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Prevalence of heart attack and stroke and associated risk factors among Inuit in Canada: A comparison with the general Canadian population

Xue Feng Hu, Kavita Singh, Tiff-Annie Kenny, Hing Man Chan*

Department of Biology, University of Ottawa, Ontario, K1N 6N5, Canada

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ABSTRACT

Background: It is generally believed that cardiovascular disease (CVD) is rare in the Inuit population because of their traditional marine-based diet, but the evidence is inconsistent.
Objective: To describe the cardiovascular health profile of Canadian Inuit, including disease prevalence, risk factors, country food consumption, and contaminant exposure, and compare to that of the general Canadian population.
Methods: Cardiovascular outcomes and risk factors were obtained for 2070 Inuit adults aged 20–79 years from the Inuit Health Survey (IHS, 2007–2008) and for 3464 general Canadian adults aged 20–79 years from the Canadian Health Measures Survey, Cycle 1 (CHMS, 2007–2009) and Cycle 3 (2012–2013). Sex- and age-specific (20–39, 40–59, 60–79) estimates are reported. To compare results between the IHS and CHMS, age-standardized estimates were calculated for males and females, using the CHMS as the reference population.
Results: Inuit had higher prevalence of heart attack (3.1% vs. 1.8% females), stroke (2.1% vs. 0.8% males and 2.2% vs. 1.0% females), diabetes (14.6% vs. 9.0% elderly females), obesity (35.8% vs. 24.2% females), and hypertension (12.2% vs. 2.5% young males and 7.5% vs. 2.5% young females). However, Inuit had better blood lipid profile (hyperlipidemia: 29.0% vs. 46.5% males and 28.4% vs. 35.2% females). Metals and persistent organic pollutant exposures were higher among the Inuit compared with general Canadians.
Conclusion: Inuit and the general Canadian population differ in cardiovascular health profiles. Further research is needed to characterize the health transition among Inuit, especially among the youth and female.

1. Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide. It is generally believed that CVD is rare in the Inuit population because of marine-based country foods that are high in essential fatty acids. However, the evidence is inconsistent (Bjerregaard et al., 2003b). The inverse relationship between country foods diet that is rich in n-3 polyunsaturated fatty acids (PUFAs) and the occurrence of CVD was first reported in Inuit from Greenland in the 1970s (Bang et al., 1976; Dyerberg et al., 1978). While the age-standardized mortality and morbidity of CVD have declined dramatically in the developed countries over the last few decades (GBD, 2013 Mortality and Causes of Death Collaborators, 2015), CVD and its risk factors are becoming more prevalent among Inuit (Kue and Rawat, 2012). The epidemiology of ischemic heart disease (IHD) and stroke, the two major types of CVD, differ among Inuit and other circumpolar Indigenous populations (Young, 2012). Whereas lower or comparable IHD mortality has been reported for Inuit in comparison with the general population, higher stroke mortality has been reported in both the Alaska Natives, Greenland Inuit and Sami in Sweden (Bjerregaard and Dyerberg, 1988; Bjerregaard et al., 2003b; Chateau-Degat et al., 2010; Hassler et al., 2005; Schumacher et al., 2003). It is noteworthy that cause-specific mortality and incidence rates among Inuit tend to be variable because of small population size (Institut National de Santé Publique et al., 2006; Nunavik Statistics Program, 2015). Disease prevalence data, which is more stable, may provide better insight into the cardiovascular

Abbreviations: CVD, cardiovascular disease; IHD, ischemic heart disease; n-3 PUFAs, omega-3 polyunsaturated fatty acids; Hg, mercury; Se, selenium; Cd, cadmium; Pb, lead; MeHg, methylmercury; POPs, persistent organic pollutants; PCBs, polychlorinated biphenyls; MEC, mobile examination center; CHMS, Canadian Health Measures Survey; IHS, International Polar Year Inuit Health Survey; ATC, Anatomical Therapeutic Chemical Classification; BMI, body mass index; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein; LOD, limits of detection; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; GM, geometric mean

* Corresponding author. 30 Marie Curie, Ottawa, ON, K1N 6N5, Canada.
E-mail address: laurie.chan@uottawa.ca (H.M. Chan).

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health of Inuit.

Inuit are experiencing rapid changes in diet and lifestyle, which may be contributing to the increasing risk of cardiovascular disease (Bjerregaard et al., 2004; Dewailly et al., 2001; Kuhnlein and Receveur, 1996). Exposure to methylmercury (MeHg) and persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), is an emerging risk factor for cardiovascular disease (Aminov et al., 2013; Ha et al., 2017; Ruiz et al., 2016). Both MeHg and PCBs have been shown to cause adverse cardiovascular effects in laboratory studies and epidemiological analyses of human populations (Mailloux et al., 2015, 2014; Roman et al., 2011; Valera et al., 2013a, 2013b, 2013c). POPs are known to be transported and accumulated at elevated concentrations in the Arctic ecosystem, particularly marine mammals (Arctic Monitoring and Assessment Programme, 2015). Arctic Indigenous populations are more likely to be exposed to POPs than the general populations because of country diets that include marine mammals (Laird et al., 2013b, 2013a). Inuit populations in Greenland and Canada have higher blood levels of MeHg and PCBs compared to the general populations (Laird et al., 2013a; Valera et al., 2009, 2013a).

The objective of the present study is to compare the cardiovascular health profile of Inuit adults residing in northern Canada (Inuit Nunangat) to the general Canadian population, including the prevalence of heart attack, stroke, the levels of established cardiovascular disease risk factors, and environmental contaminant exposures as emerging risk factors. This analysis provides a baseline characterization of cardiovascular health for Inuit in relationship to general Canadians. Given the increasing rates of chronic disease among Inuit communities, it is important to have a sound understanding of the population's cardiovascular health profile to identify potential gaps and needs for public health interventions and health care.

2. Methods

2.1. Study populations

The International Polar Year Inuit Health Survey (IHS, 2007–2008) was conducted in 36 communities, across three regions of the Canadian Inuit Nunangat, Nunatsiavut, Nunavut, and the Inuvialuit Settlement Region (ISR), between 2007 and 2008. Detailed methodology for the IHS has been published elsewhere (Saudny et al., 2012). In brief, baseline data on dietary habits, nutrient status, food security, prevalence, and risk factors for chronic disease (e.g. cardiovascular disease and diabetes), was assessed via questionnaires, dietary interviews, and clinical samples (e.g. anthropometric measurements and blood samples). The survey employed a random sampling of households in each community. Inuit adults 18 years of age and older were invited to participant in the survey. A total of 2595 Inuit adults were invited, of whom 2172 provided blood samples (participation rate 83.7%).

Cardiovascular health profiles for the general Canadian population were obtained from the Canadian Health Measures Survey (CHMS), Cycles 1 2007–2009. A detailed description of the CHMS has been provided elsewhere (Tremblay and Gorber, 2007). The CHMS is a complex multistage survey that was developed to assess the health status and environmental exposures of the civilian, non-institutionalized, Canadian population (Health Canada, 2010). The CHMS targets the population aged 6–79 years living at home and residing in the ten provinces and three territories in Canada. Cycle 1 included sampling from 15 collection sites in Atlantic, Quebec, Ontario, Prairies and British Columbia covering 96.3% of the Canadian population. The CHMS did not collect data from Inuit living in Nunatsiavut, Nunavut, and the Inuvialuit Settlement Region reported by the IHS. As part of the CHMS, household interviews were conducted to collect demographic and socioeconomic data, and information about lifestyle, medical history, and current health status. Physical measurements and collection of biological specimens were conducted during the visit of a mobile examination center (MEC). The survey incorporated survey weights and bootstrap sample weights to produce nationally representative estimates and confidence intervals while accounting for the unequal selection probabilities. The CHMS cycle 1 2007–2009 included approximately 5600 respondents.

The final study sample for this study was based on participants aged 20–79 years of age who had blood samples. It was comprised of 2072 Inuit adults from the IHS 2007–2008 and 3464 individuals without Inuit ethnic background from CHMS, Cycle 1 2007–2009. As a supplementary analysis, we also compared fatty acids profile between the IHS and the CHMS, Cycle 3 2011–2012 (1984 individuals). The two databases analyzed in the project were briefly summarized in Table S1 in the appendix.

2.2. Cardiovascular conditions and established risk factors

Heart attack and stroke were self-reported, and doctor confirmed conditions (details in supplementary files, Table S2). Individuals refused to answer the question or answered “unknown” was coded as “healthy”. Hypertension was defined as systolic blood pressure $\geq$140 mmHg or diastolic blood pressure $\geq$90 mmHg, or taking blood pressure lowering medication. High cholesterol was defined as low-density lipoprotein cholesterol (LDL-C) $\geq$ 3.5 mmol/L or taking cholesterol-lowering medication. Diabetes was defined as fasting glucose $\geq$7.0 mmol/L or taking blood glucose lowering medication. Obesity was defined as body mass index (BMI) $\geq$ 30 kg/m^2. Medication information in the IHS was based on self-reported data from the medication and supplement questionnaire. Medication information for CHMS respondents was also based on self-reported data from the medication questionnaire with Anatomical Therapeutic Chemical (ATC) Classification System codes. Both the IHS and the CHMS use automatic devices for blood pressure measurement. For the IHS participants, blood pressure measurements were based on three readings of a BpTRU™ Vital Signs Monitor at 2-min intervals. For the CHMS participants, blood pressure was based on five measurements using an oscillometric blood pressure measurement device at 1-min intervals. Other risk factor data included current smoking status, total cholesterol, high-density lipoprotein cholesterol (HDL-C), C-reactive protein (CRP), and fatty acids.

The blood sampling and laboratory procedures, limits of detection (LOD), and between-day coefficients of variation (CV) of the IHS have been described elsewhere (Laird et al., 2013b, 2013a). Briefly, total mercury (Hg), selenium (Se), cadmium (Cd) and lead (Pb) in whole blood was measured by ICP-MS on an ELAN DRC II instrument. POP concentrations in plasma were analyzed by GC-MS (Laird et al., 2013a). Selected POPs associated with cardiovascular outcomes were reported in the present study: total polychlorinated biphenyls (PCBs), dichlorodiphenyldichloroethylene (p,p’-DDE), trans-nonachlor, oxychlordane, hexachlorocyclohexane (β-HCH), and hexachlorobenzene (HCB). Serum lipids were analyzed by LifeLabs. Fatty acids concentrations in RBC were measured by gas-liquid chromatography (Zhou et al., 2011). The blood sampling procedure of the CHMS has been described elsewhere (Wong and Lye, 2008). Whole laboratory procedures for the CHMS data has been described elsewhere (Haines et al., 2016). The procedure and measurement of fatty acids concentrations are described elsewhere (Nagasaka et al., 2014). Analysis of serum lipids was conducted by the LifeLabs for the IHS and by Health Canada Bureau of Nutritional Sciences laboratories (Ottawa) for the CHMS. Fatty acids concentrations in RBC were measured by gas-liquid chromatography, according to predefined protocols at the Lipid Analytical Laboratories, University of Guelph Research Park (Zhou et al., 2011). The procedure and measurement of fatty acids concentrations for CHMS are described elsewhere (Nagasaka et al., 2014).

2.3. Statistical analysis

For both the IHS and CHMS participants, the prevalence of health

outcomes, mean and corresponding 95% confidence interval (CI) for established continuous risk factors (e.g. blood pressure, RBC fatty acids) are reported by sex and age group. Geometric mean (GM), and the corresponding 95% confidence interval (CI) are reported for log-normally distributed data (i.e. blood concentrations of selected heavy metals and POPs). Whole blood concentrations of heavy metals and selenium are expressed as μg per liter, while plasma concentrations of POPs are described as μg per kg lipid. Values below the LOD were replaced with half the LOD for all statistical tests. Fatty acids were expressed as the weight percentage of total fatty acids in RBC phospholipids (wt %). Percentage of missing values were low in both database, with the highest of 4.3% for BMI measurement in the IHS and 3.3% for BMI in the CHMS cycle 1. No particular pattern of missing values was observed for both the databases.

All analyses were performed using the complex survey module in Stata SE® (version 14). Sample weights and 500 bootstrap weights were used to adjust for sampling design, generate population-representative statistics, and to produce appropriate variance estimation for the CHMS. Sex-specific age-standardized estimates were calculated for the IHS participants using the direct method, to match the CHMS age structure. Two-sample proportion-test was performed to compare the prevalence of health outcomes between the IHS and CHMS participants. A two-sample *t*-test was performed to compare the continuous risk factors (i.e. blood cholesterol, RBC fatty acid profile, body burden of heavy metals, and POPs). The modified Wilcoxon test was used to test the trend of fatty acid profiles and country food intake across age groups, for the IHS participants. Statistical significant results were based on a p-value less than 5% (i.e., $\alpha = 0.05$). Descriptive statistics, such as the prevalence of health outcomes and GMs, were calculated using Statistics Canada guidelines to protect confidentiality and ensure the release of quality estimates. If an estimate in the CHMS was based on fewer than 10 observations, or if the coefficient of variation (CV) was larger than 33.3%, it was not reported.

3. Results

3.1. Disease prevalence

A summary of the results for cardiovascular disease and risk factors for Inuit in relation to the general Canadian population was summarized in Fig. S1, Tables 1 and 2. Table 1 shows the prevalence of metabolic and cardiac diseases for Canadian Inuit and the general Canadian population, stratified by age and sex. The point estimates for both heart attack and stroke are higher for Inuit, relative to the general Canadian population (for both sexes), although there is overlap in the 95% confidence intervals. Hypertension is likewise more prevalent among Inuit, relative to the general Canadian population, particularly among the youngest age category (20–39 years) (Fig. S1A). The prevalence of hyperlipidemia (Fig. S1D), however, is significantly lower among Inuit adults, across all groups, with the most significant difference expressed between Inuit men and men from the general Canadian population. Diabetes point estimates are lower for Inuit. However, there is overlap between the 95% confidence intervals. Among elderly Inuit females 60–79 years of age, diabetes prevalence is higher compared with general Canadians of the same age range (14.6% vs. 9.0%).

3.2. Risk factors for cardiovascular disease and diabetes

Disease risk factors, stratified by sex and age, are presented in Table 2. The prevalence of obesity is higher among Inuit females aged, 20–39, 40–59, and 60–79 years when compared with females of the same group in the general Canadian population. Both systolic and diastolic blood pressure were higher among Inuit (both sexes) of the youngest age group (20–39), compared with Canadians from the general population (Fig. S1 B, C). No significant differences were observed for total cholesterol. IHS participants had lower LDL and higher HDL concentrations, compared to CHMS participants (Fig. S1 E, F). BMI was higher among Inuit females of all age categories. No significant differences were observed for glucose, although older Inuit females tended to have a higher glucose level, compared with older females from the general Canadian population (data not shown). Prevalence of smoking was much higher among Inuit, particularly among younger adults. C-reactive protein was also much higher among older Inuit adults (60–79), compared with older adults from the general Canadian population.

3.3. Heavy metals and persistent organic pollutants

Blood concentrations of heavy metals and selected POPs are presented in Table 3 and Table 4, respectively. All contaminant concentrations were significantly higher in the Inuit compared with the general Canadian population. While blood contaminant levels were generally comparable between sexes in the general Canadian population, higher contaminant levels were observed among Inuit males compared to Inuit females with an exception for selenium and cadmium. Blood levels of both metals (except cadmium) and POPs increased with age among Inuit. Similarly, blood levels of POPs increased with age among general Canadians.

3.4. Fatty acids in red blood cell

RBC fatty acid profiles are presented in Table S3. No obvious differences were observed between sexes, among both the Inuit and general Canadian populations. Inuit had higher eicosapentaenoic acid (EPA) levels, and lower docosahexaenoic acid (DHA), and docosapentaenoic acid (DPA), levels, compared to the general Canadian population. A significant age-dependent trend in EPA, DHA, and DPA, was observed for Inuit, but not general Canadians.

4. Discussion

Inuit living in Canada experience a significant disparity in health status, coincident with socioeconomic and political inequities, relative to the general Canadian population (Adelson, 2005; Reading and Wein, 2009). However, it has been postulated that Inuit benefit from superior cardiovascular health outcomes given the country diet, rich in n-3 PUFAs (Bang et al., 1976). There has been evidence both in support and against this idea. The marine-based diet provides other nutrients, e.g. selenium, and Vitamin D which are also beneficial to cardiovascular health (Kenny et al., 2018; Kuhnlein et al., 2006). At the same time, the high level of mercury and other persistent organic pollutants identified in the country food typically consumed by Inuit have been reported to be associated with adverse cardiovascular health outcomes (Bjerregaard et al., 2001; Kuhnlein and Chan, 2000; Singh et al., 2014).

The present study provides a comprehensive assessment of cardiovascular disease (including risk factors) for Inuit in Canada and the general Canadian population. Some of the health outcomes, e.g., the crude prevalence of CHD, stroke, hypertension, and diabetes in the IHS participants have been reported in previous papers (Hu et al., 2017a, 2017b; 2017c, 2018; Singh and Chan, 2017). The dietary intake of country food and nutrients has also been reported (Kenny et al., 2018). The present work expands on these previous papers by presenting age-standardized disease prevalence and summarizing many emerging risk factors, such as exposure to mercury and POPs, allowing us to better characterize the unique challenges Inuit communities face in the prevention, and management, of chronic disease.

We found that the age-standardized prevalence of heart attack and stroke in Inuit living in northern Canada were higher compared to the general Canadian population. The prevalence of stroke in this study was similar to those previously reported for the Nunavik Inuit (2.5%) and Alaska Eskimos (3.6% in age > 45) (Chateau-Degat et al., 2010; Howard et al., 2010). The higher prevalence of stroke among Inuit is

Table 1
Prevalence of metabolic and cardiac conditions by sex and age in Canadian Inuit (IHS, 2007–2008) and general Canadian population (CHMS, 2007–2009).

	Male		Female	
	Inuit n = 800	General Canadian n = 1622	Inuit n = 1270	General Canadian n = 1832
Heart attack				
Age-standardized[a]	5.0 (3.7–6.7)	3.9 (2.5–5.3)	3.1 (2.2–4.4)	1.8 (0.9–2.8)*
20–39	0.5 (0.1–1.9)	0	0.6 (0.2–1.5)	< Reportable Criteria
40–59	4.7 (3.0–7.3)	3.9 (1.1–6.7)	2.6 (1.6–4.2)	1.8 (0.4–3.3)
60–79	14.6 (9.9–21.2)	11.3 (6.5–16.2)	6.6 (3.8–11.0)	4.6 (2.1–7.2)
Stroke				
Age-standardized[a]	2.1 (1.3–3.3)	0.8 (0.4–1.3)*	2.2 (1.5–3.3)	1.0 (0.4–1.6)*
20–39	0.7 (0.2–2.2)	0*	1.1 (0.6–2.2)	0*
40–59	2.9 (1.6–5.1)	< Reportable Criteria	2.5 (1.5–4.0)	< Reportable Criteria
60–79	3.2 (1.3–7.5)	2.8 (1.2–4.3)	3.5 (1.7–7.3)	2.9 (1.1–4.8)
Diabetes				
Age-standardized[a]	4.4 (3.2–6.0)	5.4 (3.6–7.1)	5.5 (4.3–7.1)	4.1 (2.0–6.3)
20–39	1.2 (0.5–2.9)	< Reportable Criteria	1.1 (0.6–2.2)	< Reportable Criteria
40–59	3.6 (2.2–6.1)	4.5 (1.8–7.2)	4.1 (2.8–6.0)	4.8 (0.5–9.1)
60–79	12.1 (7.8–18.3)	15.1 (9.0–21.2)	14.6 (10.3–20.3)	9.0 (3.7–14.3)*
Hypertension				
Age-standardized[a]	24.8 (22.2–27.6)	21.4 (19.3–23.5)	25.1 (23.0–27.3)	20.9 (19.1–22.6)
20–39	12.2 (9.4–15.8)	2.5 (1.2–3.8)*	7.5 (5.8–9.7)	2.5 (1.2–3.8)*
40–59	24.0 (19.9–28.5)	21.3 (16.4–26.2)	26.1 (22.8–29.8)	19.3 (15.7–22.8)
60–79	54.8 (46.9–62.5)	58.0 (50.9–65.1)	52.5 (45.5–59.4)	56.7 (50.6–62.9)
Hyperlipidemia				
Age-standardized[a]	29.0 (26.2–31.9)	46.5 (40.0–53.0)*	28.4 (26.1–30.7)	35.2 (31.3–39.2)*
20–39	16.5 (13.3–20.4)	32.1 (22.6–41.7)*	11.5 (9.4–14.1)	14.9 (8.7–21.2)*
40–59	32.8 (28.3–37.7)	47.8 (39.2–56.4)*	30.4 (26.9–34.2)	41.1 (32.9–49.2)*
60–79	51.6 (43.7–59.4)	71.4 (64.1–78.7)*	50.0 (43.0–57.0)	59.3 (53.0–65.7)*

*$p < 0.05$.
All estimates are percent (95% CI). Missing rate for is 4.0% for heart attack, 4.3% for stroke, 2.9% for hypertension, 3.3% for diabetes, and 2.6% for hyperlipidemia in the IHS, the corresponding missing rate was less than 0.5% for all the outcomes in the CHMS cycle 1.
[a] Age-standardized to the CHMS Cycle 1 population. Population restricted to 20–79 years of age in CHMS and IHS.

consistent with the higher mortality of cerebrovascular disease documented previously for other circumpolar Indigenous peoples (Bjerregaard and Dyerberg, 1988; Schumacher et al., 2003). The prevalence of heart attack in this study was higher than the Nunavik Inuit (2.5%) (Chateau-Degat et al., 2010), similar to Alaska Eskimos (4.8% in age > 45) (Howard et al., 2010), but lower than the Greenland Inuit (7.1%) (Eika et al., 2008). Further investigation with a uniformed questionnaire and clinical protocol is needed to fully understand whether the difference between the prevalence of MI and IHD observed in Inuit in different circumpolar regions is real or due to the difference in methodology. The findings of the higher prevalence of heart attack and stroke in the present study are somewhat inconsistent with the general notion that Inuit benefit from superior cardiovascular health. One explanation is that the Inuit mortality statistics are not stable given the population size, as suggested by Bjerregaard and colleagues (Bjerregaard et al., 2003b). A more recent example showed that the reported mortality from all CVDs varied from 450 per 100,000 person-years (2000–2003) to 56 per 100,000 person-years (2004–2008) in Nunavik, whereas comparing to 218 and 217 for the province of Quebec as a whole (Institut National de Santé Publique et al., 2006; Nunavik Statistics Program, 2015). Another explanation may be that Inuit used to have superior cardiovascular health in the past (Bang et al., 1976; Kjærgaard et al., 2009). However, recent changes in diet and lifestyles may have increased the risk factors resulting in the increase in the prevalence of cardiovascular diseases (Dewailly et al., 2001).

Many of the modifiable CVD risk factors, such as smoking, blood pressure, and blood cholesterol have been declining since the 1990s in the general Canadian population (Lee et al., 2009). In contrast, many of these risk factors are increasing among Inuit. In the two consecutive health surveys conducted in Nunavik in 1992 and 2004, the smoking rate was found to increase from 74% to 84%, prevalence of obesity (BMI ≥ 30 kg/m^2) from 19% to 49%, and mean systolic blood pressure from around 114 mmHg–118 mmHg (Bjerregaard et al., 2003a; Chateau-Degat et al., 2010; Dewailly et al., 2001). The recently conducted 2017 Nunavik Health Survey will provide more updates on CVD and its risk factors among Nunavik Inuit. Inuit living in Greenland and Nunavik used to have lower blood pressure levels and lower prevalence of hypertension compared to the Danish and Canadian population, respectively (Bjerregaard et al., 1997; Chateau-Degat et al., 2010). The blood pressure levels and prevalence of hypertension were comparable between Inuit and general Canadians overall, which is in line with the findings from Alaska (Howard et al., 2010). The self-reported prevalence of hypertension was 12% in the APS 2012 cycle (Wallace and Susan Wallace, 2014). However, we should note our definition (blood pressure measurement and/or medication use) would classify more people as hypertensive than the self-reported measure. The prevalence of diabetes in Inuit is comparable to general Canadians, which is supported by the Alaska, Nunavik and APS 2012 surveys (Chateau-Degat et al., 2010; Howard et al., 2010; Jørgensen et al., 2012; Jorgensen et al., 2002; Wallace and Susan Wallace, 2014). Although the prevalence of diabetes in Inuit is not high, especially comparing to other Aboriginal communities, it is concerning that the rate is increasing (Public Health Agency of Canada). The prevalence of self-reported prevalence of diabetes among Inuit increased from 2% to 4%, according to APS 2006 and 2012 (Tait, 2008; Wallace and Susan Wallace, 2014). Nevertheless, Inuit continue to enjoy a better blood cholesterol profile compared to general Canadians, and this result is consistent with other studies (Bjerregaard et al., 1997; Chateau-Degat et al., 2010; Howard et al., 2010).

Sex and age differences in cardiovascular health outcomes and risk factors are observed in Inuit. Two issues needed to be addressed. Firstly, whether there is a difference in CVD prevalence and its risk factors between Inuit male and female, youth and elderly. Secondly, whether the sex or age difference follows the same pattern as the general Canadians. The age- and sex-discrepancies in health, compared to the Canadian population may provide more insight into dietary, lifestyle transition and their impact on cardiovascular health among Inuit. Inuit

Table 2
Risk factors by sex and age in Canadian Inuit (IHS, 2007–2008) and general Canadian population (CHMS, 2007–2009).

	Male		Female	
	Inuit n = 800	General Canadian n = 1622	Inuit n = 1270	General Canadian n = 1832
Current Smoker (%)				
Age-standardized[a]	56.2 (53.0–59.3)	23.3 (20.4–26.1)*	57.5 (54.9–60.0)	19.8 (16.7–23.0)*
20–39	67.1 (62.5–71.5)	29.1 (22.9–35.4)*	67.9 (64.4–71.2)	20.8 (16.2–25.5)*
40–59	53.9 (48.9–58.9)	23.4 (17.5–29.3)*	57.8 (53.9–61.7)	23.4 (17.8–28.9)*
60–79	36.9 (29.7–44.8)	11.7 (6.9–16.4)*	38.9 (32.3–45.9)	11.3 (7.6–15.0)*
Obesity				
Age-standardized[a]	22.7 (20.1–25.5)	24.6 (20.8–28.5)	35.8 (33.3–38.3)	24.2 (19.8–28.7)*
20–39	16.3 (13.1–20.2)	19.0 (14.5–23.6)	31.9 (28.6–35.5)	20.9 (15.6–26.3)*
40–59	25.5 (21.4–30.1)	26.9 (20.7–33.1)	37.7 (34.0–41.7)	24.0 (18.2–29.8)*
60–79	31.8 (25.0–39.6)	30.7 (24.7–36.8)	40.4 (33.7–47.4)	30.2 (24.2–36.2)*
SBP (mmHg)				
Age-standardized[a]	120.2 (119.1–121.3)	115.2 (113.8–116.5)*	117.5 (116.5–118.5)	112.8 (108.7–116.9)*
20–39	116.9 (115.5–118.2)	110.0 (108.1–111.8)*	110.2 (109.2–111.2)	101.5 (99.3–103.6)*
40–59	120.7 (118.9–122.5)	116.5 (114.3–118.6)*	118.5 (116.9–120.0)	115.8 (106.6–125.0)
60–79	126.4 (123.3–129.4)	122.5 (120.9–124.0)*	128.8 (125.4–132.1)	127.0 (125.0–129.0)
TC (mmol/L)				
Age-standardized[a]	4.9 (4.9–5.0)	4.9 (4.7–5.0)	5.1 (5.0–5.2)	5.0 (4.8–5.1)
20–39	4.6 (4.5–4.8)	4.7 (4.5–4.8)	4.6 (4.5–4.7)	4.5 (4.3–4.8)
40–59	5.2 (5.0–5.3)	5.0 (4.8–5.1)	5.4 (5.3–5.4)	5.2 (4.9–5.4)
60–79	5.2 (5.0–5.4)	5.0 (4.7–5.3)	5.4 (5.3–5.6)	5.4 (5.2–5.5)
BMI (kg/m^2)				
Age-standardized[a]	27.2 (26.9–27.6)	27.6 (27.2–28.1)	29.2 (28.8–29.6)	28.3 (27.4–29.1)*
20–39	26.0 (25.5–26.6)	26.6 (26.3–26.9)	28.8 (28.2–29.3)	29.4 (27.4–31.5)*
40–59	27.9 (27.3–28.4)	28.3 (27.6–29.1)	29.6 (29.0–30.2)	27.1 (26.3–27.9)*
60–79	28.9 (28.0–29.8)	28.3 (27.8–28.8)	29.8 (28.8–30.8)	28.5 (27.9–29.1)*
CRP (mg/L)				
Age-standardized[a]	3.6 (3.0–4.2)	2.0 (1.7–2.4)*	4.3 (3.1–5.6)	2.4 (2.1–2.6)*
20–39	2.6 (1.7–3.4)	1.8 (1.2–2.3)*	2.8 (2.1–3.4)	1.9 (1.4–2.3)*
40–59	3.3 (2.4–4.1)	2.1 (1.7–2.5)*	3.2 (2.8–3.7)	2.6 (2.1–3.0)*
60–79	6.4 (4.7–8.1)	2.6 (2.2–2.9)*	8.4 (5.2–11.6)	2.9 (2.4–3.5)*

*$p < 0.05$.
All estimates are arithmetic mean/percent (95% CI). Missing rate is 4.9% for obesity, 3.9% for SBP, 4.3% for BMI, and 2.8% for CRP in the IHS, the missing rate is 0.8% for obesity and BMI, and 3.3% for CRP in the CHMS cycle 1, respectively.
[a] Age-standardized to the CHMS Cycle 1 population. Population restricted to 20–79 years of age in CHMS and IHS.

Table 3
Geometric mean (95% CI) of heavy metal concentration in whole blood by sex and age in Canadian Inuit (IHS, 2007–2008) and general Canadian population (CHMS, 2007–2009).

	Male		Female	
	Inuit n = 800	General Canadian n = 1622	Inuit n = 1270	General Canadian n = 1832
Mercury (μg/L)				
Age-standardized[a]	8.4 (7.8–9.1)	0.9 (0.8–1.0)	7.0 (6.5–7.4)	0.8 (0.6–0.9)
20–39	5.2 (4.6–5.8)	0.6 (0.5–0.8)	4.2 (3.8–4.7)	0.7 (0.5–0.9)
40–59	10.0 (9.0–11.1)	1.0 (0.8–1.3)	7.9 (7.2–8.7)	1.0 (0.8–1.3)
60–79	18.2 (15.8–21.1)	1.0 (0.7–1.3)	14.8 (12.8–16.9)	0.8 (0.6–1.1)
Selenium (μg/L)				
Age-standardized[a]	333.1 (320.3–346.6)	209.7 (204.0–215.4)	325.3 (315.0–335.9)	201.2 (196.6–205.9)
20–39	283.9 (269.9–298.7)	211.2 (201.7–220.8)	273.5 (263.4–283.9)	198.8 (193.6–204.0)
40–59	350.5 (330.4–371.8)	209.7 (202.7–216.7)	337.5 (321.7–354.1)	201.4 (197.6–205.6)
60–79	430.3 (386.5–478.7)	206.8 (199.8–213.8)	424.8 (385.5–468.2)	204.9 (196.8–213.0)
Lead (μg/L)				
Age-standardized[a]	45.8 (43.9–47.9)	1.8 (1.7–2.0)	32.7 (31.5–33.9)	1.4 (1.3–1.5)
20–39	34.1 (31.9–36.4)	1.4 (1.3–1.6)	21.0 (19.9–22.2)	0.9 (0.8–1.0)
40–59	53.1 (50.0–56.4)	1.7 (1.6–1.9)	37.7 (35.5–40.0)	1.5 (1.3–1.7)
60–79	67.0 (60.3–74.6)	2.3 (2.1–2.6)	56.7 (51.4–62.4)	1.9 (1.7–2.1)
Cadmium (μg/L)				
Age-standardized[a]	1.6 (1.4–1.7)	0.4 (0.3–0.4)	1.6 (1.5–1.7)	0.5 (0.4–0.6)
20–39	2.0 (1.8–2.3)	0.3 (0.3–0.4)	1.9 (1.7–2.1)	0.4 (0.3–0.4)
40–59	1.5 (1.3–1.7)	0.4 (0.3–0.5)	1.7 (1.5–1.8)	0.6 (0.5–0.7)
60–79	1.0 (0.8–1.2)	0.4 (0.4–0.5)	1.0 (0.8–1.2)	0.5 (0.4–0.6)

The percentage lower than the limit of detection was 1.0% for cadmium and 5.7% for mercury in the CHMS cycle 1, the corresponding percentages were less than 0.1% for the IHS.
[a] Age-standardized to the CHMS Cycle 1 population.

Table 4
Geometric mean (95% CI) of persistent organic pollutant concentrations in plasma by sex and age in Canadian Inuit (IHS, 2007–2008) and general Canadian population (CHMS, 2007–2009).

	Male		Female	
	Inuit n = 800	General Canadian n = 805	Inuit n = 1270	General Canadian n = 891
Total PCBs (μg/kg lipid)				
Age standardized[a]	962.6 (890.4–1040.7)	112.9 (102.5–124.3)	639.2 (598.2–683.0)	115.9 (106.3–126.3)
20–39	493.2 (438.4–554.7)	71.2 (63.9–79.4)	251.3 (228.9–275.9)	75.6 (67.2–85.0)
40–59	1091.9 (948.1–1257.5)	125.4 (111.1–141.5)	798.7 (706.9–902.4)	130.3 (118.1–143.8)
60–79	3025.0 (2502.4–3656.7)	218.9 (194.3–246.6)	2290.8 (1975.8–2656.0)	191.0 (171.3–213.0)
p,p'-DDE (μg/kg lipid)				
Age standardized[a]	403.8 (375.7–434.1)	134.5 (110.9–163.3)	300.2 (283.5–317.9)	172.2 (140.9–210.5)
20–39	241.1 (215.9–269.3)	88.2 (69.5–112.0)	126.4 (115.7–138.2)	102.3 (74.8–139.8)
40–59	458.7 (409.0–514.4)	145.2 (117.3–179.7)	378.8 (344.8–416.1)	195.1 (150.4–253.0)
60–79	914.6 (783.0–1068.3)	259.0 (213.4–314.3)	870.9 (756.5–1002.7)	326.2 (257.1–413.8)
Trans-nonachlor (μg/kg lipid)				
Age standardized[a]	128.3 (116.9–140.8)	5.9 (5.2–6.8)	75.6 (70.2–81.4)	6.0 (5.3–6.9)
20–39	60.9 (52.1–71.1)	3.0 (2.5–3.6)	25.6 (22.7–28.7)	3.1 (2.5–3.9)
40–59	157.8 (138.0–180.4)	7.2 (6.1–8.5)	97.6 (86.6–109.9)	7.4 (6.5–8.5)
60–79	423.8 (349.0–514.5)	14.5 (12.6–16.8)	332.0 (282.8–389.8)	12.7 (10.8–15.0)
Oxychlordane (μg/kg lipid)				
Age standardized[a]	88.2 (79.5–97.9)	4.0 (3.6–4.5)	50.5 (46.5–55.0)	4.4 (4.0–4.9)
20–39	40.0 (33.9–47.2)	2.3 (2.1–2.6)	15.8 (13.9–17.9)	2.3 (2.0–2.7)
40–59	106.9 (91.9–124.4)	4.7 (4.1–5.3)	64.6 (56.5–74.0)	5.3 (4.8–5.9)
60–79	334.9 (264.0–425.0)	8.4 (7.3–9.7)	263.1 (216.4–320.0)	9.2 (8.1–10.4)
β-HCH (μg/kg lipid)				
Age standardized[a]	17.1 (15.7–18.6)	5.5 (4.1–7.3)	12.1 (11.4–12.9)	7.5 (5.4–10.4)
20–39	9.5 (8.4–10.8)	3.3 (2.4–4.5)	4.8 (4.4–5.2)	4.8 (3.1–7.6)
40–59	20.0 (17.6–22.8)	6.6 (4.7–9.3)	15.4 (13.9–17.1)	8.3 (5.3–12.9)
60–79	46.4 (37.4–57.5)	9.8 (7.2–13.4)	43.4 (37.4–50.5)	13.2 (10.6–16.4)
HCB (μg/kg lipid)				
Age standardized[a]	88.5 (82.5–94.8)	8.5 (7.7–9.4)	69.6 (65.9–73.6)	9.8 (8.4–11.4)
20–39	46.1 (41.2–51.5)	6.8 (5.9–7.8)	26.1 (23.8–28.7)	7.0 (5.6–8.7)
40–59	104.3 (93.9–115.8)	9.2 (8.2–10.4)	88.1 (80.6–96.3)	10.2 (8.6–12.1)
60–79	256.8 (219.8–299.9)	10.8 (9.2–12.7)	266.0 (235.3–300.7)	15.8 (13.3–18.7)

Missing rate was 1.9% for PCBs and p,p'-DDE, and 2.0% for the rest of POPS reported in this table in the IHS, the missing rate was 2.2% for PCBs and p,p'-DDE, and 1.8% for the rest of POPs reporting in this table for the CHMS cycle 1, respectively.

[a] Age-standardized to the CHMS Cycle 1 population.

females had a higher prevalence of diabetes and obesity, and higher average BMI and CRP levels compared to Inuit males. The difference in the prevalence of hypertension and hyperlipidemia between male and female Inuit is smaller compared to the difference between male and female general Canadians. Prevalence of CVD and its risk factors are usually higher among the elderly. However, Inuit elderly are doing better in smoking and n-3 relative abundance in RBC compared to Inuit youth, and they are also doing relatively better in the prevalence of stroke, diabetes, hypertension, and the average levels of systolic blood pressure and HDL cholesterol (by comparing to the corresponding age categories in general Canadians).

The pattern of country food consumption may provide a plausible explanation for the observed age and sex differences. Traditional Inuit dietary pattern rich in oily fish and marine mammals is associated with better cardiovascular profiles (Dewailly et al., 2001; Hu et al., 2018). Male and older Inuit consumed more country foods compared to female, and younger, Inuit, respectively (Kenny et al., 2018). The percentage of energy from country foods and the PUFA intake in older Inuit are three times as high as younger Inuit (Kenny et al., 2018). High intake of n-3 PUFAs has been demonstrated to associate with better fatty acid and lipid profile (Kris-Etherton et al., 2002). Likewise, the intake of both selenium and vitamin D intake are two times higher among older Inuit (Kenny et al., 2018). Vitamin D helps to reduce the risk of cardiovascular disease, osteoporosis, and help to maintain muscle function (Holick, 2007). Selenium has been shown to have a protective effect against mercury on various cardiovascular health outcomes (Hu et al., 2017a, 2017c). Over the past 3 decades, the decline of n-3 fatty acid intake and the increase in CVD and its risk factors have occurred simultaneously in Inuit. The n-3 PUFAs levels of participants in the IHS are considerably lower than previously reported values from Greenland, Nunavik, the Baffin Bay and Alaska (Counil et al., 2008; Dewailly et al., 2001; Ebbesson et al., 2005; Proust et al., 2014; Rudkowska et al., 2013).

It is surprising to find that the overall n-3 PUFAs profile among Inuit was comparable to the general Canadian population, although Inuit still had lower n-6 PUFAs and more favourable n-6/n-3 ratio. The n-3 PUFAs levels of participants in the IHS were considerably lower than previously reported values from Greenland, Nunavik, the Baffin Bay and Alaska (Counil et al., 2008; Dewailly et al., 2001; Ebbesson et al., 2005; Proust et al., 2014; Rudkowska et al., 2013). The observed decreasing trend in n-3 fatty acid intake from country food may be one reason. The estimated total n-3 fatty acid intake in Greenland Inuit dropped from 8.5 to 3.8 g/day, from 1976 to 2004 (Deutch et al., 2006). The estimated EPA + DHA intake from country food in the IHS participants was about 2 g/day (Laird et al., 2013b). The difference in fatty acids quantification methods over time and in the total fatty acids identified in each survey may also explain the discrepancy in the reported n-3 fatty acid relative abundances. Over the past 3 decades, the decline of n-3 fatty acid intake and the increase in CVD and its risk factors occurred simultaneously in Inuit. The causal relationship between the two needs further investigation.

Although this study is largely descriptive in nature, the comprehensive description of Inuit cardiovascular health outcomes and risk factors provides a foundation for further inquiry into the role of the Inuit diet in the development or prevention of cardiovascular disease. The cross-sectional design of the IHS precludes the possibility of causally investigating the contribution of diet and lifestyle transition to cardiovascular health. While we have compared Inuit health, as reported in the IHS, to the general Canadian population, as reported in the CHMS Cycles 1, the respective survey designs and methodologies

(e.g. questionnaires, anthropometric and blood measurement protocols), though similar, are not precisely equivalent. The difference in survey questions and cultural differences between Inuit and general Canadians in health perceptions may have also introduced some bias in the comparisons.

Despite the limitations of this study, a better understanding of cardiovascular disease status among Inuit has several important implications. First, diabetes and cardiovascular disease are emerging health concerns in Inuit communities. Hence, a comprehensive portrait of cardiovascular health status can help to inform the development of population-specific public health policies to help prevent the emergence of chronic disease. Furthermore, given the unique challenges of delivering health care in remote northern communities (i.e. high cost of transportation, potential delay in first aid), this information provides important baseline data for future healthcare delivery planning (Canada et al., 2011; Young and Marchildon, 2012). Secondly, country food consumption, despite the high levels of environmental contaminants, supports favourable cardiovascular health outcomes. Country foods have many known benefits for Inuit such as providing nutrients, encouraging physical activity, and promoting cultural values. Although country foods also contain environmental contaminants, the effects of these contaminants on human health, at the levels observed, are largely unclear. These results may also be relevant to other Indigenous peoples residing in coastal marine regions. Ultimately, efforts to support positive health outcomes among Inuit must address the systemic socioeconomic, political and environmental, inequalities, which are recognized as key factors underlying the health inequalities experienced by Indigenous peoples across Canada (Adelson, 2005; McDonald and Trenholm, 2010; Reading and Wein, 2009).

5. Conclusion

We characterized the cardiovascular health profiles of Inuit and the general Canadian population. Inuit had a higher prevalence of heart attack, stroke, diabetes, obesity, and hypertension for certain sex and age-categories. Inuit still showed better blood lipid profile compared to the general Canadian population. Specifically, Inuit female had less favourable cardiovascular health (i.e. higher prevalence of diabetes and obesity), and Inuit youth had a higher prevalence of hypertension. Further research is needed to characterize the health transition among Inuit, especially among the youth and female.

Ethics approval and consent to participate

All work was approved by the research ethics boards of the University of Northern British Columbia, McGill University and the University of Ottawa. Scientific Research Licenses for the IHS were obtained from relevant northern research institutions (the Aurora Research Institute, Northwest Territories and Qaujisaqtulirijikkut, Nunavut).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijheh.2018.12.003.

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