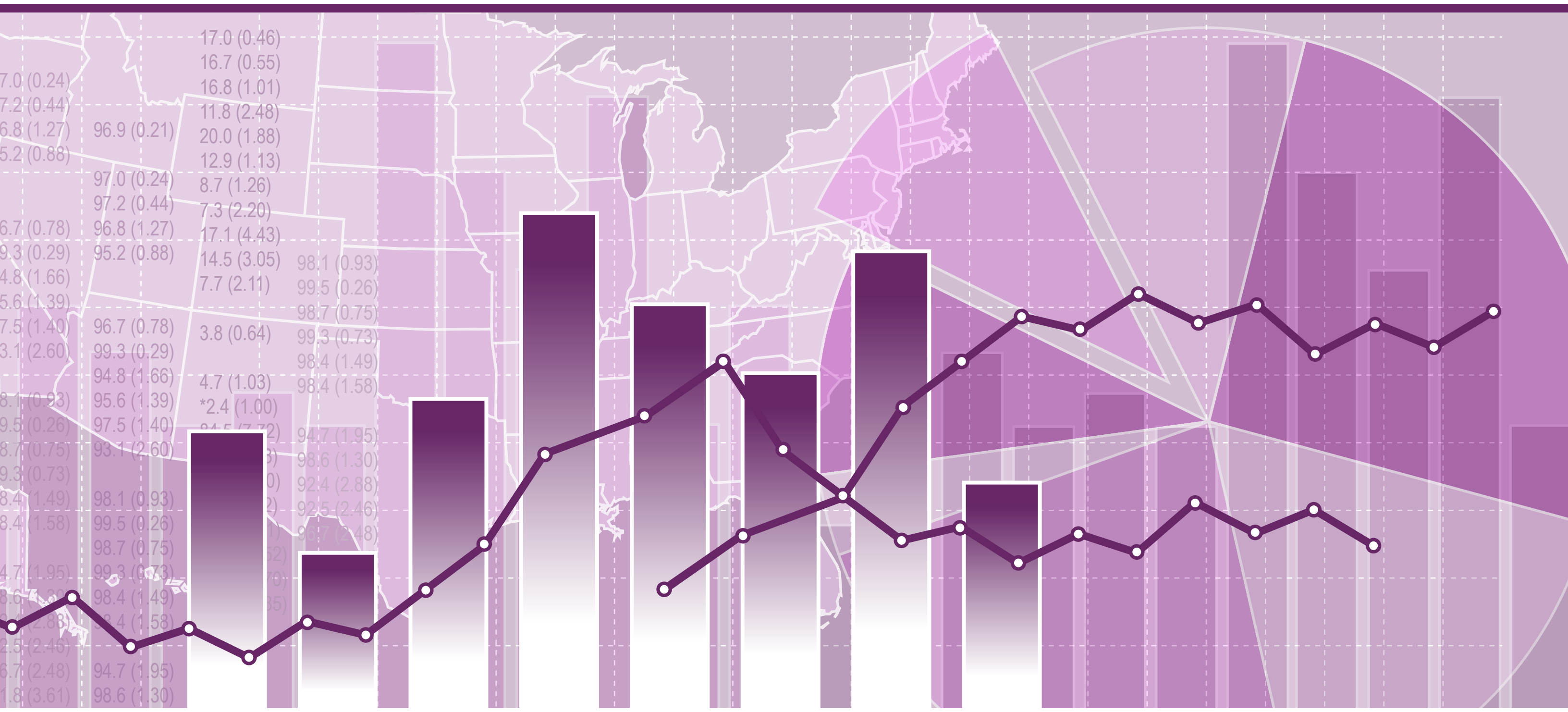
NATIONAL CENTER FOR HEALTH STATISTICS
Vital and Health Statistics

Series 3, Number 49 April 2023



Trends in Blood Lead, Cadmium, and Mercury: United States, 1999–2000 Through 2017–2018 and Canada, 2007–2009 Through 2016–2017

Analytical and Epidemiological Studies

Centers for Disease Control and Prevention
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Suggested citation

Aoki Y, Earl S, Clarke J, Servais J, Karthikeyan S. Trends in blood lead, cadmium, and mercury: United States, 1999–2000 through 2017–2018 and Canada, 2007–2009 through 2016–2017. National Center for Health Statistics. Vital Health Stat 3(49). 2023.
DOI: https://dx.doi.org/10.15620/cdc:123891.

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Analytical and Epidemiological Studies

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Health Statistics

Hyattsville, Maryland
April 2023

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Trends in Blood Lead, Cadmium, and Mercury: United States, 1999–2000 Through 2017–2018 and Canada, 2007–2009 Through 2016–2017

by Yutaka Aoki, Ph.D., National Center for Health Statistics; Steven Earl, M.P.H., Janine Clarke, M.Sc., Jennifer Servais, B.Sc., Statistics Canada; and Subramanian Karthikeyan, Ph.D., Health Canada

Abstract

Objectives

Exposures to toxic metals have been monitored by measuring blood concentrations in national surveys. This report presents time trends in blood concentrations of three metals (lead, cadmium, and mercury) for the United States and Canada.

Methods

Data from the National Health and Nutrition Examination Survey (NHANES) (1999–2018; *n* = 69,458) and the Canadian Health Measures Survey (CHMS) (2007–2017; *n* = 26,944) were used for time trend analyses of geometric mean whole blood and red blood cell (RBC) concentrations of lead, cadmium, and mercury. Censored regression (overall and stratified by sex and age) was used to account for detection limits. Quadratic time trends were tested, and annual percent change (APC) was estimated for the entire survey period or two periods separated by a detected joinpoint, as appropriate.

Results

For blood and RBC levels of lead and cadmium in both the United States and Canada and for blood and RBC mercury in the United States, statistically significant declining trends were noted in the total population aged 3–79 years as well as in most sex-age subgroups. For blood and RBC mercury in Canada, declining trends were limited to some adult sex-age subgroups, with no statistically significant trends in the total population aged 3–79. APCs in the total population aged 3–79 based largely on available data through 2017 were -5.20% and -5.09% for RBC lead, -2.02% and -2.69% (unreliable) for RBC cadmium, respectively, for the United States and Canada, and -2.70% for RBC mercury in the United States. No blood or RBC metals showed significant differences between the two countries in APCs for the total population aged 3–79.

Conclusions

Decreasing trends over time were observed for lead and cadmium in the United States and Canada and for mercury in the United States. Continued survey-based biomonitoring is needed to track trends in population exposures.

Keywords: red blood cell lead • red blood cell cadmium • red blood cell mercury • biomonitoring • National Health and Nutrition Examination Survey (NHANES) • Canadian Health Measures Survey (CHMS)

Introduction

Exposures to lead, cadmium, and mercury have been implicated in adverse health outcomes, and they remain population health concerns globally (1). Chronic exposure to lead can result in neurodevelopmental, neurodegenerative, renal, cardiovascular, and reproductive effects (2,3). In infants and children, even very low levels of lead exposure have been linked to neurodevelopmental effects (2). Cadmium accumulates in the kidney and can cause severe renal tubular damage; exposure may also result in gastrointestinal and lung effects, including emphysema. Cadmium is a probable human carcinogen when inhaled (4). Mercury is a neurotoxicant, and exposure to organic mercury in young children may result in developmental neurotoxicity; at high doses, mercury in its various forms may also result in gastrointestinal damage, lung damage, and kidney failure (5).

Over the past few decades, in the United States and Canada, a number of regulatory measures have been implemented to reduce population exposure to these toxic metals (2,4–7). Exposure-reducing regulatory measures have included prohibitions or restrictions on the import, manufacture, and sale of products that are known sources of exposure, restrictions on environmental releases from mining and industrial operations, and regulations aimed at air, drinking water, food, and therapeutic products.

Monitoring human exposure to lead, cadmium, and mercury may help to evaluate potential health risks posed by these chemicals and to assess the effectiveness of regulatory actions to reduce population exposures. To this point, human biomonitoring, the measurement of environmental chemicals, their metabolites, or conjugates in human tissues such as blood, urine, or hair has become a widely used tool in the assessment of population exposure to several environmental chemicals of concern (8). National efforts, such as biomonitoring conducted as part of the U.S. National Health and Nutrition Examination Survey (NHANES) or the Canadian Health Measures Survey (CHMS), have established national baselines for chemical exposures and have tracked temporal trends. With ongoing collection of data, beginning in 1999 for NHANES and 2007 for CHMS, these nationally representative data sets have been the basis of numerous studies investigating factors associated with chemical exposures, linking exposure to health effects, or assessing spatial and temporal trends in exposure (9–16). For example, the biomonitoring data from CHMS were recently used in the assessment of trends in exposure to a number of environmental chemicals, including lead, cadmium, and mercury in the general population in Canada (17); however, age- and sex-specific trends were not examined.

This report presents detailed time trends for mean blood lead, cadmium, and mercury using data collected for the United States from 1999–2000 through 2017–2018 and for Canada from 2007–2009 through 2016–2017. The trends also were assessed using red blood cell (RBC) metals (metal concentration in RBC portion of the whole blood) derived as blood metals corrected for hematocrit. Comparing time trends for the two countries may inform examination of temporal changes in exposure.

Methods

Data Sources

In the United States, NHANES is conducted by the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics as a serial cross-sectional survey; it has been conducted continuously since 1999, with data releases in biannual cycles. The NHANES sample is selected through a complex, multistage probability design to represent the U.S. civilian noninstitutionalized population (18–21). Certain race and Hispanic-origin groups are oversampled to obtain reliable estimates for population subgroups. Oversampling of non-Hispanic Black and Mexican-American people began in 1999, while oversampling of all Hispanic people (including Mexican Americans) began in 2007 and oversampling of non-Hispanic Asian people began in 2011. NHANES survey data are collected through interviews conducted in participants' homes and standardized physical examinations conducted in mobile examination centers (MEC). Blood and other biological specimens are collected at the MEC for biomarkers of exposure to environmental agents. This study includes 69,458 examined people aged 3–79 years from 10 NHANES 2-year cycles 1999–2018, for whom at least one of the three blood metal concentrations had a nonmissing value. The age range was limited to 3–79 for this study to be compatible with the Canadian survey sample. The overall examination response rate was 76.3% for 1999–2000 and then generally decreased to 48.8% (2017–2018).

In Canada, CHMS is conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada. It is also a continuous survey with biannual collection periods and data releases. CHMS uses a similar collection strategy: Household interviews are completed, then respondents visit a MEC and undergo a wide range of physical and other health examination tests. Blood and other biological samples are collected at the MEC visit. CHMS employs a stratified three-stage sample design consisting of one or two respondents from homes selected within sampled collection sites. The full sample consists of people living in the 10 Canadian provinces and excludes the territories, Indigenous reserves and settlements, full-time members of the Canadian Forces, the institutionalized population, and certain remote regions. Targeted age ranges were 6–79 years for 2007–2009 and 3–79 years for 2009–2017. CHMS does not incorporate oversampling by racial or cultural group, but does oversample children aged 3–19 years. This study includes 26,944 examined respondents from five CHMS 2-year cycles from 2007 through 2017, for whom at least one of the three blood metal concentrations had a nonmissing value. The combined (household and MEC) overall examination response rates over the five cycles ranged from 48.5% in 2016–2017 to 55.5% in 2009–2011.

Laboratory Methods

In NHANES, whole blood specimens were analyzed for lead, cadmium, and mercury concentrations by the Division of Laboratory Sciences at the CDC National Center for Environmental Health. For 1999–2002, blood lead and cadmium were measured by graphite furnace atomic absorption spectrometry; blood mercury was measured by flow injection cold vapor atomic absorption. For 2003–2018, the three metals were measured by inductively coupled plasma mass spectrometry. Limits of detection for blood lead (µg/dL) were 0.3 for 1999–2002, 0.28 for 2003–2004, 0.25 for 2005–2012, and 0.07 for 2013–2018. Limits of detection for blood cadmium (µg/L) were 0.3 for 1999–2002, 0.14 for 2003–2004, 0.20 for 2005–2010, 0.16 for 2011–2012, and 0.10 for 2013–2018. Limits of detection for blood mercury (µg/L) were 0.14 for 1999–2002, 0.20 for 2003–2004, 0.33 for 2005–2010, 0.16 for 2011–2012, and 0.28 for 2013–2018. Hematocrit was measured at the MEC on the Beckman

Coulter MAXM analyzer for 1999–2012 and the Beckman Coulter DxH 800 analyzer for 2013–2018 (Beckman Coulter Corporation, Brea, Calif.). Detailed descriptions of the NHANES laboratory methods used to produce the biomarker data are found at the NHANES website under "Laboratory Methods" (https://wwwn.cdc.gov/nchs/nhanes/default.aspx).

In CHMS, blood specimens were analyzed for lead, cadmium, and mercury concentrations by the Institut national de santé publique du Québec laboratory. Blood lead, cadmium, and mercury were measured using inductively coupled plasma mass spectrometry using the ICP-MS, Perkin Elmer Sciex, Elan DRC II instrument. Limits of detection for blood lead (µg/dL) were 0.02 in 2007–2009, 0.01 in 2009–2011, 0.16 in 2012–2015, and 0.17 in 2016–2017. Limits of detection for blood cadmium (µg/L) were 0.040 in 2007–2011, 0.080 in 2012–2015, and 0.097 in 2016–2017. Limits of detection for blood mercury (µg/L) were 0.10 in 2007–2011, 0.42 in 2012–2015, and 0.20 in 2016–2017. Hematocrit was measured at the MEC on the Beckman Coulter HmX analyzer (Beckman Coulter Corporation, Brea, Calif.). An overview of laboratory analytical methods used for CHMS has been published elsewhere (22).

In blood, the majority of lead, cadmium, and mercury exist within RBCs (23–25); therefore, blood metal concentrations within RBCs (termed RBC metal in this report) more accurately reflect exposure compared with concentrations in whole blood because these measurements take into account the concentration of RBCs within the blood (that is, hematocrit), which can vary as a result of toxic exposure (for example, lead exposure [23]) and other physiological reasons (such as hydration levels [26]). In this study, RBC metal is calculated as the concentration of a metal in whole blood divided by the hematocrit (a dimensionless ratio of RBC to whole blood volumes). RBC metal is also called erythrocyte metal or hematocrit-corrected whole blood metal.

Demographic Covariates

Results are stratified by participant sex and age. Age was reported during pre-interview screening in NHANES and during the household interview for CHMS, and grouped into five categories (all in years) for this analysis: 3–5, 6–19, 20–39, 40–59, and 60–79. In reporting results, two additional age groups also were used: 3–79 to cover the entire age range and 20–79 to cover the age range for adults. Results are not reported for certain sex-age subgroups and survey years because those subgroups were not targeted for measurements of whole blood lead, cadmium, or mercury in NHANES or the age group was not included in CHMS.

Blood levels of the three metals may vary by sex and age (for example, male adults having higher blood lead than female adults and older adults generally having higher blood lead than younger adults [27–29]) and their time trends also may be sex- and age-dependent, making overall results for the total population potentially less informative. As a result, this report focuses primarily on the sex-specific results by age groups in the text, figures, and statistical comparisons of time trends between the two countries. Therefore, descriptions of country-specific differences by sex and age or between-country comparisons of such differences, along with formal statistical comparisons across sex or age, are omitted.

Statistical Analysis

Geometric mean (GM) estimation

GMs of blood metals and RBC metals were estimated using a censored regression model with natural logarithm-transformed blood and RBC metal concentrations. Left censoring occurred due to unknown measured values less than the lower limit of detection using available laboratory methods.

For age groups 3–79 and 20–79, GM estimation and time trend analyses were age standardized to account for the age composition difference across countries and changes over time. Age standardization was done through reweighting (that is, modifying poststratified survey weights [30] such that for each survey cycle the age composition of the weighted sample matched the age distribution in the 2000 projected U.S. Census population [31]). Nonetheless, the two countries' age compositions are similar. The age composition (or percentage) for the population aged 3–79 based on the 2000 projected U.S. Census population is 4.5, 22.0, 30.6, 28.7, and 14.2 for those aged 3–5, 6–19, 20–39, 40–59, and 60–79, respectively, which is similar to the distribution for Canada (3.7, 20.7, 30.2, 30.0, and 15.4) based on the Canadian Census 2006 (32).

Time trend analyses

Data from different survey years were covered in the time trend analyses depending on data availability for an analyte or for an age or sex group. In the United States, biomonitoring data for lead and cadmium are available for the period 1999–2018 for all age-sex subgroups covered by this analysis. However, blood mercury data are available for males and females aged 3 and over only starting in 2003; before this, between 1999–2002, mercury was measured only in children aged 3–5 and women aged 20–39. Similarly, for mercury, trends for males, females, the total population aged 3–5, and women aged 20–39 were assessed for 1999–2018. Trends for all other age-sex subgroups were assessed for 2003–2018. For Canada, because respondents aged 3–5 were not sampled in 2007–2009, trends for lead, cadmium, and mercury could be calculated for the total population, males, and females aged 3–5 and 3–79 only for 2009–2017. However, trends for other age groups 6 and over could be assessed for 2007–2017.

The linearity of time trends was assessed by examining the significance of quadratic trends using polynomial orthogonal contrasts in censored linear regression models with adjacent survey cycles treated as equally spaced. Trends by sex and age group were assessed in separate, stratified models.

For NHANES data, when the quadratic trend was not significant ($p \geq 0.05$), the slope for all survey cycles was estimated with survey cycle used as a single continuous covariate in the censored linear regression model (33). When the quadratic trend was significant ($p < 0.05$), the mean and standard error of log-transformed estimates were supplied to Joinpoint software (34), which was used to determine a maximum of one joinpoint restricted to be at least two time points away from the first or last time point. When a quadratic trend was detected, Joinpoint always detected a joinpoint. If a joinpoint was identified, piecewise censored linear regression was used to estimate the slope for each line segment and test the significance of each slope. The significance of the difference between the two slopes was also tested. Slope estimates were backtransformed and rescaled to allow interpretation as annual percent change (APC), assuming log-linear change and using the equation:

$$\text{APC} = 100 \cdot (e^{\beta} - 1) \qquad [1]$$

where e is the base for a natural logarithm and β is the estimated slope regression coefficient. Due to the restriction in joinpoint detection, possible time points detectable as a joinpoint were between 2003–2004 and 2013–2014 for most analyte-sex-age combinations for which data were available from 1999–2018. As an exception, for blood mercury and RBC mercury among sex-age subgroups other than the total population aged 3–5, boys aged 3–5, and females aged 3–5 and 20–39, the 2013–2014 cycle was the only time point detectable as a joinpoint because data were available from 2003 through 2018.

For a given sex-age subgroup, CHMS data consisted of only five survey cycles or fewer, which is fewer than the seven recommended by Joinpoint as a minimum number of datapoints for detecting a single joinpoint. Therefore, for CHMS data, no attempt to detect a joinpoint was made, and, assuming no joinpoint, the slopes were estimated using data from all survey cycles (and backtransformed).

There are methods other than the joinpoint methodology used in this report for describing complicated time trends that allow the rate of change to vary over time (33). The joinpoint method was chosen for this study because it is conceptually straightforward and produces summary statistics for relative changes over time that can easily be compared across the two surveys.

Comparison between United States and Canada

The sex-specific time trends for the overall age range of 3–79 were compared across the two countries, presenting the ratio of annual relative changes for the two countries as a summary statistic. Annual relative change is:

$$e^{\beta} \qquad [2]$$

while (as mentioned earlier) APC is:

$$100 \cdot (e^{\beta} - 1) \qquad [3]$$

The annual relative change ratio was calculated as annual relative change for Canada over annual relative change for the United States. When both counties had decreasing trends (that is, APC < 0), the ratio being > 1 indicates a slower decrease in Canada than in the United States. Statistical significance was evaluated for the logarithm of the ratio using t tests; this evaluation entails testing the equality of two slope coefficients and is mathematically equivalent to testing the equality of two APCs. For the United States, overall annual relative change was used when no statistically significant quadratic trend was observed, and the annual relative change for the second time segment was used when a joinpoint was in the trend. For Canada, overall annual relative change was used. These allow comparison of annual relative changes applicable to the most recent overlapping survey years covered for each of the two countries, even though annual relative changes were estimated based on data from different survey years depending on country, analyte, and sex. When a joinpoint was detected for the United States, survey years at and after the joinpoint were used to estimate the annual relative change, while data from 2009–2017 were used consistently for Canada. As a result, all of the comparisons were made in terms of the annual relative changes relevant to the year 2017, the latest year with data available in both countries.

As a sensitivity analysis, trend analyses were restricted to the survey years 2009–2018 for the United States, which is nearly identical to 2009–2017 (the years covered for those aged 3–79 for Canada). With this restriction, each relative annual change for the United States was estimated without a joinpoint because the United States had five survey cycles, fewer than the seven recommended by Joinpoint as a minimum number of datapoints for detecting a single joinpoint.

Complex survey design and other considerations

For both NHANES and CHMS, examination sample weights (or appropriate subsample weights when a blood metal was measured for only a proportion of NHANES participants) were used to account for probability of selection, noncoverage, and nonresponse. For NHANES, variance was estimated using the Taylor series linearization method to account for the complex sample design (35). For CHMS, variance was estimated using the bootstrap method (36). For both surveys, a relative standard error (RSE) (standard error of an estimate divided by the estimate) is used as a measure of reliability. RSE for APC is calculated as the standard error of APC divided by the absolute value of APC. RSE greater than 30% is used to define estimates that are considered not statistically reliable (37). Any estimates with RSEs greater than 30% are indicated as such in the tables.

All analyses for GM and APC estimations were performed using Stata Version 16 (38) for NHANES and Version 14 (39) for CHMS. Stata command “svy: intreg” was used for censored regression to account for the complex survey design.

Results

Blood Lead

United States

Blood lead measurements were available for 69,457 participants. Table I shows sample sizes by sex-age subgroup and survey years. Estimates of GM blood lead from 1999–2000 through 2017–2018 are presented in Table 1 and Figures 1–3, and trend results are presented in Table 2. Blood lead GM for the total population aged 3–79 decreased from 1.65 µg/dL in 1999–2000 to 0.81 µg/dL in 2013–2014 (APC = -4.93%) and again to 0.69 µg/dL in 2017–2018 (APC = -4.64%). Blood lead GMs tended to be higher for adult men than for women and had a tendency to decrease from those aged 3–5 to 6–19 and then increase during adulthood.

The GM blood lead for males aged 3–79 decreased from 2.02 µg/dL in 1999–2000 to 0.81 µg/dL in 2017–2018 (APC = -5.14%), and a significant decline in blood lead GM was seen from 1999–2000 to 2017–2018 for all age groups. APC ranged from -6.70% (aged 3–5) to -4.26% (aged 60–79). Similar to the total population, males aged 6–19 and 60–79 had the lowest and highest GMs, respectively, within a given NHANES cycle. Blood lead for those aged 6–19 decreased from 1.46 µg/dL in 1999–2000 to 0.49 µg/dL in 2017–2018 (APC = -5.87%). The corresponding change for those aged 60–79 was from 2.81 µg/dL to 1.33 µg/dL.

Blood lead GM for females aged 3–79 decreased from 1.36 µg/dL in 1999–2000 to 0.69 µg/dL in 2013–2014 (APC = -4.71%) and again to 0.60 µg/dL in 2017–2018 (APC = -4.24%). Among females aged 3–5 and 20–39, significant declines in GM blood lead were seen between 1999–2000 and 2017–2018 (2.29 µg/dL to 0.60 µg/dL for those aged 3–5 and 1.10 µg/dL to 0.49 µg/dL for 20–39), with APCs of -7.01% and -4.38%, respectively. Decreases occurred in other age groups, but the rate of decline changed over 1999–2018, and the years at which the rate of decline changed (that is, the joinpoint) differed by age group.

Canada

Blood lead measurements were available for 26,942 participants. Table II shows sample sizes by sex-age group and survey years. Estimates of GM blood lead are presented in Table 3 and Figures 1–3, and trends are presented in Table 4. GM blood lead for the total population aged 3–79 decreased from 1.07 µg/dL in 2009–2011 to 0.83 µg/dL in 2016–2017 (APC = -4.49%). The observed patterns for differences by sex and age generally were similar to those for the United States (that is, males tended to have higher GMs and a decrease from those aged 3–5 to 6–19 was seen, followed by increases with increasing age).

The GM blood lead for males aged 3–79 decreased from 1.21 µg/dL in 2009–2011 to 0.94 µg/dL in 2016–2017 (APC = -4.52%). For the rest of the individual and combined male age groups, there also was a significant decline in GM blood lead over time, with APCs ranging from -7.46% (aged 3–5) to -4.27% (aged 20–39). Within a given CHMS cycle, those aged 6–19 and 60–79 consistently had the lowest and highest GMs, respectively. GM blood lead for those aged 6–19 decreased from 0.87 µg/dL in 2007–2009 to 0.57 µg/dL in 2016–2017. The corresponding change for those aged 60–79 was from 2.26 µg/dL to 1.46 µg/dL.

The GM blood lead for females aged 3–79 decreased from 0.95 µg/dL in 2009–2011 to 0.73 µg/dL in 2016–2017 (APC = -4.46%). For the rest of the individual and combined female age groups as well, a significant decline in GM blood lead was observed over time, with APCs ranging from -7.76% (aged 3–5) to -3.54% (aged 60–79). Again, those aged 6–19 and 60–79 consistently had the lowest and highest GMs, respectively, within a given CHMS cycle. GM blood lead for those aged 6–19 decreased from 0.76 µg/dL in 2007–2009 to 0.45 µg/dL in 2016–2017. The corresponding change for those aged 60–79 was from 1.84 µg/dL to 1.37 µg/dL.

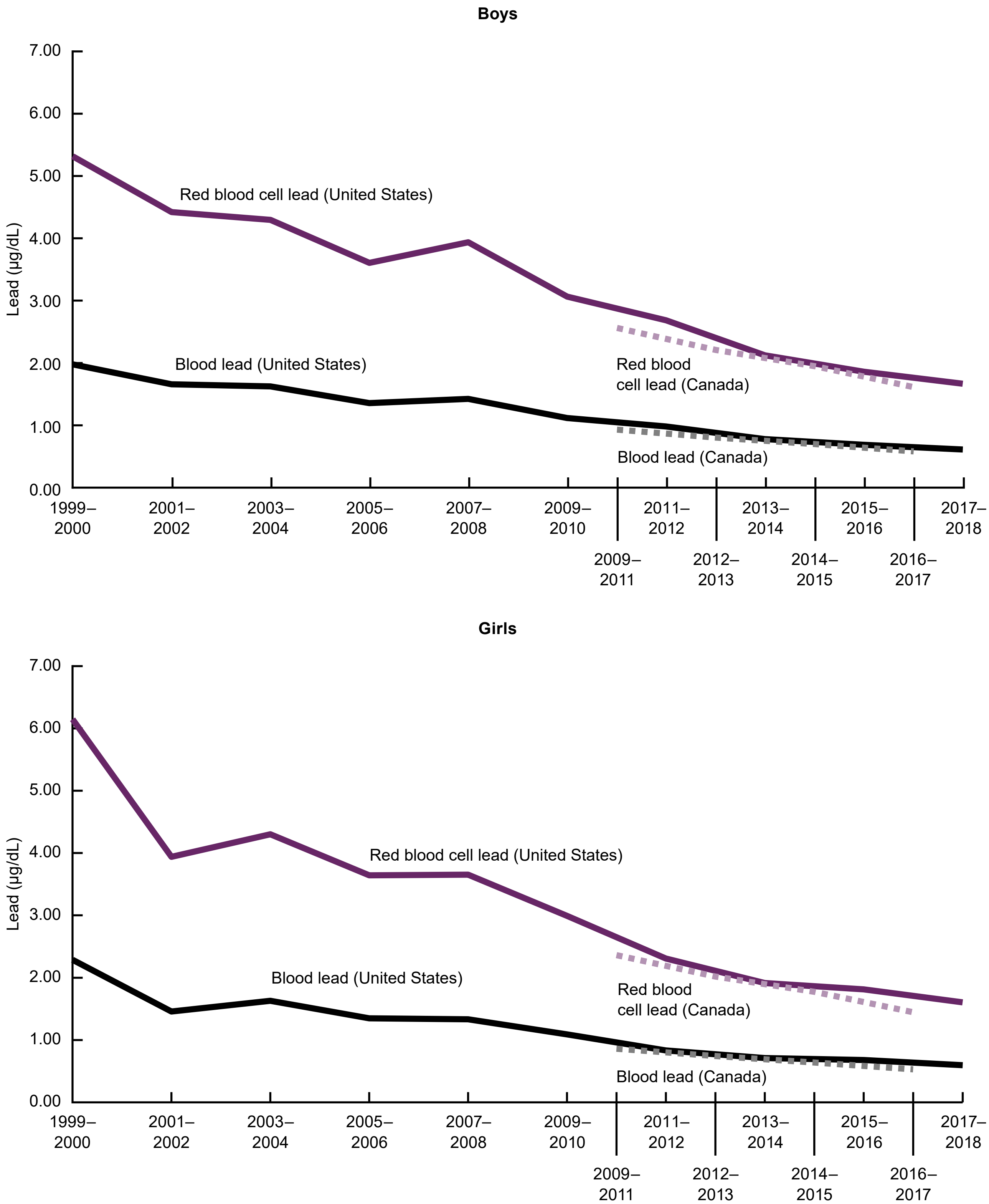
RBC Lead

United States

RBC lead measurements were available for 69,339 participants. Table III shows sample sizes by sex-age subgroup and survey years. Estimates of GM RBC lead are presented in Table 5 and Figures 1–3, and trends are presented in Table 6. GM RBC lead for the total population aged 3–79 decreased from 3.94 µg/dL in 1999–2000 to 1.97 µg/dL in 2013–2014 (APC = -4.68%) and again to 1.68 µg/dL in 2017–2018 (APC = -5.20%). However, the differences between the two APCs were not significant. The observed patterns for sex and age differences generally were similar to their counterparts for blood lead.

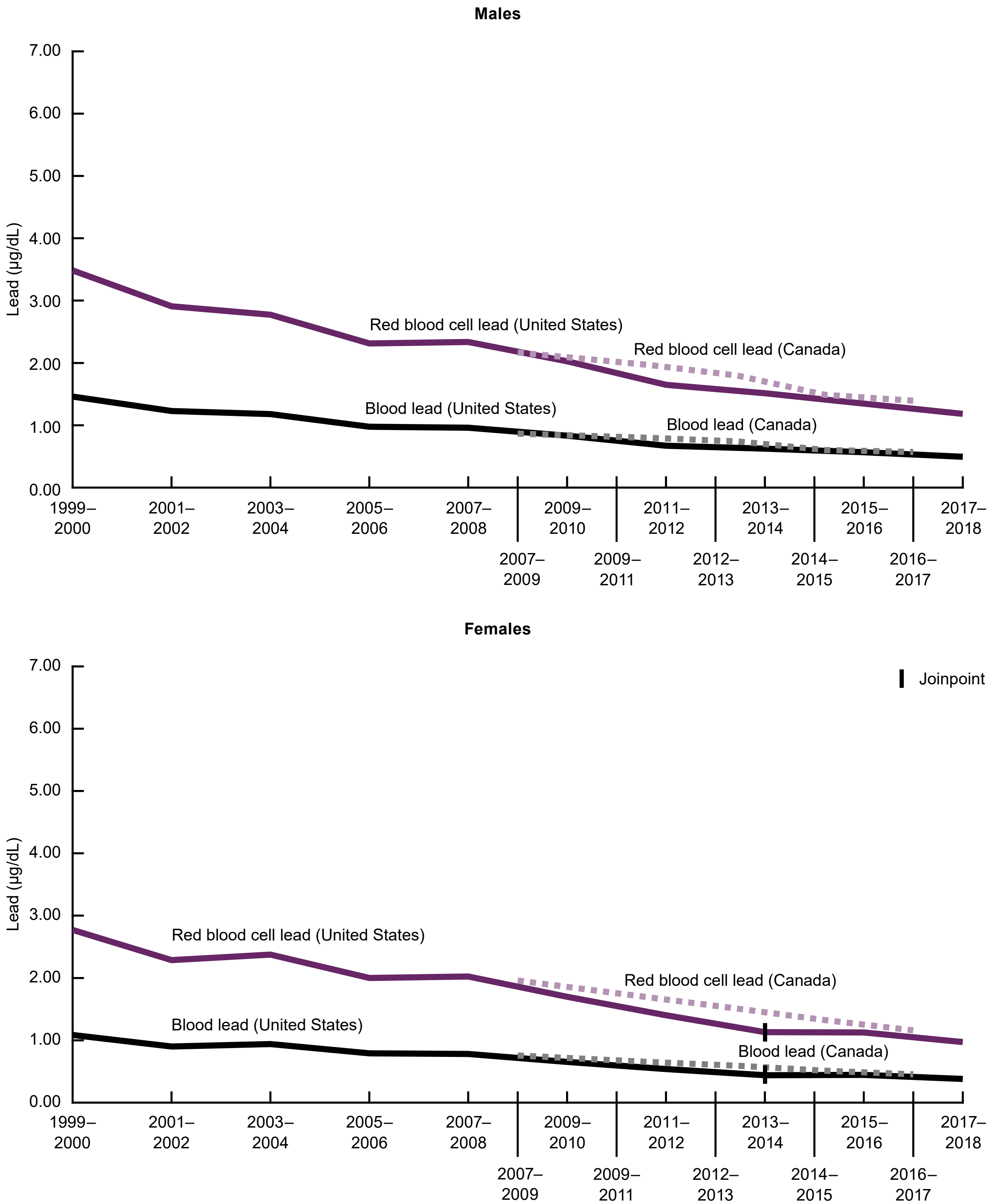
GM RBC lead for males aged 3–79 decreased from 4.56 µg/dL in 1999–2000 to 3.70 µg/dL in 2003–2004 (APC = -3.86%) and again to 1.85 µg/dL in 2017–2018 (APC = -5.07%, not significantly different from the earlier time period). Similar to the results for blood lead, those aged 6–19 and 60–79 consistently had the lowest and highest observed RBC lead GMs, respectively, within a given NHANES cycle. GM blood lead for those aged 6–19 decreased from 3.48 µg/dL in 1999–2000 to 1.18 µg/dL in 2017–2018 (APC = -5.78%). The corresponding change for those aged 60–79 was from 6.34 µg/dL to 3.07 µg/dL. In males aged 3–5, 6–19, 20–39, and

Figure 1. Geometric mean blood and red blood cell lead levels in boys and girls aged 3–5 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2009–2011 through 2016–2017



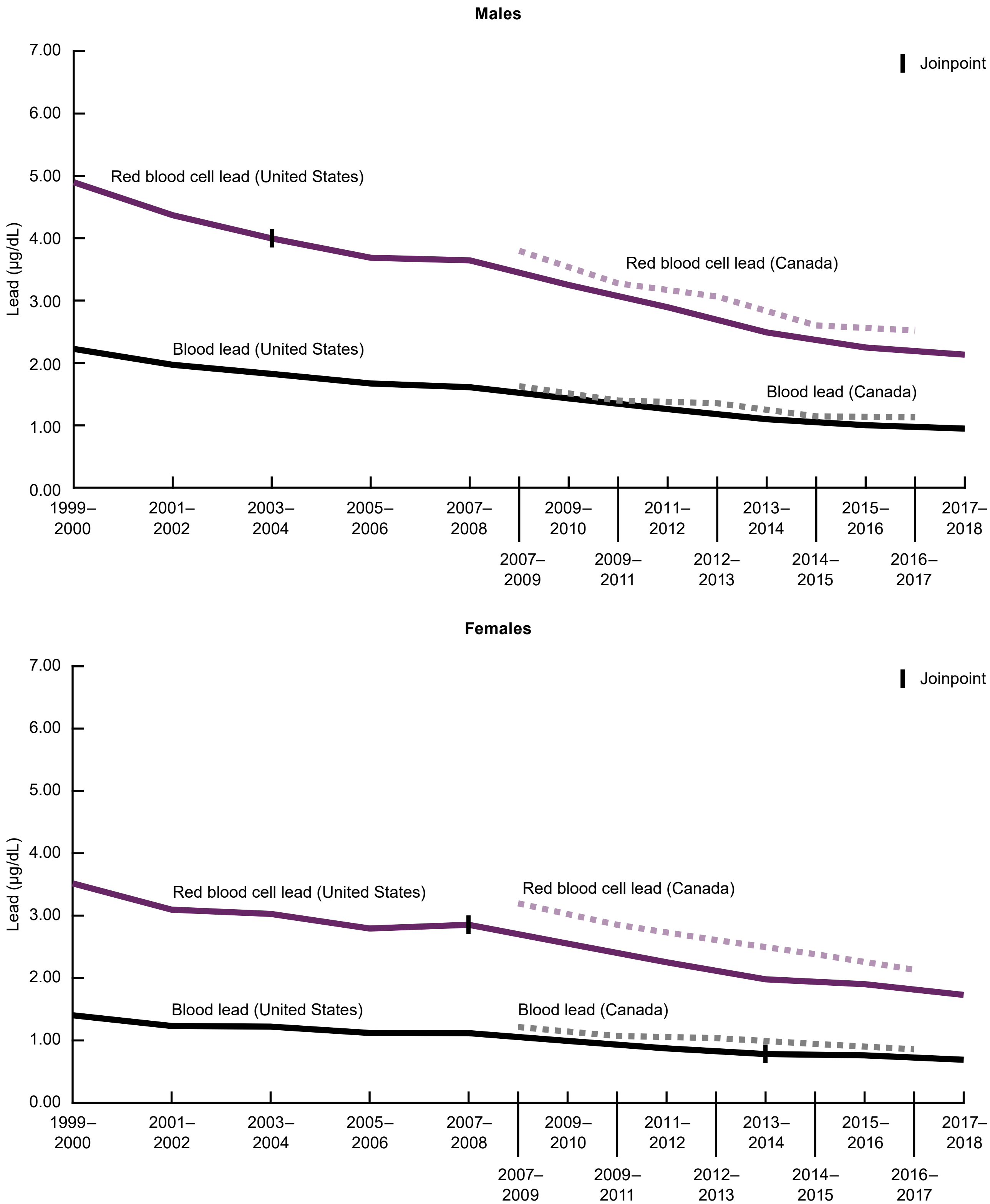
SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2009–2011 through 2016–2017.

Figure 2. Geometric mean blood and red blood cell lead levels in males and females aged 6–19 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2007–2009 through 2016–2017



SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2009 through 2016–2017.

Figure 3. Geometric mean blood and red blood cell lead levels in males and females aged 20–79 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2007–2009 through 2016–2017



NOTE: Geometric mean is age adjusted by the direct method to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79.
SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2009 through 2016–2017.

60–79, a significant decline in GM RBC lead was seen from 1999–2000 to 2017–2018, with APCs ranging from -6.56% (aged 3–5) to -4.18% (aged 60–79). For men aged 40–59 and 20–79, the trend was more variable, although some APC estimates were unreliable and the differences were not significant.

GM RBC lead for females aged 3–79 decreased from 3.42 µg/dL in 1999–2000 to 1.75 µg/dL in 2013–2014 (APC = -4.52%) and again to 1.52 µg/dL in 2017–2018 (APC = -4.86%). Among females aged 3–5 and 20–39, from 1999–2000 to 2017–2018 a significant decline in GM RBC lead was seen (from 6.15 µg/dL to 1.61 µg/dL, APC = -6.99% and 2.79 µg/dL to 1.25 µg/dL, APC = -4.35%). In other female age groups (6–19, 40–59, 60–79, and 20–79), quadratic time trends were seen, with variable APCs by age group (some APCs were unreliable).

Canada

RBC lead measurements were available for 26,771 participants. Table IV shows sample sizes by sex-age subgroup and survey years. Estimates of GM RBC lead are presented in Table 7 and Figures 1–3, and trends are presented in Table 8. The GM RBC lead for the total population aged 3–79 decreased from 2.70 µg/dL in 2009–2011 to 2.00 µg/dL in 2016–2017 (APC = -5.09%). The observed patterns for sex and age differences generally were similar to the blood lead counterparts for the United States and Canada as well as for the RBC lead counterparts for the United States.

The GM RBC lead for males aged 3–79 decreased from 2.90 µg/dL in 2009–2011 to 2.17 µg/dL in 2016–2017 (APC = -5.03%). A significant decline in GM blood lead was seen over time, with APCs ranging from -7.34% (aged 3–5, unreliable) to -4.80% (aged 20–39). Similar to blood lead, those aged 6–19 and 60–79 consistently had the lowest and highest observed GMs, respectively, within a given CHMS cycle. GM blood lead for those aged 6–19 decreased from 2.17 µg/dL in 2007–2009 to 1.39 µg/dL in 2016–2017 (APC = -5.63%). The corresponding change for those aged 60–79 was from 5.34 µg/dL to 3.33 µg/dL (APC = -5.95%).

The GM RBC lead for females aged 3–79 decreased from 2.52 µg/dL in 2009–2011 to 1.83 µg/dL in 2016–2017 (APC = -5.16%). A significant decline in GM blood lead was seen over time, with APCs ranging from -7.74% (aged 3–5) to -4.29% (aged 20–39). Similar to males, those aged 6–19 and 60–79 consistently had the lowest and highest observed blood lead GMs, respectively, within a given CHMS cycle. GM blood lead for those aged 6–19 decreased from 1.96 µg/dL in 2007–2009 to 1.16 µg/dL in 2016–2017 (APC = -6.26%). For those aged 60–79, the corresponding change was from 4.75 µg/dL to 3.33 µg/dL (APC = -4.41%).

Blood Cadmium

United States

Blood cadmium measurements were available for 69,457 participants. Table V shows sample sizes by sex-age subgroup and survey years. Estimates of GM blood cadmium from 1999–2000 through 2017–2018 are presented in Table 9 and Figures 4–6, and trends are presented in Table 10. GM blood cadmium for the total population aged 3–79 decreased from 0.41 µg/L in 1999–2000 to 0.27 µg/L in 2003–2004 (APC = -6.43%) and again to 0.22 µg/L in 2017–2018 (APC = -2.09%). Adult men tended to have higher GMs than adult women, and they generally increased with age, which also was observed in a sex-specific manner.

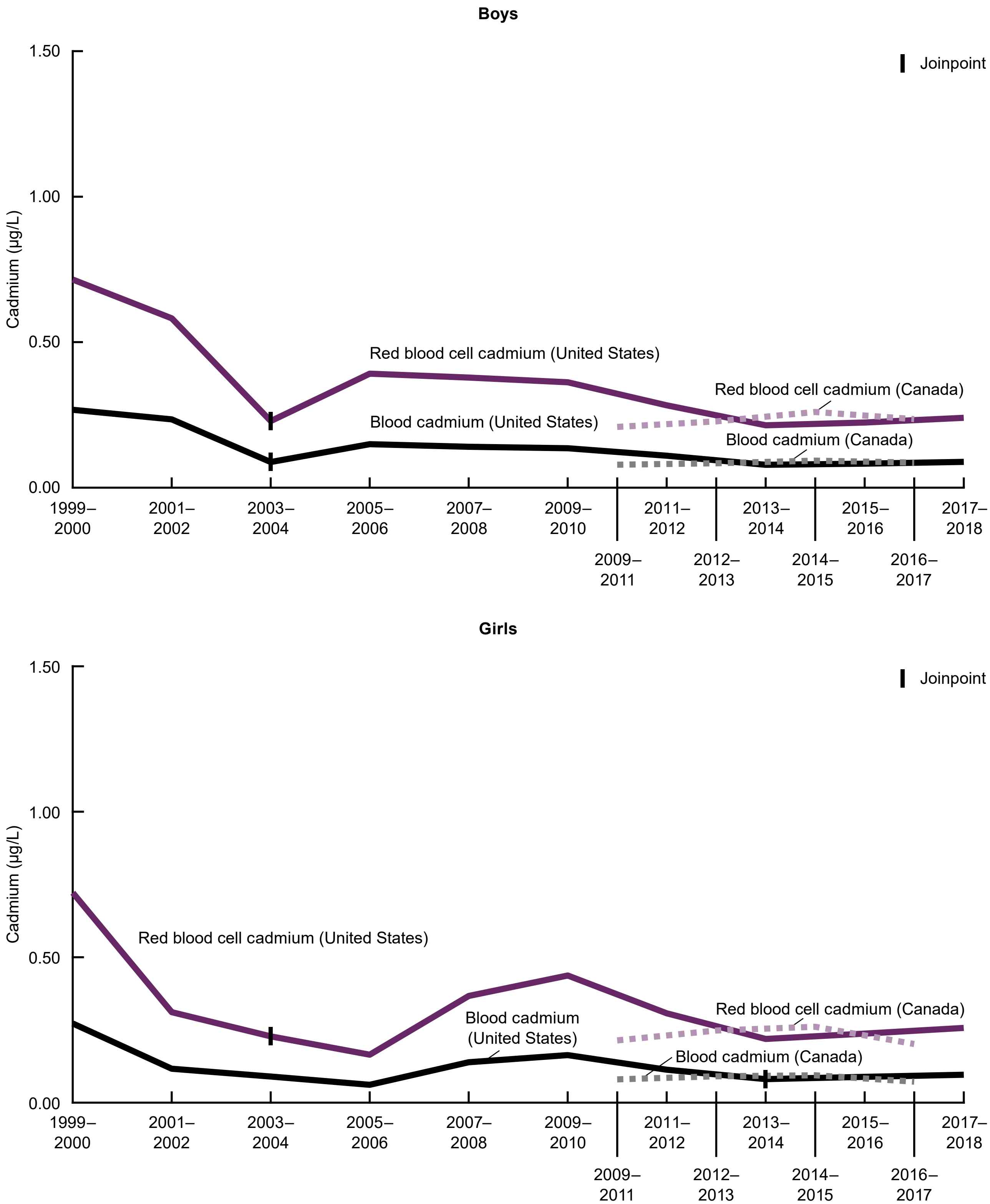
GM blood cadmium for males aged 3–79 decreased from 0.40 µg/L in 1999–2000 to 0.25 µg/L in 2003–2004 (APC = -7.37%) and again to 0.20 µg/L in 2017–2018 (APC = -2.46%). For men aged 40–59, 60–79, and 20–79, a significant decline in GM blood cadmium was seen from 1999–2000 to 2017–2018, with APCs ranging from -2.81% (aged 40–59) to -2.45% (aged 60–79). For males aged 3–79, 3–5, 6–19 and 20–39, decreases in GM blood cadmium were steeper between 1999–2000 and 2003–2004 compared with 2005–2006 through 2017–2018, ranging from -16.76% (aged 3–5) to -7.24% (aged 20–39) for the earlier period and from -2.46% (aged 3–79) to -2.21% (aged 3–5) for the later period. Within a given NHANES cycle, those aged 3–5 and 6–19 consistently had the lowest GMs, and those aged 60–79 had the highest. GM blood cadmium for those aged 3–5 (and 6–19) decreased from 0.27 µg/L (0.29 µg/L) in 1999–2000 to 0.09 µg/L (0.11 µg/L) in 2017–2018. The corresponding change for those aged 60–79 was from 0.52 µg/L to 0.32 µg/L.

GM blood cadmium for females aged 3–79 decreased from 0.41 µg/L in 1999–2000 to 0.29 µg/L in 2003–2004 (APC = -5.58%) and again to 0.25 µg/L in 2017–2018 (APC = -1.73%). From 1999–2000 to 2017–2018, among women aged 20–39, 40–59, 60–79, and 20–79, significant declines were seen in GM blood cadmium, with APCs ranging from -2.22% for those aged 60–79 to -1.29% for those aged 40–59. Among females aged 3–5 and 6–19, trends were more variable, although several of the GM values and the APC for the later period did not meet statistical reliability criteria for the youngest group.

Canada

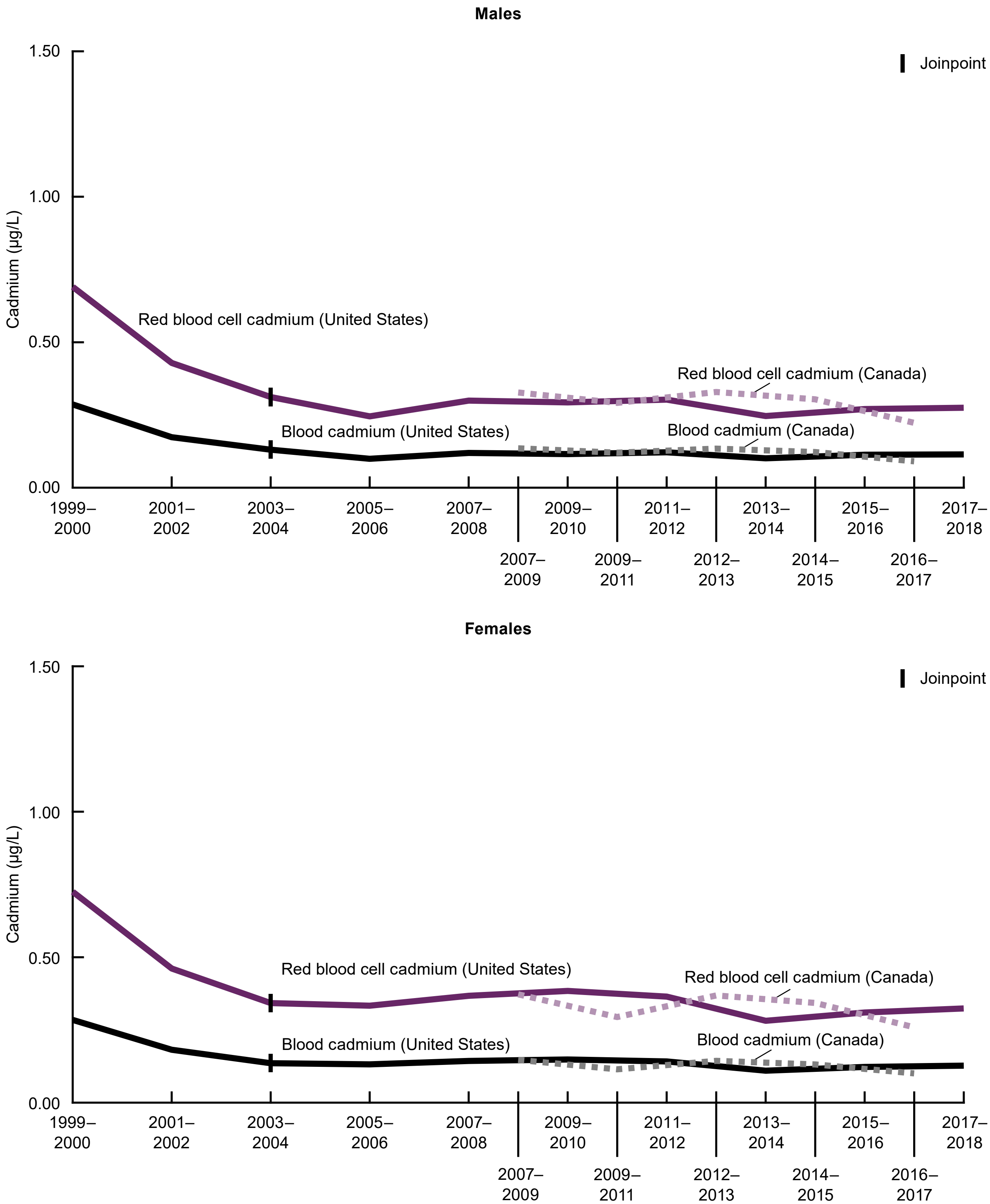
Blood cadmium measurements were available for 26,941 participants. Table VI shows sample sizes by sex-age subgroup and survey years. Estimates of GM blood cadmium are presented in Table 11 and Figures 4–6, and trends are presented in Table 12, which shows that most of the APC estimates did not meet statistical reliability criteria and need to be interpreted with caution. GM for blood cadmium in the total population aged 3–79 decreased from 0.26 µg/L in 2009–2011 to 0.23 µg/L in 2016–2017 (APC = -2.63%).

Figure 4. Geometric mean blood and red blood cell cadmium levels in boys and girls aged 3–5 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2009–2011 through 2016–2017



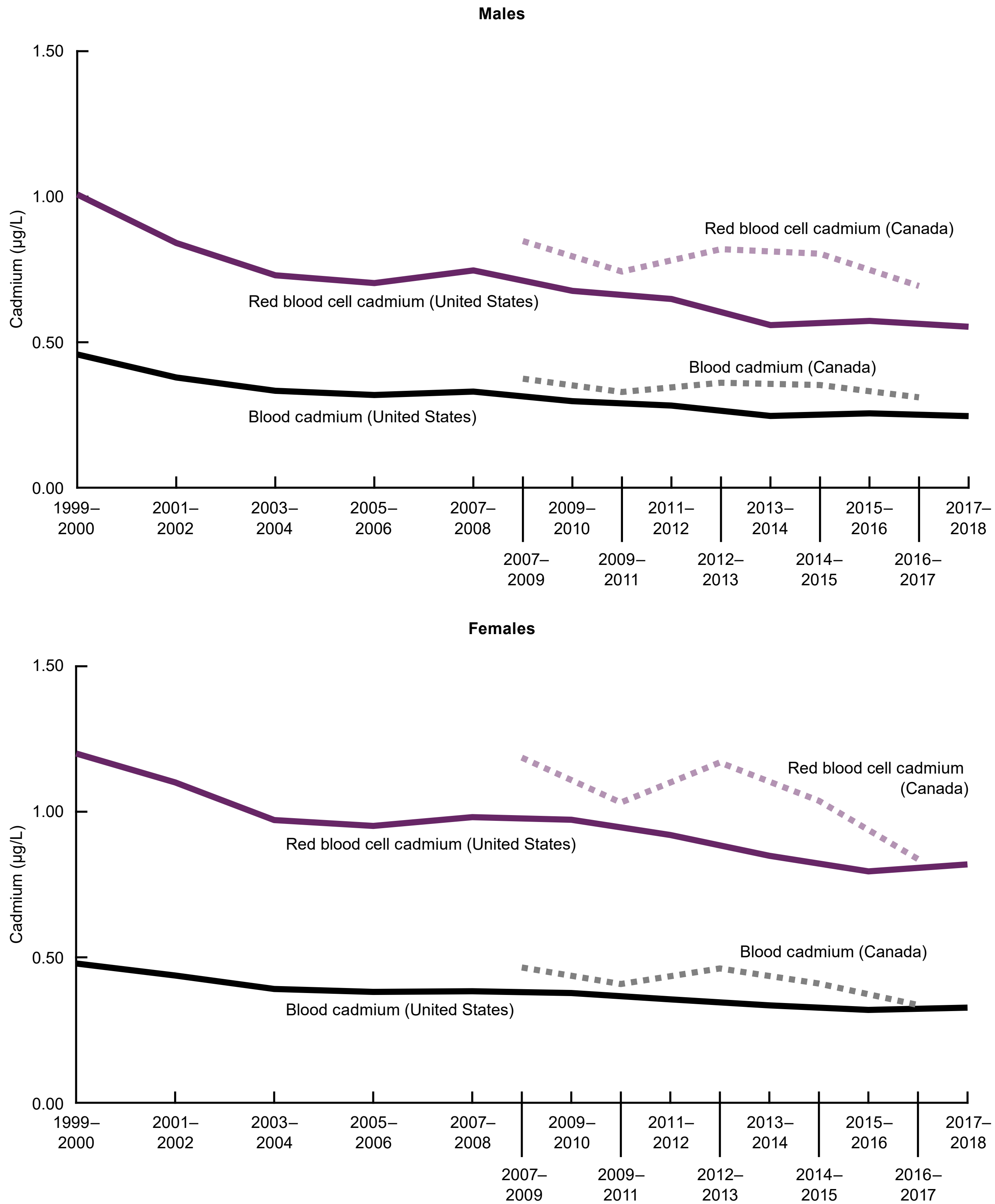
SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2009–2011 through 2016–2017.

Figure 5. Geometric mean blood and red blood cell cadmium levels in males and females aged 6–19 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2007–2009 through 2016–2017



SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2009 through 2016–2017.

Figure 6. Geometric mean blood and red blood cell cadmium levels in males and females aged 20–79 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2007–2009 through 2016–2017



NOTE: Geometric mean is age adjusted by the direct method to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79.
SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2009 through 2016–2017.

The observed patterns for differences by sex and age were generally similar to their counterparts in the United States.

GM blood cadmium for males aged 3–79 decreased from 0.25 µg/L in 2009–2011 to 0.21 µg/L in 2016–2017 (APC = -1.96%). For males aged 6–19, a significant decline in GM blood cadmium was observed from 2007–2009 (0.14 µg/L) to 2016–2017 (0.09 µg/L), with an APC of -3.90%. Quadratic time trends were observed for males aged 3–79, 3–5, and 6–19.

GM blood cadmium for females aged 3–79 decreased from 0.29 µg/L in 2009–2011 to 0.24 µg/L in 2016–2017 (APC = -3.34%, unreliable). Among females aged 3–79, 6–19, 40–59, 60–79, and 20–79, a significant decline in GM blood cadmium was seen over time, with APCs ranging from -4.86% (aged 40–59) to -1.73% (aged 60–79, unreliable). The comparisons of cadmium GMs for the age groups with significant declines showed that, within a given CHMS cycle, those aged 6–19 consistently had the lowest GM blood cadmium estimates, and either those aged 40–59 or 60–79 had the highest. GM blood cadmium for those aged 6–19 decreased from 0.15 µg/L in 2007–2009 to 0.10 µg/L in 2016–2017 (APC = -3.16%, unreliable). The corresponding changes for those aged 40–59 and 60–79 were from 0.58 µg/L to 0.37 µg/L and from 0.50 µg/L to 0.43 µg/L, respectively. Quadratic time trends were observed for females aged 3–79 and 3–5.

RBC Cadmium

United States

RBC cadmium measurements were available for 69,339 participants. Table VII shows sample sizes by sex-age subgroup and survey years. Estimates of GM RBC cadmium are presented in Table 13 and Figures 4–6, and trends are presented in Table 14. GM RBC cadmium for the total population aged 3–79 decreased from 0.97 µg/L in 1999–2000 to 0.65 µg/L in 2003–2004 (APC = -6.24%) and again to 0.53 µg/L in 2017–2018 (APC = -2.02%). The observed patterns for sex and age differences generally were similar to those seen for Canada.

GM RBC cadmium for males aged 3–79 decreased from 0.90 µg/L in 1999–2000 to 0.57 µg/L in 2003–2004 (APC = -7.17%) and again to 0.45 µg/L in 2017–2018 (APC = -2.35%). Similar to blood cadmium, a significant decline in GM RBC cadmium was observed from 1999–2000 to 2017–2018 in men aged 40–59, 60–79, and 20–79, with APCs around -2.5%. For males aged 3–5, 6–19, and 20–39, GM RBC cadmium decreased more steeply from 1999–2000 through 2003–2004, with APCs of -16.94%, -13.28%, and -7.06%, respectively, followed by a more gradual decline through 2017–2018, with APCs near -2%. Within a given NHANES cycle, a consistent pattern was seen that either those aged 3–5 or 6–19 had the lowest RBC cadmium GM estimate and those aged 60–79 had the highest. For those aged 3–5, GM RBC cadmium decreased from 0.72 µg/L in 1999–2000 to 0.23 µg/L in 2003–2004 and then increased slightly to 0.24 µg/L in 2017–2018. For those aged 6–19, the corresponding decrease was from 0.69 µg/L to 0.31 µg/L and then to 0.27 µg/L. For those aged 60–79, GM RBC cadmium decreased from 1.18 µg/L in 1999–2000 to 0.74 µg/L in 2017–2018, with an APC of -2.37%.

GM RBC cadmium for females aged 3–79 decreased from 1.05 µg/L in 1999–2000 to 0.62 µg/L in 2017–2018 (APC = -1.94%). RBC cadmium GM estimates for girls aged 3–5 in 2001–2002 and 2005–2006 did not meet statistical reliability criteria. From 1999–2000 to 2017–2018, a significant decline in GM RBC cadmium was observed in most female age groups (3–79, 20–39, 40–59, 60–79, and 20–79), with APCs ranging from -2.22% (aged 60–79) to -1.25% (aged 40–59). In females aged 3–5 and 6–19, a steeper decline (APCs of -16.24% and -11.49%) was seen in the period until 2003–2004 compared with the period afterward (APCs of -2.03% and -2.19%). GM RBC cadmium for those aged 3–5 changed from 0.72 µg/L in 1999–2000 to 0.23 µg/L in 2003–2004 and then to 0.26 µg/L in 2017–2018.

Canada

RBC cadmium measurements were available for 26,770 participants. Table VIII shows sample sizes by sex-age subgroup and survey years. Estimates of GM RBC cadmium are presented in Table 15 and Figures 4–6. Trends are presented in Table 16, which shows that most of the APC estimates did not meet statistical reliability criteria and need to be interpreted with caution. GMs for RBC cadmium in the total population aged 3–79 decreased from 0.64 µg/L in 2009–2011 to 0.55 µg/L in 2016–2017 (APC = -2.69%, unreliable).

GM RBC cadmium for males aged 3–79 decreased from 0.57 µg/L in 2009–2011 to 0.49 µg/L in 2016–2017 (APC = -1.98%, unreliable). Similar to blood cadmium, a significant decline in GM RBC cadmium was observed from 2007–2009 (0.33 µg/L) to 2016–2017 (0.22 µg/L) in males aged 6–19, with an APC of -3.62%. Quadratic time trends were observed for males aged 3–79, 3–5, 6–19, and 60–79.

GM RBC cadmium for females aged 3–79 decreased from 0.73 µg/L in 2009–2011 to 0.60 µg/L in 2016–2017 (APC = -3.44%). Similar to blood cadmium, a significant decline over time for GM RBC cadmium was seen among females aged 3–79, 6–19, 40–59, 60–79, and 20–79, with APCs ranging from -5.24% (aged 40–59) to -2.07% (aged 60–79). Among these age groups, those aged 6–19 and 40–59 or 60–79 had the lowest and highest GMs, respectively, within a given CHMS cycle. GM RBC cadmium for those aged 6–19 decreased from 0.37 µg/L in 2007–2009 to 0.26 µg/L in 2016–2017 (APC = -2.95%, unreliable). For those aged 60–79, the corresponding decrease was from 1.24 µg/L to 1.06 µg/L (APC = -2.07%, unreliable). Quadratic time trends were observed for the combined age groups 3–5, 3–79, and 20–79, but not for most of the narrower age groups (6–19, 20–39, 40–59, and 60–79).

Blood Mercury

United States

Blood mercury measurements were available for 54,833 participants. Table IX shows sample sizes by sex-age subgroup and survey years. Because targeted sex-age subgroups changed across survey cycles, blood mercury measurements are available for 2003–2018 for most sex-age combinations except for the total population aged 3–5, boys aged 3–5, and females aged 3–5 and 20–39, for which 1999–2018 is covered. Estimates of GM blood mercury from 1999–2000 through 2017–2018 are presented in Table 17 and Figures 7–9, and trends are presented in Table 18. GM blood mercury for the total population aged 3–79 decreased from 0.80 µg/L in 2003–2004 to 0.56 µg/L in 2017–2018 (APC = -2.79%). No consistent pattern of difference in blood mercury by sex was observed for the total population, although men tended to have higher GM blood mercury than women in the older age groups. GM blood mercury generally increased with increasing age in the total population, and the same was seen for the sex-specific results, with decreases from age 40–59 to age 60–79 observed for some survey cycles.

GM blood mercury for males aged 3–79 decreased from 0.82 µg/L in 2003–2004 to 0.58 µg/L in 2017–2018 (APC = -2.88%). For males aged 6–19, 20–39, and 40–59, a significant decline was seen in GM blood mercury over this time frame, with APCs ranging from -3.43% (aged 20–39) to -2.80% (aged 40–59). For boys aged 3–5, a nonsignificant increase in GM blood mercury was seen until 2005–2006; however, a significant decline was observed between 2005–2006 (0.36 µg/L) and 2017–2018 (0.22 µg/L) (APC = -3.42%). For men aged 60–79, a nonsignificant increase was seen between 2003–2004 (1.01 µg/L) and 2009–2010 (1.34 µg/L); this was followed by a significant decrease through 2017–2018 (0.90 µg/L) (APC = -4.22%).

GM blood mercury for females aged 3–79 decreased from 0.78 µg/L in 2003–2004 to 0.55 µg/L in 2017–2018 (APC = -2.71%). A significant decline in GM blood mercury was seen between 1999–2000 (0.38 µg/L) and 2017–2018 (0.21 µg/L) for those aged 3–5. For those aged 6–19, 60–79, and 20–79, significant declines were observed between 2003–2004 and 2017–2018, with APCs ranging from -4.81% (aged 3–5) to -1.51% (aged 60–79, unreliable). Among women aged 40–59, GM blood mercury did not change significantly between 2003–2004 (1.02 µg/L) and 2009–2010 (1.13 µg/L); this was followed by a steeper, significant decline through 2017–2018 (0.75 µg/L) (APC = -3.94%).

Canada

Blood mercury measurements were available for 26,913 participants. Table X shows sample sizes by sex-age subgroup and survey years. Estimates of GM blood mercury are presented in Table 19 and Figures 7–9, and trends are presented in Table 20, which shows that none of the APC estimates met statistical reliability criteria and need to be interpreted with caution. GM blood mercury for the total population aged 3–79 did not show a significant decrease, with values of 0.63 µg/L in 2009–2011 and 0.56 µg/L in 2016–2017. The observed patterns of difference by sex and age were similar to those seen for the United States.

GM blood mercury for males aged 3–79 did not show a statistically significant decrease, with values of 0.65 µg/L in 2009–2011 and 0.56 µg/L in 2016–2017. For men aged 40–59, 60–79, and 20–79, a significant (although unreliable) decline in GM blood mercury was seen from 2007–2009 to 2016–2017, with APCs ranging from -3.90% (aged 40–59) to -3.27% (aged 20–79). GM blood mercury for those aged 20–79 decreased from 0.84 µg/L in 2007–2009 to 0.70 µg/L in 2016–2017. For those aged 40–59, which was the group with the highest blood mercury GM within each of four out of the five CHMS cycles, GM blood mercury decreased from 1.05 µg/L in 2007–2009 to 0.86 µg/L in 2016–2017.

GM blood mercury for females aged 3–79 also did not show a significant decrease, with values of 0.61 µg/L in 2009–2011 and 0.56 µg/L in 2016–2017. Except for a quadratic time trend observed for women aged 60–79, no other significant trends were seen in any female age groups.

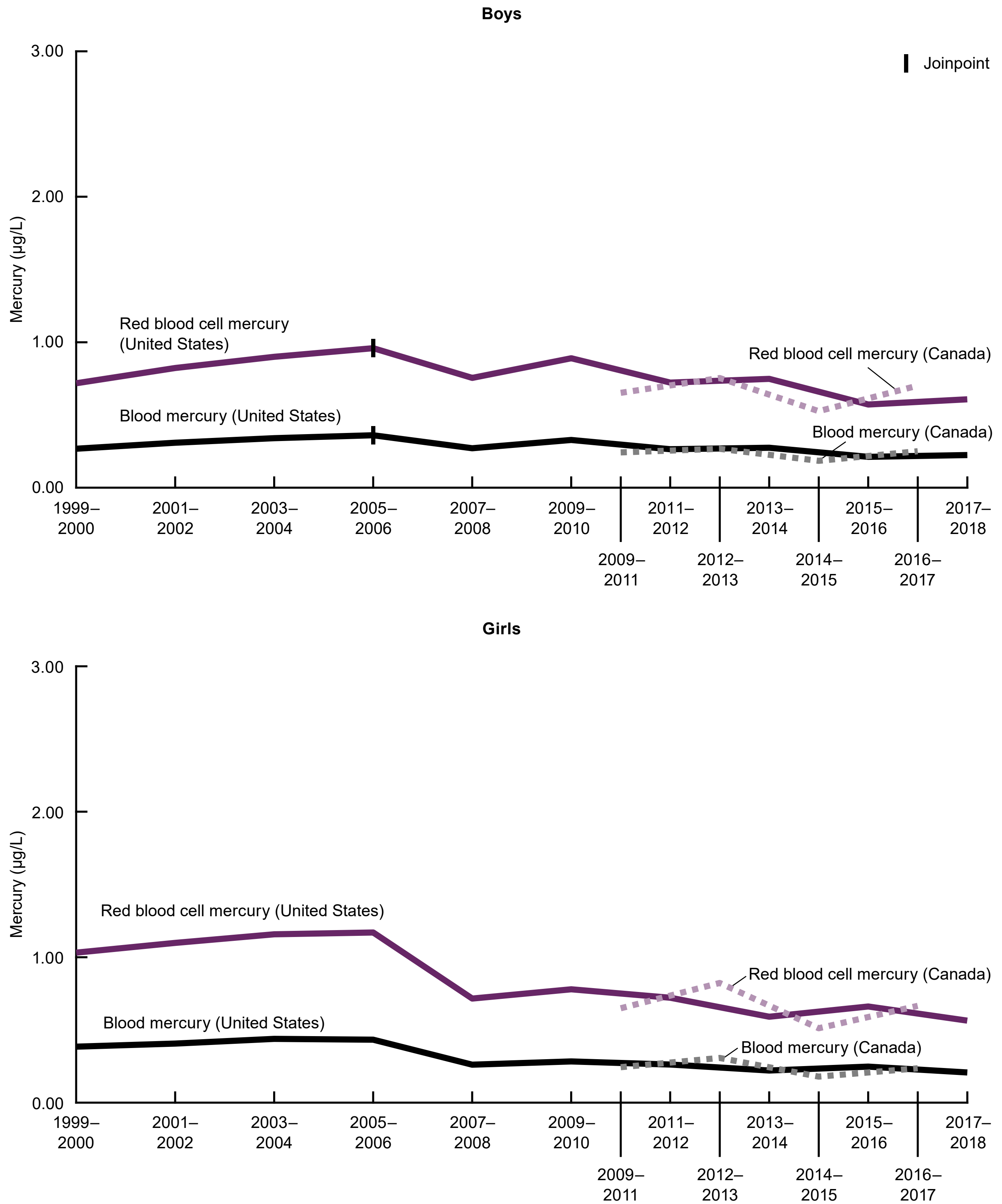
RBC Mercury

United States

RBC mercury measurements were available for 54,720 participants. Table XI shows sample sizes by sex-age subgroup and survey years. Because sex-age subgroups targeted for blood mercury measurements, which were used for deriving RBC mercury, changed across survey cycles, RBC mercury data are available for 2003–2018 for most sex-age combinations except for the total population aged 3–5, boys aged 3–5, girls aged 3–5, and women aged 20–39, for which 1999–2018 is covered. Estimates of GM RBC mercury are presented in Table 21 and Figures 7–9, and trends are presented in Table 22. GM RBC mercury for the total population aged 3–79 decreased from 1.89 µg/L in 2003–2004 to 1.36 µg/L in 2017–2018 (APC = -2.70%). The observed patterns for sex and age differences generally were similar to the corresponding blood mercury patterns for the United States and Canada.

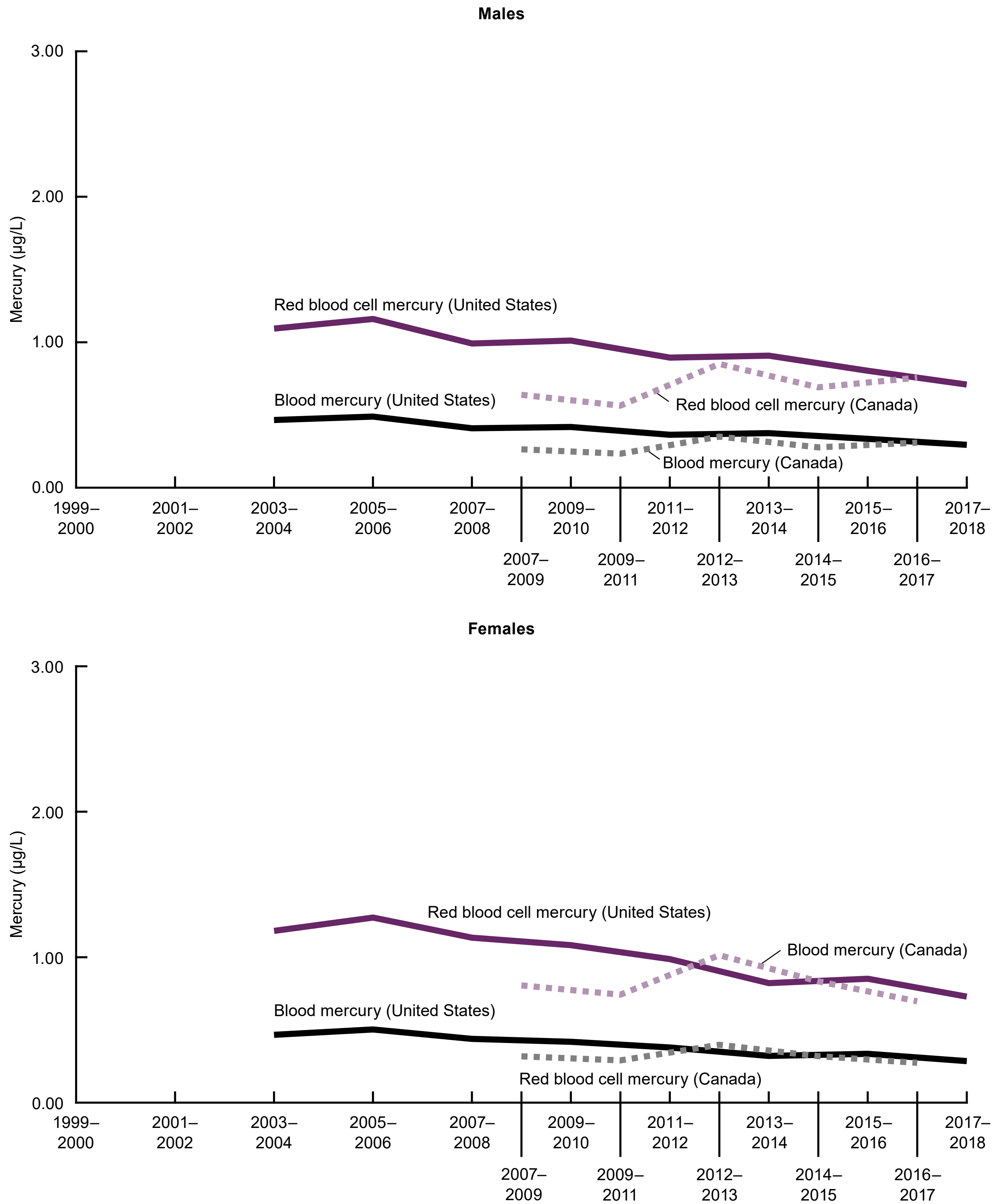
GM RBC mercury for males aged 3–79 decreased from 1.85 µg/L in 2003–2004 to 1.33 µg/L in 2017–2018 (APC = -2.75%). Similarly, in males aged 6–19, 20–39, 40–59, and 20–79, statistically significant declines were seen, with APCs ranging from -3.31% (aged 20–39) to -2.67% (aged 40–59). Among these four age groups, those aged 6–19 and 40–59 or 60–79 had the lowest and highest mercury GMs, respectively, within a given NHANES cycle. RBC mercury GMs for those aged 6–19 decreased from 1.09 µg/L in 2003–2004 to 0.71 µg/L in 2017–2018. For those aged 40–59, the corresponding change was from 2.54 µg/L to 1.92 µg/L. As with blood mercury, for boys aged 3–5 (1999–2018) and men aged

Figure 7. Geometric mean blood and red blood cell mercury levels in boys and girls aged 3–5 years, by survey cycle: United States, 1999–2000 through 2017–2018 and Canada, 2009–2011 through 2016–2017



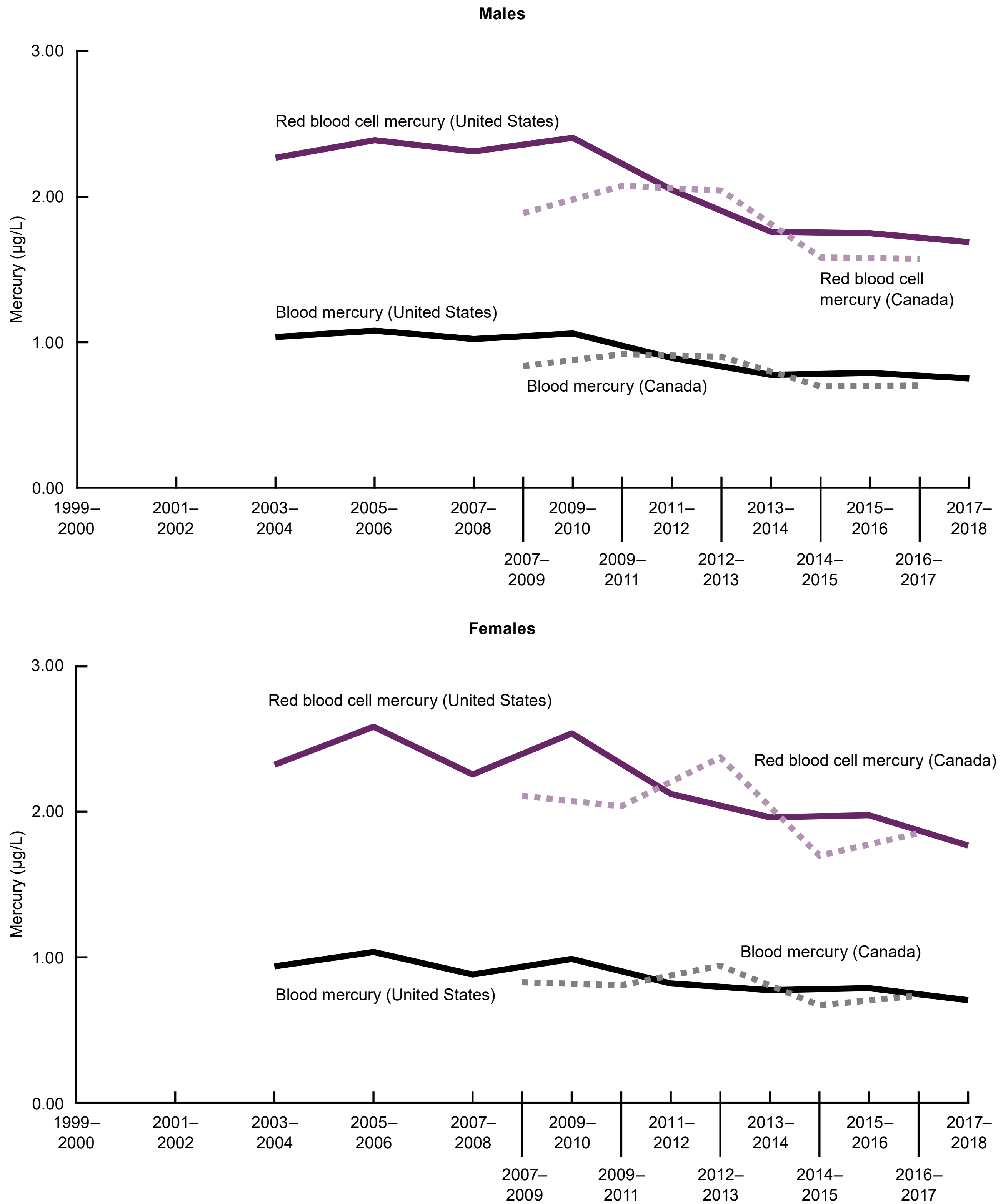
SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2000 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2009–2011 through 2016–2017.

Figure 8. Geometric mean blood and red blood cell mercury levels in males and females aged 6–19 years, by survey cycle: United States, 2003–2004 through 2017–2018 and Canada, 2007–2009 through 2016–2017



SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 2003–2004 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2009 through 2016–2017.

Figure 9. Geometric mean blood and red blood cell mercury levels in males and females aged 20–79 years, by survey cycle: United States, 2003–2004 through 2017–2018 and Canada, 2007–2009 through 2016–2017



NOTE: Geometric mean is age adjusted by the direct method to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79.
SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 2003–2004 through 2017–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2009 through 2016–2017.

60–79 (2003–2018), nonsignificant increases were observed through 2005–2006 (0.72 µg/L to 0.96 µg/L) and 2009–2010 (2.29 µg/L to 3.14 µg/L), respectively. These nonsignificant increases were followed by significant declines through 2017–2018, down to 0.61 µg/L (APC = -3.30%) and 2.07 µg/L (APC = -4.51%), respectively.

GM RBC mercury for females aged 3–79 decreased from 1.94 µg/L in 2003–2004 to 1.39 µg/L in 2017–2018 (APC = -2.67%). Similar to blood mercury, except for those aged 40–59, a significant decline in GM RBC mercury was seen over the entire period for the survey years for which RBC mercury data were available (see "Survey years" in Table 22). For the female age groups with significant declines, initial values for the earliest NHANES cycle ranged from 1.03 µg/L (aged 3–5, 1999–2000) to 2.48 µg/L (aged 20–39, 2003–2004); final values for 2017–2018 ranged from 0.56 µg/L (aged 3–5) to 2.05 µg/L (aged 60–79); APCs ranged from -4.78% (aged 3–5) to -1.53% (aged 60–79, unreliable). For women aged 40–59, no significant change was seen from 2003–2004 through 2009–2010 (2.52 µg/L to 2.89 µg/L), followed by a significant decline through 2017–2018 (1.88 µg/L) (APC = -4.31%).

Canada

RBC mercury measurements were available for 26,742 participants. Table XII shows sample sizes by sex-age subgroup and survey years. Estimates of RBC mercury GMs are presented in Table 23 and Figures 7–9. Trends are presented in Table 24, which shows that none of the APC estimates met statistical reliability criteria and need to be interpreted with caution. GM RBC mercury for the total population aged 3–79 did not show a significant decrease, with estimated values of 1.53 µg/L in 2009–2011 and 1.36 µg/L in 2016–2017. The observed patterns for sex and age differences generally were similar to the blood mercury counterparts for the United States and Canada as well as for their RBC mercury counterparts for the United States.

GM RBC mercury for males aged 3–79 also did not show a significant decrease, with estimated values of 1.49 µg/L in 2009–2011 and 1.30 µg/L in 2016–2017. Similar to blood mercury, in men aged 40–59, 60–79, and 20–79, a significant (although unreliable) decline was observed in GM RBC mercury from 2007–2009 (2.39 µg/L, 2.25 µg/L, and 1.89 µg/L) to 2016–2017 (1.93 µg/L, 1.88 µg/L, and 1.57 µg/L), with APCs of -4.02%, -3.43% and -3.29%, respectively.

As with males, no significant decline in GM RBC mercury was observed for females aged 3–79, with estimated values of 1.56 µg/L in 2009–2011 and 1.42 µg/L in 2016–2017. Except for a quadratic time trend among women aged 60–79, no other statistically significant trends were seen.

United States–Canada Comparison

The GMs for six sex-age subgroups (males aged 3–5, 6–19, and 20–79, and females aged 3–5, 6–19, and 20–79) are plotted separately for lead, cadmium, and mercury (Figures 1–9). Consistent with the time trend results presented previously, lead and cadmium measured either in whole blood or RBC in most sex-age subgroups declined over time in both countries. For mercury, the patterns are less consistent between the two countries and among sex-age subgroups.

For males and females aged 3–79, no significant differences between the United States and Canada were seen for annual relative change of any of blood or RBC metals (Table 25). Annual relative change ratios for comparable years were close to 1 (range from 0.98 to 1.01), indicating very small APC differences between the two countries.

The sensitivity analysis, in which the U.S. survey years were restricted to 2009–2018, yielded the results materially unchanged, with the statistically nonsignificant annual relative change ratios ranging from 0.99 to 1.01 (not shown in tabular form).

Discussion

GM blood and RBC concentrations of lead and cadmium declined among people aged 3–79 years in the United States (1999–2018) and Canada (2007–2017). In the United States, blood and RBC mercury also declined between 2003 and 2018 (or 1999–2018 for some sex-age subgroups with data available for more years). Declining trends for blood mercury were limited to a few age subgroups in Canada (2007–2017). For the United States, a higher rate of decline in blood and RBC lead and a lower rate of decline of cadmium were seen in the more recent survey cycles compared with earlier survey cycles. Still, the rates of decline in the concentrations of all three metals were similar in the two countries among both males and females aged 3–79. The decreasing time trends observed in the current analysis for lead and cadmium and the absence of a trend for mercury in the Canadian population aged 3–79 between 2009–2017 are consistent with findings from a previous assessment of trends for the total population aged 6–79 based on data from CHMS 2007–2017 (17).

Previous studies have reported associations between sex, age, and other factors and levels of lead, cadmium, and mercury measured in blood. For instance, in the United States and Canada, blood lead has been shown to decrease with age among youth (29,40,41) but increase with age among adults (27–29). In the United States, there is little sex difference in blood lead levels among youth (40,41), while adult men in both the United States and Canada have higher GM blood lead than adult women (27–29). Being a smoker (27–29) and living in an older home (29,42,43) are associated with higher GM blood lead. Previous studies in the United States and Canadian populations showed that blood cadmium tends to increase with age and is higher among smokers (44,45). The patterns observed in this study both for the United States and Canada related to age and sex are largely consistent with the previously reported results described above, although no formal comparison across sex-age subgroups was performed in this study. In addition, intake of seafood and use of dental amalgam have been associated with higher blood mercury levels in the United States and Canada (15,16,46,47).

Various regulatory measures for reducing exposure to lead, cadmium, and mercury have been implemented in the United States and Canada (2,4–7). In the United States, leaded gasoline began to be phased out in the 1970s, and lead-based paint for consumer use and lead-containing pipes and other products in plumbing systems were banned in 1978 and 1986, respectively (48). Other lead-related measures also were implemented in the United States (2). Key regulatory interventions to reduce exposure to lead in Canada include restrictions on lead content in paints starting in 1976, prohibition of lead in new water service lines in 1975 and in solder used for water pipes in 1990, discontinued use of solder in food cans in the early 1980s, and the reduction of lead content in gasoline, which began in the 1970s and was later managed under the Gasoline Regulations in 1990; these were complemented by various other measures involving reduction in releases of lead from manufacturing sectors such as base metals smelting and steel production, and setting of limits on lead content in consumer products, foods, and drugs (7). Similarly, risk management measures aimed at reducing cadmium content in consumer products, children's jewelry, cosmetics, and drinking water and at industrial releases from the mining and energy sectors have been implemented (49,50). While cadmium in foods may constitute the primary source of exposure to cadmium among the nonsmoking population, it does not represent a health concern (50). However, a recent analysis of CHMS data showed that smoking was the largest contributor to cadmium levels among all Canadians aged 20–79 (45). It is known that lead and cadmium are common contaminants in tobacco products (2,4). Accordingly, measures undertaken in both countries, aimed at reducing smoking, for example, through cigarette taxes and labeling regulations for tobacco products (51,52), have led to decreases in the prevalence of smoking, which in turn may contribute to declines in lead and cadmium levels. For mercury exposure, both the United States and Canadian governments have instituted national and local seafood consumption advisories about limiting consumption of fish containing elevated levels of mercury (53–55). Additional risk management measures instituted in Canada include those targeting human exposure through consumer and therapeutic products, drinking water, air, and other environmental media (6). Mercury originating from foreign emission sources remains a major source of mercury deposited into Canada (6).

Previous studies documented substantial declines in blood lead concentrations in the United States and Canada following the phaseout of leaded gasoline in the years preceding the period covered in this study (29,56). The decline in GM blood and RBC lead observed among adults in this study may be related to the ongoing effects of the leaded gasoline phaseout as well as the other aforementioned risk reduction efforts related to lead that have been undertaken over the past decades. In each newer survey cycle, older individuals who had higher exposures to lead before the leaded gasoline phaseout were replaced with younger individuals from more recent birth cohorts who had lower or no exposure to lead from gasoline. The shift in birth cohorts over survey cycles can manifest in the observed decline in blood and RBC lead because the lead absorbed in the distant past has been stored in bones and is released to the blood many years later (2); as a result, blood lead levels reflect exposure experienced long ago. Other regulatory measures such as prohibition of lead in paints and plumbing materials (2) may also have had similar long-lasting influences on blood and RBC lead.

Regulatory measures also could have resulted in declining GM blood and RBC metals more directly through reduction in concurrent exposure. For example, tobacco control policies have contributed to a decrease in active and passive smoking (51), which in turn would have contributed to the decreasing trend in biomarkers of exposure (lead and cadmium). Similarly, mercury-related seafood consumption advisories (53–55) and measures targeting consumer and therapeutic products, drinking water, air, and other environmental media (6) may limit exposure to mercury.

In this study, whole blood concentrations with and without adjustment for hematocrit were used to evaluate time trends. Whole blood concentrations of metal without adjustment for hematocrit (termed blood metal in this report) have been widely used as exposure biomarkers. However, as a biomarker for assessing time trends in metal exposure, RBC metal may arguably be better than blood metal because blood metal can vary as a result of a change in hematocrit, which may be caused by changes in exposure to lead, cadmium, and mercury (25,57,58) or other unrelated factors (for example, iron deficiency [59]) that may have their own time trends. Unlike for RBC metal, time trends for blood metal may be attenuated compared with the underlying trend for metal exposure because, at the population level, a decrease in exposure to lead, cadmium, and mercury would result in a decrease in anemia, leading to an increase in hematocrit, which in turn would have an effect of increasing whole blood concentrations of these metals. Recognizing the inherent limitations in blood metal as an exposure biomarker, recent epidemiological studies have successfully used RBC metal as an exposure biomarker (13,60).

A major strength of this study is the use of the longest continuous and nationally representative data sets, spanning over 2 decades in the United States and a decade in Canada to evaluate time trends. These large, nationally representative data sets, along with consistent laboratory methods, provide for a robust assessment.

A limitation of this study is that an assessment of joinpoints was not performed for the Canadian data due to a limited number of time points. Such an analysis will become feasible in the future when data from more survey cycles become available. While some potential contributing factors to the observed time trends for both the United States and Canada are discussed, further analysis of differences between both countries are beyond the scope of this work and will require consideration of other factors such as survey and analytical methodological differences (61,62). Specifically, analyses by race and ethnicity are of interest but could not be done because NHANES and CHMS included no comparable race and ethnicity variable. Another limitation of the study is that some (although not many, fewer than 1 in 10) estimates of GMs and APCs did not meet statistical reliability criteria.

Unreliable GMs combined with an APC, reliable or unreliable, can result in an apparent contradiction between two time trend indicators in terms of direction and magnitude: the observed GM change from the beginning to the end of a period and the estimated APC for the same period. This may be considered another limitation of this study. An instance of contradictions of this type was seen for RBC blood cadmium among U.S. girls aged 3–5 where the estimated APC for the period between 2003–2004 and 2017–2018 was negative (indicating a decrease for the period), while the GM estimates showed a slight increase for the same time period. Generally speaking, this type of mismatch is possible when GMs fluctuate considerably because of small sample sizes or inherently high variation across survey cycles. In the above-mentioned case, the small sample size of girls aged 3–5 likely contributed to the observed contradiction. Compared with female children aged 3–5, the 6–19 counterpart had a much larger sample size (for example, 245 compared with 1,479 for 2003–2004), with the observed GM decrease between 2003–2004 and 2017–2018 consistent with the negative APC estimated for the same period.

This report shows the general similarities in time trends for lead, cadmium, and mercury in the United States and Canada. While the concentrations in the general population significantly declined over time for lead and cadmium in both countries and mercury in the United States, the declines in mercury in Canada were limited to certain age-sex subgroups. Continued biomonitoring of lead, cadmium, and mercury, as well as other chemicals of concern to human health, will inform the tracking of effectiveness of ongoing and new regulatory interventions aimed at reducing exposures to determine specific contributions of several sociodemographic, environmental, and behavioral determinants of exposures to observed levels, and to relate chemical exposures to burden of disease.

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Table 1. Geometric mean for blood lead levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total	Geometric mean[1] (standard error)									
3–79[2]	1.65 (0.03)	1.42 (0.03)	1.38 (0.03)	1.24 (0.03)	1.22 (0.03)	1.07 (0.02)	0.92 (0.03)	0.81 (0.02)	0.76 (0.02)	0.69 (0.01)
3–5	2.12 (0.15)	1.56 (0.07)	1.63 (0.09)	1.35 (0.06)	1.38 (0.08)	1.10 (0.05)	0.91 (0.06)	0.74 (0.04)	0.68 (0.04)	0.60 (0.03)
6–19	1.27 (0.03)	1.05 (0.03)	1.06 (0.04)	0.88 (0.02)	0.87 (0.03)	0.74 (0.02)	0.60 (0.02)	0.53 (0.02)	0.50 (0.02)	0.43 (0.01)
20–39	1.42 (0.04)	1.21 (0.04)	1.18 (0.04)	1.01 (0.02)	1.04 (0.03)	0.90 (0.02)	0.75 (0.02)	0.69 (0.02)	0.65 (0.02)	0.62 (0.02)
40–59	1.91 (0.05)	1.75 (0.03)	1.65 (0.06)	1.53 (0.04)	1.50 (0.04)	1.36 (0.04)	1.23 -0.05	1.04 (0.03)	0.99 (0.03)	0.89 (0.03)
60–79	2.33 (0.06)	2.05 (0.05)	1.98 (0.06)	2.02 (0.07)	1.79 (0.06)	1.63 (0.04)	1.52 (0.05)	1.35 (0.05)	1.26 (0.04)	1.17 (0.02)
20–79[3]	1.76 (0.03)	1.55 (0.03)	1.49 (0.04)	1.36 (0.03)	1.34 (0.04)	1.19 (0.02)	1.04 (0.03)	0.92 (0.02)	0.87 (0.03)	0.81 (0.02)
Male										
3–79[2]	2.02 (0.04)	1.76 (0.04)	1.65 (0.03)	1.47 (0.04)	1.43 (0.04)	1.26 (0.02)	1.08 (0.04)	0.95 (0.03)	0.87 (0.03)	0.81 (0.02)
3–5	1.98 (0.18)	1.66 (0.11)	1.62 (0.10)	1.36 (0.09)	1.42 (0.09)	1.12 (0.08)	0.98 (0.10)	0.78 (0.04)	0.69 (0.04)	0.61 (0.04)
6–19	1.46 (0.05)	1.23 (0.03)	1.18 (0.05)	0.98 (0.03)	0.96 (0.04)	0.83 (0.03)	0.67 (0.02)	0.62 (0.03)	0.57 (0.02)	0.49 (0.01)
20–39	1.83 (0.05)	1.58 (0.04)	1.50 (0.04)	1.32 (0.05)	1.33 (0.04)	1.14 (0.03)	0.96 (0.04)	0.86 (0.04)	0.79 (0.03)	0.77 (0.02)
40–59	2.45 (0.10)	2.20 (0.05)	1.99 (0.06)	1.87 (0.07)	1.76 (0.06)	1.61 (0.05)	1.42 (0.07)	1.22 (0.06)	1.11 (0.05)	1.00 (0.04)
60–79	2.81 (0.07)	2.52 (0.07)	2.35 (0.06)	2.21 (0.07)	2.05 (0.06)	1.84 (0.05)	1.77 (0.06)	1.50 (0.10)	1.36 (0.08)	1.33 (0.04)
20–79[3]	2.23 (0.04)	1.97 (0.04)	1.83 (0.04)	1.67 (0.05)	1.61 (0.05)	1.43 (0.03)	1.26 (0.04)	1.10 (0.04)	1.00 (0.03)	0.95 (0.03)
Female										
3–79[2]	1.36 (0.03)	1.16 (0.02)	1.17 (0.04)	1.05 (0.03)	1.04 (0.02)	0.91 (0.02)	0.78 (0.02)	0.69 (0.01)	0.67 (0.02)	0.60 (0.01)
3–5	2.29 (0.19)	1.46 (0.06)	1.63 (0.13)	1.35 (0.06)	1.33 (0.09)	1.09 (0.05)	0.83 (0.03)	0.71 (0.05)	0.68 (0.05)	0.60 (0.03)
6–19	1.09 (0.03)	0.90 (0.03)	0.94 (0.04)	0.79 (0.02)	0.78 (0.02)	0.65 (0.02)	0.54 (0.02)	0.44 (0.02)	0.44 (0.02)	0.38 (0.01)
20–39	1.10 (0.04)	0.94 (0.04)	0.93 (0.04)	0.78 (0.02)	0.82 (0.02)	0.72 (0.01)	0.59 (0.02)	0.56 (0.02)	0.54 (0.02)	0.49 (0.02)
40–59	1.53 (0.04)	1.39 (0.04)	1.38 (0.07)	1.28 (0.04)	1.29 (0.03)	1.15 (0.03)	1.07 (0.03)	0.89 (0.02)	0.88 (0.04)	0.80 (0.03)
60–79	1.99 (0.07)	1.74 (0.07)	1.72 (0.07)	1.87 (0.08)	1.60 (0.07)	1.47 (0.04)	1.32 (0.05)	1.23 (0.04)	1.18 (0.05)	1.06 (0.03)
20–79[3]	1.40 (0.03)	1.23 (0.03)	1.22 (0.04)	1.12 (0.03)	1.12 (0.03)	0.99 (0.02)	0.87 (0.02)	0.78 (0.01)	0.76 (0.03)	0.69 (0.02)

[1]Micrograms per deciliter (µg/dL).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 2. Trends in blood lead levels, by sex and age: United States, 1999–2018

		Overall trend (no quadratic trend detected)			Trends in two time segments (quadratic trend detected)					
						First time segment		Second time segment		
Sex and age (years)	Survey years	Overall annual percent change (standard error)	*p* value	*p* for quadratic trend	Detected joinpoint (survey cycle)	Annual percent change (standard error)	*p* value	Annual percent change (standard error)	*p* value	*p* for annual percent change difference between segments
Total										
3–79[1]	1999–2018	…	…	0.022	2013–2014	-4.93 (0.21)	Less than 0.001	-4.64 (0.63)	Less than 0.001	0.710
3–5	1999–2018	-6.86 (0.32)	Less than 0.001	0.190	…	…	…	…	…	…
6–19	1999–2018	-5.99 (0.18)	Less than 0.001	0.054	…	…	…	…	…	…
20–39	1999–2018	-4.68 (0.16)	Less than 0.001	0.958	…	…	…	…	…	…
40–59	1999–2018	…	…	0.003	2007–2008	-2.68 (0.48)	Less than 0.001	-5.08 (0.30)	Less than 0.001	0.001
60–79	1999–2018	…	…	0.029	2013–2014	-3.86 (0.30)	Less than 0.001	-4.15 (0.77)	Less than 0.001	0.774
20–79[2]	1999–2018	…	…	0.044	2013–2014	-4.44 (0.21)	Less than 0.001	-4.26 (0.68)	Less than 0.001	0.826
Male										
3–79[1]	1999–2018	-5.14 (0.15)	Less than 0.001	0.119	…	…	…	…	…	…
3–5	1999–2018	-6.70 (0.39)	Less than 0.001	0.087	…	…	…	…	…	…
6–19	1999–2018	-5.87 (0.20)	Less than 0.001	0.550	…	…	…	…	…	…
20–39	1999–2018	-4.97 (0.19)	Less than 0.001	0.720	…	…	…	…	…	…
40–59	1999–2018	-4.93 (0.24)	Less than 0.001	0.072	…	…	…	…	…	…
60–79	1999–2018	-4.26 (0.23)	Less than 0.001	0.417	…	…	…	…	…	…
20–79[2]	1999–2018	-4.82 (0.17)	Less than 0.001	0.150	…	…	…	…	…	…
Female										
3–79[1]	1999–2018	…	…	0.011	2013–2014	-4.71 (0.22)	Less than 0.001	-4.24 (0.67)	Less than 0.001	0.554
3–5	1999–2018	-7.01 (0.39)	Less than 0.001	0.832	…	…	…	…	…	…
6–19	1999–2018	…	…	0.003	2013–2014	-6.33 (0.32)	Less than 0.001	-5.18 (0.82)	Less than 0.001	0.276
20–39	1999–2018	-4.38 (0.22)	Less than 0.001	0.919	…	…	…	…	…	…
40–59	1999–2018	…	…	0.003	2007–2008	-1.97 (0.56)	0.001	-4.60 (0.37)	Less than 0.001	0.001
60–79	1999–2018	…	…	0.017	2005–2006	†-0.73 (0.81)	0.373	-4.18 (0.33)	Less than 0.001	0.001
20–79[2]	1999–2018	…	…	0.045	2013–2014	-4.05 (0.23)	Less than 0.001	-3.89 (0.78)	Less than 0.001	0.860

… Category not applicable.
† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 3. Geometric mean for blood lead levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total			Geometric mean[1] (standard error)		
3–79[2]	---	1.07 (0.02)	1.02 (0.02)	0.89 (0.02)	0.83 (0.03)
3–5	---	0.90 (0.03)	0.77 (0.02)	0.67 (0.03)	0.56 (0.06)
6–19	0.81 (0.03)	0.72 (0.01)	0.67 (0.02)	0.56 (0.01)	0.51 (0.02)
20–39	1.09 (0.04)	0.94 (0.05)	0.91 (0.05)	0.80 (0.03)	0.78 (0.04)
40–59	1.54 (0.07)	1.34 (0.04)	1.34 (0.03)	1.15 (0.05)	1.05 (0.05)
60–79	2.03 (0.09)	1.79 (0.04)	1.64 (0.04)	1.46 (0.04)	1.41 (0.04)
20–79[3]	1.41 (0.05)	1.22 (0.04)	1.19 (0.03)	1.04 (0.03)	0.98 (0.04)
Male					
3–79[2]	---	1.21 (0.02)	1.16 (0.02)	0.97 (0.02)	0.94 (0.05)
3–5	---	0.93 (0.04)	0.80 (0.05)	0.70 (0.04)	0.58 (0.08)
6–19	0.87 (0.03)	0.80 (0.02)	0.74 (0.02)	0.60 (0.02)	0.57 (0.03)
20–39	1.36 (0.06)	1.09 (0.05)	1.05 (0.05)	0.94 (0.05)	0.94 (0.06)
40–59	1.67 (0.09)	1.53 (0.04)	1.54 (0.05)	1.23 (0.05)	1.20 (0.08)
60–79	2.26 (0.11)	1.98 (0.06)	1.82 (0.07)	1.52 (0.06)	1.46 (0.06)
20–79[3]	1.63 (0.07)	1.40 (0.04)	1.35 (0.03)	1.14 (0.03)	1.13 (0.06)
Female					
3–79[2]	---	0.95 (0.03)	0.90 (0.03)	0.81 (0.03)	0.73 (0.02)
3–5	---	0.86 (0.03)	0.74 (0.03)	0.64 (0.03)	0.53 (0.05)
6–19	0.76 (0.03)	0.65 (0.02)	0.59 (0.02)	0.51 (0.01)	0.45 (0.02)
20–39	0.86 (0.04)	0.81 (0.05)	0.78 (0.07)	0.69 (0.03)	0.64 (0.03)
40–59	1.42 (0.08)	1.17 (0.05)	1.17 (0.04)	1.08 (0.06)	0.92 (0.05)
60–79	1.84 (0.10)	1.63 (0.06)	1.50 (0.06)	1.42 (0.06)	1.37 (0.05)
20–79[3]	1.21 (0.05)	1.07 (0.04)	1.04 (0.04)	0.94 (0.03)	0.86 (0.03)

--- Data not available.
[1]Micrograms per deciliter (µg/dL).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 4. Trends in blood lead levels, by sex and age: Canada, 2007–2017

Sex and age (years)	Survey years	Overall trend: Overall annual percent change (standard error)	Overall trend: p value	p for quadratic trend
Total				
3–79[1]	2009–2017	-4.49 (0.64)	Less than 0.001	0.726
3–5	2009–2017	-7.61 (1.72)	Less than 0.001	0.758
6–19	2007–2017	-5.76 (0.55)	Less than 0.001	0.756
20–39	2007–2017	-4.04 (0.63)	Less than 0.001	0.415
40–59	2007–2017	-4.42 (0.65)	Less than 0.001	0.729
60–79	2007–2017	-4.50 (0.50)	Less than 0.001	0.223
20–79[2]	2007–2017	-4.11 (0.55)	Less than 0.001	0.636
Male				
3–79[1]	2009–2017	-4.52 (0.83)	Less than 0.001	0.828
3–5	2009–2017	-7.46 (2.20)	0.002	0.837
6–19	2007–2017	-5.38 (0.62)	Less than 0.001	0.622
20–39	2007–2017	-4.27 (0.80)	Less than 0.001	0.050
40–59	2007–2017	-4.29 (0.83)	Less than 0.001	0.619
60–79	2007–2017	-5.55 (0.63)	Less than 0.001	0.585
20–79[2]	2007–2017	-4.39 (0.63)	Less than 0.001	0.427
Female				
3–79[1]	2009–2017	-4.46 (0.63)	Less than 0.001	0.403
3–5	2009–2017	-7.76 (1.54)	Less than 0.001	0.724
6–19	2007–2017	-6.15 (0.65)	Less than 0.001	0.997
20–39	2007–2017	-3.75 (0.75)	Less than 0.001	0.685
40–59	2007–2017	-4.55 (0.85)	Less than 0.001	0.968
60–79	2007–2017	-3.54 (0.67)	Less than 0.001	0.226
20–79[2]	2007–2017	-3.82 (0.65)	Less than 0.001	0.952

[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 5. Geometric mean for red blood cell lead levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total	Geometric mean[1] (standard error)									
3–79[2]	3.94 (0.07)	3.41 (0.07)	3.28 (0.08)	2.95 (0.07)	2.98 (0.07)	2.62 (0.05)	2.27 (0.06)	1.97 (0.05)	1.83 (0.05)	1.68 (0.03)
3–5	5.69 (0.42)	4.18 (0.19)	4.30 (0.25)	3.62 (0.14)	3.80 (0.22)	3.03 (0.14)	2.50 (0.16)	2.01 (0.11)	1.84 (0.10)	1.64 (0.09)
6–19	3.12 (0.08)	2.59 (0.08)	2.57 (0.10)	2.15 (0.06)	2.18 (0.07)	1.86 (0.05)	1.52 (0.05)	1.31 (0.05)	1.23 (0.04)	1.08 (0.02)
20–39	3.33 (0.09)	2.85 (0.09)	2.74 (0.08)	2.38 (0.06)	2.51 (0.07)	2.18 (0.04)	1.83 (0.06)	1.65 (0.06)	1.55 (0.04)	1.46 (0.04)
40–59	4.50 (0.12)	4.12 (0.08)	3.84 (0.14)	3.59 (0.09)	3.61 (0.09)	3.28 (0.08)	2.98 (0.11)	2.49 (0.08)	2.33 (0.08)	2.11 (0.06)
60–79	5.51 (0.15)	4.90 (0.13)	4.69 (0.15)	4.79 (0.16)	4.34 (0.13)	4.00 (0.09)	3.73 (0.13)	3.27 (0.11)	2.99 (0.10)	2.81 (0.06)
20–79[3]	4.13 (0.08)	3.66 (0.07)	3.47 (0.09)	3.20 (0.08)	3.22 (0.08)	2.87 (0.04)	2.54 (0.07)	2.21 (0.05)	2.06 (0.06)	1.92 (0.05)
Male										
3–79[2]	4.56 (0.08)	4.00 (0.09)	3.70 (0.07)	3.32 (0.10)	3.32 (0.09)	2.92 (0.05)	2.55 (0.08)	2.22 (0.09)	1.99 (0.06)	1.85 (0.04)
3–5	5.32 (0.48)	4.42 (0.30)	4.30 (0.26)	3.61 (0.21)	3.94 (0.26)	3.07 (0.21)	2.68 (0.27)	2.12 (0.10)	1.86 (0.10)	1.67 (0.12)
6–19	3.48 (0.13)	2.91 (0.08)	2.77 (0.11)	2.31 (0.07)	2.34 (0.09)	2.03 (0.06)	1.65 (0.05)	1.51 (0.08)	1.35 (0.04)	1.18 (0.03)
20–39	3.97 (0.12)	3.45 (0.09)	3.23 (0.08)	2.87 (0.10)	2.97 (0.09)	2.54 (0.06)	2.19 (0.08)	1.93 (0.08)	1.76 (0.06)	1.72 (0.05)
40–59	5.40 (0.22)	4.88 (0.12)	4.36 (0.13)	4.13 (0.14)	3.99 (0.14)	3.66 (0.11)	3.25 (0.15)	2.77 (0.15)	2.49 (0.12)	2.25 (0.09)
60–79	6.34 (0.15)	5.80 (0.17)	5.32 (0.12)	5.03 (0.16)	4.73 (0.13)	4.32 (0.11)	4.15 (0.15)	3.49 (0.22)	3.10 (0.18)	3.07 (0.10)
20–79[3]	4.90 (0.10)	4.37 (0.09)	4.00 (0.07)	3.69 (0.11)	3.65 (0.10)	3.25 (0.06)	2.89 (0.10)	2.49 (0.09)	2.25 (0.07)	2.13 (0.06)
Female										
3–79[2]	3.42 (0.07)	2.93 (0.07)	2.92 (0.11)	2.63 (0.06)	2.68 (0.06)	2.35 (0.04)	2.03 (0.05)	1.75 (0.04)	1.69 (0.06)	1.52 (0.04)
3–5	6.15 (0.52)	3.94 (0.18)	4.30 (0.35)	3.64 (0.18)	3.65 (0.25)	2.99 (0.13)	2.31 (0.09)	1.92 (0.13)	1.81 (0.14)	1.61 (0.09)
6–19	2.77 (0.09)	2.29 (0.09)	2.38 (0.10)	2.00 (0.06)	2.02 (0.06)	1.70 (0.05)	1.40 (0.05)	1.13 (0.04)	1.13 (0.04)	0.97 (0.02)
20–39	2.79 (0.11)	2.39 (0.09)	2.33 (0.11)	1.98 (0.05)	2.13 (0.05)	1.87 (0.03)	1.55 (0.05)	1.42 (0.05)	1.37 (0.06)	1.25 (0.04)
40–59	3.82 (0.10)	3.47 (0.10)	3.41 (0.18)	3.16 (0.09)	3.29 (0.08)	2.95 (0.08)	2.75 (0.08)	2.26 (0.07)	2.19 (0.10)	1.99 (0.08)
60–79	4.91 (0.18)	4.28 (0.16)	4.22 (0.18)	4.60 (0.21)	4.03 (0.16)	3.74 (0.10)	3.39 (0.13)	3.10 (0.11)	2.90 (0.13)	2.60 (0.07)
20–79[3]	3.52 (0.09)	3.10 (0.07)	3.03 (0.12)	2.79 (0.07)	2.85 (0.07)	2.55 (0.04)	2.25 (0.06)	1.98 (0.04)	1.90 (0.08)	1.73 (0.05)

[1]Micrograms per deciliter (μg/dL).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 6. Trends in red blood cell lead levels, by sex and age: United States, 1999–2018

Sex and age (years)	Survey years	Overall trend (no quadratic trend detected): Overall annual percent change (standard error)	Overall trend (no quadratic trend detected): *p* value	*p* for quadratic trend	Trends in two time segments (quadratic trend detected): Detected joinpoint (survey cycle)	First time segment: Annual percent change (standard error)	First time segment: *p* value	Second time segment: Annual percent change (standard error)	Second time segment: *p* value	*p* for annual percent change difference between segments
Total										
3–79[1]	1999–2018	…	…	0.001	2013–2014	-4.68 (0.22)	Less than 0.001	-5.20 (0.65)	Less than 0.001	0.520
3–5	1999–2018	-6.78 (0.33)	Less than 0.001	0.115	…	…	…	…	…	…
6–19	1999–2018	…	…	0.011	2013–2014	-5.92 (0.29)	Less than 0.001	-5.93 (0.75)	Less than 0.001	0.993
20–39	1999–2018	-4.56 (0.16)	Less than 0.001	0.432	…	…	…	…	…	…
40–59	1999–2018	…	…	Less than 0.001	2007–2008	-2.10 (0.48)	Less than 0.001	-5.19 (0.31)	Less than 0.001	Less than 0.001
60–79	1999–2018	…	…	0.002	2005–2006	†-1.39 (0.63)	0.031	-4.33 (0.25)	Less than 0.001	Less than 0.001
20–79[2]	1999–2018	…	…	0.004	2013–2014	-4.18 (0.22)	Less than 0.001	-4.86 (0.70)	Less than 0.001	0.411
Male										
3–79[1]	1999–2018	…	…	0.021	2003–2004	-3.86 (0.62)	Less than 0.001	-5.07 (0.19)	Less than 0.001	0.105
3–5	1999–2018	-6.56 (0.39)	Less than 0.001	0.060	…	…	…	…	…	…
6–19	1999–2018	-5.78 (0.21)	Less than 0.001	0.254	…	…	…	…	…	…
20–39	1999–2018	-4.77 (0.18)	Less than 0.001	0.375	…	…	…	…	…	…
40–59	1999–2018	…	…	0.020	2003–2004	†-3.35 (1.04)	0.002	-4.87 (0.28)	Less than 0.001	0.206
60–79	1999–2018	-4.18 (0.24)	Less than 0.001	0.142	…	…	…	…	…	…
20–79[2]	1999–2018	…	…	0.033	2003–2004	-3.63 (0.64)	Less than 0.001	-4.73 (0.20)	Less than 0.001	0.155
Female										
3–79[1]	1999–2018	…	…	0.001	2013–2014	-4.52 (0.24)	Less than 0.001	-4.86 (0.70)	Less than 0.001	0.683
3–5	1999–2018	-6.99 (0.40)	Less than 0.001	0.596	…	…	…	…	…	…
6–19	1999–2018	…	…	0.001	2013–2014	-6.18 (0.33)	Less than 0.001	-5.58 (0.84)	Less than 0.001	0.575
20–39	1999–2018	-4.35 (0.23)	Less than 0.001	0.596	…	…	…	…	…	…
40–59	1999–2018	…	…	Less than 0.001	2007–2008	†-1.42 (0.57)	0.015	-4.77 (0.37)	Less than 0.001	Less than 0.001
60–79	1999–2018	…	…	0.001	2005–2006	†-0.11 (0.83)	0.898	-4.29 (0.32)	Less than 0.001	Less than 0.001
20–79[2]	1999–2018	…	…	0.005	2007–2008	-2.28 (0.45)	Less than 0.001	-4.71 (0.31)	Less than 0.001	Less than 0.001

… Category not applicable.
† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 7. Geometric mean for red blood cell lead levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total	Geometric mean[1] (standard error)				
3–79[2]	---	2.70 (0.06)	2.48 (0.06)	2.17 (0.06)	2.00 (0.08)
3–5	---	2.46 (0.08)	2.11 (0.07)	1.86 (0.08)	1.53 (0.16)
6–19	2.06 (0.07)	1.83 (0.04)	1.65 (0.05)	1.41 (0.03)	1.27 (0.06)
20–39	2.69 (0.10)	2.32 (0.12)	2.16 (0.13)	1.92 (0.08)	1.85 (0.09)
40–59	3.84 (0.16)	3.39 (0.10)	3.19 (0.08)	2.76 (0.12)	2.48 (0.12)
60–79	5.02 (0.22)	4.52 (0.09)	3.96 (0.10)	3.53 (0.10)	3.33 (0.10)
20–79[3]	3.49 (0.12)	3.06 (0.09)	2.83 (0.08)	2.49 (0.07)	2.32 (0.09)
Male					
3–79[2]	---	2.90 (0.06)	2.68 (0.05)	2.27 (0.05)	2.17 (0.12)
3–5	---	2.56 (0.10)	2.21 (0.14)	1.95 (0.11)	1.61 (0.23)
6–19	2.17 (0.07)	1.97 (0.04)	1.80 (0.05)	1.49 (0.04)	1.39 (0.08)
20–39	3.14 (0.13)	2.51 (0.12)	2.34 (0.12)	2.12 (0.12)	2.08 (0.14)
40–59	3.93 (0.17)	3.63 (0.11)	3.49 (0.13)	2.79 (0.12)	2.69 (0.17)
60–79	5.34 (0.27)	4.71 (0.15)	4.21 (0.18)	3.53 (0.13)	3.33 (0.15)
20–79[3]	3.80 (0.13)	3.28 (0.10)	3.07 (0.07)	2.60 (0.06)	2.52 (0.13)
Female					
3–79[2]	---	2.52 (0.07)	2.29 (0.08)	2.07 (0.07)	1.83 (0.06)
3–5	---	2.36 (0.09)	2.02 (0.07)	1.77 (0.07)	1.45 (0.13)
6–19	1.96 (0.07)	1.69 (0.05)	1.51 (0.05)	1.32 (0.04)	1.16 (0.06)
20–39	2.29 (0.10)	2.13 (0.14)	1.98 (0.17)	1.74 (0.07)	1.63 (0.09)
40–59	3.75 (0.20)	3.16 (0.13)	2.92 (0.10)	2.73 (0.16)	2.27 (0.14)
60–79	4.75 (0.26)	4.35 (0.13)	3.74 (0.15)	3.54 (0.15)	3.33 (0.12)
20–79[3]	3.20 (0.14)	2.85 (0.10)	2.61 (0.11)	2.38 (0.09)	2.13 (0.08)

--- Data not available.
[1]Micrograms per deciliter (µg/dL).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 8. Trends in red blood cell lead levels, by sex and age: Canada, 2007–2017

Sex and age (years)	Survey years	Overall trend: Overall annual percent change (standard error)	Overall trend: *p* value	*p* for quadratic trend
Total				
3–79[1]	2009–2017	-5.09 (0.64)	Less than 0.001	0.955
3–5	2009–2017	-7.53 (1.70)	Less than 0.001	0.714
6–19	2007–2017	-5.95 (0.55)	Less than 0.001	0.924
20–39	2007–2017	-4.56 (0.64)	Less than 0.001	0.368
40–59	2007–2017	-5.26 (0.63)	Less than 0.001	0.730
60–79	2007–2017	-5.15 (0.50)	Less than 0.001	0.371
20–79[2]	2007–2017	-4.79 (0.55)	Less than 0.001	0.655
Male				
3–79[1]	2009–2017	-5.03 (0.85)	Less than 0.001	0.671
3–5	2009–2017	†-7.34 (2.26)	0.003	0.810
6–19	2007–2017	-5.63 (0.64)	Less than 0.001	0.823
20–39	2007–2017	-4.80 (0.82)	Less than 0.001	0.066
40–59	2007–2017	-4.97 (0.75)	Less than 0.001	0.624
60–79	2007–2017	-5.95 (0.66)	Less than 0.001	0.673
20–79[2]	2007–2017	-4.94 (0.62)	Less than 0.001	0.448
Female				
3–79[1]	2009–2017	-5.16 (0.61)	Less than 0.001	0.739
3–5	2009–2017	-7.74 (1.46)	Less than 0.001	0.670
6–19	2007–2017	-6.26 (0.66)	Less than 0.001	0.933
20–39	2007–2017	-4.29 (0.77)	Less than 0.001	0.848
40–59	2007–2017	-5.56 (0.83)	Less than 0.001	0.946
60–79	2007–2017	-4.41 (0.68)	Less than 0.001	0.395
20–79[2]	2007–2017	-4.63 (0.65)	Less than 0.001	0.950

† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 9. Geometric mean for blood cadmium levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total	Geometric mean[1] (standard error)									
3–79[2]	0.41 (0.02)	0.33 (0.01)	0.27 (0.01)	0.27 (0.01)	0.28 (0.01)	0.26 (0.01)	0.25 (0.01)	0.22 (0.01)	0.22 (0.01)	0.22 (0.01)
3–5	0.27 (0.01)	0.18 (0.04)	0.09 (0.01)	0.11 (0.02)	0.14 (0.01)	0.15 (0.01)	0.11 (0.01)	0.08 (0.00)	0.09 (0.00)	0.09 (0.00)
6–19	0.29 (0.02)	0.18 (0.01)	0.13 (0.01)	0.12 (0.01)	0.13 (0.01)	0.13 (0.01)	0.13 (0.01)	0.11 (0.00)	0.12 (0.00)	0.12 (0.00)
20–39	0.41 (0.03)	0.34 (0.02)	0.30 (0.01)	0.29 (0.01)	0.30 (0.01)	0.28 (0.01)	0.26 (0.01)	0.24 (0.01)	0.24 (0.01)	0.24 (0.01)
40–59	0.50 (0.02)	0.44 (0.02)	0.39 (0.02)	0.38 (0.02)	0.40 (0.02)	0.36 (0.01)	0.35 (0.01)	0.32 (0.01)	0.31 (0.01)	0.31 (0.01)
60–79	0.53 (0.02)	0.48 (0.01)	0.47 (0.01)	0.45 (0.01)	0.41 (0.01)	0.41 (0.01)	0.39 (0.02)	0.34 (0.01)	0.34 (0.01)	0.35 (0.01)
20–79[3]	0.47 (0.02)	0.41 (0.01)	0.36 (0.01)	0.35 (0.01)	0.36 (0.01)	0.34 (0.01)	0.32 (0.01)	0.29 (0.01)	0.29 (0.01)	0.28 (0.01)
Male										
3–79[2]	0.40 (0.02)	0.31 (0.01)	0.25 (0.01)	0.24 (0.01)	0.26 (0.01)	0.23 (0.01)	0.22 (0.01)	0.19 (0.01)	0.20 (0.01)	0.20 (0.00)
3–5	0.27 (0.02)	0.23 (0.02)	0.09 (0.01)	0.15 (0.01)	0.14 (0.02)	0.14 (0.02)	0.11 (0.01)	0.08 (0.01)	0.08 (0.00)	0.09 (0.00)
6–19	0.29 (0.02)	0.17 (0.01)	0.13 (0.01)	0.10 (0.01)	0.12 (0.01)	0.12 (0.01)	0.12 (0.01)	0.10 (0.00)	0.11 (0.00)	0.11 (0.00)
20–39	0.42 (0.03)	0.32 (0.02)	0.28 (0.02)	0.25 (0.01)	0.29 (0.01)	0.25 (0.01)	0.23 (0.02)	0.21 (0.01)	0.21 (0.01)	0.22 (0.01)
40–59	0.47 (0.03)	0.39 (0.02)	0.34 (0.02)	0.33 (0.02)	0.35 (0.02)	0.31 (0.01)	0.29 (0.02)	0.27 (0.02)	0.27 (0.02)	0.24 (0.01)
60–79	0.52 (0.02)	0.45 (0.01)	0.44 (0.01)	0.43 (0.02)	0.38 (0.01)	0.38 (0.01)	0.39 (0.02)	0.29 (0.02)	0.34 (0.02)	0.32 (0.01)
20–79[3]	0.46 (0.03)	0.38 (0.02)	0.33 (0.01)	0.32 (0.01)	0.33 (0.01)	0.30 (0.01)	0.28 (0.01)	0.25 (0.01)	0.26 (0.01)	0.25 (0.01)
Female										
3–79[2]	0.41 (0.02)	0.35 (0.01)	0.29 (0.01)	0.29 (0.01)	0.30 (0.01)	0.29 (0.01)	0.27 (0.01)	0.24 (0.01)	0.24 (0.01)	0.25 (0.01)
3–5	0.27 (0.02)	†0.12 (0.05)	0.09 (0.01)	†0.06 (0.02)	0.14 (0.02)	0.16 (0.01)	0.11 (0.01)	0.08 (0.00)	0.09 (0.00)	0.10 (0.00)
6–19	0.28 (0.02)	0.18 (0.01)	0.14 (0.01)	0.13 (0.01)	0.14 (0.01)	0.15 (0.01)	0.14 (0.01)	0.11 (0.01)	0.12 (0.00)	0.13 (0.00)
20–39	0.41 (0.03)	0.36 (0.02)	0.31 (0.01)	0.31 (0.01)	0.31 (0.01)	0.32 (0.01)	0.30 (0.01)	0.27 (0.02)	0.27 (0.01)	0.26 (0.02)
40–59	0.53 (0.02)	0.48 (0.02)	0.43 (0.02)	0.42 (0.02)	0.45 (0.01)	0.42 (0.01)	0.41 (0.01)	0.38 (0.01)	0.37 (0.02)	0.39 (0.02)
60–79	0.54 (0.03)	0.51 (0.02)	0.50 (0.02)	0.47 (0.02)	0.43 (0.02)	0.43 (0.02)	0.40 (0.02)	0.39 (0.02)	0.34 (0.02)	0.38 (0.02)
20–79[3]	0.48 (0.02)	0.44 (0.02)	0.39 (0.01)	0.38 (0.01)	0.38 (0.01)	0.38 (0.01)	0.36 (0.01)	0.33 (0.01)	0.32 (0.01)	0.33 (0.01)

† Relative standard error greater than 30%.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 10. Trends in blood cadmium levels, by sex and age: United States, 1999–2018

		Overall trend (no quadratic trend detected)			Trends in two time segments (quadratic trend detected)					
						First time segment		Second time segment		
Sex and age (years)	Survey years	Overall annual percent change (standard error)	*p* value	*p* for quadratic trend	Detected joinpoint (survey cycle)	Annual percent change (standard error)	*p* value	Annual percent change (standard error)	*p* value	*p* for annual percent change difference between segments
Total										
3–79[1]	1999–2018	…	…	0.004	2003–2004	-6.43 (1.20)	Less than 0.001	-2.09 (0.22)	Less than 0.001	0.001
3–5	1999–2018	…	…	Less than 0.001	2003–2004	-16.46 (1.54)	Less than 0.001	-2.17 (0.42)	Less than 0.001	Less than 0.001
6–19	1999–2018	…	…	Less than 0.001	2003–2004	-12.53 (1.50)	Less than 0.001	-2.32 (0.28)	Less than 0.001	Less than 0.001
20–39	1999–2018	-2.19 (0.28)	Less than 0.001	0.088	…	…	…	…	…	…
40–59	1999–2018	-2.05 (0.26)	Less than 0.001	0.397	…	…	…	…	…	…
60–79	1999–2018	-2.33 (0.21)	Less than 0.001	0.352	…	…	…	…	…	…
20–79[2]	1999–2018	-2.19 (0.19)	Less than 0.001	0.125	…	…	…	…	…	…
Male										
3–79[1]	1999–2018	…	…	0.003	2003–2004	-7.37 (1.36)	Less than 0.001	-2.46 (0.25)	Less than 0.001	0.001
3–5	1999–2018	…	…	Less than 0.001	2003–2004	-16.76 (1.92)	Less than 0.001	-2.21 (0.54)	Less than 0.001	Less than 0.001
6–19	1999–2018	…	…	Less than 0.001	2003–2004	-13.52 (1.72)	Less than 0.001	-2.39 (0.39)	Less than 0.001	Less than 0.001
20–39	1999–2018	…	…	0.011	2003–2004	-7.24 (1.69)	Less than 0.001	-2.33 (0.41)	Less than 0.001	0.012
40–59	1999–2018	-2.81 (0.35)	Less than 0.001	0.836	…	…	…	…	…	…
60–79	1999–2018	-2.45 (0.29)	Less than 0.001	0.334	…	…	…	…	…	…
20–79[2]	1999–2018	-2.71 (0.22)	Less than 0.001	0.100	…	…	…	…	…	…
Female										
3–79[1]	1999–2018	…	…	0.019	2003–2004	-5.58 (1.18)	Less than 0.001	-1.73 (0.25)	Less than 0.001	0.004
3–5	1999–2018	…	…	Less than 0.001	2013–2014	-4.75 (0.58)	Less than 0.001	†3.83 (1.77)	0.029	Less than 0.001
6–19	1999–2018	…	…	Less than 0.001	2003–2004	-11.55 (1.57)	Less than 0.001	-2.25 (0.31)	Less than 0.001	Less than 0.001
20–39	1999–2018	-1.73 (0.34)	Less than 0.001	0.549	…	…	…	…	…	…
40–59	1999–2018	-1.29 (0.28)	Less than 0.001	0.123	…	…	…	…	…	…
60–79	1999–2018	-2.22 (0.29)	Less than 0.001	0.535	…	…	…	…	…	…
20–79[2]	1999–2018	-1.68 (0.20)	Less than 0.001	0.219	…	…	…	…	…	…

… Category not applicable.
† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 11. Geometric mean for blood cadmium levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total		Geometric mean[1] (standard error)			
3–79[2]	---	0.26 (0.01)	0.30 (0.01)	0.28 (0.01)	0.23 (0.01)
3–5	---	0.08 (0.00)	0.09 (0.01)	0.09 (0.00)	0.08 (0.01)
6–19	0.14 (0.01)	0.12 (0.00)	0.14 (0.01)	0.13 (0.00)	0.10 (0.01)
20–39	0.35 (0.02)	0.29 (0.02)	0.31 (0.04)	0.33 (0.02)	0.27 (0.02)
40–59	0.49 (0.02)	0.42 (0.02)	0.50 (0.03)	0.41 (0.02)	0.35 (0.02)
60–79	0.45 (0.02)	0.46 (0.02)	0.48 (0.03)	0.44 (0.02)	0.39 (0.02)
20–79[3]	0.42 (0.01)	0.37 (0.02)	0.41 (0.02)	0.38 (0.01)	0.32 (0.01)
Male					
3–79[2]	---	0.25 (0.01)	0.27 (0.01)	0.26 (0.01)	0.21 (0.01)
3–5	---	0.08 (0.00)	0.08 (0.01)	0.09 (0.00)	0.09 (0.01)
6–19	0.14 (0.01)	0.12 (0.01)	0.13 (0.01)	0.12 (0.00)	0.09 (0.01)
20–39	0.33 (0.03)	0.26 (0.02)	0.28 (0.04)	0.30 (0.02)	0.27 (0.03)
40–59	0.40 (0.04)	0.38 (0.02)	0.42 (0.03)	0.38 (0.02)	0.33 (0.04)
60–79	0.41 (0.03)	0.42 (0.03)	0.43 (0.02)	0.42 (0.02)	0.35 (0.02)
20–79[3]	0.37 (0.02)	0.33 (0.02)	0.36 (0.02)	0.35 (0.01)	0.31 (0.02)
Female					
3–79[2]	---	0.29 (0.02)	0.33 (0.02)	0.30 (0.01)	0.24 (0.01)
3–5	---	0.08 (0.00)	0.09 (0.01)	0.09 (0.00)	0.07 (0.01)
6–19	0.15 (0.01)	0.11 (0.00)	0.14 (0.01)	0.13 (0.00)	0.10 (0.01)
20–39	0.37 (0.02)	0.33 (0.04)	0.34 (0.04)	0.36 (0.04)	0.27 (0.03)
40–59	0.58 (0.03)	0.47 (0.04)	0.59 (0.07)	0.44 (0.03)	0.37 (0.02)
60–79	0.50 (0.03)	0.49 (0.02)	0.52 (0.03)	0.46 (0.02)	0.43 (0.03)
20–79[3]	0.47 (0.02)	0.41 (0.03)	0.46 (0.03)	0.41 (0.02)	0.34 (0.02)

--- Data not available.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 12. Trends in blood cadmium levels, by sex and age: Canada, 2007–2017

Sex and age (years)	Survey years	Overall trend: Overall annual percent change (standard error)	Overall trend: *p* value	*p* for quadratic trend
Total				
3–79[1]	2009–2017	†-2.63 (0.80)	0.002	Less than 0.001
3–5	2009–2017	†-0.24 (1.21)	0.846	0.006
6–19	2007–2017	-3.53 (0.84)	Less than 0.001	0.022
20–39	2007–2017	†-1.67 (1.18)	0.164	0.955
40–59	2007–2017	-3.38 (0.75)	Less than 0.001	0.049
60–79	2007–2017	†-1.84 (0.70)	0.012	0.031
20–79[2]	2007–2017	-2.30 (0.62)	0.001	0.106
Male				
3–79[1]	2009–2017	†-1.96 (1.08)	0.080	0.005
3–5	2009–2017	†0.06 (1.50)	0.967	0.033
6–19	2007–2017	-3.90 (1.03)	Less than 0.001	0.033
20–39	2007–2017	†-0.96 (1.65)	0.564	0.433
40–59	2007–2017	†-1.93 (1.44)	0.190	0.324
60–79	2007–2017	†-1.96 (1.05)	0.070	0.053
20–79[2]	2007–2017	†-1.45 (0.94)	0.133	0.545
Female				
3–79[1]	2009–2017	†-3.34 (1.02)	0.002	Less than 0.001
3–5	2009–2017	†-0.50 (1.32)	0.707	0.013
6–19	2007–2017	†-3.16 (1.03)	0.004	0.137
20–39	2007–2017	†-2.48 (1.34)	0.073	0.318
40–59	2007–2017	-4.86 (0.88)	Less than 0.001	0.126
60–79	2007–2017	†-1.73 (0.83)	0.045	0.159
20–79[2]	2007–2017	-3.19 (0.70)	Less than 0.001	0.059

† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 13. Geometric mean for red blood cell cadmium levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total					Geometric mean[1] (standard error)					
3–79[2]	0.97 (0.05)	0.80 (0.03)	0.65 (0.02)	0.64 (0.02)	0.68 (0.02)	0.64 (0.01)	0.61 (0.02)	0.53 (0.01)	0.53 (0.02)	0.53 (0.01)
3–5	0.72 (0.04)	0.46 (0.09)	0.23 (0.03)	0.28 (0.05)	0.37 (0.03)	0.39 (0.03)	0.29 (0.03)	0.22 (0.01)	0.23 (0.01)	0.25 (0.01)
6–19	0.71 (0.04)	0.44 (0.02)	0.32 (0.02)	0.29 (0.02)	0.33 (0.01)	0.34 (0.02)	0.33 (0.02)	0.26 (0.01)	0.29 (0.01)	0.30 (0.01)
20–39	0.97 (0.06)	0.82 (0.05)	0.69 (0.03)	0.67 (0.03)	0.72 (0.03)	0.68 (0.02)	0.64 (0.03)	0.57 (0.02)	0.57 (0.02)	0.56 (0.03)
40–59	1.17 (0.05)	1.03 (0.04)	0.90 (0.04)	0.89 (0.04)	0.96 (0.04)	0.87 (0.02)	0.85 (0.02)	0.78 (0.03)	0.74 (0.03)	0.73 (0.03)
60–79	1.26 (0.05)	1.15 (0.03)	1.11 (0.02)	1.06 (0.03)	0.98 (0.02)	1.00 (0.03)	0.97 (0.04)	0.83 (0.03)	0.81 (0.03)	0.83 (0.03)
20–79[3]	1.10 (0.05)	0.97 (0.03)	0.85 (0.02)	0.83 (0.03)	0.86 (0.03)	0.82 (0.01)	0.78 (0.02)	0.69 (0.02)	0.68 (0.02)	0.68 (0.02)
Male										
3–79[2]	0.90 (0.05)	0.71 (0.03)	0.57 (0.03)	0.55 (0.02)	0.60 (0.02)	0.54 (0.02)	0.52 (0.02)	0.44 (0.02)	0.46 (0.02)	0.45 (0.01)
3–5	0.72 (0.05)	0.58 (0.05)	0.23 (0.04)	0.39 (0.03)	0.38 (0.04)	0.36 (0.05)	0.28 (0.03)	0.21 (0.02)	0.22 (0.01)	0.24 (0.01)
6–19	0.69 (0.04)	0.43 (0.02)	0.31 (0.03)	0.25 (0.02)	0.30 (0.02)	0.29 (0.02)	0.30 (0.03)	0.25 (0.01)	0.27 (0.01)	0.27 (0.01)
20–39	0.91 (0.06)	0.71 (0.05)	0.61 (0.04)	0.55 (0.03)	0.64 (0.03)	0.55 (0.03)	0.52 (0.04)	0.47 (0.03)	0.47 (0.03)	0.49 (0.02)
40–59	1.03 (0.06)	0.87 (0.05)	0.75 (0.04)	0.73 (0.04)	0.80 (0.04)	0.70 (0.03)	0.67 (0.03)	0.61 (0.04)	0.60 (0.04)	0.54 (0.02)
60–79	1.18 (0.05)	1.04 (0.03)	1.00 (0.03)	0.98 (0.04)	0.87 (0.03)	0.90 (0.03)	0.92 (0.04)	0.68 (0.05)	0.78 (0.06)	0.74 (0.03)
20–79[3]	1.01 (0.05)	0.84 (0.04)	0.73 (0.03)	0.70 (0.03)	0.75 (0.03)	0.68 (0.02)	0.65 (0.03)	0.56 (0.02)	0.57 (0.02)	0.55 (0.01)
Female										
3–79[2]	1.05 (0.05)	0.89 (0.03)	0.74 (0.02)	0.74 (0.02)	0.76 (0.02)	0.75 (0.02)	0.70 (0.02)	0.62 (0.02)	0.60 (0.02)	0.62 (0.02)
3–5	0.72 (0.05)	†0.31 (0.14)	0.23 (0.04)	†0.16 (0.06)	0.37 (0.05)	0.44 (0.02)	0.31 (0.03)	0.22 (0.01)	0.24 (0.01)	0.26 (0.01)
6–19	0.73 (0.05)	0.46 (0.03)	0.34 (0.02)	0.33 (0.02)	0.37 (0.02)	0.38 (0.02)	0.36 (0.02)	0.28 (0.01)	0.31 (0.01)	0.32 (0.01)
20–39	1.03 (0.06)	0.93 (0.05)	0.79 (0.04)	0.79 (0.03)	0.81 (0.04)	0.83 (0.03)	0.78 (0.03)	0.69 (0.04)	0.68 (0.03)	0.65 (0.04)
40–59	1.31 (0.05)	1.19 (0.05)	1.07 (0.06)	1.04 (0.04)	1.13 (0.03)	1.07 (0.02)	1.04 (0.03)	0.97 (0.04)	0.91 (0.04)	0.98 (0.04)
60–79	1.33 (0.06)	1.25 (0.04)	1.22 (0.05)	1.14 (0.05)	1.09 (0.03)	1.09 (0.04)	1.01 (0.05)	0.98 (0.05)	0.84 (0.04)	0.93 (0.04)
20–79[3]	1.20 (0.05)	1.10 (0.04)	0.97 (0.03)	0.95 (0.03)	0.98 (0.03)	0.97 (0.02)	0.92 (0.02)	0.85 (0.03)	0.80 (0.03)	0.82 (0.03)

† Relative standard error greater than 30%.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 14. Trends in red blood cell cadmium levels, by sex and age: United States, 1999–2018

		Overall trend (no quadratic trend detected)			Trends in two time segments (quadratic trend detected)					
						First time segment		Second time segment		
Sex and age (years)	Survey years	Overall annual percent change (standard error)	*p* value	*p* for quadratic trend	Detected joinpoint (survey cycle)	Annual percent change (standard error)	*p* value	Annual percent change (standard error)	*p* value	*p* for annual percent change difference between segments
Total										
3–79[1]	1999–2018	…	…	0.019	2003–2004	-6.24 (1.16)	Less than 0.001	-2.02 (0.21)	Less than 0.001	0.001
3–5	1999–2018	…	…	Less than 0.001	2003–2004	-16.61 (1.56)	Less than 0.001	-2.02 (0.42)	Less than 0.001	Less than 0.001
6–19	1999–2018	…	…	Less than 0.001	2003–2004	-12.39 (1.48)	Less than 0.001	-2.28 (0.27)	Less than 0.001	Less than 0.001
20–39	1999–2018	-2.08 (0.27)	Less than 0.001	0.199	…	…	…	…	…	…
40–59	1999–2018	-1.94 (0.26)	Less than 0.001	0.709	…	…	…	…	…	…
60–79	1999–2018	-2.30 (0.21)	Less than 0.001	0.823	…	…	…	…	…	…
20–79[2]	1999–2018	-2.10 (0.19)	Less than 0.001	0.349	…	…	…	…	…	…
Male										
3–79[1]	1999–2018	…	…	0.010	2003–2004	-7.17 (1.31)	Less than 0.001	-2.35 (0.25)	Less than 0.001	0.001
3–5	1999–2018	…	…	Less than 0.001	2003–2004	-16.94 (1.93)	Less than 0.001	-2.01 (0.55)	Less than 0.001	Less than 0.001
6–19	1999–2018	…	…	Less than 0.001	2003–2004	-13.28 (1.66)	Less than 0.001	-2.39 (0.36)	Less than 0.001	Less than 0.001
20–39	1999–2018	…	…	0.021	2003–2004	-7.06 (1.64)	Less than 0.001	-2.15 (0.41)	Less than 0.001	0.010
40–59	1999–2018	-2.64 (0.34)	Less than 0.001	0.894	…	…	…	…	…	…
60–79	1999–2018	-2.37 (0.30)	Less than 0.001	0.630	…	…	…	…	…	…
20–79[2]	1999–2018	-2.55 (0.22)	Less than 0.001	0.220	…	…	…	…	…	…
Female										
3–79[1]	1999–2018	-1.94 (0.22)	Less than 0.001	0.072	…	…	…	…	…	…
3–5	1999–2018	…	…	Less than 0.001	2003–2004	-16.24 (1.97)	Less than 0.001	-2.03 (0.53)	Less than 0.001	Less than 0.001
6–19	1999–2018	…	…	Less than 0.001	2003–2004	-11.49 (1.60)	Less than 0.001	-2.19 (0.31)	Less than 0.001	Less than 0.001
20–39	1999–2018	-1.72 (0.34)	Less than 0.001	0.841	…	…	…	…	…	…
40–59	1999–2018	-1.25 (0.28)	Less than 0.001	0.314	…	…	…	…	…	…
60–79	1999–2018	-2.22 (0.28)	Less than 0.001	0.914	…	…	…	…	…	…
20–79[2]	1999–2018	-1.66 (0.20)	Less than 0.001	0.576	…	…	…	…	…	…

… Category not applicable.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 15. Geometric mean for red blood cell cadmium levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total			Geometric mean[1] (standard error)		
3–79[2]	---	0.64 (0.03)	0.73 (0.03)	0.68 (0.02)	0.55 (0.02)
3–5	---	0.21 (0.01)	0.24 (0.01)	0.26 (0.01)	0.22 (0.02)
6–19	0.35 (0.02)	0.29 (0.01)	0.35 (0.02)	0.32 (0.01)	0.24 (0.02)
20–39	0.84 (0.04)	0.69 (0.06)	0.75 (0.09)	0.80 (0.06)	0.65 (0.06)
40–59	1.17 (0.06)	1.00 (0.05)	1.19 (0.07)	0.98 (0.04)	0.82 (0.04)
60–79	1.09 (0.04)	1.11 (0.05)	1.15 (0.06)	1.07 (0.04)	0.92 (0.05)
20–79[3]	1.00 (0.03)	0.88 (0.04)	0.98 (0.05)	0.91 (0.03)	0.77 (0.04)
Male					
3–79[2]	---	0.57 (0.02)	0.63 (0.03)	0.61 (0.02)	0.49 (0.03)
3–5	---	0.21 (0.01)	0.23 (0.03)	0.26 (0.01)	0.24 (0.02)
6–19	0.33 (0.02)	0.29 (0.02)	0.33 (0.02)	0.30 (0.01)	0.22 (0.02)
20–39	0.75 (0.08)	0.57 (0.05)	0.64 (0.09)	0.68 (0.05)	0.60 (0.07)
40–59	0.92 (0.08)	0.86 (0.06)	0.95 (0.08)	0.86 (0.04)	0.74 (0.08)
60–79	0.95 (0.07)	0.97 (0.06)	1.01 (0.06)	0.98 (0.05)	0.78 (0.06)
20–79[3]	0.85 (0.05)	0.74 (0.04)	0.82 (0.05)	0.80 (0.03)	0.69 (0.05)
Female					
3–79[2]	---	0.73 (0.04)	0.84 (0.04)	0.76 (0.03)	0.60 (0.02)
3–5	---	0.21 (0.01)	0.25 (0.01)	0.26 (0.01)	0.20 (0.02)
6–19	0.37 (0.02)	0.29 (0.01)	0.37 (0.02)	0.34 (0.01)	0.26 (0.03)
20–39	0.94 (0.05)	0.84 (0.11)	0.88 (0.10)	0.93 (0.10)	0.70 (0.07)
40–59	1.49 (0.09)	1.17 (0.10)	1.49 (0.16)	1.11 (0.07)	0.89 (0.05)
60–79	1.24 (0.07)	1.25 (0.05)	1.31 (0.08)	1.16 (0.05)	1.06 (0.06)
20–79[3]	1.19 (0.04)	1.03 (0.07)	1.17 (0.07)	1.04 (0.05)	0.84 (0.04)

--- Data not available.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 16. Trends in red blood cell cadmium levels, by sex and age: Canada, 2007–2017

Sex and age (years)	Survey years	Overall trend: Overall annual percent change (standard error)	Overall trend: *p* value	*p* for quadratic trend
Total				
3–79[1]	2009–2017	†-2.69 (0.84)	0.003	Less than 0.001
3–5	2009–2017	†0.41 (1.31)	0.758	0.004
6–19	2007–2017	-3.28 (0.83)	Less than 0.001	0.015
20–39	2007–2017	†-1.68 (1.22)	0.179	0.922
40–59	2007–2017	-3.63 (0.74)	Less than 0.001	0.031
60–79	2007–2017	†-2.11 (0.72)	0.005	0.015
20–79[2]	2007–2017	-2.46 (0.63)	Less than 0.001	0.072
Male				
3–79[1]	2009–2017	†-1.98 (1.11)	0.085	0.003
3–5	2009–2017	†0.85 (1.61)	0.598	0.024
6–19	2007–2017	-3.62 (1.04)	0.001	0.030
20–39	2007–2017	†-1.01 (1.68)	0.554	0.510
40–59	2007–2017	†-2.02 (1.44)	0.171	0.283
60–79	2007–2017	†-2.14 (1.06)	0.051	0.035
20–79[2]	2007–2017	†-1.52 (0.93)	0.112	0.413
Female				
3–79[1]	2009–2017	-3.44 (1.01)	0.002	Less than 0.001
3–5	2009–2017	†-0.01 (1.35)	0.996	0.006
6–19	2007–2017	†-2.95 (1.02)	0.006	0.092
20–39	2007–2017	†-2.46 (1.37)	0.082	0.340
40–59	2007–2017	-5.24 (0.87)	Less than 0.001	0.100
60–79	2007–2017	†-2.07 (0.83)	0.016	0.084
20–79[2]	2007–2017	-3.43 (0.72)	Less than 0.001	0.048

† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 17. Geometric mean for blood mercury levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total					Geometric mean[1] (standard error)					
3–79[2]	---	---	0.80 (0.05)	0.85 (0.04)	0.75 (0.04)	0.80 (0.04)	0.67 (0.04)	0.62 (0.03)	0.62 (0.03)	0.56 (0.03)
3–5	0.32 (0.03)	0.35 (0.03)	0.38 (0.03)	0.39 (0.01)	0.26 (0.03)	0.31 (0.03)	0.26 (0.02)	0.25 (0.02)	0.23 (0.02)	0.22 (0.02)
6–19	---	---	0.47 (0.03)	0.50 (0.02)	0.42 (0.02)	0.42 (0.03)	0.37 (0.03)	0.35 (0.02)	0.34 (0.02)	0.29 (0.02)
20–39	---	---	0.90 (0.07)	0.90 (0.05)	0.83 (0.06)	0.85 (0.05)	0.70 (0.06)	0.63 (0.04)	0.68 (0.03)	0.61 (0.04)
40–59	---	---	1.09 (0.06)	1.20 (0.06)	1.08 (0.07)	1.15 (0.05)	0.94 (0.07)	0.89 (0.06)	0.87 (0.05)	0.80 (0.04)
60–79	---	---	0.98 (0.07)	1.14 (0.07)	0.95 (0.06)	1.21 (0.08)	1.06 (0.12)	0.90 (0.05)	0.88 (0.07)	0.86 (0.06)
20–79[3]	---	---	0.98 (0.06)	1.06 (0.05)	0.95 (0.06)	1.02 (0.04)	0.85 (0.06)	0.77 (0.04)	0.79 (0.03)	0.73 (0.04)
Male										
3–79[2]	---	---	0.82 (0.05)	0.86 (0.04)	0.79 (0.05)	0.82 (0.04)	0.69 (0.05)	0.63 (0.04)	0.62 (0.03)	0.58 (0.04)
3–5	0.27 (0.04)	0.31 (0.03)	0.34 (0.03)	0.36 (0.01)	0.27 (0.04)	0.33 (0.04)	0.26 (0.02)	0.27 (0.02)	0.21 (0.03)	0.22 (0.03)
6–19	---	---	0.46 (0.03)	0.49 (0.03)	0.41 (0.02)	0.42 (0.03)	0.36 (0.03)	0.37 (0.03)	0.34 (0.02)	0.29 (0.03)
20–39	---	---	0.94 (0.08)	0.90 (0.05)	0.93 (0.08)	0.87 (0.06)	0.74 (0.06)	0.62 (0.05)	0.67 (0.03)	0.61 (0.05)
40–59	---	---	1.16 (0.08)	1.22 (0.07)	1.11 (0.07)	1.17 (0.07)	0.98 (0.07)	0.88 (0.07)	0.86 (0.07)	0.86 (0.07)
60–79	---	---	1.01 (0.08)	1.25 (0.09)	1.06 (0.06)	1.34 (0.11)	1.11 (0.13)	0.97 (0.09)	0.94 (0.08)	0.90 (0.08)
20–79[3]	---	---	1.04 (0.07)	1.08 (0.05)	1.02 (0.07)	1.06 (0.05)	0.89 (0.06)	0.78 (0.05)	0.79 (0.03)	0.75 (0.05)
Female										
3–79[2]	---	---	0.78 (0.04)	0.85 (0.04)	0.72 (0.03)	0.78 (0.04)	0.66 (0.04)	0.61 (0.03)	0.61 (0.03)	0.55 (0.03)
3–5	0.38 (0.05)	0.41 (0.05)	0.44 (0.04)	0.43 (0.03)	0.26 (0.05)	0.28 (0.03)	0.26 (0.02)	0.22 (0.04)	0.25 (0.03)	0.21 (0.02)
6–19	---	---	0.47 (0.03)	0.50 (0.03)	0.44 (0.02)	0.42 (0.03)	0.38 (0.03)	0.32 (0.03)	0.34 (0.02)	0.29 (0.02)
20–39	0.98 (0.10)	0.82 (0.06)	0.86 (0.07)	0.91 (0.06)	0.76 (0.05)	0.82 (0.05)	0.67 (0.06)	0.64 (0.04)	0.69 (0.03)	0.61 (0.05)
40–59	---	---	1.02 (0.06)	1.18 (0.07)	1.04 (0.07)	1.13 (0.04)	0.91 (0.06)	0.91 (0.05)	0.89 (0.06)	0.75 (0.04)
60–79	---	---	0.95 (0.08)	1.06 (0.07)	0.87 (0.06)	1.11 (0.07)	1.02 (0.12)	0.85 (0.06)	0.83 (0.08)	0.83 (0.06)
20–79[3]	---	---	0.94 (0.06)	1.04 (0.04)	0.88 (0.05)	0.99 (0.04)	0.82 (0.05)	0.77 (0.04)	0.79 (0.04)	0.70 (0.04)

--- Data not available.
[1]Micrograms per liter (μg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 18. Trends in blood mercury levels, by sex and age: United States, 1999–2018

Sex and age (years)	Survey years	Overall trend (no quadratic trend detected): Overall annual percent change (standard error)	Overall trend (no quadratic trend detected): *p* value	*p* for quadratic trend	Trends in two time segments (quadratic trend detected): Detected joinpoint (survey cycle)	First time segment: Annual percent change (standard error)	First time segment: *p* value	Second time segment: Annual percent change (standard error)	Second time segment: *p* value	*p* for annual percent change difference between segments
Total										
3–79[1]	2003–2018	-2.79 (0.41)	Less than 0.001	0.305	…	…	…	…	…	…
3–5	1999–2018	…	…	0.028	2005–2006	†0.11 (1.43)	0.937	-4.37 (0.55)	Less than 0.001	0.008
6–19	2003–2018	-3.31 (0.45)	Less than 0.001	0.483	…	…	…	…	…	…
20–39	2003–2018	-2.99 (0.50)	Less than 0.001	0.897	…	…	…	…	…	…
40–59	2003–2018	-2.62 (0.44)	Less than 0.001	0.116	…	…	…	…	…	…
60–79	2003–2018	†-1.61 (0.56)	0.005	0.057	…	…	…	…	…	…
20–79[2]	2003–2018	-2.56 (0.41)	Less than 0.001	0.224	…	…	…	…	…	…
Male										
3–79[1]	2003–2018	-2.88 (0.46)	Less than 0.001	0.338	…	…	…	…	…	…
3–5	1999–2018	…	…	0.035	2005–2006	†2.01 (1.93)	0.295	-3.42 (0.70)	Less than 0.001	0.016
6–19	2003–2018	-2.90 (0.53)	Less than 0.001	0.642	…	…	…	…	…	…
20–39	2003–2018	-3.43 (0.57)	Less than 0.001	0.620	…	…	…	…	…	…
40–59	2003–2018	-2.80 (0.54)	Less than 0.001	0.532	…	…	…	…	…	…
60–79	2003–2018	…	…	0.036	2009–2010	†2.51 (1.81)	0.163	-4.22 (1.25)	0.001	0.016
20–79[2]	2003–2018	-2.83 (0.46)	Less than 0.001	0.263	…	…	…	…	…	…
Female										
3–79[1]	2003–2018	-2.71 (0.41)	Less than 0.001	0.305	…	…	…	…	…	…
3–5	1999–2018	-4.81 (0.58)	Less than 0.001	0.274	…	…	…	…	…	…
6–19	2003–2018	-3.73 (0.49)	Less than 0.001	0.394	…	…	…	…	…	…
20–39	1999–2018	-2.44 (0.45)	Less than 0.001	0.905	…	…	…	…	…	…
40–59	2003–2018	…	…	0.018	2009–2010	†-0.40 (0.88)	0.652	-3.94 (0.75)	Less than 0.001	0.012
60–79	2003–2018	†-1.51 (0.63)	0.019	0.179	…	…	…	…	…	…
20–79[2]	2003–2018	-2.30 (0.41)	Less than 0.001	0.229	…	…	…	…	…	…

… Category not applicable.
† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 19. Geometric mean for blood mercury levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total	Geometric mean[1] (standard error)				
3–79[2]	---	0.63 (0.06)	0.73 (0.07)	0.55 (0.04)	0.56 (0.04)
3–5	---	0.24 (0.04)	0.28 (0.04)	0.18 (0.04)	0.24 (0.03)
6–19	0.29 (0.03)	0.26 (0.03)	0.37 (0.04)	0.30 (0.03)	0.29 (0.03)
20–39	0.66 (0.07)	0.64 (0.09)	0.81 (0.08)	0.51 (0.05)	0.55 (0.06)
40–59	1.03 (0.10)	1.02 (0.11)	0.98 (0.11)	0.79 (0.06)	0.87 (0.07)
60–79	0.88 (0.11)	1.14 (0.14)	1.04 (0.10)	0.89 (0.08)	0.84 (0.06)
20–79[3]	0.83 (0.08)	0.86 (0.10)	0.92 (0.09)	0.68 (0.05)	0.72 (0.06)
Male					
3–79[2]	---	0.65 (0.07)	0.70 (0.07)	0.55 (0.04)	0.56 (0.05)
3–5	---	0.24 (0.05)	0.27 (0.03)	†0.19 (0.06)	0.25 (0.06)
6–19	0.26 (0.04)	0.23 (0.03)	0.35 (0.05)	0.28 (0.04)	0.31 (0.03)
20–39	0.62 (0.07)	0.62 (0.10)	0.86 (0.10)	0.50 (0.08)	0.54 (0.08)
40–59	1.05 (0.11)	1.25 (0.17)	0.89 (0.16)	0.86 (0.06)	0.86 (0.10)
60–79	0.99 (0.13)	1.14 (0.15)	1.01 (0.11)	0.86 (0.09)	0.81 (0.06)
20–79[3]	0.84 (0.08)	0.92 (0.12)	0.90 (0.11)	0.70 (0.05)	0.70 (0.07)
Female					
3–79[2]	---	0.61 (0.06)	0.75 (0.07)	0.55 (0.04)	0.56 (0.04)
3–5	---	0.24 (0.04)	0.31 (0.06)	0.18 (0.04)	0.24 (0.03)
6–19	0.32 (0.03)	0.29 (0.04)	0.40 (0.06)	0.32 (0.03)	0.27 (0.03)
20–39	0.70 (0.09)	0.67 (0.11)	0.77 (0.11)	0.53 (0.06)	0.57 (0.06)
40–59	1.01 (0.11)	0.83 (0.09)	1.08 (0.08)	0.73 (0.08)	0.89 (0.10)
60–79	0.79 (0.10)	1.13 (0.15)	1.08 (0.11)	0.92 (0.09)	0.87 (0.08)
20–79[3]	0.83 (0.09)	0.81 (0.09)	0.94 (0.08)	0.67 (0.06)	0.74 (0.07)

--- Data not available.
† Relative standard error greater than 30%.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 20. Trends in blood mercury levels, by sex and age: Canada, 2007–2017

Sex and age (years)	Survey years	Overall trend: Overall annual percent change (standard error)	Overall trend: *p* value	*p* for quadratic trend
Total				
3–79[1]	2009–2017	†-3.34 (2.01)	0.110	0.750
3–5	2009–2017	†-3.40 (3.35)	0.324	0.430
6–19	2007–2017	†-0.15 (1.76)	0.932	0.417
20–39	2007–2017	†-3.10 (1.75)	0.086	0.266
40–59	2007–2017	†-2.92 (1.43)	0.050	0.858
60–79	2007–2017	†-2.03 (1.56)	0.203	0.079
20–79[2]	2007–2017	†-2.67 (1.42)	0.069	0.391
Male				
3–79[1]	2009–2017	†-3.62 (2.22)	0.117	0.943
3–5	2009–2017	†-2.04 (4.75)	0.673	0.291
6–19	2007–2017	†1.76 (2.17)	0.417	0.827
20–39	2007–2017	†-2.71 (2.15)	0.219	0.146
40–59	2007–2017	†-3.90 (1.77)	0.035	0.947
60–79	2007–2017	†-3.53 (1.55)	0.029	0.228
20–79[2]	2007–2017	†-3.27 (1.55)	0.043	0.338
Female				
3–79[1]	2009–2017	†-3.07 (2.06)	0.149	0.575
3–5	2009–2017	†-4.84 (3.55)	0.190	0.803
6–19	2007–2017	†-2.10 (1.59)	0.198	0.176
20–39	2007–2017	†-3.49 (1.87)	0.072	0.719
40–59	2007–2017	†-1.92 (1.67)	0.260	0.627
60–79	2007–2017	†-0.64 (1.88)	0.736	0.045
20–79[2]	2007–2017	†-2.07 (1.56)	0.195	0.550

† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 21. Geometric mean for red blood cell mercury levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total	Geometric mean[1] (standard error)									
3–79[2]	---	---	1.89 (0.11)	2.04 (0.09)	1.83 (0.10)	1.96 (0.09)	1.66 (0.10)	1.50 (0.08)	1.48 (0.07)	1.36 (0.08)
3–5	0.85 (0.07)	0.95 (0.09)	1.01 (0.07)	1.05 (0.03)	0.73 (0.09)	0.84 (0.07)	0.72 (0.06)	0.67 (0.07)	0.62 (0.06)	0.59 (0.06)
6–19	---	---	1.14 (0.07)	1.21 (0.06)	1.06 (0.04)	1.05 (0.07)	0.94 (0.07)	0.86 (0.06)	0.83 (0.04)	0.72 (0.05)
20–39	---	---	2.09 (0.16)	2.12 (0.11)	2.01 (0.15)	2.03 (0.11)	1.71 (0.14)	1.50 (0.10)	1.60 (0.06)	1.45 (0.11)
40–59	---	---	2.53 (0.15)	2.82 (0.15)	2.59 (0.16)	2.78 (0.12)	2.29 (0.16)	2.15 (0.14)	2.06 (0.13)	1.90 (0.11)
60–79	---	---	2.31 (0.18)	2.71 (0.17)	2.31 (0.14)	2.97 (0.20)	2.62 (0.30)	2.18 (0.13)	2.08 (0.17)	2.06 (0.14)
20–79[3]	---	---	2.29 (0.14)	2.48 (0.11)	2.28 (0.13)	2.47 (0.10)	2.08 (0.14)	1.86 (0.10)	1.86 (0.08)	1.73 (0.10)
Male										
3–79[2]	---	---	1.85 (0.11)	1.95 (0.09)	1.82 (0.12)	1.90 (0.09)	1.62 (0.11)	1.46 (0.09)	1.41 (0.06)	1.33 (0.10)
3–5	0.72 (0.11)	0.82 (0.09)	0.90 (0.09)	0.96 (0.03)	0.75 (0.12)	0.89 (0.12)	0.72 (0.05)	0.75 (0.05)	0.57 (0.09)	0.61 (0.07)
6–19	---	---	1.09 (0.07)	1.16 (0.06)	0.99 (0.05)	1.01 (0.06)	0.89 (0.07)	0.91 (0.07)	0.80 (0.05)	0.71 (0.07)
20–39	---	---	2.03 (0.18)	1.96 (0.12)	2.07 (0.20)	1.93 (0.13)	1.68 (0.14)	1.39 (0.12)	1.45 (0.07)	1.35 (0.10)
40–59	---	---	2.54 (0.16)	2.70 (0.15)	2.52 (0.16)	2.66 (0.16)	2.24 (0.17)	1.99 (0.16)	1.92 (0.15)	1.92 (0.16)
60–79	---	---	2.29 (0.18)	2.84 (0.20)	2.45 (0.14)	3.14 (0.26)	2.62 (0.31)	2.25 (0.21)	2.15 (0.17)	2.07 (0.20)
20–79[3]	---	---	2.27 (0.14)	2.39 (0.12)	2.31 (0.15)	2.40 (0.12)	2.05 (0.14)	1.76 (0.12)	1.75 (0.07)	1.69 (0.12)
Female										
3–79[2]	---	---	1.94 (0.11)	2.13 (0.09)	1.85 (0.08)	2.03 (0.10)	1.70 (0.11)	1.54 (0.09)	1.55 (0.09)	1.39 (0.08)
3–5	1.03 (0.12)	1.10 (0.13)	1.16 (0.10)	1.17 (0.07)	0.72 (0.13)	0.78 (0.07)	0.72 (0.07)	0.59 (0.11)	0.66 (0.08)	0.56 (0.06)
6–19	---	---	1.18 (0.09)	1.27 (0.07)	1.13 (0.04)	1.08 (0.09)	0.99 (0.07)	0.82 (0.07)	0.85 (0.06)	0.73 (0.05)
20–39	2.48 (0.26)	2.09 (0.16)	2.15 (0.17)	2.29 (0.15)	1.96 (0.14)	2.13 (0.13)	1.75 (0.15)	1.62 (0.12)	1.76 (0.08)	1.55 (0.13)
40–59	---	---	2.52 (0.16)	2.93 (0.18)	2.66 (0.18)	2.89 (0.11)	2.35 (0.16)	2.31 (0.12)	2.20 (0.17)	1.88 (0.09)
60–79	---	---	2.33 (0.20)	2.60 (0.17)	2.20 (0.16)	2.84 (0.17)	2.62 (0.31)	2.12 (0.14)	2.03 (0.21)	2.05 (0.16)
20–79[3]	---	---	2.32 (0.15)	2.58 (0.11)	2.26 (0.12)	2.54 (0.10)	2.12 (0.14)	1.96 (0.10)	1.98 (0.10)	1.77 (0.09)

--- Data not available.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 22. Trends in red blood cell mercury levels, by sex and age: United States, 1999–2018

		Overall trend (no quadratic trend detected)			Trends in two time segments (quadratic trend detected)					
						First time segment		Second time segment		
Sex and age (years)	Survey years	Overall annual percent change (standard error)	*p* value	*p* for quadratic trend	Detected joinpoint (survey cycle)	Annual percent change (standard error)	*p* value	Annual percent change (standard error)	*p* value	*p* for annual percent change difference between segments
Total										
3–79[1]	2003–2018	-2.70 (0.42)	Less than 0.001	0.117	…	…	…	…	…	…
3–5	1999–2018	…	…	0.017	2005–2006	†0.53 (1.45)	0.713	-4.34 (0.55)	Less than 0.001	0.005
6–19	2003–2018	-3.23 (0.46)	Less than 0.001	0.277	…	…	…	…	…	…
20–39	2003–2018	-2.90 (0.51)	Less than 0.001	0.566	…	…	…	…	…	…
40–59	2003–2018	…	…	0.033	2009–2010	†-0.27 (0.96)	0.782	-4.15 (0.77)	Less than 0.001	0.011
60–79	2003–2018	…	…	0.019	2009–2010	†2.66 (1.64)	0.102	-4.08 (1.06)	Less than 0.001	0.006
20–79[2]	2003–2018	-2.48 (0.42)	Less than 0.001	0.075	…	…	…	…	…	…
Male										
3–79[1]	2003–2018	-2.75 (0.46)	Less than 0.001	0.149	…	…	…	…	…	…
3–5	1999–2018	…	…	0.027	2005–2006	†2.39 (1.97)	0.222	-3.30 (0.70)	Less than 0.001	0.013
6–19	2003–2018	-2.79 (0.52)	Less than 0.001	0.385	…	…	…	…	…	…
20–39	2003–2018	-3.31 (0.58)	Less than 0.001	0.377	…	…	…	…	…	…
40–59	2003–2018	-2.67 (0.54)	Less than 0.001	0.287	…	…	…	…	…	…
60–79	2003–2018	…	…	0.016	2009–2010	†3.24 (1.81)	0.072	-4.51 (1.26)	0.001	0.006
20–79[2]	2003–2018	-2.72 (0.46)	Less than 0.001	0.110	…	…	…	…	…	…
Female										
3–79[1]	2003–2018	-2.67 (0.42)	Less than 0.001	0.113	…	…	…	…	…	…
3–5	1999–2018	-4.78 (0.58)	Less than 0.001	0.196	…	…	…	…	…	…
6–19	2003–2018	-3.68 (0.50)	Less than 0.001	0.249	…	…	…	…	…	…
20–39	1999–2018	-2.38 (0.46)	Less than 0.001	0.742	…	…	…	…	…	…
40–59	2003–2018	…	…	0.003	2009–2010	†0.16 (0.91)	0.859	-4.31 (0.75)	Less than 0.001	0.002
60–79	2003–2018	†-1.53 (0.63)	0.019	0.067	…	…	…	…	…	…
20–79[2]	2003–2018	-2.26 (0.43)	Less than 0.001	0.073	…	…	…	…	…	…

… Category not applicable.
† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table 23. Geometric mean for red blood cell mercury levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total	Geometric mean[1] (standard error)				
3–79[2]	---	1.53 (0.16)	1.77 (0.16)	1.34 (0.10)	1.36 (0.11)
3–5	---	0.65 (0.10)	0.77 (0.12)	0.52 (0.11)	0.68 (0.09)
6–19	0.71 (0.08)	0.65 (0.07)	0.93 (0.11)	0.76 (0.08)	0.73 (0.08)
20–39	1.58 (0.16)	1.52 (0.22)	1.94 (0.19)	1.23 (0.12)	1.31 (0.13)
40–59	2.47 (0.27)	2.43 (0.27)	2.34 (0.28)	1.89 (0.16)	2.07 (0.17)
60–79	2.11 (0.26)	2.78 (0.33)	2.51 (0.26)	2.15 (0.19)	2.01 (0.15)
20–79[3]	1.99 (0.20)	2.06 (0.23)	2.20 (0.22)	1.64 (0.13)	1.71 (0.14)
Male					
3–79[2]	---	1.49 (0.16)	1.64 (0.17)	1.28 (0.10)	1.30 (0.12)
3–5	---	0.65 (0.13)	0.75 (0.09)	†0.53 (0.17)	0.70 (0.15)
6–19	0.64 (0.09)	0.56 (0.07)	0.85 (0.12)	0.69 (0.10)	0.76 (0.09)
20–39	1.38 (0.17)	1.38 (0.21)	1.93 (0.22)	1.13 (0.17)	1.19 (0.16)
40–59	2.39 (0.27)	2.82 (0.39)	2.03 (0.35)	1.96 (0.14)	1.93 (0.23)
60–79	2.25 (0.29)	2.66 (0.34)	2.34 (0.26)	1.99 (0.20)	1.88 (0.15)
20–79[3]	1.89 (0.18)	2.07 (0.26)	2.04 (0.24)	1.58 (0.12)	1.57 (0.15)
Female					
3–79[2]	---	1.56 (0.16)	1.91 (0.18)	1.41 (0.11)	1.42 (0.12)
3–5	---	0.65 (0.11)	0.82 (0.17)	0.51 (0.11)	0.67 (0.09)
6–19	0.81 (0.07)	0.74 (0.10)	1.01 (0.15)	0.83 (0.09)	0.70 (0.08)
20–39	1.81 (0.23)	1.67 (0.27)	1.95 (0.28)	1.35 (0.15)	1.44 (0.16)
40–59	2.56 (0.30)	2.09 (0.22)	2.70 (0.21)	1.84 (0.21)	2.22 (0.25)
60–79	1.98 (0.26)	2.90 (0.38)	2.69 (0.30)	2.31 (0.23)	2.15 (0.22)
20–79[3]	2.11 (0.24)	2.04 (0.22)	2.37 (0.22)	1.70 (0.15)	1.85 (0.18)

--- Data not available.
† Relative standard error greater than 30%.
[1]Micrograms per liter (µg/L).
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[3]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 24. Trends in red blood cell mercury levels, by sex and age: Canada, 2007–2017

Sex and age (years)	Survey years	Overall trend: Overall annual percent change (standard error)	Overall trend: *p* value	*p* for quadratic trend
Total				
3–79[1]	2009–2017	†-3.34 (2.04)	0.114	0.688
3–5	2009–2017	†-2.76 (3.28)	0.411	0.515
6–19	2007–2017	†0.02 (1.81)	0.990	0.397
20–39	2007–2017	†-3.15 (1.78)	0.087	0.258
40–59	2007–2017	†-3.06 (1.48)	0.047	0.856
60–79	2007–2017	†-2.12 (1.57)	0.187	0.064
20–79[2]	2007–2017	†-2.75 (1.46)	0.068	0.382
Male				
3–79[1]	2009–2017	†-3.62 (2.22)	0.115	0.849
3–5	2009–2017	†-1.46 (4.79)	0.764	0.376
6–19	2007–2017	†1.96 (2.19)	0.370	0.805
20–39	2007–2017	†-2.76 (2.14)	0.209	0.113
40–59	2007–2017	†-4.02 (1.83)	0.035	0.930
60–79	2007–2017	†-3.43 (1.52)	0.031	0.190
20–79[2]	2007–2017	†-3.29 (1.57)	0.044	0.302
Female				
3–79[1]	2009–2017	†-3.08 (2.13)	0.162	0.553
3–5	2009–2017	†-4.13 (3.58)	0.264	0.858
6–19	2007–2017	†-1.96 (1.63)	0.240	0.162
20–39	2007–2017	†-3.54 (1.95)	0.080	0.753
40–59	2007–2017	†-2.07 (1.69)	0.231	0.597
60–79	2007–2017	†-0.89 (1.94)	0.650	0.040
20–79[2]	2007–2017	†-2.21 (1.61)	0.182	0.572

† Relative standard error greater than 30%.
[1]Age adjusted to the projected U.S. Census 2000 population using age groups 3–5, 6–19, 20–39, 40–59, and 60–79 years.
[2]Age adjusted to the projected U.S. Census 2000 population using age groups 20–39, 40–59, and 60–79 years.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table 25. United States–Canada comparison of annual relative changes, by sex

Analyte	Males aged 3–79 years			Females aged 3–79 years		
	Overlapping survey years based on which United States–Canada comparison was made	Ratio of annual relative changes (standard error)[1]	*p* value for testing the ratio of annual relative changes = 1	Overlapping survey years based on which United States–Canada comparison was made	Ratio of annual relative changes (standard error)[1]	*p* value for testing the ratio of annual relative changes = 1
Blood lead	2009–2017	1.01 (0.01)	0.462	2013–2017	1.00 (0.01)	0.815
Red blood cell lead	2009–2017	1.00 (0.01)	0.962	2013–2017	1.00 (0.01)	0.753
Blood cadmium	2009–2017	1.01 (0.01)	0.651	2009–2017	0.98 (0.01)	0.128
Red blood cell cadmium	2009–2017	1.00 (0.01)	0.744	2009–2017	0.98 (0.01)	0.153
Blood mercury	2009–2017	0.99 (0.02)	0.746	2009–2017	1.00 (0.02)	0.865
Red blood cell mercury	2009–2017	0.99 (0.02)	0.703	2009–2017	1.00 (0.02)	0.853

[1]Annual relative change for Canada divided by annual relative change for the United States. The value of 1 for the ratio is equivalent to no difference between annual percentage changes for the two countries (and no difference between time trend slope coefficients for the two countries).

SOURCES: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018; and Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Appendix. Supporting Tables

Table I. Unweighted sample size for geometric mean blood lead levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total										
3–79	7,323	8,135	7,497	7,608	7,530	8,002	7,318	4,714	4,460	6,870
3–5	380	462	459	501	440	420	414	454	429	350
6–19	3,040	3,275	2,937	2,930	2,085	2,192	2,177	1,702	1,588	1,863
20–39	1,477	1,725	1,568	1,711	1,707	1,921	1,772	910	871	1,495
40–59	1,214	1,497	1,285	1,379	1,730	1,935	1,668	936	855	1,589
60–79	1,212	1,176	1,248	1,087	1,568	1,534	1,287	712	717	1,573
20–79	3,903	4,398	4,101	4,177	5,005	5,390	4,727	2,558	2,443	4,657
Male										
3–79	3,580	3,945	3,721	3,693	3,782	3,965	3,677	2,331	2,215	3,346
3–5	205	233	245	248	249	213	222	239	225	173
6–19	1,552	1,624	1,480	1,453	1,082	1,153	1,120	866	797	933
20–39	634	727	731	744	832	890	889	448	416	697
40–59	576	772	633	680	844	953	790	439	410	741
60–79	613	589	632	568	775	756	656	339	367	802
20–79	1,823	2,088	1,996	1,992	2,451	2,599	2,335	1,226	1,193	2,240
Female										
3–79	3,743	4,190	3,776	3,915	3,748	4,037	3,641	2,383	2,245	3,524
3–5	175	229	214	253	191	207	192	215	204	177
6–19	1,488	1,651	1,457	1,477	1,003	1,039	1,057	836	791	930
20–39	843	998	837	967	875	1,031	883	462	455	798
40–59	638	725	652	699	886	982	878	497	445	848
60–79	599	587	616	519	793	778	631	373	350	771
20–79	2,080	2,310	2,105	2,185	2,554	2,791	2,392	1,332	1,250	2,417

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table II. Unweighted sample size for geometric mean blood lead levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total					
3–79	---	6,070	5,538	5,498	4,517
3–5	---	495	471	479	473
6–19	1,855	1,958	1,921	1,899	1,032
20–39	1,165	1,313	1,032	1,074	1,038
40–59	1,220	1,222	1,071	1,051	990
60–79	1,079	1,082	1,043	995	984
20–79	3,464	3,617	3,146	3,120	3,012
Male					
3–79	---	2,940	2,769	2,754	2,257
3–5	---	253	229	249	240
6–19	948	1,011	983	953	514
20–39	514	552	507	532	519
40–59	577	617	538	521	496
60–79	537	507	512	499	488
20–79	1,628	1,676	1,557	1,552	1,503
Female					
3–79	---	3,130	2,769	2,744	2,260
3–5	---	242	242	230	233
6–19	907	947	938	946	518
20–39	651	761	525	542	519
40–59	643	605	533	530	494
60–79	542	575	531	496	496
20–79	1,836	1,941	1,589	1,568	1,509

--- Data not available.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table III. Unweighted sample size for geometric mean red blood cell lead levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total										
3–79	7,320	8,132	7,495	7,583	7,512	7,978	7,307	4,711	4,434	6,867
3–5	379	462	459	496	439	420	411	454	427	350
6–19	3,040	3,274	2,936	2,922	2,080	2,187	2,175	1,700	1,575	1,862
20–39	1,476	1,724	1,567	1,702	1,706	1,913	1,771	910	865	1,495
40–59	1,214	1,496	1,285	1,378	1,726	1,931	1,665	936	853	1,588
60–79	1,211	1,176	1,248	1,085	1,561	1,527	1,285	711	714	1,572
20–79	3,901	4,396	4,100	4,165	4,993	5,371	4,721	2,557	2,432	4,655
Male										
3–79	3,580	3,943	3,720	3,681	3,773	3,951	3,671	2,330	2,202	3,345
3–5	205	233	245	246	249	213	221	239	225	173
6–19	1,552	1,623	1,479	1,449	1,079	1,151	1,119	865	789	933
20–39	634	727	731	740	831	886	888	448	413	697
40–59	576	771	633	679	844	949	789	439	409	740
60–79	613	589	632	567	770	752	654	339	366	802
20–79	1,823	2,087	1,996	1,986	2,445	2,587	2,331	1,226	1,188	2,239
Female										
3–79	3,740	4,189	3,775	3,902	3,739	4,027	3,636	2,381	2,232	3,522
3–5	174	229	214	250	190	207	190	215	202	177
6–19	1,488	1,651	1,457	1,473	1,001	1,036	1,056	835	786	929
20–39	842	997	836	962	875	1,027	883	462	452	798
40–59	638	725	652	699	882	982	876	497	444	848
60–79	598	587	616	518	791	775	631	372	348	770
20–79	2,078	2,309	2,104	2,179	2,548	2,784	2,390	1,331	1,244	2,416

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table IV. Unweighted sample size for geometric mean red blood cell lead levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total					
3–79	---	6,044	5,533	5,495	4,441
3–5	---	494	470	478	467
6–19	1,842	1,952	1,920	1,899	1,024
20–39	1,150	1,311	1,032	1,073	1,016
40–59	1,207	1,217	1,071	1,051	976
60–79	1,059	1,070	1,040	994	958
20–79	3,416	3,598	3,143	3,118	2,950
Male					
3–79	---	2,929	2,767	2,751	2,224
3–5	---	252	228	248	238
6–19	943	1,010	983	953	510
20–39	505	552	507	531	508
40–59	569	614	538	521	490
60–79	528	501	511	498	478
20–79	1,602	1,667	1,556	1,550	1,476
Female					
3–79	---	3,115	2,766	2,744	2,217
3–5	---	242	242	230	229
6–19	899	942	937	946	514
20–39	645	759	525	542	508
40–59	638	603	533	530	486
60–79	531	569	529	496	480
20–79	1,814	1,931	1,587	1,568	1,474

--- Data not available.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table V. Unweighted sample size for geometric mean blood cadmium levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total										
3–79	7,323	8,135	7,497	7,608	7,530	8,002	7,318	4,714	4,460	6,870
3–5	380	462	459	501	440	420	414	454	429	350
6–19	3,040	3,275	2,937	2,930	2,085	2,192	2,177	1,702	1,588	1,863
20–39	1,477	1,725	1,568	1,711	1,707	1,921	1,772	910	871	1,495
40–59	1,214	1,497	1,285	1,379	1,730	1,935	1,668	936	855	1,589
60–79	1,212	1,176	1,248	1,087	1,568	1,534	1,287	712	717	1,573
20–79	3,903	4,398	4,101	4,177	5,005	5,390	4,727	2,558	2,443	4,657
Male										
3–79	3,580	3,945	3,721	3,693	3,782	3,965	3,677	2,331	2,215	3,346
3–5	205	233	245	248	249	213	222	239	225	173
6–19	1,552	1,624	1,480	1,453	1,082	1,153	1,120	866	797	933
20–39	634	727	731	744	832	890	889	448	416	697
40–59	576	772	633	680	844	953	790	439	410	741
60–79	613	589	632	568	775	756	656	339	367	802
20–79	1,823	2,088	1,996	1,992	2,451	2,599	2,335	1,226	1,193	2,240
Female										
3–79	3,743	4,190	3,776	3,915	3,748	4,037	3,641	2,383	2,245	3,524
3–5	175	229	214	253	191	207	192	215	204	177
6–19	1,488	1,651	1,457	1,477	1,003	1,039	1,057	836	791	930
20–39	843	998	837	967	875	1,031	883	462	455	798
40–59	638	725	652	699	886	982	878	497	445	848
60–79	599	587	616	519	793	778	631	373	350	771
20–79	2,080	2,310	2,105	2,185	2,554	2,791	2,392	1,332	1,250	2,417

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table VI. Unweighted sample size for geometric mean blood cadmium levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total					
3–79	---	6,070	5,538	5,497	4,517
3–5	---	495	471	479	473
6–19	1,855	1,958	1,921	1,899	1,032
20–39	1,165	1,313	1,032	1,074	1,038
40–59	1,220	1,222	1,071	1,050	990
60–79	1,079	1,082	1,043	995	984
20–79	3,464	3,617	3,146	3,119	3,012
Male					
3–79	---	2,940	2,769	2,753	2,257
3–5	---	253	229	249	240
6–19	948	1,011	983	953	514
20–39	514	552	507	532	519
40–59	577	617	538	520	496
60–79	537	507	512	499	488
20–79	1,628	1,676	1,557	1,551	1,503
Female					
3–79	---	3,130	2,769	2,744	2,260
3–5	---	242	242	230	233
6–19	907	947	938	946	518
20–39	651	761	525	542	519
40–59	643	605	533	530	494
60–79	542	575	531	496	496
20–79	1,836	1,941	1,589	1,568	1,509

--- Data not available.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table VII. Unweighted sample size for geometric mean red blood cell cadmium levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total										
3–79	7,320	8,132	7,495	7,583	7,512	7,978	7,307	4,711	4,434	6,867
3–5	379	462	459	496	439	420	411	454	427	350
6–19	3,040	3,274	2,936	2,922	2,080	2,187	2,175	1,700	1,575	1,862
20–39	1,476	1,724	1,567	1,702	1,706	1,913	1,771	910	865	1,495
40–59	1,214	1,496	1,285	1,378	1,726	1,931	1,665	936	853	1,588
60–79	1,211	1,176	1,248	1,085	1,561	1,527	1,285	711	714	1,572
20–79	3,901	4,396	4,100	4,165	4,993	5,371	4,721	2,557	2,432	4,655
Male										
3–79	3,580	3,943	3,720	3,681	3,773	3,951	3,671	2,330	2,202	3,345
3–5	205	233	245	246	249	213	221	239	225	173
6–19	1,552	1,623	1,479	1,449	1,079	1,151	1,119	865	789	933
20–39	634	727	731	740	831	886	888	448	413	697
40–59	576	771	633	679	844	949	789	439	409	740
60–79	613	589	632	567	770	752	654	339	366	802
20–79	1,823	2,087	1,996	1,986	2,445	2,587	2,331	1,226	1,188	2,239
Female										
3–79	3,740	4,189	3,775	3,902	3,739	4,027	3,636	2,381	2,232	3,522
3–5	174	229	214	250	190	207	190	215	202	177
6–19	1,488	1,651	1,457	1,473	1,001	1,036	1,056	835	786	929
20–39	842	997	836	962	875	1,027	883	462	452	798
40–59	638	725	652	699	882	982	876	497	444	848
60–79	598	587	616	518	791	775	631	372	348	770
20–79	2,078	2,309	2,104	2,179	2,548	2,784	2,390	1,331	1,244	2,416

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table VIII. Unweighted sample size for geometric mean red blood cell cadmium levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total					
3–79	---	6,044	5,533	5,494	4,441
3–5	---	494	470	478	467
6–19	1,842	1,952	1,920	1,899	1,024
20–39	1,150	1,311	1,032	1,073	1,016
40–59	1,207	1,217	1,071	1,050	976
60–79	1,059	1,070	1,040	994	958
20–79	3,416	3,598	3,143	3,117	2,950
Male					
3–79	---	2,929	2,767	2,750	2,224
3–5	---	252	228	248	238
6–19	943	1,010	983	953	510
20–39	505	552	507	531	508
40–59	569	614	538	520	490
60–79	528	501	511	498	478
20–79	1,602	1,667	1,556	1,549	1,476
Female					
3–79	---	3,115	2,766	2,744	2,217
3–5	---	242	242	230	229
6–19	899	942	937	946	514
20–39	645	759	525	542	508
40–59	638	603	533	530	486
60–79	531	569	529	496	480
20–79	1,814	1,931	1,587	1,568	1,474

--- Data not available.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table IX. Unweighted sample size for geometric mean blood mercury levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total										
3–79	---	---	7,497	7,608	7,530	8,002	7,318	4,714	4,460	6,870
3–5	377	457	459	501	440	420	414	454	429	350
6–19	---	---	2,937	2,930	2,085	2,192	2,177	1,702	1,588	1,863
20–39	---	---	1,568	1,711	1,707	1,921	1,772	910	871	1,495
40–59	---	---	1,285	1,379	1,730	1,935	1,668	936	855	1,589
60–79	---	---	1,248	1,087	1,568	1,534	1,287	712	717	1,573
20–79	---	---	4,101	4,177	5,005	5,390	4,727	2,558	2,443	4,657
Male										
3–79	---	---	3,721	3,693	3,782	3,965	3,677	2,331	2,215	3,346
3–5	205	230	245	248	249	213	222	239	225	173
6–19	---		1,480	1,453	1,082	1,153	1,120	866	797	933
20–39	---	---	731	744	832	890	889	448	416	697
40–59	---	---	633	680	844	953	790	439	410	741
60–79	---	---	632	568	775	756	656	339	367	802
20–79	---	---	1,996	1,992	2,451	2,599	2,335	1,226	1,193	2,240
Female										
3–79	---	---	3,776	3,915	3,748	4,037	3,641	2,383	2,245	3,524
3–5	172	227	214	253	191	207	192	215	204	177
6–19	---	---	1,457	1,477	1,003	1,039	1,057	836	791	930
20–39	842	991	837	967	875	1,031	883	462	455	798
40–59	---	---	652	699	886	982	878	497	445	848
60–79	---	---	616	519	793	778	631	373	350	771
20–79	---	---	2,105	2,185	2,554	2,791	2,392	1,332	1,250	2,417

--- Data not available.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table X. Unweighted sample size for geometric mean blood mercury levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total					
3–79	---	6,070	5,538	5,498	4,488
3–5	---	495	471	479	465
6–19	1,855	1,958	1,921	1,900	1,015
20–39	1,165	1,313	1,032	1,073	1,037
40–59	1,220	1,222	1,071	1,051	987
60–79	1,079	1,082	1,043	995	984
20–79	3,464	3,617	3,146	3,119	3,008
Male					
3–79	---	2,940	2,769	2,754	2,241
3–5	---	253	229	249	234
6–19	948	1,011	983	954	506
20–39	514	552	507	531	518
40–59	577	617	538	521	495
60–79	537	507	512	499	488
20–79	1,628	1,676	1,557	1,551	1,501
Female					
3–79	---	3,130	2,769	2,744	2,247
3–5	---	242	242	230	231
6–19	907	947	938	946	509
20–39	651	761	525	542	519
40–59	643	605	533	530	492
60–79	542	575	531	496	496
20–79	1,836	1,941	1,589	1,568	1,507

--- Data not available.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

Table XI. Unweighted sample size for geometric mean red blood cell mercury levels, by survey years, sex, and age: United States, 1999–2018

Sex and age (years)	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
Total										
3–79	---	---	7,495	7,583	7,512	7,978	7,307	4,711	4,434	6,867
3–5	376	457	459	496	439	420	411	454	427	350
6–19	---	---	2,936	2,922	2,080	2,187	2,175	1,700	1,575	1,862
20–39	---	---	1,567	1,702	1,706	1,913	1,771	910	865	1,495
40–59	---	---	1,285	1,378	1,726	1,931	1,665	936	853	1,588
60–79	---	---	1,248	1,085	1,561	1,527	1,285	711	714	1,572
20–79	---	---	4,100	4,165	4,993	5,371	4,721	2,557	2,432	4,655
Male										
3–79	---	---	3,720	3,681	3,773	3,951	3,671	2,330	2,202	3,345
3–5	205	230	245	246	249	213	221	239	225	173
6–19	---	---	1,479	1,449	1,079	1,151	1,119	865	789	933
20–39	---	---	731	740	831	886	888	448	413	697
40–59	---	---	633	679	844	949	789	439	409	740
60–79	---	---	632	567	770	752	654	339	366	802
20–79	---	---	1,996	1,986	2,445	2,587	2,331	1,226	1,188	2,239
Female										
3–79	---	---	3,775	3,902	3,739	4,027	3,636	2,381	2,232	3,522
3–5	171	227	214	250	190	207	190	215	202	177
6–19	---		1,457	1,473	1,001	1,036	1,056	835	786	929
20–39	841	990	836	962	875	1,027	883	462	452	798
40–59	---	---	652	699	882	982	876	497	444	848
60–79	---	---	616	518	791	775	631	372	348	770
20–79	---	---	2,104	2,179	2,548	2,784	2,390	1,331	1,244	2,416

--- Data not available.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–2018.

Table XII. Unweighted sample size for geometric mean red blood cell mercury levels, by survey years, sex, and age: Canada, 2007–2017

Sex and age (years)	2007–2009	2009–2011	2012–2013	2014–2015	2016–2017
Total					
3–79	---	6,044	5,533	5,495	4,412
3–5	---	494	470	478	459
6–19	1,842	1,952	1,920	1,900	1,007
20–39	1,150	1,311	1,032	1,072	1,015
40–59	1,207	1,217	1,071	1,051	973
60–79	1,059	1,070	1,040	994	958
20–79	3,416	3,598	3,143	3,117	2,946
Male					
3–79	---	2,929	2,767	2,751	2,208
3–5	---	252	228	248	232
6–19	943	1,010	983	954	502
20–39	505	552	507	530	507
40–59	569	614	538	521	489
60–79	528	501	511	498	478
20–79	1,602	1,667	1,556	1,549	1,474
Female					
3–79	---	3,115	2,766	2,744	2,204
3–5	---	242	242	230	227
6–19	899	942	937	946	505
20–39	645	759	525	542	508
40–59	638	603	533	530	484
60–79	531	569	529	496	480
20–79	1,814	1,931	1,587	1,568	1,472

--- Data not available.

SOURCE: Statistics Canada, Canadian Health Measures Survey, 2007–2017.

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