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More Than Half of US Youth Consume Seafood and Most Have Blood Mercury Concentrations below the EPA Reference Level, 2009–2012

Samara Joy Nielsen[4,*], **Yutaka Aoki**[4], **Brian K Kit**[4,5], **Cynthia L Ogden**[4]

[4]Division of Health and Nutrition Examination Surveys, National Center for Health Statistics, CDC, Hyattsville, MD;

[5]US Public Health Service, Rockville, MD

Abstract

Background: Consuming seafood has health benefits, but seafood can also contain methylmercury, a neurotoxicant.Exposure to methylmercury affects children at different stages of brain development, including during adolescence.

Objective: The objective was to examine seafood consumption and blood mercury concentrations in US youth.

Methods: In the 2009–2012 NHANES, a cross-sectional nationally representative sample of the US population, seafood consumption in the past 30 d and blood mercury concentrations on the day of examination were collected from 5656 youth aged 1–19 y. Log-linear regression was used to examine the association between frequency of specific seafood consumption and blood mercury concentration, adjusting for race/Hispanic origin, sex, and age.

Results: In 2009–2012, 62.4% ± 1.4% (percent ± SE) of youth consumed any seafood in the preceding month; 38.4% ± 1.4% and 48.5% ± 1.5% reported consuming shellfish and fish, respectively. In 2009–2012, the geometric mean blood mercury concentration was 0.50 ± 0.02 μg/L among seafood consumers and 0.27 ± 0.01 μg/L among those who did not consume seafood. Less than 0.5% of youth had blood mercury concentrations ≥5.8 μg/L. In adjusted log-linear regression analysis, no significant associations were observed between frequency of breaded fish or catfish consumption and blood mercury concentrations, but frequency of consuming certain seafood types had significant positive association with blood mercury concentrations: high-mercury fish (swordfish and shark) [exponentiated β coefficient (expβ): 2.40; 95% CI: 1.23, 4.68]; salmon (expβ: 1.41; 95% CI: 1.26, 1.55); tuna (expβ: 1.38; 95% CI: 1.29, 1.45); crabs (expβ: 1.35; 95% CI: 1.17, 1.55); shrimp (expβ: 1.12; 95% CI: 1.05, 1.20), and all other seafood (expβ: 1.23; 95% CI: 1.17, 1.32). Age-stratified log-linear regression analyses produced similar results.

Conclusion: Few US youth have blood mercury concentrations ≥5.8 μg/L, although more than half of US youth consumed seafood in the past month.

*To whom correspondence should be addressed. wjf7@cdc.gov.

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The findings and conclusions in this report are those of the authors and are not necessarily those of the CDC.

Keywords

seafood; fish; shellfish; blood mercury; youth

Introduction

The Dietary Guidelines for Americans 2010 state that seafood is part of a healthy eating pattern (1). The Dietary Guidelines for Americans 2010 also encourage increasing seafood consumption and replacing some meat and poultry with seafood (1). Seafood, both fish and shellfish, contains ω-3 FAs. ω-3 FAs help the brain and nervous system to develop in utero and during infancy and childhood (1, 2). Consumption of ω-3 FAs also positively affects cognitive function, including general intelligence, verbal ability, and motor ability (2). Methylmercury is a neurotoxicant found in seafood. Evidence shows that the health benefits from the ω-3 FAs in seafood outweigh the risks of the methylmercury in seafood (1). Individuals are encouraged to choose seafood with higher amounts of ω-3 FAs and lower amounts of methylmercury (1).

Methylmercury is a neurotoxicant associated with impaired neurologic development. Most previously published studies measure the hair mercury amounts of mothers and children (3–13). Certain studies show exposure to methylmercury can lead to developmental delays and neurologic dysfunctions (10,11). Quantitative analyses show that methylmercury exposure in utero can lead to decreased IQ scores (8) and to differences in other scholastic and psychological test scores (12). Neuropsychological dysfunctions because of mercury exposure can occur in language, attention, and memory and in visuospatial and motor functioning (13). However, no association between prenatal methylmercury exposure and adverse effects on children’s neurodevelopment, including cognitive and behavioral outcomes up to 17 y of age, was reported in the Seychelles birth cohort (3–8).

Previous studies that examine the relation between seafood consumption and mercury concentrations focus on adults (14), women of childbearing age (15–20), and infants and young children (20–26). Exposure to methylmercury can affect the central nervous system at any age but can specifically affect the different stages of brain development throughout childhood (12). The purpose of this study is to describe the consumption of seafood among US youth 1–19 y of age and to analyze the association between seafood consumption and blood mercury concentrations using the most recent nationally representative data.

Methods

Study design.

The NHANES, a nationally representative survey, measures the health and nutritional status of the civilian, noninstitutionalized US population. NHANES is conducted by the CDC’s National Center for Health Statistics. The sample is selected on the basis of a complex, multistage probability design. During 2009–2012, NHANES oversampled non-Hispanic blacks and Hispanics among other groups. NHANES was approved by the NCHS Research Ethics Review Board. Informed consent was obtained for persons 18 y and older. For participants younger than 18 y, written parental consent was obtained, and child assent was obtained for those 7–17 y.

NHANES has 2 components: an in-home interview and standardized physical assessments in the mobile examination center. Self-reported race and Hispanic origin were collected during the in-home interview. During the examination at the mobile examination center, participants' blood was drawn, and they were asked about seafood consumption in the past 30 d (27–29). For children aged 6 y and younger, a proxy respondent always responded. For children 6–8 y old the proxy was the primary respondent with help from the child. For children 9–11 y old, the child was the primary respondent with help from the proxy. In most cases, children aged 12 y and older responded for themselves (29). In 2009–2010, the unweighted NHANES examination response rate for ages 1–19 y was 86%, and in 2011–2012 it was 77% (30).

Blood mercury measurements.

Blood specimens were analyzed by the Division of Laboratory Sciences, National Center for Environmental Health, CDC. Total blood mercury was determined by quadrupole inductively coupled plasma mass spectrometry. Diluted whole blood samples are converted into an aerosol, ionized, and then fed into the mass spectrometer. More information about blood specimen processing is available (31).

Seafood consumption.

At the mobile examination center, participants answered questions about fish and shellfish consumption during the previous 30 d. Participants were asked, "During the past 30 days, did you eat any types of fish (shellfish) listed on this card? Include any foods that had fish (shellfish) in them such as sandwiches, soups, or salads." Fish included breaded fish, tuna, bass, catfish, cod, flatfish, haddock, mackerel, perch, pike, pollock, porgy, salmon, sardines, sea bass, shark, swordfish, trout, walleye, other fish, and other unknown fish. Shellfish included clams, crabs, crayfish, lobsters, mussels, oysters, scallops, shrimp, other shellfish, and other unknown shellfish. In this analysis, mutually exclusive categories of seafood consumption were presented: shellfish only, fish only, both shellfish and fish. The following specific types (consumed by ≥5% of the population) were also presented: shrimp, tuna, salmon, breaded fish, crabs, catfish, along with high-mercury fish. High-mercury fish consisted of swordfish and shark.

The Dietary Guidelines for Americans 2010 state that shark, tilefish, swordfish, and king mackerel should not be consumed by pregnant women (1). Our high-mercury fish category consisted of shark and swordfish. Data on tilefish were not collected as part of the limited FFQ. Furthermore, no distinction was made between king mackerel (high in mercury) and Atlantic and Pacific mackerel (low in mercury) in the FFQ. For this analysis mackerel was included in the all other seafood category. A similar grouping was used in a previous NHANES analysis for the adult population (14).

Covariates.

Age was categorized into 3 groups (1–5 y, 6–11 y, and 12–19 y). These age groupings were consistent with the NHANES sample design and allowed for sufficient sample size for analysis (29). Youth aged 1–5 y may be more susceptible to methylmercury exposure because of their brain development stage. Race/Hispanic origin groups were defined as non-Hispanic white, non-Hispanic black, and Hispanic (which includes Mexican American and other Hispanic persons). All other persons, including individuals reporting multiple races, were classified as other. Total estimates included persons classified as other.

Statistical analysis.

The percentage of youth consuming high-mercury fish, any seafood, shellfish only, fish only, and both shellfish and fish was estimated by age. In addition, the percentage of youth consuming the specific species listed in *Seafood consumption* was also presented.

The distribution of blood mercury was right skewed; therefore, geometric mean blood mercury was presented. Linear trends in blood mercury concentrations between age groups were examined with orthogonal polynomials. Pairwise comparisons between blood mercury among youth who do not consume seafood and blood mercury among youth in each of the seafood categories were performed for total and for each age group. The percentage of youth with blood mercury concentrations ≥5.8 µg/L, a reference concentration below which the National Research Council panel identified as being without appreciable harm (12), was also calculated. Results were based on a single log-linear regression analysis that examined the association between consumption frequencies of specific seafood types (number of times eaten in the past 30 d) and blood mercury concentration adjusted for sex, race/Hispanic origin, and age. The seafood categories in this model were mutually exclusive and included all seafood consumption.

To account for different probabilities of selection, nonresponse, and noncoverage, all analyses used examination sample weights. The SEs of the percentages were estimated with Taylor series linearization, a method that incorporated the complex sample design. All statistical tests were considered significant at $P = 0.05$. SAS version 9.3 (SAS Institute Inc.) and SUDAAN version 11.0.1 (Research Triangle Institute) were used for all statistical analyses. Data are expressed as percents or means ± SEs.

Missing data.

A total of 1313 youth (18.8%) who had seafood consumption data were missing blood mercury concentrations; 33.9%, 15.9%, and 7.6% of 1- to 5-y-olds, 6- to 11-y-olds, and 12- to 19-y-olds had missing blood mercury concentrations. When data are missing unequally in relation to the domains used for generating sampling weights, the analytical sample may no longer be representative of the underlying population. To evaluate the impact of missing data, alternative estimates of geometric mean blood mercury concentration were obtained with direct adjustment for age, sex, and race/Hispanic origin via proc wtadjust in SUDAAN (32). Estimates with and without this reweighting were similar, so the estimates without adjustments are presented. In addition, age-stratified (1–5 y, 6–19 y) analyses were also conducted.

In NHANES 2009–2012, 9114 youth 1–19 y of age were screened, 7695 were interviewed, and 7439 participated in the physical examination. Youth with missing information on seafood consumption or blood mercury concentration were excluded. Approximately 5% of youth (5.3%) were missing information on seafood consumption. This resulted in a sample size of 5656, of whom 3607 youth consumed seafood.

Results

We found that 62.4% ± 1.4% of youth reported consuming seafood during the previous 30 d (Table 1); 38.4% ± 1.4% and 48.5% ± 1.5% reported consuming shellfish and fish, respectively (results not tabulated). Fourteen percent ± 0.7% consumed shellfish only, 24.1% ± 0.9% consumed fish only, and 24.4% ± 1.3% consumed both fish and shellfish. The percentage of shellfish-only consumers increased linearly with age ($P < 0.001$), whereas the percentage of fish-only consumers decreased linearly with age ($P < 0.001$).

The specific fish and shellfish that US youth consumed, by age, are shown in Figure 1. Shrimp was the most commonly consumed seafood in all age groups; 31.7% (95% CI: 29.5%, 34.4%) of youth consumed shrimp in the previous 30 d. Tuna was consumed by 16.3% (95% CI: 14.5%,18.4%) of youth, and 12.5% (95% CI: 10.6%, 14.7%) of youth consumed salmon. Shrimp consumption increased with age ($P < 0.001$) as did crab consumption ($P < 0.001$), whereas breaded fish consumption decreased with age ($P < 0.001$). Other seafood species were consumed by 29.4% (95% CI: 26.9%, 32.5%) of youth.

Figure 2 shows the percent of youth consuming specific fish and shellfish by consumption frequency. Any seafood was consumed by 31.2% of youth 1–2 times in the past month, and 31.2% of youth consumed seafood ≥3 in the past month. In the past month, 24.5% of youth consumed shrimp 1–2 times and 7.2% consumed shrimp 3 or more times, whereas 11.9% of youth consumed tuna 1–2 times per month, and 4.4% consumed tuna 3 or more times in the past 30 d. Less than 1% of youth consumed high-mercury fish; 0.5% consumed high-mercury fish 1–2 times and 0.1% consumed high-mercury fish ≥3 times in the past 30 d.

Geometric mean blood mercury concentration was 0.40 ± 0.02 μg/L for all youth, and 0.4% of youth had blood mercury concentration ≥5.8 μg/L (not tabulated). This small percentage of youth with blood mercury concentrations at or above 5.8 μg/L did not allow for analysis by seafood consumption status. The geometric mean blood mercury concentrations by age and type of seafood consumption among US youth is shown in Figure 3. Among each category of seafood consumption (none, any seafood, shellfish only, fish only, and both fish and shellfish), blood mercury concentration was higher among the older adolescents ($P < 0.05$). For example, among youth who consumed any seafood, geometric mean blood mercury concentration was 0.36 ± 0.02 μg/L among 1- to 5-y-olds, 0.46 ± 0.01 mg/L among 6- to 11-y-olds, and 0.60 ± 0.03 μg/L among 12- to 19-y-olds. Trends were also significant for shellfish-only consumers, fish-only consumers, and both fish and shellfish consumers ($P < 0.001$).

Among consumers of any seafood, geometric mean blood mercury concentration was 0.50 ± 0.02 μg/L, which is significantly higher ($P < 0.05$) than among youth who did not consume seafood (0.27 ± 0.01 μg/L). Among both fish and shellfish consumers, the geometric mean blood mercury concentration was 0.65 ± 0.03 μg/L, significantly higher ($P < 0.05$) than among youth who did not consume seafood.

Log-linear regression results showed that frequency of specific seafood species consumption had a positive association with blood mercury concentrations (Table 2). Consumption of certain seafood was associated with blood mercury concentrations. The adjusted exponentiated β coefficients for blood mercury concentrations associated with unit increase in monthly consumption were 2.40 (95% CI: 1.23, 4.68) for high-mercury fish, 1.41 (95% CI: 1.26, 1.55) for salmon, 1.38 (95% CI: 1.29, 1.45) for tuna, 1.35 (95% CI: 1.17, 1.55) for crabs, 1.12 (95% CI: 1.05, 1.20) for shrimp, and 1.23 (95% CI: 1.17, 1.32) for all other seafood. For example, compared with no tuna consumption, consumption of tuna once per month was associated with 1.38 times higher blood mercury concentration. Similarly, compared with no tuna consumption, consumption of tuna twice per month was associated with $1.38^2 = 1.90$ times higher blood mercury concentration. No association was found for consumption of breaded fish or catfish. Age-stratified models showed similar results for the age groups of 1–5 y and 6–19 y (data not shown).

Discussion

In 2009–2012, ~60% of US youth consumed seafood in the past month. Almost half of youth (48.5%) consumed fish, and ~38% consumed shellfish in the past month. Less than 0.5% of youth had blood mercury concentrations ≥5.8 μg/L; however, frequency of certain seafood consumption was positively associated with blood mercury concentrations.

These results are different from those among adults (14). Most adults (83%), aged 20 y and older, consumed seafood. Although blood mercury concentrations are associated with specific types of seafood consumption, including high-mercury fish, tuna, salmon, and other seafood, the percentage of adults with blood mercury concentrations ≥5.8 μg/L is almost 4.6% (14).

These results are similar to previous results that were based on national data on US children (20–22); however, the present analyses expanded the range of ages examined and were based on more recent data. In the previous analyses that were based on data from NHANES 1999–2002, only young children ages 1–5 y and women of childbearing age were examined (20–22). Similar to these other studies, we found that geometric mean blood mercury concentrations were well below 1.0 mg/L. In 1999–2002, the geometric mean blood mercury concentrations was 0.33 μg/L (95% CI: 0.30, 0.37) for 1- to 5-y-olds (21), and in this study we reported a value of 0.40 ± 0.02 μg/L for all youth ages (1–19 y).

High-mercury concentrations in some children were previously reported. Among 155 Inuit children with an average age of 25 mo, 14% had blood mercury concentrations greater than the Canadian blood guidance concentration (40 nmol/L = ~8 μg/L as opposed to the US reference concentration of 5.8 μg/L) (24). Blood mercury concentrations in this population were associated with consumption of seal meat (24). Other studies have also shown high concentrations of mercury (using various mercury measures) in specific groups of children in cultures that consume high quantities of seafood (23, 26).

Most exposure to mercury in the United States is from methylmercury in seafood (16). One way to assess recent mercury exposure, especially methylmercury exposure from seafood consumption, is blood mercury concentration (12). Our study examined only seafood consumption and did not examine other potential sources of mercury exposure, including dental amalgams and thimerosal (33). Thimerosal's half-life is short (5.6 d) (34), and most vaccinations no longer have thimerosal, so this would not likely contribute significantly to blood mercury concentration. Mercury released from dental amalgam is primarily inorganic, yet some studies do show an association between dental amalgams and blood mercury concentration (35–38). Mercury found in the blood is almost entirely organic mercury, specifically methylmercury (12, 34). Nonetheless, our results showed that youth who did not consume seafood had measurable concentrations of mercury. The potential sources of mercury in these youth include seafood that was consumed but not reported and seafood consumed before the previous 30 d.

In our study, older age was found to be associated with higher blood mercury concentrations. A possible reason for this is the different types of seafood eaten by older children and adolescents compared with the types consumed by younger children. Adolescents, in fact, were found to consume less breaded fish and more salmon than younger children. Breaded fish was not associated with higher mercury concentrations, whereas salmon consumption was associated with higher blood mercury concentrations.

This analysis has some limitations. Seafood consumption data do not contain portion size information, whereas the amount of mercury an individual consumes is based on the amount of fish consumed (and the mercury amount in the fish). Furthermore, depending on the child's age, multiple respondents answered the seafood consumption questions which may have affected the results. As mentioned earlier, seafood consumed before the previous 30 d was also missed. In addition, approximately one-fifth of youth were missing blood mercury concentrations. Evaluation of the impact of the missing data, however, showed estimates to be similar even after reweighting the data. Age-stratified log-linear regression analyses produced estimates almost identical to those shown in Table 2.

This study has 3 main strengths. The analysis examined all US youth and not just young children. Furthermore, type and frequency of seafood consumption were considered. Finally, both blood mercury and seafood consumption reflected similar time frames. The half-life of blood mercury is ~50 d (12), and seafood consumption was measured for the past 30 d.

Our results show that >60% of youth report consuming seafood during the past 30 d. The Dietary Guidelines for Americans 2010 encourage seafood consumption for everyone, including youth; however, <50% of youth consume fish and <40% consume shellfish. Less than 0.5% of children 1–19 y of age has blood mercury concentrations ≥5.8 μg/L.

Acknowledgments

SJN and CLO designed the research; SJN, YA, and BKK analyzed the data; SJN, YA, BKK, and CLO wrote the paper; SJN had primary responsibility for the final content. All authors read and approved the final manuscript.

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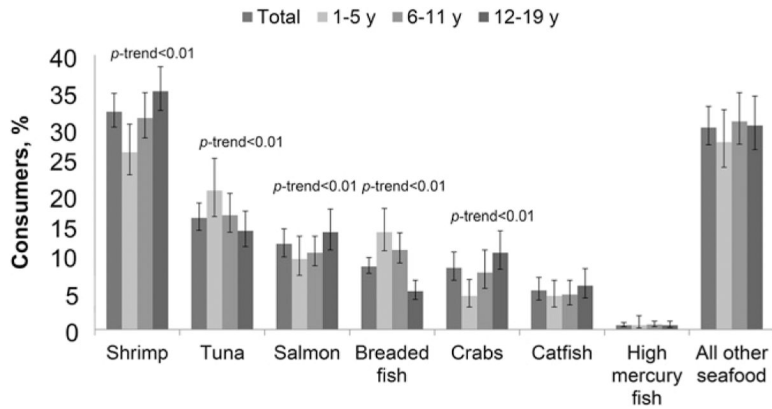

FIGURE 1.

Percentage of US youth aged 1–19 y who consumed specific fish and shellfish in the past 30 d, by age, NHANES 2009–2012. Total (n = 5656), 1–5 y (n = 1486), 6–11 y (n = 1943), and 12–19 y (n = 2227). Significant linear trend by age for shrimp, tuna, salmon, breaded fish, and crabs, $P < 0.01$. The 12- to 19-y-olds were significantly different than both the 1- to 5-y-olds and the 6- to 11-y-olds for breaded fish.

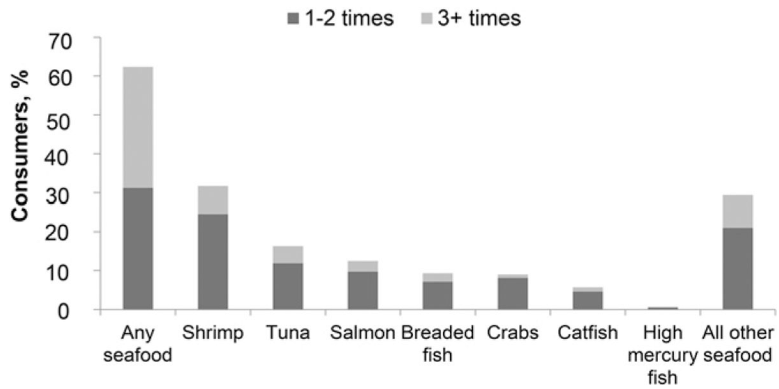

FIGURE 2.

Percentage of US youth aged 1–19 y who consumed specific fish and shellfish by frequency in the past 30 d, NHANES 2009–2012. $n = 5656$.

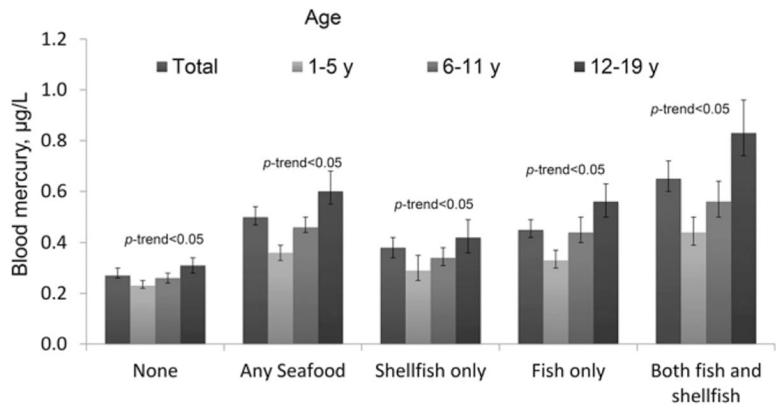

FIGURE 3.

Geometric mean blood mercury (µg/L) (95% CI) by type of seafood consumption in the past 30 d and age for US youth aged 1–19 y, NHANES 2009–2012. Total (n = 5656), 1–5 y (n = 1486), 6–11 y (n = 1943), and 12–19 y (n = 2227). Significant linear trend by age for none, any seafood, shellfish only, fish only and both fish and shellfish, $P < 0.05$ (pairwise comparison between the youngest and oldest age group). None is significantly different from each seafood category except for shellfish only, 1- to 5-y-olds, $P < 0.05$.

TABLE 1

US youth who consume shellfish or fish by age group, sex, and Hispanic origin, NHANES 2009–2012[1]

	Any	Shellfish only	Fish only	Both shellfish and fish
Age group				
Total (n = 5656)	62.4 ± 1.4	14.0 ± 0.7	24.1 ± 0.9	24.4 ± 1.3
1–5 y (n = 1486)	62.3 ± 2.1	9.2 ± 1.2	32.2 ± 1.3	21.0 ± 2.1
6–11 y (n = 1943)	62.1 ± 1.7	12.0 ± 1.0	25.0 ± 1.3	25.0 ± 1.6
12–19 y (n = 2227)	62.7 ± 2.0	17.2 ± 1.1	20.0 ± 1.1	25.5 ± 1.7
P-trend		0.001	0.001	0.05
Sex[2]				
Male (n = 2929)	63.5 ± 1.3	13.7 ± 0.9	24.5 ± 1.0	25.2 ± 1.4
Female (n = 2727)	61.3 ± 1.8	14.2 ± 0.8	23.6 ± 1.3	23.5 ± 1.6
Race/Hispanic origin[3]				
Non-Hispanic white (n = 1518)	60.3 ± 2.1	13.6 ± 1.1	23.7 ± 1.7	23.0 ± 1.9
Non-Hispanic black (n = 1420)	69.2 ± 1.9	14.5 ± 1.3	27.7 ± 1.3	27.0 ± 1.3
Hispanic (n = 2096)	61.2 ± 2.1	14.1 ± 1.2	23.4 ± 1.2	23.7 ± 2.0

[1]Values are percents ± SEs and are based on seafood consumption in the past 30 d.

[2]No statistically significant differences are found between males and females.

[3]Among any seafood consumers, non-Hispanic blacks are significantly different than non-Hispanic whites and Hispanics, $P <$, 0.01; for shellfish only, fish only, and both fish and shellfish all race/Hispanic groups are not significantly different from one another.

TABLE 2

Change in blood mercury concentration (μg/L) for each unit increase per month in seafood consumption among US youth, NHANES 2009–2012[1]

Seafood consumption	Unadjusted change (95% CI)	Adjusted change[2] (95% Cl)
Shrimp	1.15 (1.07, 1.23)	1.12 (1.05, 1.20)
Tuna	1.35 (1.29, 1.45)	1.38 (1.29, 1.45)
Salmon	1.41 (1.26, 1.55)	1.41 (1.26, 1.55)
Breaded fish	0.93 (0.85, 1.02)	1.00 (0.91, 1.07)
Crabs	1.38 (1.20, 1.58)	1.35 (1.17, 1.55)
Catfish	1.02 (0.89, 1.17)	0.98 (0.85, 1.10)
High-mercury fish	2.19 (1.15,4.27)	2.40 (1.23,4.68)
All other seafood	1.26 (1.17, 1.32)	1.23 (1.17, 1.32)

[1] *n* = 5656. Based on frequency of seafood consumption in the past 30 d.

[2] Adjusted for race/Hispanic origin, sex, and age group.