Differences in dietary intakes, food sources and determinants of total flavonoids between Mediterranean and non-Mediterranean countries participating in the European Prospective Investigation into Cancer and Nutrition (EPIC) study

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Abstract

A greater adherence to the traditional Mediterranean (MED) diet is associated with a reduced risk of developing chronic diseases. This dietary pattern is based on higher consumption of plant products that are rich in flavonoids. We compared the total flavonoid dietary intakes, their food sources and various lifestyle factors between MED and non-MED countries participating in the EPIC study. Flavonoid intakes and their food sources for 35 628 subjects, aged 35–74 years and recruited between 1992 and 2000, in twenty-six study centres were estimated using standardised 24 h dietary recall software (EPIC-Soft®). An *ad hoc* food composition database on flavonoids was compiled using analytical data from the United States Department of Agriculture and Phenol-Explorer databases. Moreover, it was expanded to include using recipes, estimations of missing values and flavonoid retention factors. No significant differences in total flavonoid mean intake between non-MED countries (373·7 mg/d) and MED countries (370·2 mg/d) were observed. In the non-MED region, the main contributors were proanthocyanidins (48·2 %) and flavan-3-ol monomers (24·9 %) and the principal food sources were tea (25·7 %) and fruits (32·8 %). In the MED region, proanthocyanidins (59·0 %) were by far the most abundant contributor and fruits (55·1 %), wines (16·7 %) and tea (6·8 %) were the main food sources. The present study shows similar results for total dietary flavonoid intakes, but significant differences in flavonoid class intakes, food sources and some characteristics between MED and non-MED countries. These differences should be considered in studies about the relationships between flavonoid intake and chronic diseases.

Key words: Flavonoids: Intake: Sources: Phenolics: European Prospective Investigation into Cancer and Nutrition

A Mediterranean (MED) diet is the traditional dietary pattern observed in countries bordering the Mediterranean Sea. It is characterised by a high consumption of fruits, vegetables, unrefined cereals, legumes, nuts and seeds, olive oil, a moderate wine consumption and lower intake of animal products. The MED diet was proposed as a healthy dietary pattern based on the evidence of its protective role in some chronic diseases[1–5]. As these plant-based products are high in flavonoids[6,7], a possible link between flavonoids and reported health benefits may be considered.

Flavonoids constitute a wide group of secondary plant metabolites that are ubiquitously distributed in the plant kingdom. Flavonoids are polyphenolic compounds possessing fifteen carbons, with two aromatic rings (rings A and B) joined by a linear three-carbon chain usually forming a closed pyran ring (ring C). According to the modifications of the central C-ring, they are often divided into six classes: anthocyanidins, flavonols, flavanones, flavones, isoflavones and flavanols or flavan-3-ols, including monomers, proanthocyanidins (PA) (oligomers and polymers of flavan-3-ol monomers) and flavanol-derived compounds (theaflavins and thearubigins)[8].

Despite their low-to-moderate bioavailability, high inter- and intra-individual variation in absorption and rapid conjugation[9], flavonoids have been extensively studied in the last two decades due to their potential health effects, such as antioxidant, anti-inflammatory, anticarcinogenic, anti-obesity, anti-allergic and anti-diabetic properties[10,11]. Associations between the consumption of total or classes of flavonoids and chronic disease prevention have also been suggested in several case–control and a few cohort studies[12,13]. Epidemiological evidence of the role of flavonoid intake against the risk of some chronic diseases is promising, but not conclusive. Complete descriptive studies of dietary intake are the first step in the assessment of the potential relationship between flavonoids and health.

To date, total flavonoid intake has been estimated in a few descriptive studies (Table 1)[14–24]. Moreover, these results varied widely among the studies because of differences in the flavonoid classes included, food composition tables used and dietary assessment methodologies utilised. It is difficult, therefore, to compare the existing data, and the present total dietary flavonoid estimations do not yet allow us to conclude which countries, i.e., MED or non-MED countries, consume more flavonoids. Hence, the present study aimed to estimate total flavonoid intake among European adults from MED and non-MED countries participating in the European

Table 1. Estimated flavonoid intake in adults in several countries

Study	Year	Country	Population	Dietary assessment	FCDB	Flavonoid without PA intake (mg/d)	PA intake (mg/d)	Total flavonoid intake (mg/d)	Major class contributor	Main food sources	Reference
SUVIMAX	1994	France	4942	Dietary history	Phenol explorer*	201	227	428	PA (53%)	Fruits, wine, tea	[20]
Stomach cancer case–control	1997–2007	Italy	777	FFQ	USDA†	127‡	291	417	PA (70%)	Fruits, wine, tea	[17]
EPIC	1992–2000	Spain	40 683	Dietary history	USDA§	124‡	189	313	PA (60%)	Fruits, wine	[19]
NHANES	1999–2002	USA	8809	24-HDR	USDA†	190‡	95	285	Flavan-3-ols (64%)	Tea, citrus fruit juices, fruits	[14,15]
FINDIET	2002	Finland	2007	48-HDR	Finnish FCDB	93‖	116	209	PA (50%)	Fruits, tea, chocolate	[16]
EPIC	1994–1999	Greece	28 572	FFQ	USDA§	86‡	75	161	PA (47%)	Fruits, wine, tea	[18]
National Nutrition Survey	1995	Australia	17 326	24-HDR	USDA†	454‡			Flavan-3-ols (93%)	Tea, fruits	[21]¶
Dutch National Food Consumption Survey	1985	The Netherlands	10 312	Dietary history	USDA†	211‡			Flavan-3-ols (69%)	Tea, fruits	[23,24]¶**
Danish Household Consumption Survey	1987	Denmark		Dietary history	USDA†	175‡			Flavan-3-ols (85%)	Tea, fruits	[22]¶**

FCDB, food composition database; PA, proanthocyanidins; SUVIMAX, SUpplémentation en VItamines et Minéraux Anti-oXydants Study; USDA, United States Department of Agriculture; EPIC, European Prospective Investigation into Cancer and Nutrition; NHANES, National Health and Nutrition Examination Survey; 24-HDR, 24 h dietary recall; FINDIET, National Finnish Diet Study; 48-HDR, 48 h dietary recall.

* Database with dihydroflavonols which were included in total flavonoid intake presented in this table.
† USDA database on flavonoids, version 1, March 2003.
‡ Thearubigins were included in total flavonoid intake presented in this table.
§ USDA database on flavonoids, version 2.1, January 2007.
‖ Theaflavins and thearubigins were not included in total flavonoid intake presented in this table.
¶ Calculated taking into account flavonoid intake without PA, because PA intake was not available at the time the study was done.
** Recalculated using USDA databases by Johannot & Somerset[21].

Prospective Investigation into Cancer and Nutrition (EPIC) study. Furthermore, the present study also aimed to assess the main flavonoid food sources and lifestyle characteristics that could partly explain the flavonoid intake variability among these countries.

Materials and methods

Study population

The EPIC study is an ongoing prospective cohort study conducted in twenty-three centres throughout ten European countries to investigate the role of nutrition, lifestyle, biomarkers and genetic factors in the aetiology of cancer and other chronic diseases[25,26]. A total of 521 448 subjects (29·4 % men), aged 21–83 years, were enrolled between 1992 and 2000. Most of the participants were recruited from the general population within defined geographical areas, with some exceptions: women who were members of a health insurance programme for state school employees (France), women attending breast cancer screening (Utrecht, the Netherlands and Florence, Italy), blood donors (some centres in Italy and Spain) and vegetarians (the 'health conscious' cohort in Oxford, UK). For the purpose of dietary analyses, the twenty-three administrative EPIC centres were redefined into twenty-seven geographical areas[27]. A total of nineteen of the twenty-seven redefined EPIC centres had both male and female participants, and eight recruited only women (France; Norway; Utrecht, The Netherlands; and Naples, Italy).

Dietary data used in the present paper were obtained from the EPIC calibration study, in which a 24 h dietary recall (24-HDR) was administered to a stratified random sample of approximately 8 % (36 994 subjects) of the entire EPIC cohort[27]. A total of 35 628 subjects with 24-HDR data from twenty-six centres were included in the present analysis, after exclusion of sixteen subjects due to missing baseline FFQ data, 941 subjects aged less than 35 years or over 74 years (because these age groups had low representation) and all participants from the health conscious group (409 subjects), because vegetarians and vegans consume a very different diet from the rest of the cohort[28]. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by ethical review boards from the International Agency for Research on Cancer (IARC) and all local participating centres approved the study. Written informed consent was obtained from all subjects.

Dietary and lifestyle information

Dietary information was obtained through a single standardised 24-HDR interview using computerised software (EPIC-Soft®; International Agency for Research on Cancer)[29,30], which was administered face-to-face in all centres, except in Norway, where it was done by telephonic interview[31]. In the EPIC study, about 2000 aggregated food items were reported per country in the 24-HDR, of which approximately forty food items were not present in our food composition database (FCDB). Most of these food items, except coffee substitutes and cola drinks, do not contain flavonoids in their composition (such as water, sugar, margarine, caramel, white chocolate, tonic soft drink, chewing gum, artificial sweetener, salt and gelatine) or they are infrequently consumed in the EPIC population (such as bamboo sprouts, carambola, pumpkin flower, orgeat, rose hips, physalis and vanilla). Data on other lifestyle factors, including education, anthropometry, physical activity (combining both occupation, household and leisure time activities) and smoking history, were collected at baseline through standardised questionnaires and have been described elsewhere[26,27,32]. Data on age, as well as on body weight and height, were mostly self-reported by the participants during the 24-HDR interview. The mean time interval between these baseline measures and the 24-HDR interview varied by country, from 1 d to 3 years later[27].

Flavonoid Food Composition Database

Our FCDB gathered composition data on six flavonoid classes: anthocyanidins (cyanidin, delphinidin, malvidin, pelargonidin, peonidin and petunidin), flavanols (flavan-3-ol monomers (catechin, epigallocatechin, epicatechin, epicatechin-3-gallate, epigallocatechin-3-gallate, gallocatechin and catechin-3-gallate), PA (dimers, trimers, 4–6-mers, 7–10-mers and >10-mers) and theaflavins (theaflavin, theaflavin-3,3′-digallate, theaflavin-3′-gallate and theaflavin-3-gallate)), flavonols (isorhamnetin, kaempferol, myricetin and quercetin), flavones (apigenin and luteolin), flavanones (eriodictyol, hesperetin and naringenin) and isoflavones (daidzein, genistein, glycetin, biochanin A, formononetin and equol)[33–36]. Thearubigins were not included in the present study because they were obtained by a non-specific spectrophotometric method[7].

Flavonoid data were mainly obtained from the United States Department of Agriculture FCDB on flavonoids (version 2.1 released in 2007, although more recently a new version has been developed in 2011)[7], isoflavones (updated in 2008)[37] and PA (released in 2004)[38], and the Phenol-Explorer FCDB (developed in 2009)[6] and the UK Food Standards Agency FCDB on isoflavones (released in 2010)[39]. The United States Department of Agriculture and Phenol-Explorer FCDB contain flavonoid data from a systematic and comprehensive collection of worldwide analytical data. Furthermore, our flavonoid FCDB was expanded by using retention factors, calculating flavonoid content of recipes, estimating missing values based on similar foods (by botanical family and plant part), obtaining consumption data for food group items and employing botanical data for logical zeros. The retention factors applied to all flavonoid classes, except isoflavones, were 0·70, 0·35 and 0·25 after frying, cooking in a microwave oven and boiling, respectively[40]. These retention factors were not applied to isoflavones, because their cooking losses are usually minimal[41]. The final FCDB on flavonoids contained 1877 food items and 10 % of these food items had missing values.

Statistical analyses

Dietary flavonoid values were calculated using generalised linear models and presented as means with standard errors stratified by sex and the redefined centres, which were ordered geographically from south to north. These models were adjusted for age (continuous variable) and weighted by season and weekday of the 24-HDR to control for different distributions of participants across seasons and weekdays of the recall. The contribution of each individual compound and class of flavonoids to the total intake was calculated as a percentage according to the two European regions (MED countries: all centres in Greece, Spain, Italy and the south of France; non-MED countries: all centres in the north-east and north-west of France, Germany, the Netherlands, UK general population, Denmark, Sweden and Norway). The contribution of each food group to overall flavonoid intake by European region was also computed as a percentage.

Differences in flavonoid intakes stratified by European region were also compared using general linear models according to the categories of sex, age (35–44, 45–54, 55–64 or 65–74 years), BMI (<25, 25 to <30 or ≥ 30 kg/m^2), educational level (none, primary completed, technical/professional, secondary school or university degree), smoking status (never smoker, present smoker or former smoker) and level of physical activity (inactive, moderately inactive, moderately active or active). All these models were adjusted for sex (categorical), age (continuous), centre (categorical), BMI (continuous) and energy intake (continuous) and weighted by season and weekday. P values <0.05 (two-tailed) were considered significant. All analyses were conducted using the SPSS Statistics software (version 19.0; SPSS Inc.).

Results

For both sexes, consumers with the highest total flavonoid intake were from the UK general population (in men 548·8 mg/d and in women 501·7 mg/d). Meanwhile, consumers with the lowest total flavonoid intake were in Greece

(in men 250·7 mg/d and in women 203·6 mg/d; Fig. 1). There was no statistically significant difference in flavonoid intake when adjusted for sex, age, centre, BMI and energy consumption and weighted by season and weekday of 24-HDR between the MED region (370·2 mg/d) and the non-MED region (373·7 mg/d; $P=0.349$; Table 2). Men had a statistically higher intake of total flavonoids than women in MED countries, while the inverse was found in non-MED countries. Younger people had significantly lower flavonoid consumption than older people in MED and non-MED regions. An inverse trend between BMI and total flavonoid intake was observed in both regions. According to educational level, participants with technical/professional studies and university graduates had the highest consumption of flavonoids in MED and non-MED countries, respectively. Never and former smokers had the highest flavonoid intakes in both MED and non-MED countries. Physically active participants had the highest intakes, particularly in the MED region.

Table 3 shows the flavonoid class contributors to the total flavonoid intake. Flavanol class was the main contributor in both regions, ranging from 72·5 to 75·0%. More specifically, in MED countries, PA contributed 59·0% and flavan-3-ol monomers only 13·1%, whereas in non-MED region, PA and flavan-3-ol monomers contributed 48·2 and 24·9% respectively. Flavonols, flavanones and anthocyanidins were intermediate contributors in all regions (7·3–10·1%). Finally, the contributions of flavones and isoflavones were minor ($<1.5\%$).

The main food sources of dietary flavonoid intake according to European region are presented in Table 4. In non-MED countries, tea and fruits were the main food items contributing 25·7 and 32·8% of total flavonoid intake, respectively. Other moderate contributors consisted of wines, juices, cereals, sweets and chocolate products. However, in MED countries, fruits (55·1%, mainly apples and pears), wines (16·7%), tea (6·8%) and vegetables (4·5%) were the most important food sources.
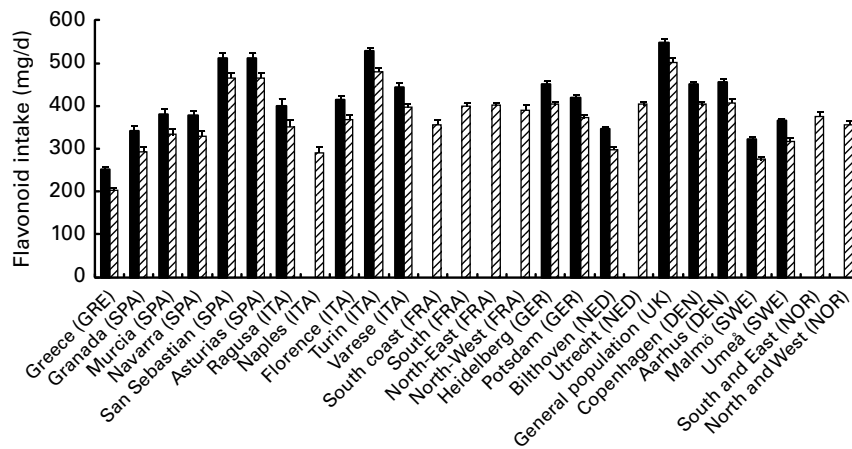

Fig. 1. Adjusted daily flavonoid intake (mg/d), stratified by sex and centre ordered from south to north, adjusted for age and weighted by season and weekday of dietary recall. GRE, Greece; SPA, Spain; ITA, Italy, FRA, France, GER, Germany; NED, The Netherlands; DEN, Denmark; SWE, Sweden; NOR, Norway; ■, men; ▨, women. Values are means, with standard errors represented by vertical bars.

Table 2. Estimated mean total flavonoid intake (mg/d) in Mediterranean (MED) and non-MED countries of the European Prospective Investigation into Cancer and Nutrition cohort by socio-demographic and lifestyle factors*

(Mean values with their standard errors)

Stratification variable	MED countries				Non-MED countries				
	n	Mean	SEM	$P\dagger$	n	Mean	SEM	$P\dagger$	$P\ddagger$
All	11 285	370·2	3·0		24 443	373·7	2·1		0·349
Sex				<0·001				<0·001	
Men	4533	397·7	4·8		8382	335·8	3·6		<0·001
Women	6752	356·3	3·9		16 061	400·5	2·6		<0·001
Age (years)				<0·001				<0·001	
35–44	1070	314·3	9·3		2230	341·7	6·5		0·014
45–54	3846	349·6	5·1		8632	368·7	3·5		0·002
55–64	4583	409·1	4·7		10 242	387·9	3·1		<0·001
65–74	1786	349·9	7·7		3339	367·2	5·5		0·065
BMI (kg/m²)				<0·001				<0·001	
< 25	4037	372·1	5·0		12 596	388·5	3·0		0·005
25 to <30	4804	370·3	4·5		8895	368·0	3·4		0·709
≥ 30	2444	348·0	6·5		2952	338·6	5·8		0·244
Level of schooling				<0·001				<0·001	
No formal education	1639	338·8	8·1		70	299·1	37·5		0·354
Primary completed	4360	366·5	4·9		6109	311·2	4·1		<0·001
Technical/professional	975	413·5	9·8		7012	366·6	3·8		<0·001
Secondary school	2297	384·0	6·5		4814	387·1	4·7		0·586
University degree	1902	357·3	7·0		6097	432·8	4·1		<0·001
Smoking status				<0·001				<0·001	
Never smoker	5927	366·7	4·2		11 386	390·1	3·1		<0·001
Former smoker	2624	406·0	6·1		7551	389·0	3·6		0·010
Present smoker	2508	345·3	6·2		5193	316·6	4·4		<0·001
Physical activity				<0·001				<0·001	
Inactive	3668	338·5	5·2		3723	354·9	5·0		0·020
Moderately inactive	3956	368·7	4·8		7889	370·1	3·4		0·878
Moderately active	2280	392·6	6·3		6050	380·8	3·9		0·110
Active	1380	425·4	8·0		4948	389·4	4·3		<0·001

* Adjusted for sex, age, centre, energy intake and BMI and weighted by season and weekday of recall. P value is for differences in means.
† Differences between each stratification variable in each region.
‡ Differences between MED-countries and non-MED countries.

Discussion

The present study is the first large descriptive study presenting differences in the total dietary flavonoid intake, the related food sources and socio-demographic and lifestyle determinants between MED and non-MED countries. The results could be readily compared among centres and among regions, because a standardised 24-HDR (EPIC-Soft) and a common flavonoid FCDB were used for the entire EPIC cohort.

In the present study, there was no significant difference in total flavonoid intake between MED (370·2 mg/d) and non-MED countries (373·7 mg/d; $P < 0·349$), although a large variation in flavonoid intake and food sources was observed among centres. In MED countries, a wide range in total dietary flavonoids was found, ranging from 203·6 mg/d for Greek women to 527·6 mg/d for men from Turin (Italy). The highest flavonoid class contributor was by far PA (59·0%), with its main food sources being fruits, wines and tea[35], as was also reported in an Italian case–control study of gastric cancer[17] and in the Spanish EPIC cohort[19]. Greek men and women were the lowest flavonoid consumers in the present study and these findings are consistent with a recent study[18]. Furthermore, a south to north gradient of increasing total flavonoids was observed within Spain and Italy, as previously described in the EPIC-Spain cohort[19]. This gradient could be due to participants in northern areas of MED

countries consuming more apples and pears and red wine than southern areas[42,43].

In non-MED countries, there was also a broad range of flavonoid intakes from 275·7 mg/d for women from Malmö (Sweden) to 548·8 mg/d for men of the UK general population. In this region, the main food sources were clearly tea (25·7%) and fruits (32·8%) and the major flavonoid class contributors were PA and flavan-3-ol monomers. Countries where tea is widely consumed, such as the UK, The Netherlands, Denmark or Australia will generally have high flavonoid

Table 3. Percentage contribution of classes of total flavonoid intake in the European Prospective Investigation into Cancer and Nutrition cohort*

Compound	MED countries (%)	Non-MED countries (%)
Anthocyanidins	10·1	7·3
Flavonols	6·7	7·9
Flavanones	9·1	8·5
Flavones	1·5	1·1
Flavanols	72·5	75·0
Flavan-3-ol monomers	13·1	24·9
Proanthocyanidins	59·0	48·2
Theaflavins	0·4	1·9
Isoflavones	0·1	0·2

MED, Mediterranean.
* Adjusted for age, sex and weighted by season and weekday of dietary recall.

Table 4. Percentage contributions of food groups and some main foods to the intake of flavonoids by European region*

Food items	MED countries (%)	Non-MED countries (%)
Potatoes and other tubers	0·1	0·2
Vegetables	4·5	2·1
Leafy vegetables	1·8	0·6
Fruiting vegetables	0·8	0·3
Root vegetables	0·1	0·2
Cabbages	0·1	0·2
Grain and pod vegetables	0·4	0·1
Onion, garlic	0·9	0·5
Other vegetables	0·3	0·2
Legumes	1·4	0·5
Fruits	55·1	32·8
Citrus fruit	7·0	3·7
Apples and pears	25·9	17·2
Grapes	5·6	2·6
Stone fruits	11·7	4·0
Berries	2·9	3·5
Kiwi	0·2	0·1
Other fruits	1·9	1·7
Nuts and seeds	0·7	0·4
Dairy products	0·5	1·1
Cereals, cakes, biscuits and sweets	3·7	6·1
Chocolate products	3·6	4·4
Non-alcoholic beverages	9·4	35·3
Tea	6·8	25·7
Fruit and vegetable juices	2·4	7·1
Other non-alcoholic beverages	0·2	2·5
Alcoholic beverages	19·4	13·0
Wines	16·7	9·8
Beer and cider	2·6	2·6
Other alcoholic beverages	0·1	0·5
Condiments and sauces	0·7	0·6
Soups, bouillons	0·7	3·2
Soya products	0·1	0·1
Meat, fish and eggs	0·0	0·0
Fat and oils	0·0	0·0

* Values are percentages derived from models adjusted for age and sex and weighted by season and weekday of recall.

intake, as a result of the sum of flavan-3-ol monomers and flavanol-derived compounds (theaflavins and thearubigins), the latter being the highest contributing class[21–24]. However, in the present study, thearubigins were not included because they were obtained by an unsuitable method[7]. Excluding thearubigins from the analysis, PA became the major flavonoid contributor in the non-MED region, especially in countries where tea consumption is less prevalent, for instance, in our Scandinavian centres (data not shown) or in a recent Finnish study.[16].

Differences between MED and non-MED countries were also explained by some socio-demographic, anthropometric and lifestyle factors. With respect to sex, men had a higher flavonoid intake than women in MED countries as men tend to drink more wine, particularly red wine[19]. However, in non-MED countries, the opposite was found, as women tended to consume more tea than men[44]. Flavonoid intake was also shown to increase with age in both these regions[19,44]. Again, the observed differences were largely due to variations in wine and tea consumption. A US study[14] showed that flavonoid intake increased up to the age group of 51–70 years, but in the age group >70 years, the consumption decreased significantly. In the present study, this reduction was also

clearly detected in the oldest age group (65–74 years). Also, in the present study, participants living in the non-MED region and having a BMI of less than 25 kg/m^2 had a significantly higher flavonoid consumption than those in any other BMI groups. In the MED countries, no statistical difference was observed between normal and overweight participants and flavonoid intake. However, in a previous analysis from the EPIC-Spain cohort, overweight people had the highest flavonoid intake; the difference was small but statistically significant[19]. In the non-MED region, less-educated adults had the lowest flavonoid intake, while people with a university degree had the highest; thus, flavonoid intake seems to increase with higher educational level. In contrast, in an US study, flavonoid intake was higher among those with a higher poverty income ratio[14]. People with a higher education and/or income are usually more conscious of good nutrition and health, so they may take more care of themselves and consume more healthy foods such as fresh fruit and vegetables[45,46]. However, in MED countries, the highest flavonoid intake was observed in the subjects of technical/professional education, who also tended to have the highest wine intakes[47]. Never and former smokers had a higher flavonoid intake than present smokers in both MED and

non-MED countries, as was observed previously in the EPIC-Spain cohort[19]. However, smoking status was not associated with flavonoid intake in the USA[14]. In both regions, the trend of increasing flavonoid intake with more physical activity was probably observed because physically active people generally consume more fruits and vegetables, as shown in the EPIC-Spain cohort[48].

Since the *in vitro* evidence on health effects of flavonoids was published[10,11], some epidemiological studies have reported inverse associations between flavonoid intake and chronic diseases such as CVD[49] and some cancers[17,50–53]. Despite the comparable flavonoid intakes between MED and non-MED countries in the present study, there is a well-established south to north gradient of CVD mortality[54]. This might be explained in part by the different consumption patterns of flavonoid classes and their food sources, as observed in the present study. In addition, other established dietary and lifestyle risk factors of CVD are more prevalent in non-MED countries[5,55,56]. Further basic and epidemiological studies are needed to clarify the potential role of flavonoids against CVD and other chronic diseases.

The present study has a number of relevant strengths. The first is the large number of participants in the EPIC calibration subcohort. The second is the complete list of flavonoids used. The third strength is the use of the most updated and relatively large FCDB on worldwide analytical flavonoid data, which was expanded with plant–plant estimations, thus obtaining a final database with 1877 food items with only 10 % of unknown values. The fourth stems from the collection of dietary data using a standardised 24-HDR in the whole cohort[57]; thus, the results are easily comparable across the countries. Nevertheless, some limitations were encountered. As not all the EPIC cohorts are population based, these findings cannot be extrapolated to the general population of each region[28]. A relevant weakness is the likely underestimation of real flavonoid intake, due to the unknown food flavonoid composition data (10 % of data in our FCDB and thearubigin data), and the omission of some food items (such as coffee substitutes) and herb/plant supplement intakes in the present analysis (which are up to 5 % of the population in Denmark, the highest supplement consuming country)[58]. Another limitation is the use of a single 24-HDR, which is less likely to reflect true usual individual diet. However, analyses were weighted by season and weekday of dietary recall and 24-HDR is a useful method to describe the average dietary intake of a group, particularly when estimated from a large number of subjects[59].

In summary, the data obtained in the present study show total flavonoid intake among the twenty-six EPIC participating centres in ten European countries. We also describe the major dietary flavonoid class contributors and the main food sources that differentiated the MED and non-MED regions. There was no significant difference in total flavonoid intake between MED and non-MED countries, although there were differences in flavonoid classes and their food sources between both regions. Significant socio-demographic and lifestyle factors related to total flavonoid intakes were also highlighted by European region. These descriptive data should be of value in the future as a first step in dietary flavonoid assessment and their potential role in health and disease.

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