Blood Total Mercury Concentrations in the Canadian Population: Canadian Health Measures Survey Cycle 1, 2007-2009

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ABSTRACT

OBJECTIVES: We present total mercury (THg) in blood of Canadians 6-79 years of age from the first to-date nationally-representative survey, the Canadian Health Measures Survey (CHMS). This analysis is particularly relevant in the context of recent changes to Health Canada's blood Hg guidance values.

METHODS: We used data from cycle 1 (2007-2009) of the CHMS, in particular focussing on 5,319 respondents aged 6-79 years for whom blood THg data were available. We calculated descriptive statistics of blood Hg levels and analyzed the associations between blood THg levels and relevant variables. We also compared blood THg levels to existing Health Canada blood Hg guidance values.

RESULTS: The geometric mean blood THg level of the Canadian population was 0.69 µg/L (95% CI 0.56-0.86 µg/L). The majority (97.8%) of Canadian women aged 16-49 years, including pregnant women, had blood Hg values below the provisional HC blood guidance value of 8 µg/L. Mean blood THg levels were significantly higher in the "other or mixed" (1.14 µg/L, $p=0.0003$) and Asian (1.41 µg/L, $p=0.0476$) groups compared to those who self-identified as solely Caucasian (0.62 µg/L). There was however no significant difference between participants self-identified as Aboriginal Canadians versus Caucasians (0.56 µg/L vs 0.62 µg/L, $p=0.2902$).

Fish and shellfish consumption significantly influenced blood Hg levels, as did alcohol consumption and the presence of dental amalgams.

CONCLUSION: This paper presents the first description of blood THg levels in the general Canadian population. These findings will serve as a national baseline for monitoring future changes should they arise.

KEY WORDS: Mercury; methylmercury; blood; biomonitoring; Canada; Canadian Health Measures Survey

La traduction du résumé se trouve à la fin de l'article.

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Mercury (Hg) is a heavy metal and a constituent of the rocks within the Earth's crust. It is released from the crust through natural events and industrial processes.¹ Following its release to the atmosphere, Hg undergoes long-range atmospheric transport resulting in deposition to aquatic and terrestrial systems far away from the original source of emission.¹ In the aquatic environment, Hg is converted into methylmercury (MeHg) by sulfate-reducing bacteria and subsequently accumulates in fish, shellfish and marine mammals.² Hg and its compounds are recognized as highly toxic substances, the potential human health impacts of which should be considered with prudence.

Documented human health effects of MeHg exposure include renal, reproductive, cardiovascular, developmental and neurological toxicity.^{3,4} Neurological damage resulting from acute and chronic exposure is the most documented effect in adults and children.^{3,4}

Existing Health Canada blood MeHg guidance values were recently expanded to include a harmonized provisional guidance value for children, pregnant women and women of childbearing age (16-49 years).⁵ The existing guidance value of 20 µg/L is considered to provide adequate protection for females ≥50 years and males >18 years. The provisional guidance value of 8 µg/L is intended to provide added protection against neurodevelopmental effects for the developing fetus, infants and children.⁵

Recently, MeHg research has begun to focus on the potential for adverse health effects at low levels of exposure; as such, ongoing biomonitoring for this substance is important for public health pro-

tection.⁶ The objective of this paper is to present total Hg (THg) in blood of Canadians 6-79 years of age from cycle 1 (2007-2009) of the first nationally-representative survey, the Canadian Health Measures Survey (CHMS). This analysis is particularly relevant given recent changes to Health Canada's blood Hg guidance values, providing the opportunity to update assessment of Hg exposure in Canadians.

METHODS

Data source

Data for this study are from cycle 1 of the CHMS, which was conducted between March 2007 and February 2009. The CHMS was developed to address important data gaps and limitations in existing health information by collecting directly measured indicators of health and wellness on a representative sample of approximately 5,600 Canadians aged 6 to 79 years. The CHMS used a complex multi-stage sampling strategy. Fifteen collection sites were allocated, taking into account population size, region, seasonality and other operational and logistical constraints. Within each site,

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dwellings with known household composition at the time of the 2006 Census were stratified by age at the time of the survey and a simple random sample of dwellings was selected in each stratum. Each selected dwelling was contacted and asked to provide a list of current household members, and this list was used to select survey participants. One or two people were selected per dwelling, depending on the household composition. The sample represented approximately 96% of the Canadian population. Full-time members of the Canadian Forces, as well as residents of Crown lands, Indian reserves, institutions and certain remote regions were excluded.^{6,7}

Data collection for the CHMS included a household personal interview and a clinic visit to a Mobile Examination Centre (MEC) specifically designed for the survey. The household interview collected demographic and socio-economic data and information about lifestyle, medical history, current health status, the environment, and housing conditions. A food frequency questionnaire (FFQ) was also administered during the household interview, and it included questions related to overall frequency of fish and shellfish consumption. During the clinic visit at the MEC, health professionals collected physical measurements, such as height, weight, blood pressure, and physical fitness, and collected blood and urine specimens from participants.^{6,7}

The ethics approval process for the CHMS has been described previously, and all participants gave their informed consent.⁸

Blood collection and mercury analysis

Venous whole blood for the THg analysis was collected from 5,319 respondents. Field blanks were performed at all 15 sites to account for any contamination. No significant levels of contamination for blood THg were found at any site. Laboratory analysis of THg was performed at L'Institut national de santé publique du Québec (INSPQ) in Quebec City. The laboratory is accredited under ISO 17025.⁹ THg was analyzed by inductively coupled plasma mass spectrometry, Perkin Elmer Sciex, Elan DRC II (M-572). Matrix matched calibration was performed using blood from a non-exposed individual.⁹ The limit of detection (LOD) for THg, as determined by INSPQ, was established at 0.10 µg/L. Individuals whose blood THg concentration fell below the LOD were assigned a value of LOD/2.⁹ Full details of the collection protocol and laboratory analysis are described elsewhere.⁹

Relevant variables

Age, sex, ethnicity, Canadian citizenship status, household education level, household income, fish and shellfish consumption, number of dental amalgams, smoking status and alcohol consumption were examined in association with blood THg concentrations.

Five age groups were specified: 6-11, 12-19, 20-39, 40-59, and 60-79 years. Ethnicity was based on self-reported ethnicity and categorized into Caucasian, Asian (includes Chinese, Filipino, Japanese, Korean, South Asian, and Southeast Asian), Aboriginal, or other and multiracial. Participants were deemed to be Canadian citizens if they were born in Canada or they were a Canadian citizen at birth. Household education level was based on the highest level attained by each household member and categorized as: secondary graduation or less, some post-secondary education, and post-secondary graduation. Household income quartiles were derived

Table 1. Demographic Characteristics for the CHMS, 2007-2009

Variable	N*	% (95% CI)†
Age group (years)	5319	
6-11	910	6.5 (6.1-6.9)
12-19	945	10.9 (10.6-11.3)
20-39	1165	31.2 (30.9-31.6)
40-59	1220	34.2 (33.6-34.8)
60-79	1079	17.2 (16.9-17.4)
Sex	5319	
Male	2576	50.2 (49.8-50.5)
Female	2743	49.8 (49.5-50.2)
Highest level of education in household	5182	
Secondary graduation or less	890	17.5 (13.5-22.3)
Some post-secondary	336	6.7 (5-8.8)
Post-secondary graduation	3956	75.9 (69.4-81.4)
Household income adjusted for household size	4984	
First quartile (\$25,000 or less)	1446	25.4 (21.4-29.9)
Second quartile (\$25,001 to \$40,000)	1232	24.2 (21.2-27.4)
Third quartile (\$40,001 to \$64,000)	1194	25.2 (22.1-28.5)
Fourth quartile (>\$64,000)	1112	25.2 (21-29.9)
Citizenship at birth	5318	
Born in Canada or Canadian citizen at birth	4345	78.8 (69.2-86.1)
Not born in Canada or non-Canadian citizen at birth	973	21.2 (13.9-30.8)‡
Cultural/racial background	5312	
Caucasian	4402	81.3 (71.3-88.4)
Asian	400	8.9 (4.6-16.6)‡
Aboriginal	146	3.2 (2.2-4.5)
Other or multiracial	364	6.6 (3.7-11.6)‡
Smoking status§	4393	
Current smoker	790	20.4 (18-23)
Former smoker	1135	27.2 (24.4-30.1)
Never-smoker	2468	52.4 (49.2-55.7)
Alcohol consumption	3397	
<1 time per week	1569	44.1 (40.1-48.1)
1 to 3 times per week	1212	37.4 (34.1-40.8)
4 to 6 times per week	282	8.7 (7.1-10.6)
Daily	334	9.8 (7.8-12.4)
Amalgam count	5005	
Zero amalgams	2099	35.1 (30.7-39.8)
1-10 amalgams	1700	38.5 (34.7-42.4)
11-25 amalgams	958	20.9 (18.7-23.4)
26+ amalgams	248	5.4 (3.9-7.6)
Salt and freshwater fish or shellfish consumption	5319	
Never eats fish or shellfish	486	8.6 (7.4-10)
Eats fish or shellfish less than once per week	1754	31.6 (27.8-35.7)
Eats fish or shellfish 1 to less than 3 times per week	2181	41.9 (39.4-44.4)
Eats fish or shellfish 3 or more times per week	898	17.9 (14.5-21.9)

* Unweighted sample size.

† Estimated percentage of the Canadian population, based on survey sample weights, with associated 95% confidence intervals.

‡ Use with caution (data with a coefficient of variation (CV) from 16.6% to 33.3%).

§ Excludes respondents <12 years old.

from the reported total household income adjusted for the number of people in the household. Fish and shellfish consumption was based on the participants' total reported consumption in the previous 12 months of freshwater fish, saltwater fish, and shellfish. Number of dental amalgams was based on the number of tooth surfaces with amalgam fillings that were identified by trained professionals on site. Frequency of alcohol consumption was based on participants' reported consumption in the previous 12 months and categorized in the following manner: less than once a week, 1 to 3 times a week, 4 to 6 times a week, or every day. Smokers were classified as never-, former or current smokers. Children younger than 12 years of age were not asked about smoking or alcohol consumption and were, therefore, not assigned to a category.

Statistical analysis

Analyses were weighted using the CHMS weights generated by Statistics Canada.⁷ The data were analyzed with SAS version 9.1 and SUDAAN version 10.0 software, specifying 11 denominator degrees of freedom (DDF=11) in the SUDAAN procedure statements.⁷ The

Table 2. Weighted Geometric Means (GMs) and Selected Percentiles of Total Blood Mercury (Hg) Concentrations in µg/L for the Canadian Population, Ages 6-79 Years-CHMS, 2007-2009

	n	%<LOD*	GM (95% CI)	10 th (95% CI)	25 th (95% CI)	50 th (95% CI)	75 th (95% CI)	95 th (95% CI)
Total, 6-79 (years)	5319	11.64	0.69 (0.56-0.86)	0.12 (<LOD-0.14)	0.33 (0.26-0.39)	0.81 (0.64-0.97)	1.61 (1.17-2.04)	4.70† (2.61-6.78)
6-19	1855	22.8	0.29 (0.22-0.37)	<LOD (<LOD-<LOD)	0.12 (<LOD-0.15)	0.30 (0.24-0.37)	0.73 (0.5-0.96)	2.17† (1.02-3.33)
20-39	1165	8.76	0.65 (0.53-0.82)	0.12 (<LOD-0.16)	0.30 (0.24-0.36)	0.77 (0.62-0.92)	1.49† (0.93-2.06)	4.89† (2.45-7.32)
40-59	1220	3.52	1.02 (0.81-1.28)	0.27 (0.19-0.35)	0.56 (0.42-0.70)	1.11 (0.86-1.37)	1.93 (1.50-2.36)	6.39† (3.03-9.76)
60-79	1079	4.73	0.87 (0.65-1.18)	0.17† (<LOD-0.26)	0.47 (0.33-0.61)	0.97 (0.70-1.23)	1.89 (1.23-2.54)	4.83† (2.73-6.92)
Males, Total	2576	12.11	0.68 (0.55-0.85)	0.10 (<LOD-0.14)	0.32 (0.25-0.39)	0.79 (0.64-0.94)	1.61 (1.15-2.07)	5.13† (2.70-7.57)
Males, 6-19	948	23.31	0.27 (0.19-0.38)	<LOD (<LOD-<LOD)	0.1† (<LOD-0.15)	0.27 (0.18-0.36)	0.63† (0.33-0.94)	2.14† (0.61-3.67)
Males, 20-39	514	9.34	0.62 (0.47-0.80)	<LOD (<LOD-<LOD)	0.27 (0.19-0.36)	0.73 (0.56-0.90)	1.51† (0.72-2.30)	4.61† (2.60-6.63)
Males, 40-59	577	3.47	1.04 (0.82-1.31)	0.28 (0.19-0.37)	0.59 (0.43-0.75)	1.07 (0.81-1.32)	1.83 (1.52-2.15)	‡
Males, 60-79	537	4.28	0.98 (0.71-1.34)	0.21† (0.10-0.31)	0.51 (0.37-0.66)	1.05 (0.69-1.40)	2.20 (1.61-2.79)	‡
Females, Total	2743	11.19	0.70 (0.56-0.89)	0.13 (0.10-0.16)	0.33 (0.25-0.40)	0.83 (0.63-1.03)	1.58 (1.15-2.00)	4.45† (2.55-6.36)
Females, 6-19	907	22.27	0.32 (0.26-0.38)	<LOD (<LOD-<LOD)	0.14 (0.10-0.18)	0.33 (0.27-0.39)	0.82 (0.62-1.03)	2.24 (1.59-2.88)
Females, 20-39	651	8.29	0.70 (0.53-0.91)	0.16 (0.10-0.22)	0.33 (0.23-0.42)	0.80 (0.59-1.02)	1.49 (0.96-2.02)	4.77† (2.07-7.46)
Females, 40-59	643	3.58	0.99 (0.77-1.28)	0.24 (0.14-0.34)	0.53 (0.36-0.69)	1.16 (0.88-1.44)	2.02 (1.44-2.60)	5.35† (2.02-8.67)
Females, 60-79	542	5.17	0.79 (0.58-1.06)	0.13 (<LOD-0.22)	0.40† (0.21-0.58)	0.92 (0.71-1.12)	1.70 (1.20-2.19)	4.37 (2.97-5.77)

* LOD (limit of detection) = 0.10 µg/L.

† Use with caution (data with a coefficient of variation (CV) from 16.6% to 33.3%).

‡ Too unreliable to be published (data with a CV greater than 33.3%; suppressed due to extreme sampling variability).

DDF were calculated by subtracting the number of regional strata (4: BC, Prairies, Ontario, Quebec/Atlantic) from the number of collection sites (15). Geometric means (GMs) and percentile estimates and their 95% confidence intervals (CIs) were calculated by selected age groups and sex. Linear regression analysis was used to calculate adjusted least squares geometric means (LSGM). A separate regression was run for each covariate, controlling for age group and sex, to estimate adjusted LSGM THg concentrations. The percentage of the population with blood mercury levels below their respective guidance values was also calculated for selected age and sex groups.

Because the concentrations of THg were not normally distributed, their log transformations were used in the regression models. Given the 11 degrees of freedom available for variance estimation, Satterthwaite-adjusted statistics were used to test the significance of each regression model's coefficients. T-tests were used to compare GMs and LSGMs between categories. Statistical significance was set at $p < 0.05$, with Bonferroni adjustments depending on the number of comparisons.

Under the *Statistics Act*, Statistics Canada is required to ensure participant confidentiality. Therefore, estimates based on a small number of participants are suppressed in order to prevent the possibility of identifying those participants.

RESULTS

Table 1 shows demographic characteristics of the participants who had their blood THg levels measured. The population was evenly divided between males and females (50.2% and 49.8%, respectively), with the majority belonging to either the 20-39 or 40-59 age groups. Three quarters (75.9%) of participants had graduated from post-secondary education, but were evenly distributed across all four income quartiles (\$25,000 or less; \$25,001 to \$41,000; \$41,001 to \$64,000; more than \$64,000). The majority of participants (78.8%) were born in Canada or were a Canadian citizen at birth, and 81.3% of participants self-identified as Caucasian.

Overall, 11.6% of the Canadian population aged 6-79 had blood THg levels below the LOD (0.10 µg/L) (Table 2). The weighted GM blood THg level for Canadians aged 6-79 years was 0.69 µg/L (Table 2). Males and females had very similar THg levels (0.68 µg/L and 0.70 µg/L, respectively). There was a trend towards increasing

Table 3. Age- and Sex-adjusted Least Squares Geometric Means (LSGMs) of Blood Total Mercury Concentrations in µg/L, by Selected Characteristics, for the Canadian Population, Ages 6 to 79 Years, CHMS 2007-2009

	Adjusted LSGM* (95% CI)	P-value
Smoking status† (p=0.0104)‡		
Current smoker§	0.58 (0.49-0.68)	
Former smoker	0.87 (0.72-1.06)	0.0001
Never-smoker	0.75 (0.56-1.0)	0.0176
Alcohol consumption † (p=0.0035)		
<1 time per week§	0.71 (0.56-0.89)	
1 to 3 times per week	0.84 (0.70-1.01)	0.0292
4 to 6 times per week	1.07 (0.79-1.44)	0.0002
Daily	1.05 (0.85-1.29)	0.0001
Highest education level (p=0.0145)		
Secondary graduation or less	0.56 (0.44-0.7)	0.0293
Some post-secondary	0.53 (0.41-0.7)	0.002
Post-secondary graduation§	0.74 (0.59-0.93)	
Income quartiles (p=0.0006)		
First quartile (\$25,000 or less)	0.63 (0.50-0.78)	0.0008
Second quartile (\$25,001 to \$40,000)	0.61 (0.50-0.73)	0.0001
Third quartile (\$40,001 to \$64,000)	0.64 (0.51-0.80)	0.0021
Fourth quartile (>\$64,000)§	0.98 (0.75-1.27)	
Fresh and saltwater fish or shellfish consumption (p=0.0000)		
Never eats fish or shellfish§	0.14 (0.12-0.18)	
Eats fish or shellfish less than once per week	0.48 (0.43-0.54)	0
Eats fish or shellfish 1 to less than 3 times per week	0.90 (0.75-1.08)	0
Eats fish or shellfish 3 or more times per week	1.55 (1.07-2.25)	0
Canadian citizenship/place of birth (p=0.0015)		
Born in Canada or Canadian citizen at birth§	0.62 (0.52-0.72)	
Not born in Canada or non-Canadian citizen at birth	1.09 (0.75-1.58)	0.0015
Cultural/racial background (p=0.0274)		
Caucasian§	0.62 (0.54-0.72)	
Asian	1.41 (0.6-3.3)	0.0476
Aboriginal	0.56 (0.47-0.66)	0.2902
Other or multiracial	1.14 (0.86-1.51)	0.0003
Amalgam count (p=0.0116)		
Zero amalgams§	0.60 (0.41-0.86)	
1-10 amalgams	0.69 (0.56-0.85)	0.3088
11-25 amalgams	0.88 (0.72-1.06)	0.0079
26+ amalgams	1.28 (1.09-1.51)	0.0009

* Adjusted by age group and sex.

† Excludes respondents <12 years old.

‡ Satterthwaite-adjusted p-value.

§ Reference category.

|| Significantly different from reference category ($p < 0.05$).

Table 4. Estimated Geometric Mean (GM) Blood Mercury Concentrations in µg/L and Percentage with Blood Mercury Levels Below Their Respective Guidance Values for Selected Canadian Population Groups

Population Group	GM (95% CI)	% <8 µg/L (95% CI)	% <20 µg/L (95% CI)
Females 16-49 yrs (incl. pregnant women)	0.72 (0.5-0.94)	97.78 (92.11-99.40)	*
Females 6-49 yrs, pregnant women, males ≤18 yrs	0.52 (0.40-0.68)	98.39 (93.59-99.61)	*
Females ≥50 yrs, males >18 yrs	0.85 (0.69-1.04)	*	†

* Guidance value not applicable to selected population.

† The estimated percentage of females ≥50 yrs and males >18 yrs with blood mercury levels <20 µg/L were not calculated in order to meet the confidentiality requirements of the Statistics Act of Canada.

blood THg levels with age through the sixth decade, with a slight decrease in the 60-79 year age group.

Table 3 shows a statistically significant higher LSGM blood THg for those who self-reported their cultural or racial background as “Asian” and as “other and multiracial” compared with those who self-identified solely as Caucasian. There was no difference between those who self-identified as Aboriginal Canadians and Caucasians (Table 3).

Participants who consumed no fish or shellfish had statistically significant lower blood THg levels compared with participants who consumed fish and shellfish, regardless of the frequency of consumption (Table 3).

Survey participants in the highest income quartile had statistically significant higher mean blood THg levels compared with those in the lower quartiles. Similarly, participants with post-secondary graduation had higher blood THg levels compared with participants with some post-secondary education or secondary graduation or less. When the regression analyses were re-run, controlling for total consumption of fish and shellfish, there were no significant differences in blood THg concentrations between categories for either income or education.

Former or never-smokers had statistically significant higher blood THg levels compared with current smokers. The association between blood THg levels and smoking status remained statistically significant ($p=0.0001$ for former smoker, $p=0.003$ for never-smoker) when total fish and shellfish consumption was included in the regression analysis. With respect to alcohol consumption, survey participants who consumed alcoholic drinks four to six times per week or more had statistically significant higher blood THg levels compared with those who reported drinking less than once a week (Table 3). These significant differences also persisted after controlling for fish and shellfish consumption ($p=0.0002$ for 4 to 6 times per week, $p=0.0001$ for daily).

It was observed that survey participants with no dental amalgams had significantly lower mean blood THg levels compared with participants who had 11-25 amalgams and with participants who had 26 or more amalgams. This difference remained statistically significant ($p=0.0077$ for 11-25 amalgams, $p=0.0003$ for 26 or more amalgams) when the regression analysis was re-run, controlling for total fish and shellfish consumption. No difference was observed between participants with no amalgams and those with 1-10 amalgams (Table 3).

Table 4 shows the estimated percentage of the Canadian population within selected groups with blood THg levels below their respective guidance values. The GM blood THg concentration of females aged 16-49 years (including pregnant women) was 0.72 µg/L (95% CI 0.5-0.94) and slightly over 2% of this group exceeded the provisional blood Hg guidance value of 8 µg/L. The GM blood THg level for females 6-49 years (including pregnant

women) and males ≤18 years was 0.52 µg/L (95% CI 0.40-0.68) and slightly less than 2% exceeded the provisional guidance value of 8 µg/L (Table 4). The GM blood THg level for females ≥50 years and males >18 years was 0.85 µg/L (95% CI 0.69-1.04). The percentage of females ≥50 years and males >18 years who had blood THg levels <20 µg/L could not be reported in order to meet the confidentiality requirements of the Canadian *Statistics Act*.

DISCUSSION

The GM blood THg level of 0.69 µg/L from this first to-date nationally-representative study showed that the Canadian population aged 6-79 years had blood levels similar to those documented in the US National Health and Nutrition Examination Survey (NHANES) data from 2007-2008, which identified a GM blood Hg level for a representative US population, aged 1 year and older, of 0.769 µg/L (95% CI 0.689-0.859).¹⁰ In addition, the trend of increasing blood THg levels with increasing age, which attenuated in the seventh decade, was seen in both the CHMS and the NHANES surveys.¹¹

Fish and shellfish consumption has long been documented as the main contributor to MeHg body burden in the non-occupationally exposed population,⁴ particularly when the intake is habitual.¹² Results from this survey support previous observations by showing that age- and sex-adjusted mean THg in blood increased as total fish and shellfish consumption increased (Table 3). The estimated mean blood THg for those who consume fish and shellfish 3 or more times per week was higher than the national average at 1.55 (CI 1.07-2.25).

The fish and shellfish component of the FFQ did not include recalls of portion size or species, and as such intake of MeHg was not calculated. Future CHMS cycles that do include consumption of specific species may be helpful to flag species or types of fish that most and least contribute to Hg exposure.

Previous Canadian studies have flagged unusual blood and hair THg levels in sport fishermen, Aboriginal peoples and Asian immigrants, reflecting consumption of traditional and/or locally harvested fish and shellfish.^{5,13} Results from the CHMS did show blood Hg levels to be significantly higher in the “other or mixed” and Asian groups. There was, however, no significant difference between participants self-identified as Aboriginal Canadians versus Caucasians (Table 3). The CHMS was not designed to target subgroups at risk for MeHg exposure and recruitment did not take place on Aboriginal Reserves or certain remote regions like the Arctic. The trend towards higher blood THg levels in the Asian and “other or mixed” groups supports results from previous Canadian studies on Chinese-Canadian children in Vancouver¹⁴ and Asian-Canadian anglers from Ontario.¹⁵ It is likewise consistent with NHANES data, which identified higher blood Hg levels due to fish consumption in those who, as a group, self-identified as Asian, Pacific Islander, Native American or multiracial.^{12,16} These results

highlight the need for further studies focused on immigrants and underscore the importance for health care professionals to provide personalized clinical evaluations and advice in ethnically diverse Canada.¹⁷

The findings of increasing blood THg levels with increasing income and education level are consistent with data from other studies.^{18,19} It has been hypothesized that well-educated, affluent individuals consume larger amounts of fish for their perceived health benefits, and they may also consume more expensive types of fish (e.g., swordfish, shark), which are predatory and tend to be higher in Hg content.^{18,19} This hypothesis was confirmed when the regression analyses were re-run, controlling for total consumption of fish and shellfish; the observed differences in blood THg concentrations were no longer statistically significant.

Other noteworthy findings are the associations between smoking, alcohol consumption and blood THg levels (Table 3). Few studies in the literature have examined the link between smoking status and Hg body burden. A biomonitoring study carried out in the Czech Republic identified significantly higher blood Hg levels in non-smokers compared with smokers.²⁰ Additionally, a biomonitoring study of adults living in New York City showed a similar trend, although the differences were not statistically significant.²¹ In contrast, a population-based survey in Korea identified the opposite trend of higher blood Hg levels in smokers compared with non-smokers.²² Although the association between blood THg status and smoking status remained statistically significant after controlling for fish and shellfish consumption, the biological implications of this result are still unknown. The pattern of significantly increasing blood THg levels with increasing alcohol consumption was also highlighted in a population-based survey in Korea and in a subgroup of females in Austria.^{22,23} Other investigators have suggested that this may be accounted for by differential Hg excretion rates as a result of the effect of alcohol consumption on kidney function.²⁴ (and references therein)

Exposure to Hg from dental amalgam is more commonly measured through analysis of urinary inorganic Hg levels; however, the CHMS results indicate that blood THg levels are also positively correlated with dental amalgam, even after controlling for fish and shellfish consumption. Although limited data exist on the relationship between dental amalgam and blood THg levels, similar trends have been observed in a number of other studies.^{23,25,26} These results indicate that dental amalgam restorations contribute to THg exposure and that blood THg may be used as a biomarker of exposure from dental amalgam, provided fish and shellfish consumption are also accounted for.

While slightly more than 2% of Canadian females aged 16-49 (including pregnant women) exceeded the provisional Hg blood guidance value of 8 µg/L, 4.7% of US women aged 16-49 years exceeded the US EPA RfD* of 5.8 µg/L during 1999-2004.²⁷ The GM blood Hg level of 0.72 µg/L for Canadian females aged 16-49 (including pregnant women) was also comparable to 0.920 µg/L (95% CI 0.826-1.03) for US females aged 16-49 years in 2005-2006.¹¹

Limitations

Due to cost and logistics considerations, only 15 collection sites across Canada were chosen, thereby limiting analysis to the national level only. The overall response rate to the CHMS was slightly above 50%. While the survey weights ensured that the sample was

representative of the target population, bias might exist if the blood THg concentrations of non-participants differed systematically from those of participants. The design of the survey also limited the number of covariates of interest that could be included in a single model when doing regression analysis. Dietary surveys, such as a FFQ, relying on self-reporting may result in over- or under-estimation of fish and/or shellfish consumption,²⁹ which may then compromise the inference with blood THg levels. However, fish and shellfish are viewed as a distinct and more easily recalled component of the diet, which lends support to the reliability of the consumption data.²⁸

CONCLUSIONS

Total blood Hg levels in the general Canadian population increased with age through the fifth decade, and then decreased slightly. Asians and those from an "other" or mixed background tend to have higher blood Hg levels compared with Caucasians, which is related to a higher prevalence of fish and shellfish consumption in these groups. Total blood Hg levels were also influenced by smoking, alcohol consumption, and number of dental amalgams. Canadians with more education and higher incomes tend to have higher blood Hg levels, associated with increased fish and shellfish consumption in these populations. Women of child-bearing age, pregnant women, and children have blood Hg levels that are slightly lower than the general Canadian population and the majority are well below the Health Canada guidance value.

In conclusion, the CHMS has provided the first and only Canadian nationally-representative data on blood Hg levels and will serve as a national baseline for monitoring future changes should they arise.

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RÉSUMÉ

OBJECTIFS : Nous présentons les concentrations en mercure total (HgT) dans le sang des Canadiens de 6 à 79 ans tirées de la première enquête représentative nationale à ce jour : l'Enquête canadienne sur les mesures de la santé (ECMS). Notre analyse est particulièrement pertinente dans le contexte des modifications récentes aux valeurs de référence de Santé Canada pour le Hg sanguin.

MÉTHODE : Nos données proviennent du cycle 1 (2007-2009) de l'ECMS, plus précisément des 5 319 répondants de 6 à 79 ans pour lesquels il existe des données sur le mercure total dans le sang. Nous avons fait des calculs de statistique descriptive pour les concentrations en Hg sanguin et analysé les associations entre les concentrations en HgT dans le sang et les variables pertinentes. Nous avons aussi comparé les concentrations en HgT dans le sang aux valeurs de référence existantes de Santé Canada pour le Hg sanguin.

RÉSULTATS : La moyenne géométrique des concentrations en HgT dans le sang de la population canadienne est de 0,69 µg/L (IC de 95 % : 0,56-0,86 µg/L). La majorité (97,8 %) des Canadiennes de 16 à 49 ans, y compris les femmes enceintes, ont des valeurs de Hg sanguin inférieures à la valeur de référence provisoire de Santé Canada (8 µg/L). Les concentrations moyennes en HgT dans le sang sont sensiblement plus élevées dans les populations « autres ou mixtes » (1,14 µg/L, $p=0,0003$) et asiatiques (1,41 µg/L, $p=0,0476$) que dans la population s'identifiant comme blanche (0,62 µg/L). Il n'y a toutefois aucun écart significatif entre les participants s'identifiant comme des Canadiens autochtones ou blancs (0,56 µg/L contre 0,62 µg/L, $p=0,2902$).

La consommation de poissons, crustacés et coquillages influence de façon significative les concentrations en Hg sanguin, tout comme la consommation d'alcool et la présence d'amalgames dentaires.

CONCLUSION : Cet article présente la première description des concentrations en HgT dans le sang de la population canadienne dans son ensemble. Nos constatations serviront de base de référence nationale pour la surveillance des changements éventuels.

MOTS CLÉS : mercure; méthylmercure; sang; biosurveillance; Canada; Enquête canadienne sur les mesures de la santé