Omega-3 Fatty Acids and Total Polychlorinated Biphenyls in 26 Dietary Supplements

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ABSTRACT: A limited sampling and analysis of commercial supplements found 51% to 124% eicosapentaenoic acid (EPA) and 61% to 153% docosahexaenoic acid (DHA) as provided on product labels. Daily intakes of EPA plus DHA from label recommendations would provide 123% to 1087% of the adequate intake (AI) for pregnant and lactating women (that is, 0.13 to 0.14 g/day) and up to 43% of the daily reference dose (RfD) for polychlorinated biphenyls (PCB) for a 60-kg person. However, if a smaller dose of the supplements were taken to meet the AI, only 0.9% to 11.5% of the RfD for PCB would be obtained. Algal oil supplements did not have detectable PCB residues, but those products only provided DHA and not EPA.

Keywords: fish oil, dietary supplements, EPA, DHA, PCB

Introduction

Polyunsaturated fatty acids, particularly omega-3 fatty acids, have been reported to exhibit favorable physiological (Mishra and others 1993; Simopoulos and others 1999) and therapeutic (Minnis and others 1998; Simopoulos 1991) benefits. Public awareness of the nutritional benefits of long chain omega-3 fatty acids found in fish and fish oil is growing rapidly (Mishra and others 1993). Docosahexaenoic acid (DHA, C22:6n-3), are purported to be important for brain development (Crawford 1993; Francois and others 1998; Hornstra 2000; Crawford 2000). DHA is concentrated in the brain (Horrobin 2001). In adults, adequate levels are implicated in preserving mental function, whereas EPA supplementation has been reported to improve symptoms of schizophrenia in patients receiving standard therapy (Peet and others 2001). DHA is also important for neural tissue and retina development in infants (Crawford 1993; Horrocks and Yeo 1999). Fish oil is a favored source of these fatty acids because it provides higher amounts of DHA and EPA than vegetable oils (Bourre and others 1997). Sufficient amounts of omega-3 fatty acids are required to maintain both fetal and maternal demands during pregnancy (Bourre and others 1997; Horrocks and Yeo 1999). Moreover, it has been reported that the status of EPA and DHA in pregnant and lactating women influences the levels found in the fetus and the nursing infant (Francois and others 1998; Hornstra 2000; Velzing-Aarts and others 2001; DeVriese and others 2002). Adequate amounts of omega-3 fatty acids in fish oil capsules taken during pregnancy effectively increased the omega-3 status in the newborn (Velzing-Aarts and others 2001).

The adequate intake (AI) of the omega-3 fatty acid, α-linolenic acid, during pregnancy is 1.4 g/d and during lactation is 1.3 g/d (Natl. Academy of Sciences 2002). EPA and DHA can contribute up to 10% of the AI for α-linolenic acid. Therefore, the effective AI for EPA plus DHA for pregnant and lactating women is 0.14 and 0.13 g/d, respectively (Natl. Academy of Sciences 2002). The Intl. Society for the Study of Fatty Acids and Lipids (ISSFAL 1999) recommends an intake of 0.65 g/d of EPA plus DHA for pregnant and lactating women (with a minimum of 0.22 g EPA/d and 0.3 g DHA/d). The American Heart Assn. (AHA) recommends that individuals that have coronary heart disease consume 1 g of EPA plus DHA each day (Kris-Etherton and others 2002). To meet each of these recommendations, a significant amount of fish must be consumed (Table 1). The amount of fish that must be consumed to obtain 1 g of EPA plus DHA ranges from 52 g for farmed Atlantic salmon to 781 g for canned light tuna in oil. The average amount of 'prepared' fish consumed by women ages 15 to 44 y is 11.31 g/day (Environmental Protection Agency 2002). In addition to species variations for EPA and DHA content, there are also variations between farmed and wild fish of the same species. Dietary intake of omega 3 fatty acids is primarily responsible for variations within species (Easton and others 2002). Thus, if the feed for farmed fish is high in omega-3 fatty acids, the fish fillet will also have higher levels of EPA and DHA. It is apparent that consumers either need to eat the appropriate amount of those species that will provide an adequate amount of EPA and DHA or supplement their intake with a dietary supplement if they want to meet the AHA recommended daily intake of EPA plus DHA. Moreover, non–fish eaters or those that have a fish allergy are left with few options outside of taking dietary supplements.

Polychlorinated biphenyls (PCBs) were used in numerous industrial and commercial applications including electrical heat transfer and hydraulic equipment (Smith and Gangolli 2002). Due to their chemical stability and lipophilic nature, PCBs are prevalent compounds in the environment even though PCBs are no longer commercially produced in the U.S. (Huisman and others 1995). Because PCBs do not readily degrade in the environment and tend to bioaccumulate in the lipid-rich tissue, the concentration of PCBs found in fish tissue can be elevated (Walker and others 2003). Therefore, fish oils are likely to contain PCBs (Huisman and others 1995; Jimenez and others 1996; Smith and Gangolli 2002; Walker and others 2003). Some have reported that fish oils contain a significant concentration of PCBs (Wells and Boer 1994; Jacobs and others 1997; Hilbert and others 1998) and may contribute to the daily intake of PCBs (Huisman and others 1995; Jacobs and others 1997). Fish oils taken as dietary supplements and medicinal products have also been found to contain PCB residues (Jacobs and Johnston 1996; Jimenez

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and others 1996; Stringer and others 1996; MAFF 1997; Jacobs and others 1998; Smith and Gangolli 2002). High fish consumption coupled with fish oil supplements may increase PCB body burden and the risk from these contaminants (Jacobs and others 1998). Whereas, refined and concentrated omega-3 fatty acid fish oil supplements contain lower levels of organochlorine contaminants (Hilbert and others 1998), less refined oils can contain higher levels (Jacobs and others 1998). The Agency for Toxic Substances and Disease Registry (ATSDR) and the Environmental Protection Agency have established a reference dose (RfD non-cancer endpoint: estimate daily intake of a chemical that is likely to be without an appreciable risk of health effects) for PCBs of 2×10^{-5} mg/kg body weight/d (Environmental Protection Agency 1996; ATSDR 2001).

PCBs cross the placenta (Schecter and others 1990; Peterson and others 1993; Patandin and others 1998; Jacobson and Jacobson 1996) and can get transferred to the infant in breast milk (Ryan and others 1994; Guo and others 1997; Abraham and others 1998; Jacobson and Jacobson 2001). Several researchers have reported a correlation between PCB body burden and fish consumption in both pregnant and lactating women. Studies have indicated that there is a similarity between PCB residues in maternal and umbilical cord blood (Covaci and others 2002; Walker and others 2003). This relationship is significant because PCBs have also been associated with deficits in fetal and postnatal growth (Fein and others 1984; Patandin and others 1998; Longnecker 2001). Therefore, fish oils taken as dietary supplements should be assessed for benefits compared with possible health risks, especially for pregnant and lactating women who need additional omega-3 fatty acids and who may convey PCBs at a critical time during fetal or infant development.

The objectives of this study were to verify the supplement facts claims for EPA and DHA as provided on commercial product labels and to measure PCB residues in fish oil and algal oil dietary supplements.

Table 1—Daily intake of fish required to meet recommended intakes for EPA[a] plus DHA[a]

		Amount of fish[b] (ounces [g])		
Fish species	**Type**	**AI[c]**	**ISSFAL[d]**	**AHA[e]**
Coho salmon	Farmed	0.39 (11.61)	1.80 (57.14)	2.76 (82.92)
	Wild	0.43 (12.90)	2.00 (59.91)	3.07 (92.17)
Atlantic salmon	Farmed	0.24 (7.33)	1.13 (35.60)	1.74 (52.33)
	Wild	0.32 (9.75)	1.51 (68.54)	2.32 (69.64)
Channel catfish	Farmed	1.70 (51.09)	7.91 (328.36)	12.17 (364.96)
	Wild	1.28 (38.46)	5.95 (178.57)	9.16 (274.73)
Rainbow trout	Farmed	0.50 (15.09)	2.33 (84.62)	3.59 (107.76)
	Wild	0.80 (23.85)	3.69 (131.74)	5.68 (170.36)
Tuna	Canned light (in oil)	3.65 (109.38)	16.93 (506.42)	26.04 (781.25)
	Canned white (in water)	0.54 (16.24)	2.51 (94.42)	3.87 (116.01)

[a]EPA, eicosapentaenoic acid (20:5n3); DHA, docosahexaenoic acid (22:6n3).
[b]Amount of cooked (dry heat) fish one must consume to meet recommended EPA plus DHA intakes according to the USDA Nutrient Database for Standard Reference, Release 14 (2001), The Nutrient Data Laboratory of the Agricultural Research Service of the U.S. Dept. of Agriculture (http://www.nal.usda.gov.fnic/foodcomp/ Data/ index.html).
[c]Adequate intake of EPA plus DHA (0.14 to 0.13 g/d) set for pregnant and lactating women (Natl. Academy of Sciences 2002).
[d]Int. Society for the Study of Fatty Acids and Lipids recommended daily intake of EPA plus DHA of 0.65 g for pregnant and lactating women (minimum EPA of 0.22g/d and DHA of 0.3g/d) (ISSFAL 1999).
[e]American Heart Assn. recommended daily intake of EPA plus DHA of 1 g for those who have coronary heart disease (Kris-Etherton and others 2002).

Materials and Methods

A single bottle of 24 commercial fish oil supplements and 2 algal oil supplements were purchased from local stores around Lafayette, Indiana. From a single bottle, oil from 10 capsules was combined to obtain a composite sample. Two composites from each bottle were analyzed in duplicate for omega-3 fatty acids and PCB residues.

The determination of fatty acids in the composite fish oil samples was carried out using the AOAC Official Method, 991.39, for "Fatty Acids in Encapsulated Fish Oils." The fatty acid analysis quantified polyunsaturated fatty acids including linoleic acid (LA, 18:2n-6), α-linolenic acid (ALA, 18:3n-3), arachidonic acid (ARA, 20:4n-6), EPA (all-*cis*-5, 8, 11, 14, 17-eicosapentanoic acid or 20:5n-3), docosapentaenoic acid (DPA, 22:5n-3), and DHA (all-*cis*-4, 7, 10, 13, 16, 19-docosahexaenoic acid or 22:6n-3). Theoretical detector correction factors for measurement of fatty acids were 0.99 for LA; 0.98 for ALA; 0.96 for ARA; 0.94 for DPA (Christie 1989); 0.99 for EPA; and 0.97 for DHA (AOAC 2000). Fatty acids in the fish oils were derivatized to methyl esters and analyzed by gas chromatography with a flame ionization detector (GC/FID, Varian 3900 GC, CP-8400 auto sampler, CP-8410 auto injector, Varian Analytical Instruments, Walnut Creek, Calif., U.S.A.). Operating conditions were injection port temperature, 240 °C; detector temperature, 300 °C; oven programmed from 175 °C for 4 min to final hold temperature of 240 °C for 5 min with an increase of 3 °C/min; helium carrier gas (99.999% pure, Inweld, Inc., Lafayette, Ind., U.S.A.); and WCOT fused silica capillary column, 30 m $\times$ 0.32 mm coated with cp wax 52CB, DF 0.25 mm (CP 8843, Varian Analytical Instruments).

Tricosanoic acid methylester (99% pure, 23:0 methyl esters, Sigma, Inc., St. Louis, Mo., U.S.A.) reagent was used as an internal standard. Menhaden oil (PUFA No. 3, Supelco, Bellefonte, Pa., U.S.A.) was used as an external standard and for peak identification. The acid forms of EPA and DHA (99% pure, Nu Chek Prep, Inc., Elysian, Minn., U.S.A.) were used to determine recovery. Marine oil (Reference Oil No.2, American Oil Chemist's Society [AOCS] Reference Sample Program, Champaign, Ill., U.S.A.) was used to generate a fatty acid profile for the GC proficiency test. A reference marine oil (AOCS) with fatty acids profiles was used to test GC proficiency for the determination of omega-3 fatty acids in fish oil supplements. The results met the standards of proficiency with a coefficient of variation less than 10% between the 4 replicates.

For the measurement of total PCB in composite oils, an enzyme linked immunosorbent assay (ELISA) (Rapid Assays, Strategic Diagnostics, Inc., Newark, Del., U.S.A.) was applied (Lasrado and others 2003). Quantification of total PCB was accomplished using a standard curve in the range of 0.01 to 0.5 ppm. PCB standards were made in triolein (95%, 1,2,3-tri [*cis* 9-octadecenoyl] glycerol; Sigma Inc.) by spiking oil with Aroclor 1254 (Ultra Scientific, North Kingstown, R.I., U.S.A.). Total PCB concentration was determined from the mean of 2 composite samples, which were each analyzed twice and reported as ng total PCB per g oil. The lower limit of detection for total PCB concentration in fish oil by ELISA was 10 ppb. The recovery of total PCB in fish oils was between 98% and 105%.

Results and Discussion

Polyunsaturated fatty acids were determined in 20 fish oil, 4 cod liver oil, and 2 algal oil dietary supplements (Table 2). The concentration of LA, ALA, and ARA in the 24 fish oil dietary supplements ranged from 5 to 69 mg/g oil ($\bar{x}$ = 12 mg/g oil in 20 fish oil supplements, $\bar{x}$ = 35 mg/g oil in 4 cod liver oil supplements), 3 to 19 mg/g oil ($\bar{x}$ = 5 mg/

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Table 2—Polyunsaturated fatty acids in fish oil and algal oil dietary supplements

Sample[a]	Daily intake from label,[b] g (Nr of capsules)	Measured fatty acids[c] (mg/g oil)						% of stated label concentration		Daily EPA plus DHA intake[d]
		LA	ALA	ARA	EPA	DPA	DHA	EPA	DHA	
1	6 (6)	10.0 ± 0.5	7.3 ± 0.5	8.1 ± 0.2	164.8 ± 3.5	17.0 ± 1.1	88.2 ± 4.2	91.6	73.6	1.5 (1084)
2	6 (6)	9.5 ± 0.1	6.2 ± 0.2	8.0 ± 0.1	158.6 ± 2.4	15.5 ± 1.5	90.1 ± 3.7	88.1	75.1	1.4 (1066)
3	2 (2)	8.2 ± 0.2	4.9 ± 0.2	6.9 ± 0.1	130.2 ± 4.6	14.0 ± 2.2	77.1 ± 1.3	72.4	64.3	0.4 (296)
4	6 (6)	9.2 ± 0.1	6.0 ± 0.3	8.6 ± 0.1	141.1 ± 4.2	14.9 ± 0.5	82.2 ± 5.4	78.4	68.6	1.3 (957)
5	6 (6)	7.9 ± 0.4	5.1 ± 0.2	8.6 ± 0.2	143.4 ± 2.5	16.9 ± 2.4	94.9 ± 2.9	79.7	79.1	1.4 (1021)
6	3 (3)	9.2 ± 0.3	5.3 ± 0.4	8.4 ± 0.1	148.8 ± 3.6	15.7 ± 2.1	86.6 ± 5.3	82.7	72.2	0.7 (504)
7	6 (6)	8.2 ± 0.2	5.0 ± 0.2	6.7 ± 0.2	134.1 ± 4.5	13.9 ± 1.9	93.9 ± 3.5	74.5	78.3	1.3 (977)
8	3 (3)	8.3 ± 0.1	5.5 ± 0.3	6.1 ± 0.1	131.9 ± 3.1	13.3 ± 2.3	93.3 ± 2.1	73.3	77.8	0.6 (482)
9	4 (4)	17.9 ± 0.3	6.6 ± 0.1	4.8 ± 0.1	62.6 ± 1.3	22.2 ± 1.5	82.1 ± 1.8	78.4	68.5	0.5 (413)
10	6 (6)	7.3 ± 0.3	4.4 ± 0.2	5.9 ± 0.1	116.4 ± 2.3	12.0 ± 1.7	80.2 ± 4.2	64.7	66.9	1.2 (843)
11	3 (3)	8.1 ± 0.2	4.3 ± 0.1	6.4 ± 0.1	118.2 ± 1.5	13.4 ± 2.1	86.2 ± 3.2	50.5	69.0	0.6 (438)
12	2 (2)	5.8 ± 0.4	3.9 ± 0.1	15.4 ± 0.1	256.1 ± 2.5	14.9 ± 2.3	61.6 ± 1.3	56.9	61.0	0.6 (454)
13	4 (4)	11.9 ± 0.2	6.3 ± 0.1	10.2 ± 0.2	186.1 ± 3.3	18.1 ± 2.8	89.1 ± 5.2	66.5	74.3	1.1 (786)
14	6 (6)	7.3 ± 0.4	4.1 ± 0.2	6.1 ± 0.2	111.4 ± 4.6	12.1 ± 3.0	80.4 ± 6.2	61.9	67.0	1.1 (822)
15	6 (6)	8.4 ± 0.2	5.5 ± 0.1	6.2 ± 0.1	129.8 ± 5.4	13.0 ± 1.5	90.3 ± 5.1	72.1	75.3	1.3 (943)
16	2 (2)	5.5 ± 0.3	3.3 ± 0.2	16.9 ± 0.4	249.7 ± 6.7	37.3 ± 2.4	149.3 ± 2.3	83.2	74.6	0.8 (570)
17	1 (1)	39.5 ± 0.4	9.7 ± 0.1	4.7 ± 0.2	105.7 ± 1.9	15.1 ± 3.1	67.6 ± 3.1	81.4	96.6	0.2 (123)
18	6 (6)	12.3 ± 0.3	6.0 ± 0.1	7.5 ± 0.1	143.9 ± 1.4	17.1 ± 1.6	109.7 ± 5.2	80.0	91.4	1.5 (1087)
19	6 (6)	9.2 ± 0.1	5.0 ± 0.1	6.0 ± 0.2	102.1 ± 0.8	11.9 ± 1.4	82.1 ± 4.2	56.7	68.5	1.1 (789)
20	2 (2)	49.2 ± 0.3	4.6 ± 0.1	5.3 ± 0.1	108.1 ± 1.8	10.1 ± 0.8	79.7 ± 5.1	60.1	66.4	0.4 (268)
21	2 (2)	35.1 ± 0.5	19.5 ± 0.1	3.6 ± 0.1	52.8 ± 2.1	14.1 ± 1.2	61.6 ± 6.2	—[e]	—	0.2 (163)
22	1.5 (3)	68.6 ± 0.4	11.9 ± 0.2	3.5 ± 0.1	50.6 ± 2.6	14.1 ± 1.3	64.3 ± 4.2	123.6	153.1	0.2 (123)
23	1.5 (3)	20.9 ± 0.2	6.8 ± 0.2	4.6 ± 0.1	73.2 ± 2.4	24.6 ± 0.7	80.0 ± 3.8	—	—	0.2 (164)
24	1.5 (3)	24.1 ± 0.3	9.1 ± 0.2	5.8 ± 0.1	82.9 ± 2.4	21.5 ± 4.1	98.2 ± 4.1	—	—	0.3 (194)
25	1 (2)	ND[f]	ND	2.2 ± 0.3	4.1 ± 0.4	ND	162.5 ± 5.6	—	162.5	0.1 (119)
26	1 (2)	ND	ND	1.2 ± 0.2	4.1 ± 0.4	ND	127.9 ± 7.8	—	128.0	0.1 (94)

[a]1: Sundown, Rexall Sundown Inc.; 2: Finest Natural, Walgreen Co.; 3: Natrol, Natrol Inc.; 4: GNC, General Nutrition Corp.; 5: CVS Natural, CVS Pharmacy Inc.; 6: Your Life, Lenier Health Products Inc.; 7: Meijer Natural, Meijer Distribution, Inc.; 8: Save-on Osco, Albertson's Inc.; 9: Nature's Bounty, Nature's Bounty Inc.; 10: Nature's Valley, Albertson's Inc.; 11: Dale Alexander, Twin Lab. Inc.; 12: Source Naturals, Source Naturals, Inc.; 13: Kyolic-EPA, Wakunaga of America Co.; 14: Vitasmart, Kmart Corp.; 15: Omega-3 Fish Oils, Olympian Labs Incorp.; 16: Carlson, Carlson Lab., Inc.; 17: Solaray, Solaray Inc.; 18: Now, Now Foods; 19: Kal, Kal Inc.; 20: Solgar MaxEPA/GLA, Solga Vitamin and Herb; 21: GNC Cod Liver Oil, General Nutrition Corp.; 22: Dale Alexander Emulsified Norweigan Cod Liver Oil, Twin Lab. Inc.; 23: Nature Made Cod Liver Oil, Nature Made Natl. Products; 24: Now Cod Liver Oil Double Strength, Now Foods; 25: DHA Neuromins, Solaray Inc.; 26: Solgar Neuromine' DHA, Solga Vitamin and Herb
[b]Suggested daily intake from product label.
[c]LA: linoleic acid (18:2n6), ALA: a-linolenic acid (18:3n3), ARA: arachidonic acid (20:4n6), EPA: eicosapentaenoic acid (20:5n3), DPA: docosapentaenoic acid (22:5n3), DHA: docosahexaenoic acid (22:6n3). Each value is the mean of the 4 replicates with the standard deviation.
[d]When following label recommendations (g) (% of AI). AI = Adequate intake of EPA plus DHA (0.14 to 0.13 g/d) set for pregnant and lactating women (Natl. Academy of Sciences 2002).
[e]No information provided on label of EPA and DHA concentration.
[f]Not detected at the lower limit of detection (1 mg/g oil)

g oil in 20 fish oil supplements, $\bar{x}$ = 11 mg/g oil in 4 cod liver oil supplements), and 3 to 17 mg/g oil ($\bar{x}$ = 7 mg/g oil in 20 fish oil supplements, $\bar{x}$ = 3 mg/g oil in 4 cod liver oil supplements), respectively. The concentration of EPA in 20 fish oil and 4 cod liver oil ranged from 62 to 256 mg/g oil ($\bar{x}$ = 142 mg/g oil) and 51 to 83 mg/g oil ($\bar{x}$ = 52 mg/g oil), respectively. The concentration of DPA was 10 to 37 mg/g oil ($\bar{x}$ = 15 mg/g oil in 20 fish oil, $\bar{x}$ = 19 mg/g oil 4 cod liver oil supplements) in 24 fish oil dietary supplements. DHA in 20 fish oil and 4 cod liver oil supplements ranged from 62 to 149 mg/g ($\bar{x}$ = 88 mg/g oil) and 62 to 98 mg/g oil ($\bar{x}$ = 76 mg/g oil), respectively. Total omega-6 fatty acids (including LA plus ARA) in 24 supplements were between 9 to 80 mg/g oil. EPA and DHA were the predominant omega-3 fatty acids (including ALA, EPA, DPA, and DHA). Fish oil supplements generally contained higher amounts of total omega-3 fatty acids than the cod liver oil supplements. Concentrations of ARA, EPA, and DHA in 2 algal oil supplements were between 1 to 2 mg/g oil, 4 mg/g oil, and 162 mg/g oil, respectively.

Twenty fish oil supplements and 1 cod liver oil supplement had EPA and DHA concentrations stated on the product labels. The concentrations of EPA and DHA were between 51% to 124% and 61% to 153%, respectively, of the amounts stated on the label (Table 2). Similar results were reported by Consumer Lab (2001) that found EPA and DHA ranging from 50% to 150% and from 33% to 150% of the amounts stated on the labels for 20 fish oil supplements. Two algal oil supplements contained between 128% and 162% of the DHA listed on the label.

The amounts of EPA and DHA measured were used to estimate the daily intakes of EPA and DHA for consumers that follow label recommendations. The daily intake of EPA and DHA ranged from 0.1 to 1.5 g for 20 fish oil supplements, 0.2 to 0.3 g for 4 cod liver oil supplements, and averaged 0.12 g for 2 algal oil supplements. Daily intake of EPA plus DHA in 24 fish oil supplements, when following the label recommendations, ranged from 123% to 1087% of the AI (0.14 g of EPA plus DHA/day) for pregnant women. Two algal oil supplements provided between 94% and 119% of the AI. Algal oil supplements contain only DHA and ISSFAL (1999) recommends that adults consume a minimum of 0.22 g EPA/day.

Total PCB concentrations in 24 fish oil supplements and 2 algal oil supplements were measured by ELISA (Table 3). Total PCB was between 10 and 94 ng/g oil for 20 fish oil supplements and between 47 and 276 ng/g oil for the 4 cod liver oil supplements. Jacobs and others (1997, 1998) also found higher levels of PCBs in cod liver oils than in other fish oil supplements. PCBs were not detected in 2 algal oil supplements because these were derived from *Crypthecodinium cohnii* and PCB contamination was avoided.

The daily dose of PCB from 24 fish oil di-

Table 3—PCB in fish oil and algal oil dietary supplements

Sample[a]	Daily intake from label,[b] g (Nr of capsules)	Total PCB[c]	Daily PCB intake[d]	% of RfD[e] for PCB	% of RfD for PCB[f] (Nr of capsules)		
		(ng/g oil)	(ng)		AI	ISSFAL	AHA
1	6 (6)	42.6 ± 5.2[f]	255.6	21.3	3.6 (1)[g]	16.5 (5)	25.4 (7)
2	6 (6)	79.1 +/- 3.6	474.6	39.6	6.6 (1)	30.6 (5)	47.1 (7)
3	2 (2)	49.3 +/- 4.2	98.6	8.2	4.1 (1)	19.1 (5)	29.3 (7)
4	6 (6)	53.3 +/- 4.8	319.8	26.7	4.4 (1)	20.6 (5)	31.7 (7)
5	6 (6)	51.6 +/- 3.9	309.6	25.8	4.3 (1)	20.0 (5)	30.7 (7)
6	3 (3)	27.1 +/- 3.1	81.3	6.8	2.3 (1)	10.5 (5)	16.1 (7)
7	6 (6)	77.3 +/- 2.8	463.8	38.7	6.4 (1)	29.9 (5)	46.0 (7)
8	3 (3)	43.6 +/- 4.2	130.8	10.9	3.6 (1)	16.9 (5)	26.0 (7)
9	4 (4)	94.3 +/- 5.2	377.2	31.4	7.9 (1)	36.5 (5)	56.1 (7)
10	6 (6)	60.0 +/- 3.3	360.0	30.0	5.0 (1)	23.2 (5)	35.7 (7)
11	3 (3)	70.3 +/- 1.3	210.9	17.6	5.9 (1)	27.2 (5)	41.8 (7)
12	2 (2)	51.8 +/- 4.5	310.8	25.9	4.3 (1)	20.0 (5)	30.8 (7)
13	4 (4)	68.5 +/- 2.3	274.0	22.8	5.7 (1)	26.5 (5)	40.8 (7)
14	6 (6)	85.5 +/- 5.5	513.0	42.8	7.1 (1)	33.1 (5)	50.9 (7)
15	6 (6)	39.1 +/- 4.3	234.6	19.6	3.3 (1)	15.1 (5)	23.3 (7)
16	2 (2)	10.3 +/- 2.3	20.6	1.7	0.9 (1)	4.0 (5)	6.1 (7)
17	1 (1)	47.5 +/- 4.6	47.5	4.0	4.0 (1)	18.4 (5)	28.3 (7)
18	6 (6)	23.7 +/- 4.2	142.2	11.9	2.0 (1)	9.2 (5)	14.1 (7)
19	6 (6)	35.2 +/- 6.5	211.2	17.6	2.9 (1)	13.6 (5)	21.0 (7)
20	2 (2)	24.6 +/- 2.8	49.2	4.1	2.1 (1)	9.5 (5)	14.6 (7)
21	2 (2)	47.4 +/- 5.7	94.8	7.9	7.9 (2)	36.7 (9)	56.4 (14)
22	1.5 (3)	74.4 +/- 4.6	111.6	9.3	6.2 (2)	28.8 (9)	44.3 (14)
23	1.5 (3)	276.2 +/- 4.5	414.3	34.5	11.5 (1)	53.4 (5)	82.2 (7)
24	1.5 (3)	232.3 +/- 9.8	348.4	29.0	9.7 (1)	44.9 (5)	69.1 (7)
25	1 (2)	ND[h]	—	—	—	—	—
26	1 (2)	ND	—	—	—	—	—

[a]1: Sundown, Rexall Sundown Inc.; 2: Finest Natural, Walgreen Co.; 3: Natrol, Natrol Inc.; 4: GNC, General Nutrition Corp.; 5: CVS Natural, CVS Pharmacy Inc.; 6: Your Life, Lenier Health Products Inc.; 7: Meijer Natural, Meijer Distribution, Inc.; 8: Save-on Osco, Albertson's Inc.; 9: Nature's Bounty, Nature's Bounty Inc.; 10: Nature's Valley, Albertson's Inc.; 11: Dale Alexander, Twin Lab. Inc.; 12: Source Naturals, Source Naturals, Inc.; 13: Kyolic-EPA, Wakunaga of America Co.; 14: Vitasmart, Kmart Corp.; 15: Omega-3 Fish Oils, Olympian Labs Incorp.; 16: Carlson, Carlson Lab., Inc.; 17: Solaray, Solaray Inc.; 18: Now, Now Foods; 19: Kal, Kal Inc.; 20: Solgar Max EPA/GLA, Solga Vitamin and Herb; 21: GNC Cod Liver Oil, General Nutrition Corp.; 22: Dale Alexander Emulsified Norweigan Cod Liver Oil, Twin Lab. Inc.; 23: Nature Made Cod Liver Oil, Nature Made Natl. Products; 24: Now Cod Liver Oil Double Strength, Now Foods; 25: DHA Neuromins, Solaray Inc.; 26: Solgar Neuromine' DHA, Solga Vitamin and Herb.
[b]Suggested daily intake from product label.
[c]Each value is the mean of the 4 replicates with the standard deviation.
[d]When following label recommendations
[e]Reference dose is given for PCB at 2×10^{-5} mg/kg body weight/d; that is, a total of 1200 ng of PCB per d for a 60-kg adult (US EPA 1996; ATSDR 2001).
[f]At recommended daily intakes of EPA plus DHA. Adequate intake (AI) of EPA plus DHA (0.13 to 0.14 g/d) set for pregnant and lactating women (Natl. Academy of Sciences 2002), Intl. Society for the Study of Fatty Acids and Lipids (ISSFAL 1999) recommended 0.65g/day of EPA plus DHA for pregnant and lactating women; American Heart Assn. recommended 1 g/d of EPA plus DHA for people who have coronary heart disease (Kris-Etherton and others 2002).
[g]Number of capsules to reach an intake at the AI
[h]ND: not detected at the lower limit of detection (10 ppb).

etary supplements based upon label recommendations was determined. Although total PCB detected in the capsules was small, the daily dose of total PCB ranged from 21 to 513 ng in 20 fish oil supplements and 95 to 414 ng in the 4 cod liver oil products. PCB body burden from fish oil dietary supplements therefore, depends on the recommended intake provided on the product label. Based on the RfD of 2×10^{-5} mg PCB/kg of body weight/d, the daily upper limit for exposure for a 60-kg body adult is 1200 ng PCB (Environmental Protection Agency 1996; ATSDR 2001). The percentage of the RfD when following label recommendations for the 24 products was between 2% and 43% (Table 3). However, when pregnant or lactating women take only the amount of fish oil supplement required to meet the AI, the contribution of PCB from a dietary supplement would only be from 1% to 12% of the RfD. The RfD for PCB was established to protect the developing fetus and nursing infant from excessive risk to PCB consumed by the mother. Generally, cod liver oil supplements provided a higher percentage of the RfD for PCB at the AI than the fish oil supplements. Taking fish oil dietary supplements at the recommended dosage in addition to consumption of contaminated fish may increase the risk from PCB toxicity. In addition, consumers should be aware that consuming certain fish species (for example, tilefish, swordfish, shark, king mackerel, and tuna steaks) may increase the risk to the fetus or nursing infant from mercury, which is also a developmental toxin (FDA 2001). Fortunately, mercury is not measured at significant levels in fish oil supplements (Consumer Lab 2001).

When pregnant or lactating women consume only a dietary supplement to meet the ISSFAL recommended intake for EPA plus DHA of 0.65 g/day, then the exposure to PCB ranged from 4% to 53% of the RfD. For those following the AHA intake for EPA plus DHA of 1.0 g/d, the exposure ranged from 6% to 82% of the RfD. Thus, recommending higher intakes of EPA plus DHA, which may be difficult to achieve with fish consumption alone, may increase the risk from contaminants, in a dietary supplement and increased the risk to those most vulnerable to these contaminants, including the developing fetus and the nursing infant.

Conclusions

The current AI for EPA plus DHA for pregnant or nursing women can be reached by consuming fishes that have high levels of these lipids. However, intakes of EPA and DHA that are recommended by some organizations (ISSFAL and AHA) may require higher intakes of fish than practical and may encourage use of a dietary supplement. This study demonstrates that omega-3 supplements have a high degree of variation between the lipids concentrations provided on the supplement facts panel and the actual lipids in the supplement. The fatty acid concentrations ranged from 51% to 153% of the amounts on the label. In addition, label recommendations encourage higher intakes of EPA and DHA than the current AI (0.13 to 0.14 g/d of EPA plus DHA for pregnant and lactating women), which could increase exposure to PCBs with levels approaching the RfD. Thus, the fetus and infant may have an increased risk from PCBs if the mother consumes fish oil supplements at levels recommended by supplement manufacturers. However, if the dietary supplements are taken to just meet the AI, then exposure to PCBs drops significantly. Pregnant or nursing women should also avoid certain species of fish (tilefish, shark, swordfish, king mackerel, and tuna steaks) that have been shown to have high levels of mercury, which is a developmental toxin that may harm the developing fetus or nursing infant. The PCB concentrations in the 2 algal oil supplements were found to be below detection limits. Thus, consumption of the suggested daily dose of these supplements would not increase PCB exposure. SPECIAL NOTE: Individuals with cardiovascular disease and taking fish oil supplements under the direction of a physician should be aware that the risks from PCBs in fish oil supplements may be much lower than the risks from sudden cardiac death. Consult with your physician before altering your intake of these supplements.

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