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A Taiwanese food frequency questionnaire correlates with plasma docosahexaenoic acid but not with plasma eicosapentaenoic acid levels: questionnaires and plasma biomarkers

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Abstract

Background: Little evidence is available for the validity of dietary fish and polyunsaturated fatty acid intake derived from interviewer-administered questionnaires and plasma docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) concentration.

Methods: We estimated the correlation of DHA and EPA intake from both questionnaires and biochemical measurements. Ethnic Chinese adults with a mean (± SD) age of 59.8 (±12.8) years (n = 297) (47% women) who completed a 38-item semi-quantitative food-frequency questionnaire and provided a plasma sample were enrolled. Plasma fatty acids were analyzed by capillary gas chromatography.

Results: The Spearmen rank correlation coefficients between the intake of various types of fish and marine n-3 fatty acids as well as plasma DHA were significant, ranging from 0.20 to 0.33 ($P < 0.001$). In addition, dietary EPA, C22:5 n-3 and DHA were significantly correlated with the levels of marine n-3 fatty acids and DHA, with the Spearman rank correlation coefficients ranging from 0.26 to 0.35 ($P < 0.001$). Moreover, compared with those in the lowest fish intake quintile, participants in the highest quintile had a significantly higher DHA level (adjusted mean difference, 0.99 ± 0.10%, test for trend, $P < 0.001$). Similar patterns between dietary DHA intake and plasma DHA levels were found. However, the association between dietary fish intake and plasma EPA was not significant (test for trend, $P = 0.69$).

Conclusions: The dietary intakes of fish and of long chain n-3 fatty acids, as determined by the food frequency questionnaire, were correlated with the percentages of these fatty acids in plasma, and in particular with plasma DHA. Plasma DHA levels were correlated to dietary intake of long-chain n-3 fatty acids.

Keywords: N-3 fatty acid, Biomarker, Food frequency questionnaire

Background

Dietary eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) intake from marine fish is associated with cardiovascular disease prevention [1]. In addition, nutrient assessment instruments have improved our understanding of the causal factors of disease and are used in clinical and counseling situations, and in public policy decisions and recommendations. Although nutrient assessments of EPA and DHA intake were available in Caucasian [2-4], a tailored food frequency questionnaire (FFQ) to assess food intake in Taiwan is lacking.

Interviewer-administered semi-quantitative FFQs are considered to be the most feasible method for use in large-scale epidemiological research, and the validation of dietary EPA and DHA intake has been examined in an older population [5], for lipid concentration [6], and for coronary heart disease risk. However, validation of

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FFQ performance to determine how well an FFQ estimates nutrient intake as compared with diet records or repeated 24-hour recalls was affected by the correlated recall errors [7,8].

The measurement of plasma fatty acids by gas chromatography provides useful measurements of EPA and DHA, especially in high-throughput technology [9,10]. Furthermore, the errors of the dietary intake measurements from FFQs and serum biomarkers are independent, so it is feasible to evaluate the correlation of an FFQ in assessing EPA, DHA and other fatty acid intake in a clinical setting. In addition, the measured EPA and DHA concentrations are related to dietary intake and they are time-integrated, so it is feasible to use serum concentrations as the correlation tool for the reported FFQ [11].

Few FFQs have been developed specifically for use in ethnic Chinese populations [12], although literature about fish intake and n-3 fatty acids were available among European populations [13-15]. In addition, validation for the performance of FFQs using biochemical indicators of EPA and DHA intake have been reported in various populations[16-21]; however, the data for ethnic Chinese was scanty.

The validity of nutrient intake using an interviewer-administered FFQ was tested among young adults in Taiwan [12], and FFQs have been shown to be feasible for association studies between dietary intake and disease risk [12,22-24]. Therefore, we aimed to investigate the validity of an interviewer-administered FFQ and biochemical indicators of plasma marine fatty acids among Taiwanese in various clinical settings.

Methods

Study population

We conducted this cross-sectional study during 2009 and collected the participants from various settings, including patients from the outpatient clinic and health examination station at National Taiwan University Hospital, and a clinic in the local hospital in Chin-Shan community, where we have followed a cohort since 1990 [25-27]. We used the same protocol to recruit participants from the outpatient settings for the semi-quantitative food frequency questionnaire and blood sampling as the standard procedure, and we have conducted a dietary assessment study in the same setting [28].

Blood pressure was measured by trained medical assistants in a resting position. Body mass index (BMI) was calculated as weight (in kilograms)/height (in meters)^2. Waist circumference was measured according to the standard procedure [25,29].

Dietary assessment

A 38-item Chinese FFQ, combined with open questions on cooking oils most frequently consumed, was administered by an interviewer to estimate dietary intake over the preceding year; it was a shortened version of a validated FFQ for Taiwanese [12]. In brief, this FFQ was designed to assess usual dietary intake over a 1-year period. Each participant was asked the frequency with which he/she ate a certain amount of each specific food. Photographs of foods, showing different portion sizes, were used to facilitate quantification of intake. Major contributor foods and predictors for fat, protein, carbohydrate, vitamin A, vitamin C and calcium and n-3 fatty acids were included [12]. Food items were arranged into sections of the major food groups; dairy, eggs, meat, poultry, fish, seafood, organ meat, soybean products, vegetables, fruits, staples, sugary drinks, pickles, sodium containing condiments, cooking methods, cooking oils, and use of supplements. Similar foods were listed close to each other to prevent redundant recollection. The frequency response section included seven categories; "never or less than once per month", "1 to 3 times per month", "once per week", "2 to 4 times per week", "5 to 6 times per week" "once per day", "twice or more per day". Tea intake and alcoholic drinks were included in the FFQ.

Dietary intake estimates for various fatty acids were derived from the FFQ by summing the product of nutrient content of each food item derived from a previously established nutrient database [30,31], portion size, and frequency of consumption. The food-composition database used to calculate nutrient values was based primarily on the Taiwan Food Composition Data Base [32-34] and other published data resources [22,23,35].

With regards to the intake of fish and seafood, the questionnaire included three questions on fish and seafood consumption (Additional file 1): "deep sea fishes, such as codfish and salmon"; "other fishes, including farmed and fresh water fishes, such as mouthbreeder, hair-tail fish or mackerel pike (samba fish)"; and "seafood, such as shrimps, oysters, clams and cuttlefish". Information on the use of either cod-liver oil or n-3 fatty acid supplements was obtained as part of the FFQ in the form of yes/no questions.

Laboratory examination of lipids

Blood samples were sent to the core laboratory of the Department of Internal Medicine, National Taiwan University Hospital. The procedures for blood sampling and analytic methods have been described previously [25]. In brief, blood samples were collected from each participant after fasting for at least 12 hours. Serum total cholesterol levels were measured using the CHOD-PAP method (Boehringer Mannheim, Germany). HDL-C was measured following precipitation of apolipoprotein B-containing lipoproteins with phosphotungstic acid and magnesium ions (Boehringer Mannheim, Germany) [36]. Triglyceride concentrations were measured by the

GPO-DAOS method (Wako Co., Japan). All of the lipids were measured using a Hitachi 7450 automated analyzer (Hitachi, Japan). LDL-C concentrations were calculated using the Friedewald formula [37]. The coefficient of variation was 5%.

Measurements of plasma fatty acids

A 10-ml tube of EDTA-anticoagulated blood was collected, refrigerated at the site centers, and sent back within 3 hours to the National Taiwan University Hospital core laboratory. The blood was centrifuged at 800 × *g* for 10 min, then plasma was separated and dispensed into several aliquots and frozen at -70°C for analysis for fatty acid (FA) content by a single technician. After thawing, 0.5 mL of plasma was extracted with 0.5 mL methanol followed by 1.0 mL chloroform under a nitrogen atmosphere, and the lipid extract was filtered to remove protein. The methyl esters were then separated and measured on a 5890 gas chromatograph (Hewlett Packard, Avondale, PA) equipped with a 30 m-FFAT WCOT glass capillary column (J & W Scientific, Folsom, CA) and a flame-ionization detector. The identities of individual fatty acid peaks were ascertained by comparing each peak's retention time to the retention times of known standards. The relative amount of each component (% of total fatty acids) was quantified by integrating the area under the peak, and dividing the result by the total area for all fatty acids.

Statistical analysis

All data were presented as mean ± standard deviation for continuous variables and frequency for categorical variables. Means and standard deviations of various nutrients, including EPA and DHA, were calculated from total nutrient intake from the questionnaires. Fish and seafood were summarized as one entity from the FFQ. In addition, in calculating correlation coefficients, we expressed dietary fatty acid intake as a percentage of total fat intake to correspond with the measurement of fatty acids in plasma [18,38].

The total energy intake variables were examined for outliers, and erroneous values were corrected if possible and deleted if not [39]. To ensure the results were not sensitive to these values, analyses were repeated with and without outliers and the results were not obviously different. We estimated the partial Spearman correlation coefficient, after adjusting for gender, age, and total energy intake, between various intakes derived from the FFQ and plasma concentrations [2]. In addition, kappa statistics were applied to estimate the consistency between intakes derived from the FFQ and plasma measurement [40]. We adjusted gender, age, and total energy intake when we tested the association between fish, EPA and DHA concentrations. To further evaluate the associations between the biochemical indicators and FFQ-estimated intakes, we compared the mean blood values of DHA and EPA concentrations across quintiles of fish and DHA intake. We also calculated the mean blood levels of fatty acids for the quintiles of fish intake and compared levels between these extremes of intake, and used linear regression models to estimate the change in blood value as a function of FFQ intake, adjusted for the set of confounders noted above [41]. In addition, we used the Bland-Altman plot to check the potential systematic bias between biomarker and intake of FFQ between biomarker and intake of FFQ [20]. All analyses were performed with SAS software, Version 9.1 (SAS Institute, Cary, NC).

Sample size and power calculation

From correlation coefficient estimates obtained from the validation of the nutrients between questionnaires and biomarker concentrations, we estimated the sample size and power calculation from polyunsaturated fat. From the literature (Additional file 2: Table S1), the correlation coefficients of EPA and DHA are around 0.40. Applying the correlation coefficient as 0.4, we estimated that a sample size of 150 was likely to have enough power (90%) to test the significance level at 0.05.

Results

Among the 306 participants sampled for this study, six had an estimated total energy intake outside the set allowable range (800–3245 kcal/day for men, 500–2842 kcal/day for women), and an additional three participants whose energy intake was beyond mean +/− 3 standard deviations were excluded from the analysis. Of the remaining 297 participants (47% women, average age 59.8 ± 12.8 years), all had complete FFQ data.

Table 1 shows the basic characteristics of the study participants, specified by gender. Compared with men, women were more likely to have a lower waist circumference, fasting glucose level, and uric acid level, yet higher triglycerides. In addition, the smoking and alcohol drinking rates were less for women than for men. The distributions of age, blood pressure, total cholesterol, HDL and LDL cholesterol, and medical history of hyperlipidemia, hypertension and type 2 diabetes were similar between genders, as were the percentages of lipid-lowering medications.

Table 2 shows various dietary components derived from the FFQs and plasma measurements of the study participants. Compared with men, women were more likely to have a lower total energy intake, and lower protein, fat, carbohydrate and cholesterol intake; however, the percentages of energy derived from protein and carbohydrates were similar between genders. In addition, the fish intake, including deep sea fish, was similar between genders. With regards to dietary fatty acid intake

Table 1 General characteristics of the study participants by gender

	Women (n = 140)		Men (n = 157)		
	Mean	SD	Mean	SD	P value
Age (yr)	59.7	12.5	59.8	12.8	0.97
BMI (kg/m^2)	19.9	2.7	20.5	2.5	0.08
Waist circumference (cm)	85.6	9.4	89.7	8.9	0.001
Systolic blood pressure (mmHg)	122.6	16.9	120.9	14.6	0.37
Diastolic blood pressure (mmHg)	73.6	11.0	75.1	12.2	0.25
Total cholesterol (mg/dL)	198.7	33.7	193.0	40.9	0.19
HDL cholesterol (mg/dL)	136.1	143.7	153.4	125.7	0.27
Triglyceride (mg/dL)	52.6	10.4	44.8	9.6	<.0001
LDL cholesterol (mg/dL)	120.9	31.1	119.6	34.2	0.73
Glucose (mg/dL)	98.0	14.2	102.0	17.0	0.031
Uric acid (mg/dL)	5.42	1.33	6.60	1.48	<.0001
Postprandial glucose (mg/dL)	134.5	53.6	153.2	96.4	0.18
HbA1c (%)	5.63	0.65	5.61	0.72	0.86
	%		%		
Current cigarette smoker	2.1		19.1		<.0001
Current drinking	2.9		31.2		<.0001
Hyperlipidemia	27.1		29.9		0.59
Hypertension	42.9		49.0		0.29
Type 2 diabetes	7.9		12.7		0.17
On Lipid-lowering medication					
Statins	21.4		22.3		0.86
Ezetimibe	2.1		3.2		0.58
Fibrates	1.4		4.5		0.13

BMI: body mass index; HbA1c: glycated hemoglobin; HDL: high density lipoprotein; LDL: low density lipoprotein; SD: standard deviation.

Table 2 Dietary components derived from the FFQs and plasma measurements by gender

	Women (n = 140)		Men (n = 157)		
FFQ	Mean	SD	Mean	SD	P value
Total energy intake (kcal/d)	1306.7	420.8	1599.6	413.9	<.0001
Protein (g)	45.3	16.9	55.8	18.8	<.0001
Protein (% energy)	14.0	3.3	14.4	3.1	0.34
Fat (g)	46.6	19.2	51.8	19.2	0.020
Fat (% energy)	32.3	8.6	30.0	7.5	0.014
Carbohydrate (g)	176.0	65.1	216.4	67.1	<.0001
Carbohydrate (% energy)	53.6	10.3	55.6	9.4	0.09
Cholesterol (mg)	149.4	93.4	216.0	115.4	<.0001
Fish consumption serving (/d)					
Deep sea fish	0.49	0.76	0.51	0.74	0.82
Other fish	0.69	0.83	0.76	0.91	0.50
Seafood	0.15	0.27	0.25	0.46	0.034
Total fish & seafood	1.33	1.37	1.51	1.48	0.28
Saturated fat (g/d)	12.2	5.1	15.0	5.8	<.0001
Monounsaturated fat (g/d)	18.8	8.9	20.8	9.8	0.07
Polyunsaturated fat (g/d)	12.7	6.8	13.8	5.5	0.15
Saturated fat (% fat)	27.5	6.0	30.1	4.9	<.0001
Monounsaturated fat (% fat)	41.3	8.1	40.5	6.5	0.31
Polyunsaturated fat (% fat)	28.1	7.8	27.9	6.9	0.77
EPA (% fat)	0.48	0.46	0.46	0.40	0.77
C22:5 (% fat)	0.20	0.14	0.22	0.12	0.26
DHA (% fat)	0.77	0.65	0.78	0.54	0.89
Plasma concentration (/dL)					
Saturated fat (g)	1733	612	1774	606	0.56
Monounsaturated fat (g)	718	303	784	393	0.11
Polyunsaturated fat (g)	1726	487	1743	441	0.77
N-6 fatty acid	1511	442	1531	394	0.68
N-3 fatty acid	215.5	59.9	211.8	62.2	0.60
Marine fatty acid	147.9	45.4	146.9	47.2	0.85
EPA (20:5n-3)	20.7	6.4	19.4	4.0	0.034
DHA (22:6n-3)	127.2	42.3	127.5	46.0	0.95
Percentage of total fat, %					
Saturated fat	38.9	2.6	38.7	2.2	0.45
Monounsaturated fat	15.9	2.2	16.6	2.5	0.02
Polyunsaturated fat	39.2	3.5	38.8	3.8	0.29
N-6 fatty acid	34.3	3.4	34.1	3.6	0.56
N-3 fatty acid	4.93	0.89	4.72	0.86	0.04
Marine fatty acid	3.41	0.87	3.28	0.78	0.19
EPA (20:5n-3)	0.48	0.14	0.45	0.11	0.014
DHA (22:6n-3)	2.93	0.82	2.84	0.75	0.34

derived from the FFQ, women were more likely to eat less saturated fat than men. However, monounsaturated fat, polyunsaturated fat and EPA as well as DHA intakes were similar between genders.

With regards to plasma fatty acid concentrations, women were more likely to have a higher percentage of fat intake from n-3 fatty acids, EPA and DHA, compared with men, although the absolute concentrations for both genders were similar. The correlation coefficients between dietary fishes and fatty acid intake as well as plasma fatty acid components in the study participants, after adjusting for gender, age, and total energy intake, are shown in Table 3. The coefficients between all kinds of fishes and marine n-3 fatty acid intake as well as plasma DHA ranged from 0.20 to 0.33 ($P < 0.001$). In addition, dietary EPA, C22:5 n-3 and DHA were correlated to plasma marine n-3 fatty acid and DHA, with partial Spearman correlation coefficients ranging from 0.26 to 0.35 ($P < 0.001$). In addition, the correlations from dietary fatty acids by either absolute intakes (g/day) and

Table 3 Spearman correlation coefficients between food-frequency questionnaire derived dietary fish as well as fatty acid compositions and plasma fatty acid compositions in all study participants, after adjusting for age, gender and total energy intake

Questionnaire	Deep sea fish	Other fish	Seafood	Total fish & seafood	Saturated fat (% fat)	Monounsaturated fat (% fat)	Polyunsaturated fat (% fat)	C20:5 (% fat)	C22:5 (% fat)	C22:6 (% fat)
Plasma composition										
Saturated fat	−0.125*	0.044	−0.053	−0.013	0.116*	−0.030	−0.007	−0.073	−0.055	−0.048
Monounsaturated fat	0.007	−0.042	0.003	−0.025	0.145*	0.054	−0.131*	0.001	0.060	0.019
Polyunsaturated fat	0.042	−0.004	0.036	0.012	−0.208***	−0.016	0.087	0.010	−0.040	−0.014
N-6 fatty acid	−0.002	−0.069	0.025	−0.056	−0.214***	−0.018	0.082	−0.067	−0.102	−0.090
N-3 fatty acid	0.193***	0.274***	0.035	0.313***	−0.016	0.043	0.032	0.334***	0.261***	0.321***
Marine fatty acid	0.196***	0.284***	0.038	0.318***	0.015	0.074	0.000	0.336***	0.271***	0.328***
EPA (20:5n-3)	−0.012	0.003	−0.040	0.023	−0.070	−0.076	0.091	−0.009	−0.034	−0.028
DHA (22:6n-3)	0.207***	0.294***	0.043	0.327***	0.021	0.088	−0.010	0.351***	0.287***	0.346***

The corresponding dietary intake includes all isomers of 20:1.
*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Table 4 Diagonal proportions in cross-classification of nutrient distribution and estimated kappa values and 95% confidence intervals for dietary intake of DHA, from fish intake, FFQs and plasma measurements in the study participants, categorized by quintile distribution

		Diagonal proportion %	Kappa	SE	95% Conf limit	
Total fish intake	C22:6	50.2	0.63	0.03	0.58	0.68
Total fish intake	DHA	26.9	0.18	0.04	0.10	0.26
C22:6	DHA	25.9	0.20	0.04	0.12	0.28

intakes as percentage of total energy intake were similar as the percentage of total fat intake (Additional file 2: Table S2 and S3).

With regards to the cross-classification of tabulations (Table 4) according to the total dietary fish and DHA intakes as well as plasma DHA quintiles, the diagonal proportions between fish intake and DHA ranged from 26% to 50%, and the highest kappa value was for total fish intake and DHA (0.63, 95% confidence interval, 0.58-0.68).

The adjusted mean plasma DHA levels plotted against median daily fish as well as dietary DHA intakes by quintiles are shown in Figure 1. Compared with those in the lowest quintile, participants in the highest fish intake quintile had a significantly higher DHA level (adjusted mean difference, 0.99 ± 0.10%, test for trend, $p < 0.001$). We tested the non-linearity assumption of the quintiles and the linearity was not rejected, so that the dip in the fourth quintile for the relationship between dietary fish and seafood intake and DHA concentration may be due to a random error. Similar patterns between dietary DHA intake and plasma DHA level were found. However, the association between dietary fish intake and EPA was not significant (test for trend, $p = 0.69$). In addition, the Bland-Altman plot showed that the estimated from biomarker DHA concentrations were higher than the intakes from FFQ estimate: when the DHA intakes increased, the estimate of DHA concentration was higher than the intakes of DHA from FFQ (Figure 2).

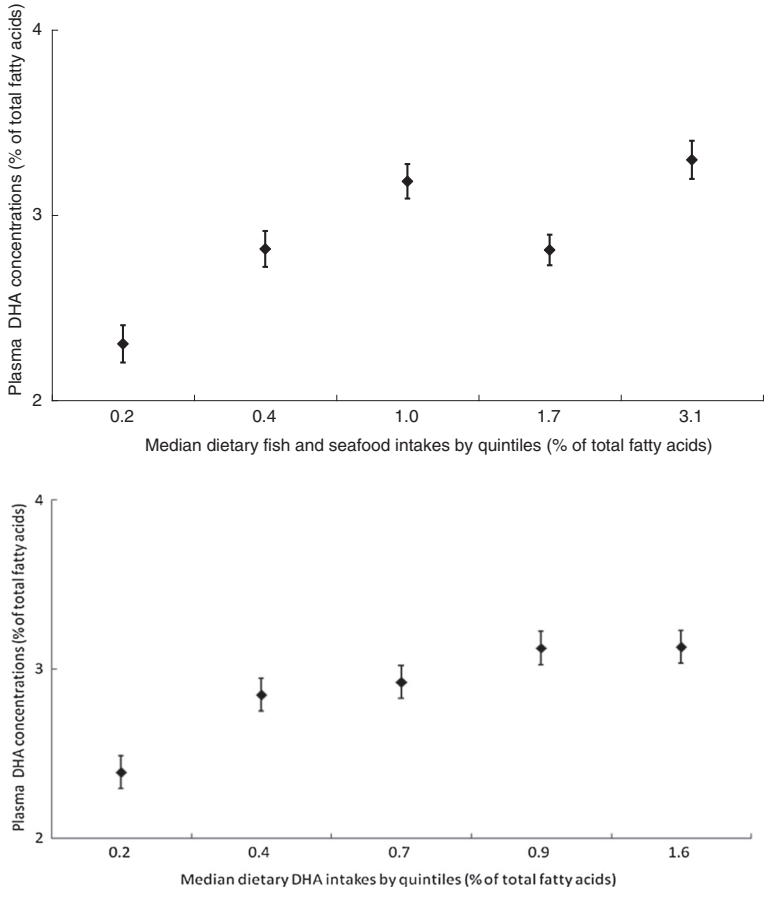

Figure 1 Mean (± SEM) plasma DHA plotted against median daily fish and seafood (Upper) as well as DHA (Lower) intakes by quintile, after adjustment for age, sex, and total energy; both $P < 0.001$, test for trend.

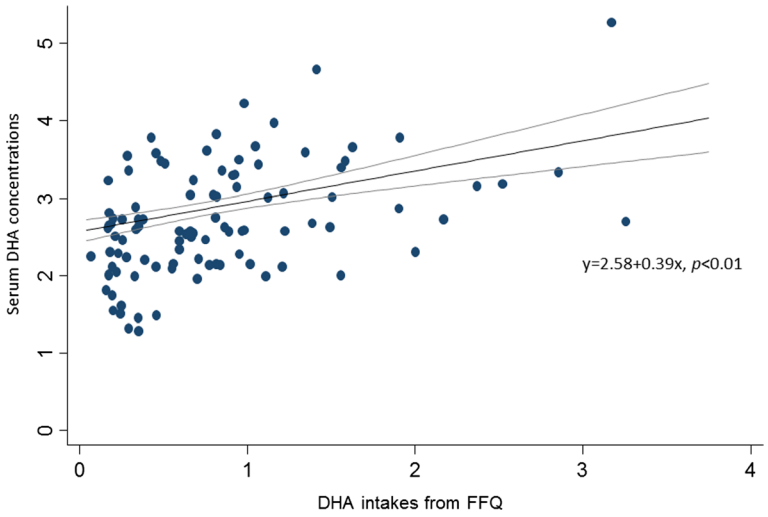

Figure 2 The Bland-Altman plot for the reliability of serum DHA concentration and intakes of DHA from FFQ and the estimated linear regression coefficients in the study participants.

Discussion

In this cross-sectional study, we clearly demonstrated that dietary fish intakes measured from the interviewer-administered FFQ were correlated for plasma DHA levels among ethnic Chinese adults in Taiwan; however, the association for plasma EPA was not significant. In addition, a dose-response relationship between the FFQ and plasma DHA levels was shown.

The use of FFQs is feasible in epidemiological studies for the association between diet and disease. In a study by Arsenault *et al*., the correlation coefficients were 0.37 for EPA and 0.48 for DHA among 327 older adults (> = 65 yrs), and the magnitude was stable irrespective of the status of cognitive impairment [5]. Sullivan and colleagues conducted a validation study based on 53 healthy Australian adults to collect FFQs and 3-day weighed food records to estimate the long-chain n-3 polyunsaturated fatty acids and they found that the correlations were 0.62 for EPA and 0.72 for DHA [20]. In addition, this FFQ has been validated from plasma biomarker validation: the correlations were 0.54 for EPA and 0.48 for DHA [21]. Another validation study based on electronic FFQ, plasma biomarkers and weighted food records among 41 healthy adults showed high correlations for EPA and DHA [19].

Various resources have been used to provide the biochemical measurements, including adipose tissue, red blood cells, platelet membranes and subfractions of phospholipids (Additional file 2: Table S1). The correlation coefficients for EPA and DHA derived from adipose tissues have been found to be smaller than those for n-6 fatty acids and trans fats, and the correlation coefficients of n-3 fatty acids have been shown to range from 0.3 to 0.6. Only oil fish and EPA association was found among Australian population [15]. However, our study indicated that the coefficient was significant only for DHA, but not for EPA. From an European study, fish intake showed a statistically significant relationship with n-3 PUFA, EPA and DHA in serum [14]. These findings are consistent with previous literature based on middle American adults [4] and African Americans with prostate cancer [42]. Two possible explanations for the discrepancy between DHA and EPA coefficients are that firstly the proportion of DHA was much higher than that of EPA for the total fat contribution; and secondly that DHA was more biologically active than EPA due to its longer-chain characteristics [43]. Indeed, it was not clear why the proportion of DHA being higher would matter: the lower variability of EPA may better explain of a lack of association. And other sources of EPA that the questionnaire may have missed: Our data showed that dietary EPA values were less than other Asian populations.

The coefficients in our study were somewhat smaller than previous studies, especially for EPA. The validity of biochemical indicators is vulnerable to the problems of nutrient homeostatic mechanisms, bioavailability, time integration, medical condition, genetic backgrounds, and types of analytic procedures [11]. Admittedly, only a few biochemical indicators provide a sensitive and time-integrated reflection of nutrient intake. Our study indicated that plasma DHA, but not EPA, was related to dietary fish and marine n-3 fatty acid measurements. In addition, we did not consider the cod liver oil and n-3 fatty acid supplements because scanty data were available.

The association between DHA and EPA concentrations and lipid profiles in the general population is inconsistent. A population study based on Japanese and Americans showed that EPA was associated with HDL cholesterol

only in Caucasians, but not in Japanese [6]. In addition, DHA was inversely associated with triglycerides in Caucasians, but not in Japanese. Our findings provided further evidence about the correlation of plasma fatty acid biomarkers as the surrogate indicators of dietary intakes [11], and contributed to the studies with the population with an Asian dietary habit. With regards to the reproducibility of the FFQ, our previous study [12] has shown that the FFQ is reproducible for Chinese-speaking people in Taiwan, and the correlation coefficients for n-3 fatty acids were similar to Sullivan and colleagues' study [20].

This study has two strengths. First, we collected a well-established sample with archived clinical samples, adequate sample size, and extensive measures of various nutrient intakes and clinical information. Second, the participants were recruited from community and hospital settings, and the results can be applied to general practice. However, some limitations of this study should be mentioned. First, no other information, such as dietary record and recall, was available and the 32 items of questionnaire was relatively short form, so that the correlations were modest in strength although they were statistically significant. Second, only 3 questions for fish/seafood consumptions in the questionnaire may decrease the power of detecting dietary intake. Third, our study lacked the gold standard of the weighed food records data for intake of fatty acids. Finally, we did not measure the total energy expenditure, basal metabolic rate and energy intake among participants. Instead, we used the cutoff of convenient criteria from the Taiwanese community survey [12]. Goldberg and colleagues developed a feasible tool to assess the energy balance in populations [44] and evidence showed that the Goldberg cut-off for energy intake: basal metabolic rate information was a good indicator to define the under-, acceptable- and over-reporters for diet intake [45].

Conclusion

In conclusion, our study demonstrated that the dietary intakes of fish and of long chain n-3 fatty acids, as determined by our food frequency questionnaire, are correlated with the percentages of these fatty acids in plasma, and in particular with plasma DHA.

Additional file

Additional file 1: A translation of the Chinese version of the 32-item FFQ.

Additional file 2: Table S1. Literature review comparing measures of dietary fatty acid intake by biochemical indicators, food frequency questionnaire (FFQ) and diet record (DR) methods. **Table S2:** Spearman correlation coefficients between the dietary fish and fatty acids by absolute intake (g/day) food-frequency questionnaire and plasma fatty acid components (g) in the study participants, after adjusting for age, gender and total energy intake. **Table S3:** Spearman correlation coefficients between the dietary fish and fatty acids by the percentage of total energy intake in the food-frequency questionnaire and plasma fatty acid concentrations in the study participants, after adjusting for age and gender.

Abbreviations

DHA: Docosahexaenoic acid; EPA: Eicosapentaenoic acid; FFQ: Food frequency questionnaire.

Competing interests

The authors declare no competing interests.

Authors' contributions

KLC carried out the study design, data collection and analysis, and wrote the draft. MSL provided the food frequency questionnaire and test the correlation. PRC provided the nutritional survey and revised draft. HCH carried out the laboratory measurements and quality control and assurance. YTL participated in the design of the study and revised the draft. MFC conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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