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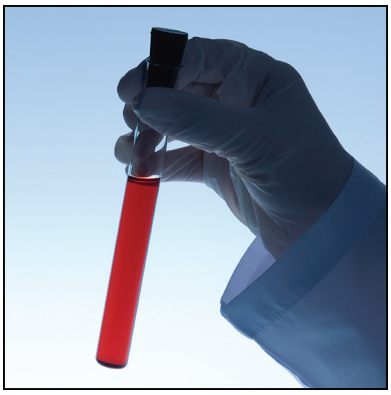

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Abstract

The Canadian Health Measures Survey (CHMS), the most comprehensive direct health measures survey ever undertaken on a national scale in Canada, includes measurement of the heavy metals, lead, mercury and cadmium, which are toxic to humans at excessive levels. The geometric mean blood concentrations for lead, total mercury and cadmium were 1.37µg/dL, 0.76µg/L, and 0.35µg/L, respectively. Blood lead concentrations have fallen substantially since 1978, when national levels were last measured. Much of this decline may be attributed to the phase-out of leaded gasoline, lead-containing paints and lead solder in food cans since the 1970s. Fewer than 1% of Canadians now have blood lead concentrations above the Health Canada guidance value of 10µg/dL. Similarly, fewer than 1% of Canadian adults have total blood mercury concentrations above the Health Canada guidance value of 20µg/L for adults. CHMS data will be used to assess current population levels for a broad range of environmental chemicals, chronic diseases, nutritional status and infectious diseases; to provide a baseline for emerging trends, and to enable comparisons with other countries.

Keywords

biomonitoring, body burden, Canadian Health Measures Survey, environmental exposure, environmental pollution, heavy metals, public health

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The heavy metals lead, mercury and cadmium are widely dispersed in the environment, and at excessive levels, are toxic to humans.[1] Chronic exposure to these substances may also be hazardous. Although these metals occur naturally, exposure may be increased by human activities that release them into the air, soil, water and food, and by products that contain heavy metals.

This article presents preliminary data on blood levels of lead, total mercury, and cadmium in Canadians from the new Canadian Health Measures Survey (CHMS). These preliminary results are based on 8 collection sites from the CHMS. Results based on data from all 15 sites will be available in 2010.

The CHMS was launched by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada to collect data from approximately 5,000 Canadians aged 6 to 79 at 15 sites across Canada from March, 2007 to March, 2009. The CHMS entails an in-home general health interview and a subsequent visit to a mobile clinic where direct physical measures, including blood and urine samples, are taken.

The blood and urine samples are used to test for infectious diseases, nutritional status and cardiovascular disease risk factors, and also, for biomonitoring—that is, to measure levels of environmental chemicals. This biomonitoring component of the CHMS will help meet the need for nationally representative data on current population levels for a broad range of environmental chemicals, provide a baseline for emerging trends, and allow comparisons with other countries.

Lead

Sources of lead exposure include lead-based paint, lead plumbing, food grown in lead-contaminated soil, and toys, fuels or other products that contain lead or lead-based paints. Exposure to high lead levels can severely damage the brain and kidneys. Chronic exposure can result in decreased neurological performance. In pregnant women, exposure to high lead levels may cause

The data

Estimates are based on data from the Canadian Health Measures Survey (CHMS). During an in-home interview, demographic and socioeconomic data and information about lifestyle, medical history, current health status, the environment, and housing characteristics are collected. At a mobile clinic, physical measurements, such as blood pressure, height, weight and physical fitness are assessed. Blood and urine samples are taken to test for infectious diseases, nutritional status, cardiovascular disease risk factors, and levels of environmental chemicals, including heavy metals.

The CHMS covers the population aged 6 to 79 living in private households at the time of the interview. Residents of Indian Reserves or Crown lands, institutions and certain remote regions and full-time members of the Canadian Forces are excluded. Approximately 97% of Canadians are represented. Data are collected from 15 sites across Canada from March, 2007 through March, 2009. Ethics approval was obtained from Health Canada's Research Ethics Board. Informed written consent was obtained from respondents older than 14. For younger children, a parent or legal guardian provided written consent, and the children provided written assent. Participation is voluntary; participants can opt out of any part of the survey at any time. Additional information about the CHMS is available in print and online.[2-7]

The data in this article pertain to 2,678 participants from the first 8 data collection sites. Blood samples were drawn at the mobile clinic by a certified phlebotomist into 6 mL EDTA Becton Dickinson Vacutainer BD367863. Samples were stored in the mobile clinic freezer at -20°C, and once a week, were shipped on ice packs to the reference laboratory, the Centre de toxicologie du Québec (CTQ) of L'Institut national de santé publique du Québec (INSPQ). Blood samples were diluted in a basic solution containing octylphenol ethoxylate and ammonia, and analyzed for lead, total mercury and cadmium using inductively coupled plasma mass spectrometry (ICP-MS, DRC). INSPQ compiled, encrypted and electronically transmitted the results to Statistics Canada's Head Office. The laboratory is accredited under ISO 17025 and uses numerous external quality control programs, including the German External Quality Assurance Scheme (EQAS) and Lead and Multi-element Proficiency Testing (LAMP). Periodically, blind replicates and commercial controls are tested to monitor the precision of the assay.

For each heavy metal, the proportion above the limit of detection (LOD), proportion equal to or above the guidance value (where guidance values exist), geometric mean, selected percentiles, and 95% confidence intervals for the geometric mean and percentiles were calculated. The LOD is the level at which the blood concentration was so low that it could not be reliably or accurately determined by the laboratory test method. For lead, the LOD was 0.02µg/dL; for mercury, 0.10µg/L; and for cadmium, 0.04µg/L. To calculate the geometric mean and percentiles, blood concentrations less than the LOD were assigned a value equal to half the LOD.[8-10]

Geometric means were calculated by taking the log of each individual result, calculating the mean of those log values, and then taking the antilog of that mean. Compared with the arithmetic mean, the geometric mean is less influenced by high values, and therefore, provides a better estimate of central tendency for data that are distributed with a long tail at the upper end of the distribution—a common distribution when measuring environmental chemicals in blood.

The use of preliminary data limited the analyses that were possible for this article. Because data were available for only 8 of the 15 collection sites, the sample size was too small and/or the variability was too high to calculate statistically reliable estimates of the percentile distribution for mercury and selected percentiles for lead and cadmium, or to perform analyses by age groups, sex and smoking status. These analyses and others will be possible upon survey completion. For example, previous research suggests that heavy metal exposure is unlikely to be equal across the population; lead exposure varies by socioeconomic status,[11,12] and cadmium exposure[13-15] varies by smoking status. Future CHMS studies will be able to explore issues such as these.

Statistical analyses were based on weighted data. To account for survey design effects, standard errors, coefficients of variation and 95% confidence intervals were estimated using the bootstrap technique.[16-18]

miscarriage, and chronic exposure may affect the development of the foetus.[19]

Preliminary results from the CHMS show that the geometric mean blood lead concentration of Canadians is 1.37µg/dL (Table 1). Over 99% of Canadians aged 6 to 79 have measurable amounts of lead, that is, levels above the laboratory test method's limit of detection of 0.02µg/dL. However, having a measurable amount of lead in the blood does not necessarily mean that it will cause adverse health effects. Indeed, the current Health Canada blood lead guidance value for the general population is 10µg/dL.[20] A guidance value is the level above which follow-up actions may be considered to reduce exposure.

Fewer than 1% of the population have blood lead concentrations above the current Health Canada guidance value. (The coefficient of variation for this estimate was too high to reliably report a specific value.) This is a noticeable decline from 1978-1979 when results of the Canada Health Survey showed that 25% of Canadians aged 6 or older had blood lead concentrations above 10µg/dL.[21] Much of this decline may reflect the phase-out of leaded gasoline, lead-containing paints, and lead solder in food cans since the 1970s.[22]

The United States and Germany are among the few countries that have conducted nationally representative biomonitoring surveys that include testing for heavy metals. In the United States, the 2001-2002 National Health and Nutrition Examination Survey (NHANES) reported blood lead levels for the population aged 1 or older.[23] The 1998 German Environmental Survey (GerES III) and 2003-2006

Table 1
Geometric mean and selected percentiles of blood concentrations (in µg/dL) of lead, by age group, household population aged 6 to 79, 2007/2008

	Geo-metric mean	95% confidence interval		25th percen-tile	95% confidence interval		50th percen-tile	95% confidence interval		75th percen-tile	95% confidence interval		90th percen-tile	95% confidence interval		95th percen-tile	95% confidence interval	
		from	to		from	to		from	to		from	to		from	to		from	to
Total	1.37	1.19	1.58	0.88	0.74	1.02	1.32	1.14	1.50	2.06	1.73	2.39	3.13	2.60	3.65	3.87	3.14	4.61
6 to 19	0.88	0.77	0.99	0.62	0.55	0.69	0.85	0.74	0.97	1.14	0.89	1.39	1.61	1.29	1.92	2.05	1.57	2.54
20 to 79	1.50	1.32	1.72	1.00	0.88	1.12	1.44	1.27	1.60	2.23	1.87	2.58	3.35	2.84	3.87	4.11	3.18	5.03

Source: 2007/2008 Canadian Health Measures Survey.

Table 2
Geometric mean blood lead (µg/dL), total mercury (µg/L) and cadmium (µg/L) concentrations, by age group, Canadian Health Measures Survey and other selected surveys

	CHMS		NHANES (2001-2002)		GerES (1998 and 2003-2006)		INSPQ (2004)	
	Age group	Geometric mean	Age group	Geometric mean	Age group	Geometric mean	Age group	Geometric mean
Lead	6 to 19	0.88	6 to 11	1.25	6 to 8	1.73		
			12 to 19	0.94	9 to 11	1.56		
					12 to 14	1.45		
	20 to 79	1.50	20 or older	1.56	18 to 69	3.07	18 to 65	2.15
Total mercury	6 to 19	0.31[E]			6 to 8	0.23		
					9 to 11	0.22		
			16 to 49	0.83	12 to 14	0.26		
	20 to 79	0.91[E]	(females)		18 to 69	0.58	18 to 65	0.74
Cadmium	6 to 19	0.15	6 to 11	less than 0.3	6 to 8	less than 0.12		
			12 to 19	less than 0.3	9 to 11	less than 0.12		
					12 to 14	0.14		
	20 to 79	0.42	20 or older	less than 0.3	18 to 69	0.58	18 to 65	0.69

[E] use with caution (coefficient of variation 16.6% to 33.3%)
CHMS = 2007/2008 Canadian Health Measures Survey
NHANES = United States National Health and Nutrition Examination Survey
GerES = German Environmental Survey III and IV
INSPQ = Institut national de santé publique du Québec

German Environmental Survey for Children (GerES IV) reported blood lead levels for adults aged 18 to 69 and children aged 6 to 14, respectively.[13,24] Blood lead levels have also been reported from a survey of the non-occupationally exposed general population aged 18 to 65 in the Quebec City Region.[14] A comparison of the geometric mean blood lead concetrations showed that Canadians overall have similar or slightly lower blood lead levels, compared with these populations (Table 2).

Total mercury

There are three chemical forms of mercury: elemental, inorganic, and organic, notably, methylmercury. Exposure of the general population is primarily to methylmercury and occurs through the consumption of fish and seafood.[25] To a much lesser extent, the general population is exposed to inorganic mercury through dental amalgams.[25] Previous studies have shown that inorganic mercury comprises 14% to 26% of total blood mercury.[26-28] Thus, a measurement of total blood mercury consists primarily of methylmercury.

Table 3
Geometric mean blood concentrations (in ug/L) of total mercury, by age group, household population aged 6 to 79, 2007/2008

Age group	Geometric mean	95% confidence interval	
		from	to
Total	0.76[E]	0.51	1.13
6 to 19	0.31[E]	0.23	0.43
20 to 79	0.91[E]	0.63	1.32

[E] use with caution (coefficient of variation 16.6% to 33.3%)
Note: The coefficient of variation was too high to reliably report the percentiles.
Source: 2007/2008 Canadian Health Measures Survey.

Table 4
Geometric mean and selected percentiles of blood concentrations (in µg/L) of cadmium, by age group, household population aged 6 to 79, 2007/2008

Age group	Geometric mean	95% confidence interval		25th percentile	95% confidence interval		50th percentile	95% confidence interval		75th percentile	95% confidence interval	
		from	to		from	to		from	to		from	to
Total	0.35	0.31	0.39	0.15	0.12	0.18	0.28	0.25	0.31	0.62	0.49	0.75
6 to 19	0.15	0.12	0.18	0.09	0.07	0.10	0.13	0.11	0.15	0.21	0.18	0.24
20 to 79	0.42	0.37	0.48	0.19	0.17	0.21	0.34	0.31	0.37	0.79	0.55	1.02

Note: The coefficient of variation for additional percentiles was too high to reliably report the corresponding estimates.
Source: 2007/2008 Canadian Health Measures Survey.

Chronic exposure to methylmercury may cause numbness and tingling in the extremities, blurred vision, deafness, lack of muscle coordination and intellectual impairment, as well as adverse effects on the cardiovascular, gastrointestinal and reproductive systems. Prenatal exposure may interfere with foetal development of the central nervous system and cause neurological and developmental delays. Women who are exposed to methylmercury and breastfeed may also expose the child through the milk.[29]

Preliminary CHMS results show that the geometric mean blood mercury level of Canadians aged 6 to 79 is 0.76µg/L (Table 3), with approximately 90% having concentrations above the limit of detection of 0.10µg/L. (Because the coefficient of variation for this estimate was between 16.6% and 33.3%, it should be interpreted with caution.) However, fewer than 1% of Canadians aged 20 to 79 have total mercury concentrations above the current Health Canada blood guidance value of 20 µg/L[30] established for the general adult population. (The coefficient of variation for this estimate was too high to reliably report a specific value.)

A comparison of the geometric mean blood mercury concentrations shows that Canadians overall have similar or slightly higher levels than those of the general population in Germany,[13,24] females aged 16 to 49 in the United States,[23] and a non-occupationally exposed population in the Quebec City region[14] (Table 2).

Cadmium

Sources of exposure to cadmium include diet, drinking water and occupational exposure. For the non-occupationally exposed population, cigarette smoking is considered to be a major source of exposure.[31,32]

Chronic exposure to cadmium may cause kidney damage, bone mineral density loss and hypertension.[32,33] Acute and chronic inhalation of cadmium can cause potentially fatal pulmonary dysfunction.[32] In addition, cadmium has been classified as carcinogenic by the International Agency for Research on Cancer, with exposure being primarily associated with lung cancer.[34]

According to preliminary CHMS results, the geometric mean blood cadmium of Canadians aged 6 to 79 is 0.35µg/L, with about 98% having levels above the limit of detection of 0.04µg/L (Table 4). No Canadian blood cadmium guidance value has been established for the general population. Occupational exposure guidance values exist, but they are not applicable to the population overall. Previous research has shown that cigarette smoking can raise blood cadmium to levels that are at least 2.5 to 4 times higher than in non-smokers,[13-15] but because of the small sample size, such associations could not be examined in this article.

A comparison of the geometric mean blood cadmium concetrations shows that Canadians' blood cadmium levels are similar to those of the general population of the United States[23] and Germany,[13,24] and a non-occupationally exposed population in the Quebec City region[14] (Table 2).

Summary

These preliminary findings from the Canadian Health Measures Survey provide national population estimates for blood lead levels, which have not been measured since 1978, as well as the first national population estimates for total mercury and cadmium levels. While most Canadians have measurable amounts of these heavy metals in their blood, this does not necessarily mean that they experience adverse health effects. Indeed, fewer than 1% of Canadians aged 6 to 79 have blood lead levels above the current Health Canada general population guidance value of 10µg/dL, and fewer than 1% of those aged 20 to 79 have total blood mercury levels above the Health Canada guidance value of 20µg/L for the general adult population. Canadians' levels of lead, total mercury and cadmium are similar to those of people in the United States[23] and Germany.[13,24]

Further information about the CHMS can be found at:

- Statistics Canada: www.statcan.ca/chms

Further information about biomonitoring, and specifically, lead, mercury and cadmium, their health effects, and ways to minimize exposure can be found at:

- Health Canada: www.hc-sc.gc.ca
- Chemical Substances in Canada: www.chemicalsubstances-chimiques.gc.ca.

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