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Blood mercury concentrations in pregnant and non-pregnant women in the United States; National Health and Nutrition Examination Survey 1999–2006

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Abstract

Background—Prenatal exposure to methylmercury is associated with adverse neurological development in children. We examined total blood mercury (BHg) concentrations and predictors of higher BHg concentrations in pregnant and non-pregnant women.

Methods—We analyzed data from 1,183 pregnant and 5,587 non-pregnant women aged 16–49 years from the 1999–2006 National Health and Nutrition Examination Survey (NHANES). We estimated geometric mean BHg concentrations and characteristics associated with higher mercury concentrations (≥3.5 μg/L) in crude and adjusted linear and logistic regression models.

Results—After adjusting for age and race/ethnicity, geometric mean BHg concentrations were clinically similar but significantly lower for pregnant (0.81 μg/L, 95% confidence interval [CI]: 0.71, 0.91) and non-pregnant women of childbearing age (0.93 μg/L, 95% CI: 0.87, 0.99); 94% of pregnant and 89% of non-pregnant women had BHg concentrations below 3.5 μg/L. The most significant predictor of higher BHg concentrations for both pregnant and non-pregnant women was any seafood consumption vs. no consumption in the last 30 days (Odds ratio [OR]: 18.7, 95% CI: 4.9, 71.1; OR: 15.5, 95% CI: 7.5, 32.1, respectively). Other characteristics associated with ≥3.5 μg/L BHg concentrations were older age (35+ years), higher education (greater than high school), and higher family income to poverty ratio (3.501+) for both pregnant and non-pregnant women.

Conclusion—Pregnancy status was not strongly associated with BHg concentrations in women of childbearing age and BHg concentrations above the 3.5 μg/L cut were uncommon.

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Disclosure Statement
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The findings and conclusion in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention

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Keywords

pregnant; mercury; seafood; NHANES

Introduction

Mercury is a naturally-occurring element that is widespread in the environment and exists as elemental, inorganic, and organic mercury (methylmercury) [1]. Inorganic and elemental mercury, measured in urine, are usually associated with dental amalgams, occupational exposures, and herbs and medicines adulterated with inorganic mercury [2]. Methylmercury (MeHg) exposure, which can be estimated by measuring concentrations in blood and hair comes almost exclusively from consumption of fish or shellfish [1,3–5]. Studies have consistently reported that increasing frequency of seafood intake is the single most influential predictor of blood MeHg concentrations [6–9].

Fetuses are a high-risk group for MeHg exposure because of the increased susceptibility of the developing brain to environmental insults [1,10]. Three long-term studies, the Seychelles Island study [11–13], the Faroe Islands study [14–16], and a third study conducted in New Zealand[17–19], have investigated MeHg in children who were prenatally exposed to MeHg through maternal seafood consumption. MeHg dose-related deficits in tests of memory, attention, and language were observed in children of different ages [13–16,19]. Given that permanent damage to the developing brain can occur, MeHg exposure in pregnant women is a source for concern [10]. The US Environmental Protection Agency (EPA) set the reference dose (RfD) - a dose which is unlikely to have deleterious effects - for MeHg at 0.1 μg/Kg/day [20].

Total blood mercury (BHg) includes all form of mercury and is used in biomonitoring as a proxy for MeHg, although the distribution of mercury types in blood can vary [6,21,22]. Although the RfD varies by body weight, the value 5.8 μg/L (ppb) for BHg has been widely used in place of a weight-specific value in studies of mercury concentrations and health outcomes [23]. Originally, it was thought that cord blood and maternal blood mercury levels were equivalent when calculating the RfD [20]; however, studies comparing maternal and cord blood concentrations of MeHg have found that cord-blood mercury is higher than maternal blood mercury. According to the EPA, a review of the literature identified 21 studies that reported cord-blood mercury and maternal blood mercury data; these data indicated that cord-blood mercury concentrations are higher than maternal mercury concentrations, with a ratio of approximately 1.7 [20,24–26]. Studies have therefore suggested and used a lower RfD reflecting exposures equivalent to RfD of 3.5 μg/L total blood mercury concentration [24–26].

Two previous studies have examined and compared BHg concentrations in pregnant and non-pregnant women; one reported no significant differences between the two groups using hair total mercury concentrations from NHANES 1999–2000 [27], and the other found significantly lower concentrations of total BHg in pregnant women aged 17–39 years using NHANES 2003–2010 [28]. The objective of our study was to assess whether predictors of BHg concentrations were the same in pregnant and non-pregnant women.

Methods

Data Source

We used the National Health and Nutrition Examination Survey (NHANES) data obtained from 1999 through 2006. NHANES is a stratified, multistage probability sample of the civilian, noninstitutionalized population of the U.S. conducted by the National Center for Health Statistics (NCHS) of the U.S. Centers for Disease Control and Prevention (CDC). The NCHS Research Ethics Review Board approved the NHANES protocol. The consent form to participate in the survey as well to store specimens of their blood for future research were signed by all participants of the survey. NHANES includes an in-home questionnaire and an examination at a Mobile Examination Center (MEC) [29,30].

Study Sample

Our study included all women 16–49 years of age, who completed both the interview and examination portions of NHANES. The NHANES variable RIDEXPREG was used to determine pregnancy status for this analysis. Women who were identified as pregnant through a positive lab pregnancy test or who self-reported as pregnant at the time of the interview were considered pregnant and those who specified that they were not pregnant at the time of the interview and who did not test positive in the lab pregnancy test were considered non-pregnant. Women with missing pregnancy status and those for whom pregnancy status could not be ascertained were not included in this analysis. NHANES 1999–2006 were used for this study since pregnant women aged 15–39 years were oversampled during these years. We excluded NHANES 2007–2010 because pregnant women were no longer oversampled during this time and therefore they would have been disproportionately represented in the analysis, with much less stable estimates able to be produced from these later data. In addition, beginning in 2007 the age ranges included in the public release dataset for pregnant women were restricted to 20 to 44 years of age, while for previous years there was essentially no bound (variable available for ages 8 to 59 years).

Blood Mercury Measurement

Total blood mercury (BHg) was measured in micrograms per liter (μg/L) of whole blood using cold vapor atomic absorption spectrometry for NHANES 1999–2002, and inductively-couple plasma dynamic reaction cell mass spectrometry for NHANES 2003–2006. There is no documentation of differences due to methodologic changes in BHg measurement. Analysis of blood samples was done at the CDC’s Division of Laboratory Sciences, National Center for Environmental Health (NCEH). Other than measurement technique, no changes in lab procedures or equipment were reported over the study period. The BHg limit of detection (LOD) for both methods was 0.14 μg/L; 58 pregnant and 197 non-pregnant women in this study had BHg concentrations below 0.14 μg/L (weighted percentages: 5.6 and 3.2, respectively). According to the NHANES, results below the LOD are replaced with a value equal to the detection limit divided by the square root of two. These values in NHANES cycles for this analysis were 0.07 and 0.1 and were used for our analysis. We excluded pregnant (N=77) and non-pregnant (N=261) women with missing blood mercury concentrations. Because we were primarily interested in the potential for fetal exposure to

MeHg, we defined maternal methyl mercury concentrations at or above 3.5 μg/L as high exposure concentrations [24–26].

Mercury intake via Fish and Shellfish Consumption and Other Covariates

Survey participants, including all women aged 16 to 49 years of age, were asked about fish and shellfish consumption during the previous 30 days. Respondents were asked whether they consumed fish and/or shellfish in the past 30 days, and if so, the frequency of consumption during that time. Participants were then asked about consumption of different types of fish and shellfish including a category for "other and unknown" fish or shellfish. No information was obtained about portion sizes or preparation methods.

Demographic information including race and ethnicity, educational attainment, and income and family size were self-reported at the time of the interview. We categorized race and ethnicity into the following categories: non-Hispanic white, non-Hispanic black, Mexican American and other race/ethnicity, which includes other Hispanics, Asians, Pacific Islanders, Native Americans, Alaskan Natives, and those with multiple races and/or ethnicities. NHANES data do not allow representative estimates to be made for racial/ethnic subgroups other than non-Hispanic white, non-Hispanic Black and Mexican Americans, therefore, these subgroups were combined. Family income to poverty ratio (FIPR) is the total household income divided by the poverty threshold for the year of the interview. The poverty threshold is determined annually by the U.S. Census Bureau, taking into account geographic location, rate of inflation, and family size [31].

Statistical Analysis

Analyses were conducted using SAS (version 9.3; SAS Institute, Cary, NC) and SUDAAN (version 10.0; Research Triangle Institute, Research Triangle Park, NC). MEC examination sample weights and the appropriate sample design variables were used in the analysis to account for the complex survey design, oversampling, and differential nonresponse and noncoverage in order to obtain nationally representative estimates of the U.S. civilian non-institutionalized population.

The distribution of BHg concentrations in pregnant and non-pregnant women were described through the calculation of percentiles and geometric means. SUDAAN's Taylor series linearization method was used to calculate 95% confidence intervals (CIs) for the estimated prevalences, and chi-square statistics were used to compare pregnant to non-pregnant women. We estimated both crude and adjusted geometric means of mercury concentration, with age group and race/ethnicity controlled for in the adjusted estimate. Logistic regression was used to examine the potential associations between having high BHg concentrations and selected characteristics including age, race/ethnicity, education, socioeconomic status, and seafood consumption in pregnant and, separately, non-pregnant women.

Results

We analyzed data on 6,770 women: 1,183 pregnant and 5,587 non-pregnant women from 1999 to 2006 who had completed interviews, exams, and valid pregnancy data. Geometric mean BHg concentrations were significantly lower in pregnant women compared to non-pregnant women (0.71 and 0.92 μg/L, respectively; $p<0.0001$). After adjustment for age and race/ethnicity, the difference in geometric mean BHg concentration between the groups was smaller, 0.81 and 0.93μg/L, respectively, although still statistically significant (Table 1). We also examined geometric mean BHg concentrations by trimester of pregnancy alone as well as adjusting for age and found no significant differences by trimester of pregnancy (p=0.88). There were statistically significant differences between pregnant and non-pregnant women by age (p=<0.0001) and race/ethnicity (p=<0.0001). Among pregnant women, 91% were younger than 35 years of age, compared to approximately 53% of non-pregnant women; and a greater percentage of pregnant women were Mexican American compared to non-pregnant women, approximately 16% and 9%, respectively (Table 1). Pregnant women were less likely to have reported consuming any seafood (fish or shellfish) compared to non-pregnant (73.0% and 78.1%, respectively; p=0.05), and fish specifically (62.5% and 68.8%, respectively; p=0.03) in the last 30 days but not shellfish. There were no significant differences observed between pregnant and non-pregnant women in education level or family income to poverty ratio (Table 1).

In examining the factors associated with having a high BHg concentration (at or above 3.5 μg/L), we observed that pregnancy status was not a strong predictor after adjusting for other factors (Odds Ratio [OR] for pregnant vs. non-pregnant: 0.7; 95% CI: 0.5, 1.0). Reported seafood consumption was the strongest predictor of high BHg concentrations for both pregnant (OR: 18.7; 95% CI: 4.9, 71.1) and non-pregnant (OR: 15.5; 95% CI: 7.5, 32.1) women. Among non-pregnant women, other factors significantly associated with high BHg concentrations were increasing age (OR for 26–35 vs. 16–25 years: 1.8; 95% CI: 1.3, 2.5; OR for 36–49 vs. 16–25 years: 2.0; 95% CI: 1.5, 2.7), other/multiracial ethnicity (OR compared to non-Hispanic white: 2.2; 95% CI: 1.4, 3.4), greater than high school education (OR compared to less than high school: 1.4; 95% CI: 1.0, 1.9), and higher family income to poverty ratio (OR for FIPR>3.5 compared to FIPR≤1.3: 95% CI: 2.1; 1.4, 3.3) for non-pregnant women. Similar, but non-significant patterns were observed for pregnant women, for whom the sample size was smaller (Table 2).

We assessed trends in BHg concentrations stratified by several factors among both pregnant and non-pregnant women, for which similar patterns were seen. Overall, 94% of pregnant and 89% of non-pregnant women had BHg concentrations below 3.5 μg/L. BHg concentrations increased with increasing age for both pregnant and non-pregnant women (Figure 1). There was little difference in the distribution of BHg concentrations by race/ethnicity (Figure 2), except among those in the highest 20% of the distribution, for whom non-Hispanic whites and those classified in the "other" race/ethnicity group had higher BHg concentrations than non-Hispanic blacks or Mexican Americans; Mexican Americans had the lowest BHg concentrations across the entire distribution for both groups. BHg concentrations also increased with increasing educational attainment (Figure 3) and FIPR (Figure 4), with both pregnant and non-pregnant women with highest education and FIPR having markedly higher BHg concentrations. Increasing seafood consumption was associated with higher BHg concentrations for both pregnant and non-pregnant women (Figure 5), with over 10% of women in each group who consumed seafood on 3 or more occasions in the past 30 days having BHg above 3.5μg/L.

To assess whether differences in the types of seafood consumed could explain the small but statistically significant difference in the adjusted geometric mean BHg concentrations observed among pregnant and non-pregnant women, we estimated the geometric mean BHg concentrations for pregnant and non-pregnant women stratified by seafood intake. After adjusting for age group and race/ethnicity, the geometric mean BHg concentration among those who reported consumption of seafood in the past 30 days was 0.93μg/L (95% CI: 0.89, 0.98) for pregnant women and 1.10μg/L (95% CI: 1.07, 1.13) for non-pregnant women ($p=0.004$). Among those who reported no consumption of seafood in the past 30 days, the adjusted geometric mean BHg among pregnant women was 0.45 (95% CI: 0.38, 0.52) μg/L and among non-pregnant women was 0.47 (95% CI: 0.43, 0.50) μg/L ($p=0.64$).

Discussion

We observed that geometric mean BHg concentrations were slightly, but statistically significantly, lower in pregnant women compared to non-pregnant women after adjusting for age and race/ethnicity. Given that the most significant driver of high BHg concentrations was seafood consumption for both pregnant and non-pregnant women, the lower concentrations of BHg in pregnant women may be due to fewer pregnant women consuming any seafood at all (a finding supported by this analysis), consuming fewer servings of seafood, and/or properly avoiding high risk seafood species. Our findings complement the findings of the only other study of which we are aware using BHg concentrations where they also found lower levels of BHg concentrations in pregnant women [28].

The United States Food and Drug Administration (FDA) as well as the EPA have issued warnings recommending that pregnant women and women of childbearing age who may become pregnant avoid consumption of certain types of fish that have high concentrations of mercury including shark, swordfish, king mackerel, and tile fish [32,33]. Many local and state agencies issue additional fish advisories and bans relating to locally caught fish [33,34]. Although the FDA and EPA also advise consumption of two servings per week of seafood with low mercury levels, such as shrimp and salmon [32,33], these messages may not be as well-understood by pregnant women and their health care providers. A qualitative study of fish consumption during pregnancy reported that many pregnant women knew that fish might contain mercury and had received advice on limiting fish consumption but had not received advice on the types of fish that are safer to consume or contain less mercury. As such, they reported that they avoided fish consumption altogether [35]. Our finding of lower BHg concentrations among pregnant women could also be partially due to the fact that pregnant women who consume seafood are consuming seafood less often than non-pregnant women or that they are consuming fish low in mercury as observed in related analysis conducted by our research group (data unpublished). These potential explanations are supported by the geometric mean BHg estimates stratified by seafood consumption and could possibly be due to pregnant women adhering to recommendations put forth by the FDA [32] and EPA [34] about which fish to eat during pregnancy.

Although there are concerns with MeHg exposure during pregnancy because of the high susceptibility of the developing brain [1,10]; fish and shellfish are also the primary dietary sources of long-chain Omega 3 (N-3) polyunsaturated fatty acids, specifically docosahexaenoic acid (DHA) and eicosapentaenoic acid, which are essential for optimal neurodevelopment of the fetus during pregnancy and infancy through breastmilk exposure [33,36–40]. The Dietary Guidelines for Americans 2010, from the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (HHS), recommends consumption of at least 8 ounces of variety of seafood per week for the general public corresponding to intake of an average of 250 mg/d of fatty acids, including DHA. These Guidelines also include the recommendation for pregnant and breastfeeding women to consume 8 to 12 ounces of variety of seafood per week to receive the benefits from fatty acids with the onus on the obstetricians to discuss the types of seafood and servings that are appropriate[41].

Strengths of our study include its large sample size; oversampling of pregnant women during the 1999–2006 NHANES allowed us sufficient power to stratify our analysis and make comparisons between pregnant and non-pregnant women. One limitation is that as the reference doses for mercury are based on total blood mercury, therefor total blood mercury was used as a proxy for methylmercury. There are also several limitations of the NHANES data on seafood consumption. Self-reported data on fish and shellfish consumption in the past 30 days is subject to misreporting. Not all types of higher mercury fish were specifically queried, and even among those that were queried we did not have power to examine BHg concentrations by the type of seafood that was consumed. In addition, the data did not contain information about serving size or cooking methods for seafood.

While it is reassuring that the majority of pregnant women did not have BHg levels above the reference dose (≥3.5 μg/L), our observation that almost 1 out of 4 pregnant women consumed no seafood in the past 30 days is of concern given the important nutrients contained in seafood. Additional measures may be needed to increase awareness of how to balance the benefits and risks of seafood consumption during pregnancy and breastfeeding.

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References

1. US EPA. Mercury Study Report to Congress, Volume I: Exececutive summary. Washington, DC: Environmnetal Protection Agency; 1997. Publication EPA-452/R-97-003
2. Dye B, Schober S, Dillon C, et al. Urinary mercury concentrations associated with dental restorations in adult women aged 16–49 years: United States, 1999–2000. Occupational and Environmental Medicine. 2005; 62(6)
3. Knobeloch L, Gliori G, Anderson H. Assessment of methylmercury exposure in Wisconsin. Environmental Research. 2007; 103(2):205–210. [PubMed: 16831413]
4. Zhang Y, Nakai S, Masunaga S. An Exposure Assessment of Methyl Mercury via Fish Consumption for the Japanese Population. Risk Analysis. 2009; 29(9):1281–1291. [PubMed: 19645754]

5. Esteban-Vasallo MD, Aragonés N, Pollan M, López-Abente G, Perez-Gomez B. Mercury, Cadmium and Lead Levels in Human Placenta: A Systematic Review. Environmental health perspectives. 2012
6. Mahaffey KR, Mergler D. Blood Levels of Total and Organic Mercury in Residents of the Upper St. Lawrence River Basin, Québec: Association with Age, Gender, and Fish Consumption. Environmental Research. 1998; 77(2):104–114. [PubMed: 9600803]
7. Weihe P, Grandjean P, Debes F, White R. Health implications for Faroe Islanders of heavy metals and PCBs from pilot whales. Science of The Total Environment. 1996; 186(1–2):141–148. [PubMed: 8685706]
8. Schober SE, Sinks TH, Jones RL, et al. Blood mercury levels in US children and women of childbearing age, 1999–2000. the journal of the American Medical Association. 2003; 289(13): 1667–1674. [PubMed: 12672735]
9. Mahaffey KR, Clickner RP, Jeffries RA. Adult women's blood mercury concentrations vary regionally in the United States: association with patterns of fish consumption (NHANES 1999–2004). Environmental health perspectives Jan. 2009; 117(1):47–53.
10. National Research Council. Toxicologic Effects of Methylmercury. Washington, DC: National Academy Press; 2000.
11. Davidson PW, Myers GJ, Cox C, et al. Longitudinal neurodevelopmental study of Seychellois children following in utero exposure to methylmercury from maternal fish ingestion: outcomes at 19 and 29 months. Neurotoxicology. 1995; 16(4)
12. Davidson PW, Myers GJ, Cox C, et al. Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment: outcomes at 66 months of age in the Seychelles Child Development Study. the journal of the American Medical Association. 1998; 280(8):701–707. [PubMed: 9728641]
13. Davidson PW, Strain JJ, Myers GJ, et al. Neurodevelopmental effects of maternal nutritional status and exposure to methylmercury from eating fish during pregnancy. Neurotoxicology. 2008; 29(5): 767–775. [PubMed: 18590763]
14. Grandjean P, Weihe P, White RF, Debes F. Cognitive performance of children prenatally exposed to "safe" levels of methylmercury. Environmental research. 1998; 77(2):165–172. [PubMed: 9600810]
15. Grandjean P, Budtz-Jørgensen E, White RF, et al. Methylmercury Exposure Biomarkers as Indicators of Neurotoxicity in Children Aged 7 Years. American Journal of Epidemiology. 1999; 150(3):301–305. [PubMed: 10430235]
16. Grandjean P, Weihe P, White RF, et al. Cognitive Deficit in 7-Year-Old Children with Prenatal Exposure to Methylmercury. Neurotoxicology and Teratology. 1997; 19(6):417–428. [PubMed: 9392777]
17. Kjellstrom, T.; Kennedy, P.; Wallis, S.; Mantell, C. National Swedish Environmental Protection Board Report 3080. Solna, Sweden: 1986. Physical and mental development of children with prenatal exposure to mercury from fish. Stage I: Preliminary tests at age 4.
18. Kjellstrom, T.; Kennedy, P.; Wallis, S., et al. National Swedish Environmental Protection Board Report 3642. Solna, Sweden: 1989. Physical and mental development of children with prenatal exposure to mercury and fish. Stage II: Interviews and psychological tests at age 6.
19. Crump KS, Kjellstrom T, Shipp AM, Silvers A, Stewart A. Influence of prenatal mercury exposure upon scholastic and psychological test performance: benchmark analysis of a New Zealand cohort. Risk analysis: an official publication of the Society for Risk Analysis. 1998; 18(6):701–713. [PubMed: 9972579]
20. United States Environmental Protection Agency. [Accessed April 17, 2013] Integrated Risk Information System (IRIS): Methylmercury (MeHg). 2002. http://www.epa.gov/iris/subst/0073.htm
21. Grandjean P, Weihe P, Jorgensen PJ, Clarkson T, Cernichiari E, Videro T. Impact of maternal seafood diet on fetal exposure to mercury, selenium, and lead. Archives of environmental health. 1992; 47(3):185–195. [PubMed: 1596101]
22. Hansen JC, Tarp U, Bohm J. Prenatal exposure to methyl mercury among Greenlandic polar Inuits. Archives of environmental health. 1990; 45(6):355–358. [PubMed: 2270954]

23. Mahaffey K, Sunderland E, Chan H, et al. Balancing the benefits of n-3 polyunsaturated fatty acids and the risks of methylmercury exposure from fish consumption. Nutrition reviews. 2011; 69(9): 493–508. [PubMed: 21884130]
24. Stern A. A revised probabilistic estimate of the maternal methyl mercury intake dose corresponding to a measured cord blood mercury concentration. Environmental health perspectives. 2005; 113(2):155–163. [PubMed: 15687052]
25. Stern A, Smith A. An assessment of the cord blood:maternal blood methylmercury ratio: implications for risk assessment. Environmental health perspectives. 2003; 111(12):1465–1470. [PubMed: 12948885]
26. Council NR. Seafood Choices. Committee on Nutrient Relationships in Seafood, Food and Nutrition Board, Institute of Medicine; Washing, DC: National Academy Press; 2006. Selections to Balance Benefits and Risks.
27. McDowell MA, Dillon CF, Osterloh J, et al. Hair mercury levels in U.S. children and women of childbearing age: reference range data from NHANES 1999–2000. Environmental health perspectives. 2004; 112(11):1165–1171. [PubMed: 15289161]
28. Jain R. Effect of pregnancy on the levels of blood cadmium, lead, and mercury for females aged 17–39 years old: data from National Health and Nutrition Examination Survey 2003–2010. Journal of toxicology and environmental health. Part A. 2013; 76(1):58–69. [PubMed: 23151210]
29. National Center for Health Statistics. National Health and Nutrition Examination Survey: 1999–2012. Survey connts. 2012. http://www.cdc.gov/nchs/data/nhanes/survey_content_99_12.pdf
30. National Center for Health Statistics. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey. 2012. http://www.cdc.gov/nchs/nhanes/about_nhanes.htm
31. U.S. Census Bureau. How the census bureau measures poverty (official measure). http://www.census.gov/hhes/www/poverty/about/overview/measure.html
32. Center for Food Safety and Applied Nutition, US Food and Drug Administationm. [Accessed August 10, 2012] An important message for pregnant women and women of childbreaing age who may become pregnant about the risks of mercury in fish. http://www.fda.gov/Food/ResourcesForYou/Consumers/ucm110591.htm
33. Nesheim, M.; Yaktine, A. Seafood choices: Balancing Benefits and Risks. The National Academics Press; 2007.
34. United States Environmental Protection Agency. [Accessed August 10, 2012] Fish advisories. http://www.epa.gov/ost/fish/
35. Bloomingdale A, Guthrie LB, Price S, et al. A qualitative study of fish consumption during pregnancy. The American journal of clinical nutrition. 2010; 92(5):1234–1240. [PubMed: 20844071]
36. Hosomi R, Yoshida M, Fukunaga K. Seafood consumption and components for health. Global Journal of Health Science. 2012; 4(3):72–86. [PubMed: 22980234]
37. Oken E, Osterdal ML, Gillman MW, et al. Associations of maternal fish intake during pregnancy and breastfeeding duration with attainment of developmental milestones in early childhood: a study from the Danish National Birth Cohort. The American journal of clinical nutrition. 2008; 88(3):789–796. [PubMed: 18779297]
38. Hibbeln JR. Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): an observational cohort study. Lancet. 2007; 369(9561):578–585. [PubMed: 17307104]
39. Dunstan JA, Simmer K, Dixon G, Prescott SL. Cognitive assessment of children at age 2(1/2) years after maternal fish oil supplementation in pregnancy: a randomised controlled trial. Archives of disease in childhood Fetal and neonatal edition. 2008; 93(1):F45–F50. [PubMed: 17185423]
40. Belfort MB, Rifas-Shiman SL, Kleinman KP, et al. Infant Feeding and Childhood Cognition at Ages 3 and 7 Years, Effects of Breastfeeding Duration and Exclusivity. JAMA : the journal of the American Medical Association. 2013 Published online.
41. Dietary Guidelines Advisory Committee. Report of the dietary guidelines advisory committee on the dietary guidelines for Americans, 2010, to the Secretary of Agriculture and the Secretary of Health and Human Services. Washington, DC: 2010.

1a. age group

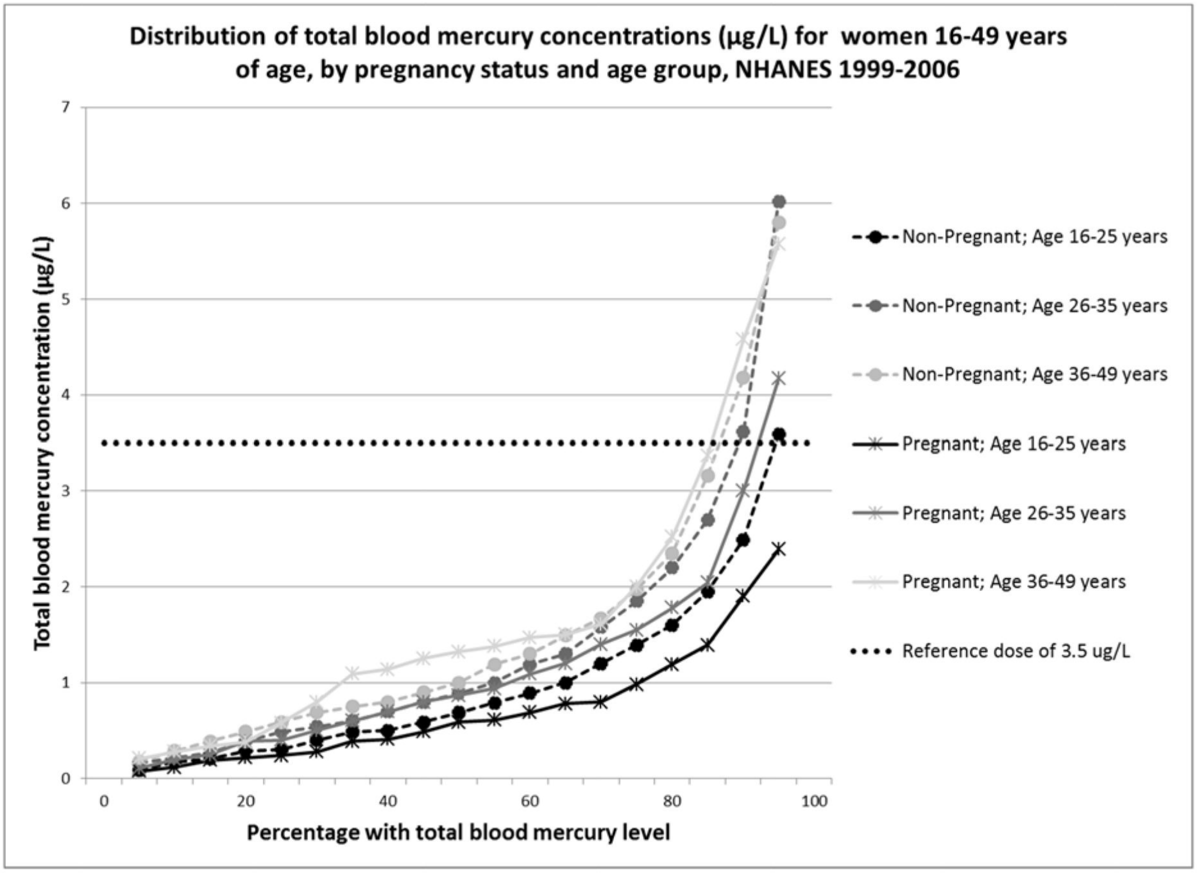

Figure 1.

Figure 1 shows the distribution of total blood mercury concentrations (µg/L) for pregnant and non-pregnant women 16–49 years of age in the National Health and Nutrition Examination Survey (NHANES), 1999–2006 by age group.

1b. race/ethnicity

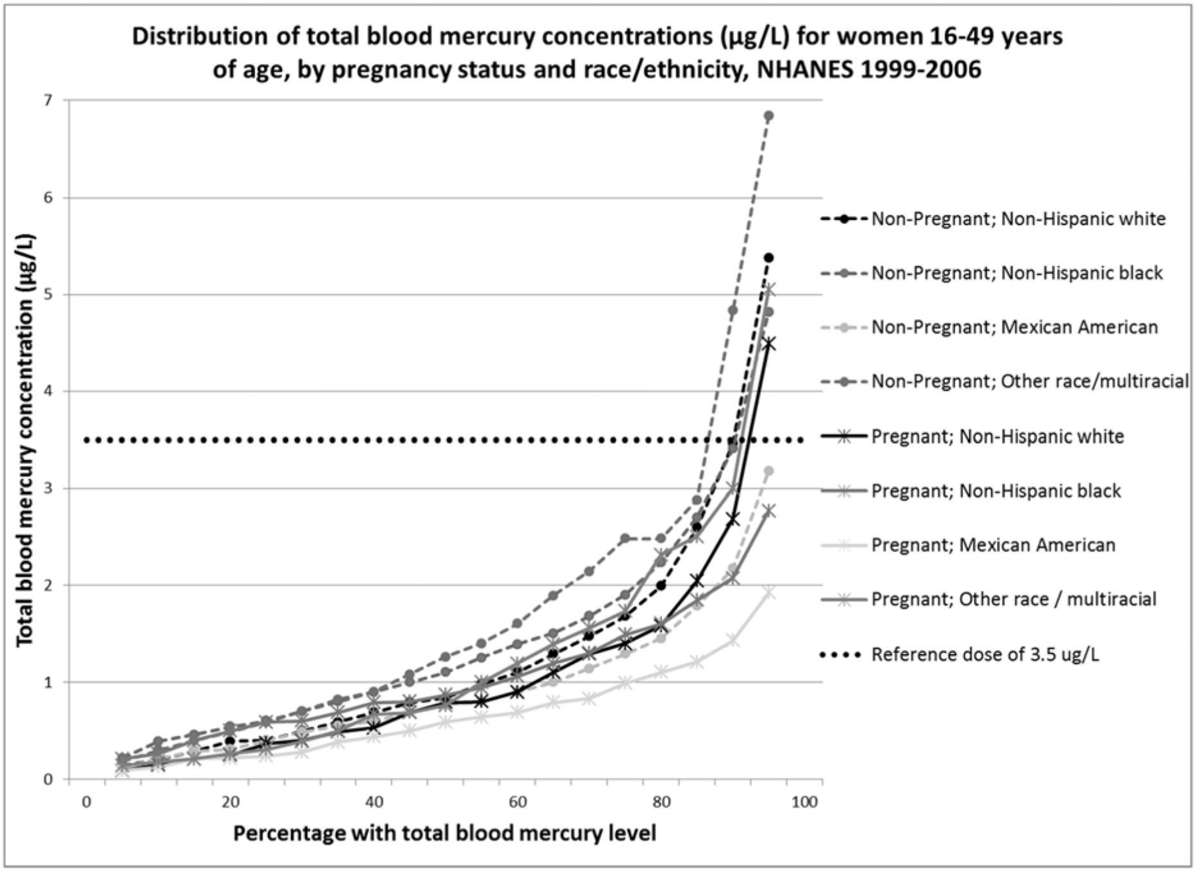

Figure 2.

Figure 2 shows the distribution of total blood mercury concentrations (μg/L) for pregnant and non-pregnant women 16–49 years of age in the National Health and Nutrition Examination Survey (NHANES), 1999–2006 by race/ethnicity group.

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1c. education level

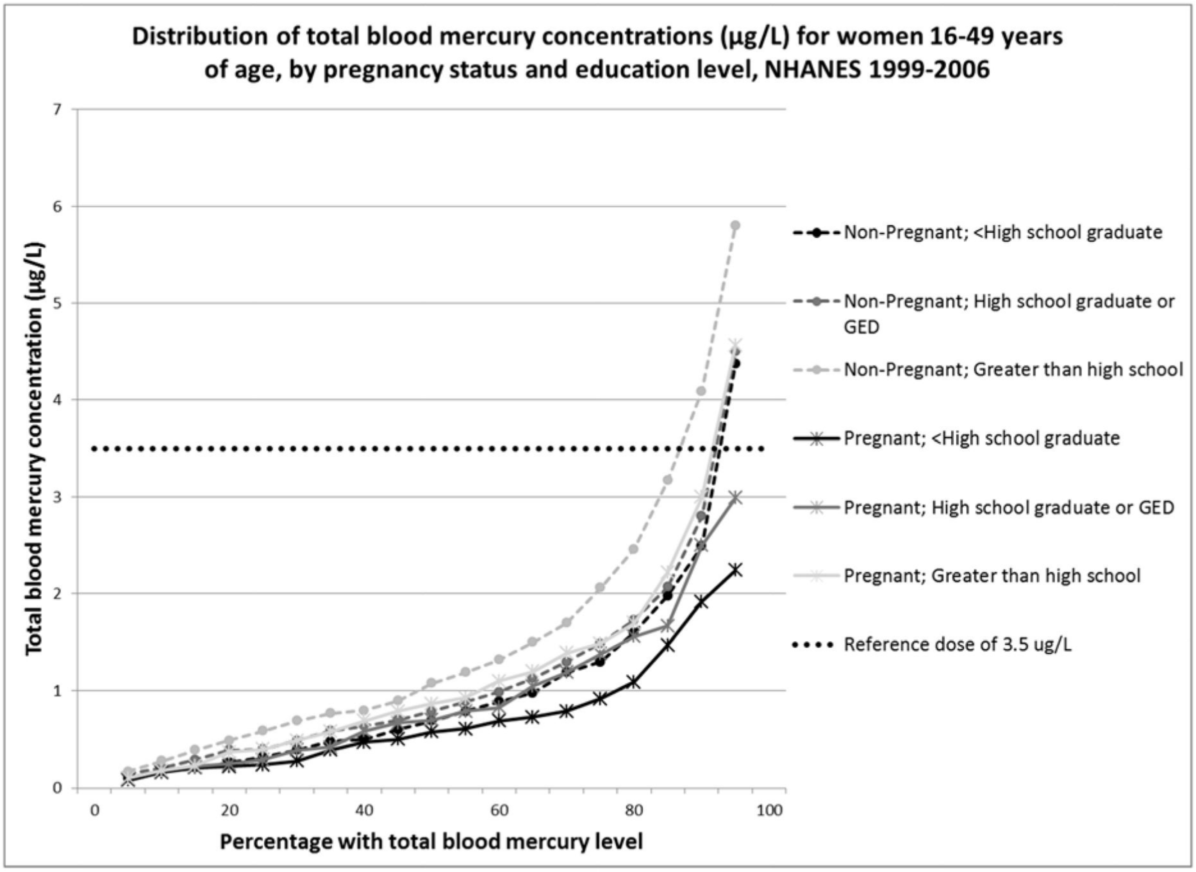

Figure 3.

Figure 3 shows the distribution of total blood mercury concentrations (µg/L) for pregnant and non-pregnant women 16–49 years of age in the National Health and Nutrition Examination Survey (NHANES), 1999–2006 by education.

GED, General Education Development

1d. Family income to poverty Ratio

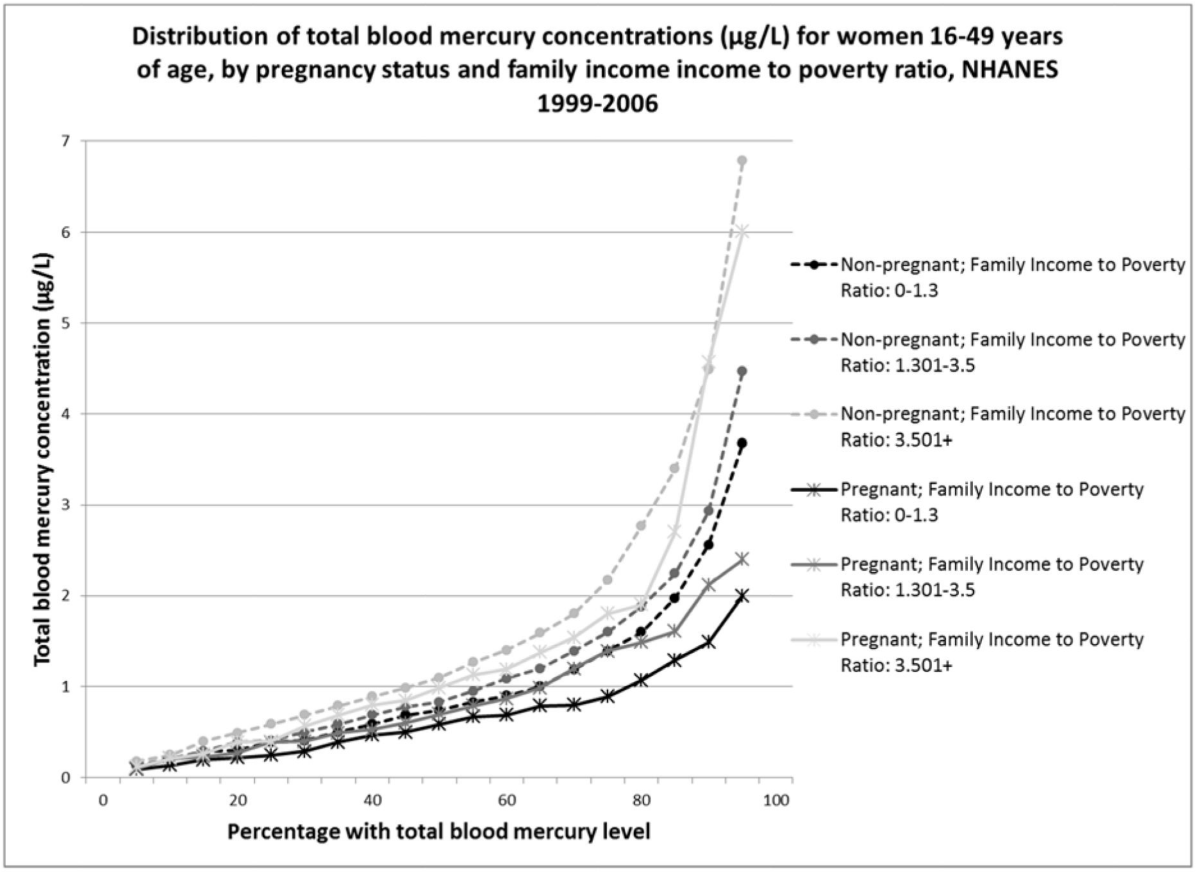

Figure 4.

Figure 4 shows the distribution of total blood mercury concentrations (µg/L) for pregnant and non-pregnant women 16–49 years of age in the National Health and Nutrition Examination Survey (NHANES), 1999–2006 by family income to poverty ratio.

Family income to poverty ratio is the total household income divided by the poverty threshold for the year of the interview

1e. seafood consumption

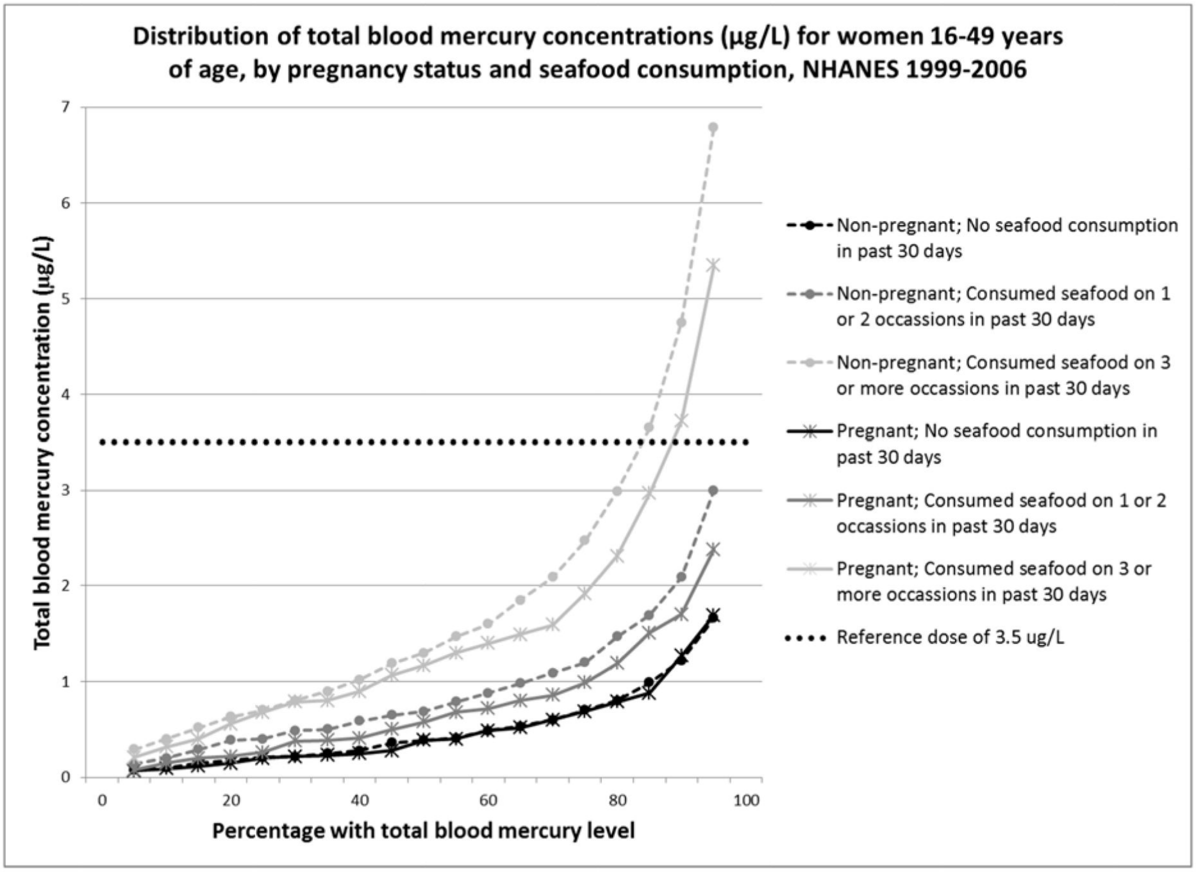

Figure 5.

Figure 5 shows the distribution of total blood mercury concentrations (μg/L) for pregnant and non-pregnant women 16–49 years of age in the National Health and Nutrition Examination Survey (NHANES), 1999–2006 by seafood consumption.

Table 1

Characteristics of U.S. Pregnant women and U.S. Non-Pregnant women in National Health and Nutrition Examination Survey (NHANES) 1999–2006

Variable	Pregnant Women		Non-Pregnant Women	
Total mean blood mercury (μg/L)	0.71 (0.63, 0.79)		0.92 (0.85, 0.99)	
		P^{*}<0.0001		
Total mean blood mercury (μg/L) adjusted for age & race	0.81 (0.71, 0.91)		0.93 (0.87, 0.99)	
		P^{*}=0.0001		
	N[a]	%[b] (95% CI)	N[a]	%[b] (95% CI)
Total	1183		5587	
Age				
16–25	551	41.6 (37.0, 46.4)	2386	25.9 (24.4, 27.5)
26–35	558	49.4 (43.8, 55.0)	1209	26.6 (25.0, 28.2)
36–49	74	9.0 (5.9, 13.6)	1992	47.5 (45.5, 49.5)
		P^{*}<0.0001		
Race				
Non-Hispanic white	526	56.3 (50.3, 62.1)	2189	66.8 (63.5, 70.0)
Non-Hispanic black	183	15.1 (11.5, 19.6)	1405	12.7 (10.8, 15.0)
Mexican American	350	16.0 (13.0, 19.5)	1494	8.7 (7.2, 10.4)
Other race and/or multiracial	124	12.7 (8.8, 18.0)	499	11.8 (9.7, 14.2)
		P^{*}<0.0001		
Education Level				
<High school graduate	374	23.1 (19.4, 27.2)	2017	20.3 (18.8, 21.9)
High school graduate or GED	259	18.7 (15.2, 22.7)	1218	22.9 (21.3, 24.5)
Greater than high school	549	58.2 (53.3, 36.0)	2347	56.7 (54.4, 59.0)
Missing	1	--[c]	5	--[c]
		P^{*}=0.07		
Family income to poverty ratio[d]				
0–1.3	399	25.6 (21.7, 29.9)	1849	23.6 (21.4, 25.9)
1.301–3.5	389	35.5 (31.7, 39.6)	1853	32.8 (30.7, 35.0)
3.501+	319	32.1 (27.0, 37.7)	1516	38.2 (35.5, 40.9)
Missing	76	--[c]	369	5.4 (4.5, 6.5)
		P^{*}=0.09		
Fish or shellfish consumption in the past 30 days				
Yes	849	73.0 (67.2, 78.0)	4160	78.1 (76.0, 80.1)
No	292	23.6 (19.2, 28.6)	1226	18.7 (17.0, 20.6)
Missing	42	--[c]	201	3.2 (2.5, 4.0)
		P^{*}=0.05		
Fish consumption in the past 30 days				

Variable	Pregnant Women		Non-Pregnant Women	
Yes	700	62.5 (56.8, 67.8)	3545	68.8 (66.6, 71.0)
No	441	34.1 (29.4, 39.2)	1843	28.1 (26.1, 30.2)
Missing	42	--[c]	199	3.1 (2.5, 4.0)
		P^{*}=0.03		
Shellfish consumption in the past 30 days				
Yes	545	46.1 (41.0, 51.4)	2769	51.4 (48.6, 54.2)
No	596	50.4 (45.5, 55.4)	2615	45.4 (42.7, 48.1)
Missing	42	--[c]	203	3.2 (2.6, 4.1)
		P^{*}=0.13		

[a]Unweighted N

[b]Weighted row percentage

[c]Estimates suppressed because minimum degrees of freedom (12) for strata not met

[d]Family income to poverty ratio is the total household income divided by the poverty threshold for the year of the interview

[*]p-values for χ^2 test

GED, General Education Development; CI, Confidence Interval

Table 2

Adjusted odds ratios (95% CI) for mercury concentrations ≥3.5 μg/L among U.S. women of childbearing age and stratified by pregnancy status, NHANES 1999–2006

	All Women	Pregnant Women	Non-pregnant women
	OR (95% CI) N=621	OR (95% CI) N=55	OR (95% CI) N=566
Pregnancy Status			
No	1.0 (Ref)	N/A	N/A
Yes	0.70 (0.47, 1.03)		
Age (years)			
16–25	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
26–35	2.00 (1.46, 2.75)	2.25 (0.72, 7.02)	1.79 (1.28, 2.49)
36–49	2.33 (1.71, 3.19)	3.78 (0.68, 20.90)	1.98 (1.46, 2.68)
Race			
Non-Hispanic white	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Non-Hispanic black	1.39 (0.97, 1.99)	0.44 (0.19, 1.02)	1.23 (0.85, 1.78)
Mexican American	0.66 (0.45, 0.95)	0.31 (0.10, 0.98)	0.64 (0.43, 0.95)
Other/multiracial	2.13 (1.43, 3.19)	1.19 (0.23, 6.21)	2.21 (1.44, 3.38)
Education Level			
< high school graduate	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
high school graduate or GED	0.99 (0.70, 1.40)	2.95 (0.77, 11.37)	0.95 (0.66, 1.37)
Greater than high school	1.39 (1.03, 1.89)	1.66 (0.50, 5.53)	1.39 (1.03, 1.87)
Family income to poverty ratio[a]			
0–1.3	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
1.301–3.5	1.09 (0.75, 1.60)	0.91 (0.30, 2.80)	1.13 (0.77, 1.66)
3.501+	2.04 (1.33, 3.13)	6.59 (1.51, 28.69)	2.14 (1.41, 3.26)
Fish and shellfish consumption in the last 30 days			
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	15.70 (7.83, 31.48)	18.69 (4.91, 71.13)	15.50 (7.48, 32.12)

[a] Family income to poverty ratio is the total household income divided by the poverty threshold for the year of the interview

The models were adjusted for all other variables in the table

CI, Confidence Interval; GED, General Education Development