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Short communication

Mercury in fish available in supermarkets in Illinois: Are there regional differences

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Abstract

Media coverage has made the public aware of both the benefits and the risks from eating self-caught fish, but information on contaminants in commercial fish is much more limited, especially on a local level. The U.S. Food and Drug Administration website provides methylmercury data for a variety of fish, but for many species sample sizes are small and data are more than a decade old, whereas commercial fish sources are highly dynamic. A few state agencies are beginning to provide contaminant information for commercial fish, including canned tuna. We examined the mercury concentration of six types of fish purchased in supermarkets in Chicago, Illinois in 2005. We measured total mercury (methylmercury accounts for about 90% of the total mercury in fish). One key question was whether the concentrations of mercury in fish available locally were similar to those reported in other areas of the country and in the FDA U.S. national data base. Such information is critical for the public, especially pregnant women or those planning on pregnancy, making decisions about types and quantities of fish to consume. Some fish are available generally throughout the U.S., but others are more locally available, suggesting a need for site-specific information. This research was stakeholder driven, and reflected local interest in the safety of local fish. There were significant differences in mercury concentrations among the fish, ranging from a mean of 0.03 µg/g (ppm-wet weight) for salmon (*Salmo spp.*) to 1.41 ppm for swordfish (*Xiphias gladius*). Maximum values for three species of fish (orange roughy *Hoplostethus atianticus*, swordfish walleye *Sander vitreus*) were over 1 ppm (FDA action level), and all of the fish except salmon had some values above 0.5 ppm, the action level set by some states and countries. There were significant differences in mercury concentrations among three types of canned tuna (*Thunnus* spp): “gourmet tuna” had the least amount of mercury, and white tuna had the most. The mean concentrations reported in this study were generally similar to those reported by the FDA, but there were important differences: 1) although the mean mercury concentrations for orange roughy for the Chicago data was similar to the FDA data, the maximum concentration was higher; 2) the mean for the Chicago swordfish was higher than the FDA data (1.26 vs 0.97 ppm, methylmercury); 3) the maximum for tuna steaks was higher in the FDA data set; and, 4) mean values for grouper (*Epinephelus* spp.) were higher in the FDA data set than the Chicago data. Further, the FDA has virtually no data on walleye and none on “gourmet tuna”. These conclusions suggest that there are enough variations between the local data (Chicago) and the FDA data to warrant periodic local monitoring of commercial fish to provide up-to-date information to consumers about mercury in the fish they eat.

Keywords: Fish consumption; Risk; Human health; Commercial fish; Stakeholder-driven research; Mercury

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1. Introduction

Fish is an excellent, low-fat source of protein for humans that provides many benefits, such as providing omega-3 (n-3) fatty acids that reduce cholesterol levels and the incidence of stroke, heart disease, and pre–term delivery (Daviglus et al., 2002; Patterson, 2002). However, some fish also contain contaminants, such as mercury and polychlorinated biphenyls (PCBs) that could pose harm to human health and particularly neurobehavioral development (IOM, 1991). Increasingly, the public is interested in the potential risks from mercury and other contaminants in fish, stimulating state agencies and policy-makers to examine the question for their regions. While nearly all states issue consumption advisories for self-caught fish, far fewer state agencies have examined contaminant concentrations in commercial fish (Burger et al., 2004).

The only significant source of methylmercury for the public is fish consumption (Rice et al., 2000). Methylmercury (MeHg) and PCBs concentrations are sufficiently high in some fish to cause adverse human health effects in people consuming fish frequently (IOM, 1991; Gochfeld, 2003; Hites et al., 2004). Methylmercury counteracts the cardioprotective effects of omega-3 fatty acids (Guallar et al., 2002) and can damage developing fetuses and young children (NRC, 2000). Chemicals can be transferred across the placenta, posing direct risk to developing fetuses (Gulson et al., 1998). There is a positive relationship between PCB and/or mercury concentrations in fish, fish consumption by pregnant women, and deficits in neurobehavioral development in children (Lonky et al., 1996; Schantz et al., 2003). There is also a decline in fecundity in women who consume large quantities of contaminated fish from Lake Ontario (Buck et al., 2000). Mercury poisoning has even been reported in adults eating fish weekly or daily (Hightower and Moore, 2003).

Consumers thus face the need for weighing the benefits and risks of fish consumption (Knuth et al., 2003), as well as balancing the benefits and risks of fish versus other protein sources (Willett, 2005). This leads to the conclusion that women should continue eating fish during pregnancy, but choose fish with lower mercury concentrations (Oken et al., 2005). Women, however, can make this choice only if they have information about mercury concentrations in commercial fish in their region. Regardless of whether individual responsibility for consumption is a reasonable solution to environmental problems (Halkier, 1999), consumers should have the necessary information to make informed decisions about the fish they eat.

In this paper we examine the concentrations of mercury in fish collected from supermarkets in the Chicago, Illinois area. We were particularly interested in three questions: 1) were the concentrations of mercury in commercial fish species generally available throughout the U.S. (salmon *Salmo* spp., tuna *Thunnus* spp., swordfish *Xiphias gladius*) similar to those reported from elsewhere or by the FDA (2001, 2006)? 2) what were the concentrations of mercury in fish bought locally? and, 3) how do the concentrations of mercury in different types of tuna compare? The first question deals with whether the public can make assumptions about the mercury concentrations in fish in their markets based on nationally available data. The second question addresses the information needed by consumers. The third question examines the generality of the finding that light tuna has less mercury than white tuna, and addresses the question of mercury concentrations in the tuna marketed as a gourmet product (sold in gourmet shops, marketed under "tonna").

This research was unique in that it was stakeholder–driven. The media became interested in mercury in fish, and sought university collaboration to ensure appropriate study design and validity. Media interest, in turn, was stimulated by public response and questions about the safety of fish available in supermarkets. While the main questions addressed in this research were those posed by the public in Chicago, the answers are important for people generally because they examine the applicability of FDA data for local consumers.

2. Methods

Fish were purchased in 2005 from supermarkets in the greater Chicago area. The initial design for the study was developed by us, in conjunction with Sam Roe, an investigative reporter for the Chicago Tribune. His interest was stimulated, in part, by an article in Environmental Health Perspectives (Burger et al., 2005) and by growing public concern about mercury. Fish were purchased by S. Roe and M. Hawthorne of the Chicago Tribune from 44 markets (3.7 fish/market) selected randomly from a database of telephone books for the greater Chicago area, in the 312, 773, 847, 708, 630, and 224 area codes. For fresh fish, the counter staff selected the samples. About 20 samples of each species were collected, labelled, wrapped in plastic, and immediately frozen. Cans of tuna were sent intact.

Fish were shipped to the Environmental and Occupational Health Sciences Institute (EOHSI) of Rutgers University for metal analysis. 2 g (wet weight) sample of fish tissue was digested in ultrex ultrapure nitric acid in a microwave (MD 2000 CEM), using a digestion protocol of three stages of ten min each under 50, 100 and 150 pounds per square inch (3.5, 7, and 10.6 kg/cm^2) at 80X power. Digested samples were subsequently diluted

Table 1
Mercury levels (ppm, wet weight) in supermarket fish from Chicago

Species	(N)	Mean±Std. Error	Geom Mean	Min	Max
canned tuna - light	20	0.10±0.02 (E, F)	0.07	0.02	0.31
canned tuna - white	22	0.31±0.03 (C, D, E)	0.24	0.01	0.51
canned tuna - gourmet	18	0.06±0.06 (F)	0.05	0.01	0.25
grouper	18	0.26±0.06 (D, E, F)	0.14	0.01	0.76
orange roughy	19	0.57±0.06 (B)	0.52	0.18	1.38
salmon	18	0.03±0.01 (F)	0.02	0.01	0.16
swordfish	18	1.40±0.18 (A)	1.07	0.15	3.07
tuna steak	18	0.34±0.06 (B, C, D)	0.22	0.01	0.94
walleye	18	0.51±0.13 (B, C)	0.33	0.11	1.74
X^2 (p)		106(0.0001)			

Shown are arithmetic mean with standard error, and geometric mean (GM). Letters that differ are significantly different. ANOVA F(p)=23.3 (<0.0001).

in 100 ml deionized water. All laboratory equipment and containers were washed in 10% HNO_3 solution and rinsed with deionized water prior to each use.

Total mercury was analyzed by cold vapor atomic absorption using the Portable Zeeman Lumex (RA-915) mercury analyzer, with an instrument detection concentration of 0.2 ng/g, and a matrix concentration of quantification of 0.002 ug/g. All concentrations were expressed in parts per million (ppm=μg/g) on a wet weight basis. Methylmercury was not analyzed in this study. Many studies have shown that about 90% of total mercury in fish is methylmercury, and in our laboratory the average across species is 89% (Burger et al., 2001a,b). The percentage varies among fish types and laboratories, but not appreciably by age (Lansens et al., 1991).

DORM-2 Certified dogfish tissue was used as the calibration verification standard. Recoveries between 90-110% were accepted to validate the calibration. All specimens were run in batches that included blanks, a standard calibration curve, 2 spiked specimens, and one duplicate. The accepted recoveries for spikes ranged from 85% to 115%; no batches were outside of these limits. 10% of samples were digested twice and analyzed as blind replicates. The laboratory periodically runs a random subset of samples in the Quebec Laboratory of Public Health; the correlation between the two laboratories is over 0.90 ($P<0.0001$, Burger and Gochfeld, 2004).

We used Kruskal Wallis non-parametric one way analysis of variance (generating a χ^2 statistic) to examine differences among fish species. We also used ANOVA with Duncan Multiple Range test on log-transformed data to identify the significant differences (SAS, 1999). The level for significance was designated as $P<0.05$.

3. Results

The arithmetic and geometric mean results for total mercury and the estimated mean MeHg concentration for the Chicago fish are shown in Table 1. There were significant differences in the mean concentrations of mercury as a function of species, with swordfish having the highest concentrations, and salmon and canned gourmet tuna having the lowest concentrations (Table 1). Maximum concentrations for orange roughy (*Hoplostethus atianticus*), walleye (*Sander vitreus*) and swordfish were above the 1 ppm U.S. FDA action level. The greatest variation in concentrations was found in the fish with the highest mean concentrations of mercury (Table 1). Table 2 shows the percent of fish above 0.3 ppm (the action level used by some states), 0.5 ppm (the action level used by many other

Table 2
Percent of fish with levels above 0.3, 0.5, and 1 ppm, the safety guidelines of different countries and states

Species	(N)	% >0.3 ppm	% >0.5 ppm	% >1 ppm
canned tuna - light	20	10	0	0
canned tuna - white	22	64	9	0
canned tuna - gourmet	18	0	0	0
grouper	18	44	17	0
orange roughy	19	95	58	5
salmon	18	0	0	0
swordfish	18	94	89	67
tuna steak	18	56	22	0
walleye	18	44	22	22

Table 3
Comparison of FDA (2006) data for mercury in fish (ppm) and data from Chicago (2005)

	Chicago, Illinois 2005		FDA data	
	N	Mean (Max)	N	Mean (Max)
Grouper	18	0.23 (0.68)	22	0.55 (1.21)
Orange Roughy	19	0.51 (1.24)	26	0.54 (0.80)
Salmon	18	0.03 (0.14)	34	0.01 (0.19)
Swordfish	18	1.26 (2.76)	605	0.97 (3.22)
Tuna Steak	18	0.31 (0.85)	131	0.38 (1.30)
Tuna Canned				
White	22	0.28 (0.46)	179	0.35 (0.85)
Light	20	0.09 (0.28)	131	0.12 (0.85)
Gourmet	18	0.05 (0.22)	none	
Walleye	18	0.46 (1.54)		

Total mercury from this study converted to MeHg to compare with FDA data.

states and countries), and 1 ppm (the U.S. FDA action level, see discussion) for some species of fish from Chicago markets. Only light and gourmet tuna, and salmon had no mercury concentrations above 0.5 ppm.

4. Discussion

4.1. Variations in mercury concentrations

The species-specific differences in mercury concentrations found in this study were expected; other studies (Burger et al., 2005), as well as the FDA (2006), report high mercury concentrations for swordfish and tuna steaks, and low mercury concentrations for salmon. Several factors are associated with differences in mercury concentrations in fish, including trophic level, and both age and size of the fish (Bidone et al., 1997; Burger et al., 2001a; Green and Knutzen, 2003). Larger fish usually have higher concentrations than smaller fish, especially within a species. Fish that are high in the food chain accumulate higher concentrations of biomagnifying contaminants, such as mercury (Campbell, 1994; Fairey et al., 1997; Burger et al., 2001a,b). There are some exceptions, since bottom-feeding fish sometimes have higher concentrations than predicted by their trophic position (Burger et al., 2001a), and not all larger or older fish have high mercury concentrations (Stafford and Haines, 2001).

The information available for commercial fish is insufficient to understand the causes for differences in mercury concentrations, except in generalities. That is, tuna and swordfish are top-level predators, and are expected to have high mercury concentrations, and they did. Our inability to relate mercury concentrations to specific factors is due directly to the lack of information about age, size, and location of capture of fish obtained from supermarkets. This same lack of information affects consumer's ability to select fish low in mercury.

The mean concentrations reported in this study were generally similar to those reported on the FDA web site (Table 3), but there were important differences: 1) although the mean for orange roughy in the Chicago data was similar to the FDA data set, the maximum concentration was higher; 2) the mean for the Chicago swordfish was higher than the FDA data when converted to MeHg (1.3 vs 0.97 ppm); 3) conversely, the maximum for tuna steaks was higher in the FDA data set; and, 4) mean value for grouper (*Epinephelus* spp.) was higher in the FDA data set than the Chicago data. The FDA web site has no data on walleye or on gourmet tuna. These observations have implications for fish consumers in the Chicago area and elsewhere, because they identify the general applicability as well as limitations in the available data set.

The current Chicago data on canned light tuna agree closely with both the FDA data and with our previous study (Burger and Gochfeld, 2004). However, the Chicago white tuna averaged slightly lower, raising the desirable prospect of a downward temporal trend, which we had anticipated as overfishing may result in the capture of smaller fish. The swordfish data were similar to 24 samples reported by the Mercury Policy Project (2005) from around the county. Those averaged 1.11 ppm (total mercury) with a maximum of 2.33 ppm. The same report on tuna averaged 0.33 with a maximum of 0.68 (n=31 Mercury Policy Project, 2005). However, our survey of tuna steaks purchased in NJ markets in 2003 (n=50) averaged 0.6 ppm (max=2.5 ppm; total Hg, wet weight).

4.2. Risk to consumers

Protection of public health with respect to fish consumption is generally a state responsibility, and states handle this responsibility by issuing consumption advisories. These advisories generally apply to self-caught, freshwater fish, although some states have begun to address commercial fish. Recently, however, the U.S. Food and Drug Administration (FDA, 2001, 2003, 2004) issued consumption advisories based on methylmercury that suggested that pregnant women and women of childbearing age who may become pregnant should avoid eating four types of marine fish (shark, swordfish, king mackerel, tilefish) and should limit their consumption of all other fish to just 12 ounces per week (FDA, 2001). These FDA (2001, 2003) advisories have raised concern about the safety of fish available in supermarkets. However, there is countervailing evidence on the benefits of fish that lead us to recommend that pregnant women include fish as part of a healthful diet (Gochfeld and Burger, 2005). One study suggests that these advisories may have led to a reduction in fish consumption (Oken et al., 2003).

Contaminants in commercial fish are of importance because of the potential for adverse effects from mercury on developing fetuses, young children, and even adults (see references in introduction). The task for concerned consumers is to obtain enough information on the risks and benefits from consuming different species of fish to make informed decisions. The FDA, consumer groups, web sites, and now the scientific literature are the sources of information available to the public. Information varies in detail, clarity, and quality. In addition to having site–specific data for commonly-eaten fish, other information can provide insights into possible mercury concentrations, but this information is generally not available. For example, some information on mercury concentrations can be estimated from knowing the species of fish (in the case of tuna), the size of the fish (bigger, older fish have higher concentrations), the source (wild or farmed), and perhaps the location of capture (for all species). The size of the fish can sometimes be assumed from the size and shape of the fillet displayed at the supermarket. Most supermarkets do not provide information on where fish were caught, and do not have the information when asked. Cans of tuna usually do not list the location of the catch, nor the species of tuna, although sometimes the processing country is listed. In this study, only 33% of the gourmet tuna cans listed the species (all yellowfin tuna, *Thunnus albacaras*).

4.3. Maximum concentrations and dose rate

There are two important aspects of these differences that relate to acute exposure from one or two meal, and chronic exposure from higher than expected concentrations. Sensitive populations, such as pregnant women or young children, may be at risk from eating only one or two fish meals with high mercury concentrations (acute exposure). The higher maximum concentrations for some fish (compared to the FDA data) means that a pregnant women relying only on the FDA data may underestimate her exposure. Ginsberg and Toal (2000) have suggested that there may be risk during pregnancy for exposure to a single-meal of high mercury if it occurred at a critical period. It may be essential to develop single-meal fish consumption advisories, especially for fish species high in methylmercury. For pregnant women it may be prudent to avoid any fish with maximum mercury concentrations over 0.3 ppm, not just those with means over 0.3 ppm.

The question of the “safe” level of exposure is controversial (NRC, 2000; Stern et al., 2004), and the role of one peak exposure has not been definitively answered. For a non-pregnant adult with a fully developed brain, it may be sufficient to determine risk based on chronic exposure. For the developing embryo, however, exposure to high mercury concentrations could occur at a critical period. Chronic exposure to higher than expected concentrations can affect adults. For example, the mean FDA (2006) mercury concentration for swordfish was below 1 ppm, while in the Chicago data the mean for MeHg was approximately 1.2 ppm. Thus a consumer who ate swordfish several times a week in Chicago would be getting nearly 20% more mercury than he expected, based on the FDA data. This is not a theoretical issue, since Hightower and Moore (2003) have reported clinical signs of mercury toxicity in patients with high consumption of fish that usually have high mercury concentrations.

Some fish tested in this study have not previously been examined for mercury (gourmet canned tuna, walleye fillets). While the concentrations of mercury in gourmet canned tuna were generally very low, the concentrations of mercury in walleye averaged 0.5 ppm, with a maximum of 1.74, within the range where FDA or states issue consumption advisories.

4.4. Action levels and risk levels

The USFDA has an action level for methylmercury in fish (FDA, 2001); the level of 1.0 mg/kg (ppm w/w) is a regulatory action level, rather than a risk level. However, the FDA currently does not regularly test fish. Originally (1969) the FDA had set 0.5 ppm as an administrative guideline, comparable to many other nations (see review in Burger and Gochfeld, 2004). The United Kingdom and the European Union have established criteria for certain metals in fish, (e.g. the concentration for mercury is 0.5 ppm in edible fish, with up to 1 ppm allowed for certain ‘exempt’ predatory fish species). China has set standards for methylmercury in canned fish (ppm wet weight) of 0.5 ppm (except 1 ppm is allowed in shark, sailfish, tuna, pike and other high–mercury fish). Thus, the values in Table 2 can be used to assess whether a given species of fish falls within the FDA action level (1 ppm), or the more restrictive 0.5 ppm level set by some states and countries.

4.5. Stakeholder–driven research

Because the research was stakeholder-driven, the information was of sufficient interest to result in a three-part feature story in the Chicago Tribune dealing with seafood safety, regulatory control, public response, and industry involvement. In this manner the data were made available to the public, as well as to the scientific community. While the full data were not printed in the paper, the salient highpoints were of general interest, particularly for canned tuna. Continued interest resulted in the story being carried in other newspapers across the country, leading to a general increase in awareness of the risks from mercury in commercial fish. This suggests that scientists can contribute directly to providing information to help people make informed decisions that impact public health.

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