean adjusted intake was computed by using the ANACOVA procedure to adjust for age and by applying weights to ANACOVA estimates to consider the categorical variables weekday (two categories) and season (four categories). For all analyses SAS Version 6.12 (SAS Institute Inc., Cary, NC, USA) was used.

Results

Table 2 shows the distribution of study participants by sex and age. Men and women were not equally distributed because some countries and centres decided not to recruit men for different reasons (France, Norway, Naples). Age distribution differed in the participating countries as EPIC cohorts are convenience samples and no strict criteria of selection were used.

Summing up the answers of all countries, the most frequently consumed food groups of meat and fish were processed meat (including all kinds of sausages, ham, bacon, processed meat cuts, processed minced meat), fish, pork,

beef, chicken, crustacean and molluscs, minced meat, lamb and turkey (in decreasing order). These food groups counted for 94.3% of all items specified and each was mentioned more than 1000 times in the 24 h recalls. They are included in the following analyses.

In Table 3, the specific cooking methods used in each region are listed. The most important were frying, boiling, baking, stewing, roasting, stir frying, grilling, as well as breading and frying. These eight cooking methods amounted to 62% of the preparation methods of meat and fish. The variation of cooking methods between the regions is large, for example frying was used for the preparation of 45.2% of meat and fish in the EPIC cohort of The Netherlands but only for 1.6% in Greek participants. Stir frying varied between 0.9% in the cohort of Norway and 20.1% in the cohort of southern France.

In Figure 1, high-temperature cooking methods that are often investigated in studies because of their possible influence on cancer risk (barbecuing, grilling, frying) are shown for the different study regions. The frequency of these three cooking methods ranged from a low of 11.5% in northern Italian centres to a high of 46.5% in the Dutch cohort. Although barbecuing was a rarely used cooking method in most EPIC regions, more than 8% of meat and fish was barbecued in Greece.

Cooking methods were not specified for 5080 meat and fish consumption events (8.3%; Table 3), varying from 0.3% in the Greek cohort to 22.0% in the UK. Even more often indicated were the descriptors 'raw' and 'cooking method not applicable', which were regrouped in this analysis and were both included in 'no cooking method applied'. This means that in 7.8 to 39.5% of the consumption events, a food was not cooked before consumption or was eaten raw; the first applies especially to processed meat items (see below).

Table 2 Study participants completing the 24-hour recall in EPIC by sex and age groups

Region/country ^a	Women					Men				
	35–44	45–54	55–64	65–74	Total	35–44	45–54	55–64	65–74	Total
Northern France ^b		1091	1064	475	2630					
Southern France		824	814	370	2008					
Northern Italy	181	681	958	151	1971	101	411	662	102	1276
Ragusa	38	52	41	7	138	16	73	72	7	168
Naples	29	174	174	26	403					
Northern Spain	148	320	316	55	839	136	548	515	121	1320
Southern Spain	104	226	224	50	604	33	119	243	62	457
Great Britain	64	203	174	130	571	39	116	123	126	404
Netherlands	342	1071	1084	463	2960	268	418	330	8	1024
Greece	169	390	449	366	1374	117	244	376	575	1312
Germany	552	629	941	29	2151	276	709	1197	86	2268
Sweden	256	892	1274	863	3285	113	517	1239	896	2765
Denmark		771	1144	80	1995		752	1107	64	1923
Norway	320	1200	278		1798					
Total	2203	8515	8926	3056	22727	1099	3907	5864	2047	12917

^aParticipants of EPIC recruited in each country or region are not a representative subsample of the population. The participants of the calibration study are a representative subsample of each cohort.

^bThe regions/countries include study centres as given in the figure captions.

Looking at the relative contribution of different cooking methods of meat and fish subgroups, 34.3% of the beef consumed in the EPIC centres of southern France, but only 20% in northern France or less than 1% in the Danish cohort, was stir fried (Table 4). A high variation in the use of frying with respect to all meat and fish groups can be observed. In southern regions of Europe, processed meat was more often grilled or roasted, whereas people in the north preferred frying, boiling or baking. In case of fish, crustacean and processed meat, a high percentage was consumed raw or no cooking method was applied, because the foods had already been cooked or processed when they were bought.

Mean daily intake of fried red meat, including beef, veal, lamb and pork, was high in the northern European countries as well as among the EPIC participants in northern Spain and Naples, where it ranged from 13.1 to 38.0 g in women and from 21.6 to 59.7 g in men, respectively (Table 5). In contrast, a high portion of red meat in the cohort of northern France was consumed baked, in the southern French cohort stir-fried, or stewed in Greece, Ragusa and northern Italy. Higher amounts of grilled red meat were eaten in the southern than in the northern EPIC countries (note that mean

adjusted intake of barbecued red meat in Ragusa amounted to 14.8 g/day among women and that this estimate was based on the consumption of only four women; in fact unadjusted intake was 3.7 g/day).

White meat (including chicken and turkey) was predominantly consumed baked. In the centres of Germany, Denmark and The Netherlands most white meat was eaten fried. Regarding processed meat, there was no dominant cooking method with respect to the consumed amounts of these foods. Baking, boiling as well as frying were common. In the EPIC cohorts of some countries, high portions of processed meat were eaten without cooking at home (which means that no cooking method was applied before the foods were consumed).

In case of fish and crustaceans, highest amounts were consumed boiled or coated and fried. High-temperature cooking methods were less important regarding the preparation of these foods, except for the cohort of northern Spain, where men consumed 25.3 g and women 14.6 g fried fish and crustaceans per day. However, one must keep in mind that a high proportion of these foods was described by 'no cooking method applicable' or 'raw' and might have been prepared

Table 3 Use of different cooking methods (percentage of consumption events) to prepare meat and fish by region/country in EPIC assessed by 24 h recalls in 22 727 women and 12 917 men

Specified cooking method (n) ^b	Percentage consumption events of specified CM														Total
	Northern France ^a	Southern France	Northern Italy	Ragusa	Naples	Northern Spain	Southern Spain	Great Britain	Netherlands	Greece	Germany	Sweden	Denmark	Norway	
	3601	2527	5677	443	570	5861	2809	1258	5720	2905	7279	9052	5560	2508	55 768
Fried	5.4	4.2	5.0	4.1	19.8	25.5	9.8	8.0	45.2	1.6	19.8	27.4	38.1	26.9	21.6
Boiled	14.2	13.2	8.7	8.3	13.4	12.1	14.0	5.2	4.7	8.7	25.1	15.3	17.7	23.2	14.2
Baked	10.8	11.6	4.5	7.3	2.4	4.6	3.7	16.9	1.8	2.9	3.1	13.3	14.9	6.8	7.4
Stewed	7.8	5.5	13.2	19.0	11.7	11.8	9.2	7.2	2.3	26.3	4.3			2.4	6.5
Roasted	15.0	9.1	7.0	9.5	6.1	4.4	12.2	8.7	0.4	17.8	0.8	5.9	2.0	2.2	5.8
Stir fried	12.3	20.1	3.8	1.2	1.3	6.9	9.8	6.2	3.1	4.7	2.5	4.4	0.9	0.9	5.1
Grilled	8.5	13.8	6.3	10.2	3.7			15.2	3.2	8.0	3.3	4.5	4.1	4.5	4.7
Breaded and fried	0.5	1.2	3.4	6.6	2.2	3.3	1.0	1.2	0.7	1.0	3.7	1.6	4.4	0.2	2.2
Barbecued	3.5	1.4	0.2	2.4	1.1	1.0	0.9	2.1	0.9	8.8	1.3	2.4	0.6	2.1	1.8
Battered and fried	0.1	0.1	0.6		0.6	6.5	2.7	2.7	0.2	0.5	0.1	2.3	0.4	0.5	1.5
In flour and fried	1.8	1.4	1.3	1.2	1.8	0.4	2.2	0.2	0.1	10.2	0.1	0.2	0.7	0.3	1.2
Reheated	2.0	1.0	0.4			0.2	0.3	0.8	3.2		3.4	0.2	0.1	1.1	1.2
Griddled	0.3	0.2	4.3	3.9	5.9	2.3	0.4	1.2	0.2	0.6	1.3		0.1	1.0	1.1
Deep fried	0.1	0.1	0.8	2.0	1.7	1.1	3.9	0.5	1.8		0.1	0.4	0.5	0.1	0.8
Microwaved	2.0	1.6	0.2		0.4	0.2	0.3	2.7	0.5		0.3	0.6	0.2	0.3	0.6
Steamed	0.9	1.3	0.4	0.2		0.4	0.9	1.3	0.2		0.1		0.9	2.5	0.5
Shallow fried	0.4	0.1	0.2	0.7	0.2	1.3	2.5	0.9	0.6	1.1	0.3			0.1	0.5
Poached	0.1	0.3				0.3		1.1	0.2			0.1		1.7	0.2
Breaded and baked	0.1		0.2	0.2	0.7			2.0	0.1		0.1		0.1	0.1	0.1
No cooking method applied ^c	14.1	13.9	39.5	22.9	27.2	17.8	26.2	15.6	30.6	7.8	30.1	21.1	14.4	23.1	23.0
Cooking method not specified (n)	398	356	289	15	1	229	53	355	362	10	148	1778	736	350	5080

^aThe regions/countries include following study centres as given in the figure captions.

^bn = number of consumption events.

^cNo cooking method applied: includes 'raw' and 'cooking method not applicable'.

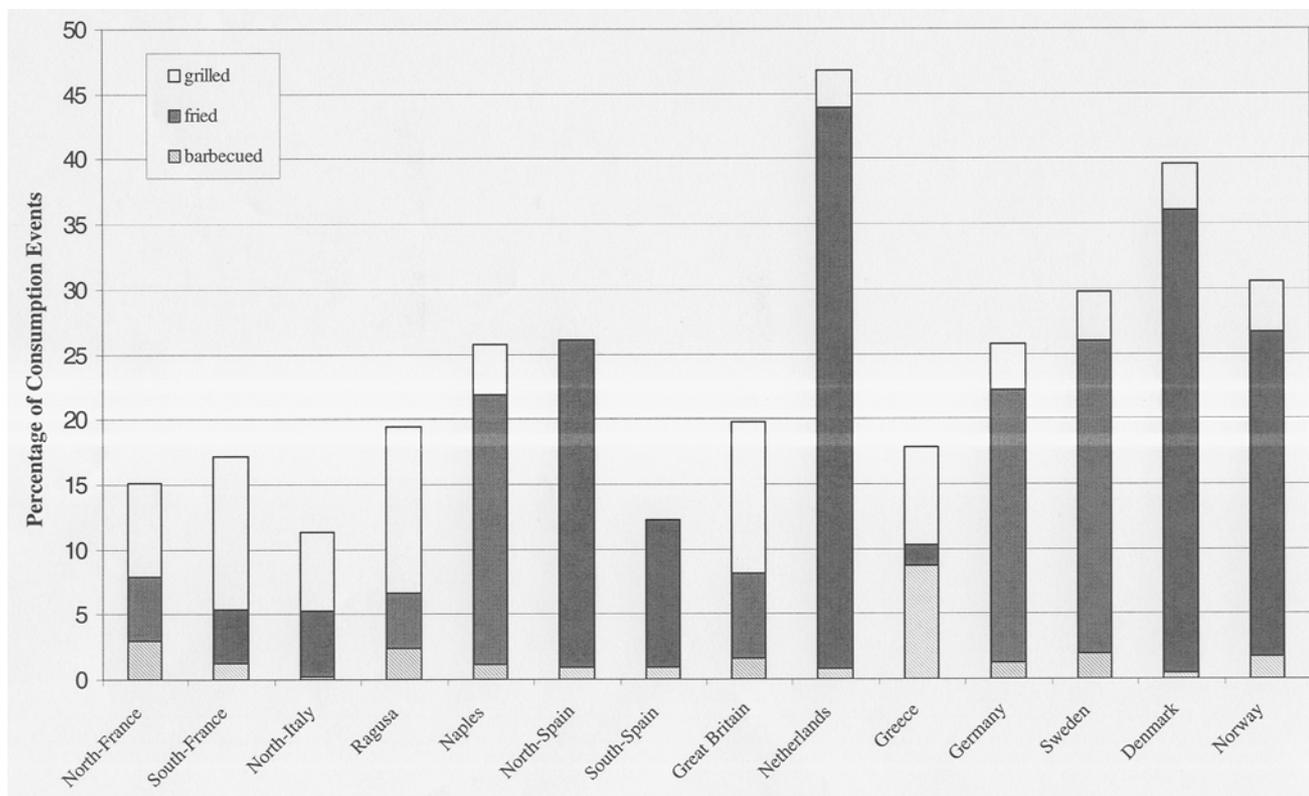


Figure 1 Frequency (percentage of consumption events) of barbecued, fried and grilled meat and fish by region/country in EPIC assessed by 24 h recalls in 22 727 women and 12 917 men. The regions/countries include the following study centres: *northern France*—north east, north west; *southern France*—south, south coast; *northern Italy*—Varese, Turin, Florence; *northern Spain*—Oviedo, Pamplona, San Sebastian; *southern Spain*—Granada, Murcia; *Great Britain*—general population; *Netherlands*—Bilthoven, Utrecht; *Germany*—Heidelberg, Potsdam; *Sweden*—Malmo, Umea; *Denmark*—Copenhagen, Aarhus; *Norway*—northwest, southeast. The cooking method 'fried' does not include deep fried and stir fried. Mean adjusted for age, season and week day.

outside the home. For these foods no information about the method of preparation outside home is available and no justified assumptions can be made.

With respect to high-temperature cooking methods (Figure 2), mean daily intake of fried, grilled and barbecued meat and fish varied between 11 g (southern Spain) and 55 g (Netherlands) for women and between 20 g (northern Italy) and 91 g (northern Spain) for men. In the northern parts of Europe as well as in the cohort of northern Spain, these high-temperature cooking methods were more often used than in the centres in France, Greece, Italy and the UK. The intake of grilled meat and fish was higher in French, Greek, Italian and British EPIC cohorts than in the north of Europe, but the consumption of fried meat and fish was lower. No grilled meat was consumed in the EPIC cohorts of Spain. Whereas the intake of fried and barbecued meat and fish was highest in northern Spain for men, the highest consumption of red meat prepared by these high-temperature cooking techniques (Figure 3) was observed in The Netherlands (women, 39.4 g/day; men, 59.7 g/day).

Discussion

This is the first study to look at meat and fish cooking methods in different Western European countries. For this study we used data of the 24 h recall that was applied in a representative sub-sample of the EPIC cohort. Detailed information how a food was consumed was assessed by means of the program EPIC-SOFT. Information on cooking methods of meat and fish was assessed by means of 29 descriptors specifying the method by which the food item was cooked by the participant just before consumption. Consequently, neither cooking methods used for preservation nor cooking nor preparation methods applied before the food has been bought were covered by this facet.

For a varying proportion of meat and fish items (ranging from 0.3% in the cohort of Greece to 22.0% in cohort in the UK) the participants were not able to recall the cooking method of the consumed food item. In these cases a non-specific cooking method was used for coding the reported answer. No information about a specific recall bias for certain cooking methods is available. However, it seems to be that

Table 4 Frequency of cooking methods (number and percentage of consumption events) most often applied to prepare meat and fish by region/country in EPIC assessed by 24 h recalls in 22 727 women and 12 917 men

Cooking method	Northern France ^a	Southern France	Northern Italy	Ragusa (Italy)	Naples (Italy)	Northern Spain	Southern Spain	Great Britain	Netherlands	Greece	Germany	Sweden	Denmark	Norway
Beef (n)	516	359	765	104	43	35	1	129	891	74	435	858	971	269
Baked/roasted (%) ^b	23.4	18.9	12.8	7.7	7.0	25.7	100.0	30.2	0.9	24.3	0.7	19.8	17.8	10.4
Barbecued (%)	6.6	0.8	0.1	1.9		14.3		2.3	0.2		0.5	1.9	0.7	3.0
Boiled (%)	6.6	5.0	9.9	9.6	4.7	5.7		7.8	2.7		26.9	4.2	4.1	8.2
Fried (%) ^c	12.0	4.5	8.4	7.7	41.9	14.3		8.5	82.2		40.0	39.6	65.9	55.8
Stir fried (%)	20.0	34.3	7.2	1.0	4.7			11.6	1.7		2.1	23.0	0.5	2.2
Grilled (%)	17.8	27.0	13.9	21.2	9.3	2.9		6.2	0.6		6.0	10.1	5.6	
Stewed (%)	9.7	7.5	23.7	21.2	11.6	11.4		28.7	8.6	74.3	21.4	0.1		16.4
Coated and fried (%) ^d	0.4		7.3	19.2	2.3	8.6			0.1			0.2	0.5	
Other cooking method (%) ^e	3.5	1.9	16.8	10.6	18.6	17.1		4.6	3.0	1.4	2.5	1.0	4.8	4.1
Veal (n)	172	141	326	9	59	698	104	0	47	590	38	42	125	8
Baked/roasted (%) ^b	37.2	23.4	16.3			12.2	31.7			26.9	2.6	21.4	32.0	12.5
Barbecued (%)	2.9	0.7			1.7	2.0				2.4		2.4	0.8	
Boiled (%)	5.8	7.1	11.0		10.2	10.0	17.3		8.5	4.1		33.3	4.0	25.0
Fried (%) ^c	12.8	5.0	8.3	11.1	35.6	39.5	4.8		74.5		36.8	26.2	53.6	25.0
Stir fried (%)	13.4	34.0	10.1	11.1	3.4	3.0	14.4			15.1			0.8	
Grilled (%)	2.9	7.1	4.9		11.9					3.2	5.3		2.4	
Stewed (%)	20.9	14.9	26.1	33.3	15.3	11.5	29.8		10.6	47.1	34.2			
Coated and fried (%) ^d	2.3	6.4	9.8	11.1	8.5	14.2	1.9		2.1	0.2	21.1	16.7	6.4	37.5
Other cooking method (%) ^e	1.7	1.4	13.5	33.3	13.6	7.5			4.2	1.0				
Pork (n)	294	172	203	19	30	272	248	97	863	294	1080	1422	983	168
Baked/roasted (%) ^b	50.3	33.1	30.0	10.5		12.1	23.0	45.4	0.6	16.0	5.5	18.8	30.2	22.6
Barbecued (%)	5.8	2.3	0.5	15.8	3.3	1.5	1.6	4.1	1.3	32.0	3.7	5.1	0.5	8.9
Boiled (%)	8.5	7.0	0.5	5.3	13.3	3.7	4.4	3.1	3.5	1.4	13.9	12.0	6.1	11.9
Fried (%) ^c	3.4	2.9	5.4	5.3	40.0	51.1	22.2	4.1	76.0	5.1	37.7	41.1	47.9	36.9
Stir fried (%)	12.6	27.9	9.4			8.1	19.4	9.3	7.9	4.1	0.6	6.3	1.3	4.8
Grilled (%)	7.5	13.4	19.2	5.3	6.7			20.6	4.3	11.9	5.1	7.2	4.0	5.4
Stewed (%)	7.8	7.6	18.2	47.4	6.7	11.0	19.8	5.2	0.9	26.5	12.4	0.1		1.8
Coated and fried (%) ^d		0.6	3.4		6.7	6.6	3.2	2.1	1.6	2.0	13.5	6.9	8.6	1.8
Other cooking method (%) ^e	4.1	5.2	13.3	10.5	23.3	5.9	6.5	6.2	3.9	1.0	7.7	2.5	1.3	6.0
Lamb (n)	176	140	22	4	5	154	47	67	66	169	26	52	72	71
Baked/roasted (%) ^b	45.5	46.4	40.9	50.0	20.0	30.5	51.1	55.2	3.0	50.9	7.7	19.2	56.9	25.4
Barbecued (%)	6.8	2.9		25.0	20.0	9.7	12.8	1.5	4.5	15.4	3.8	11.5	2.8	1.4
Boiled (%)	0.6	1.4				3.2	8.5	4.5	3.0	4.1	7.7	21.2	5.6	54.9
Fried (%) ^c	9.7	0.7	9.1		20.0	21.4	8.5	7.5	69.7	0.6	65.4	36.5	27.8	14.1
Stir fried (%)	10.8	20.7	4.5			1.9	8.5	10.4	1.5	1.8		11.5		
Grilled (%)	10.2	20.0	18.2					10.4	10.6	5.3	11.5		1.4	1.4
Stewed (%)	14.8	6.4	13.6	25.0	20.0	23.4	4.3	6.0	6.1	21.9				1.4
Coated and fried (%) ^d			13.6			3.9								
Other cooking method (%) ^e	1.7	1.4			20.0	5.8	6.4	4.5	1.5		3.8		5.6	1.4
Minced meat (n)	3	7	86	8	23	12	16	2	248	15	154	597	287	34
Baked/roasted (%) ^b		28.6	25.6	50.0	26.1	25.0	56.3	50.0	4.0	20.0	39.6	15.2	4.5	11.8
Barbecued (%)									0.4		0.6	3.5		2.9
Boiled (%)	33.3		2.3		8.7	8.3	18.8		2.4		3.9	4.5	2.8	23.5
Fried (%) ^c		28.6	24.4		21.7	16.7	6.3		73.0	13.3	31.8	75.0	88.9	52.9
Stir fried (%)			8.1			33.3	12.5		4.4	26.7	13.0	1.0		
Grilled (%)	33.3		15.1		4.3				0.4		3.2	0.2		2.9
Stewed (%)	33.3		2.3	25.0	13.0	8.3	6.3	50.0	0.4	40.0	3.9			2.9
Coated and fried (%) ^d		14.3	4.7			8.3					1.9	0.3	3.8	
Other cooking method (%) ^e		28.6	17.5	25.0	26.0				14.9		1.9	0.2		2.9
Processed meat (n)	551	386	2190	127	198	1915	852	409	2190	202	4293	2965	874	957
Baked/roasted (%) ^b	15.1	12.2	5.6	19.7	8.6	3.7	8.8	11.7	2.3	18.8	2.4	14.5	9.3	5.7
Barbecued (%)	4.5	2.1	0.2	1.6		0.2	1.1	2.7	0.8	6.4	1.1	1.3	0.8	2.1
Boiled (%)	17.6	19.2	2.3	1.6	3.5	16.3	12.4	3.9	1.5	7.9	31.4	12.6	43.8	29.3
Fried (%) ^c	3.4	6.2	2.2	3.1	19.7	23.1	7.4	10.3	19.9	1.0	12.4	24.0	28.8	30.8
Stir fried (%)	9.3	11.9	1.4	0.8	0.5	6.1	4.1	4.4	2.8	1.5	3.2	0.8		
Grilled (%)	18.5	23.8	1.1	6.3	1.5			29.8	2.0	6.9	1.0	6.2	8.7	1.4
Stewed (%)	7.3	7.8	2.8	4.7	2.0	13.8	11.7	0.2	0.6	1.0	0.3			0.1
Coated and fried (%) ^d	0.2	0.3		0.8		2.2	0.9		0.2		0.1	0.2	0.8	0.2

Table 4 continued.

Table 4 cont.

Cooking method	Northern France ^a	Southern France	Northern Italy	Ragusa (Italy)	Naples (Italy)	Northern Spain	Southern Spain	Great Britain	Netherlands	Greece	Germany	Sweden	Denmark	Norway
No CM applied (%) ^f	16.7	13.5	81.3	56.7	61.1	31.2	46.6	27.6	58.7	41.1	41.5	38.3	6.9	22.3
Other cooking method (%)	7.4	3.1	3.0	4.7	3.0	3.2	6.9	9.3	11.2	15.3	6.7	2.0	0.9	8.2
<i>Chicken (n)</i>	309	227	459	35	32	499	314	207	529	414	300	518	440	138
Baked/roasted (%) ^b	60.8	51.5	20.0	37.1	25.0	28.9	26.1	46.9	2.5	27.3	6.3	58.3	24.5	6.5
Barbecued (%)	1.9	1.8	0.7	2.9	3.1	0.6	0.6	2.4	1.7	11.8	0.3	9.1	0.7	2.2
Boiled (%)	5.8	3.5	15.7	5.7	18.8	8.2	21.3	2.9	11.9	19.3	30.0	8.1	46.4	5.1
Fried (%) ^c	3.2	0.9	7.8	2.9	21.9	30.9	17.5	6.8	60.5		22.7	17.0	18.2	23.9
Stir fried (%)	10.0	23.3	5.7	5.7		6.0	18.8	7.7	1.7		0.3	5.0	2.5	2.9
Grilled (%)	3.2	10.1	14.6	5.7	6.3	0.2		2.9	12.7	13.8	27.3	0.8	5.7	57.2
Stewed (%)	11.0	4.8	15.7	22.9	3.1	8.6	11.5	16.9	1.7	25.4	1.3			0.7
Coated and fried (%) ^d	1.0		12.9	5.7	6.3	12.6	1.6	7.7	1.7	0.7	6.3	0.6	0.5	
Other cooking method (%) ^e	2.9	4.0	7.0	11.5	15.6	4.0	2.5	3.7	5.7	1.7	5.3	1.2	1.6	1.4
<i>Turkey (n)</i>	78	55	187	6	20	27	27	42	58	29	178	37	213	15
Baked/roasted (%) ^b	33.0	29.2	20.3	16.7	30.0	14.8	18.5	47.6	3.4	17.2	5.6	51.4	13.6	20.0
Barbecued (%)	1.7					3.7			5.2			2.7	0.9	
Boiled (%)	3.5	1.4	3.2	16.7	5.0			22.2	7.1	6.9	17.2	1.7	13.5	5.6
Fried (%) ^c	7.8	2.8	12.3		10.0	29.6	48.1	2.4	70.7		56.7	16.2	57.3	13.3
Stir fried (%)	25.2	36.1	4.8					11.9	3.4		0.6		6.1	
Grilled (%)	8.7	11.1	10.7	16.7				4.8	3.4	20.7	6.2		4.7	6.7
Stewed (%)	10.4	4.2	22.5	50.0	35.0	33.3	7.4	2.4		24.1	4.5			6.7
Coated and fried (%) ^d	4.3	8.3	18.2			18.5	3.7			10.3	16.9	8.1	9.9	13.3
Other cooking method (%) ^e	5.2	7.0	8.0		20.0			23.8	6.9	10.1	7.9	8.1	1.8	20.0
<i>Fish (n)</i>	832	559	696	67	105	1458	725	208	554	742	504	1602	984	474
Baked/roasted (%) ^b	12.1	7.9	14.1	20.9	4.8	6.9	15.3	8.2	5.4	12.0	2.2	17.0	6.4	11.0
Barbecued (%)	1.2	1.4	0.3	1.5	1.9	0.4	0.4	0.5	0.2	3.9	0.8	0.4	0.2	0.2
Boiled (%)	20.2	17.5	13.1	11.9	27.6	3.6	8.3	3.8	5.8	7.3	9.7	16.6	13.1	17.7
Fried (%) ^c	2.8	5.5	2.3	1.5	1.9	22.9	5.0	6.3	10.3	0.5	6.5	8.9	3.2	11.4
Stir fried (%)	5.4	6.3	1.7		1.9	2.0	1.2	0.5		1.2		0.6	0.1	0.2
Grilled (%)	1.8	4.1	3.6	7.5				8.7	2.2	10.0	1.4	0.6		0.2
Stewed (%)	1.7	0.9	14.8	14.9	21.0	11.2	2.1	1.4	1.8	10.9	6.7			1.1
Coated and fried (%) ^d	7.2	7.0	10.3	10.4	14.3	18.9	14.9	14.9	4.0	38.1	12.9	14.5	13.7	2.7
No cooking method applied (%) ^f	34.9	37.0	32.3	25.4	23.8	25.4	38.9	26.4	63.4	15.8	54.0	39.0	56.8	42.8
Other cooking method (%)	12.7	12.3	7.5	6.0	2.9	8.6	13.9	29.3	7.0	0.3	5.8	2.4	6.5	12.7
<i>Crustaceans (n)</i>	161	116	279	31	30	529	345	41	156	171	63	496	164	200
Baked/roasted (%) ^b	4.5	4.5	1.8			1.5	8.1	12.2	3.8		14.3	16.3	11.0	1.5
Barbecued (%)	0.7					0.4	0.3			7.6				
Boiled (%)	38.4	40.7	42.3	32.3	53.3	34.2	29.0	34.1	41.0	26.3	22.2	73.8	37.2	38.0
Fried (%) ^c	1.1	2.3	4.3	3.2	3.3	6.0	9.0	14.6	19.2	10.5	9.5	0.6	7.3	0.5
Stir fried (%)	22.0	23.7	2.9			30.6	26.4	9.8	2.6	4.1		3.0		1.5
Grilled (%)	0.4	2.8	5.0	9.7	3.3				1.9	1.2	1.6			
Stewed (%)	6.3	2.8	35.5	45.2	33.3	5.5	2.9			36.3	1.6			
Coated and fried (%) ^d	0.4	1.7	3.2	3.2		11.0	7.0		3.2	10.5	6.3		4.9	
No cooking method applied (%) ^f	23.1	18.6	0.7	3.2		4.0	7.0	12.2	19.2	3.5	38.1	3.8	33.5	55.0
Other cooking method (%)	3.0	2.8	4.3	3.2	6.7	6.8	10.4	17.1	9.0		6.3	2.4	6.1	3.5

^aThe regions/countries include the centres as given in the figure captions.

^b% = Percentage of specified cooking methods.

^cFried does not include deep fried and stir fried.

^dCoated and fried: includes breaded and fried, battered and fried, in flour and fried.

^eOther cooking method includes 'no cooking method applied'.

^fNo cooking method applied: includes 'raw' and 'cooking method not applicable'.

eating in restaurants or canteens may be the main reason for missing specification of cooking methods, since unspecific cooking methods were more often used for meat and fish not consumed at home (data not shown). It can be assumed that these foods, especially in canteens, were prepared according

to the distribution of the specific cooking methods in each country and region.

Furthermore, for an even greater proportion of meat and fish items (mean = 23%) no cooking method was applied before consumption. The descriptors 'raw' and 'cooking

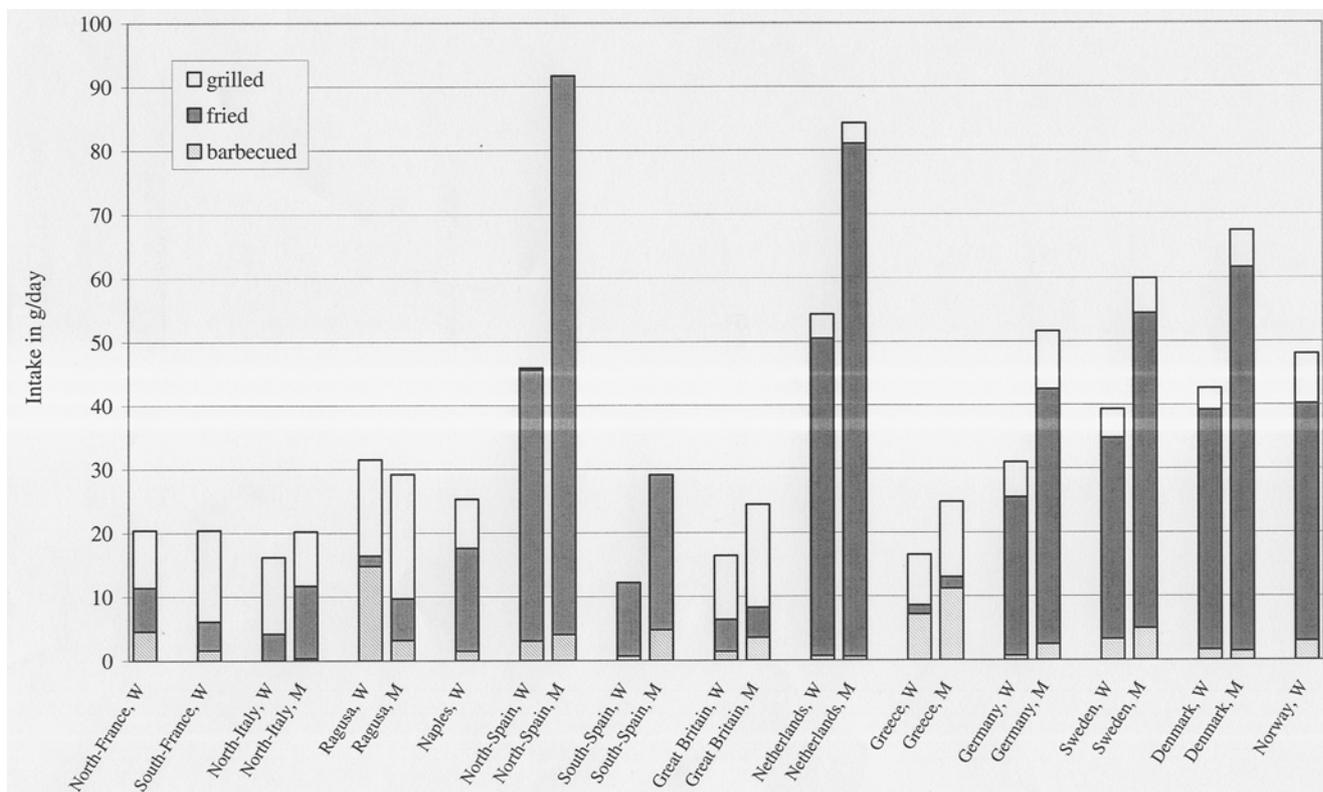


Figure 2 Mean intake of barbecued, fried, and grilled meat and fish by region/country in EPIC assessed by 24 h recalls in 22 727 women and 12 917 men. The regions/countries include the following study centres: *northern France*—northeast, northwest; *southern France*—south, south coast; *northern Italy*—Varese, Turin, Florence; *northern Spain*—Oviedo, Pamplona, San Sebastian; *southern Spain*—Granada, Murcia; *Great Britain*—general population; *Netherlands*—Bilthoven, Utrecht; *Germany*—Heidelberg, Potsdam; *Sweden*—Malmo, Umea; *Denmark*—Copenhagen, Aarhus; *Norway*—northwest, southeast. W=women; M=men. The cooking method 'fried' does not include deep fried and stir fried. Mean adjusted for age, season and week day.

method not applicable' were mostly used for processed meat, fish and crustaceans. Since these descriptors do not exclude cooking outside the home or preparation in another way, no assumptions can be made about the way in which these foods were consumed. In particular mean daily intake of processed meat to which no cooking method was applied is as high as 17 g in some countries. Furthermore, for a subgroup of meat and fish items, especially for processed meat, the cooking method was not assessed because these foods were usually not cooked before consumption, eg salami-type sausages. These foods were not included in the data set used for the present analysis. As a consequence, the intake of meat given in Tables 4 and 5 is lower than the intake of meat estimated by the 24 h recalls. The difference is larger for processed meat than for red and white meat.

Differences in under- or over-reporting among the study regions might influence the data. Meat intake is affected by under-reporting in Greece and southern Spain. With adjustment for energy intake, total meat intake results increased

distinctly in these EPIC centres (Linseisen *et al*, 2002). The topic of underreporting in the EPIC calibration study will be discussed in a special paper (Ferrari *et al*, 2002).

To calculate the mean intake of cooked meat and fish, adjustment for different variables was made. Mean adjusted intake was computed by using the ANACOVA procedure to adjust for age and to apply weights to the ANACOVA estimates when considering the categorical variables weekday and season. Weighing factors for weekday and season were included because the 24 h recalls were not equally distributed concerning the different seasons and weekdays. This is important especially for foods prepared by cooking methods which were applied only during a certain season, eg barbecuing during the summer. If more interviews were made in the winter than in the summer, the intake of barbecued meat and fish would have been underestimated without adjustment for season.

The data from this study suggests that dietary habits concerning meat and fish consumption differ greatly by

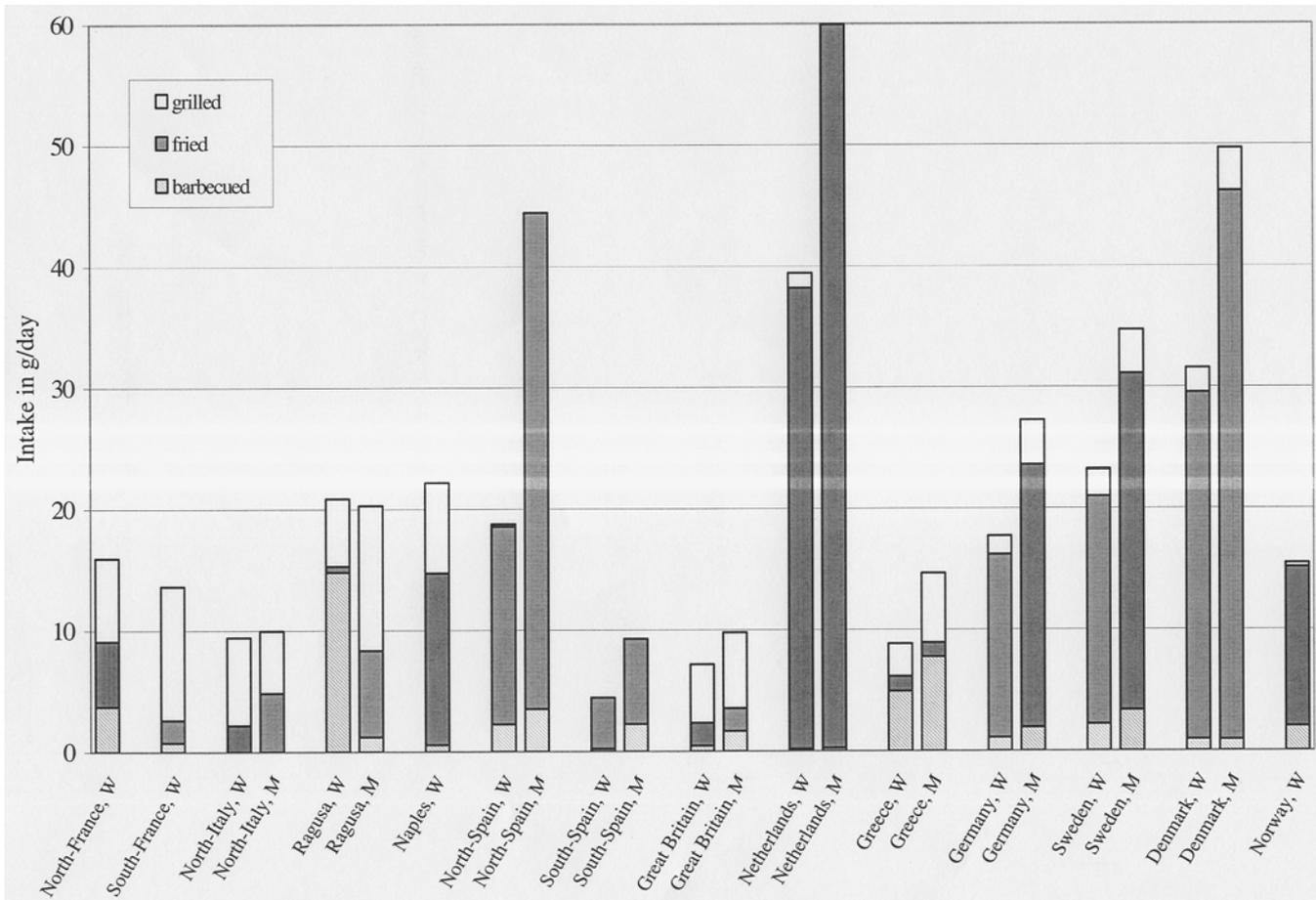


Figure 3 Mean intake of barbecued, fried and grilled red meat by region/country in EPIC assessed by 24 h recalls in 22 727 women and 12 917 men. The regions/countries include the following study centres: *northern France*—northeast, northwest; *southern France*—south, south coast; *northern Italy*: Varese, Turin, Florence; *northern Spain*: Oviedo, Pamplona, San Sebastian; *southern Spain*: Granada, Murcia; *Great Britain*—general population; *Netherlands*—Bilthoven, Utrecht; *Germany*—Heidelberg, Potsdam; *Sweden*—Malmo, Umea; *Denmark*—Copenhagen, Aarhus; *Norway*—northwest, southeast. W=women; M=men. The cooking method ‘fried’ does not include deep fried and stir fried. Mean adjusted for age, season, and week day.

country and region. In general, frying is more common in EPIC cohorts of northern European countries and less in the south, whereas roasting and stewing are more frequently used in the south than in the north. This indicates characteristics in meat and fish preparation patterns across Europe. Comparable data concerning the application of cooking methods are quite rare. A study in Sweden aimed to look at cooking methods of meat and fish in an elderly population (124 men and women between 50 and 75 y old) in Stockholm (Augustsson *et al*, 1999a). Their results indicated a dominant role of frying (61% of consumed meat and fish). Twenty percent of meat and fish was baked/roasted and 15% boiled. They asked only for the frequency of four cooking methods (grilling, frying, boiling and baking/roasting). Taking into account only these four cooking methods in the present study, frying contributes 42.2% to the preparation of meat and fish in the Swedish study centres and baking/roasting 28.2%. This confirms the results of Augustsson *et al* (1999a).

Cooking methods differ by cooking temperature, the use of direct heat (flame) and the use of fat. This influences the production of possibly carcinogenic compounds like HCA and PAH. Steaming, boiling and stewing expose food to temperatures mostly below or around 100°C. Baking, microwaving and roasting produces temperatures up to 200°C, but foods are not exposed directly to a hot surface. In contrast, grilling, barbecuing, frying and stir frying expose foods to a hot surface or to direct flame for a longer or shorter period of time (Augustsson *et al*, 1999a; Skog *et al*, 1998; World Cancer Research Fund, 1997). However, since the contact with the hot surface is only for a short time period, the production of HCA is lower during stir frying compared with the other cooking methods (World Cancer Research Fund, 1997).

Most studies dealing with cooking methods put their main focus on high-temperature cooking methods, where most carcinogenic substances are produced (Skog *et al*, 1995,1998; Knize *et al*, 1996; Johansson & Jägerstad, 1994). Extracting high-temperature methods applied in the present

study, it turns out that the variation between countries or regions is enormously high, the intake in the study centres in north Spain being at least four times higher than that in northern Italy. High-temperature cooking methods are used less often in the EPIC cohorts in France, northern Italy, Greece, and southern Spain; the amount of meat and fish eaten fried, grilled or barbecued is low as well in these countries compared to the cohorts in the northern part of Europe. Most interesting is northern Spain. In men, more than 90 g of meat and fish are eaten fried and barbecued, which is the highest intake in EPIC, but both methods account for only 26% of meat and fish cooking in northern Spain. This indicates that exclusively qualitative information, eg frequency of consumption, has to be supported by a quantitative estimate of the exposure. A specially designed questionnaire can help to get both kinds of information. Keating and Bogen (2001) analysed data of about 20 000 participants of the Continuing Survey of Food Intakes by Individuals for cooking methods used to prepare meat and fish. Additionally, they made assumptions about the doneness level of the consumed foods and calculated the HCA intake based on these assumptions. In EPIC, however, it can be assumed that the preferred doneness level differs quite strongly and therefore it seems to be more appropriate to use a specially designed questionnaire to assess the HCA intake.

Incidence rates of cancer differ quite substantially in Europe, especially between northern and southern countries. Age-adjusted cancer incidence rates for colorectal and breast cancer are higher in the northern and western countries of Europe than in the south, whereas the incidence of stomach cancer is higher in the south than in the west and the north of Europe (Parkin *et al*, 1997). An influence of different cooking techniques on cancer incidences might be possible. The report of the World Cancer Research Fund (1997) concludes that cooking meat at high temperatures possibly increases the risk of colorectal cancer and grilling and barbecuing possibly increase the risk of stomach cancer. For frying results are conflicting. Several studies have explored these relationships with contradicting results concerning cancer risk. The general problem of these international studies is the different definition of cooking methods (Sinha & Rothman, 1999). For example, barbecuing has different meanings worldwide and grilling can mean heating on an open fire as well as heating on a hot surface (World Cancer Research Fund, 1997). In this study, the same definitions (and coding) of cooking methods across countries were used which excludes this kind of bias at least partly.

Some case-control studies observed a higher cancer risk for persons eating more red meat. A recently published study from Italy (Tavani *et al*, 2000) showed higher risks for persons eating red meat ≥ 7 times per week compared to those eating red meat ≤ 3 times per week for different cancer sites, including colon, rectum and stomach. In contrast, Kampman *et al* (1999) were not able to observe an association between the consumption of red meat and the risk of colon cancer. Not only the quantity of red meat intake is of interest

but also the cooking of it. Associations between the consumption of fried, grilled, barbecued or pan-fried red meat and the risk of colon cancer (Schiffman & Felton, 1990), colorectal adenomas (Sinha *et al*, 1999), breast cancer (Zheng *et al*, 1999) and stomach cancer (Ward *et al*, 1997) were found, but there are several investigations that were not able to detect any association (Delfino *et al*, 2000; Gertig *et al*, 1999; Ambrosone *et al*, 1998). In the present study, the preparation of red meat shows a great variability across the participating countries and regions. Whereas in the EPIC centres in northern Spain, the Netherlands, Germany, Sweden, Denmark and Norway, frying is the common way to prepare it, other cooking methods are preferred in the south. Considerable amounts of red meat are consumed boiled and stewed in the cohorts of Italy, southern Spain and Greece, underlining that high-temperature cooking methods were more often used in northern Europe.

In addition to the cooking method, the degree of browning that individuals prefer when eating prepared meat and fish is a further important characteristic. On this basis, Sinha *et al* (1999) showed an increased risk of colorectal adenomas for the consumption of red meat in general as well as of well-done and very well-done red meat and of grilled red meat in a case-control study. This correlation was also apparent in study conducted in California (Ward *et al*, 1997). In a case-control study conducted by Zheng *et al* (1999), women who ate bacon, beef steak, and hamburgers well-done had a significantly higher breast cancer risk than women who preferred rare or medium meat. However, two earlier studies found no evidence for an association between cooking method, degree of doneness and cancer risk (Muscat & Wynder, 1994; Lyon & Mahoney, 1988). In the present study no data on the degree of browning or doneness were obtained.

EPIC offers the opportunity to compare data on cooking methods in Europe, because cooking methods used in the program EPIC-Soft were defined for all participating countries by the coordinating centre in Lyon and these definitions were used equally in each country. The results of this study will be used to develop a questionnaire on cooking methods of meat and fish that could be applied in all EPIC countries. It will allow the assessment of the applied food preparation methods from all EPIC participants. Apart from the cooking methods, this questionnaire will, in contrast to the program EPIC-SOFT, also be able to assess the degree of doneness and browning of prepared meat and fish. By means of such data, the heterogeneity within EPIC provides a fairly good chance to proceed in our knowledge of the relationship between food preparation methods and cancer risk.

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References

- Adamson RH, Thorgeirsson UP, Snyderwine EG, Thorgeirsson SS, Reeves J, Dalgard DW, Takayama S & Sugimura T (1990): Carcinogenicity of 2-amino-3-methylimidazo[4,5-f]quinoline in non-human primates: induction of tumors in three macaques. *Jpn. J. Cancer Res.* **81**, 10–14.
- Ambrosone CB, Freudenheim JL, Sinha R, Graham S, Marshall JR, Vena JE, Laughon R, Nemoto R & Shields PG (1998): Breast cancer risk, meat consumption and N-acetyltransferase (NAT2) genetic polymorphisms. *Int. J. Cancer* **75**, 825–839.
- Augustsson K, Lindblad J, Övervik E & Steineck G (1999a): A population-based dietary inventory of cooked meat and assessment of the daily intake of food mutagens. *Food Additives Contamin.* **16**, 215–225.
- Augustsson K, Skog K, Jägerstad M, Dickman PW & Steineck G (1999b): Dietary heterocyclic amines and cancer of the colon, rectum, bladder, and kidney: a population-based study. *Lancet* **353**, 703–707.
- Deitz AC, Zheng W, Leff MA, Gross M, Wen W-Q, Doll MA, Xiao GH, Folsom AR & Hein DW (2000): N-Acetyltransferase 2 genetic polymorphisms, well-done meat intake, and breast cancer risk among postmenopausal women. *Cancer Epidemiol. Biomark. Prev.* **9**, 905–910.
- Delfino RJ, Sinha R, Smith C, West J, White E, Lin HJ, Liao S-Y, Gim JSY, Ma HL, Butler J & Anton-Culver H (2000): Breast cancer, heterocyclic amines from meat and N-acetyltransferase 2 genotype. *Carcinogenesis* **21**, 607–615.
- De Stefani E, Doneo-Pellegrini H, Mendilaharsu M & Ronco A (1997a): Meat intake, heterocyclic amines and risk of colorectal cancer: a case-control study in Uruguay. *Int. J. Oncol.* **10**, 573–580.
- De Stefani E, Ronco A, Mendilaharsu M, Guidobono M & Doneo-Pellegrini H (1997b): Meat intake, heterocyclic amines, and risk of breast cancer: a case-control study in Uruguay. *Cancer Epidemiol. Biomark. Prev.* **6**, 573–581.
- De Stefani E, Boffetta P, Mendilaharsu M, Carzoglio J & Deneo-Pellegrini H (1998a): Dietary nitrosamines, heterocyclic amines, and risk of gastric cancer: a case-control study in Uruguay. *Nutr. Cancer* **30**, 158–162.
- De Stefani E, Ronco A, Mendilaharsu M & Doneo-Pellegrini H (1998b): Case-control study on the role of heterocyclic amines in the etiology of upper aerodigestive cancers in Uruguay. *Nutr. Cancer* **32**, 43–48.
- Doneo-Pellegrini H, De Stefani E, Ronco A, Mendilaharsu M & Carzoglio JC (1996): Meat consumption and risk of lung cancer; a case-control study from Uruguay. *Lung Cancer* **14**, 195–205.
- Ferrari P, Slimani N, Ciampi A, Trichopoulos D, Naska A, Lauria C, Veglia F, Bueno-de-Mesquita HB, Ocké MC, Brustad M, Braaten T, Tormo MJ, Amiano P, Mattisson I, Johansson G, Welch A, Davey G, Overvad K, Tjønneland A, Clavel-Chapelon F, Thiebaut A, Linseisen J, Boeing H, Hemon B & Riboli E (2002): Evaluation of misreporting in the 24-hour diet recalls in EPIC. *Pub. Health Nutr.* (in press).
- Gerhardsson de Verdier M, Hagman U, Peters UK, Steineck G & Övervik E (1991): Meat, cooking methods and colorectal cancer: a case-referent study in Stockholm. *Int. J. Cancer* **49**, 520–525.
- Gertig DM, Hankinson SE, Hough H, Spiegelman D, Colditz GA, Willett WC, Kelsey KT & Hunter DJ (1999): N-Acetyltransferase 2 genotypes, meat intake and breast cancer risk. *Int. J. Cancer* **80**, 13–17.
- Guillén MD, Sopolana P & Partearroyo (1997): Food as a source of polycyclic aromatic carcinogens. *Rev. Environ. Health* **13**, 133–146.
- Jägerstad M, Laser Reuterswärd A, Öste R, Dalquist A, Grivas S, Olsson K & Nyhammar T (1983): Creatine and Maillard reaction products as precursors of mutagenic compounds formed in fried beef. *ACS Symp. Ser.* **215**, 507–519.
- Johansson MAE & Jägerstad M (1994): Occurrence of mutagenic/carcinogenic heterocyclic amines in meat and fish products, including pan residues, prepared under domestic conditions. *Carcinogenesis* **15**, 1511–1518.
- Kampman E, Slattery ML, Bigler J, Leppert M, Samowitz W, Caan BJ & Potter JD (1999): Meat consumption, genetic susceptibility, and colon cancer risk: a United States multicenter case-control study. *Cancer Epidemiol. Biomark. Prev.* **8**, 14–24.
- Keating GA & Bogen KT (2001): Methods to estimate heterocyclic aromatic amine concentrations in cooked meats in the US diet. *Food Chem. Toxicol.* **11**, 29–43.
- Knize MG, Sinha R, Salmon CP, Metha SS, Dewhirst KP & Felton JS (1996): Formation of heterocyclic amine mutagens/carcinogens during home and commercial cooking of muscle food. *J. Muscle Foods* **7**, 271–279.
- Larsson BK, Sahlberg GP, Eriksson AT & Busk LÅ (1983): Polycyclic aromatic hydrocarbons in grilled food. *J. Agric. Food Chem.* **31**, 867–873.
- Linseisen J, Kesse E, Slimani N, Bueno-de-Mesquita HB, Ocké MC, Skeie G, Kumle M, Iraeta MD, Gómez PM, Janzon L, Stattin P, Welch A, Spencer EA, Overvad K, Tjønneland A, Clavel-Chapelon F, Miller AB, Klipstein-Grobusch K, Lagiou P, Kalapothaki V, Masala G, Giurdanella MC, Norat T & Riboli E (2002): Meat consumption in the EPIC cohorts—results from the 24-hour dietary recalls. *Pub. Health Nutr.* (in press).
- Lyon JL & Mahoney AW (1988): Fried foods and the risk of colon cancer. *Am. J. Epidemiol.* **128**, 1000–1006.
- Muscat JE & Wynder EL (1994): The consumption of well-done red meat and the risk of colorectal cancer. *Am. J. Public Health* **84**, 856–858.
- Norrish AE, Ferguson LR, Knize MG, Felton JS, Sharpe SJ & Jackson RT (1999): Heterocyclic amine content of cooked meat and risk of prostate cancer. *J. Natl Cancer Inst.* **91**, 2038–2044.
- Parkin DM, Whelan SL, Ferlay J, Raymond L & Young J (1997): *Cancer Incidence in Five Continents*, Vol. VII. IARC Scientific Publications no. 143. Lyon: International Agency for Research on Cancer.
- Probst-Hensch NM, Sinha R, Longnecker MP, Witte JS, Ingles SA, Frankl HD, Lee ER & Haile RW (1997): Meat preparation and colorectal adenomas in a large sigmoidoscopy-based case-control study in California (United States). *Cancer Causes Control* **8**, 175–183.
- Riboli E (1992): Nutrition and cancer: background and rationale of the European Prospective Investigation into Cancer and Nutrition (EPIC). *Ann. Oncol.* **3**, 783–791.
- Riboli E & Kaaks R (1997): The EPIC Project: rationale and study design. *Int. J. Epidemiol.* **26**(Suppl 1), S6–S14.
- Rothman N, Correa-Villasenor A, Ford DP, Poirier MC, Haas R, Hansen JA, O'Toole T & Strickland PT (1993): Contribution of occupation and diet to white blood cell polycyclic aromatic hydrocarbon-DNA adducts in Wildland firefighters. *Cancer Epidemiol. Biomark. Prev.* **2**, 341–347.
- Schiffman MH & Felton JS (1990): Re: 'Fried foods and the risk of colon cancer'. *Am. J. Epidemiol.* **131**, 376–378.
- Shirai T, Tamano S, Sano M, Masui T, Hasegawa R & Ito N (1995): Carcinogenicity of 2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP) in rats: dose-response studies. *Princess Takamatsu Symposia* **23**, 232–239.
- Sinha R & Rothman N (1999): Role of well-done, grilled red meat, heterocyclic amines (HCAs) in the etiology of human cancer. *Cancer Lett.* **143**, 189–194.
- Sinha R, Kulldorff M, Curtin J, Brown CC, Alavanja MCR & Swanson C A (1998): Fried, well-done red meat and risk of lung cancer in women (United States). *Cancer Causes Control* **9**, 621–630.
- Sinha R, Chow WH, Kulldorff M, Denobile J, Butler J, Garcia-Closas M, Weil R, Hoover RN & Rothman N (1999): Well-done, grilled red meat increases the risk of colorectal adenomas. *Cancer Res.* **59**, 4320–4324.
- Sinha R, Gustafson DR, Kulldorff M, Wen W-Q, Cerhan JR & Zheng W (2000a): 2-Amino-1-methyl-6-phenylimidazo[4,5-b]pyridine, a carcinogen in high-temperature-cooked meat, and breast cancer risk. *J. Natl Cancer Inst.* **92**, 1352–1354.
- Sinha R, Kulldorff M, Swanson CA, Curtin J, Brownson RC & Alavanja MCR (2000b): Dietary heterocyclic amines and the risk of lung cancer among Missouri women. *Cancer Res.* **60**, 3753–3757.

- Sinha R, Kulldorff M, Chow W-H, Denobile J & Rothman N (2001): Dietary intake of heterocyclic amines, meat-derived mutagenic activity, and risk of colorectal adenomas. *Cancer Epidemiol. Biomark. Prev.* **10**, 559–562.
- Skog K, Steineck G, Augustsson K & Jägerstad M (1995): Effect of cooking temperature on the formation of heterocyclic amines in fried meat products and pan residues. *Carcinogenesis* **16**, 861–867.
- Skog KI, Johansson MAE & Jägerstad MI (1998): Carcinogenic heterocyclic amines in model systems and cooked foods: a review on formation, occurrence and intake. *Food Chem. Toxicol.* **36**, 879–896.
- Slimani N, Deharveng G, Charrondière RU, van Kappel AL, Ocké MC, Welch A, Lagiou A, van Liere M, Agudo A, Pala V, Brandstetter B, Andren C, Stripp C, van Staveren WA & Riboli E (1999): Structure of the standardised computerized 24-h recall interview used as reference method in the 22 centers participating in the EPIC project. *Comp. Meth. Progr. Biomed.* **58**, 251–266.
- Slimani N, Ferrari P, Ocké MC, Welch A, Boeing H, van Liere A, Pala V, Amiano P, Lagiou A, Mattisson I, Stripp C, Engset D, Charrondière R, Buzzard M, van Staveren W & Riboli E (2000): Standardization of the 24-hour diet recall calibration method used in the European Prospective Investigation into Cancer and Nutrition (EPIC): general concepts and preliminary results. *Eur. J. Clin. Nutr.* **54**, 900–917.
- Steineck G, Hagman U, Gerhardsson de Verdier M & Norell SE (1990): Vitamin A supplements, fried foods, fat and urothelial cancer. A case-referent study in Stockholm in 1985–87. *Int. J. Cancer* **45**, 1006–1011.
- Tavani A, La Vecchia C, Gallus S, Lagiou P, Trichopoulos D, Levi F & Negri E (2000): Red meat intake and cancer risk. *Int. J. Cancer* **86**, 425–429.
- Ward MH, Sinha R, Heineman EF, Rothman N, Markin R, Weisenburger DD, Correa P & Zahm SH (1997): Risk of adenocarcinoma of the stomach and esophagus with meat cooking method and doneness preference. *Int. J. Cancer* **71**, 14–19.
- World Cancer Research Fund (1997): Food, nutrition and the prevention of cancer: a global perspective. Washington, DC: American Institute for Cancer Research.
- Zheng W, Gustafson DR, Sinha R, Cerhan JR, Moore D, Hong C-P, Anderson KE, Kushi LH, Sellers TA & Folsom AR (1998): Well-done meat intake and the risk of breast cancer. *J. Natl Cancer Inst.* **90**, 1724–1729.
- Zheng W, Deitz AC, Campbell DR, Wen W-Q, Cerhan JR, Sellers TA, Folsom AR & Hein DW (1999): N-Acetyltransferase 1 genetic polymorphism, cigarette smoking, well-done meat intake, and breast cancer risk. *Cancer Epidemiol. Biomark. Prev.* **8**, 233–239.