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Contaminant profiles in Southeast Asian immigrants consuming fish from polluted waters in northeastern Wisconsin

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Abstract

Recent immigrants to the U.S. from Southeast Asia may be at higher risk of exposure to fish-borne contaminants including polychlorinated biphenyls (PCBs), p, p'-dichlorodiphenyldichloroethene (DDE) and methyl mercury (MeHg) because of their propensity to engage in subsistence fishing. Exposure to contaminants was assessed in men and women of Hmong descent living in Green Bay, Wisconsin, where the Fox River and lower Green Bay are contaminated with PCBs, and to a lesser extent with mercury. Serum samples from 142 people were analyzed for PCBs and p,p'-DDE by capillary column gas chromatography with electron capture detection (ECD). Whole blood was analyzed for total mercury by cold vapor atomic absorption spectrometry and atomic fluorescence spectroscopy. Lipid-adjusted total PCB concentrations ranged from 8.7-3,091 ng/g (full range of the data), with a geometric mean of 183.6 ng/g (estimated after eliminating one outlier). DDE ranged from 0.3-7,083 (full range of the data) with a geometric mean of 449.8 ng/g (estimated after eliminating two outliers). Men had higher PCB and DDE concentrations than women. Serum PCB concentrations were significantly correlated with fish consumption ($r=0.43$, $p<0.0001$), whereas DDE concentrations were not ($r=0.09$, $p=0.29$). Instead serum DDE was strongly associated with the number of years spent in a Thai refugee camp before immigrating to the US ($r=0.60$; $p<0.0001$). PCB congeners 138, 153, 118 and 180 accounted for a smaller percentage of the total PCBs than has been reported in other fish eating populations, and several lightly chlorinated congeners were present in relatively large amounts. Mercury exposure was low in this population. In conclusion, Hmong immigrants in northeastern Wisconsin are at risk of elevated PCB exposure from consumption of locally caught fish. The pattern of exposure is somewhat different than patterns in other fish eating populations, possibly due to use of Aroclor 1242 by the paper industry in this region.

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Human subjects approval: This study has been reviewed by the Institutional Review Boards of the University of Illinois (the lead institution and IRB for this project), Texas A&M University System Health Science Center, and Michigan State University. All IRB reviews and approvals for this project are on file at the University of Illinois IRB office, under Protocol # 99012 and # 02037.

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Keywords

PCBs; DDE; mercury; Southeast Asian immigrants; contaminated fish

Introduction

During the past two decades, immigration to the U.S. has been at an all-time high. Many of these new immigrants are from developing countries in Asia and Latin America and are at higher than average risk of exposure to environmental chemicals due to economic, lifestyle and cultural factors. Southeast Asian refugees are among this group. Since the Vietnam War ended over 1.5 million refugees have arrived in the U.S. from Vietnam, Laos and Kampuchea (formerly Cambodia). Many of these people were peasant farmers and fishermen from rural areas before emigrating to the U.S. This includes the Hmong whose ancestors originated in southern China and migrated to the mountainous regions of northern Myanmar (formerly Burma), Thailand, Vietnam and Laos in the early nineteenth century (Chan 1994). Virtually all of the Hmong currently in the U.S. came from remote mountainous areas of Laos. During the Vietnam War they were enlisted by the American Central Intelligence Agency to fight against the communists in Laos. Before the Vietnam War, the Hmong in Laos were almost completely self-sufficient and they lived virtually independent of the country's market economy (Koltyk 1998). They grew rice, corn and vegetable crops, raised goats, pigs, chickens and some cattle, gathered wild roots, tubers, fruits and herbs in the nearby jungles, and hunted and fished as a further means of subsistence.

In the U.S. most Hmong families continue to be as self-sufficient as possible—both because this lifestyle is an important part of their cultural identity and because economic resources for many families are limited due to a lack of education and job skills (Koltyk 1998). Most of the Hmong refugees in the U.S. settled in three States: California, Minnesota and Wisconsin. The vast majority of Hmong in Wisconsin—over 95%—live in urban areas (Karon et al. 2003). Thus, raising livestock is no longer an option for them. Similarly, the Hmong are aware that most Americans do not engage in foraging as a way to obtain food and many are hesitant to gather food from the countryside because they perceive that this practice is viewed as strange or unacceptable by the dominant culture (Koltyk 1998). In contrast, the Hmong recognize that most Americans do view hunting and fishing as acceptable pastimes and these activities, along with extensive gardening, remain as very important sources of food for Hmong families (Koltyk 1998). In one survey conducted in northeastern Wisconsin (Hutchison and Kraft 1994) over 50% of Hmong families reported eating sport-caught fish on a regular basis. In contrast, only about 8% of the general population of Wisconsin consumes sport-caught fish (Tilden et al. 1997).

Hmong families that engage in subsistence fishing are likely to be at greater risk of exposure to fish-borne contaminants such as polychlorinated biphenyls (PCBs) and mercury (Hg). This is a particular concern in northeastern Wisconsin where fish in the Fox River and lower Green Bay are highly contaminated with PCBs as a result of PCB deposition by the paper industry (2001), and to a lesser extent with Hg. Both PCBs and Hg are known to be developmental neurotoxicants (Newland and Paletz 2000; Schantz et al. 2003). The Hmong have a birthrate over twice that of the general population in the U.S. (Wisconsin Department of Health and Family Services, 2004), so the fact that these fish-borne contaminants are developmental neurotoxicants further increases the concern about exposure in this ethnic minority. To assess this risk we measured blood PCB and total Hg concentrations in reproductive age Hmong women and men residing in the Green Bay, Wisconsin area. Another chemical of concern to this population is DDE, a long-lived metabolite of DDT. DDT was once widely used as an insecticide and its stable metabolite, DDE is still present in fish, even though the parent

compound, DDT was banned from use in the US in 1973 (Turusov et al. 2002). Additionally, there was a potential for exposure to DDT prior to immigration in this population since DDT was used for malaria control extensively in Southeast Asia (Chareonviriyaphap et al. 2000). Therefore, blood serum concentrations of DDE were also measured.

Methods

Sample

The women and men who provided blood samples for analysis were participants in an ongoing study, the Fox River Environment and Diet Study (FRIENDS) the goal of which was to recruit Green Bay, Wisconsin area Hmong women and men to participate in a reproductive and neuropsychological health study. All procedures were approved by the Institutional Review Boards (IRBs) of the collaborating universities and all participants gave written informed consent. Consent documents were available in both English and Hmong, and were read aloud by the interviewer in cases where the participants' literacy was in question.

Households were identified by searching the Green Bay, Wisconsin electronic telephone directory for 34 recognized Hmong surnames and spelling variants. Based on 2000 census figures the Hmong population in Brown County, which includes the city of Green Bay, was 2,957. The telephone directory search identified 1,111 potential Hmong households. These households were contacted by phone during two phases of recruitment. In the first recruitment phase, Hmong adults were recruited for a study focusing on reproductive health and exposure to contaminants in locally caught fish. Individuals were identified as eligible if they were female, of Hmong descent, between 18 and 46 years of age, and had a partner who was at least 18 years of age. At enrollment, women and their partners were consented and then interviewed in their homes to obtain information on demographic background, lifestyle factors, reproductive history and fish consumption patterns. A total of 366 Hmong individuals (182 couples, 1 single female, 1 single male) from 184 households enrolled in the study during the initial recruitment phase. Later, these households were re-contacted and study participants were asked to provide a blood sample for contaminant analysis and complete a neuropsychological test battery to evaluate cognitive function. We successfully re-contacted 156 of the 184 households enrolled in the initial phase of recruitment; 66 women and 55 men (37% of previously enrolled women and 30% of previously enrolled men) from 77 of the previously enrolled households agreed to provide a blood sample.

In the second recruitment phase, additional Hmong adults were also recruited for the study focusing on the impact of contaminants in fish on cognitive functioning. Individuals were identified as eligible if they were determined to be of Hmong descent and were 18 years or older. Participants who were recruited during this second phase completed the same enrollment interview as participants recruited in the first phase. Twenty-one people (13 females and 8 males) from 15 households agreed to provide a blood sample during the second phase of recruitment. Some of these participants were recruited from households of participants enrolled during the first recruitment phase, and some were recruited from new Hmong households identified in phone directory searches done in 2006 and 2007. Blood samples of all of the participants were collected at our research office between July 2003 and October 2007. This paper reports exposure data for the subset of 142 study participants (79 women and 63 men) who provided a blood sample for contaminant analysis.

There were 185 participants (85 females and 100 males) from 108 households enrolled in the first phase of recruitment who were re-contacted but did not provide a blood sample. One of these participants was unable to give a blood sample due to health reasons, the remainder declined to give a blood sample: 38% gave no reason for the refusal or their reason was vague, 32% refused due to lack of time, 12% were not interested because they did not eat fish, and

the remainder (18%) gave a variety of other reasons. On average, participants who agreed to provide a blood sample for analysis were slightly younger than those who refused (31.1 years vs 34.3 yrs). Those who provided a blood sample also had about 2.7 more years of formal education, had resided in the US about 4.8 years longer, and reported eating local sport-caught fish for about 1 year longer than refusers.

Blood Collection

The blood samples were collected by a certified phlebotomist from a local hospital. Three 10 ml glass vacutainer tubes with no additives and no interior coating were taken for PCB and DDE analysis and one 7 ml trace element glass vacutainer tube was taken for mercury analysis. The blood collected for PCB and DDE analysis was centrifuged and the serum was transferred to a new vacutainer tube, whereas the whole blood samples collected for mercury analysis were left in their original vacutainer tubes. It should be noted that hair mercury is normally used as a biomarker for exposure to mercury. However, because of cultural issues, hair samples could not be collected from the Hmong immigrants that were the focus of this study. Whole blood was therefore used as a surrogate measure of mercury exposure. The PCB/DDE samples were packed in dry ice and shipped to the Analytical Toxicology Lab at SUNY Buffalo where they were stored frozen at -40°C . until analysis. The mercury samples were shipped to the same lab packed in cubed ice and stored refrigerated at 4°C . until analysis.

PCB and Pesticide Analysis

The congener-specific analysis of PCB congeners and DDE was performed based upon the methods described by Greizerstein et al. (1997). The PCB congeners and DDE were extracted from the serum by pressurized liquid (n-hexane) extraction using the Dionex (Sunnyvale, CA) ASE 300® Accelerated Solvent Extraction System. The serum sample was mixed with 4 g Hydromatrix and then loaded into 34-ml extraction cells containing 5 g of Florisil. The extract was collected, 0.2 ml of isooctane was added, and it was then evaporated to a volume of 1.0 ml using a Zymark (Hopkinton, MA) Turbovap® II Concentration Workstation. Further cleanup of the extract was carried out by eluting through a 500 mg Florisil® Sep-Pak® (Waters Corporation, Milford, MA) adsorbent column with 10.0 ml n-hexane. The extract was evaporated to a final volume of 0.2 ml and internal standards (PCB 30 and PCB 204) were added. The extract was then injected (1 μL) into an Agilent (Palo Alto, CA) 6890N Gas Chromatograph (GC) with Ni^{63} electron capture detection (ECD). The individual PCB congeners and DDE were separated on a 60 m RTX-5 fused-silica capillary column (0.25 mm i.d., 0.25 μm film thickness) from Restek (Bellefonte, PA). The carrier gas was ultra pure helium at an initial head pressure of 34 psi and constant flow rate of 1.5 ml/min. The detector make-up gas was ultra pure nitrogen at a flow rate of 60 ml/min. The sample was injected into a 4 mm gooseneck glass insert containing deactivated glass wool, operated in the splitless mode (0.75 min split-less vent time, 100 ml/min) at a temperature of 260°C . The detector temperature was 310°C . The oven temperature program started at 130°C , then went to 200°C at $4^{\circ}\text{C}/\text{min}$, 210°C at $1.0^{\circ}\text{C}/\text{min}$, and finally to 280°C at $2.0^{\circ}\text{C}/\text{min}$, for 5 minutes.

The GC data were acquired and quantified using Agilent ChemStation software. The identification and quantification of the individual congeners were performed by comparison with reference standards. The analytes were identified by their retention times relative to the respective internal standards (congener #30 for peaks eluting before congener #101, and congener #204 for congener #101 and those eluting thereafter). Results were corrected (blank-subtracted) for the mean concentration of each congener determined in sheep serum blank samples containing very low background levels of PCBs. Results were also adjusted for the percent recovery of the surrogates (PCB 46 and PCB142), which were added to each sample at the start of analysis. Calibration curves (2nd order polynomial) were generated following analysis of Accustandard PCB congener calibration mix standards (CS-01 to CS-05) and

pesticide calibration standards. The quality control program consisted of analysis of serum samples in batches of six to ten samples with the addition of four quality control samples. The QC samples consisted of one reagent blank, one matrix (serum) blank, three QC check samples, and one randomly selected duplicate sample. The limit of detection for each congener and pesticide was determined to be 3 times the standard deviation of the mean of the serum blanks. Total lipids (TL) for serum were determined from total cholesterol (TC), and triglycerides (TG) using the equation: $TL = 2.27 (TC) + TG + .623$ (Phillips et al. 1989).

Mercury analysis

The analysis of mercury in whole blood samples was performed in the laboratory of Dr. Thomas Clarkson and Gene Watson at the University of Rochester. Two methods were employed during the duration of the study. The earliest samples were analyzed by the selective determination of total and inorganic mercury in whole blood samples using a procedure adapted from Greenwood et al. (1977). The method measured MeHg as the difference between total and inorganic mercury in the blood sample (Magos and Clarkson, 1972), using an atomic absorption monitor Model 1235 from Laboratory Data Control (thermos Separation Products). Quality Control was assured by analysis of reference samples used daily prior to analysis of the samples. The Limit of Detection of the instrument was estimated to be 0.75 ng (3 SD of the Blank) in the aliquot used for analysis. Since the majority of mercury in the initial samples was found to be in the organic form and since a number of samples had undetectable levels of mercury, Atomic Fluorescence, which has a lower detection limit, was employed for subsequent samples and all data for mercury is expressed as total mercury values in whole blood. The determination of total Hg by cold vapor atomic fluorescence spectroscopy (CVAFS Merlin Merlin/Galahad system, PA 10.035; PANalytical Ltd, Orpington, Kent, United Kingdom) was performed after acid-digestion of samples in HNO_3 and H_2O_2 (95°C). The limit of detection, calculated as three times the standard deviation (SD) for the blanks, was 0.10 ng/l. All samples were measured in duplicate. The accuracy of the procedure was validated with the use of reference material (Seronom lot # 0503109). In addition, certified human blood samples from Centre de Toxicologie du Quebec, International Comparison Program, Canada were used.

Data Analysis

Lipid-adjusted PCB and DDE values were obtained by dividing the concentration of the contaminant by the concentration of lipid in the serum. All results are reported as ng/g lipid. PCB and DDE concentrations in serum followed a log-normal distribution. Hence geometric means (median of the long normal distribution) and confidence intervals are reported. To facilitate comparisons with other published exposure data both arithmetic means (mean of the long normal distribution) and geometric means are included in the tables. A large number of the samples (32 of 142) had total Hg levels below the detection limit of the instrument. These were excluded from the calculations of descriptive statistics. Spearman correlation coefficients were used to assess the associations among total PCBs, DDE and Hg as well as associations between these exposure variables and selected predictor variables.

Results

The sociodemographic characteristics of the sample are shown in Table 1. Most of the women and men sampled were between 20 and 46 years of age. Household incomes were generally low, with many reporting a total household income less than \$25,000. The women in the sample had on average 8.2 years of formal education, whereas the men had on average 9.6 years of education. However, some participants (25 women (32%) and 12 men (19%)) reported having no formal education. Among the 70 of 79 women for whom pregnancy history was available the average was 5 pregnancies (range 0-15). PCB (Spearman $r = .08$) and DDE (Spearman $r = .18$) concentrations were not significantly correlated with gravidity (Reliable data on parity

and breast feeding were not available.). A majority of the participants (67.1% of women and 77.8% of men) were born in Laos or Thailand. Education was negatively correlated with age (Spearman $r = -.30$, $p < .001$) and positively correlated with years in the United States (Spearman $r = .59$, $p < .0001$). As expected, the subset of participants born in the United States were younger (mean age 21.5 years) than those born outside the United States (mean age 34.5 years) and better educated; 77.1% had at least a high school education compared with 50% of those born outside the United States. Most participants born in Laos or Thailand had been in the United States for an extended period (about 20 years on average).

Most participants (85%) reported eating sport-caught fish, with women reporting an average of 6.6 years of consumption and men 7.9 years of consumption. Fewer participants (65%) reported having eaten sport caught fish within the 12 months immediately preceding collection of the blood sample. Fish consumption during the most recent 12 months was relatively modest, with women reporting a median of 6 fish meals and men reporting a median of 8 fish meals over the 12 months. PCB contamination in the Fox River was widely publicized in the local media during the time frame of the study and that was reflected in the participants' awareness of the fishing advisories. Virtually all respondents (134 of the 138 who answered the question) were aware of the fishing advisories for local waters. Only 9.7% of respondents reported no change in their fishing habits in response to the advisories. Others reported one or more of the following changes: stopped consuming local fish (49.5%), reduced consumption of local fish (31.5%), changed fishing locations (31.5%), changed types of fish eaten (14.4%) or changed how the fish is cleaned or prepared (7.2%).

Tables 2 and 3 show exposure data for total PCBs, p,p'-DDE, and total Hg. Men had higher serum PCB and DDE concentrations than women, but this difference did not reach statistical significance. Hg exposure was low in this population overall, but Hg concentrations were significantly higher in men than in women. Only 21 of the 142 people who provided a blood sample were not sport-caught fish consumers, but fish eaters had much higher total serum PCB concentrations (arithmetic mean of 347.6 ng/g lipid) than non-fish eaters (arithmetic mean of 87.8 ng/g lipid). The individual with the highest PCB concentration was a woman who reported consuming locally caught fish for 15 years. This one extreme value was excluded before calculating the summary statistics shown in Table 2. Similarly, two extreme DDE values, one male and one female, were excluded prior to calculation of means and confidence intervals. The participants born in Laos or Thailand had higher serum PCB concentrations and much higher serum DDE concentrations than the smaller subset of individuals born in the United States. Thirty two participants had Hg concentrations below the detection limit of the method and only five of the 142 participants who provided blood samples had total Hg concentrations above 5.8 ng/ml, the blood concentration upon which the EPA reference dose (RfD) was based (Rice et al. 2003).

Table 4 shows the Spearman correlation coefficients among total PCBs, DDE and Hg. Moderate correlations between PCBs and DDE, PCBs and Hg, and DDE and Hg were observed. Among fish eaters serum PCB concentration was positively correlated with years of sport-caught fish consumption (Spearman $r = 0.43$; $p < 0.0001$), but surprisingly, serum DDE and blood total Hg concentrations were not (see Table 4). The strongest predictor of serum DDE concentrations was the number of years spent in a Thai refugee camp prior to coming to the US (Spearman $r = .60$; $p < 0.0001$).

Table 5 shows the lipid-adjusted serum concentrations of individual PCB congeners that were detectable in at least 40% of the participants. PCB congeners 118, 138, 153, and 180 accounted for a relatively large percentage (44%) of the total PCBs. However, a number of lightly chlorinated congeners including PCB 28, PCB 33-20-53, PCB 66-95, and PCB 74 that are not

routinely detected in human serum were detected in over 40% of the participants and each of these accounted for, on average, about 3-7% of the total PCBs.

Discussion

Total PCB, DDE and Hg Exposure

As has been documented in other populations, total PCB concentrations were higher in men than in women and higher in fish eaters than in non-fish eaters (DeCaprio et al. 2005; Humphrey et al. 2000). Because the subset of PCB congeners quantified differs considerably from study to study, comparisons of total PCBs across published reports can be misleading. Therefore, PCB congener 153, which is present in quantifiable amounts in nearly 100% of human serum samples, has sometimes been used as a marker congener for comparisons of exposure across studies (e.g. Longnecker et al. 2003). As shown in Table 6, the geometric mean concentration of PCB congener 153 in this group of sport-caught fish consumers from northeastern Wisconsin sampled in 2003-2007 was very similar to concentrations of PCB congener 153 measured in two other fish eating cohorts recruited approximately a decade earlier in New York and Massachusetts (Longnecker et al. 2003) and about 1/3 that in a sample of Inuit women from northern Quebec who were recruited during that same time period (Muckle et al. 2001). Interestingly, in the Inuit women PCB congener 153 appeared to account for a much larger percentage of the total PCBs (approximately 33%) than it did in the FRIENDS sample (approximately 15%). In the New York study, maternal PCB exposure was associated with several persistent adverse neurodevelopmental outcomes (Darvill et al. 2000; Stewart et al. 2003; Stewart et al. 2003). Thus, our data illustrate that reproductive age female sport-caught fish consumers in some areas of the U.S. continue to be exposed to concentrations of PCBs that may put their unborn children at risk of neurodevelopmental delays or deficits.

Hg exposure in this sample of sport-caught fish consumers was relatively low. Over 20% of the participants who provided a blood sample had total Hg levels below the detection limit of the instrument and only five of the 142 individuals sampled (3.5%) had blood Hg concentrations above 5.8 µg/L, the concentration upon which the EPA's RfD of 0.1 µg/Kg/day was based (Rice et al. 2003). The median blood Hg concentration of 1.44 µg/L in the female participants was slightly higher than the median of 0.70 µg/L reported for 16-49 year-old females in the NHANES sample. The NHANES report does not include Hg data for adult men. The lack of elevated blood Hg concentrations most likely reflects the fact that fish caught in inland rivers and lakes in the Green Bay Wisconsin area have relatively low levels of Hg contamination in comparison to fish caught in inland lakes in the more northern part of the state of Wisconsin and in comparison to certain types of ocean fish including tuna and swordfish.

Whereas other fish eating populations such as the Inuit have serum DDE concentrations very similar to those in the general US population (Muckle et al. 2001; NCHS, 2005), Hmong refugees from northeastern Wisconsin had serum p,p'-DDE concentrations that were significantly higher than either of these groups. Interestingly, this elevated DDE exposure did not appear to be related to fish consumption. DDT was the predominant method of malaria control in Thailand for over half a century—beginning in the early 1940's and continuing into the 1990's (e.g. Chareonviriyaphap et al. 2000; Kamolratanakul et al. 2001). The significant correlation between years in a refugee camp (see Table 4) and serum DDE concentrations suggests that the elevated body burdens of DDE in these Hmong refugees likely reflect exposure that occurred during their often-extended stays in refugee camps in Thailand prior to emigration to the US. Given an estimated half-life of 8 years (NRC, 1977; Wolff et al., 2000), and an average of 20 years residency in the US, these DDE levels likely reflect a very high level of past exposure.

PCB Congener Profile

Four highly chlorinated, stable and bio-accumulative PCB congeners—PCBs 118, 138, 153 and 180—which typically account for a large percentage of the total PCBs in human tissue accounted for only 44% of the total PCBs in this population. In contrast, in some other populations the same four congeners have accounted for as much as 70-75% of the total PCBs (Humphrey et al. 2000; Muckle et al. 2001). Several lightly chlorinated and less bio-accumulative congeners including PCBs 28, PCB 33-20-53, PCB 66-95, and PCB 74 were detected with increased frequency and accounted for a larger percentage of the total PCBs in these sport-caught fish consumers from northeastern Wisconsin. This somewhat unique pattern of exposure may reflect the heavy use of Aroclor 1242, a lightly chlorinated mixture of PCBs, in the paper industry in northeastern Wisconsin.

A relatively low percentage of individuals recruited for the larger study (37% of women and 30% of men) agreed to provide a blood sample for contaminant analysis. This was not unexpected given the skepticism of Western medicine in the Hmong culture. Consistent with this we found that those who did agree to provide a blood sample were on average younger and more highly educated, and had resided in the US for a longer period of time. It is unclear how this may have impacted the results. PCB exposure in these individuals occurred primarily after immigration to the US and serum PCB concentrations were significantly and positively associated with years of residence in the US. In general, more educated individuals would be expected to be more aware of the health risks from consuming contaminated fish, and also would have more financial resources, so their reliance on subsistence fishing as a food source would likely be lower. The situation in northeastern Wisconsin is somewhat unusual in that there has been intense and sustained media coverage of the PCB contamination in the Fox River. As a result, nearly 100% of study participants were aware of the fishing advisories for local waterways and over 90% reported changes in their fish consumption practices in response to the advisories. Despite broad knowledge of the fishing advisories, we did find that the subset of study participants born in the US—who were as a group younger and more educated—did have lower serum PCB concentrations than the rest of the sample.

In summary, these data illustrate that some sport-caught fish consumers in the US remain at risk of PCB exposure at concentrations that may put the fetus at risk for neurodevelopmental delays or deficits. Recent immigrants from Southeast Asia may be particularly likely to have elevated PCB exposure because they are more likely to engage in subsistence fishing. They also have a relatively high birth rate compared to the US population as a whole. This study evaluated exposures in Hmong refugees, but Laotian and Vietnamese immigrants are also heavy fish consumers and could also be at increased risk. These data also highlight the fact that recent immigrants to the U.S., particularly those from parts of the world where DDT has been used extensively for malaria control, may have elevated body burdens of DDE irrespective of their fish eating status. It will be important to define the potential long term health risks from this exposure.

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Table 1Demographic Characteristics of the Sample^a.

Characteristic	Female n (%)	Male n (%)
Age		
18-25	32 (40.5)	13 (20.6)
26-35	29 (36.7)	30 (47.6)
36-45	18 (22.8)	13 (20.6)
≥46	0 (0.0)	7 (11.1)
Years of education		
No formal educ.	25 (31.7)	12 (19.1)
< High School	11 (13.9)	14 (22.2)
High School	32 (40.5)	13 (20.6)
Some college	4 (5.1)	17 (27.0)
College grad+	7 (8.9)	7 (11.1)
Years in US		
2-10	14 (17.7)	9 (14.3)
11-20	34 (43.0)	19 (30.2)
21-25	22 (27.9)	19 (30.2)
26+	6 (7.5)	14 (22.2)
Missing/unknown	3 (3.8)	2 (3.2)
Years in ref. camp		
0	23 (29.1)	18 (28.6)
1-5	28 (35.4)	22 (34.9)
6-10	8 (10.1)	7 (11.1)
11+	7 (8.9)	7 (11.1)
Missing/unknown	13 (16.5)	9 (14.3)
Place of Birth		
Laos or Thailand	53 (67.1)	49 (77.8)
United States	23 (29.1)	12 (19.1)
Missing	3 (3.8)	2 (3.2)
Years sport-caught fish consumed		
0	13 (16.5)	8 (12.7)
1-5	29 (36.7)	19 (30.2)
6-10	21 (26.6)	21 (33.3)
11+	15 (19.0)	13 (20.6)
Missing	1 (1.3)	2 (3.2)
Income		
< \$25,000	31 (39.2)	28 (44.4)
\$25,000 – 39,999	19 (24.1)	13 (20.6)
\$40,000 – 59,999	18 (22.8)	13 (20.6)
≥\$60,000	7 (8.9)	6 (9.5)

Characteristic	Female n (%)	Male n (%)
Refused/Missing	4 (5.1)	3 (4.8)

^aReported values are for the sample of 142 participants who provided a baseline blood sample.

Table 2

Total serum PCB and DDE (ng/g lipid) in 79 women and 63 men who provided baseline blood samples.

	<u>Arithmetic Mean</u> (95% CI)	<u>Geometric Mean</u> (95% CI)	Min.	Max.
Females (n=79)				
Total PCB ^a	215.4 (169.8, 273.2)	136.2 (110.1, 168.4)	8.7	3090.6
DDE ^{a,b}	1226.5 (800.6, 1879.1)	395.1 (282.9, 551.8)	0.7	7083.4
Males (n=63)				
Total PCB ^a	420.48 (324.4, 545.0)	265.9 (209.9, 336.8)	9.7	1392.9
DDE ^{a,b}	1643.7 (1038.6, 2601.4)	529.5 (364.1, 770.2)	0.3	5592.0
Total (n=142)				
Total PCB ^a	306.9 (249.8, 377.1)	183.6 (155.4, 217.1)	8.7	3090.6
DDE ^{a,b}	1411.2 (977.3, 2037.7)	449.8 (350.2, 577.9)	0.3	7083.4

^a ng/g, based on log-normal distribution of lipid-adjusted values Deleted one extreme PCB and two extreme DDE values.

^b Two subjects were missing DDE values. The LOD was substituted for these two cases.

Table 3

Total Hg (ng/ml) in 79 women and 63 men who provided baseline Blood samples. Values for 32 participants with levels below the detection Limit were excluded.

	Arithmetic Mean (95% CI)	Geometric Mean (95% CI)	Min	Max ^a
Females (n=79)				
Total Hg	1.88 (1.55, 2.28)	1.46 (1.22, 1.76)	0.00	13.20
Males (n=63)				
Total Hg	2.38 (1.94, 2.92)	1.85 (1.53, 2.25)	0.00	19.20
Total (n=142)				
Total Hg	2.20 (1.82, 2.46)	1.64 (1.43, 1.87)	0.00	19.20

^aThe range of values includes all samples.

Table 4

Spearman correlations for selected variables.

Variable	With Variable	N	Correlation Estimate	95% Confidence Limits	p-value
Total PCB	DDE	142	0.44	0.30 0.57	<.0001
Total PCB	Hg	142	0.30	0.14 0.44	0.0003
DDE	Hg	142	0.29	0.13 0.43	0.0005
Total PCB	Years of fish consumption	139	0.43	0.28 0.55	<.0001
Total PCB	Years in a refugee camp	120	0.18	-0.004 0.344	0.05
DDE	Years of fish consumption	139	0.09	-0.08 0.25	0.29
DDE	Years in a refugee camp	120	0.60	0.47 0.70	<.0001
Hg	Years of fish consumption	139	0.15	-0.032 0.30	0.112
Hg	Years in a refugee camp	120	0.16	-0.024 0.33	0.09

Total PCB, DDE are lipid adjusted

Hg=Total Hg; zero value imputed for 32 individuals with Hg<LOD.

Missing data: Years in US, n=5; Years of fish consumption, n=3; Years in refugee camp, n=22

Table 5

Congener profile of baseline blood samples in 142 Hmong participants^a

IUPAC No.	% > LOD	% of Total PCB	Geometric mean (ng/g lipid)			Arithmetic mean (ng/g lipid)		
			Estimate	95% CI	Estimate	95% CI	Min	Max
118	99	8.0	14.32	(12.08, 16.97)	24.26	(19.66, 29.95)	1.97	167.1
138-163	97	13.5	25.15	(21.42, 29.54)	40.00	(32.92, 48.59)	3.13	199.84
153	96	15.0	28.58	(24.41, 33.45)	44.49	(36.81, 53.78)	4.30	274.42
180	96	7.2	13.28	(11.20, 15.75)	22.21	(18.00, 27.40)	1.28	123.28
146	91	2.8	5.53	(4.61, 6.63)	9.63	(7.68, 12.09)	0.38	42.46
187	91	4.1	7.84	(6.52, 9.44)	13.97	(11.06, 17.63)	0.49	74.53
132-105	88	3.0	5.54	(4.64, 6.60)	9.17	(7.39, 11.38)	0.67	57.87
203-196	82	1.5	3.04	(2.57, 3.61)	4.74	(3.86, 5.83)	0.32	26.23
199	82	3.1	3.59	(2.99, 4.33)	6.04	(4.80, 7.59)	0.33	30.49
99	81	4.6	9.81	(8.16, 11.80)	16.35	(13.02, 20.52)	0.67	91.72
170	79	2.9	5.70	(4.66, 6.98)	10.30	(7.99, 13.29)	0.24	53.15
171-156	77	1.7	2.99	(2.51, 3.57)	4.68	(3.78, 5.78)	0.59	26.39
128-167	75	1.1	1.87	(1.54, 2.28)	3.21	(2.52, 4.10)	0.17	21.20
183	75	1.2	2.59	(2.15, 3.12)	4.18	(3.34, 5.24)	0.30	21.48
114	71	0.8	1.57	(1.24, 1.99)	3.14	(2.31, 4.26)	0.00	30.65
172	71	0.9	1.94	(1.60, 2.34)	3.12	(2.47, 3.93)	0.17	10.46
177	70	1.3	2.76	(2.25, 3.39)	4.78	(3.70, 6.17)	0.32	21.19
206	66	0.8	1.33	(1.08, 1.65)	2.29	(1.76, 2.97)	0.10	15.93
66-95	65	4.2	8.73	(7.05, 10.81)	15.08	(11.55, 19.68)	0.51	159.42
74	62	5.7	9.54	(7.67, 11.85)	16.39	(12.51, 21.48)	1.44	165.21
130-176	59	5.1	4.58	(3.46, 6.04)	10.66	(7.30, 15.57)	0.36	285.65
194	59	1.9	3.07	(2.47, 3.83)	5.19	(3.96, 6.81)	0.17	29.92
195	57	0.5	1.31	(1.09, 1.58)	1.88	(1.51, 2.33)	0.00	6.72
147-109	54	0.8	1.90	(1.56, 2.32)	2.80	(2.21, 3.54)	0.00	13.25
158	54	0.7	1.53	(1.24, 1.89)	2.35	(1.82, 3.02)	0.00	12.14
157-201	53	1.2	1.55	(1.22, 1.98)	2.71	(2.00, 3.67)	0.00	15.25

IUPAC No.	% > LOD	% of Total PCB	Geometric mean (ng/g lipid)			Arithmetic mean (ng/g lipid)		
			Estimate	95% CI	Estimate	95% CI	Min	Max
129-126-178	51	1.1	2.60	(2.04, 3.32)	4.58	(3.37, 6.21)	0.20	13.59
28	51	2.9	4.42	(3.49, 5.60)	7.48	(5.58, 10.03)	0.63	144.20
101	48	1.9	4.36	(3.48, 5.46)	6.84	(5.21, 8.98)	0.60	113.04
190	48	0.6	1.78	(1.45, 2.18)	2.59	(2.03, 3.30)	0.30	10.16
33-20-53	46	6.8	7.87	(5.73, 10.80)	18.60	(12.06, 28.68)	0.61	153.99
Total PCB	100	100.0	183.6	(155.4, 217.1),	306.9	(249.8, 377.1)	8.71	3090.58

^aBased on lipid-adjusted values.

Table 6

Comparison of PCB, DDE (ng/g lipid), and Total Hg (ng/ml) Exposure in the FRIENDS sample to other cohorts.

STUDY	Total PCBs (geometric mean)	PCB 153 (geometric mean/median ^a)	DDE (geometric mean)	Total Hg (geometric mean)
FRIENDS	183.6	28.58	449.8	1.64
New York ¹	--	40.0 ^a	--	--
Massachusetts ¹	--	30.0 ^a	--	--
Inuit ²	313.2	105.3	307.3	10.4

¹Longnecker et al., 2003.

²Muckle et al., 2001.