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An Analysis of Mercury Exposures Among the Adult Population in New York State

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Abstract The extent of methylmercury exposures among adults in New York State (NYS) has not been well characterized. Over the past few years, the NYS Heavy Metals Registry (HMR) has seen an increase in both blood mercury tests being reported, and nonoccupational exposures to mercury, which appear primarily due to fish consumption. This study will, (1) Characterize the adults who are tested for blood mercury in NYS; (2) Examine the circumstances for blood mercury testing; and (3) Characterize this population in terms of exposure history, specifically those individuals who are non-occupationally exposed through a diet of seafood consumption in reference to blood mercury levels. Data available from HMR laboratory results, including basic demographics and test results, were combined with data from telephone interviews. The interview contains information on the reasons for testing, possible sources of exposure, and the individual's work and home environment. Approximately 99 % of adults reported to the HMR, with identifiable exposures to mercury, had non-occupational exposures resulting from seafood consumption. Common types of fish consumed include salmon, tuna, and swordfish, with 90 % of adults eating seafood a few times or more per week. Information will be provided on the reasons for being tested and the range of blood mercury levels in relation to their seafood consumption. NYS residents who frequently eat fish should be aware of what types of fish contain mercury and avoid or reduce consumption of fish with high mercury levels.

Background

Mercury is a metal that occurs naturally in the environment in several forms. Metallic or elemental mercury is used primarily in the production of thermometers, fluorescent lights and batteries [1] as well as in ethnic folk medicines and religious practices [26], while inorganic mercury is used in antiseptic creams, ointments, disinfecting agents, and skin lightening creams or other medicinal products [1, 26]. Mercury, naturally occurring in mineral form, can be released into the air through natural weathering processes, or through industrial processes and discharges. Once in the environment, it can be transformed into organic methylmercury. In aquatic environments, the methylmercury bioaccumulates up the food chain. Nearly all fish contain traces of methylmercury. However, it accumulates more in certain types of fish, depending on what the fish eat, resulting in varying mercury levels. Also, larger fish (swordfish, shark, king mackerel and tilefish) that have lived longer, have the highest levels of methylmercury because of the longer time for accumulation. In general, methylmercury levels for most fish range from below 0.01 parts per million (ppm) to 0.5 ppm [28]. Only in a few species of fish are methylmercury levels 1 ppm or greater. This occurs most frequently in some large predator fish, such as shark and swordfish and in certain species of large tuna, typically sold as fresh steaks or sushi [27]. Ingested organic mercury compounds are absorbed through the gastrointestinal tract and are transported throughout the body in the blood. Measurement of methylmercury via blood is most appropriate [5]. An elevated blood test for

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mercury indicates a recent exposure to a high concentration of mercury vapor or exposure to an organic mercury source (for example, methylmercury from a recent fish meal) [19, 20].

Exposure to mercury compounds is primarily through ingestion, but can occur through other pathways. Exposure to elemental mercury most often comes from breathing air with elemental mercury vapor and can occur during particular jobs or when devices containing mercury such as thermometers break and release elemental mercury droplets and vapor into the air. Small amounts of elemental mercury vapor are also released from dental amalgams (fillings) [19, 20]. However, the American Dental Association has reviewed the literature and has concluded that dental amalgam is still a safe way to repair teeth [2]. Some Latino and Afro-Caribbean cultures follow religious practices such as Santeria and Voodoo, and use metallic mercury for medicinal purposes, to attract luck, to ward off evil and for other rituals [26].

Once absorbed, elemental mercury can be rapidly distributed to all body tissues, but the greatest accumulation occurs in the kidney. Because elimination of elemental mercury predominantly occurs through urine and other waste products, measurement of elemental mercury via urine is best [5]. Urine and blood are the most commonly accepted methods to assess mercury exposure for medical purposes.

The National Health and Nutrition Examination Survey (NHANES) is a series of surveys conducted by the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics, and is designed to collect data on the health and nutritional status of the U.S. population. NHANES geometric mean blood mercury level for women 16–49 years old was 1.02 nanograms per milliliter (ng/mL) (95th percentile was 7.10 ng/mL) in 1999–2000, and 0.833 ng/mL (95th percentile was 4.60 ng/mL) in 2001–2002 [6]. Preliminary findings from the 2007–2008 Canadian Health Measures Survey show that the geometric mean blood mercury level for Canadians 20–79 years old was 0.91 ng/mL [30]. Blood mercury levels in these subsample populations are below those associated with known health effects. The National Academy of Sciences recommends keeping blood mercury levels below than 5.0 ng/mL [17].

The New York State (NYS) Department of Health (DOH) maintains a Heavy Metals Registry (HMR). The HMR is a tool used for the surveillance of adult exposures to mercury, lead, cadmium and arsenic [18]. All laboratories, whether in-state or out of state, performing tests for any of these metals on individuals residing or employed in NYS must report the results of the test to the NYSDOH. All mercury blood tests of 5 ng/mL and greater and urine tests of 20 ng/mL and greater conducted on NYS residents

must be reported to the HMR. These databases serve as rich sources for the study of mercury exposure trends.

Objectives

The source of mercury exposures among the adult population in NYS has not been well characterized, and the non-occupational diet-based component of this exposure has been inadequately described in the literature. For the purposes of this study, we only look at blood mercury levels, because a blood test will best indicate exposure to mercury via the consumption of seafood [19, 20]. Over the past decade, NYSDOH has seen an increase in both blood mercury tests being reported to the HMR, and non-occupational exposures to mercury primarily due to fish consumption. From 1993 to 1998, there were on average, less than 100 reports each year of blood mercury, almost 500 in 2000, to more than 2,200 in 2004 and to more than 5,300 in 2008. To further investigate possible sources of exposure in the NYS adult population our study objectives were to:

- Characterize the population of adults who are tested for blood mercury in NYS;
- Examine the circumstances for blood mercury testing; and
- Characterize this population in terms of exposure history, specifically those individuals who are non-occupationally exposed through a diet of seafood consumption in reference to blood mercury levels.

Methods

NYSDOH registry staff interview individuals with blood mercury levels 15 ng/mL and higher. Although originally designed to assess occupational exposures, the interview also contains questions on potential non-occupational exposure sources. Information obtained from the interview includes reasons for testing, reason for initial doctor visit, demographic data, possible mercury spills in residence, fish consumption habits, including type of fish and how often consumed, and history of recent vaccine or immunoglobulin shots. Interviews are also used to provide education to individuals to assist them in reducing their exposures. Due to difficulties in identifying the sources of exposure for individuals reported with blood mercury levels (BMLs) below 15 ng/mL, in 2000, NYSDOH raised the interview level for adults from BMLs above 5 ng/mL to those with BMLs above 15 ng/mL.

Data from the interviewed cases from 2000 to 2008 (those individuals with BMLs at or above 15 ng/mL) were abstracted and combined with all mercury laboratory data

Table 1 Demographic characteristics of individuals interviewed by the NYS HMR, 2001–2008

	15–24		25–34		35+		Total	
	N	%	N	%	N	%	N	%
Blood mercury values (ng/mL)								
Total adults	1,984	64.6	646	21.0	448	14.6	3,078	100
Age (years)								
<50	940	47.4	281	43.5	183	40.9	1,404	45.6
50+	1,044	52.6	365	56.5	265	59.2	1,674	54.4
Gender								
Male	1,073	54.1	381	59.0	267	59.6	1,721	55.9
Female	911	45.9	265	41.0	181	40.4	1,357	44.1
Ethnicity								
White, non-Hispanic	1,624	81.9	524	81.1	364	81.3	2,512	81.6
Black, non-Hispanic	66	3.3	25	3.9	15	3.4	106	3.4
Hispanic	49	2.5	25	3.9	13	2.9	87	2.8
Asian, non-Hispanic	101	5.1	29	4.5	31	6.9	161	5.2
Other[a]	55	2.8	16	2.5	4	0.9	75	2.4
Unknown	89	4.5	27	4.2	21	4.7	137	4.4
Geographic location								
NYS, exc. NYC	784	39.5	247	38.2	162	36.2	1,193	38.8
NYC	1,158	58.4	385	59.6	282	63.0	1,825	59.3
Out of state[b]	35	1.8	12	1.9	3	0.7	50	1.6
Unknown	7	0.4	1	0.2	1	0.2	10	0.3
Education								
High school	216	10.9	74	11.5	43	9.6	333	10.8
Some college	302	15.2	92	14.2	55	12.3	449	14.6
College graduate	535	27.0	188	29.1	138	30.8	861	28.0
Some graduate/ Prof. school	904	45.6	284	44.0	207	46.2	1,395	45.3
Unknown	27	1.4	8	1.2	5	1.1	40	1.3

[a] Other includes people of Middle Eastern descent, American Indian descent, Alaskan Native descent or unclassified ethnicity

[b] Out of State refers to those participants who do not reside in New York State but are reported to the HMR because they work in New York State

(those individuals with BMLs at or above 5 ng/mL) reported to the HMR, to create a database for analysis. The database was analyzed using SAS 9.2 [21] to characterize the NYS population being tested for mercury. The exposure source was categorized as occupational, non-occupational, both, or unknown, based on information obtained in the interview. Detailed analyses were conducted on adults with non-occupational exposures, including reasons for testing, reasons for initial doctor visit and frequency and type of fish consumed. Analyses were also conducted by categories of BMLs. For ease of analysis and because the nature of some of the interview questions are open-ended and therefore the choices unlimited, we limited our analyses to those fish that were reportedly consumed by 20 or more individuals. To test for differences in characteristics by BMLs, χ^2 tests were conducted. The means and t test procedures were used to produce descriptive statistics on mean BMLs within groups of seafood consumption usage. MapInfo Professional 8.5 [14] was used to plot residence of mercury cases, by ZIP code and median household income of county of residence, as determined from NYS Bureau of Census data [22, 23].

Table 2 Gender, race and education level of individuals interviewed by the NYS HMR, 2001–2008, compared to the 2000 census demographic profile

	NYS percent[a]	HMR mercury percent[b]	χ^2
Race			
White, non-Hispanic	67.9	83.9	289.7*
Black, non-Hispanic	15.9	4.0	
Hispanic	15.1	3.0	
Asian, non-Hispanic	5.5	5.5	
Other	7.2	3.6	
Education			
High school graduate or higher	79.1	96.8	220.1*
Bachelor's degree or higher	27.4	57.6	
Gender			
Male	48.2	55.9	77.3*
Female	51.8	44.1	

U.S. Census Bureau, Census 2000 Summary File, Profile of General Demographic Characteristics: 2000, Geographic Area: New York

* p value <0.001

[a] Totals are greater than 100 % since more than one race can be listed

[b] Percentages are calculated excluding 'unknown/refused' responses

Results

During the period 2001–2008, there were 17,000 participants tested with 20,006 blood mercury tests reported to the HMR; BMLs ranged from 5 to 760 ng/mL. Some participants had multiple tests done during this time period, but only their highest result is included in the analysis. Almost 75 % of the participants tested had BMLs between 5 and 14 ng/mL, approximately 17 % had BMLs between 15 and 24 ng/mL, 5 % had BMLs between 25 and 34 ng/mL and almost 4 % had BMLs 35 ng/mL or greater (data not shown). There was a significantly higher percent of individuals older than 50 years of age (5–14 ng/mL vs. all others, $\chi^2 = 27.95$, $p < 0.001$), and male (5–14 ng/mL vs. all others, $\chi^2 = 119.97$, $p < 0.001$) with lower BMLs. The mean age of individuals tested was 49.2 years.

Among the 4,290 individuals with BMLs 15 ng/mL or greater, 3,078 (72 %) had completed interviews. Table 1 describes the demographic characteristics of those individuals interviewed for blood mercury. There was a significantly higher percentage of participants interviewed in the 15–24 ng/mL blood mercury category that were less than 50 years old, compared to all cases in the same

category (65 vs. 50 % respectively, data not shown). Among those interviewed, 82 % were White, non-Hispanic, 5 % were Asian non-Hispanic, 3 % were Black non-Hispanic, and 3 % were Hispanic, almost 60 % were residents of New York City (NYC) and 73 % had a college degree or higher education.

The demographic characteristics of the participants interviewed for blood mercury were compared to the 2000 New York Census Demographic Profile (Table 2) [22, 23]. Chi squares were used to analyze the differences and those interviewed for mercury in NYS were more likely to be White, non-Hispanic ($p < 0.001$), male ($p < 0.001$) and highly educated ($p < 0.001$) when compared to the general NYS population. As seen in Fig. 1, a higher number of participants reported for blood mercury in NYS, as mapped by ZIP code, resided in the NYS counties with the higher median income levels [23]. The highest percentages of participants reported for blood mercury also tended to reside in the larger cities and in the suburban areas surrounding these cities (data not shown). Almost forty percent of the participants reported for mercury in NYS resided in counties with the two highest median household income brackets; $61,200–$72,300, which included
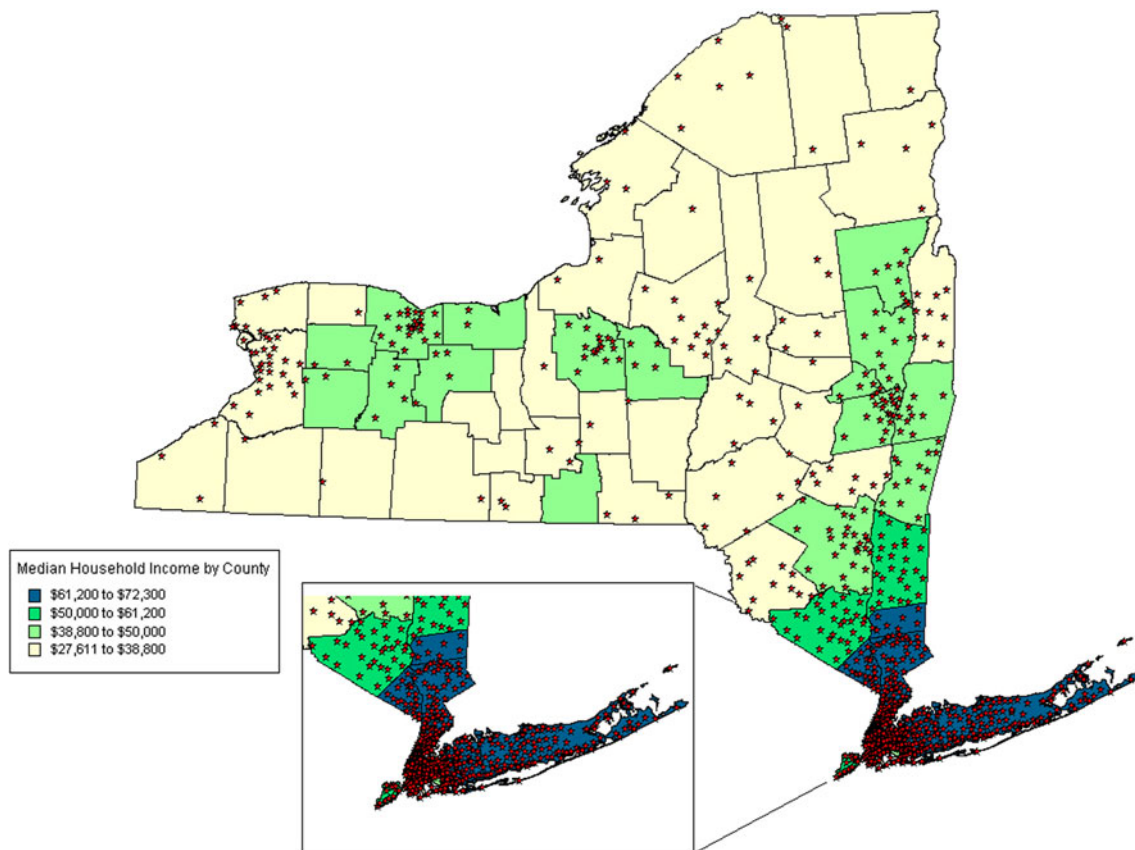
Fig. 1 Residence of individuals reported to the NYS HMR, by median household income [23]

Table 3 Characteristics of individuals reported to the NYS HMR, 2001–2008, who indicated they were tested for blood mercury due to their own decision or due to their doctor's advice

Blood mercury value (ng/mL)	Tested own decision (N = 1,331)		Tested doctor's advice (N = 1,423)		χ^{2}*
	N	%	N	%	
15–24	848	63.7	908	63.8	0.6
25–34	281	21.1	312	21.9	
35+	202	15.2	203	14.3	
Age (years)					
<50	657	49.4	594	41.7	16.1**
50+	674	50.6	829	58.3	
Gender					
Female	620	46.6	599	42.1	5.6
Male	711	53.4	824	57.9	
Ethnicity					
White, non-Hispanic	1,118	84.0	1,159	81.4	4.1
Other	163	12.2	212	14.9	
Unknown	50	3.8	52	3.7	
Geographic location					
NYS, exc. NYC	515	38.7	549	38.6	0.7
NYC	785	59.0	833	58.5	
Out of state	29	2.2	38	2.7	
Unknown	2	0.2	3	0.2	
Education					
High school	119	8.9	164	11.5	6.6
Some college	185	13.9	214	15.0	
College graduate	387	29.1	383	26.9	
Some graduate school	626	47.0	647	45.5	
Unknown	14	1.1	15	1.1	
Reason for initial doctor's visit					
Fish eater	486	36.5	163	11.5	836.9**
Just for the test	416	31.3	69	4.8	
Sick/symptomatic	93	7.0	424	29.8	
Physical exam	218	16.4	628	44.1	
Accidents and spills	33	2.5	82	5.8	
Other	51	3.8	29	2.0	
Unknown	34	2.6	28	2.0	

* χ^{2} calculated excluding unknown values

** p value <0.001

Westchester, Rockland, Putnam, Suffolk and Nassau counties, and $50,000–$61,200, which included Richmond, Dutchess and Orange counties. In contrast, only 27 % of the entire NYS population resided in these areas [23].

Twenty-eight percent of participants did not complete the entire interview; however, we were able to collect enough information to identify the potential sources of exposure for 3,145 participants. Of the identifiable exposures, 99 % were due to fish consumption. Other exposure sources included accidental ingestion (n = 24), dental (individuals who indicated they had amalgam fillings

pulled immediately preceding the test, n = 10), and use of herbs and folk medications (n = 9) (data not shown).

Further analysis of the reasons the participants were tested indicated that 46 % of participants were tested due to their doctor's advice, while 42 % were tested due to their own decision. The mercury test may not have been the original reason the person went to the doctor, but they still requested the test during their visit. Of those individuals indicating they were tested due to their own decision (N = 1,331), 36 % had BMLs 25 ng/mL or greater, 53 % were male, 84 % were White, non-Hispanic, 76 % had a

Fig. 2 Mean mercury level (ppm) of fish type consumed versus mean and median blood mercury level (ng/mL) of participants tested who ate particular type of fish [28]. Only those types of fish with more than 40 responses are listed
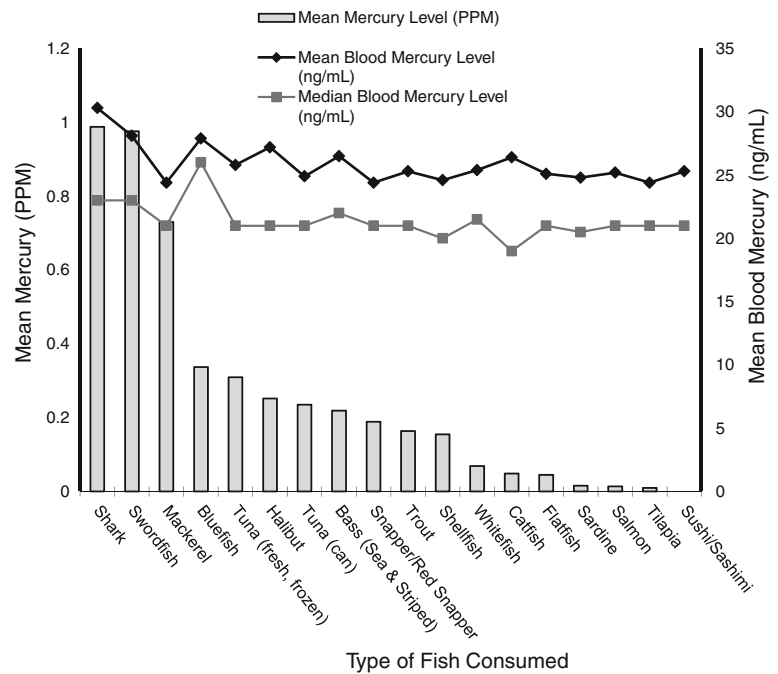
Table 4 Mean, median and range blood mercury level[a] compared to the amount of fish consumed

Fish/seafood use	Mean blood mercury level (ng/mL)	Median blood mercury level (ng/mL)	Range of blood mercury levels (ng/mL)[b]
Daily (N = 611)	30.8[c]	25.0	(15, 161)
Few times/week (N = 1,978)	24.1	20.0	(15, 176)
About once/week (N = 188)	22.1	19.0	(15, 78)
Less than once/week (N = 56)	22.3	20.0	(15, 92)
About once/month (N = 41)	23.6	18.0	(15, 98)
Less than once/month (N = 19)	25.6	23.0	(15, 51)

[a] For purposes of this analysis, 4 outliers of 760, 336, 271 and 233 ng/mL have been excluded

[b] Interviews were conducted for those only with BMLs above 15 ng/mL, therefore, the bottom end of range is unknown

[c] There is a significantly higher mean BML among those who eat fish daily when compared to those who eat fish less frequently (p value <0.001)

college degree or higher, and 59 % resided in the NYC area (Table 3). These results were similar to those 1,423 individuals who indicated they were tested due to their doctor's advice, with the exception of age; these individuals were younger (Table 3). A χ^2 analysis of the two groups shows that the differences in the ages between the two groups as well as the reason for the initial doctors visit are statistically different (p value <0.001).

Further analysis of the reasons for the initial doctor visit indicated that 27 % of participants went just for the test or because they were fish consumers, 19 % were sick or symptomatic and 14 % went for a general health physical.

Among the 1,331 participants who stated that they were tested due to their own decision, 37 % denoted that they were fish consumers, 31 % indicated the reason for their initial doctor visit was just for the test, and another 16 % initially went to the doctor for a physical exam (Table 3).

Among the 1,423 participants indicating they were tested due to their doctor's advice, 44 % went to the doctor for a physical exam, 30 % initially visited their doctor because they were sick/symptomatic, and 12 % indicated they were fish consumers (Table 3). The differences in the reasons for initial doctor's visit between the two groups are statistically different.

An analysis of fish consumption patterns among the individuals interviewed by the HMR showed the most commonly consumed types of seafood were: salmon (15.6 % of all responses); canned tuna (10.6 %); fresh or frozen tuna (9.6 %); bass, including sea bass, striped bass, and rockfish (8.7 %); swordfish (7.8 %); shellfish, including shrimp, crabs, clams, lobsters, oysters, and scallops (7.1 %); and sushi/sashimi (non-specific fish type, 7.0 %). Participants could give more than one type of seafood in their answer. More than 68 % of participants indicated they

consumed fish a few times per week, while 21 % consumed fish daily. Almost 90 % of the fish consumed was purchased from a grocery store or restaurant, while more than 9 % of the fish consumed was considered game fish, or fish pursued for sport by recreational anglers. Of the game fish consumed where location was known, 91 % were caught in the ocean and 9 % were caught in a river, lake or stream. On average, individuals indicated they consumed slightly more than 3 different types of seafood, with a range from 1 to 9 (data not shown).

Figure 2 compares the mean mercury level (ppm) in commercial fish as determined by the FDA [28], compared to the mean and median BML of individuals tested for mercury who indicated they consumed that type of fish. There is no apparent link between ppm levels of mercury in the fish and the level of blood mercury in the fish consumer, with the exception of the two types of fish with the highest mean mercury levels, shark (0.988 ppm) and swordfish (0.976 ppm), whose consumers had the two highest mean BMLs of 30.3 ng/mL and 28.1 ng/mL, respectively. Although not shown in this chart, since only those types of fish with more than forty responses were listed, consumers of Mahi–Mahi, with a mean mercury level of 0.19 ppm, had the highest mean BML of 30.5 ng/mL.

A t test was used to compare the differences between those who consumed fish daily to those who consumed fish less frequently. There was a statistically significantly higher mean BML among those who consumed fish daily (p value <0.001) (Table 4). The 611 participants who indicated they consumed fish on a daily basis had a mean BML of 30.8 ng/dL (range of 15–161 ng/mL), as compared to those non-daily fish consumers who had a mean BML of 24.4 ng/mL (range of 15–176 ng/mL).

Conclusions

The participants reported for blood mercury appear to be health conscious residents of suburban or urban areas of NYS. They are highly educated, with a high socioeconomic status when compared to the general NYS population. They live in or near large cities and appear to have better access to and can afford to eat more expensive types of seafood such as swordfish and shark, which also have higher methylmercury levels. These results are consistent with other studies in which women among higher income groups and women living in urban areas were at higher risk of mercury exposure [9, 13].

The majority of the HMR population and their physicians are aware that consuming seafood may increase their blood mercury level. More than 68 % of participants were tested due to doctor's advice or their own decision. However, although many physicians do recognize when their patients are at risk and test, 54 % of participants tested gave other reasons for having the blood mercury test. There is a potential that many at risk residents may be going untested. It doesn't appear as if our HMR population includes a lot of sport fishers (only 9 % of those interviewed indicated they caught their own fish) who may eat even larger amounts of fish than what was seen in this analysis. Physicians should be better educated to prioritize mercury blood testing in any person presenting as a fish consumer, especially those individuals who are sport fishers and women of childbearing age since there is a neurotoxic risk to a developing fetus.

Since mercury testing is voluntary, the HMR does not represent those sub-groups potentially at greatest risk. A recent New York City survey [15] showed high levels of BMLs among Asian New Yorkers, and an examination of national NHANES data also identified Asian, Pacific Islanders and Native Americans at high risk for dietary exposure to methylmercury through fish consumption [10]; this is not reflected in the HMR interview data. Other recent studies that measured BMLs in at-risk populations in New York City found higher levels in Caribbean-born blacks and Dominicans than for White, non-Hispanics [8, 16]. Since more than 80 % of HMR participants are White, non-Hispanic, we are potentially missing those at higher risk. Foreign-born status is not assessed through the HMR mercury questionnaire.

Another limitation of this study arises from the fact that the HMR telephone questionnaire queries participants for a 60-day recall of fish consumption. There may be less accurate reporting of types and amounts due to recall bias [4]. A seafood consumption study conducted in Glynn County, Georgia ascertained seafood consumption levels using two types of tools, a questionnaire and a dietary diary [29]. The questionnaire provided a much broader characterization of consumption patterns, while the dietary diary provided more detailed data. Therefore, the telephone interview may be less defined in assessing specifics regarding types of fish and amounts consumed, though overall, it probably accurately assesses the general fish consumption patterns of the individuals interviewed.

Test results may also be affected by how recently an individual consumed fish prior to their test. It is possible for an individual to have a more highly elevated level due to a fish meal immediately preceding the mercury blood test. In the general population, previous research has shown that for 2–3 days after ingestion of fish contaminated with methylmercury, high mercury concentrations may be found in the blood [11]. Methylmercury has a half-life in the body of about 50 days [5].

There is also uncertainty about the interaction of many different varieties of seafood consumed and the multiple factors that can influence mercury levels. Risk assessment for different populations is complicated by hereditary

differences in the way mercury is metabolized among individuals [7, 11]. This is true for our data which show no clear connection to the mercury levels in fish and the blood levels of the individuals tested for mercury. The level of mercury in fish consumed by the participants reported to the HMR was unknown. The inconsistency between fish consumption, level of mercury in fish, and level of mercury in consumer blood, signifies that more research needs to be done to fill the data gap.

We did not specifically look at dental amalgams in our assessment of overall mercury exposure, because as noted previously the ADA has deemed amalgam a valuable and safe choice for dental patients. However, if a participant mentions the removal of amalgams during the interview, it is recorded as a possible source of exposure, especially if no other notable exposure can be documented. Since very few participants mentioned dental work, it was not considered a compelling source of exposure in this population.

Fish are nutritious; they are an important source of high quality protein (omega-3 fatty acids) and are low in saturated fat. They are part of a healthy diet because they benefit growth, brain development and good nervous system and cardiovascular health [19, 20]. Numerous research studies support the benefits of fish consumption for a reduction in the incidence of coronary heart disease [12]. The American Heart Association recommends eating fish, particularly fatty fish, at least two times a week [3]. When participants frequently consume fish, they should be aware of which fish contain methylmercury and avoid or reduce consumption of fish with high levels. Avoidance of potentially contaminated fish is a higher concern for pregnant and lactating women and children. Many types of fish do not contain elevated mercury levels. Consuming a variety of different fish and shellfish is a good way to obtain the health benefits of a fish diet while balancing the concerns of exposure to mercury. NYS residents, especially women of childbearing age, are encouraged to follow the recommendations put forth by the NYSDOH fish advisories [19, 20].

Our data indicate that, in general, the BMLs measured in most NYS residents in this study, including those consuming fish infrequently, exceed the whole blood mercury level of 5.8 ng/mL recommended by the National Academy of Sciences and the EPA. [25, 28]. The CDC estimate that approximately 6 % of childbearing women have levels at or above reference dose, and many newborns each year may have increased risk of learning disabilities associated with in utero exposure to methylmercury [6]. Our data support this estimate and suggest that many adults (and perhaps even infants and children) residing in NYS are potentially at-risk. Women may need extra protection from mercury in fish, and they should follow the specific New York State fish advisories for women of childbearing age and get screened if considering pregnancy or currently pregnant [19, 20].

Dietary histories that include fish consumption need to be part of a bigger comprehensive health screening process among adults at higher risk for elevated BMLs.

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