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ARTICLE

Women who take n-3 long-chain polyunsaturated fatty acid supplements during pregnancy and lactation meet the recommended intake

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Abstract: The aim of the current study was to estimate total intake and dietary sources of eicosapentaenoic acid (EPA), docosapentanoic (DPA), and docosahexaenoic acid (DHA) and compare DHA intakes with the recommended intakes in a cohort of pregnant and lactating women. Twenty-four–hour dietary recalls and supplement intake questionnaires were collected from 600 women in the Alberta Pregnancy Outcomes and Nutrition (APrON) cohort at each trimester of pregnancy and 3 months postpartum. Dietary intake was estimated in 2 ways: by using a commercial software program and by using a database created for APrON. Only 27% of women during pregnancy and 25% at 3 months postpartum met the current European Union (EU) consensus recommendation for DHA. Seafood, fish, and seaweed products contributed to 79% of overall n-3 long-chain polyunsaturated fatty acids intake from foods, with the majority from salmon. The estimated intake of DHA and EPA was similar between databases, but the estimated DPA intake was 20%–30% higher using the comprehensive database built for this study. Women who took a supplement containing DHA were 10.6 and 11.1 times more likely to meet the current EU consensus recommendation for pregnancy (95% confidence interval (CI): 6.952–16.07; $P < 0.001$) and postpartum (95% CI: 6.803–18.14; $P < 0.001$), respectively. Our results suggest that the majority of women in the cohort were not meeting the EU recommendation for DHA during pregnancy and lactation, but taking a supplement significantly improved the likelihood that they would meet recommendations.

Key words: eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), docosapentaenoic acid (DPA), Alberta Pregnancy Outcomes and Nutrition (APrON), n-3 long-chain polyunsaturated fatty acids (LCPUFA).

Résumé : La présenté étude a pour but d'estimer l'apport nutritionnel total et les sources alimentaires en acides eicosapentaénoïque (« EPA »), docosapentaénoïque (« DPA ») et docosahexaénoïque (« DHA ») ainsi que de comparer l'apport nutritionnel en DHA à l'apport recommandé, et ce, au sein d'une cohorte de femmes enceintes et allaitantes. Vingt-quatre enquêtes nutritionnelles et questionnaires sur la consommation de suppléments ont été recueillis auprès de 600 femmes issues de la cohorte de « l'AprON » (*Alberta Pregnancy Outcomes and Nutrition*) lors de chaque trimestre de la grossesse et trois mois après l'accouchement. L'apport nutritionnel a été estimé de deux façons : au moyen d'un logiciel commercial et à partir d'une base de donnée créée pour l'APrON. Seulement 27 % des femmes enceintes et 25 % de celles qui avaient accouché depuis trois mois satisfaisaient les recommandations consensuelles actuelles de l'Union européenne (UE) en matière d'apport en DHA. Les fruits de mer, le poisson et les produits à base d'algues comptaient pour 79 % de l'apport alimentaire global en acides gras polyinsaturés à longue chaîne de type n-3 (tirés du saumon en majeure partie). Les apports nutritionnels estimés en DHA et en EPA étaient semblables dans les deux bases de données, mais l'apport nutritionnel en DPA était de 20 à 30 % plus élevé lorsqu'il était estimé à partir de la base de données détaillée élaborée pour la présente étude. Les femmes ayant pris un supplément renfermant du DHA étaient 10,6 et 11,1 fois plus susceptibles de satisfaire l'apport nutritionnel recommandé pendant la grossesse (intervalle de confiance (IC) à 95 % : 6,952 à 16,07; $P < 0{,}001$) et le postpartum (IC à 95% : 6,803 à 18,14; $P < 0{,}001$), respectivement. Nos résultat laissent entrevoir que les femmes de cette cohorte ne satisfaisaient pas les recommandations de l'UE en matière de DHA pendant la grossesse et l'allaitement, mais que la prise d'un supplément a nettement augmenté la probabilité qu'elles satisfassent ces recommandations. [Traduit par la Rédaction]

Mots-clés : acide eicosapentaénoïque (« EPA »), acide docosahexaénoïque (« DHA »), acide docosapentaénoïque (« DPA »), *Alberta Pregnancy Outcomes and Nutrition* (« APrON »), acides gras polyinsaturés à longue chaîne (AGPLC) de type n-3.

Introduction

The dietary n-3 polyunsaturated fatty acids (PUFA) include α-linolenic acid (ALA), eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA), and docosahexaenoic acid (DHA). EPA, DPA, and DHA are usually referred to as n-3 long-chain PUFA (n-3 LCPUFA). A source of these long-chain fatty acids is required during pregnancy for fetal and placental development (reviewed by Mennitti et al. 2015; Jones et al. 2014). Maternal intake/status of n-3 LCPUFA during pregnancy and lactation has been found to positively impact maternal, infant, and child health in many systematic reviews (Yang et al. 2013; Imhoff-Kunsch et al. 2012; Larqué et al. 2012; Horvath et al. 2007). The importance of a dietary source of n-3 LCPUFA is supported by stable isotope tracer studies that found only 1%–4% of dietary ALA is converted to DHA (Pawlosky

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et al. 2001; Emken et al. 1994). Although the conversion of ALA to DHA is reported to increase during pregnancy (Williams and Burdge 2006), maternal supplementation with ALA together with linoleic acid during pregnancy was not found to be effective in increasing blood DHA concentration in pregnant women or their newborn infants (de Groot et al. 2004). Assuming that only a small amount of n-3 LCPUFA can be synthesized from the dietary precursor, at least in some women, a dietary source of n-3 LCPUFA is required during pregnancy and lactation to meet maternal and infant requirements. Although less is known about the role of DPA in fetal development, it has been suggested that there is some conversion to DHA and retro-conversion to EPA (Kaur et al. 2011). There is also recent evidence that dietary intake of DPA is associated with neuroprotective effects (Kelly et al. 2011) and heart health (Sun et al. 2008), suggesting that DPA intake may have additional benefits if consumed during pregnancy and lactation.

The American Dietetic Association (ADA) with the Dietitians of Canada (Kris-Etherton and Innis 2007) recommend at least 500 mg/day of LCPUFA for all healthy adults including pregnant and lactating women. The European Commission with the International Society for the Study of Fatty Acids and Lipids (ISSFAL) specifically recommends that pregnant and lactating women consume a minimum of 200 mg DHA per day (Koletzko et al. 2008, 2007). These recommendations could be met by consuming 1 to 2 portions per week of fish high in n-3 fatty acids, which is the recommendation by Health Canada (Health Canada 2002) and the United States Dietary Guidelines Advisory Committee (Dietary Guidelines for Americans 2005) for all women. There is currently no specific recommendation for dietary DPA.

Although maternal intake of n-3 LCPUFA is important for infant brain and retina development before and after birth (reviewed by Innis 2007), studies done in Canada, Australia, the United States, and Europe have reported that pregnant and lactating women are not meeting the suggested dietary recommendations (Cosatto et al. 2010; Sioen et al. 2010; Friesen and Innis 2009; Denomme et al. 2005; Oken et al. 2004; Innis and Elias 2003). This is likely contributed to by the low fish consumption reported by North American women (Coletto and Morrison 2011), concerns of mercury contamination (Oken et al. 2003), and low supplement use (Friesen and Innis 2009; Denomme et al. 2005; Oken et al. 2004; Innis and Elias 2003). Although n-3 supplements (Natural Health Products (NHP)) are reported to be a major source of EPA and DHA (EFSA Panel on Dietetic Products, Nutrition and Allergies 2012), the prevalence of supplement use was found to be positively associated with socioeconomic status (SES) in the Canadian Community Health survey (Vatanparast et al. 2010).

To estimate intake of dietary n-3 LCPUFA, commercial nutrient analysis programs based on the United States Department of Agriculture (USDA) and the Canadian Nutrient File (CNF) are commonly used in North America. A previous study identified problems with this data base for estimating LCPUFA intake because of missing the content of selective n-3 LCPUFA in the 2007 version of the CNF (Patterson et al. 2012). Although the nutrient file has been updated since this publication, it is not known if it still has missing values that would result in underestimating the intake of n-3 LCPUFA.

The objectives of this study were to estimate in a large maternal-infant cohort (*i*) dietary intake and sources of EPA, DPA, and DHA in each trimester during pregnancy and at 3 months postpartum and to compare intake with various recommendations; and (*ii*) to determine the contribution of supplements to total n-3 LCPUFA intake.

Materials and methods

Participants and sample collection

Participants for this study were the first 600 women enrolled in the Alberta Pregnancy Outcomes and Nutrition (APrON) study, a prospective cohort study that recruited pregnant women in Alberta, Canada. Detailed information on recruitment criteria and data collection methodology has been published elsewhere (Kaplan et al. 2014). Briefly, the inclusion criteria were females of child-bearing age (>16 years), less than 26 weeks gestation, and able to speak and write in English. Twenty-four–hour recalls and supplement intake questionnaires (SIQs) including n-3 LCPUFA supplements were collected by face-to-face interviews with participants during each pregnant visit (2–3 times during pregnancy) and at 3 months postpartum. Ethical approval for this study was obtained from the Health Research Ethics Biomedical Panel at the University of Alberta and the Health Research Ethics Board at the University of Calgary.

Developing the n-3 LCPUFA database

Dietary intake of n-3 LCPUFA (EPA, DPA, and DHA) was estimated from the face-to-face 24-h recalls using 2 methods: (*i*) a commercial program (Food Processor version 10.6; ESHA Research, Salem, Ore., USA), and (*ii*) a database created for APrON. Similar to the study developed by Innis and Elias (2003), the APrON database for n-3 LCPUFA (EPA, DPA, and DHA) included all foods reported in the 24-hour recalls that would contribute to n-3 LCPUFA intake. Foods assumed to have negligible amounts of n-3 LCPUFA, including items such as breads, fruits, and vegetables, were not included in the database. The CNF and the USDA nutrient databases were used as the primary source of n-3 LCPUFA information. Judgments based on similar energy and compositions were used to substitute food items that were not found in either the USDA or the CNF database. Eighty-five recipes were created and n-3 LCPUFA information was estimated from each individual ingredient. Examples of these recipes included sauces, dips, baked goods, and mixed seafood, fish, poultry, meat, egg, or dairy dishes. Utilizing the assigned EPA, DPA, and DHA values for all food items, the foods in the 24-h recalls were linked to the n-3 LCPUFA database using Microsoft Office Excel 2010. Formulas and functions were used to automatically calculate the individual and total n-3 LCPUFA intake for each participant at each time-point. To determine food sources contributing to intake, foods were grouped into food groups (n = 10), and seafood, fish, and seaweed products were further categorized into subcategories (n = 7), which is defined in the USDA database.

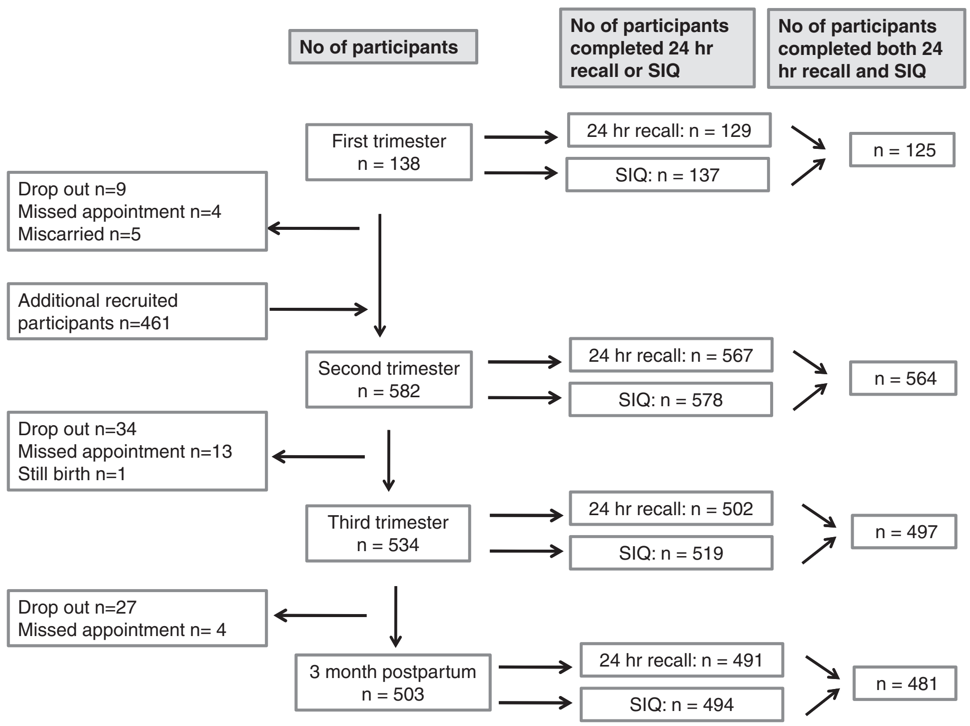
Estimating n-3 LCPUFA intake from supplements

A specially designed and validated SIQ, adapted from Health Canada and Statistics Canada (Canadian Community Health Survey - Nutrition 2004, Dietary Supplements and Prescription Medication Survey 2005–2006, and The Tomorrow Project questionnaires 2006), was used to collect NHP intake information during pregnancy and postpartum as previously described (Gómez et al. 2013). A NHP database (including 935 products) was developed for APrON to estimate supplement intake and more details on the development have been published elsewhere (Gómez et al. 2013). Briefly, at each visit during pregnancy and postpartum, women were asked to describe the type and quantity (i.e., frequency and dosage of intake) of NHPs consumed. A comprehensive file was created for each participant for all consumed NHPs with the detailed correction factor for days of week, weeks of trimester, and dosage at each time-point. This file was then linked to the NHP database to estimate the contribution of n-3 LCPUFA intake from supplements.

Statistical analysis

Data for all nutrients were tested for normality using the Kologrov–Smirnov test. If data were not normally distributed, it was log-transformed and retested to ensure normal distribution prior to using parametric statistics. A 1-way ANOVA, Kruskal–Wallis, Mann–Whitney U test, and Wilcoxon Signed Ranks Test were conducted, as appropriate, to compare the differences among sampling time-points. The binary logistic regression model was used to

Fig. 1. Participant recruitment and dietary intake data collection. Of the 600 women from the first cohort of the APrON study, 130, 572, 510 and 500 women completed the 24-h recalls at first, second, and third trimester and 3 months postpartum, respectively. Of these, 1, 5, 8, and 9 subjects (at each time-point, respectively) were excluded as they had estimated intakes of calories and/or fibre ≥3 standard deviations above the mean. SIQ, supplement intake questionnaire.



identify the likelihood of meeting the current DHA recommendation based on supplement consumption during pregnancy and at 3 months postpartum. All data were analyzed using IBM SPSS Statistics for Windows (version 21; IBM Corp., Armonk, N.Y., USA) and a 2-tailed *P* value of ≤0.05 was considered significant.

Results

Of the 600 women from the first cohort of the APrON study, 592 participants provided at least one 24-h recall and SIQ. Among those, 130, 572, 510, and 500 women provided the 24-h recalls and 137, 578, 519, and 494 women provided supplement questionnaires at the first, second, and third trimesters and 3 months postpartum visit, respectively. Among those, 1, 5, 8, and 9 subjects were excluded at each time-point, respectively, as they were defined to have nonrepresentative 24-h recalls (defined as estimated intakes of calories and/or fibre greater than 3 standard deviations from the group mean). After ensuring the complete intake (dietary and supplement) was available, 125, 564, 497, and 481 participants were included for analysis (Fig. 1).

Participant characteristics are presented in Table 1. The majority of the women had completed postsecondary education, had an annual household income ≥$100 000, and were in their second trimester. Their ages ranged from 17–44 years with a mean age of 31.6 years. Approximately one-third (*n* = 187) of participants reported taking a supplement containing n-3 LCPUFA at 1 or more of the measured time-points. At 3 months postpartum, 92% of the women (*n* = 402) reported breastfeeding their infants (Jessri et al. 2013). Among these women, 54% were exclusively breastfeeding at 3 months postpartum, while the nonexclusive breastfeeding women reported providing formula as complementary to breastfeeding (Jessri et al. 2013).

Table 1. Maternal demographic characteristics for women in the first cohort of the Alberta Pregnancy Outcomes and Nutrition study.

Maternal characteristics (*n*)	*n* (%)
Maternal age (600), y	31.6±4.4
Marital status (562)	
Married	480 (85.4)
Other	82 (14.6)
Maternal education (559)	
≤High school diploma	55 (9.8)
Trade	116 (20.8)
University degree/postgraduate	388 (69.4)
Ethnicity (558)	
Caucasian	486 (87.1)
Other	72 (12.9)
Family income (552)	
$20 000–$69 000	107 (19.4)
$70 000–$99 000	140 (25.4)
≥$100 000	305 (55.2)

Note: Maternal age is presented as mean ± SE. All other values are presented as proportion of the total response. Data are presented for all women at all time-points (*n* = 600). Participant size for individual responses may vary as data were not available for all participants.

Estimated daily intake of macronutrients and fatty acids

Table 2 shows the estimated daily intake of energy, carbohydrate, protein, and fat for the first, second, and third trimesters of pregnancy and at 3 months postpartum. The mean intake of all macronutrients met the Accepted Macronutrient Distribution Range recommended by the Institute of Medicine. With the exception of energy, carbohydrate, and saturated fatty acids (SFA), there was no significant difference in the mean intake of these nutrients among the 4 time-points (Table 2). The mean daily energy, carbohydrate, and SFA intakes were significantly higher in the third trimester compared with the first trimester and 3 months postpartum. After correcting for energy intake, carbohydrate in-

Table 2. Estimated daily dietary intake of energy, macronutrients, different types of fatty acids, and the ratio of n-6 and n-3 fatty acids during 3 trimesters of pregnancy and 3 months postpartum in the first cohort of the Alberta Pregnancy Outcomes and Nutrition study.

Nutrients	First trimester (*n* = 129)	Second trimester (*n* = 567)	Third trimester (*n* = 502)	3 mo postpartum (*n* = 491)
Energy				
kcal	2112±585a	2243±633ab	2295±641b	2089±598a
Carbohydrate				
g	285±94a	311±97b	317±96b	275±94a
% of energy	54±10	56±9	56±9	53±10
Protein				
g	91±31	92±32	93±31	88±29
% of energy	18±5	17±4	16±4	17±4
Fat (total)				
g	73±31	76±32	78±34	74±32
% of energy	31±8	30±8	30±8	31±9
Saturated fat				
g	25±13a	26±13ab	28±13b	25±13a
% of energy	11±4	10±4	11±4	11±4
% of fat	34±8	35±8	35±8	34±8
Monounsaturated fat				
g	26±13	26±12	28±14	27±13
% of energy	11±4	10±4	11±4	11±4
% of fat	35±6	34±7	35±6	36±7
Polyunsaturated fat				
g	13±7	13±8	14±8	13±7
% of energy	5.7±2.5	5.3±2.5	5.3±2.3	5.6±2.6
% of fat	19±7	18±7	18±6	18±7
LA				
g	11±6	11±6	11±7	11±6
% of energy	4.7±2.2	4.3±2.1	4.3±2.1	4.6±2.3
% of fat	15±6	15±6	14±6	15±6
ALA				
g	1.2±0.8	1.3±1.2	1.4±1.2	1.3±1.1
% of energy	0.51±0.27	0.54±0.44	0.54±0.43	0.57±0.44
% of fat	1.7±0.8	1.8±1.3	1.8±1.4	1.8±1.4
AA				
mg	104±110	106±157	113±157	112±184
% of energy	0.05±0.05	0.04±0.07	0.05±0.08	0.05±0.08
% of fat	0.15±0.17	0.16±0.28	0.16±0.29	0.16±0.25
EPA				
mg	135±259 (14, 2–132)a	141±351 (9, 2–111)a	172±389 (10, 2–191)b	140±312 (9, 2–132)a
DPA				
mg	24±44 (13, 6–21)	31±92 (13, 6–23)	40±98 (13, 6–25)	32±72 (14, 6–24)
DHA				
mg	159±268 (46, 6–173)a	187±461 (30, 5–159)a	237±508 (33, 6–216)b	186±381 (30, 5–197)a
n-3 LCPUFA (EPA+DPA+DHA)				
mg	318±517 (86, 19–324)a	359±828 (59, 20–300)a	450±924 (63, 20–465)b	358±706 (58, 21–353)a
% of energy	0.15±0.27	0.16±0.35	0.19±0.42	0.16±0.34
% of fat	0.53±1.07	0.60±1.73	0.69±1.61	0.56±0.18
LA/ALA	11±7	10±5	10±10	10±7
Total n-6 PUFA/n-3 PUFA*	9.0±6.5	8.4±4.8	8.3±8.8	8.8±7

Note: Data are presented as means ± SD. For skewed data, median and inter-quartile range (IQR) are in parenthesis (mean, IQR). % of energy is calculated by dividing calories from each nutrient to total calories. % of fat is calculated by dividing amount of individual fat to total fat. For each nutrient, time-points that do not share a common letter are significantly different ($P < 0.05$). Estimated intake for LA, ALA, EPA, DPA, and DHA include diet and supplement information. AA, arachidonic acid; ALA, α-linolenic acid; DHA, docosahexaenoic acid; DPA, docosapentanoic; EPA, eicosapentaenoic acid; LA, linoleic acid; n-3 LCPUFA, n-3 long-chain polyunsaturated fatty acids; PUFA, polyunsaturated fatty acids.

*Total n-6/n-3 PUFA ratio = (LA+AA+gamma-linolenic acid)/(ALA+EPA+DPA+DHA).

takes in the second and third trimesters were still significantly higher than the postpartum period (139 ± 23 and 139 ± 22 vs 132 ± 25 g, respectively, $P < 0.001$). The mean estimated intake of arachidonic acid (AA) and the median intake of n-3 LCPUFA (EPA+DPA+DHA) ranged from 104 to 113 mg and 58 to 86 mg per day, respectively. The ratio of total n-6 PUFA (linoleic acid+AA+gamma-linolenic acid) to n-3 PUFA (ALA+EPA+DPA+DHA) ranged from 8.3 to 9.0, but did not differ among time-points.

Using the developed database, total dietary intake of n-3 LCPUFA, EPA, and DHA was found to be significantly higher in trimester 3 than at any of the other time-points (Table 2). When the mean intake from all trimesters was calculated for each woman (for an estimation during pregnancy) and compared with 3 months postpartum, the estimated intake of EPA, DHA, and total n-3 LCPUFA was significantly lower at 3 months postpartum (Table 3). At all time-points, DHA represented approximately 50%–53% of total n-3 LCPUFA intake. The mean intake of DHA met the current European Union (EU) consensus recommendation at the third trimester of pregnancy but not at the first and second trimester of pregnancy and 3 months postpartum (Table 3). Only 27% of pregnant (means of 2 or 3 trimesters) and 25% of postpartum women met the current EU consensus recommendation of 200 mg DHA daily. When only dietary sources were considered, the median (inter-quartile range) value of DHA dropped to 28 (9–72) and 17 (3–60) mg/day and

Table 3. Estimated daily intake of EPA, DPA, and DHA from food, supplement, and food + supplement during pregnancy and postpartum.

	EPA (mg)	DPA (mg)	DHA (mg)
Pregnancy			
Food (*n* = 596)	48±110 (7, 3–26)	35±70 (15, 9–26)	122±280 (28, 9–72)
Supplement (*n* = 597)[a]	102±302 (0, 0–50)	—	80±231 (0, 0–45)
Food + supplement (*n* = 591)	150±329 (16, 4–163)	35±71 (15, 9–26)	204±380 (50, 14–214)
Postpartum			
Food (*n* = 491)	53±151 (4, 1–17)	32±72 (14, 6–25)	121±319 (17, 3–60)
Supplement (*n* = 495)[a]	88±268 (0, 0–0)[b]	—	68±214 (0, 0–0)b
Food + supplement (*n* = 481)	140±312 (9, 2–132)[b]	32±72 (14, 6–24)	186±381 (30, 5–197)b

Note: Skewed data are presented as means ± SD (median, inter-quartile range). A mean of all trimesters was used to determine values for each individual pregnant woman. The current European Union consensus recommendation is 200 mg/day DHA during pregnancy and lactation. DHA, docosahexaenoic acid; DPA, docosapentanoic; EPA, eicosapentaenoic acid.

[a]Participants who did not take supplements or those who took supplements that did not contain EPA/DHA were considered as 0 mg supplement on EPA and DHA.

[b]Indicates within a column that the intake from food and combined food and supplement were significantly ($P < 0.05$) lower than that estimated in pregnancy.

only 13% of participants met the EU consensus recommendation for both pregnancy and 3 months postpartum (data not shown). The mean intake of total n-3 LCPUFA at all time-points during pregnancy and 3 months postpartum was below the ISSFAL/EU and ADA recommendations of a minimum daily intake of 500 mg n-3 LCPUFA.

Thirty percent of the cohort reported taking a DHA supplement during at least 1 trimester of pregnancy and 23% reported taking a DHA supplement at 3 months postpartum. Among participants taking DHA supplements, 60% of pregnant and 63% of postpartum women met the EU consensus recommendation, whereas only 13% of both pregnant and postpartum women met the recommendation through diet alone (Fig. 2). Taking a DHA supplement increased the likelihood of meeting the EU recommendation during pregnancy by 10.6 times (95% confidence interval (CI): 6.952–16.07; $P < 0.001$) and at postpartum by 11.1 times (95% CI: 6.803–18.14; $P < 0.001$).

Food sources of EPA, DPA, and DHA in the diet of pregnant and postpartum women

When all time-points were combined, seafood, fish and seaweed products were the major food contributors (79%) to total daily n-3 LCPUFA intake, 87% of EPA intake, 59% of DPA intake, and 81% of DHA intake among pregnant and postpartum women (Fig. 3A; Table A1). Poultry products (14%) and meat products (11%) also made significant contributions to estimated intake of DPA intake across all time-points (Table A1). Within the seafood, fish, and seaweed category, salmon was found to be the major contributor, contributing to total n-3 LCPUFA (61%), EPA (55%), DPA (74%), and DHA (62%) intake (Fig. 3B; Table A2). The other food sources within this food category included whitefish, shellfish and crustaceans, and tuna (Fig. 3B).

Comparison for the estimated dietary n-3 LCPUFA intake between methods

To determine the completeness of the commercial nutrient analysis program, the estimated n-3 LCPUFA intake presented above was compared with the output from the commercial program. The estimated dietary n-3 LCPUFA intake from the commercial program was significantly lower (5%–10%) than the data from the developed database during pregnancy (mean of the trimesters measured for each women) and postpartum (Table 4). The major contributor to the difference was DPA, which was estimated to be 20%–30% lower than the estimate using the developed database (Table 4).

Discussion

Consistent with previous studies in Canada (Friesen and Innis 2009; Sontrop et al. 2008; Denomme et al. 2005; Innis and Elias 2003), the United States (Nochera et al. 2011; Hibbeln et al. 2007; Oken et al. 2004), and Europe (Rodriquez-Bernal et al. 2013; Franke et al. 2008), the majority of pregnant and lactating women in the APrON cohort were not meeting any of the various agencies' n-3 LCPUFA recommendations for pregnancy and lactation. However, our study is, to our knowledge, the first to report the estimated intake and sources of n-3 LCPUFA across all trimesters of pregnancy and at 3 months postpartum. The estimated intake of n-3 LCPUFA (EPA and DHA) increased significantly at the third trimester of pregnancy. As there was no difference in intake when expressed as a percentage of energy or a percentage of fat, this suggests that the increase was related to the increase in energy intake observed in this trimester.

Unlike the majority of other studies reporting n-3 LCPUFA intake during pregnancy, the majority of the participants in the APrON cohort are from high SES and 97% of the women report taking a multivitamin supplement during pregnancy (Gómez et al. 2013) Supplement use contributed to the mean intake of

Fig. 2. Estimated daily total intake of docosahexaenoic acid (DHA) for DHA supplement users and non-DHA supplement users during pregnancy and postpartum in comparison to the European Union consensus recommendation. Data are presented as means ± SE. A mean from all trimesters was used to determine values for individual pregnant women. A DHA supplement user is defined as using supplements containing DHA. *, DHA users have significantly higher estimated DHA intake than non-DHA users for both pregnancy and postpartum ($P < 0.05$).

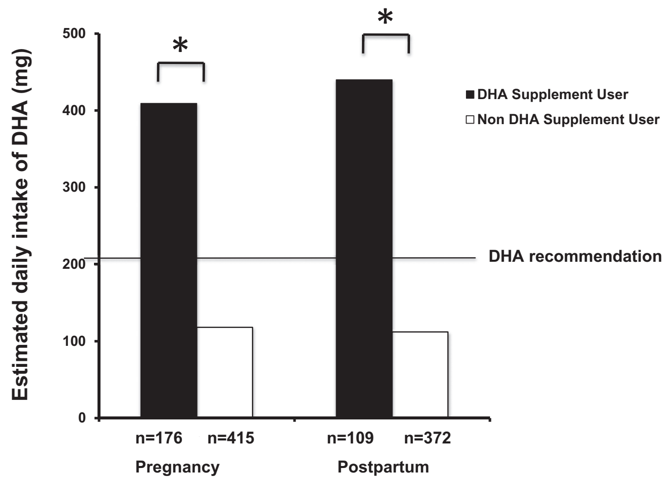


Fig. 3. (A) Relative contribution of food groups to total n-3 long chain polyunsaturated fatty acids (LCPUFA) intake from 24-h recalls. Data was combined from all time-points during pregnancy and 3 months postpartum. Food items were divided into groups based on the United States Department of Agriculture (USDA) n-3 LCPUFA database. Similar foods were combined to form larger categories. Food items that contributed to less than 1% of total n-3 LCPUFA intake were categorized under "others". This included fats and oils, mixed dishes, soups, sauces, and gravies. (B) Relative contribution of seafood sources to total n-3 LCPUFA intake from 24-h recalls combined from all time-points during pregnancy and 3 months postpartum. Seafood, fish, and seaweed products were further divided into subcategories based on the USDA n-3 LCPUFA database. Other categories of seafood, fish, and seaweed included trout, carp, sauce/broth, pickerel, and some types of sushi with unknown fish.

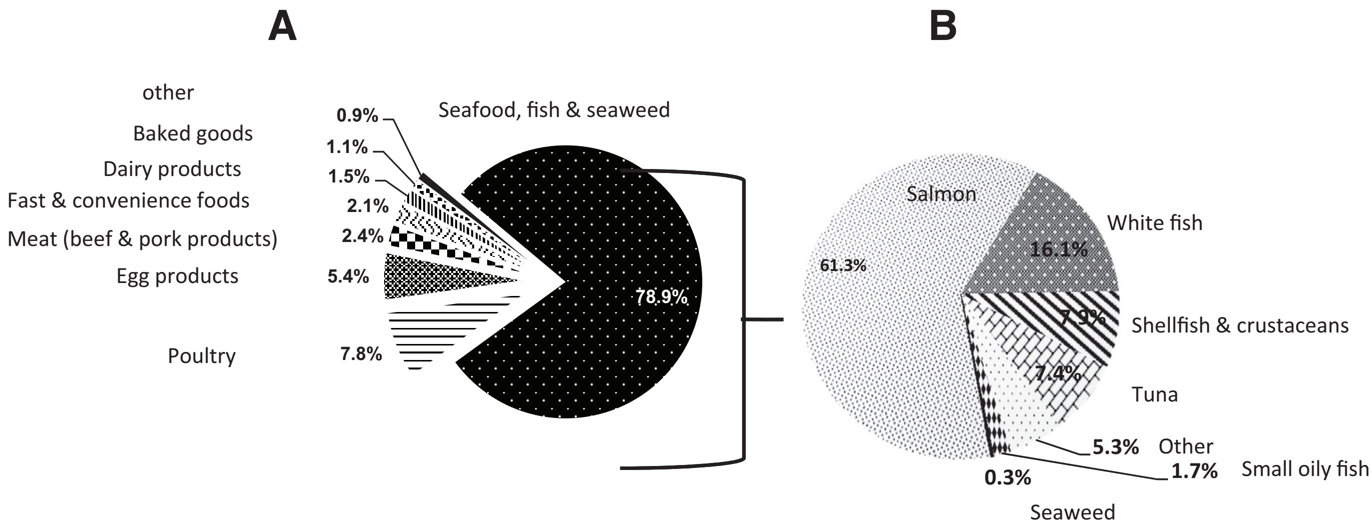


Table 4. Comparison of the estimated dietary intake of EPA, DPA, and DHA from created database and commercial nutrient analysis program during pregnancy and postpartum.

	Data from created database	Data from commercial program	Paired difference[a]	Percent of created database[b]
Pregnancy (n = 595)				
EPA (mg)	48±110 (7, 3–26)	46±110 (5, 0–25)	1.5±36 (1.2, −0.9–3.4)*	98%
DPA (mg)	35±70 (15, 9–26)	28±64 (10, 3–20)	6.1±23 (3.8, −1.2–9.9)*	80%
DHA (mg)	122±280 (28, 9–72)	119±280 (23, 10–63)	2.9±41 (2.1, −2.6–7.6)*	98%
Total n-3 LCPUFA (mg)	204±449 (51, 26–121)	193±444 (40, 20–105)	10.5±76 (8.1, −3.1–20.1)*	95%
Postpartum (n = 491)				
EPA (mg)	53±151 (4, 1–17)	51±162 (0, 0–10)	2.1±56.8 (1.1, 0–4.1)*	96%
DPA (mg)	32±72 (14, 6–25)	23±58 (10, 0–20)	9.5±51.1 (3.7, −0.6–11.5)*	72%
DHA (mg)	121±319 (17, 3–60)	114±322 (20, 0–50)	7.1±98.7 (2.5, −0.6–9.4)*	94%
Total n-3 LCPUFA (mg)	206±528 (43, 15–99)	188±517 (30, 0–80)	18.7±178.2 (9.4, 0–24.0)*	91%

Note: Skewed data are presented as means ± SD (median, inter-quartile range). Total n-3 LCPUFA equals EPA+DPA+DHA. DHA, docosahexaenoic acid; DPA, docosapentanoic; EPA, eicosapentaenoic acid; n-3 LCPUFA, n-3 long-chain polyunsaturated fatty acids.
*The difference between 2 methods reached statistical difference (P < 0.05).
[a]Mean of paired difference: data from created database – data from commercial program.
[b]% = (created database/commercial program) × 100.

DHA meeting the current EU consensus recommendation during the third trimester of pregnancy in the current study. Despite this, only 27% of the women met the EU recommendation during the third trimester of pregnancy. The vast majority (73% in pregnancy and 75% in postpartum) of women in the APrON cohort were not meeting the current EU consensus recommendation. However, participants who reported taking a DHA supplement were 10.6 and 11.1 times more likely to meet the current recommendation during pregnancy and at 3 months postpartum, respectively.

Although 10 food categories (defined in the USDA and CNF databases) contributed to total n-3 LCPUFA intake in women in this study, the largest contributor to intake was seafood, fish, and seaweed products. Other foods contributing to n-3 LCPUFA intake were poultry, egg, and meat products. These sources are consistent with other North American and Australian studies, which report that seafood, fish, meat, poultry, and eggs are the primary dietary sources of total n-3 LCPUFA (Innis et al. 2013; Sioen et al. 2010; Friesen and Innis 2009; Denomme et al. 2005; Ervin et al. 2004; Meyer et al. 2003). A few studies have evaluated food source contribution to DPA intake (Rahmawaty et al. 2013; Garneau et al. 2012; Howe et al. 2006; Meyer et al. 2003), albeit not in pregnant or lactating women. We found that seafood, fish, poultry, and meat products contributed the most to overall DPA intake throughout pregnancy and lactation. These sources of DPA are consistent with that reported by Rahmawaty et al. (2013) in children and adolescents in Australia and Howe et al. (2006) and Meyer et al. (2003) in adults in Australia.

The majority (79%) of dietary n-3 LCPUFA came from the fish and seafood group (primarily salmon) and this source is almost always accessible for people living in Edmonton and Calgary (Alberta, Canada), particularly for our cohort where the participants had medium to high levels of income. The dietary sources of n-3 LCPUFA were not found to vary significantly across pregnancy and lactation. The present study also found that the estimated intake of n-3 LCPUFA was lower at 3 months postpartum. This was found to be due to a decrease in the proportion of women who reported taking an EPA/DHA supplement (30% during pregnancy and 23% at 3 months postpartum) and not their dietary intake. Our findings are similar to Sioen et al. (2010) who reported that mean intakes of EPA+DHA decreased from 328 mg/day in pregnancy to 299 mg/day during lactation. This could be a concern as maternal intake of DHA significantly affects the concentration in breast milk (Innis 2007) and 92% of the women in APrON reported breast feeding at 3 months postpartum (Jessri et al. 2013).

A strength of this study was the development of a comprehensive dietary database for n-3 LCPUFA applicable to the maternal cohort. In the present study, we found that the estimated intake of EPA and DHA were very similar between methods, confirming that the use of a commercial database provides a reasonable estimate of intake for this cohort. However, the estimated intake of DPA was 20%–30% lower using the commercial nutrient analysis program. An underestimation of DPA intake was previously reported when a food frequency questionaire was analyzed using the Australia database (that contained DPA) and the 2007b CNF (Patterson et al. 2012). Our study suggests that there are still missing estimates for DPA in foods (mixed dishes, particularly those that contain seafood, fish, poultry, and meat) in the CNF that can be partially overcome by creating a database where the DPA content is entered from the USDA Nutrient file. However, conclusions on the accuracy of our estimation requires some caution as the created database in this study was not based on fatty acid analysis of the foods and assumed that the higher intake was due to missing values for foods rather than inaccurate measurement. Howe et al. (2006) found that, after updating the Australian database with new compositional data, the estimation of n-3 LCPUFA was 30% higher than a previously published estimate, the difference being attributable to inaccuracies in DPA content of meats. Although DPA contributes only a small amount to total n-3 LCPUFA intake, this suggests that our estimated intake, even with our developed database, may still be underestimating DPA intake. Obtaining an estimation of the intake of DPA is of interest to many as there is an emerging interest in DPA and its association with chronic diseases (Amano et al. 2011; Mozaffarian et al. 2011; Sun et al. 2008). DPA is also found in significant concentration in human breast milk (Koletzko et al. 1988), but the contribution of dietary intake of DPA to the concentration of DPA in breast milk and the role in infant development are not known.

The current study provides useful information for health practitioners and for future interventions aimed at improving the n-3 LCPUFA status of women during pregnancy and lactation. In summary, salmon and other foods in the USDA category of seafood, fish, and seaweed products contributed to 79% of overall n-3 LCPUFA intake from foods. The majority of participants in the first APrON cohort, despite a high level of education and income, were not meeting recommendations for DHA or n-3 LCPUFA that have been suggested by a number of academic and health agencies. Nutrition counselling would be one approach to improve intake as it was recently demonstrated that nutrition counselling during the first trimester of pregnancy improved n-3 LCPUFA status during pregnancy (Hautero et al. 2013). However, the current study demonstrated that taking a supplement of DHA (of approximately 275 mg during pregnancy and 299 mg at 3 months postpartum) can significantly improve a woman's chance of meeting recommendations. However, 44% percent of the women in the cohort who reported taking a supplement during pregnancy were no longer taking these supplements when breast feeding at 3 months postpartum, supporting that education on the benefits of supplements should continue after pregnancy.

Conflict of interest statement

The authors report no conflict of interest.

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Appendix

Table A1. Food sources contributing to EPA, DPA, DHA, and total n-3 LCPUFA intake combined from all time-points.

	All time-points			
Food source	EPA (%)	DPA (%)	DHA (%)	Total n-3 LCPUFA (%)
Seafood, fish, and seaweed	86.6	59.2	81.2	78.9
Poultry (chicken and turkey products)	6.8	13.6	6.6	7.8
Egg products	1.5	2.6	7.8	5.4
Meat (beef and pork products)	1.6	11.0	0.3	2.4
Fast foods and convenience foods	2.3	3.4	1.6	2.1
Diary product	0.0	9.0	0.0	1.5
Baked products	0.8	0.3	1.4	1.1
Others	0.3	0.1	0.6	0.4
Mixed dishes	0.1	0.7	0.3	0.3
Fats and oils	0.1	0.2	0.2	0.2

Note: Data are presented as percentage contribution of different food groups of EPA, DPA, DHA, and total n-3 LCPUFA based on diet contribution (not food contribution) to EPA, DPA, DHA, and total n-3 LCPUFA. Mixed dishes include dishes that have more than 1 food type and contribute similar amount to n-3 LCPUFA content. Others category includes snacks, sweets, soups, sauces and gravies, spices, and herbs. DHA, docosahexaenoic acid; DPA, docosapentanoic; EPA, eicosapentaenoic acid; n-3 LCPUFA, n-3 long-chain polyunsaturated fatty acids.

Table A2. Specific seafood, fish, and seaweed products contributing to EPA, DPA, DHA and total n-3 LCPUFA intake combined from all time-points.

	All time-points			
Seafood, fish, and seaweed	EPA (%)	DPA (%)	DHA (%)	Total n-3 LCPUFA (%)
Salmon	55.1	73.7	61.5	61.3
Whitefish	13.8	16.4	17.1	16.1
Shellfish and crustaceans	13.6	5.2	6.0	7.9
Tuna	6.3	1.7	9.1	7.4
Others	7.7	2.4	4.8	5.3
Small oily fish	2.5	0.5	1.5	1.7
Seaweed	1.0	0.0	0.0	0.3

Note: Data are presented as percentage contribution of specific seafood, fish, and seaweed products of EPA, DPA, DHA, and total n-3 LCPUFA. Whitefish category includes whitefish, cod, bass, catfish, flounder, haddock, halibut, pollock, snapper, and tilapia. Others category of fish includes trout, carp, sauce/broth, pickerel, and some types of sushi with unknown fish. DHA, docosahexaenoic acid; DPA, docosapentanoic; EPA, eicosapentaenoic acid; n-3 LCPUFA, n-3 long-chain polyunsaturated fatty acids.