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Fish intake guidelines: incorporating n-3 fatty acid intake and contaminant exposure in the Korean and Japanese communities

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Abstract

Background: Fish consumption advisories are developed to prevent overexposure to various contaminants. Recently, discussion has centered on the need to consider the benefits of fish consumption alongside possible risks when providing guidance.

Objective: As part of the Arsenic Mercury Intake Biometric Study involving the Japanese and Korean communities living in Washington State, we obtained fish and nutrient intake data. Japanese and Korean women of childbearing age ($n = 214$) participated in this longitudinal study. We used these data, along with hair-mercury data to determine the need for both the nutritional benefits and concern about contaminants to be included when providing guidance.

Design: We examined the intake of 2 n-3 long-chain fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), found in fish and associated with a variety of beneficial health effects. Intakes of these lipids were used as surrogates to characterize the beneficial effect from fish consumption, and the intake of mercury was used to establish the risk from consumption.

Results: These 2 populations provided an ideal basis from which to examine this issue because their fish consumption rates were identical and higher than national rates, but their mercury intakes vary substantially because of different consumption behaviors. Results indicate that basing fish consumption guidelines on contaminant concentrations alone can have the unintended consequence of causing a portion of the population to have inadequate intake of required nutrients.

Conclusion: Public health goals may be better served if nutritional elements and contaminant concerns are quantitatively incorporated into fish consumption guidelines.

INTRODUCTION

The health effects from mercury exposure are well understood and, depending on the type, duration, and extent of exposure, can vary with different systems or organs being affected (1). The most severe health effects observed in humans have occurred from accidental high-level exposure in Japan and Iraq (2-4). In response to results from ongoing studies in human populations and work conducted in animals, the US Environmental Protection Agency established a reference dose of $0.1 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for methylmercury (1, 5-14). Because the most prominent nonoccupational source of exposure to mercury comes from the consumption of fish, this reference dose has become the health benchmark from which to provide fish consumption guidelines and recommendations centered on mercury-contaminated fish (1).

In contrast to the detrimental developmental and neurologic effects that can come from consuming fish contaminated with mercury, many important beneficial effects are linked to fish consumption (15-27). Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are considered among the major benefits to fish consumption (28-31). This past year, proceedings of a workshop after the conference "n-3 Fatty Acids: Recommendations for Therapeutics and Prevention"

suggested that women should consume 100–300 mg DHA/d (22). Although improved data are required to determine dietary intake values or ratios among EPA, DHA, and EPA and DHA combined, the American Heart Association has recommended consuming 2 fish meals (preferably oily fish) per week, which results in an intake of \approx 400–500 mg DHA + EPA/d (15, 22, 32).

Several studies examining fish consumption have investigated nutrient intake and contaminant exposure with some works suggesting that the benefits from fish consumption may exceed the possible health effects from contaminant exposure, whereas others suggest that the benefits provided when mercury is present as a contaminant are still debatable (33–39).

In this study we examined 2 fish-consuming populations to determine how the intake of these nutrients relates to methylmercury exposure and how the relations affect fish consumption guidance.

SUBJECTS AND METHODS

Arsenic Mercury Intake Biometric Study

The main goal of the Arsenic Mercury Intake Biometric Study was to determine whether exposure to mercury in excess of the reference dose was occurring within the Japanese and Korean communities in Washington State, because these populations consumed fish in large quantity. This was a longitudinal study in which the Japanese cohort was interviewed 3 times and the Korean cohort was interviewed twice. To be included in the study, a participant had to have lived in the Puget Sound area of Washington for 6 mo, be willing to provide a hair sample from the nape of the neck (0.5 cm in diameter), and allow us to conduct a fish consumption survey. Participants were also asked, but could decline, to provide a second hair sample along with urine, blood, or toenail samples and to complete a food-frequency questionnaire (FFQ).

Group and data collection from the Arsenic Mercury Intake Biometric Study

The populations and sample collection methods were described previously (40). In brief, study participants were women of childbearing age (18–45 y) who identified themselves as Korean, Japanese, or of Japanese or Korean descent. Recruitment of participants occurred through a women's health clinic; a Women, Infants, and Children clinic; a local population-specific website; church functions; newspaper advertisements; posted project-awareness sheets; and local grocery stores that served the Asian community. Interviews were conducted in Japanese, Korean, or English, depending on the participant's preference. The fish consumption survey was based on survey instruments previously used with several Native American Tribes, recreational fishers, Asian Pacific Islanders, and the general public (41–43). The FFQ was a validated tool developed at the Fred Hutchinson Cancer Research Center that determines how often particular types of food are consumed and was augmented slightly for use in this study (eg, the addition of an accompanying section specific to food items consumed by these 2 populations) (44–46). As part of the oral survey, we asked participants a series of general demographic questions and questions about their fish consumption behavior. We provided participants a pictorial fish booklet containing pictures with names in 3 languages of finfish and shellfish that are commonly consumed by Japanese and Koreans as well as fish species commonly found in this area. We asked the participants questions about the frequency of consumption and of serving sizes for each species consumed. Serving sizes were determined with the use of fish models consisting of steaks, fillets, and sushi pieces, as well as shellfish samples. As part of the survey, participants were weighed unless they were pregnant, and we obtained self-reported prepregnancy weights from pregnant women. Participants were asked their age categories, (18–19, 20–24, 25–29, 30–34, 35–39, 40–45, 46–49, and \geq 50 y). The survey contained a series of questions that allowed for a cross-check of participant response about consumption. We determined participant sample size for each population to provide a reasonable precision of estimates of mean consumption rates such that the upper and lower bounds of CIs for means remained within 20% of an estimated mean. The study enrolled 214 women of childbearing age, (n = 106 Japanese; n = 108 Korean). We used all participant data from the orally administered fish consumption survey. We did not include FFQ data from 1 Japanese woman and 19 Korean women, based primarily on incomplete surveys (1 Korean women) or if the calculated individual caloric intake was $<$ 600 kcal/d (n = 19). We obtained informed consent from all participants. All materials, including the consent forms, were available in 3 languages (Japanese, Korean, and English) and were approved by the State of

Washington Department of Social and Health Services Human Research Review Board.

Fish tissue mercury concentrations

Fish species commonly consumed by these 2 populations were purchased at local Asian grocery stores for mercury analysis, and edible portions ($n = 115$) were measured for mercury (40). The resulting data were used along with other fish tissue analysis work (47-51) to obtain mean mercury fish tissue concentrations for the fish species consumed by these 2 populations and are described by Tsuchiya et al (40).

Outcome measures

This study uses survey and FFQ information obtained from each woman during the initial visit. The validated FFQ uses a series of 5 questions to determine consumption of various fish types [dark (fatty), light, or tuna] with DHA and EPA concentrations for the fish types derived from nutrient databases (44-46). DHA and EPA concentrations for the individual fish were combined, based on answers provided to determine individual DHA and DHA + EPA intake concentrations.

Individual fish intake estimates were also determined from each participant's consumption pattern behavior with the use of data from the fish consumption survey. For each participant, the frequency of consumption of a particular fish was multiplied by the serving size. For all species consumed, species intake values were combined and divided by body weight to obtain a daily fish intake value on a per kilogram body weight basis. The individual fish species consumption rates were used to derive DHA and DHA + EPA intake values. DHA and EPA concentrations were obtained from the literature with summary values provided by Mahaffey (52) (53-55). These values were weighted and combined, based on which species were eaten by a participant and in what amounts, so as to derive an individual DHA and DHA + EPA intake value. Either surrogate values from similar species were used or the fish species were omitted from the person's total DHA and EPA intakes for fish species without published values of fatty acids. Greater than 50 species were examined of which 8 were omitted. None of the 8 species represented >4% of the total fish consumption by each population (data not shown). To determine the effect of not having DHA and EPA values for those species consumed, sensitivity analyses were performed by comparing changes in fish consumption rates within the 2 populations. With all fish species removed for which no available DHA and EPA values could be obtained, average fish consumption values for the 2 populations changed <10% (data not shown). Accordingly, survey results and distributions depict consumption values based on all fish consumed and nutrient intake for which DHA and EPA fish values were available.

We used individual hair mercury values from each participant to determine mercury exposure for use in this comparative analyses (40). A 1.2 ppm Hg in hair value is considered to be the exposure equivalent of the reference dose and is used for the purposes of public health protection in this study (1).

Statistical analyses

We performed analysis of variance with post hoc comparisons using Tukey's honestly significant difference test to compare means of fish consumption across age groups. We used a Student's t test to compare means of fish consumption based on pregnancy status. Regression analyses were performed to compare intakes of n-3 fatty acids with mercury exposure on an individual basis. We assumed a significance level of 5% ($P < 0.05$), and we analyzed data using STATA (version 10.0; Stata Corporation, College Station, TX), EXCEL (version 2003 SP2; Microsoft Corporation, Redmond, WA), and SPSS (version 14.0; SPSS Inc, Chicago, IL).

RESULTS

All study participants had lived in the Puget Sound area of Washington State for ≥ 6 mo before enrolling in the study. Within the Japanese cohort, all but 3 of the 106 women participants preferred to speak in Japanese. In the Korean cohort, 71 of the 108 women participants preferred speaking Korean. Although 25% of the Japanese were pregnant at some point during the study, only 5% of the Koreans were pregnant during the study period. Results of a cross-check of participant response evaluating daily fish consumption using 2 sets of questions from the fish consumption survey showed a significant and positive correlation ($r = 0.79$, $r^2 =$

0.63, $P < 0.01$).

Total daily consumption rates of finfish and shellfish obtained from the fish consumption survey data for the 2 populations on a per person basis are provided in Table 1 [↓](#). Both populations consume nearly identical amounts of finfish with the Japanese consuming $59.5 \text{ g} \cdot \text{person}^{-1} \cdot \text{d}^{-1}$ and the Koreans consuming $59.1 \text{ g} \cdot \text{person}^{-1} \cdot \text{d}^{-1}$. This similarity remains across the finfish consumption distribution because the 95th percentile values do not differ markedly (159 and 147 g/d for Japanese and Koreans, respectively). Accordingly, the difference observed in total amounts of fish consumed by each population results from the Koreans consuming nearly 70% more shellfish on a daily basis (22.7 g/person) than the Japanese (13.5 g/person). Another difference between the 2 populations is in the amounts consumed of particular finfish types. For example, the Japanese cohort consumed 3 times as much salmon on a daily basis (1820 g/cohort) as did the Koreans (581 g/cohort), whereas the Korean cohort consumed ≈ 4 times the amount of squid per day (1461 g/cohort) as did the Japanese (356 g/cohort).

View this table: In this window In a new window	<p>TABLE 1</p> <p>Finfish, shellfish, and total fish consumption rates ($\text{g} \cdot \text{person}^{-1} \cdot \text{d}^{-1}$) for Japanese ($n = 106$) and Korean ($n = 108$) women along with total fish consumption norms for the United States as provided from the Continuing Survey of Food Intake by Individuals (CSFII) and the National Health and Nutrition Examination Survey (NHANES) data¹</p>
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The mean consumption rates of fish, shellfish, and total fish according to pregnancy status and age for the 2 populations on a per kilogram body weight basis are shown in Table 2 [↓](#). These data are derived from the fish consumption survey. The mean (\pm SD) weights were similar; the Japanese weighed $55 \pm 8 \text{ kg}$ and the Korean group averaged $59 \pm 11 \text{ kg}$. Most of the Japanese participants were in the age categories of 30-34 and 35-39 y, and these 2 categories represented 76 of the 106 women. The Korean population was spread evenly over all the age categories, with the highest number of participants ($n = 29$) being between 40 and 45 y of age. For analysis, age groups were combined to form 4 groups (<30, 30-34, 35-39 and, ≥ 40 y) because of the small number of subjects in some age categories. Results did not indicate a significant difference in fish consumption across the age groups for the Japanese and Koreans. In addition, an independent samples t test found no significant difference in fish consumption with pregnancy status in the Japanese population. This calculation was not performed for the Korean cohort because of the small number of pregnant women enrolled.

View this table: In this window In a new window	<p>TABLE 2</p> <p>Fish consumption for Japanese ($n = 106$) and Korean ($n = 108$) women categorized by pregnancy status and age¹</p>
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Estimated rate of total fish intake ranged from 0.05 to $6.55 \text{ g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for the Japanese women and from 0.06 to $8.31 \text{ g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for the Korean women. Shellfish intake rates were a fraction of the total fish intakes for all age groups within the Japanese population. Average intake of total fish for Japanese and Korean participants was $1.4 \text{ g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ and $1.3 \text{ g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$, respectively. Geometric mean values are provided because the fish intake distribution for both populations showed positive skew.

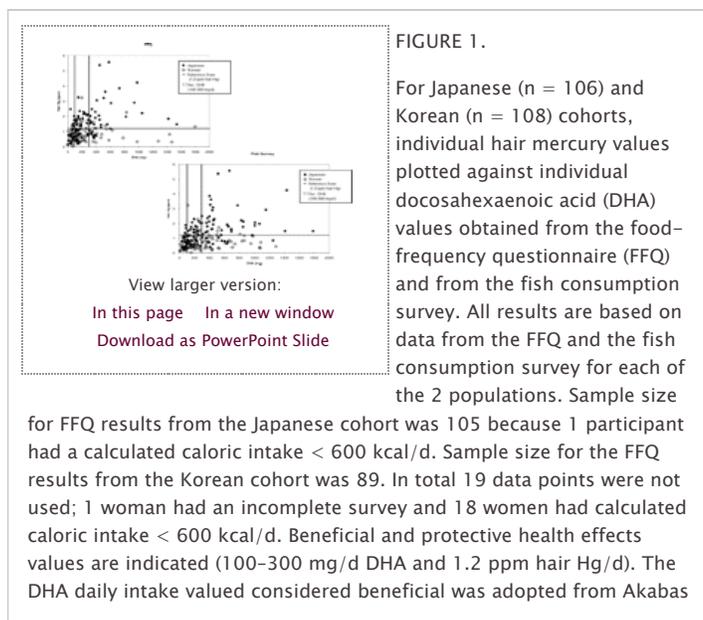
A comparison of consumption results for the Koreans and Japanese was made with US norms with the use of data from the National Health and Nutrition Examination Survey (NHANES) ([56](#)) and the Continuing Survey of Food Intake by Individuals (CSFII) ([57](#)). The CSFII data provided for an average shellfish and finfish consumption rate along with various percentile values (Table 1 [↑](#)). The NHANES results provided for a geometric mean consumption value and percentile values from within the consumption distribution (Table 1 [↑](#)). The Koreans and Japanese women consume fish in quantities that exceed the national average. Mean values for the average American consumer are $<20 \text{ g/d}$, whereas the average values for the Japanese and Korean cohorts are significantly higher (73 and 82 g/d,

respectively). Values of significance within the NHANES and CSFII distributions are the 95th percentile values (87 and 72 g/d, respectively) because the remaining 5% represent many persons. The average consumption values for the Koreans and Japanese approach or exceed these 95th percentile values, indicating that these 2 populations may be contained within the remaining 5th percentile of the NHANES and CSFII distributions. On the basis of the percentile values for the consumption distributions from CSFII and NHANES, the 2 populations investigated by us have central estimate shifts in consumption, leading to distribution patterns displaced to the right and further down the abscissa. Specifically, all the percentile consumption rates representing the national fish consumer were below those determined for the Japanese and Koreans.

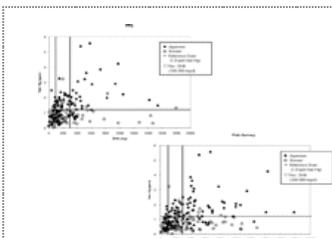
Correlations were determined between the n-3 fatty acids and total fish intake values derived from both the FFQ and the fish consumption survey data (Table 3). Correlations were significant ($P < 0.05$) in both populations with the use of data from both the FFQ and the fish consumption survey. In both data sets, the Japanese had equal or slightly higher r^2 values for DHA and DHA + EPA than did the Koreans. The r^2 values for n-3 fatty acids in the Korean cohort ranged from 0.62 to 0.79, whereas in the Japanese cohort the range was from 0.79 to 0.88. Accordingly, for both survey tools, the DHA and DHA + EPA intakes based on total fish species consumed explain a significant portion of the variability observed in the total fish consumption rates.

View this table: In this window In a new window	<p>TABLE 3</p> <p>Participants within Japanese (n = 106) and Korean (n = 108) cohorts categorized by docosahexaenoic acid (DHA) and DHA + eicosapentaenoic acid (EPA) intakes and by hair mercury values and the correlation coefficients (r and r^2) between n-3 fatty acids and fish consumption for each survey tool¹</p>
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For both populations, DHA intake values obtained from the FFQ and the fish consumption survey were plotted separately against hair mercury values (Figure 1). Intake values for DHA and EPA combined were also obtained from both data sets (FFQ and fish consumption) and distributions plotted using hair mercury values for both populations (Figure 2). A comparison of the number of persons with DHA intake < 100 mg/d based on data from the FFQ and the fish consumption survey indicates that for each population, $\approx 20\%$ of the participants are below this value (Table 3). The number of participants with an intake of <400 mg DHA + EPA/d (considered protective) within the Korean cohort were 62 and 73 (57% and 82%, respectively) with the FFQ data providing the larger number of participants (Table 3). For the Japanese, the FFQ data suggested that 61 participants (58%) were below the intake value of 400 mg DHA + EPA/d, whereas the consumption survey data provided a smaller number of 40 (38%) (Table 3).



et al (22), which pertains to proceedings of a workshop after the conference "n-3 Fatty Acids: Recommendations for Therapeutics and Prevention." The mercury exposure values used in this study for the purposes of public health protection are the reference dose and its biometric equivalent of 1.2 ppm Hg in hair (1). Note: one data point in each panel was not depicted because the hair mercury value was off the scale provided.



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FIGURE 2.

For the Japanese (n = 106) and Korean (n = 108) cohorts, individual hair mercury values plotted against individual docosahexaenoic acid (DHA) + eicosapentaenoic acid (EPA) values were obtained from the food-frequency questionnaire (FFQ) and from the fish consumption survey. All results are based on data from the FFQ and the fish consumption

survey for each of the 2 populations. Sample size for FFQ results from the Japanese cohort was 105 because 1 participant had a calculated caloric intake < 600 kcal/d. Sample size for FFQ results from the Korean cohort was 89. In total 19 data points were not used; 1 woman had an incomplete survey and 18 women had calculated caloric intake < 600 kcal/d. Beneficial and protective health effects values are indicated (400–500 mg/d DHA + EPA and 1.2 ppm hair Hg/d). DHA + EPA daily intake values considered beneficial were obtained from Gebauer et al (15), Akabas and Deckelbaum (22), and Kris-Etherton et al (32), which pertain to the American Heart Association's recommendation that persons consume 2 fish meals (preferably oily fish) per week. The mercury exposure values used in this study for the purposes of public health protection are the reference dose and its biometric equivalent of 1.2 ppm mercury in hair (1). Note: one data point in both panels depicted as hair mercury value was off the scale provided, and 1 and 3 data points in both panels, respectively, were not depicted because DHA + EPA intake values were off the scale.

An examination was also made of those participants that have low daily intakes of DHA and DHA + EPA while also exceeding the 1.2 ppm hair mercury value (Figures 1 and 2; Table 3). Results suggest that there are few women in either population that do not ingest a sufficient amount of DHA on a daily basis who also exceed the reference dose for methylmercury (no Koreans; 6 Japanese participants from the FFQ; 3 Japanese participants from the consumption survey data). Values of DHA + EPA determined from the consumption survey as well as the FFQ suggest that the Korean cohort has few participants (5 and 7 participants, respectively) that exceed the value of concern for mercury intake while not obtaining a sufficient amount of DHA + EPA. The DHA + EPA results from the FFQ data for the Japanese suggest that ≈20% of the participants fall into this category, whereas the fish consumption data suggest a value half that amount.

Correlation coefficients between DHA intake and hair mercury values were determined and found to be similar and significant for the Japanese (FFQ: $r = 0.41$, $r^2 = 0.17$, $P < 0.05$; fish survey: $r = 0.42$, $r^2 = 0.18$, $P < 0.05$), whereas the values were significant but not as similar for the Koreans (FFQ: $r = 0.12$, $r^2 = 0.02$, $P < 0.05$; fish survey: $r = 0.04$, $r^2 = 0.002$, $P < 0.05$). Results for the combination of DHA and EPA followed those seen with DHA intake compared with hair mercury values for both populations. For the Japanese, the correlation coefficients were once again significant and similar between hair mercury values and DHA values obtained from the FFQ and the fish survey (FFQ: $r = 0.40$, $r^2 = 0.16$, $P < 0.05$; fish survey: $r = 0.41$, $r^2 = 0.17$, $P < 0.05$). For the Koreans, the resulting correlations were significant but not as similar (FFQ: $r = 0.16$, $r^2 = 0.03$, $P < 0.05$; fish survey: $r = 0.04$, $r^2 = 0.001$, $P < 0.05$).

DISCUSSION

Our analyses support the premise that nutrients as well as contaminants should be concomitantly considered when providing fish consumption guidelines for public health protection. We investigated 2 populations consisting of Japanese and Korean women of childbearing age that are similar in many respects yet have important differences. Both populations consume, on average, nearly identical amounts of finfish and have 95th percentile consumption rates for finfish that are within 10% of each other (Table 1⁴). However, their finfish choices resulted in markedly different mercury intake amounts. Both populations consume fish in large quantity because they have consumption rates that are among the highest in the United States. However, regardless of which survey tool was used, both communities have a percentage of persons not obtaining their daily dietary requirement of DHA (100–300 mg/d) with the percentage being greater within the Korean cohort than in the Japanese cohort. If the DHA + EPA dietary intake of 400–500 mg/d is confirmed as the amount required to provide health benefits, both populations have a large percentage of persons who do not consume these 2 lipids in sufficient quantity on a daily basis.

When examining mercury exposure conjointly with nutrient intake, we observe that Japanese women, with 53% of the cohort exceeding the reference dose, have a lower percentage of persons not obtaining their dietary DHA and EPA intakes than do the Koreans, with only 13% of their cohort exceeding the reference dose. We cannot conclude, however, that there is a direct or linear relation between DHA or DHA + EPA and mercury exposure. The correlation coefficients were significant but weak between DHA (and DHA + EPA) intakes and hair mercury values in this study. The coefficients (*r*) observed for the Japanese cohort (range: 0.40–0.42), were similar to the correlation (*r* = 0.35) observed by Sakamoto et al (36) between fetal red blood cell mercury values and fetal plasma DHA concentrations in Japanese mothers and infants at parturition. The lack of a strong correlation between these nutrients and mercury should not be surprising because fish tissue mercury values are associated with large, long-lived fish and with piscivorous fish species more so than with nonpiscivores, whereas n-3 fatty acid intake is associated with oily fish species that are not necessarily piscivorous (58–66).

With 1 in 2 persons within the Japanese community overexposed to methylmercury, guidance needs to be presented 1) knowing that a portion of the community can reduce their exposure while still obtaining their recommended dietary intakes of these n-3 fatty acids and 2) in such a manner that the percentage of persons obtaining their dietary intake of DHA increases. The Korean community had only a small percentage of participants exceeding the reference dose (1 in 8), but 1 in 5 participants did not obtain their dietary requirement for DHA, and >1 in 2 possibly had a low DHA + EPA intake. The Korean community needs guidance that does not restrict fish consumption but actually promotes increased consumption of those oily fish species that have low amounts of mercury.

Even with limited exposure or consumption data, the goal should not be to just minimize exposure to the contaminant but also to ensure that optimal health is achieved. For example, if we consider just DHA and mercury in fish tissue, for any one species or for a combination of species consumed by a community, there are 3 consumption alternatives available relating DHA and mercury. 1) DHA concentrations in tissue so low or mercury amounts so high that based on a person's consumption rate, the person's mercury intake will reach the reference dose before meeting the nutrient intake recommendation; 2) DHA concentrations so high and mercury amounts sufficiently low that the daily nutrient requirement and consumption amount is attained without ever approaching the reference dose; or 3) at some given concentrations of DHA and mercury in fish tissue, consumption behavior will lead to the nutrient recommendation being met with some amount of exposure to mercury or the reference dose will be exceeded while the persons still lacks adequate amounts of DHA. The first 2 options allow for fish species to be identified that should be consumed rarely (or possibly not at all) as well as those that will not result in exceeding the reference dose even when fish is consumed in quantity. The third option is challenging because fish contaminant concentrations and nutrient values have to be considered in combination. An elementary approach could use a ratio between DHA intake and mercury exposure that is de minimus. For DHA and mercury, this ratio could be represented by the following simplified ratio: $DHA_{mr} \times 1/CR : RfD \times 1/CR \times BW$; in which DHA_{mr} is the minimum daily requirement of DHA (100 mg/d), CR is the daily fish consumption rate (60 g/d), RfD is the reference dose for methylmercury ($0.1 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$), and BW is body weight in kilograms (60 kg assumed for this example). The resulting ratio is 17 mg DHA to 1 μg Hg. This represents the minimum ratio of

DHA intake to mercury exposure that a person or population should have from consuming fish so as to meet the daily recommended intake for this nutrient while not exceeding the reference dose. A more accurate expression of this equality would address (among other factors) nutrients such as EPA, various individual body weights, and health effect exposure values for other contaminants. However, with a ratio such as this for DHA and mercury, even limited data sets relating exposure with consumption in a population or populations could be used to develop strategies providing for protection of public health. Along with determining fish species that should not be consumed because of elevated tissue mercury amounts, species that should be consumed because of high tissue DHA or DHA + EPA values while having low tissue mercury amounts could be provided to the consumer. The consideration of DHA and mercury in this manner would allow for the development of guidance resulting in consumption distributions that place a greater number of consumers above the recommended nutrient intake values and below the reference dose (depicted in the bottom right quadrant of each figure).

Results from this work suggest that both nutritional elements and contaminant concerns need to be quantitatively incorporated into fish consumption guidelines. Public health goals can be better served by being cognizant of both the potential harm from toxicants and the nutritional benefits when offering fish consumption recommendations.

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Footnotes

↵2 The contents of this manuscript are solely the responsibility of the authors and do not necessarily represent the official views or policies of the National Institute of Environmental Health Sciences (NIEHS), NIH, National Science Foundation (NSF), EPA, or the Washington State Department of Health.

↵3 Supported by the US Environmental Protection Agency, Region 10 [Clean Water Act, 104 (b)(3): 66-463], Pacific Northwest (PNW) Center for Human Health and Ocean Sciences (NIH, National Institute of Environmental Health: P50 ES012762; and National Science Foundation: OCE-0434087).

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