AN INVESTIGATION OF FACTORS RELATED TO LEVELS OF MERCURY IN HUMAN HAIR

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Abstract

Hair analysis provides a historical record of an individual's exposure to mercury or methylmercury. In this study hair analysis of mercury was performed on samples from self-selected volunteer participants from across the United States. Participants completed detailed questionnaires that included questions regarding their level of fish consumption (broken down by type of fish), as well as age, gender, race, hair treatments, flu vaccinations, and dental amalgams. The responses to these questions were then related to data regarding hair mercury concentrations to compare groups of interest and to use in an ANOVA statistical analysis. Total hair mercury was found to be significantly associated with age, race, gender, geographic region, and fish consumption frequency. The median hair mercury concentration for participants who consumed eight or more servings of seafood per month (including shellfish) was 0.83 ug/g more than those who reported consuming no fish, 0.68 ug/g more than those who consumed 1-2 servings per month, and 0.43 ug/g more than those who consumed 3-7 servings per month. There was not a statistically significant difference between the hair mercury concentration of those who had dental amalgams and those who did not or between those who had had a flu vaccination in the past year and those who had not, although the difference for dental amalgams was close to being statistically significant. Midwesterners had substantially lower median hair mercury concentrations than those in other regions of the US, even after adjusting for other factors such as frequency of fish consumption.

1. Introduction

Mercury is an element that cycles through the environment. It enters the environment naturally from volcanoes, mineral deposits and evaporation from soil and oceans. Anthropogenic sources of mercury such as emissions from coal-fired utility boilers (the largest source), municipal waste combustion, commercial/industrial boilers, and medical waste incinerators increase the natural mercury levels in the air, water, and soil[7]. Mercury is most often used in alloys, thermometers, batteries, and dental amalgams because it is the only common metal liquid[1].

There are three types of mercury: elemental mercury, organic mercury, and inorganic mercury. Elemental or metallic mercury is the familiar metal liquid in thermometers and is one of the most common forms found in the environment. Metallic mercury is also used in silver dental amalgam fillings which contain approximately 50% mercury[1]. Organic mercury compounds are combinations of mercury with carbon. Organic mercury takes several forms as some microorganisms (bacteria and fungi) and natural processes change the mercury in the environment from one form to another; the most common form being methylmercury. Inorganic mercury compounds form when mercury combines with elements such as chlorine, sulfur, or oxygen; some inorganic mercury compounds are used as fungicides[1].

In the United States, coal-fired utility boilers are the biggest source (33 percent) of anthropogenic mercury emissions to the atmosphere[7]. Mercury eventually falls from the atmosphere or runs off the ground into water (streams, lakes, rivers) and accumulates in the soil and bottoms of water bodies. After the mercury deposits into water, microorganisms (bacteria and fungi) convert it to a form of organic mercury. Methylmercury, a highly toxic form of organic mercury, accumulates in the water and is then absorbed by fish and plants near the source. This bioaccumulation process continues with levels of mercury increasing as it moves

up the food chain[8]. Mercury builds up through the food chain until it reaches toxic levels, many times greater than levels in the surrounding water, in predator animals such as predatory fish and mammals.[8]

The United States Environmental Protection Agency (EPA) has set the Reference Dose associated with hair mercury concentration at 1.0 μg/g [7]. Mercury is primarily considered a health risk to children and women of childbearing age because of its effects on brain and organ development. Mercury can pass from mother to child through the blood stream or through the mother's breast milk[1]. The EPA warns, "Offspring born of women exposed to methylmercury during pregnancy have exhibited a variety of developmental neurological abnormalities, including the following: delayed onset of walking, delayed onset of talking, cerebral palsy, altered muscle tone and deep tendon reflexes, and reduced neurological test scores"[7]. Mercury also poses problems for adults. In general, the nervous system is very sensitive to mercury. Current studies are also exploring the risks of continuous low levels of mercury exposure in adults and its effects on brain functions such as memory and attention. A recent study found no association between number of dental amalgams, which contain mercury, and cognitive dysfunction[2]. The study did find, however, a linear association between the total number of amalgams and the urinary mercury concentration[2]. Two other recent studies explored the relation between mercury and the risk of heart problems in men. One study found a direct association between the risk of myocardial infarction and mercury[3], while the other study's results on coronary heart disease were inconclusive[9].

Tests for mercury exposure in humans can be performed using analysis of blood, urine, nail clippings, or hair samples. The different analyses provide different information about the mercury levels in the body. Blood and urine levels are used as markers to determine if recent exposure has occurred. They are more useful for measuring recent exposures to mercury because blood concentrations decrease rapidly over a few days if exposure is stopped. Hair samples are associated mainly with methylmercury exposures and can be used to indicate exposures that occurred over the past several months or a year. However, hair concentrations are not able to detect recent exposures such as a few days prior[1]. Mercury is incorporated into hair during the growth of hair, which is about one centimeter a month[7]. Hair is a simpler means by which to do large studies because the samples are easier to obtain from a large and varied sampling group. The cost is also minimized because the hair samples are simply cut from the subject's hair and placed in a small plastic bag. Fewer individuals would be willing to draw a blood sample or return a urine sample than to provide a hair sample. The EPA presumes that hair mercury concentrations reflect blood mercury concentrations at the moment of hair growth[7]. A previous mercury-in-hair study conducted during the 1999-2000 National Health and Nutrition Examination Survey (NHANES) concluded, "Hair Hg [mercury] analysis in national samples of U.S. children and women of childbearing age provide a useful biomarker for long-term Hg exposure"[4].

In this study, samples of hair are analyzed from a nationally distributed self-selected sample. Participants complete a questionnaire about demographic factors and potential exposure to mercury. A statistical analysis is performed to relate mercury concentrations in hair to potential factors such as fish consumption and having dental amalgams.

2. Methodology

Study participants were recruited by Greenpeace, the Sierra Club, the Natural Resources Defense Council and other nonprofit organizations throughout the United States through national internet

notices, regional media coverage of the research project, special local awareness events, and other publicity efforts. Although the study is on-going, this report is based on the 6,583 samples obtained from July, 2004 to September, 2005. The study sample is not presumed to be statistically representative of the entire U.S. population, since participants were self-selected, and recruitment of study participants was focused more strongly in some areas of the country than others. Particular geographic areas, individuals who might be more concerned about this particular health issue, individuals with higher-than-average fish consumption, and individuals better able to afford the small fee to participate in the study are expected to be overrepresented in the sample.

Each volunteer was sent a hair sampling kit by the Environmental Quality Institute (EQI) consisting of gloves, plastic sample bags, labels, a cardboard weighing balance designed to tip when approximately 0.5g of hair was added, detailed instructions for cutting, weighing and labeling hair samples, and a return postage-paid mailer. After washing their hair, each volunteer participant was instructed (complete with illustrations) on how and where to cut and weigh their sample. Each sampling kit also included a detailed research questionnaire which requests information on age, gender, pregnancy status, hair color, occupation, dental amalgams and removal, flu shot history, and, several questions regarding specifics of fish consumption habits. Upon receipt at the EQI laboratory, samples were given a laboratory identification number and questionnaire data was transferred to a computerized database. Hair samples were weighed to the nearest 0.0001 gram on an analytical balance and digested using EPA Method 3050B with concentrated nitric acid and 30% hydrogen peroxide on a SCP Science Digiblock$_{TM}$ graphite block digestor. Final volume of the digestate was 50ml.

Mercury determination was performed using EPA Method 7470A. Either a Thermo-Jarrel-Ash 22 graphite furnace atomic absorption spectrometer (AAS) or a Thermo Elemental M6 AAS with a V90 continuous-flow vapor system were used to determine mercury concentration in the digestates. Each volunteer participant was sent a confidential letter with their individual results along with explanatory information regarding USEPA advisory levels.

3. Results

A comparison of the percentage of 16-49 year-old women grouped by total servings of fish consumption in this study to that in the NHANES study (Table 1) indicates that participants in this study tend to be greater consumers of fish than in the NHANES study, which came from a random sample of the U.S. population. This difference may be due to the fact that participants of this survey are self-selected but also may be caused at least partially by a national trend towards increased fish consumption from 1999-2000 to 2004-2005. Hair mercury concentration data were summarized by determining the raw medians and the proportions above the EPA's Reference Dose of 1.0 μg/g for each age group - gender combination (Table 2). The 95% confidence intervals for the medians were calculated using non-parametric confidence intervals based on ranks. Because of the potential overrepresentation of heavy consumers of fish in the current study, medians and proportions represent estimates for a higher-risk group rather than for the US population as a whole. The medians indicate that children have approximately half the mercury concentration levels of the adults. Also, among the adults, the mercury concentration levels for the females are lower than for the males.

Table 1. Comparison of Fish Consumption Between Current Study and NHANES 1999-2000 Study for Women Between 16 and 49 Years Old

Study	Fish Consumption Category	Number in Category	Percent of Group in Category
Current Study - Fish and Shellfish Combined	0	702	11.7
	1-2	1,031	17.1
	3+	4,292	71.2
NHANES 1999 - 2000 Fish Only	0	639	38.5
	1-2	573	34.5
	3+	447	26.9
NHANES 1999 - 2000 Shellish Only	0	878	52.9
	1+	782	47.1

Slightly more than 10% of women of childbearing age in the NHANES 1999-2000 study had mercury concentrations greater than those the RfD of 1.0 µg/g in hair[4]. In this study approximately 23% of 16-to-49 year old women had hair mercury concentrations greater than or equal to 1.0 µg/g (Table 2).

Table 2 – Estimated Medians (95% Confidence Interval) and Estimated Percentages 1.0 µg/g or Higher (Standard Error), Broken Down by Age Category and Gender and Weighted by Fish Consumption

Age Category	Gender	N	Median (ug/g)	Percent Above 1 ug/g
0 - 1 year	Female	13	0.29	7.7 (7.1)
	Male	20	0.17	0.0 (0.0)
2 - 5 years	Female	76	0.11 (0.09 - 0.20)	2.6 (1.8)
	Male	128	0.13 (0.09 - 0.17)	5.5 (2.0)
6 - 15 years	Female	120	0.20 (0.16 - 0.24)	5.8 (2.1)
	Male	162	0.13 (0.10 - 0.17)	4.3 (1.6)
16 - 49 years	Female	2834	0.43 (0.41 - 0.45)	22.6 (0.8)
	Male	990	0.55 (0.51 - 0.61)	29.3 (1.4)
50+ years	Female	1275	0.49 (0.45 - 0.52)	24.2 (1.2)
	Male	848	0.62 (0.55 - 0.68)	29.4 (1.6)

An analysis of variance (ANOVA) model was used to examine the relationship between hair mercury (Hg) and several potential predictor variables and demographic variables. The distribution of mercury concentrations was positively skewed, so a logarithmic transformation was used to improve normality. Fish consumption categories included: canned tuna servings, store- or restaurant-bought fish servings, local fish servings. A standard serving was defined as six ounces, and fish consumption included shellfish consumption. Fish frequency data were grouped into four categories: no fish consumed, fish consumed one or two times per month, fish consumed three or four times per month, and fish consumed more than five times per month.

Age was grouped into five categories: less than or equal to one year, two to five years, six to fifteen years, sixteen to forty-nine years, and fifty or more years. Participants' residence was grouped by the U.S. Census Bureau's definition of region[6]. Additional variables investigated included gender, race, pregnancy status, existence of silver dental amalgams, amalgams recently removed, and recent flu vaccinations. Other variables involving hair treatments (dyed or permed) were disregarded because they were found earlier to be non-significant factors and dropped from the questionnaire. Due to the large number of potential effects, interactive effects were not considered. A check of the residuals for normality in the final ANOVA model yielded acceptable homoskedasticity, a skewness of 0.22, an (adjusted) kurtosis of 0.80, and normality tests with p-values less than 0.05. Thus, the log transform did not completely correct for non-normality, but did improve normality enough for the large sample hypothesis tests considered here to be valid. The reported P-values are two-tailed, and the tests of statistical significance used $\alpha = 0.05$. Statistical analyses were performed with SAS software (Release 9.1, SAS Institute, Cary, NC).

The ANOVA results for the 3,850 participants with fully-completed questionnaires, indicated that age category, gender, geographic region, local fish servings, race, store or restaurant fish servings, and tuna fish servings were all highly statistically significant factors at the 0.05 level (Table 3). The factors: have amalgams, amalgams recently removed, a recent flu shot, and pregnancy status were not statistically significant in accounting for total mercury concentrations, although having amalgams (P-value = 0.070) was close to statistical significance.

Table 3 – Statistical Significance of Various Factors Associated with Hair Hg Concentrations for Final Model

Factor	DF	F Value	P-Value
Age Category	4	21.4	< 0.001
Amalgams Removed	1	0.2	0.654
Flu Shot	1	0.1	0.805
Gender	1	19.1	< 0.001
Geographic Region	3	54.8	< 0.001
Have Amalgams	1	3.39	0.070
Local Fish Servings	3	26.6	< 0.001
Pregnancy Status	1	0.5	0.501
Race	4	13.6	< 0.001
Store Fish Servings	3	325.6	< 0.001
Tuna Fish Servings	3	68.5	< 0.001

The unweighted medians and 95% confidence intervals for each level of each factor considered were computed using the methodology discussed previously from the raw data. Each factor was analyzed separately to include the most number of responses for each question. Because participants in this study probably tend to consume more fish than the general public, the medians are more useful for comparing levels of factors than for estimating representative US concentrations. Also, because these medians are not adjusted for other factors, the results are not necessarily consistent with those of the ANOVA model, which does consider statistical significance of a factor after adjusting each of the levels for other factors in the model. Therefore, adjusted median estimates, calculated by reverse-transforming the least-square means from the ANOVA analysis are also provided. These adjusted medians provide an estimate of what the median mercury of the given group would be if the individuals in that group were

equally divided into the levels of all the other variables considered in the ANOVA model. In particular, since the adjusted medians for any group from variables not reflecting fish consumption would assume equal proportions of individuals in each of the fish-consumption groups for each type of fish consumption, and the tuna fish and local fish actually had much less people in the higher groups, then the adjusted medians tend to be higher than the raw medians for those variables. Thus, adjusted means are useful only for making comparisons between groups within a given variable.

Medians for total fish consumption groups indicate a consistent and strong positive relationship between mercury in hair and total fish consumption (Table 4). The median for people that consume almost no fish is 0.06 ug/g, while the median for those who consume eight or more servings per month is approaching the 1.0 ug/g RfD for pregnant women. This striking difference indicates that fish consumption is clearly the primary source of hair mercury exposure for most Americans. Medians for the restaurant fish servings per month, tuna fish servings per month, and local fish servings per month follow the same pattern, although the range in mercury concentrations between low and high consumption categories is not as great. This indicates that statistically there is no segment of the fish consumption sources that does not contribute significantly to mercury exposure.

Table 4 – Unweighted Medians (µg/g) and 95% Confidence Intervals by Factor

Factor		N	Raw Median (µg/g)	95% C.I. for the Raw Median	Adjusted Estimate of Median
Age Category	0 - 1 year	33	0.18	(0.14 - 0.29)	0.56
	2 - 5 years	204	0.13	(0.10 - 0.17)	0.33
	6 - 15 years	283	0.17	(0.13 - 0.19)	0.34
	16 - 49 years	3824	0.46	(0.44 - 0.48)	0.58
	50+ years	2126	0.53	(0.50 - 0.55)	0.61
Region	Midwest	1284	0.26	(0.23 - 0.28)	0.34
	Northeast	1745	0.49	(0.44 - 0.53)	0.53
	Southeast	1550	0.44	(0.40 - 0.47)	0.49
	West	1946	0.59	(0.55 - 0.62)	0.56
Gender	Female	4385	0.43	(0.41 - 0.44)	0.44
	Male	2181	0.49	(0.46 - 0.52)	0.54
Race	Caucasian	4325	0.44	(0.42 - 0.46)	0.47
	Hispanic	135	0.33	(0.26 - 0.41)	0.45
	African-Amer.	64	0.27	(0.19 - 0.33)	0.39
	Asian	140	0.90	(0.76 - 1.14)	0.82
	Other	104	0.39	(0.30 - 0.48)	0.40
Pregnancy Status[1]	Pregnant	134	0.43	(0.35 - 0.52)	0.49
	Not pregnant	2697	0.43	(0.40 - 0.45)	0.46
Store Fish Servings Per Month	None	1304	0.12	(0.11 - 0.13)	0.22
	1 – 2	1964	0.36	(0.34 - 0.38)	0.41
	3 – 4	1426	0.57	(0.53 - 0.60)	0.56
	5+	1552	0.94	(0.90 - 1.00)	0.91
Table 4 (Continued)					
Tuna Fish	None	2237	0.25	(0.23 - 0.28)	0.34

Servings Per Month	1 – 2	2242	0.45	(0.43 - 0.48)	0.44
	3 – 4	984	0.62	(0.57 - 0.67)	0.53
	5+	862	0.83	(0.76 - 0.88)	0.63
Local Fish Servings Per Month	None	4486	0.38	(0.36 - 0.40)	0.37
	1 – 2	1105	0.57	(0.52 - 0.61)	0.45
	3 – 4	320	0.65	(0.59 - 0.79)	0.45
	5+	247	0.96	(0.85 - 1.17)	0.66
Total Fish Servings Per Month[2]	None	702	0.06	(0.06 - 0.07)	
	1 - 2	1031	0.22	(0.20 - 0.24)	
	3 - 7	2489	0.47	(0.44 - 0.49)	
	8+	1803	0.90	(0.86 - 0.94)	
Has Dental Amalgams	Yes	4078	0.49	(0.48 - 0.52)	0.49
	No	1706	0.40	(0.37 - 0.43)	0.46
Amalgams Removed (last 12 months)	Yes	841	0.52	(0.48 - 0.59)	0.47
	No	5515	0.44	(0.42 - 0.45)	0.48
Flu Shot (last 12 months)	Yes	1280	0.45	(0.42 - 0.50)	0.47
	No	5156	0.44	(0.42 - 0.46)	0.47

[1] Raw medians and confidence intervals for pregnancy status are only based on females aged 16 to 49 years, while least square median estimates for pregnancy status are based on all the data.
[2] Least square means were not calculated because the factor: total fish servings per month, was not included in the ANOVA model.

The participants with dental amalgams had an approximately 0.1 ug/g larger median value than those without dental amalgams. The fact that the difference between the two groups is not statistically significant is consistent with the result that the difference in estimated medians is only 0.03 ug/g when adjusted for other factors such as fish consumption. A better idea of the strength of the relationship between dental amalgams and hair mercury concentration might have been obtained if the number of amalgams could have been quantified for each participant. Unfortunately, a large percentage of participants left the number of amalgams question on the questionnaire unanswered. Consistent with the ANOVA results medians were approximately the same between groups for the factors: amalgams removed recently (last 12 months) and flu shot recently (last 12 months).

The Midwest region had the lowest median Hg value, while the West region had the highest median mercury. The Northeast and Southeast regions medians were similar. The median for Asians was considerably higher than the medians for the other races, while African-Americans had the lowest estimate. However, the number of responses for races other than Caucasian was small. The medians for pregnancy status were only based on females age 16 to 49 and were also approximately the same for pregnant and non-pregnant women.

Summaries of the results for states with at least 100 participants and cities with at least 50 participants are provided in Table 5 and Table 6, respectively. These summaries reinforce the findings that mercury concentrations in hair are closely related to seafood consumption. With the exception of Utah, whose participants had very high seafood consumption and moderate

mercury consumptions, the states that had higher seafood consumption also had higher mercury concentrations in hair. New York had the highest hair mercury concentrations, followed by Colorado, California, Oregon, Florida, Massachusetts and Washington. A similar pattern exists for the cities. The results for two cities stand out. Masontown PA had a relatively very low median mercury concentration of 0.08 ug/g. Masontown is close to a coal fired power plant, but participants consumed much less seafood than participants at most locations. This reinforces the idea that mercury concentrations in hair are caused by consuming food contaminated with mercury. New York City has the highest hair mercury concentrations of any city with 50 or more participants. The 191 New York City participants had a median hair mercury concentration of 0.88 ug/g and 47% were 1.0 ug/g or greater. Their median number of 6 seafood servings consumed per month was tied the second largest amount. Other cities with higher-than-average hair mercury concentrations include Portland, San Francisco, and Seattle. Except for San Francisco, which had lower than typical seafood consumption, these cities had the highest seafood consumption.

Table 5. Results for States with at Least 100 Participants.

State	n	Median Mercury (ug/g)	Percent ≥ 1.0 ug/g	Median Total Seafood Servings per Month
CA	1090	0.62	30.0	5.0
CO	135	0.67	30.4	5.0
FL	389	0.61	33.4	6.0
IL	169	0.31	15.4	5.0
MA	218	0.61	27.1	5.0
MD	218	0.48	17.4	4.0
MI	115	0.38	20.9	4.0
MN	293	0.24	8.9	4.0
NC	175	0.41	15.4	4.0
NH	133	0.46	18.8	6.0
NJ	192	0.48	27.1	5.0
NY	455	0.76	40.2	5.5
OH	415	0.22	10.6	4.0
OR	130	0.62	26.2	6.0
PA	535	0.26	11.4	3.0
TX	203	0.38	15.8	5.0
UT	139	0.36	15.1	5.0
VA	149	0.40	27.5	5.0
WA	184	0.57	28.8	6.0
WI	126	0.22	10.3	4.0

Table 6. Results for Cities with More Than 50 Participants.

City	State	n	Median Mercury (ug/g)	Percent ≥ 1.0 ug/g	Median Total Seafood Servings per Month
Austin	TX	50	0.43	24.0	5.0
Masontown	PA	64	0.08	3.1	2.0
Miami	FL	70	0.38	30.0	5.0
Minneapolis	MN	115	0.26	8.7	4.0
New York	NY	191	0.88	47.1	6.0
Philadelphia	PA	63	0.35	20.6	5.0
Pittsburgh	PA	81	0.25	4.9	3.0
Portland	OR	54	0.68	25.9	6.0
Salt Lake City	UT	77	0.35	10.4	5.0
San Francisco	CA	122	0.68	29.5	4.0
Seattle	WA	56	0.61	32.1	7.0
Washington	DC	99	0.48	26.3	5.0

4. Summary and Conclusions.

There exists a strong relationship between mercury concentration in hair and seafood consumption. In this study, participants who typically consumed 0, 1-2, 3-7, or eight or more servings of seafood (including shellfish) per month had median mercury concentrations of 0.06 ug/g, 0.21 ug/g, 0.46 ug/g, or 0.89 ug/g, respectively. In the NHANES 1999-2000 study females 16-49 years of age who had consumed 0, 1-2, or three or more servings of fish (not including shellfish) per month had geometric means of 0.11 ug/g, 0.20 ug/g, or 0.38 ug/g, respectively. The results for the lower two groups of each study are very comparable, especially considering that the NHANES results quoted here included only women aged 16-49 and did not include shellfish consumption with fish consumption. The fact that the medians for the upper two categories in the current study are higher than the geometric mean in the NHANES may be partially due to those two factors as well as the possibility that participants in the current study in the 3-7 servings group may be weighted more towards the higher end of the group than those in the three-or-more group in the NHANES group. Thus, the current results do not provide evidence of an increasing or a decreasing trend from 1999-2000 to 2004-2005 in mercury concentrations for a given amount of fish consumption. An earlier (1994) study conducted by Schweinsberg in Germany, of the relationship between fish consumption and mercury concentration in Germany, found that subjects who consumed 0-400 g, 400-1,000 g, or more than 1,000 g per month had mean hair mercury concentrations of 0.56 ug/g, 0.94 ug/g, and 1.60 ug/g.[5] Converting to 6-ounce servings, the consumption groups would be 0-2.4 servings, 2.4-5.8 servings, and more than 5.8, servings respectively. Because the mean of the positively skewed hair mercury concentrations would be expected to be 1.5 to 2.5 times the median or geometric mean, these results are consistent with those of the current study and the NHANES study, thus also providing no evidence of a time trend in hair mercury concentrations for a given amount of fish consumption.

The current study found very little evidence of a relationship between dental amalgams and mercury concentrations in hair. In the 1994 study by Schweinsberg it was found that among

individuals who had no fish consumption, individuals with no amalgams had mean blood mercury concentrations of approximately 0.3 ug/L, while individuals with more than six amalgams had mean blood mercury concentration of approximately 1.0 ug/L. In a summary of several studies, ADSTR estimated the exposure contributions from those with dental amalgams to range from 3-17 ug/day.[1] One possible explanation for the apparent discrepancy between the current study and other studies is that the inorganic mercury obtained from dental amalgams accumulates less in hair and other tissues than the methylmercury obtained from consuming fish.

Several demographic factors were found to be related to mercury concentrations in hair in the current study. One of the stronger relationships is the relationship between region and mercury concentrations. The Midwest region has raw median mercury concentrations that are much less than those for the other regions of the US. This suggests that sources of mercury exposure other than fish consumption may be less in the Midwest such as chlor-alkali plants or mines. Perhaps the ANOVA adjustment does not fully take out the effect of fish consumption. It is also possible that fish consumed in the Midwest tend to be lower in the food chain or that mercury pollution is less in Midwest water than in other US waters. Another demographic factor that seems hard to explain is the higher concentrations in Asians than in other races, even after adjusting for the level of fish consumption. There may be similar explanations as those for different regions. Also, there were not many Asians (n=240) in the current study. The fact that adults have substantially higher mercury concentrations than children after adjusting for other factors may again be partially due to the fact that the statistical adjustments are not perfect or may also be due to the fact that adults have accumulated a long-term burden that shows up in hair samples. Men tend to have higher concentrations than women but the difference in least square medians is only 0.1 ug/g.

The study described here is an ongoing study. Periodically, the questionnaire has been revised to gather more specific information. Since the beginning of the study, questions have been added to allow us to break fish consumption down more precisely. This should allow us to eventually compare the additional mercury burden caused by consuming different species as well as to be able to better compare the results of this study to other studies. As more samples are received, we should also be able to obtain more precise information about exposure to smaller subgroups of our sample, such as minority races, pregnant women and young children.

6. References

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