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Food and nutrient intakes of French frequent seafood consumers with regard to fish consumption recommendations: results from the CALIPSO study

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Abstract

Besides providing n-3 fatty acids with nutritional and health benefits, seafood consumption may contribute to the reduction of nutrient prevalences of inadequacy. To evaluate the contributions of seafood and other food groups to nutrient intakes of frequent seafood consumers, food consumption was evaluated through an FFQ on 991 French men and women (18–81 years) consuming seafood at least twice a week. Intakes, prevalence of inadequacies, risks of upper limit excess and food contributions to intakes were assessed for thirty-three nutrients. Mean fat contributions to total energy intakes (38·3 and 39·0 % for men and women, respectively) met French recommendations, but mean carbohydrate intakes (40·9 and 39·7 %, respectively) were insufficient. Micronutrient inadequacies were lower than in the French general population, the highest being for vitamin C (41·3 and 40·1 % for men and women, respectively), vitamin E (35·0 and 35·3 % for men and women, respectively) and Mg (37·5 and 25·5 % for men and women, respectively). Upper safety limits (USL) were exceeded mostly for Zn (6·2 %), Ca (3·7 %), retinol (2·0 %) and Cu (0·9 %). Mean contributions of seafood to vitamin D, B_{12}, I and Se intakes ranged 40–65 %. Molluscs and crustaceans significantly contributed to vitamin B_{12} (13·7 %), Cu (11·4 %), Fe (11·5 %), Zn (8·4 %) and I (6·1 %) intakes, and canned fish contributed to vitamin D intake (13·4 %). Besides fish, contributions of mollusc and crustacean consumption to nutrient intakes should be considered from a public health viewpoint. Consuming seafood at least twice a week induces moderate inadequacies and risks of exceeding USL for some micronutrients, whereas macronutrient intakes remained imbalanced.

Key words: Food consumption: Nutritional intakes: Frequent seafood consumers: FFQ

Fish and other seafood consumption is considered as part of a balanced and healthy diet. Most national recommendations on fish worldwide, including France, are to consume fish at least twice a week, notably, to promote the health benefits of n-3 long-chain PUFA, especially EPA and DHA[1–4]. Furthermore, n-3 long-chain PUFA may contribute to a protective health effect as regards cardiovascular health[5], some types of cancers[6] and neurodevelopment[7–9]. Apart from n-3 long-chain PUFA, fish is a good source of proteins[10] and one of the richest food sources of vitamin B_{12}, vitamin A (the second after liver, butter and margarine), and vitamins B_6, D and E[10]. Vitamin E mainly comes from vegetable oils but is now often added in farmed-fish feeding for its antioxidant properties. Fish consumption can also provide K, P, Fe and Se[10,11]. Seafood, in particular lean fish and some molluscs, is a good source of iodine[10]. In France, shellfish is one of the major sources of Cu (7·05 mg/kg fresh weight) and Zn (65·93 mg/kg)[11]. Usually, studies on the assessment of nutrient intakes of fish and seafood consumers have mainly focused on PUFA intakes. Micronutrient intakes through high fish and seafood consumption, although less extensively evaluated, can have key health impacts and might contribute to the reduction of prevalences of inadequacy[12].

According to the results of the French individual national consumption survey INCA2 (Etude Individuelle Nationale des Consommations Alimentaires 2), the mean weekly intake of total seafood (i.e. fish, molluscs and crustaceans) is 217 g in the general adult population[13,14], almost corresponding to the recommended frequency of twice a week[15]. Nevertheless, a part of the population do not consume any seafood at all[14]. The French population has been recommended to increase its seafood consumption to counteract potential health disorders associated with inadequate intakes of fatty acids (FA) and other nutrients[12]. However, seafood consumption can be an important source of human exposure to heavy metals (MeHg, Cd and As) and persistent organic pollutants (dioxins, polychlorinated biphenyls, etc.)[3,11,16–19].

At the national level, the French Food Safety Agency recently revised lipid and FA intake recommendations[20]. This may lead to a re-evaluation of the fish consumption

Abbreviations: FA, fatty acid; INCA, Etude Individuelle Nationale des Consommations Alimentaires; RDA, recommended dietary allowance; TEI, total energy intake; USL, upper safety limit.

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recommendation, balancing risks and health benefits with regard to intakes of FA but also to other nutrients, notably micronutrients. Therefore, from a public health point of view, it is of high interest to characterise the food and nutrient intakes of a population of consumers already following the recommendation on seafood consumption compared with the general population. In the perspective of a risk–benefit analysis, another issue is to identify the nutrients for which seafood consumption may contribute to the decrease in the prevalence of inadequacies in the population, and nutrients for which possible exceedance of upper safety limits (USL) should be considered.

The present study aims at evaluating the contributions of fish and other seafood and other dietary food groups of the diet to nutrient intakes of French frequent seafood consumers. Their food and nutrient intakes were then assessed considering the nutritional guidelines: recommended dietary allowances (RDA), estimated average requirements and USL.

Methods

Subjects

Dietary data were collected from 991 healthy subjects (710 women and 281 men), aged 18–81 years, who participated in the CALIPSO survey. Women were over-represented owing to other aims of the CALIPSO study in relation to the assessment of contaminant exposure. Subjects were recruited between October and December 2004 and were living in French coastal areas: Le Havre (Upper Normandy/Channel), Lorient (Brittany/North Atlantic Ocean), La Rochelle (Poitou-Charentes/North Atlantic Ocean) and Toulon (Provence-Alpes-Côte d'Azur/Mediterranean Sea). Subjects were recruited in coastal zones, which are known to concentrate 'high consumers', as confirmed by a study of the French Food Consumption Observatory carried out in 1996 (A Dufour and J-L Volatier, unpublished results). The main inclusion criterion was to be a frequent seafood consumer, defined for France as someone eating seafood at least twice a week. Subject selection has been described elsewhere[21]. The following sociodemographic and anthropometric data were recorded: sex, age, weight, BMI, socio-economic status and current and previous tobacco consumption. Subjects were divided into four categories: never smokers; ex-smokers; light smokers (smoking less than 20 cigarettes/d); heavy smokers (smoking 20 cigarettes/d or more). Socio-economic status was divided into three categories (high, middle and low) according to the current or past occupation of the interviewee or the head of household if higher than the interviewee (see Table 2 for details).

Food intake data

Food intakes were collected by means of a validated twenty-eight-page FFQ containing 201 items and filled in by a trained interviewer. For eighty-three seafoods (fish, molluscs, crustaceans, echinoderms, tunicates and seafood-based dishes), intakes were calculated by combining the recorded consumption frequency of each food with the mean consumed portion size assessed by a validated book of sample photographs[22]. Eight frequencies were proposed (from 'never' to 'once a day and more'). Details on species consumptions have been described elsewhere[19,21]. Foods other than seafood were grouped into fifteen groups (Table 1) and 118 subgroups or food items. For each subgroup, recorded consumption frequencies were combined with mean portion sizes from the French national consumption survey INCA1[23] as advised in the literature[24]. The INCA1 and INCA2 cross-sectional surveys were conducted from 1998 to 1999 and from 2006 to 2007, respectively, and designed to assess the food intakes of a representative sample of the French adult population (INCA1, *n* 1918; INCA2, *n* 2624).

Table 1. Description of the food groups of the FFQ

Food groups	Food types included in the food groups	Number of single items
Seafood	Fish, molluscs, crustaceans and seafood-based products	83
Breads and cereals	Breads, rusks, breakfast cereals, pastas, semolina and rice	7
Viennese breads, biscuits and cakes	Viennese breads, cakes, biscuits, chocolate products, honey, jams, candies and added sugar	15
Milk and dairy products	Milk, quark, yogurt, cream, ice cream, dairy desserts and cheese	14
Fat and seasoning	Oils, butter, margarine, ketchup, mustard, seasoning, tomato sauce and salt	17
Meat	Beef, veal, mutton, pork and poultry	6
Offal	Offal	6
Meat products	Ham, pâté, sausages, bacon, etc.	6
Vegetables	Legumes, mushrooms, tomato, beans, green and leafy vegetables and starchy tubers except potatoes	9
Fruits	Dried fruit, red berries, citrus fruit, melon, banana, apple, kiwi, stewed fruit, canned fruit, etc.	11
Potatoes	Potatoes including French fries and mashed potatoes	4
Beverages (excluding water)	Fruit juice, syrup, alcoholic beverages, coffee, tea, infusion and fizzy non-alcoholic drinks	12
Pizzas, quiches and sandwiches	Pizzas, quiches, burgers, sandwiches and stuffed pasta	6
Water	Water	3
Soups	Soups	2

Supply and demand are known to have an impact on the seasonality of food consumption, and to lead to a declaration bias especially for fruits and vegetables[25,26]. We considered the subjects who reported their fruit and vegetable consumption corresponding to their period of availability. To compensate for it, fruit and vegetable intakes were weighted by the period of availability to assess monthly consumption[25,27]: dry fruit, banana, stewed fruit, pulses, beans, peas, carrots, turnip, radish, beetroot, cauliflower, broccoli, artichoke, mushrooms (12 months/12); leek, onion, asparagus, apple, pear (10 months/12); salads, chicory, spinach: 8 months/12; orange, mandarin, grapefruit, tomato (5 months/12); courgette (zucchini), aubergine, pepper (4 months/12); red fruit, melon, watermelon, pineapple, kiwi (3 months/12); apricot, peach, nectarine, grape, plum, cherry (2 months/12).

Nutrient intakes

Intakes were assessed for total energy and thirty-three nutrients: total carbohydrates, starch, sugars, proteins, total lipids, PUFA, MUFA and SFA, fibres, Ca, Cu, Mg, Na, K, Fe, I, Mn, P, Se, Zn, retinol, β-carotene, total vitamin A, and vitamins B_1, B_2, B_3, B_5, B_6, B_9, B_{12}, C, D and E.

In order to assess the composition of each food item of the FFQ, they were matched to the items of the French nutrient database[10] used for the INCA2 survey[13]. One FFQ item corresponded to at most thirty-one items of the CIQUAL database. The nutrient concentrations of each FFQ item were calculated as the mean concentration of the corresponding food items from the CIQUAL nutrient database, weighted by their consumption in the general French adult population[13]. It was then hypothesised that the relative contribution of each food item in the consumption level of one food group of the FFQ was not significantly different in our surveyed population and the general one. The concentration of each nutrient was calculated according to the following formula:

$$C_{i,j} = \Sigma_{k=1}^{n}(C_{i,j,k} \times P_{i,k}/k),$$

where $C_{i,j}$ is the concentration of nutrient j in the FFQ food item i (g, mg or μg/100 g fresh weight); n is the number of correspondences between the nutrient database and the FFQ food item i (1–31); $C_{i,j,k}$ is the concentration of nutrient j in each food k of the nutrient database corresponding to the FFQ food item i (g, mg or μg/100 g); $P_{i,k}$ is the consumption part of the food k in the general adult population, k varying between 1 and n foods corresponding to i.

As the French food composition database did not contain all marine species, the USDA National Nutrient Database for Standard Reference enabled us to complete 26 % of the missing composition data, giving priority to species from the Atlantic Ocean[28].

To estimate individual nutrient intakes, consumption of each of the 198 food items was combined with the mean calculated concentration, and summed to calculate total intakes, according to the following formula:

$$I_j = \Sigma_{i=1}^{m}(C_{i,j} \times \mathrm{CL}_i/100),$$

where I_j is the intake of nutrient j for the subject considered (g, mg or μg/d); $C_{i,j}$ is the calculated concentration of nutrient j in the FFQ food item i (g, mg or μg/100 g); m is the total number of food items consumed in the FFQ; CL_i is the consumption level of the item i by the subject (g/d).

The nutrient intake through water consumption was considered to be equal to that of the general population. As water consumption is poorly assessed in the FFQ, mean Ca, Mg and Na intakes through water consumption from the French Total Diet Study[11] were added to the intakes of each subject.

The mean contribution of each food group to the total intake of each nutrient was calculated by the following formula:

$$K_{i,j} = \Pi_{\text{all subjects}}(I_{j,i}/\mathrm{TI}_j) \times 100,$$

where $K_{i,j}$ is the contribution of the food group i to the intake of the nutrient j (%); $I_{i,j}$ is the intake of nutrient j through the consumption of the food item i (g, mg or μg/d); TI_j is the total intake of nutrient j for the subject concerned (g, mg or μg/d).

Data analysis

Food intakes of men and women are presented separately – as recommendations are often different for both sexes – and expressed as means and standard deviations. For nutrient intakes, a descriptive statistical analysis was performed, and intakes are expressed as means and standard deviations, and as 25th and 95th percentiles for low and high intakes, respectively. The percentages of subjects exceeding the nutrient upper limits (USL) for when established at the European level[29], were calculated. The prevalence of inadequate intake was calculated as the percentage of men and women whose intake is under the estimated average requirements, as described elsewhere[30]: 0·77 × RDA for all nutrients, except for Mg, vitamins B_6 and B_{12} (estimated average requirements = 0·83 × RDA), for folate (estimated average requirements = 0·71 × RDA) and for vitamin D due to endogenous synthesis (approach not applicable) as its synthesis through solar exposure of the skin should be the main source of vitamin D. French RDA[31] and other French published reference values[20,32,33] have been used. For each sex, minimum and maximum recommended values (if existing) for the age span studied (18–81 years) were considered.

Parametric χ^2 and non-parametric Fisher tests were used to compare categorical variables between sexes.

Mean food and nutrient intakes were first compared between women and men in our survey, and then, for each sex, between our survey and the general adult population from INCA2[13], using Student's t tests.

Potential under- and over-reporters were identified using the Goldberg cut-off value for energy intake[34,35]. BMR for each subject was calculated by the Schofield equations, using individual age, sex, height and weight[36]. The coefficient for intra-individual variation included in these equations was considered equal to zero as the reporting method was an FFQ. Of the subjects, 14 and 27 % were identified as potential under- or over-reporters, respectively: 20 and 12 % of under-reporters, and 19 and 30 % of over-reporters among men and women, respectively. Nevertheless, they were not excluded from the study to keep the potential false over-reporters (e.g. people eating more) or false under-reporters (e.g. people who were on a diet), notably for the calculation of the percentages of intake inadequacies and exceedance of the USL.

Alpha (two-tailed) was set at 5 %. Adjustments were performed to compensate for the multiple t tests: $\alpha' = \alpha/$number of tests. Data analyses were performed using the Statistical Analysis System statistical software package version 9.1.3 (SAS Institute, Cary, NC, USA).

Ethics

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 the French consultative committee for protection of human subjects in biomedical research (CHU Henri Mondor, Créteil, France). Written informed consent was obtained from all subjects.

Results

Description of subjects and food consumptions

There were significantly more overweight subjects and smokers among men than women (Table 2). There were more women with a high and middle socio-economic status than men.

The consumer rate was 100 % for men and women for each food group. As regards fish, mean intakes suggest average seafood consumption of more than one portion per day. Dietary consumption was not significantly different between men and women except for vegetables ($P<0.0001$), fruits ($P=0.0016$) and soups ($P<0.0001$) that were significantly more consumed by women (Table 2).

Compared with the French general adult population in INCA2, recorded food consumption of women was generally significantly higher in our survey ($P<0.0001$, not shown), except for fats and condiments, and vegetables for which the consumption was not significantly different. To a lesser extent, in men, consumption of milk and dairy products, meat, and offal was also higher in our survey than in the general population ($P<0.0001$), whereas consumption of breads

Table 2. Food intakes of frequent seafood consumers

(Mean values, standard deviations, number of subjects and percentages, n 991)*

	Men (n 281)				Women (n 710)				
	Mean	SD	n	%	Mean	SD	n	%	P
Age (years)	45	16			45	16			0·5078
Wt (kg)	77	12			63	12			<0·0001
BMI (kg/m^2)	25·1	6·4			23·8	4·3			0·0011
Overweight subjects (25 kg/m^2 > BMI > 30 kg/m^2)			97	35			155	22	0·0006
Obese subjects (BMI > 30 kg/m^2)			22	8			63	9	0·5885
Tobacco status									<0·0001
Never smokers			103	37			410	58	
Ex-smokers			61	22			97	14	
Light smokers			64	23			151	21	
Heavy smokers			53	18			52	7	
SES†									<0·0001
High			85	30			255	36	
Middle			74	27			274	39	
Lower			122	43			181	25	
Food groups (g/d)									
Total seafood	176·66	102·67			166·30	97·88			0·1464
Meat	108·29	56·82			98·65	54·30			0·0128
Offal	7·33	14·76			5·84	9·37			0·1168
Meat products	36·20	34·49			31·45	27·42			0·0388
Milk	118	110			126	124			0·3720
Other dairy products	204	141			234	155			0·0038
Fats	46·83	22·94			47·26	25·17			0·8026
Vegetables	124·68	80·24			153·27	97·99			<0·0001
Fruits	164·20	142·07			197·02	150·13			0·0016
Soups	104·66	147·13			147·87	149·57			<0·0001
Potatoes	74·71	63·16			77·74	66·20			0·5087
Pizzas, quiches and sandwiches	57·40	62·54			45·72	47·88			0·0049
Breads and cereals	196·46	76·19			195·24	76·59			0·8207
Viennese breads, biscuits and cakes	87·63	77·23			77·24	66·86			0·0476
Beverages (excluding water)	1686	1477			1401	1299			0·0048

SES, socio-economic status.

* Adjusted α was set as 0·05/15 = 0·003.

† High SES: storekeepers (current or retired), corporate managers, liberal professions (medicine, law, etc.), executives, scientists, engineers and teachers. Middle SES: art or show relative professions, clergy, technical experts, foremen and employees. Low SES: farmers (current or retired), craftsmen, workers, drivers, policemen, militaries, students (living alone) and other non-occupational persons.

and cereals, and vegetables was lower ($P<0\cdot0001$). The major differences concerned, obviously, total seafood ($P<0\cdot0001$), but also dairy products other than milk, for which the mean consumption was twice higher in our survey (204 and 234 g/d for men and women, respectively, *v.* 114 and 116 g/d for men and women in the INCA2 study).

Nutrient intakes

Mean energy intake (including alcohol) ranged between 11 800 (SD 8500) kJ/d (2815 (SD 1125) kcal/d) for men and 10 400 (SD 4000) kJ/d (2485 (SD 964) kcal/d) for women *v.* 10 500 (SD 2500) kJ/d (2500 (SD 598) kcal/d) for men and 7800 (SD 1800) kJ/d (1855 (SD 426) kcal/d) for women in INCA2, respectively (Table 3). Standard deviations appeared to be high because FFQ are known to induce high variability and spread distribution, compared with 24 h recall methods, for instance.

The contributions of the three macronutrients to total energy intake (TEI, excluding alcohol) did not meet the nutritional recommendations. Mean fat contribution to energy intakes met the French recommendation, but there was an excess of lipids for 41 % of our subjects (>40 % TEI), insufficient mean carbohydrate intake and protein intake reaching high levels especially at the P95. SFA intakes were too high, probably to the detriment of MUFA.

The prevalence of inadequate micronutrient intakes was generally low, notably for I, Se, Zn, Ca, vitamins B_6 and B_{12} (Table 4). Prevalences of inadequacy were generally similar for men and women, except for Cu, vitamins A and B_1, for which the prevalence was higher in men, and for Fe, for which the prevalence was higher in women. Mean vitamin D intake was lower than the recommended intake for women only.

USL were reached for Zn (6·2 % of the subjects), Ca (3·7 %), retinol (2 %), Cu (0·9 %), I (0·2 %), Se (0·1 %) and vitamin D (0·1 %). Generally, the subjects exceeding the USL for Ca also exceeded the limit for Zn and generally corresponded to the high-energy diets.

Contributions to mean nutrient intakes

Total seafood was the second contributor to PUFA intake after fats and seasonings, before total meat (Table 5). It is mainly attributable to fish (Fig. 1). Total seafood contributions to MUFA and SFA intakes were relatively low (Table 5; Fig. 2). They were the major contributors to I (41·4 %, attributable to fish as well as molluscs and crustaceans) and Se intakes (42·9 %, mainly attributable to fish). They were also one of the major contributors to Fe intake (15·1 % with almost the same contribution of fish as well as molluscs and crustaceans) after total meats (17·1 %). They were the second main contributor to Mg and Cu intakes (mainly attributable to molluscs and crustaceans for Cu) and the third for Zn. As regards vitamins, total seafood was the major contributor to vitamin B_{12} (50·5 %, attributable to fish as well as molluscs and crustaceans) and vitamin D (64·7 %, attributable to fish as well as canned fish) intake, and the third for vitamin B_6 (17·7 %). They were also the third contributor to retinol intakes (10·6 %) after milk and other dairy products and the sum of offal and meat products. Of note, total seafood is the third contributor to Na intake after fat and condiments (which include salt) and breads and cereals.

An additional analysis was carried out with a different calculation method for the contribution of each food group. Contributions were not calculated individually but directly based on the mean intakes of the whole population to avoid the influence of potentially high variance of individual contributions. There were no major differences between the results obtained by both calculation methods. More particularly, ranks of seafood for these contributions were the same.

Discussion

To our knowledge, it is the first time that food and intakes of a large range of nutrients have been evaluated for men and women of various ages and who were high seafood consumers. Nevertheless, the nutrient intake calculations included neither dietary supplements nor fortified foods (other than fortified cereals or yogurt considered in the CIQUAL database at the time of the study). In France, almost 20 % of adults occasionally or regularly consume dietary supplements, composed of vitamins and/or minerals in more than 50 % of cases[13].

FFQ generally overestimate consumption, compared with a food record for instance[37], and particularly if they contain a large number of representative food groups or food items of a given group[38]. Then, seafood consumption was possibly overestimated as our FFQ contained eighty single items. Nevertheless, an FFQ with large numbers of seafood items can be accurate and suitable for assessing seafood consumption[39], and single items are preferable for food groups of main interest[40]. Overestimation could be due to one or both factors included in our calculations of seafood consumption: recorded consumption frequencies and usual portion sizes. For fish and seafood, portion sizes were assessed using a book of sample photographs, which is more accurate than the use of average portion size[40]. Moreover, for a given subject, the overestimation rate of portion sizes was probably the same whatever the food. On the contrary, the assessment of the consumption frequency was based on the memories of the surveyed subjects which are less accurate[38]. Moreover, the recording of frequencies may be more accurate for frequent and regular consumption (such as fish in our population) than for occasional ones. Additional analyses of our data have also shown significant associations between seafood consumption and biomarkers of intake or exposure: EPA intake calculated through seafood consumption was associated with EPA concentration in erythrocytes (*P* for overall association $=0\cdot009$)[41]. Recorded consumption of total fish or predator fish was also significantly correlated with MeHg blood concentrations (r 0·36 and 0·26, respectively)[16]. These data confirm the accurate measurement of habitual fish consumption by our FFQ.

Table 3. Macronutrient, alcohol and water intakes of frequent seafood consumers compared with existing reference intakes
(Mean values, standard deviations and percentiles)

		Men					Women				
	Reco type	Reco value	Mean	SD	P25	P95	Reco value	Mean	SD	P25	P95
TEI/d (MJ)	RDA	10·5–11·3	11·8	4·7	8·5	20·6	8·4–7·2	10·4	4·0	7·7	17·9
TEI (wa)			10·6	4·3	7·7	19·0		9·8	3·9	7·2	17·1
Lipids (g/d)			107	45	76	204		102	46	70	185
Lipids (%TEI without alcohol)	RDA	35–40*	38·3	6·3	34·7	48·7	35–40	39·0	6·5	34·8	49·7
MUFA (g/d)			38·0	15·0	27·0	69·4		36·7	16·1	25·4	65·5
MUFA (%TEI without alcohol)	RDA (for oleic acid)	15–20	13·8	3·0	11·9	18·8	15–20	14·2	3·3	12·0	20·2
PUFA (g/d)			15·3	7·3	10·3	27·4		14·7	7·6	9·8	28·8
PUFA (%TEI without alcohol)			5·6	1·8	4·4	8·4		5·7	2·0	4·4	9·5
EPA + DHA (mg/d)	RDA	500	1290	898	409	3747	500	1195	825	337	2779
SFA (g/d)			44·9	22·4	29·4	93·0		42·2	22·5	27·9	82·6
SFA (%TEI without alcohol)	Maximum	12	15·7	3·6	13·1	22·0	12	15·8	3·7	13·3	22·4
Carbohydrates (g/d)			283	160	190	546		253	128	177	473
Carbohydrates (%TEI without alcohol)	RDA	50–55*	40·9	8·7	35·3	56·2	50–55	39·7	8·0	34·8	53·0
Fibre (g/d)	RDA	25–30	18·1	7·8	12·9	33·4	25–30	19·6	7·9	14·4	33·6
Starch (g/d)			132	48	101	219		126	47	95	207
Sugars (g/d)			141	124	78	324		122	100	73	267
Proteins (g/d)			127	42	95	198		121	42	92	197
Proteins (%TEI without alcohol)	RDA	10–27*	20·8	4·1	18·3	27·6	10–27	21·4	4·0	18·8	28·3
Alcohol (g/d)			29·3	42·5	5·7	106·7		8·7	14·1	0·6	37·3
Water (g/d)			2567	1456	1485	5346		2437	1332	1539	4740

Reco, recommendation; P25, 25th percentile; P95, 95th percentile; TEI, total energy intake; RDA, recommended dietary allowance.
* Lipid, carbohydrate and protein recommended intakes were assessed by separate French Food Safety Agency expert committees, and correspond to recommended ranges, optimal intake not being necessarily the middle of the range. For each consumer, their contribution to TEI should be within the ranges.

Table 4. Micronutrient intakes of frequent seafood consumers compared with existing reference intakes and upper limits
(Mean values, standard deviations and percentiles and percentages)

		Men						Women							
	Reco type	Reco value	Mean	SD	P25	P95	Inadequacy (%)	Reco value	Mean	SD	P25	P95	Inadequacy (%)	USL	Total USL exceedance (%)
Ca (mg/d)	EAR	693–924	1269	621	865	2510	15·2	693–924	1281	630	886	2409	12·1	2500	3·7
Cu (mg/d)	EAR	1·155–1·54	2·2	1·0	1·5	3·9	23·0	1·155	2·1	0·9	1·5	3·9	7·7	5	0·9
I (μg/d)	EAR	115·5	217	80	159	352	4·6	115·5	208	79	156	359	7·4	600	0·2
Fe (mg/d)	EAR	6·93–7·7	18·2	7·3	13·3	32·1	0·0	6·92–12·32	16·4	6·4	12·1	28·1	18·4		
Mg (mg/d)	EAR	332–348·6	441	176	317	763	37·5	298·8–332	407	157	303	685	25·5		
Mn (mg/d)			3·6	1·5	2·6	6·8			4·1	2·2	2·8	8·2			
P (mg/d)	EAR	577·5–616	1852	637	1388	2994	0·0	577·5–616	1769	646	1344	2915	0·0		
K (mg/d)	Minimal requirement	390–585	4140	1582	3053	7136		390–585	4010	1449	3068	6729			
Se (μg/d)	EAR	46·2–61·6	89·6	34·0	66·1	155·1	5·3	38·5–61·6	84·9	33·6	61·4	147·9	4·5	300	0·1
Na (mg/d)	Guide value	3149	4456	1422	3462	7352		3149	4272	1497	3384	6849			
Zn (mg/d)	EAR	8·47–9·24	15·8	5·8	11·8	26·7	7·4	7·7–9·24	14·8	5·9	10·7	25·2	5·9	25	6·2
Total vitamin A (μg/d)	EAR*	539–616	1352	1179	762	2808	13·1	462	1312	802	842	2731	3·1		
β-Carotene (μg/d)			2565	1492	1497	5637			3064	1664	1902	6384			
Retinol (μg/d)			924	1120	399	2274			802	698	400	2139		3000	2·0
Vitamin B_1 (mg/d)	EAR	0·924–1·001	1·5	0·6	1·1	2·6	20·1	0·847–0·924	1·5	0·6	1·1	2·5	7·9		
Vitamin B_2 (mg/d)	EAR	1·232	2·8	1·3	1·9	5·2	2·8	1·155–1·232	2·6	1·2	1·8	4·8	2·9		
Vitamin B_3 (mg/d)	EAR	10·78	28·2	11·2	20·1	50·6	0·0	8·47	26·5	10·6	19·4	44·3	0·6		
Vitamin B_5 (mg/d)	EAR	3·85	7·9	3·5	5·5	14·6	3·9	3·85	7·4	3·1	5·3	13·3	5·2		
Vitamin B_6 (mg/d)	EAR	1·494–1·826	2·5	0·9	1·8	4·1	10·2	1·245–1·826	2·4	0·9	1·8	3·9	6·3	25	0·0
Vitamin B_9 (μg/d)	EAR	234·3–284	360·8	153·2	254·1	643·5	19·4	213–284	365·6	144·6	271·0	632·2	12·5		
Vitamin B_{12} (μg/d)	EAR	1·992–2·31	12·9	8·2	8·2	26·8	0·0	1·992–2·31	11·7	6·9	7·1	24·3	0·1		
Vitamin C (mg/d)	EAR	84·7–92·4	123	105	62	346	41·3	84·7–92·4	114	89	66	251	40		
Vitamin D (μg/d)	RDA	5–15	5·1	2·8	3·1	11·1	NA	5–15	4·8	3·4	2·8	10·4	NA	50	0·1
Vitamin E (mg/d)	EAR	9·24–38·5†	12·2	5·2	8·4	22·1	35·0	9·24–38·5†	12·4	5·9	8·4	24·1	35·3	300	0·0

Reco, recommendation; USL, upper safety limit; P25, 25th percentile; P95, 95th percentile; EAR, estimated average requirement; RDA, recommended dietary allowance; NA, not applicable.
* Corresponds to the EAR for total vitamin A.
† 38·5 mg/d corresponds to a maximal value defined for elderly (>75 years) but does not have unanimous support.

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Table 5. Mean contribution of each food group to total nutrient intakes of the study population of the CALIPSO survey (*n* 996)

	Total seafood (%)	Total meat (%)*	Milk and dairy products	Fats and condiments (%)	Vegetables and soups (%)	Fruits (%)	Potatoes	Pizzas, quiches and sandwiches (%)	Breads and cereals (%)	Viennese breads, biscuits and cakes (%)	Water and other beverages (%)
Energy	7·6	11·7	17·3	9·6	3·5	5·1	3·1	4·1	17·6†	10·2	10·2
Lipids	7·1	17·5	25·3	25·4†	1·9	2·5	1·6	5·0	3·6	9·4	0·8
MUFA	6·1	21·1	18·9	33·0†	1·5	1·8	1·2	5·2	1·9	8·7	0·7
PUFA	14·4	14·1	6·4	33·0†	4·5	7·6	1·1	4·0	7·2	6·9	0·7
SFA	4·2	16·5	38·2†	18·2	1·1	0·8	1·5	5·1	2·2	11·4	0·8
Carbohydrates	1·4	0·3	8·9	0·7	5·5	9·5	5·8	4·1	35·6†	15·9	12·2
Fibre	0·9	0·3	1·8	1·0	24·2	18·1	7·2	4·1	29·4†	7·8	5·2
Starch	2·1	0·3	0·3	0·4	5·3	1·0	10·6	6·1	64·0†	9·4	0·4
Sugars	0·7	0·4	19·3	1·1	6·5	19·9	0·7	1·1	4·7	23·9†	21·8
Proteins	22·3†	27·3	22·3†	0·3	3·9	1·3	1·4	3·8	11·5	2·8	3·1
Ca	7·3	1·9	54·6†	0·8	6·7	1·5	1·1	4·2	6·2	3·6	12·2
Cu	17·3	11·9	6·6	1·1	10·0	6·9	4·6	1·8	22·2†	5·7	11·8
I	41·4†	5·0	28·9	1·0	3·7	0·9	1·8	2·7	5·3	2·7	6·7
Fe	15·1	17·1†	6·4	1·6	12·5	3·6	2·3	3·4	14·9	7·9	15·0
Mg	14·2	8·9	13·0	2·4	8·7	6·4	3·5	2·3	12·4	4·7	23·4†
Mn	3·8	1·5	2·4	0·8	10·4	12·8	2·7	2·8	30·9†	6·6	25·3
P	17·8	18·4†	29·2	0·8	5·0	2·3	2·5	3·5	10·8	3·6	6·1
K	10·9	12·3	13·9	1·1	12·4	9·2	7·3	2·3	5·8	3·3	21·4†
Se	42·9†	22·0	10·5	1·2	4·6	0·9	0·6	2·3	8·4	2·7	3·9
Na	13·7	10·5	13·6	23·2	9·6	0·1	0·5	5·5	18·5†	3·2	1·7
Zn	15·0	28·4†	24·5	0·5	4·8	2·0	1·6	3·8	10·6	2·6	6·2
β-Carotene	2·2	0·7	4·2	2·7	72·0†	6·3	0·1	2·3	0·1	1·6	7·9
Retinol	10·6	35·1†	33·3	9·4	0·8	0·0	0·6	4·4	0·0	5·0	0·8
Vitamin B_1	7·4	22·8†	11·3	1·3	9·3	4·9	5·4	4·9	15·8	5·1	11·9
Vitamin B_2	8·7	16·7	33·4†	0·7	5·1	2·7	1·1	2·7	7·6	3·3	18·0
Vitamin B_3	19·2	31·6†	3·5	0·4	5·3	2·5	4·3	3·1	11·8	2·5	15·8
Vitamin B_5	9·4	17·3	20·2†	0·5	8·0	3·8	5·1	2·4	11·1	3·2	19·0
Vitamin B_6	17·7	21·9†	9·8	0·5	9·7	9·9	7·8	2·5	10·5	3·3	6·2
Vitamin B_9	4·5	6·6	19·1	0·5	24·2†	9·7	3·0	2·5	13·7	4·0	12·3
Vitamin B_{12}	50·5†	27·2	14·4	0·1	0·4	0·0	0·1	4·2	1·1	0·9	1·2
Vitamin C	1·3	3·0	2·8	0·6	21·1	25·4	10·3	1·2	2·3	2·7	29·3†
Vitamin D	64·7†	4·3	16·8	2·8	2·5	0·0	0·1	4·2	0·6	3·8	0·2
Vitamin E	14·3	4·7	6·7	36·8†	8·0	7·6	1·1	3·2	7·5	7·6	2·5

* Meat, offal and meat products.
† Values indicate the first contributor to the total intake.

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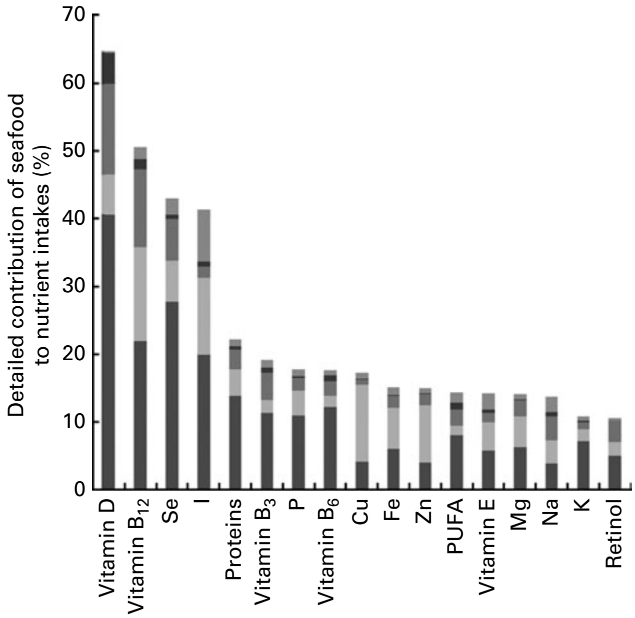

Fig. 1. Mean contribution (%) of each seafood group to nutrient intakes (for total seafood contribution >10 %). ■, Seafood-based dishes; ■, smoked fish; ■, canned fish; ■, molluscs and crustaceans (fresh and frozen); ■, fish (fresh and frozen).

As previously observed[42], our fish consumers also eat meat and meat products. There does not seem to be any substitution between meat and seafood in our population.

For foods other than seafood, mean portion sizes from the INCA1 survey were used. Therefore, possible overestimation was probably due to the consumption frequencies rather than portion sizes. Although statistical differences were observed, consumption in our population was in the range of those of the general population of the INCA2 survey[13,14], except for milk for which consumption was significantly higher in our population (approximately 30–50 %, for men and women, respectively) and dairy products (approximately 80–100 %) ($P<0\cdot0001$). However, milk consumption was rather close to the one recorded in the INCA1 survey (120 g/d)[14,23]. The present study was conducted between these surveys, and French milk consumption decreased between them, particularly for women[13,14]. Among dairy products, cheese consumption might be overestimated as our FFQ contained a list of seven items to cover the diversity of French cheese.

Recorded frequencies for seasonal products, such as fruits and vegetables, seemed accurate only for their period of availability, as the weighting of consumption in the present study led to intakes close to the general population. FFQ are valid to assess consumption by adults[43,44], including those of fruits and vegetables that are generally insufficiently assessed by one or repeated 24 h recall(s)[38,45]. Our FFQ was more detailed, as regards fruits and vegetables, than those of previously reviewed studies[38]. There was a risk of overestimation, as it consisted of nine items for vegetables (excluding potatoes), eleven items for fruits, one item for fruit juices and one item for soups, each item having a detailed list of examples. However, it may have helped better to cover the diversity of fruit and vegetable consumption in France, and have limited memory issues for consumption recording or simplification of the food record observed with other methods such as a 24 h recall[46].

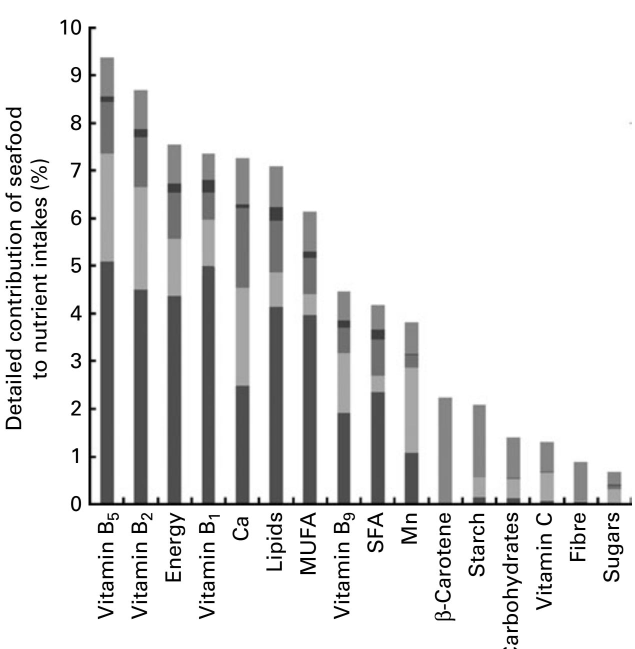

Fig. 2. Mean contribution (%) of each seafood group to nutrient intakes (for total seafood contribution <10 %). ■, Seafood-based dishes; ■, smoked fish; ■, canned fish; ■, molluscs and crustaceans (fresh and frozen); ■, fish (fresh and frozen).

As regards nutrient intakes, the contribution of pizza/quiches/sandwiches, Viennese breads/biscuits/cakes, and total dairy products and meat products to total lipid intake was higher than the contribution of total seafood (Table 5). As these groups are rich in SFA, the unbalanced FA intakes observed in other French surveys[13,47] were also found in our population in spite of a higher PUFA intake mainly through seafood. This result on PUFA was neither due to feeding practices, seasons, nor to the reproduction period, which can have an impact on lipid content in seafood[48,49], since this content was assessed from mean composition data. In particular, mean EPA + DHA intake through seafood was 1290 mg/d in men and 1195 mg/d in women (Table 3), which largely exceed the daily 500 mg EPA + DHA recommended intake. However, previous observations showed that 16 % of the subjects did not reach this recommendation[21]. This was due to their low mean consumption of fatty fish, i.e. fish with more than 5 % of lipid content (52 g/week), compared with subjects reaching this recommendation (mean consumption of oily fish of 277 g/week). Recently, revised French RDA for FA distinguished linoleic acid and α-linolenic acid RDA expressed as a percentage of TEI, and distinguished EPA and DHA expressed separately as mg/d for a total TEI of 8368 kJ (2000 kcal/d)[20]. As an overall indication, while expressing this last RDA also as a percentage (0·225 % TEI) and by summing all the PUFA RDA, the total (5·225 % TEI) approximately corresponds to mean PUFA intakes of our subjects. However, detailed PUFA intakes should be assessed after the update of the French CIQUAL composition database, which will provide detailed PUFA food composition.

Moreover, the prevalence of inadequate intakes in our population was low or moderate, the highest being observed for vitamin C (41·3 and 40·1 % for men and women, respectively), vitamin E (35·0 and 35·3 % for men and women, respectively) and Mg (37·5 and 25·5 % for men and women, respectively). Our main goal was to check whether nutrient inadequacies observed in the general population were also observed with our subjects rather than to assess the precise values and their CI. The high prevalences of inadequate intakes (up to 60 % and more) observed for some vitamins and minerals in the general population, such as Ca, Mg, Fe or vitamin C[13,30], were not observed in our seafood consumers. This prevalence was particularly low for vitamins D, B_{12}, I and Se for which seafood, consumed at least twice a week, was a high contributor (mean contribution between 40 and 65 %). Nevertheless, the differences between the sexes observed in the general population concerning the prevalence of inadequate Fe intake (higher in women) remained in our population. Previous observations have shown that finfish and shellfish consumed in France accounted for, respectively, 44, 65, 24 and 21 % of those nutrient RDA[12]. However, this study used a different method of calculation from ours, since it used national production data, national import and export data, more sources on nutrient composition data and nutrient contents of unprocessed products. As regards contribution to nutrient intakes, dairy products were the second main contributor to iodine intake after seafood. This result is concordant with observations in the French general population and is due to the use of iodated compounds in feed, animal medicine and udder cleaning solutions[50]. Seafood contribution to iodine intake reached 41·4 %, which confirms that seafood is a major source of iodine[12]. Seafood contribution to vitamin D intake in our population was higher than in the French general population (about 40 %)[12,13] or in elderly subjects (54 %)[47] but lower than in a Japanese study (90 %)[51]. Mean vitamin D intake was also lower than among Norwegian fish consumers[52] but higher than among British fish eaters[53], as well as Fe and vitamin B_{12} intakes. Differences between studies on seafood consumers may be explained by composition differences for the same species (due to seasonal variations, geographical origins, etc.), differences in consumed species and/or the ratio between fatty fish and lean fish, but also by the use of fish oil capsules, for example, in the Norwegian population. Se intake is not optimal in the French general population[13] or in elderly people[54]. Mean intakes in our population were higher than in Finnish seafood consumers[55] but lower than in a Japanese study[56]. Seafood also contributed to 15 % of Zn intakes instead of 3·3 % in the general population[13]. Mean intakes of Zn were higher than in the EPIC population of seafood consumers[53]. In our population, total seafood was also the second contributor to Cu and vitamin E intakes. Therefore, our population had high intakes of antioxidant nutrients (notably vitamin E, Zn, Se and Cu). It is all the more important since our subjects have a relatively high intake of PUFA that are more susceptible to oxidation, and may have had a high intake of contaminants promoting oxidation through seafood consumption. Many subjects were also elderly or smokers, with probably a non-optimal antioxidant status.

As observed in the general population[13,33], breads and cereals are the main contributors to Na intake (apart from table salt). Due to natural salt content, total seafood contribution is higher than that of dairy and meat products that are among the main contributors among the general population. Therefore, Na intakes seem to exceed the guide value set in France for salt in context of public health policies to reduce added salt consumption.

The percentages of people exceeding the USL were relatively low. Particularly for Ca, the 3·7 % of exceedance may be taken with caution, as there may be an overestimation of dairy product intakes. Nevertheless, these percentages were not insignificant insofar as the intake calculations included neither dietary supplements nor fortified foods. The consumption of dietary supplements may indeed increase the risk of exceeding the USL and decrease the prevalence of nutrient inadequacies[57].

Although the nutritional status of those frequent seafood consumers was not optimal as regards FA and prevalence of inadequate intakes, this diet results in satisfactory intakes of key nutrients without massive excess of USL. Some subgroups have specific needs regarding nutrients largely provided by seafood: vitamin D for elderly or pregnant and lactating women, iodine for pregnant women, antioxidants for elderly people or smokers, B_{12} for elderly people, Fe for women, etc. To our knowledge, most risk–benefit analyses concerning seafood mainly dealt with MeHg and polychlorinated biphenyls as regards contaminants, and *n*-3 FA as regards nutrients. Vitamin D is rarely considered[58], as well as other nutrients. Moreover, interactions have been reported between contaminants and/or nutrients provided by seafood such as MeHg and polychlorinated biphenyls, MeHg and Se, or MeHg and *n*-3 long-chain PUFA[59].

When considering a limited number of components and searching for an optimal consumption, one might miss some specific consumption profiles (in terms of quantities and types of seafood). These profiles could comply with nutritional and toxicological constraints, on the one hand, and meet other nutritional needs, on the other hand. For instance, molluscs and crustaceans are not major contributors to EPA + DHA. Nevertheless, the present results show that they appear interestingly to make a small but significant contribution to Cu, Fe, I, vitamin B_{12} and Zn intakes. Some of these micronutrients are of public health concern, for instance for which the elderly show inadequate intakes. Consumption of molluscs and crustaceans appears to be interesting to reduce the prevalences of inadequacy for such populations. Nutritional interest as well as relative weights of nutritional needs and risks are not the same according to the age or the physiological status of the target population.

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Conclusion

In a population of frequent consumers (more than twice a week), seafood appeared to be a major contributor to key nutrient intakes: mainly PUFA, vitamins B_{12} and D, Se and I, and, to a lesser extent, Cu, Fe, Mg and Zn. Prevalences of inadequate intake are lower than in the general French population, and percentages of subjects exceeding nutrient USL were low. Moreover, molluscs and crustaceans, usually not taken into account in consumption recommendations, seem, however, to be interesting contributors to key nutrient intakes, whatever the form (fresh, frozen or canned food).

It appears to be important to take into account other nutrients beyond *n*-3 PUFA to provide data to an expert panel in charge of adjusting consumption recommendations according to target populations. Critical issues of deficiencies of target populations as well as toxicity of contaminants provided by seafood should be taken into account for optimal public health.

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