

U.S. FISH ADVICE MAY EXPOSE BABIES TO TOO MUCH MERCURY

EWG

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ABOUT EWG

The Environmental Working Group is the nation's most effective environmental health research and advocacy organization. Our mission is to conduct original, game-changing research that inspires people, businesses and governments to take action to protect human health and the environment. With your help—and with the help of hundreds of organizations with whom we partner—we are creating a healthier and cleaner environment for the next generation and beyond.

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EXECUTIVE SUMMARY

To protect your baby from toxic mercury and ensure his or her healthy development, you should not only watch *how much* fish you eat, but *what kind* of fish.

Federal agencies advise women who are pregnant, nursing or planning to become pregnant to eat much more seafood, an excellent source of the omega-3 fatty acids essential to babies' development. The most recent draft recommendations from the Food and Drug Administration and the Environmental Protection Agency say these women should eat 8 to 12 ounces of fish and shellfish a week—more than twice as much as the average American.

The agencies also list fish they say are lower in mercury, a powerful neurotoxin harmful to the developing brains of fetuses, babies and young children. The aim is to encourage seafood consumption without overdoing the mercury. Among almost all experts, in recent years this goal has supplanted the once-prevailing view that to avoid mercury pregnant women should eat less fish or even cut it out of their diet altogether.

“When you eat seafood during pregnancy, you get the benefits from omega-3s but from mercury you have the risk of toxicity,” said Dr. Philippe Grandjean, an adjunct professor at the Harvard School of Public Health. “If you get a little bit of mercury it can be offset by the omega-3s. But that means you don’t get the full benefit of the omega-3s and other nutrients in seafood. So women should minimize mercury exposure because only then will they get the maximum benefit of seafood.”

Now a new EWG study finds that adhering to the federal government's recommendations on seafood and mercury may be risky, potentially leading women to eat too much of the wrong kind of fish. Nationwide testing found that mothers who eat the species of fish in the amounts recommended by FDA and EPA risk exposing their babies to harmful doses of mercury while not providing them with enough healthy omega-3s.

EWG recruited 254 women of childbearing age from 40 states who reported eating as much or slightly more fish than the government

recommends. A university lab tested samples of their hair, where mercury accumulates and reflects the level in the body as the hair grew.

Nearly three in 10 of the women had more mercury in their bodies than the EPA says is safe—a level many experts say is much too high for pregnant women. Almost 60 percent of participants had more mercury than a stricter limit recommended by Grandjean, who analyzed hair samples for EWG’s study, and scientists from two prestigious European institutions. The frequent seafood eaters had an average of 11 times as much mercury as a comparison group who eat seafood rarely, proving that the high mercury levels came from the fish rather than other sources.

Mercury emissions from coal-fired power plants and other industrial sources are carried by air and deposited on oceans and waterways. Bacteria convert it to methylmercury, the form that accumulates in fish and is most harmful to human health. In the U.S., an estimated 75,000 infants born each year are exposed in the womb to potentially harmful levels of mercury.

To limit mercury consumption, FDA and EPA recommend that women eat no more than six ounces a week of canned albacore tuna and no shark, swordfish, tile fish or king mackerel. But our study suggests that many women who follow that advice will not have low enough levels of mercury or get enough omega-3s in their diets.

Our analysis of the women's dietary surveys found that while only a small amount of their mercury intake came from species the government says to avoid or limit, the great majority of the toxin came from species the government does not warn against, especially tuna steaks and tuna sushi. And although the women in our study eat more than twice as much fish as the average American, almost 60 percent still don't get the amount of omega-3s recommended during pregnancy from seafood in their diets.

In light of the tradeoff between mercury and omega-3s, and because seafood harbors other contaminants, some people believe it is safer to avoid fish completely during pregnancy. We don't agree.



254
Participants

29%
Exceed
1 ppm
Mercury

59%
Exceed
0.58 ppm
Mercury

Researchers overwhelmingly recommend low mercury fish as the most reliable source of omega-3s. The mercury in seafood erodes the benefits of an otherwise healthy food, and in some cases tips the scale to the point that the fish becomes harmful. The tradeoff is like exercising outdoors even when the air quality is less than ideal: Air pollution erodes the benefits of outdoor exercise, but in most cases it is still worth it. If air quality is bad enough, you should stay indoors.

EWG and the Mercury Policy Project urge FDA and EPA to update their recommendations to specify the full list of low mercury-high omega-3 fish, such as salmon, that women should add to their diets. This information is already included in the most recent edition of the Dietary Guidelines from the Department of Agriculture and the Department of Health and Human Services, so aligning the recommendations would provide greater clarity to the government's advice, which doctors and other health professionals look to for guidance.

The advice should also educate women about the hazards of mercury and name additional species they should limit or avoid for up to a year before conception, such as seabass, halibut and marlin.

In the absence of government action, **EWG's Good Seafood Guide** provides model guidelines for consumers looking to reduce intake of mercury consumption and increase intake of omega-3 fats. The **EWG Seafood Calculator** estimates portion size and frequency based on a child or adult's weight and recommends that pregnant women and children ingest 25 percent less mercury than the current EPA guideline.

FINDINGS

Since 2010 federal agencies have recommended that all adults eat eight to 12 ounces of fish and shellfish per week. In 2014 the FDA and EPA issued a draft recommendation that pregnant women eat the same amount.¹ Currently, the average American adult eats 3.5 ounces of seafood a week.²

The recommendation to eat more seafood during pregnancy is primarily based on

the benefits of two long chain omega-3 polyunsaturated fatty acids in fish and shellfish, referred to as DHA+EPA (*docosahexaenoic acid* and *eicosapentaenoic acid*). A diet rich in these omega-3s during pregnancy has been shown to boost babies' brain development and improve their vision.³ Seafood is also a good source of high-quality protein and vitamins B and D, iodine and selenium.

The amounts of omega-3s and mercury in seafood vary widely depending on species. Women who increase the amount of fish in their diets without choosing the right species may not only fail to get the omega-3s they need but also risk ingesting too much mercury.

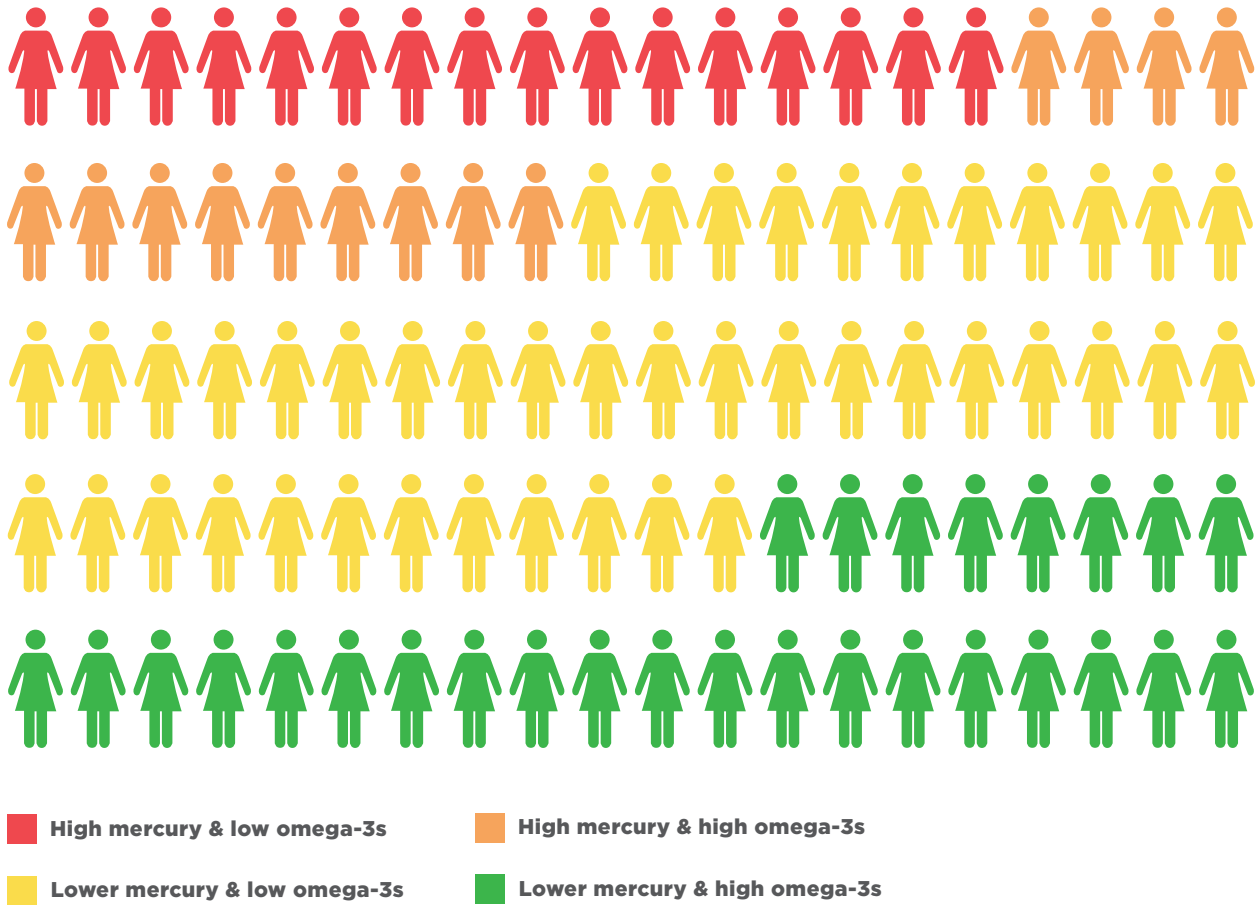
To investigate the implications of the federal seafood recommendations for pregnant women, we recruited online almost 300 women of childbearing age. We asked them to fill out a detailed questionnaire about the seafood they ate recently. From this information we chose 254 women in 40 states who ate as much as or slightly more than the FDA and EPA recommend. For comparison, we chose another 29 women who ate seafood rarely or not at all.

We collaborated with the University of Southern Denmark to measure the concentration of mercury in samples of the participants' hair. The lab analyzed a small strand of hair taken closest to the scalp (two centimeters, about three-fourths of an inch) which reflects mercury ingested in the previous one to three months.

The hair of almost 30 percent of the women who reported eating seafood often had more mercury than EPA's outdated exposure guideline of one part per million, a level that has now been associated with clear risks to a developing fetus. Nearly 60 percent of the women exceeded 0.58 part per million, the level Grandjean and other researchers say is a more protective upper limit for pregnant women.⁴ (A part per million is equal to one drop of water in 50 liters, or about 13 gallons, underscoring how tiny amounts of mercury are harmful.)

Mercury levels in the 254 women who frequently eat fish were six times higher than the median level found in a representative sample of all American women in 2004 by the

Too many study participants have high mercury or low omega-3s



Source: EWG, from 2015 survey and tests of 254 U.S. women of childbearing age
Women with hair mercury levels +/- 1 ppm and estimated omega-3 intake +/- 250 mg of DHA+EPA per day.

National Health and Nutrition Examination Survey of the Centers for Disease Control and Prevention.⁵ They had an average of 11 times more mercury than the 29 women who eat seafood rarely, clearly indicating that the high mercury levels came from the fish rather than other sources.

Mercury levels in participants' hair ranged from well below the EPA exposure guideline to 8.8 parts per million—almost nine times as high as the exposure guideline. Mercury levels were greater in those participants who ate higher mercury species frequently, suggesting that the type of fish women eat is more important than how frequently they eat fish and shellfish. (See Methodology for detailed results.)

The government recommends that adults get an average of 250 milligrams of DHA+EPA daily.⁶ One study estimates that on average American

women of childbearing age get only a third of the recommended amount of omega-3s,⁷ because most Americans don't eat much fish and shellfish, and the most popular seafoods are very low in omega-3s.

Even though our study participants eat a lot of seafood, we estimate that six in 10 do not get the recommended amount of omega-3s to support an optimal pregnancy. The median omega-3 our participants got was 230 milligrams per day from seafood alone.

Just over one-fourth of our participants had both enough omega-3 intake and mercury levels below the EPA exposure guideline of 1 part per million. About one in six had higher levels of mercury and lower than optimal omega-3s, a particularly unhealthy combination.

WHERE DO GOVERNMENT RECOMMENDATIONS FALL SHORT?

The 2014 draft recommendations from FDA and EPA advise women who are pregnant, nursing or considering pregnancy to eat 8 to 12 ounces of a variety of seafood a week.⁸ The draft retains the agencies' 2004 recommendations that such women completely avoid four fish high in mercury (swordfish, shark, king mackerel and tilefish), eat no more than six ounces of albacore tuna a week, and eat a maximum of 12 ounces of any other fish or shellfish a week. The draft names several "lower mercury" fish and shellfish, including salmon, canned light tuna, tilapia, cod and catfish. It cautions women and children to limit fish caught from local waterways that may be polluted with mercury or other harmful chemicals.

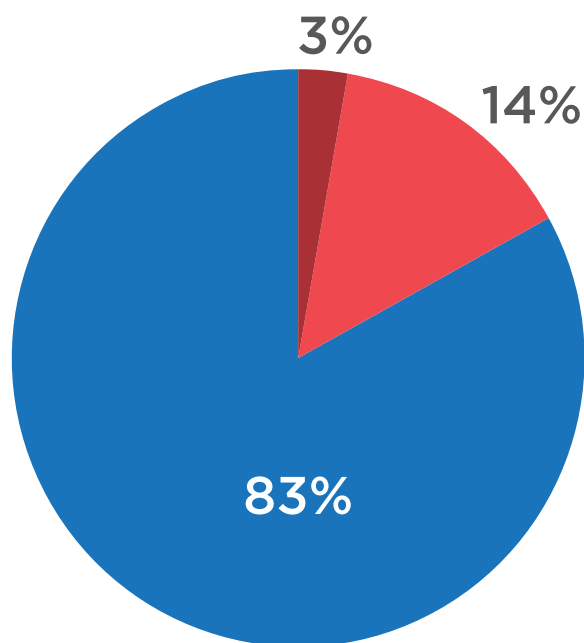
But our study shows that the government's advice is not detailed enough.

Participants reported eating lots of tuna steaks and tuna sushi, as well as other fish with high levels of mercury that FDA and EPA don't mention. Tuna contributed almost 40 percent of the mercury ingested by participants, based on their answers to the questionnaire. Other studies have estimated a similar contribution of tuna to mercury intake in the American diet.⁹ The inclusion of canned light tuna on the government's "lower mercury" list is in error, since it is in fact not low in mercury and is a significant source of mercury in women's diets.

Several other high mercury species contributed an additional 12 percent of participants' mercury intake. These include escolar, walleye and opah—species whose mercury levels are similar to those on the government's "do not eat" list but are not named in the recommendations—and popular choices like halibut, snapper, seabass, grouper, ono and Spanish mackerel, all with mercury concentrations similar to canned albacore tuna. EWG recommends that pregnant women and children avoid eating these fish whenever possible.

The FDA and EPA recommendations also fail to ensure that women get enough omega-3s. As EWG reported in 2014, eight of the 10 most

Only About One-Sixth of Participants' Mercury Intake is From Species the Food & Drug Administration Warns Women to Limit or Avoid During Pregnancy



- **4 species FDA warns women to avoid (swordfish, shark, king mackerel, tilefish)**
- **1 species FDA warns women to limit (canned albacore tuna)**
- **All other seafood**

popular seafood species are too low in omega-3s to be good sources of those fatty acids during pregnancy.¹⁰ FDA recommends tilapia and catfish as "lower mercury" species. But a pregnant woman would need to eat about 15 servings of tilapia a week, or 20 servings of catfish, to get the recommended amount of DHA+EPA.

In contrast, wild salmon stands out as a healthy and also popular choice. A single six-ounce serving of salmon can provide an entire week's worth of omega-3s and is very low in mercury. Our participants eat a lot of salmon and we estimate it provides almost half of the omega-3s in their diets. Small oily fish such as anchovies, herring, sardines and shad made up very few of participants' seafood meals but provided almost 15 percent of their omega-3s.

Confusingly, there is another set of federal guidelines for seafood. The recommendations from FDA and EPA are concerned with seafood consumption during pregnancy, while the official Dietary Guidelines of the Department of Health and Human Services and the Department of Agriculture are overarching recommendations about nutrition and health.

The newest Dietary Guidelines, published in January 2016, say all adults (not just pregnant women) should eat eight to twelve ounces of seafood a week. They conclude that people who get an average of 250 milligrams a day of DHA+EPA from seafood have lower risk of dying from heart disease, and consumption during pregnancy leads to improved infant health outcomes.

The Dietary Guidelines provide better detail to help consumers choose fish that are low in mercury and high in omega-3s, listing salmon, anchovies, herring, shad, sardines, Pacific oysters, trout and Atlantic and Pacific mackerel. They advise people to eat these species often to get the benefits of omega-3s.

Many state agencies are also providing their residents with better guidance on seafood safety. For example, California, Connecticut and Washington give clear and practical information about both mercury and omega-3s in commercial fish species.¹¹ FDA and EPA should follow the states' lead.

WHAT DOES SCIENCE SAY ABOUT SEAFOOD SAFETY?

In high doses mercury causes serious nerve damage, seizures and birth defects. In the body, mercury creates tissue-damaging free radicals—highly charged, short-lived reactive atoms—and inhibits cellular repairs, making it harmful to the heart, kidney and other body organs. A number of genes appear to affect a person's ability to metabolize and excrete mercury, and others appear to increase vulnerability to mercury's toxic effects.¹²

But of greatest concern for pregnant women, low doses of mercury can provoke subtle and lasting changes to the developing brain

and nervous system. There is strong evidence that mercury exposure during pregnancy and childhood causes lifelong deficits in learning, memory and reaction times.

During pregnancy the fetus' brain and nervous system are developing rapidly. Mercury disrupts the normal process by which brain and nerve cells form, connect and organize.

Because the placenta allows mercury from the mother's blood to pass into the fetus, mercury levels in the fetus and umbilical cord blood are consistently higher than in the mother.

Newborns are also highly vulnerable to mercury. However, mercury levels in breast milk are relatively low, and infants and young children are not typically fed a high seafood diet. As a result, public health experts have focused on pre-conception and pregnancy as key times to limit mercury ingestion.

In 2000 the EPA determined that mercury levels in pregnant women's blood should be below 5.8 micrograms per liter of cord blood to ensure that the fetus was not harmed.¹³ The guideline of 5.8 micrograms per liter in cord blood corresponds to 3.5 micrograms per liter in the mother's blood¹⁴ and roughly one part per million mercury in hair.¹⁵

In the 16 years since EPA set its mercury exposure recommendations, new studies have shown that mercury is harmful at lower doses than previously thought. One reason is that harmful effects of mercury in earlier studies were to some degree masked by the benefits of omega-3s and other nutrients in seafood.¹⁶ Newer research accounts for this through isolating and independently examining the benefits of omega-3s and the harm of mercury exposure to early childhood cognition, memory and attention.

Most studies find negative effects of mercury exposure *in utero*, and positive outcomes for children whose mothers eat more high omega-3 seafood or seafood in general. The task is complicated by the fact that each study includes women from different regions of the world, eating different amounts and varieties of seafood that vary in contaminants and beneficial nutrients.

The primary benefits of seafood are thought to come from the omega-3 fatty acids, DHA and EPA. They are a major component of cell membranes in the brain, nerve cells, retina and heart. A diet rich in omega-3s can lower blood triglycerides, and lessens the risk of cardiac disease. Omega-3s also reduce inflammation. Researchers are looking at them to treat diseases like arthritis, macular degeneration of the retina and some mental disorders.

One of the most relevant studies of the effects of seafood consumption for American babies was Project Viva, headed by Dr. Emily Oken of the Harvard Medical School and Harvard Pilgrim Health Care.¹⁷ It looked at the relationship between women's seafood intake and mercury exposure during pregnancy and their children's intelligence, memory, and motor development at six months and three years.

Oken's team found a benefit to children whose mothers ate seafood frequently during pregnancy, as long as they kept their mercury levels low. Women who ate more than two seafood meals weekly had kids with better neurological development, while children whose mothers had the highest mercury levels showed subtle neurological deficits.

In Oken's study, the benefits of eating enough seafood and the harm of ingesting too much mercury during pregnancy were roughly equivalent, with each causing about a 10 percent increase or decrease in children's memory and visual-motor skills. The research team concluded that children benefit most when mothers eat a substantial amount of seafood, but of species with low mercury. Nearly a dozen studies published since have confirmed and reinforced that conclusion.¹⁸

Similar findings were reported in a study with more than 400 women and children from New Bedford, Mass. Women with hair mercury concentrations greater than one part per million when they gave birth had children with increased risk of inattentive and impulsive or hyperactive behavior at age 8. Children whose mothers ate more than two servings of fish a week during pregnancy had a much lower risk of ADHD.¹⁹

Another study of children's visual memory and learning found that every part per million

increase of mercury in their mothers' hair during pregnancy was associated with about a 2.8 point decline in visual memory and 2.2 point decline in verbal memory, after adjusting for estimated omega-3 ingestion.²⁰

However, not all studies report the same effects.

A 2016 study by Jordi Julvez and colleagues, of the ISGlobal Center for Research in Environmental Epidemiology, examined Spanish mothers and children with high seafood-high mercury diets. The study found that greater seafood consumption was generally associated with kids' better scores on neurodevelopment tests at 14 months and 5 years. The benefits were mixed and declined somewhat for women who ate the most fish. Yet this relationship remained when the authors looked at women who primarily eat higher mercury fatty fish like tuna and swordfish.

However, the researchers noted that this finding doesn't invalidate previous studies that find mercury to be harmful. Spanish women with higher socioeconomic status tend to eat more seafood, exposing them to more mercury, so other factors could contribute to their kids' higher scores.²¹

In 2012 Julvez and his colleagues reviewed results from 27 large epidemiological studies. Many were of people in cultures that eat much more seafood than Americans, but four were of communities with diets comparable with the U.S. The authors concluded that the "majority of the publications describe neurodevelopment impairments, particularly when the exposure was measured during pregnancy." They also noted that "in some populations, nutrients from fish and seafood seemed to counterbalance the real extent of developmental neurotoxicity due to methylmercury."²²

Phillipe Grandjean of Harvard, described how this balance works: "When you eat seafood during pregnancy, you get the benefits from omega-3s but from mercury you have the risk of toxicity. If you get a little bit of mercury it can be offset by the omega-3s. But that means you don't get the full benefit of the omega-3s and other nutrients in seafood. So women should minimize mercury exposure because only then will they get the maximum benefit of seafood."

Numerous researchers have identified fish species that women should limit or avoid due to high mercury or a poor ratio of omega-3s to mercury:

Gary Ginsberg of the Yale School of Public Health and the Connecticut public health department drew on Oken's work to examine 16 common species. He estimated that nine species would, on balance, harm infants if their mothers ate six ounces a week during pregnancy: shark, swordfish, yellowfin tuna, canned albacore tuna, lobster, sea bass, halibut, cod and canned light tuna.²³

Katrina Smith and Jane Guentzel of Coastal Carolina University identified ahi tuna, sea bass, halibut, snapper, cod and canned mackerel as species with mercury risks that outweigh omega-3 benefits.²⁴

Kathryn Mahaffey of EPA used data developed by Amy Tsuchiya of the University of Washington to identify additional species—carp, monkfish, sturgeon, marlin, flounder and canned light tuna—as fish too high in mercury with too little omega-3s to be healthy during pregnancy.²⁵

Marco Zeilmaker and his colleagues at the National Institute for Public Health and the Environment in the Netherlands concluded that for people who eat fish frequently, the negative effects of mercury outweighed the benefits of omega-3s for 70 percent of the species they studied.²⁶ They suggested that women should avoid high mercury fish for up to a year before conceiving.

Clearly the science supports nutritional policies that encourage consumption of high omega-3 seafood. Research that aims to identify and promote consumption of the healthiest species is more scarce.

Emily Oken developed a simple handout to advise women about the amount and species of fish they should eat during pregnancy.²⁷ She found that pregnant women who got the handout

raised their level of consumption of the essential omega-3 DHA and kept their level of mercury low. Participants ate even more DHA when they were given a gift card to a grocery store that could be used weekly to buy healthy seafood.

Some researchers and advocates, concerned about contaminants in seafood and the sustainability of fisheries, suggest that people seek out vegetarian sources of omega-3 fatty acids. However DHA and EPA are found only in fish, shellfish and some algae-derived supplements. Nuts and vegetables, including canola oil, soybean oil, flax seeds, chia seeds and walnuts contain a third type of omega-3 fatty acid known as ALA (alpha-linolenic acid). The body can convert this fatty acid to EPA and then DHA, but in most people only a small part is converted, making these foods a less effective source of the omega-3s essential to a healthy pregnancy.

WHO'S AT RISK FOR MERCURY EXPOSURE?

The guidelines from the Departments of Health and Human Services and Agriculture, show federal nutrition advice has clearly shifted toward increased seafood consumption. But the government is ignoring its own research that increasing seafood consumption also increases mercury risks.²⁸ More than a dozen recent studies highlight specific groups at greater risk for mercury exposure.

The Centers for Disease Control and Prevention regularly monitor mercury exposure for the American public. One CDC study found that one-fourth of women eating seafood two or more times per week had mercury concentrations in their blood above 3.5 micrograms per liter—a level that, if they were pregnant, would expose their developing fetus to too much mercury.²⁹

Another analysis of CDC data found the highest levels of mercury in women in coastal regions of the U.S.,³⁰ a finding confirmed by studies in Hawaii,³¹ Florida,³² Louisiana,³³ Alaska³⁴ and New York City.³⁵ Residents of the Great Lakes region also have high mercury levels.³⁶

CDC data also suggests that Americans of Asian, Native American, Pacific Islander or Caribbean ancestry have higher levels of mercury than whites, African Americans and Latinos,³⁷ largely because they eat more fish.³⁸ This finding is affirmed by studies of Japanese Americans and Korean Americans living in Washington state,³⁹ Asian Americans in Chicago and New York City,^{40,41} and Native Americans following a subsistence diet in Washington state.⁴²

People who eat fish caught in polluted waterways are also at greater risk for mercury exposure.⁴³ More affluent people are at increased risk,⁴⁴ perhaps because they eat more expensive fish species, which tend to have more mercury because they are larger and more likely to be high in the food chain. Studies find elevated mercury exposure for people who eat a lot of sushi,⁴⁵ and other predatory ocean fish like swordfish, marlin, shark or tuna.⁴⁶

The number and diversity of Americans who are at higher risk of mercury exposure makes it imperative that federal, state, local and tribal health officials help identify women at high risk and provide language- and culture-appropriate messages about seafood safety.

RECOMMENDATIONS

1. Women who are pregnant, nursing or considering pregnancy should choose fish that are low in mercury and high in omega-3s. EWG's Good Seafood Guide identifies the safest, most sustainable species. If you don't eat fish regularly, consider taking an omega-3 supplement while you are pregnant and nursing. If you eat more than 12 ounces of seafood per week, it is even more important to select lower mercury species.

2. FDA and EPA must improve their draft seafood advice to women. American women and parents of young children urgently need better advice about seafood choices. The FDA and EPA's seafood advice for pregnant women should follow the lead of the Dietary Guidelines and clearly identify high-omega-3, low-mercury seafood choices. It must also list additional moderate- and high-mercury fish women should limit or avoid for up to a year prior to conception.

3. Federal agencies must do more to promote seafood safety. Good advice is only a first step toward healthier seafood consumption. It will also take a coordinated effort between federal agencies, health care providers and nutritionists to educate people about healthy fish choices during pregnancy and childhood. A substantial body of research identifies communities at higher risk for mercury ingestion, and should be used to target people at high risk.

4. Retailers should inform consumers about high mercury fish. Grocery stores, fish markets and restaurants must also play a role in ensuring that seafood consumption provides a net health benefit. Responsible retailers should stop selling very high mercury fish species, and should use warning labels, shelf talkers or posters at the point of sale to highlight moderate mercury species to limit and avoid during pregnancy and childhood.

5. State and federal officials must continue to reduce mercury emissions into the environment. In the U.S., coal-fired power plants are the largest source of mercury emissions. Gold mining and other historic industrial activities have polluted lakes and waterways where people fish. Despite national efforts to reduce mercury emissions, concentrations of mercury in the marine food chain are rising due to increases in global mercury pollution.

6. The U.S. must comprehensively implement the Minamata Treaty to address global mercury contamination. In 2013 the U.S. joined 127 nations and signed the Minamata Convention, a global treaty committing international governments to reducing mercury emissions, and became the first country to ratify the convention. The treaty is a good start, but mercury contamination will be long lasting. Mercury levels in the global environment are projected to double by 2050 if the Convention is not effectively implemented. This increase in global mercury pollution could lead to greater concentrations in larger predatory fish and increase risk for seafood consumers, as is already being observed in Pacific tuna.

METHODOLOGY

Our study protocol was reviewed by the Chesapeake Institutional Review Board of Columbia, Maryland. We recruited participants online via the EWG website and social media sites. Participants completed an informed consent form online, and then a longer dietary survey about their consumption habits for store-bought, restaurant, sushi and subsistence caught fish and shellfish.

EWG initially recruited more than 400 U.S. women of childbearing age. Of the initial group, 143 registered for the study online and completed the informed consent form and dietary survey but did not return a hair sample for analysis. 292 women who provided hair samples reported eating two or more seafood meals per week recently. As a control group, we also collected hair samples from 31 women who reported eating little or no seafood. All samples were anonymized and coded before being sent to the analytical laboratory.

Nine participants had significant differences between information they provided at the screening stage and their responses to study questionnaires, so we excluded them from further analysis. Thus, our final cohort included hair testing data and seafood questionnaires for 254 frequent seafood consumers and 29 who eat seafood rarely.

Study participants came from 40 states, with a majority from states on the East and West coasts. Their ages ranged from 22 to 49, with an average of 38. Participants self-reported their bodyweight, with an average of 147 pounds. Weight data was missing for 32 women in the seafood consumption group. The control group had economic, education, and racial/ethnic characteristics very similar to those of the frequent fish consumers. A substantial portion of our seafood consumers and control group reported taking fish oil supplements. The demographics of our participants are summarized in Table 1 to the right.

ESTIMATING SEAFOOD CONSUMPTION

Our study was designed to evaluate mercury consumption for women who roughly comply with the government's draft seafood advice, i.e., eat at least eight ounces of seafood a week. Pinpointing participants' actual seafood consumption proved difficult, as dietary recall surveys are imprecise and many women's diets vary a great deal over time in regard to fish and shellfish consumption.

Table 1: Study participant demographics

	Seafood Consumers	Non-Consumers
Total Study Population	254	29
By Age		
20s	28 (11%)	4 (13%)
30s	100 (39%)	18 (62%)
40s	126 (49%)	7 (24%)
By Income		
<\$25K	11 (4%)	1 (3%)
\$25-70K	71 (28%)	11 (33%)
\$70-110K	74 (29%)	9 (31%)
\$110-200K	64 (25%)	4 (14%)
>\$200K	28 (11%)	4 (14%)
Not Provided	6 (2%)	0 (0%)
Use of Fish Oil Supplements		
Fish Oil Consumers	109 (42%)	8 (28%)
No Fish Oil	143 (58%)	21 (72%)
Race/Ethnicity		
Caucasian	204 (80%)	23 (79%)
Asian/Pacific Islander	19 (7%)	2 (7%)
Hispanic/Latino	18 (7%)	3 (10%)
African American	3 (1%)	0 (0%)
Native American	1 (<1%)	0 (0%)
Multiple Races	8 (3%)	1 (<1%)
Declined to State	1 (<1%)	0 (0%)
Educational Attainment		
Less Than College Degree	31 (12%)	3 (10%)
College Degree or Higher	222 (87%)	26 (90%)
Declined to State	1 (<1%)	0 (0%)

Source: EWG, from 2015 survey and tests of 283 U.S. women of childbearing age.

Table 2: Hair mercury concentrations by estimated seafood meals per week

Estimated Number of Seafood Meals Per Week	Number of Participants	Median Hair Mercury Level (Parts Per Million)	Range	Percent of Samples That Exceed 1 ppm
<2.5	71	0.66	0.10–2.5	30%
2.5–3.4	79	0.63	0.09–6.5	23%
3.5–4.4	48	0.74	0.02–2.9	31%
4.5+	56	0.73	0.03–8.8	36%

Source: EWG, from 2015 survey and tests of 254 U.S. women of childbearing age

During the selection phase we asked women to report how much seafood they had eaten during the past week and the last two months, then enrolled those who reported at least two meals in the past week or eight meals in the past two months. We selected and enrolled a control group who reported eating no seafood in the past week, and fewer than four meals in the past two months.

Once participants were selected for the study we presented them with an online dietary questionnaire, asking for much more detailed information about the fish and shellfish species that they may have eaten in a restaurant, at home, as sushi, or that were caught by someone they knew. For the restaurant, home preparation and sushi categories we provided a list of common fish and shellfish species and asked women to estimate how many servings they typically consumed per month.

Each category also had space for participants to list other species they consume. As has been reported in other studies, women reported far more seafood consumption when presented with a comprehensive list of common species.⁴⁷ We excluded nine participants with highly divergent findings on their pre-screening and study questionnaires.

Our frequent seafood consumers reported an average of 3.7 meals per week on our pre-screening form, and 6.3 meals per week on the detailed study questionnaire. This nearly two-fold difference is of similar magnitude to differences found in other mercury and fish-consumption monitoring studies.⁴⁸ Studies have consistently found that people tend to over-report their consumption of specific fish and shellfish species when given a detailed list of species to choose from.⁴⁹

To reconcile these divergent data we created a scaled seafood consumption variable, based on a method used by a team of researchers from the Harvard School of Public Health.⁵⁰ For their 2011 study of recreational anglers in Louisiana, results from the screening questionnaire were used as the best estimate of a person’s overall frequency of seafood consumption, while the detailed questionnaire results were used to estimate the composition of seafood in a participant’s diet, and we did the same. (See Appendix 1.) Our final seafood intake estimates should still be interpreted with caution, as they represent participant’s recall, not detailed dietary tracking.

We found a slight relationship between the self reported number of seafood meals per time interval and average hair mercury levels, with sizable standard deviations and standard errors for each group (Table 2). While the median concentration of mercury in hair samples did increase in women who report more frequent consumption of seafood, a similar number of women in each group exceeded the EPA hair mercury guideline. We conclude that selecting lower mercury species is more important than limiting fish consumption.

ESTIMATING MERCURY AND OMEGA-3 INTAKE VIA SEAFOOD

Mercury and omega-3 content varies enormously between individual fish of the same species. Yet there is enough data from both peer-reviewed publications and government databases to derive robust species-level estimates of average mercury and omega-3 content for most common commercial species.

We estimated the mercury concentrations in commercial seafood from published monitoring data. Our primary source was the Stony Brook Seafood Database,⁵¹ an aggregation of more than 300 peer reviewed-studies measuring mercury in fish and shellfish. Stony Brook calculates a grand mean for each species based on the mercury measurement and sample size for the individual studies included. In some cases we included more recent information on mercury in popular species like canned tuna,⁵² and species like mahi mahi, wahoo, opah, and walleye, which are not included in the Stony Brook database.⁵³

For omega-3 fatty acid levels, EWG used the most recent data reported by the U.S. Department of Agriculture's Nutritional Database in 2013 (SR-26). We estimated the concentrations of two omega-3 fatty acids (DHA + EPA) in common species, including data for both raw and cooked food samples when available.⁵⁴ When species were not listed in the USDA database we used peer-reviewed studies;⁵⁵ when none were available we turned to informational websites or relied on estimates from related species.

Both data sources and the variability of omega-3 and mercury content of seafood is discussed in more detail in the methodology section of our 2014 report on this subject.

Our participant surveys grouped some species with reasonably similar mercury and omega-3 values, such as "breaded white fish" and "clams, scallops, mussels and oysters." We used market share data to average mercury and omega-3 content for these groups. (See Appendix 1 for a list of common fish and shellfish with the average mercury and omega-3 content.)

CANNED TUNA

The mercury and omega-3 content of canned tuna varies by species, but more than one-fourth of canned tuna consumers did not know whether they eat albacore or light tuna. For unspecified canned tuna, we estimated the mercury content to be 0.19 parts per million and omega-3 content to be 0.53 grams per four ounce serving, based on the relative market shares of albacore and light tuna.⁵⁶

The fact that many women didn't report the type of canned tuna they ate introduces uncertainty into our calculation of our participants' relative mercury and omega-3 intake. Furthermore, omega-3 concentrations are highly variable among tuna species. This applies both to species served as tuna steaks and in tuna sushi, and to species sold as canned light tuna. The USDA data show a range of DHA+EPA concentrations from as little as 0.08 grams of DHA+EPA per 4-ounce serving for fresh yellowfin (ahi) to 1.1 grams in 4 ounces of bluefin. We used an estimate of 0.37 grams of DHA+EPA as a ballpark concentration of omega-3s in tuna steaks and sushi because yellowfin is much more widely sold than bluefin and other longer-lived tuna for these purposes.

Using this method we evaluated the contribution of different species to mercury ingestion of participants. We used an estimated serving size of four ounces per meal for most fish and shellfish, and two ounces for sushi meals. This ballpark value introduces another layer of uncertainty when estimating mercury ingestion for participants who eat significantly smaller or larger servings of seafood.

SOURCES OF MERCURY FOR STUDY PARTICIPANTS

We used data from participants' self-reported fish and shellfish meals, information about the average concentration of mercury and omega-3 of commercial seafood, and assumed serving sizes to investigate the common sources of mercury and omega-3s in our participants' diets. As a group our study participants report eating more salmon and fresh tuna, and less shrimp and breaded white fish (tilapia, pangasius, catfish, pollock, and flatfish) than typical for Americans. Therefore both their mercury exposure and estimated omega-3 ingestion may be greater than the average for other frequent seafood consumers. Table 3 presents the 10 most commonly consumed species groups, and their contribution to overall mercury and omega-3 intake.

Table 3: Sources of mercury and omega-3s for study participants

Species	Percent of All Reported Meals	Percent of All Estimated Mercury Intake	Percent of All Estimated Omega-3 Ingestion
Salmon	26%	11%	45%
Shellfish	22%	11%	8%
Tuna (Canned, Steaks, Sushi)	16%	40%	14%
Canned Albacore	4%	14%	8%
Canned Light Tuna/Type Unknown	4%	7%	3%
Tuna Steaks & Sushi	7%	20%	3%
Other Lower Mercury (<0.2 ppm)	8.5%	8%	7%
Crab	5.2%	4%	3%
Cod	4.9%	6%	2%
Breaded White Fish	4.8%	1%	<1%
Other High Mercury (>=0.2 ppm)*	4.4%	12%	5%
Anchovies, Herring, Sardines, Shad	4.3%	2%	14%
Yellowtail	3%	2%	1%
Swordfish	0.2%	2%	0.4%
King Mackerel	0.1%	1%	0.1%

* including wahoo, ono, halibut, blackfish, saltwater trout, grouper, seabass, striped bass, snapper, wild caught trout, escolar, walleye, Spanish mackerel, rudderfish.

Source: EWG, from 2015 survey of 254 U.S. women of childbearing age

ESTIMATED VS. MEASURED HAIR MERCURY CONCENTRATIONS

We used participants' reported seafood meals to estimate mercury ingestion and model expected hair mercury concentrations. There was a good correlation with measured hair values, indicating that dietary data and our scaled seafood ingestion estimate were reasonably accurate indicators of mercury ingestion.

We used a one-compartment pharmacokinetic model published by Alan Stern in 1997,⁵⁷ which is commonly used to check the accuracy of self-reported fish consumption and mercury hair measurements.⁵⁸ (Appendix 3) We modeled the expected hair concentration for 222 study participants who reported their body weights, using

their self-reported seafood data and our scaled seafood consumption value. The hair mercury levels predicted by this method were slightly higher than measured values, but there was a moderate correlation between the two.

Measured hair value = 0.77 * estimated hair value, r²=0.4335

We expected some differences between estimated and measured hair values, given the multiple sources of uncertainty about actual mercury ingestion—the actual number of seafood meals eaten, the meal size and exact mercury content of these meals. Genetic and metabolic factors also affect mercury uptake, transport, storage and excretion and can lead individual values to differ widely from generic models.

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APPENDICES

Appendix 1: EWG's scaled seafood consumption value (as developed by Lincoln et al.)

$$\text{Unscaled Monthly Mercury Intake} = \text{Sum For All Species} \left[\left(\text{Mercury In Fish} \right) \times \left(\text{Serving Size} \right) \times \left(\text{Meal Per Month} \right) \right]$$

$$\text{Scaled Mercury Intake} = \frac{\text{Unscaled Mercury Intake}}{\left(\frac{\# \text{ Seafood meals in detailed survey}}{\# \text{ Seafood meals in screening survey}} \right)}$$

Appendix 2: Typical mercury and omega-3 concentrations in common species

Species	Mercury Concentration (Parts Per Million)	DHA+EPA Per 4-oz. Ounce Serving (% Weekly Recommendation)
Anchovies, Herring, Sardines, Shad	0.06	1.84 (105%)
Breaded Fish Sticks and Patties - White Fish Including Pollock, Catfish, Pansagius and Tilapia	0.02	0.09 (5%)
Canned Albacore Tuna	0.34	0.98 (18%)
Canned Light Tuna	0.12	0.31 (18%)
Canned Tuna (Type Not Reported)	0.19	0.53 (30%)
Catfish	0.02	0.08 (5%)
Clams, Scallops, Mussels, Oysters	0.03	0.12 (7%)
Cod	0.12	0.20 (11%)
Crab	0.11	0.42 (24%)
Eel	0.19	0.17 (10%)
Flatfish (Flounder, Sole, Paice)	0.11	0.28 (16%)
Freshwater Trout (Farmed)	0.04	0.92 (53%)
Haddock, Hake and Monkfish	0.16	0.45 (26%)
Halibut	0.25	1.04 (59%)
King Mackerel	1.10	0.45 (26%)

continued on next page

Species	Mercury Concentration (Parts Per Million)	DHA+EPA Per 4-oz. Ounce Serving (% Weekly Recommendation)
Lobster, Crayfish	0.17	0.22 (13%)
Mahi-Mahi	0.19	0.12 (7%)
Octopus	0.10	0.20 (11%)
Ono/Wahoo	0.27	0.38 (21%)
Oysters	0.02	0.50 (29%)
Perch and Mullet	0.09	0.29 (17%)
Pollock	0.06	0.19 (11%)
Salmon	0.05	1.08 (62%)
Scallops	0.04	0.12 (7%)
Seabass (Chilean, Striped, Black)	0.26	0.67 (38%)
Shark and Dogfish	0.26	0.96 (55%)
Shrimp or Prawns	0.05	0.07 (4%)
Snapper	0.23	0.35 (20%)
Squid (Calamari) and Octopus	0.08	0.55 (31%)
Striped Bass	0.30	0.86 (49%)
Swordfish	0.89	0.86 (49%)
Tuna Steak or Tuna Sushi	0.45	0.37 (21%)
Yellowtail (Hamachi)	0.15	0.35 (20%)

Source: EWG, from Stony Brook Seafood database, USDA National Nutrient Database and other peer-reviewed studies. For full citations see references 50-54.

Appendix 3: Mercury concentrations model

EWG estimated hair mercury concentrations using a one-compartment pharmacokinetic model as follows:

$$d = [(c * b * V) / (A * f * bw)] * HBR$$

where

d = estimated mercury intake (Ng MeHg/kg-day)

c = estimated blood concentration (Ng/L)

b = elimination constant (0.014 day⁻¹)

V = blood volume (0.037*bodyweight - kg)+1.43)

A = gastrointestinal absorption factor (0.95)

f = fraction of absorbed dose found in blood (0.059)

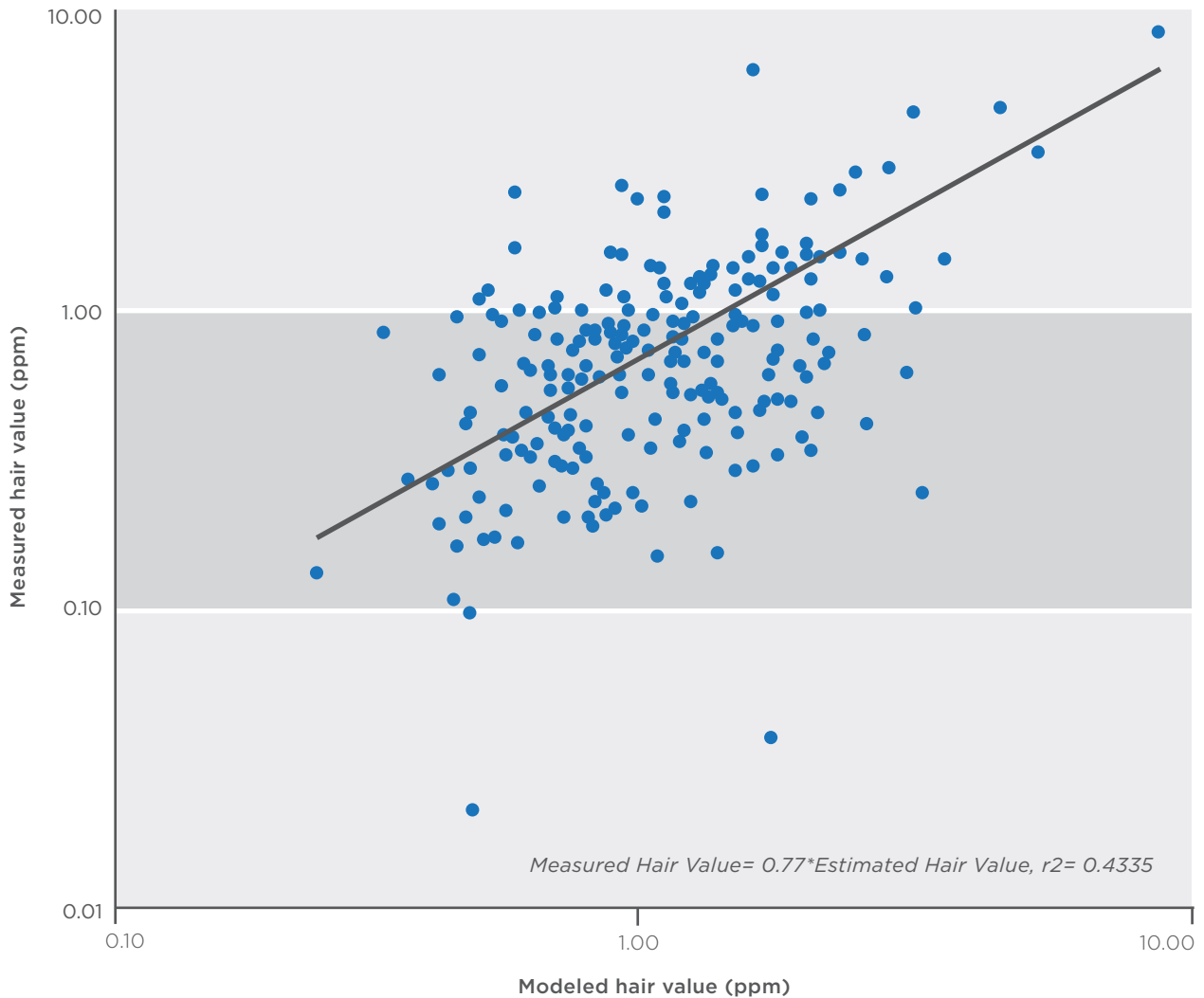
Bw = body weight (kg)

HBR = hair-to-blood ratio (250 Ng MeHg/g hair : 1 Ng MeHg/g blood

= 1 Ng MeHg/g hair : 4 Ng MeHg/L blood)

$$d = [(c * 0.014 \text{ days}^{-1} * \text{blood volume L}) / (0.95 * 0.059 * Bw \text{ (kg)})] * [(1 \text{ Ng MeHg/g hair}) / (4 \text{ Ng MeHg/L blood})]$$

Measured vs. modeled hair mercury concentrations for 222 participants self-reported seafood consumption and body weight



Source: EWG, from 2015 tests of 222 U.S. women of childbearing age