

# Age and Sex-Specific Associations in Health Risk Factors for Chronic Disease: Evidence from the Atlantic Partnership for Tomorrow's Health (PATH) Cohort

## Article

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### Résumé

L'objectif de cette étude était de discerner les facteurs de risque pour la santé des maladies chroniques selon l'âge et le sexe dans une cohorte canadienne. Les participants de la cohorte VOIE Atlantique avec des données visant des facteurs de risque liés à la santé (activité physique, tabagisme, consommation d'alcool, alimentation, IMC) ont été inclus ( $n = 16,165$ ) dans l'étude. Des modèles de régression logistique multinomiale ont été utilisés pour évaluer la relation entre les facteurs de risque, l'âge et le sexe. L'analyse de régression a révélé que la probabilité de présenter des niveaux d'activité physique élevés et d'avoir un IMC  $\geq 25$  était plus basse chez les femmes que chez les hommes pour tous les groupes d'âge, alors que la probabilité d'obésité abdominale était considérablement plus élevée chez les femmes de tous âges. La probabilité de consommer de l'alcool de façon régulière était plus faible chez les femmes que chez les hommes pour tous les groupes d'âge, et celle d'être un fumeur (ancien ou actuel) était plus faible chez les femmes plus âgées, comparativement aux hommes. La probabilité de consommer cinq portions de fruits et légumes ou plus par jour était plus élevée chez les femmes de tous âges que chez les hommes. Des différences significatives hommes-femmes et entre les différents groupes d'âge sont retrouvées pour les facteurs de risque liés à la santé. Les efforts de santé publique doivent tenir compte du rôle joué par le sexe et l'âge dans le cadre de la prise en charge des maladies chroniques chez les adultes canadiens.

### Abstract

The objective of this study was to discern health risk factors for chronic disease by age and sex in a Canadian cohort. Participants of the Atlantic Partnership for Tomorrow's Health (PATH) cohort with health risk factor data (physical activity, smoking, alcohol consumption, diet, body mass index [BMI]) were included ( $n = 16,165$ ). Multivariable logistic regression models were used to evaluate the relationship among health risk factors, age, and sex. Regression analysis revealed that the odds of engaging in high levels of physical activity and having a BMI  $\geq 25$  was lower for females than males across all age groups, whereas the odds of abdominal obesity was substantially higher for females of all ages than for males. The odds of habitually consuming alcohol was lower for females of all ages than for males, and the odds of being a former/current smoker was lower for older (57–74 years of age) females than for males. The odds of consuming five or more servings of fruit and vegetables per day was higher for females of all ages than for males. There are evident differences in health risk factors for males and for females, as well as across age groups, and public health efforts need to account for the role played by sex and age in addressing chronic disease burden in Canadian adults.

### Introduction

Both biological and behavioural differences between men and women affect the development, progression, and management of numerous chronic conditions. Modifiable health risk factors, such as smoking, diet, physical activity, and alcohol consumption contribute to the development of chronic diseases (Ng, Sutradhar, Yao, Wodchis, & Rosella, 2020; Vari et al., 2016). These health risk factors also contribute to the development of clinical risk factors such as overweight/obesity, high blood pressure, dyslipidemia, and high fasting plasma glucose. Lifestyle recommendations are suggested as the first line of defence for the prevention and management of chronic disease, and include engaging in regular physical activity, maintaining a healthy body weight, consuming a good quality diet, consuming moderate amounts of alcohol, and avoiding smoking (Beasley, Firestone, Popp, Russo, & Yi, 2020; Gaudreau et al., 2007; Puddu & Menotti, 2015).

Accumulating literature suggests that risk factors that influence health are sex and gender specific, contributing directly to risk exposure and behaviours (Crimmins, Kim, & Sole-Auro, 2011; Mauvais-Jarvis et al., 2020; O'Neil, Scovelle, Milner, & Kavanagh, 2018; Regitz-Zagrosek, 2012; Vari et al., 2016). For example, men are more likely to smoke (Crimmins et al., 2011) and women are more likely to engage in healthier dietary habits, including higher consumption of fruit and vegetables, and lower frequency of snacking and alcohol consumption (Vari et al., 2016). Crimmins et al. (2011) examined health differences in individuals 50 years of age and older across 13 different countries, and found that overall, women were more likely than men to report arthritis, depressive symptoms, and hypertension, and less likely to be current smokers, be overweight, or report heart disease. More recently, the influence of age and stage of life on health risk factors has come to light (Dash, Hoare, Varsamis, Jennings, & Kingwell, 2019; Hoare, Dash, Jennings, & Kingwell, 2018). Data from the Australian Health Survey indicate distinct patterns for fruit and vegetable consumption, sugar-sweetened beverage intake, the prevalence of overweight/obesity, and level of physical activity among younger (25–51 years of age) compared with older adults ( $\geq 65$  years of age) (Dash et al., 2019). Applying a lifespan approach to research on risk factors for chronic disease has the potential to provide additional insight into the causes of health problems, while also identifying important patterns within different age groups and those that cut across all age groups (Hankivsky, 2007). This type of information may also identify sex-specific key times of life where health intervention or health policies may be most beneficial. A sex-specific lifespan approach is necessary to consider how risk factors for chronic disease change over time; however, this approach is lacking from the existing literature and detailed data on age- and sex-specific modifiable risk factors reported for other countries is limited.

Most concerning is the recent data providing evidence for the strong relationship between mortality and various modifiable risk factors (Alam et al., 2019; Danaei et al., 2009; Global Burden of Disease Study, 2017 Risk Factor Collaborators, 2018). The top risk factors contributing to the burden of disease were recently identified as hypertension, smoking, plasma glucose, and a high body mass index (BMI) (Global Burden of Disease Study, 2017 Risk Factor Collaborators, 2018). Regional analysis has identified smoking and diet as the top health risk factors contributing to disease in Canada (Alam et al., 2019). However, more research is needed to understand how risk factors differ by sex and age. Identifying sex- and age-specific differences in risk behaviours offers an opportunity for the development of health promotion programs tailored to specific groups of individuals to reduce the burden of disease in Canada. Therefore, this study aimed to identify the sex differences in risk factors for chronic diseases in a Canadian cohort during younger (30–46), middle (47–56) and older (57–74) adulthood.

## Methods

### Ethics

Research Ethics Boards in each Atlantic Canada province (Nova Scotia, New Brunswick, Newfoundland and Labrador, and Prince Edward Island) approved the original data collection procedures.

### Study Design and Participants

Participants were part of the Atlantic Partnership for Tomorrow's Health (PATH) study, which is a regional cohort of the Canadian

Partnership for Tomorrow's Health (CanPath, formerly named the Canadian Partnership for Tomorrow Project), a pan-Canadian longitudinal study examining the role of genetic, environmental, behavioural, and lifestyle factors in the development of chronic diseases. Details on recruitment and data collection have been previously described (Dummer et al., 2018; Sweeney et al., 2017). The Atlantic PATH cohort includes 34,169 participants who completed baseline questionnaires between 2009 and 2015. The questionnaires included information about health, lifestyle behaviours, medical history, family health history, and demographic information. Additionally, physical measurements (height, weight, waist and hip circumference, body composition, and blood pressure) were collected on a subset of participants. The Global Burden of Disease Study (GBD) has identified modifiable behavioural risk factors such as tobacco and alcohol use, poor dietary habits, and low physical activity, as well as metabolic risk factors such as high blood pressure, overweight/obesity, hyperglycemia, and hyperlipidemia that are attributable to disease burden for males and females (Global Burden of Disease Study, 2017 Risk Factor Collaborators, 2018). In the Atlantic PATH cohort, data were collected on some of these modifiable and metabolic risk factors such as tobacco, alcohol, diet, physical activity, and overweight/obesity. The current study is a cross-sectional analysis of participants with baseline data on the above-mentioned risk factors, resulting in 16167 total participants. The social and demographic characteristics of the included and excluded participants are found in Supplementary Table S1.

### Demographic and Health Conditions

The Atlantic PATH cohort includes participants 30–74 years of age. To explore differences across adulthood, age categories were created based on the age tertiles of participants within the cohort. The tertiles were categorized as younger (30–46 years), middle (47–56 years), and older (57–74 years) adults. Participants reported their level of education, household income, working status, and marital status. Participants reported physician-diagnosed conditions of high blood pressure, myocardial infarction, stroke, asthma, chronic obstructive pulmonary disease, diabetes, liver cirrhosis, chronic hepatitis, Crohn's disease, ulcerative colitis, irritable bowel syndrome, eczema, lupus, psoriasis, multiple sclerosis, osteoporosis, arthritis, and cancer.

### Health Risk Factors

The health risk factors of interest were BMI, abdominal obesity, physical activity, smoking status, alcohol consumption, and dietary intake of major food groups. For smoking behaviour, participants were categorized as a current smoker (1 cigarette daily or occasionally in the past 30 days), former smoker (ever smoked at least 100 cigarettes, but not in the last 30 days), and never smoked (< 100 cigarettes ever). For alcohol consumption, participants were classified as an abstainer (never), seldom drinker (< 1/month), occasional drinker (1–3 times/month), regular drinker (1–3 times/week), and habitual drinker (4–7 times/week).

A dietary screener questionnaire was used to assess dietary intake over the past 12 months. Dietary questions were modified from the Canadian Diet History Questionnaire (CDHQ-1) and the Physical Activity and Nutrition Survey (PANS) V2. The questions included the number of typical daily servings of fruit, vegetables, grains, and proteins, as well as the frequency of highly processed foods, fast food, desserts, snack foods, and added salt (choosing

rarely/never, servings per day, servings per week, or servings per day) (DeClercq et al., 2017). Physical activity level was assessed using the International Physical Activity Questionnaire (IPAQ). Metabolic equivalents of a task were calculated for each participant and level of physical activity was classified as low/inactive, moderate, and high (Keats et al., 2017).

Height, weight, hip, and waist circumferences were measured by trained personnel in assessment centres or self-reported. Only when measured variables were unavailable were self-reported anthropometric data used to calculate abdominal obesity and BMI (approximately 67% of participants in the current study have a measured waist circumference and 68% have a measured BMI value). Differences in measured and self-reported anthropometric indices and the associations between sex and these indices can be found in the Supplementary Materials (Supplementary Tables S2 and S3). Participants with a BMI of < 18.5, 18.5–24.9, 25.0–29.9, and  $\geq 30.0$  were considered underweight, normal weight, overweight, and obese, respectively. Abdominal obesity was defined as having a waist circumference  $\geq 102$  cm for men and  $\geq 88$  cm for women. Percent body fat was assessed by bioelectrical impedance (Tanita Segmental Body Composition Analyzer).

### Statistical Analysis

IBM SPSS Statistics (version 25) software was used for all statistical analyses. Frequencies and proportions were calculated and presented for each sex and age category. Significant associations between age and demographic and health risk factors were determined by chi-square analysis. Continuous variables were presented as median  $\pm$  interquartile range (IQR) and significant differences across age categories were analyzed using the Kruskal–Wallis test. Multivariable logistic regression models were used to evaluate the relationship among health risk factors, age, and sex (male = 1, female = 2). All lifestyle variables were examined in the same regression model. All models were adjusted for education, income, work, and marital status to account for socioeconomic inequalities (Choi & Marks, 2011; Hazel & Kleyman, 2019). The age-specific associations between sex and health risk factors are presented by odds ratios (OR) with 95 per cent confidence intervals (95% CIs). All data were considered statistically significant at  $p < 0.05$ .

## Results

### Demographic Details across Age Groups

The mean age of participants was 39 years in the younger adult group ( $n = 5330$ ), 52 years in the middle age group ( $n = 5,180$ ), and 62 in the older adult group ( $n = 5,655$ ). Demographic factors by sex and age group are reported in Table 1.

### Chronic Disease across Sex and Age Groups

The prevalence of chronic conditions in females and males differed across the age groups (see Figure 1). In younger females (30–46 years), the top three most prevalent conditions were eczema, asthma, and irritable bowel syndrome, whereas in older females (57–74 years) the top three most prevalent conditions were arthritis, high blood pressure, and cancer. In younger males, the top three most prevalent conditions were high blood pressure, asthma, and eczema. Similar to older women, the top three most prevalent conditions in older men were high blood pressure, arthritis, and cancer.

The frequency of high blood pressure, diabetes, arthritis, and cancer increased across age groups in both females and males, whereas the prevalence of asthma and eczema decreased. Across all age groups, multi-morbidity was higher in females than males, but most striking was the difference in the older adults, where less than 40 per cent of males and nearly 50 per cent of females reported being diagnosed with two or more chronic conditions.

### Health Risk Factors of Chronic Disease across Sex and Age Groups

There are many health risk factors associated with the various chronic diseases listed; therefore, we explored several lifestyle and metabolic risk factors across sex and age groups (Table 2). The proportion of participants considered inactive decreased with age in both females and males, meaning more older adults overall were engaging in moderate to high levels of activity, but a greater proportion of men of all ages were engaging in a high level of activity. A greater proportion of males reported habitual consumption of alcohol compared to females, although habitual consumption across the age groups increased by 11 per cent and 15 per cent in females and males, respectively. Overall, the proportion of current smokers decreased across age groups, and a similar proportion of younger and middle-aged adults had never smoked, but more older females (47%) than older males (38%) had never smoked. A large proportion of females had a normal BMI; however, the proportion of those overweight/obese increased with age whereas the BMI for males appeared much more similar across the age groups. More pronounced was the increase in abdominal obesity across the age groups in both females and males, with 58 per cent of older females and 41 per cent of older males having abdominal obesity.

Snack food frequency ( $\geq 3$  times per week), soft drink frequency ( $\geq 1$  time per week), and fast food frequency ( $\geq 1$  time per week) all decreased whereas dessert/sweets frequency ( $\geq 3$  times per week) increased across age groups in both males and females. The proportion of males consuming soft drinks and fast food one or more times per week was much greater than for females in all age groups. The proportion of females and males consuming fruit across the age groups was similar, with both consuming fewer servings of fruit than vegetables per day. The consumption of three or more servings of vegetables per day increased across age in both females and males. There was a small increase in daily whole grain consumption and a drastic reduction in daily refined grains consumption across age groups in both females and males. In females, total servings of protein per day were similar across age groups but differed in males, and in both sexes, there was an increase in consumption of plant-based proteins across age groups (67–69% of older adults were consuming plant-based proteins daily).

### Sex-specific Association among Health Risk Factors across Age Groups

Using regression models that controlled for covariates such as education, income, work, and marital status, several of the health risk factors were found to be significantly different for females than for males (Table 3). Compared with low/inactive participants, the odds of engaging in high levels of physical activity were between 28 and 37 per cent lower for females than for males. Compared with those who never consume alcohol, the odds of habitually consuming alcohol were between 27 and 63 per cent lower for females of all ages than for males, whereas the odds of consuming alcohol seldom

**Table 1.** Social and demographic characteristics of younger (30–46), middle-aged (47–56), and older (57–74) female and male participants

Age Group (years)	Female						Male					
	Younger (30–46 years)		Middle-Aged (47–56 years)		Older (57–74 years)		Younger (30–46 years)		Middle-Aged (47–56 years)		Older (57–74 years)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Total	3,754	33.8	3,740	33.7	3,601	32.5	1,576	31.1	1,440	28.4	2,054	40.5
Education*#												
≤ High School	323	8.6%	695	18.6%	815	22.6%	208	13.2%	263	18.3%	501	24.4%
College	1,251	33.3%	1,462	39.1%	1,257	34.9%	495	31.4%	527	36.6%	572	27.8%
University	1,527	40.7%	1,109	29.7%	1,020	28.3%	624	39.6%	435	30.2%	539	26.2%
Graduate degree	649	17.3%	468	12.5%	493	13.7%	249	15.8%	215	14.9%	434	21.1%
Missing	–	0.1%	6	0.2%	16	0.4%	0	0.0%	0	0.0%	8	0.4%
Income*#												
<\$25,000	108	2.9%	119	3.2%	263	7.3%	28	1.8%	28	1.9%	76	3.7%
\$25,000 - \$74,999	1,105	29.4%	1,151	30.8%	1,753	48.7%	367	23.3%	336	23.3%	853	41.5%
\$75,000 - \$149,999	1,855	49.4%	1,710	45.7%	1,077	29.9%	863	54.8%	706	49.0%	821	40.0%
≥\$150,000	534	14.2%	580	15.5%	235	6.5%	272	17.3%	305	21.2%	195	9.5%
Missing	152	4.0%	180	4.8%	273	7.6%	46	2.9%	65	4.5%	109	5.3%
Work Status*#												
Employed <sup>a</sup>	3,459	92.1%	3,253	87.0%	1,617	44.9%	1,495	94.9%	1,308	90.8%	972	47.3%
Unemployed	290	7.7%	480	12.8%	1,973	54.8%	74	4.7%	128	8.9%	1,078	52.5%
Missing	5	0.1%	7	0.2%	12	0.3%	7	0.4%	4	0.3%	5	0.2%
Marital Status*#												
Married/living with partner	2,949	78.6%	3,020	80.7%	2,680	74.4%	1,333	84.6%	1,259	87.4%	1,840	89.6%
Divorced	170	4.5%	280	7.5%	340	9.4%	42	2.7%	60	4.2%	86	4.2%
Widowed	21	0.6%	78	2.1%	289	8.0%	–	0.1%	8	0.6%	45	2.2%
Separated	134	3.6%	130	3.5%	97	2.7%	37	2.3%	46	3.2%	34	1.7%
Single, never married	477	12.7%	222	5.9%	187	5.2%	162	10.3%	65	4.5%	46	2.2%
Missing	–	0.1%	10	0.3%	8	0.2%	0	0.0%	–	0.1%	–	0.1%

Note. \*Significant association in females ( $p < 0.05$ ); #Significant association in males ( $p < 0.05$ );

<sup>a</sup>Employed full or part-time.

–Data suppressed because of small cell counts.

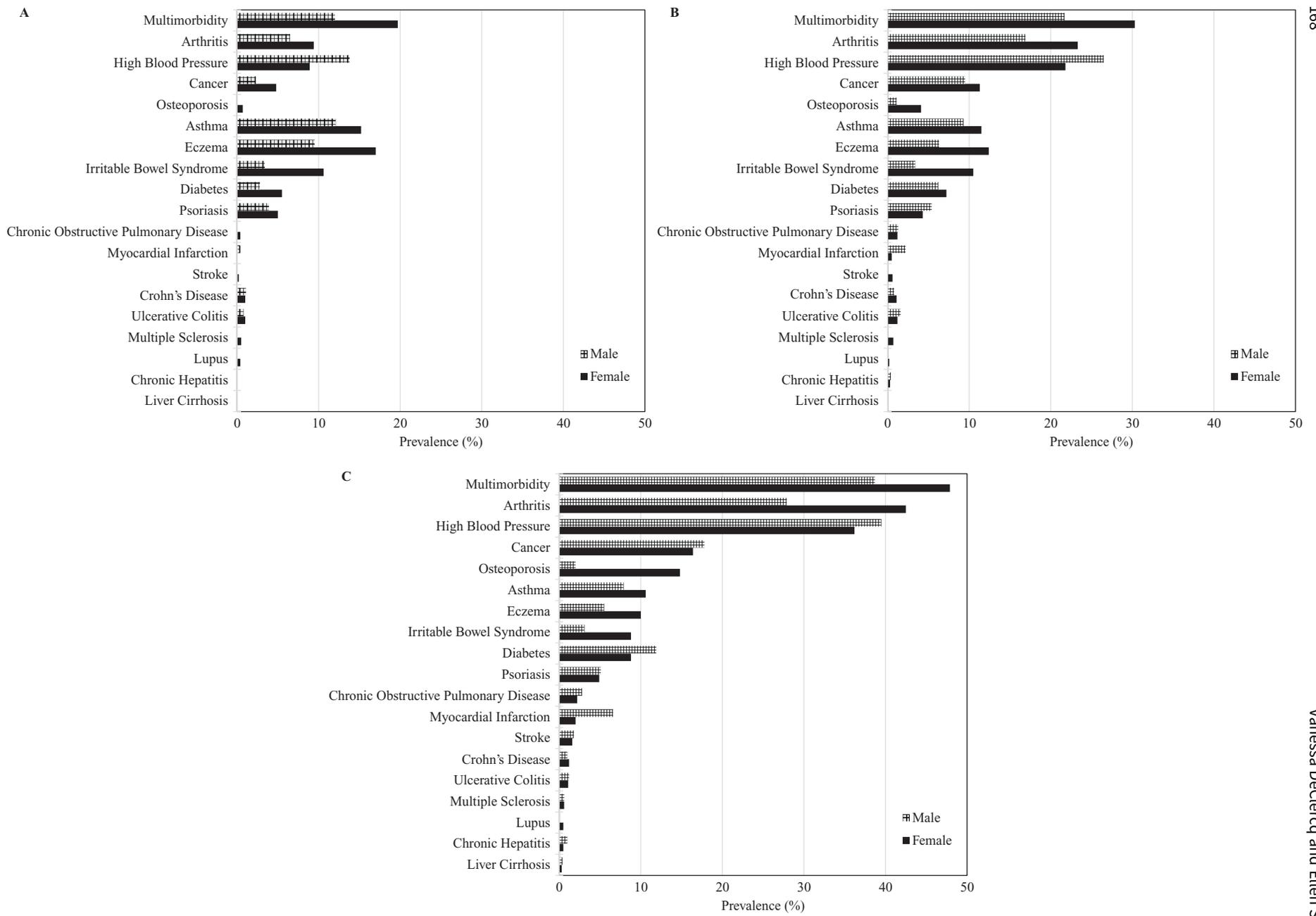
is nearly three times higher for middle and older females than for males. Compared with those who never smoked, the odds of being a former smoker were 29 per cent lower for older females than for older males. Compared with being under/normal weight, the odds of being overweight and obese were 73–84 per cent and 86–93 per cent lower for females than for males, whereas the odds of abdominal obesity were five to nine times higher for females of all ages than for males.

Compared with those who never consumed foods with added sugar such as soft drinks and desserts, the odds of consuming soft drinks up to six times per week were 21–63 per cent lower for females of all ages than for males; there was no difference in dessert consumption between females and males. The frequency of fast food consumption up to six times per week was similar between younger and middle-aged females and males; however, compared with those who never ate fast food, the odds of consuming fast food between twice a month and six times per week was 38–51 per cent lower for older females than for older males. Compared with individuals consuming no servings of fruit/vegetables, the odd of consuming five or more servings per day was five to seven times higher for females of all ages than for males. In contrast, the odds of

consuming five or more servings of whole grains per day compared with consuming none, were between 41 and 61 per cent lower for females of all ages than for males. Compared with consuming no refined grains, the odds of consuming one or more servings per day was between 22 and 55 per cent lower for young females than for younger males but was similar in the middle age group. Compared with consuming no plant protein, the odds of consuming up to four servings per day were similar between females and males; however, compared with those who never consumed plant proteins, the odds of consuming five or more servings per day were 33–34 per cent less for younger and older females than for males in the same age groups.

## Discussion

This study examines aging Canadians living in a region of the country with particularly high rates of chronic disease, and highlights important age and sex differences in health risk factors. These findings are consistent with national health and dietary surveys from the United States and Australia (Dash et al., 2019; Ford, Zhao,



**Figure 1.** Chronic disease in female and male participants by age group. Prevalence (%) of chronic disease in younger (A), middle-aged (B), and older (C) adults.

**Table 2.** Health risk factors across age groups of female and male participants

Age group (years)	Female						Male					
	Younger (30–46 years)		Middle-Aged (47–56 years)		Older (57–74 years)		Younger (30–46 years)		Middle-Aged (47–56 years)		Older (57–74 years)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
<b>Physical activity level<sup>a#</sup></b>												
Low/Inactive	996	26.5%	826	22.1%	733	20.4%	360	22.8%	299	20.8%	374	18.2%
Moderate	1,250	33.3%	1,211	32.4%	1,202	33.4%	421	26.7%	358	24.9%	588	28.6%
High	1,508	40.2%	1,703	45.5%	1,666	46.3%	795	50.4%	783	54.4%	1,092	53.2%
<b>Alcohol consumption<sup>a#</sup></b>												
Never	210	5.6%	236	6.3%	289	8.0%	76	4.8%	100	6.9%	200	9.7%
Seldom	1,071	28.5%	874	23.4%	889	24.7%	183	11.6%	145	10.1%	222	10.8%
Occasional	1,059	28.2%	836	22.4%	765	21.2%	405	25.7%	265	18.4%	335	16.3%
Regular	1,146	30.5%	1,276	34.1%	996	27.7%	680	43.1%	620	43.1%	682	33.2%
Habitual	268	7.1%	518	13.9%	662	18.4%	232	14.7%	310	21.5%	615	29.9%
<b>Smoking status<sup>a#</sup></b>												
Never	2,268	60.4%	1,795	48.0%	1,688	46.9%	954	60.5%	703	48.8%	784	38.2%
Former	1,054	28.1%	1,531	40.9%	1,672	46.4%	405	25.7%	556	38.6%	1,108	53.9%
Current	432	11.5%	414	11.1%	241	6.7%	217	13.8%	181	12.6%	162	7.9%
<b>BMI categories<sup>a#</sup></b>												
Underweight	46	1.2%	24	0.6%	33	0.9%	–	0.3%	–	0.3%	7	0.3%
Normal weight	1,488	39.6%	1,371	36.7%	1,127	31.3%	339	21.5%	265	18.4%	411	20.0%
Overweight	1,140	30.4%	1,221	32.6%	1,343	37.3%	755	47.9%	676	46.9%	968	47.1%
Obese	1,080	28.8%	1,124	30.1%	1,098	30.5%	478	30.3%	495	34.4%	668	32.5%
<b>Abdominal obesity<sup>a*#</sup></b>												
No	1,765	47.0%	1,657	44.3%	1,445	40.1%	1,085	68.8%	906	62.9%	1,179	57.4%
Yes	1,927	51.3%	2,028	54.2%	2,093	58.1%	463	29.4%	508	35.3%	839	40.8%
Missing	62	1.7%	55	1.5%	63	1.7%	28	1.8%	26	1.8%	36	1.8%
<b>Snack food frequency<sup>a#</sup></b>												
Never	252	6.7%	429	11.5%	658	18.3%	107	6.8%	125	8.7%	343	16.7%
≤2 times per week	1,538	41.0%	1,813	48.5%	1,764	49.0%	581	36.9%	626	43.5%	989	48.1%
3–4 times per week	1,138	30.3%	936	25.0%	764	21.2%	515	32.7%	422	29.3%	467	22.7%
≥5 times per week	797	21.2%	520	13.9%	360	10.0%	359	22.8%	250	17.4%	237	11.5%
Missing	29	0.8%	42	1.1%	55	1.5%	14	0.9%	17	1.2%	18	0.9%
<b>Desserts/Sweets frequency<sup>a#</sup></b>												
Never	321	8.6%	419	11.2%	365	10.1%	137	8.7%	152	10.6%	164	8.0%
≤2 times per week	1,375	36.6%	1,389	37.1%	1,125	31.2%	538	34.1%	458	31.8%	660	32.1%
3–4 times per week	997	26.6%	924	24.7%	935	26.0%	415	26.3%	385	26.7%	484	23.6%
≥5 times per week	1,032	27.5%	967	25.9%	1,120	31.1%	472	29.9%	428	29.7%	729	35.5%
Missing	29	0.8%	41	1.1%	56	1.6%	14	0.9%	17	1.2%	17	0.8%
<b>Soft drink frequency<sup>a#</sup></b>												
Never	1,187	31.6%	1,428	38.2%	1,520	42.2%	329	20.9%	336	23.3%	644	31.4%
≤ 3 times per month	1,438	38.3%	1,422	38.0%	1,375	38.2%	527	33.4%	509	35.3%	759	37.0%
1–6 times per week	783	20.9%	621	16.6%	487	13.5%	517	32.8%	445	30.9%	504	24.5%
≥1 time per day	189	5.0%	115	3.1%	111	3.1%	115	7.3%	76	5.3%	70	3.4%
Missing	157	4.2%	154	4.1%	108	3.0%	88	5.6%	74	5.1%	77	3.7%

(Continued)

Table 2. Continued

Age group (years)	Female						Male					
	Younger (30–46 years)		Middle-Aged (47–56 years)		Older (57–74 years)		Younger (30–46 years)		Middle-Aged (47–56 years)		Older (57–74 years)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
<b>Fast food frequency*#</b>												
Never	134	3.6%	275	7.4%	414	11.5%	33	2.1%	64	4.4%	163	7.9%
≤ 1 time per month	1,265	33.7%	1,670	44.7%	1,932	53.7%	394	25.0%	462	32.1%	947	46.1%
2–3 times per month	1,056	28.1%	886	23.7%	723	20.1%	448	28.4%	399	27.7%	501	24.4%
1–6 times per week	1,259	33.5%	859	23.0%	478	13.3%	679	43.1%	488	33.9%	423	20.6%
≥ 1 times per day	15	0.4%	7	0.2%	–	0.1%	7	0.4%	12	0.8%	3	0.1%
Missing	25	0.7%	43	1.1%	50	1.4%	15	1.0%	15	1.0%	17	0.8%
<b>Total fruit</b>												
None	286	7.6%	286	7.6%	290	8.1%	249	15.8%	214	14.9%	327	15.9%
1–2 servings per day	2,127	56.7%	2,109	56.4%	2,048	56.9%	971	61.6%	899	62.4%	1,301	63.3%
3–4 servings per day	1,157	30.8%	1,163	31.1%	1,092	30.3%	284	18.0%	281	19.5%	364	17.7%
≥5 servings per day	184	4.9%	182	4.9%	171	4.7%	72	4.6%	46	3.2%	62	3.0%
<b>Total vegetable**</b>												
None	163	4.3%	116	3.1%	88	2.4%	134	8.5%	98	6.8%	91	4.4%
1–2 servings per day	1,935	51.5%	1,838	49.1%	1,627	45.2%	1,002	63.6%	941	65.3%	1,296	63.1%
3–4 servings per day	1,298	34.6%	1,404	37.5%	1,510	41.9%	358	22.7%	336	23.3%	554	27.0%
≥5 servings per day	358	9.5%	382	10.2%	376	10.4%	82	5.2%	65	4.5%	113	5.5%
<b>Whole grain servings**</b>												
None	460	12.3%	388	10.4%	325	9.0%	248	15.7%	191	13.3%	207	10.1%
1–2 servings per day	2,213	59.0%	2,380	63.6%	2,212	61.4%	889	56.4%	861	59.8%	1,233	60.0%
3–4 servings per day	907	24.2%	844	22.6%	932	25.9%	343	21.8%	312	21.7%	494	24.1%
≥5 servings per day	174	4.6%	128	3.4%	132	3.7%	96	6.1%	76	5.3%	120	5.8%
<b>Refined grain servings**</b>												
None	1,470	39.2%	1,839	49.2%	2,078	57.7%	514	32.6%	609	42.3%	1,081	52.6%
1–2 servings per day	1,992	53.1%	1,688	45.1%	1,382	38.4%	897	56.9%	723	50.2%	842	41.0%
3–4 servings per day	253	6.7%	183	4.9%	118	3.3%	143	9.1%	93	6.5%	109	5.3%
≥5 servings per day	39	1.0%	30	0.8%	23	0.6%	22	1.4%	15	1.0%	22	1.1%
<b>Total protein servings#</b>												
None	19	0.5%	13	0.3%	15	0.4%	11	0.7%	15	1.0%	8	0.4%
1–2 servings per day	259	6.9%	261	7.0%	242	6.7%	86	5.5%	121	8.4%	177	8.6%
3–4 servings per day	1,142	30.4%	1,119	29.9%	1,075	29.9%	416	26.4%	416	28.9%	689	33.5%
≥5 servings per day	2,334	62.2%	2,347	62.8%	2,269	63.0%	1,063	67.4%	888	61.7%	1,180	57.4%
<b>Plant protein servings*#</b>												
None	1,420	37.8%	1,248	33.4%	1,110	30.8%	645	40.9%	546	37.9%	672	32.7%
1 serving per day	1,407	37.5%	1,425	38.1%	1,417	39.4%	550	34.9%	522	36.3%	782	38.1%
2 servings per day	651	17.3%	760	20.3%	773	21.5%	261	16.6%	257	17.8%	416	20.3%
≥3 servings per day	276	7.4%	307	8.2%	301	8.4%	120	7.6%	115	8.0%	184	9.0%
	<b>Median</b>	<b>(IQR)</b>	<b>Median</b>	<b>(IQR)</b>	<b>Median</b>	<b>(IQR)</b>	<b>Median</b>	<b>(IQR)</b>	<b>Median</b>	<b>(IQR)</b>	<b>Median</b>	<b>(IQR)</b>
Percent body fat <sup>§</sup>	34.30	11.50	35.90	10.60	38.00	9.30	22.30	9.05	24.30	8.48	25.60	7.80
Waist (cm) <sup>§</sup>	84.15	18.78	86.50	19.00	89.00	18.00	95.50	15.25	97.50	14.93	99.10	15.20
Waist-to-hip ratio <sup>§</sup>	0.82	0.10	0.84	0.10	0.85	0.10	0.92	0.08	0.93	0.09	0.95	0.10
BMI (kg/m <sup>2</sup> ) <sup>§</sup>	25.40	6.97	25.83	6.91	26.94	6.97	26.91	5.43	27.60	5.21	27.91	5.63

Note. <sup>a</sup>Abdominal obesity = waist circumference ≥ 88 cm for females and ≥ 102 cm for males.

\*Significant association in females (*p* < 0.05).

#Significant association in males (*p* < 0.05).

<sup>§</sup>Significant differences (Kruskal–Wallis Test *p* < 0.05).

–Data suppressed because of small cell counts.

BMI = body mass index; IQR = interquartile range.

**Table 3.** Age stratified association between sex and health behaviours

	Younger (30–46 years)			Middle-Aged (47–56 years)			Older (57–74 years)					
	<i>n</i>	OR	95% CI	<i>n</i>	OR	95% CI	<i>n</i>	OR	95% CI			
<b>Physical activity</b>												
Low/Inactive	1,247	Reference	–	–	1,016	Reference	–	–	1,012	Reference	–	–
Moderate	1,560	1.03	0.84	1.27	1,496	1.08	0.87	1.35	1,695	0.98	1.19	1.26
High	2,173	<b>0.63</b>	<b>0.52</b>	<b>0.76</b>	2,338	<b>0.69</b>	<b>0.56</b>	<b>0.84</b>	2,629	<b>0.72</b>	<b>0.86</b>	<b>0.91</b>
<b>Alcohol consumption</b>												
Never	261	Reference	–	–	307	Reference	–	–	453	Reference	–	–
Seldom	1,147	<b>2.14</b>	<b>1.48</b>	<b>3.09</b>	942	<b>2.83</b>	<b>1.99</b>	<b>4.02</b>	1,043	<b>2.52</b>	<b>1.91</b>	<b>3.31</b>
Occasional	1,362	0.99	0.70	1.40	1,030	<b>1.44</b>	<b>1.03</b>	<b>2.00</b>	1,040	<b>1.55</b>	<b>1.19</b>	<b>2.03</b>
Regular	1,741	<b>0.58</b>	<b>0.41</b>	<b>0.82</b>	1,792	0.86	0.63	1.17	1,584	0.97	0.76	1.25
Habitual	469	<b>0.37</b>	<b>0.25</b>	<b>0.55</b>	779	<b>0.66</b>	<b>0.47</b>	<b>0.93</b>	1,216	<b>0.73</b>	<b>0.56</b>	<b>0.95</b>
<b>Smoking status</b>												
Never	3,036	Reference	–	–	2,363	Reference	–	–	2,360	Reference	–	–
Former	1,370	1.16	0.98	1.38	1,960	1.04	0.89	1.23	2,608	<b>0.71</b>	<b>0.62</b>	<b>0.82</b>
Current	574	1.23	0.97	1.57	527	1.02	0.79	1.31	368	0.77	0.58	1.01
<b>BMI</b>												
Under/Normal weight	1,780	Reference	–	–	1,576	Reference	–	–	1,520	Reference	–	–
Overweight	1,782	<b>0.17</b>	<b>0.14</b>	<b>0.21</b>	1,801	<b>0.16</b>	<b>0.13</b>	<b>0.20</b>	2,174	<b>0.27</b>	<b>0.23</b>	<b>0.32</b>
Obese	1,418	<b>0.07</b>	<b>0.05</b>	<b>0.09</b>	1,473	<b>0.07</b>	<b>0.05</b>	<b>0.09</b>	1,642	<b>0.14</b>	<b>0.11</b>	<b>0.18</b>
<b>Abdominal Obesity<sup>a</sup></b>												
No	2,739	Reference	–	–	2,447	Reference	–	–	2,544	Reference	–	–
Yes	2,241	<b>9.21</b>	<b>7.38</b>	<b>11.49</b>	2,403	<b>7.82</b>	<b>6.31</b>	<b>9.68</b>	2,792	<b>5.17</b>	<b>4.32</b>	<b>6.18</b>
<b>Soft drinks</b>												
Never	1,488	Reference	–	–	1,726	Reference	–	–	2,108	Reference	–	–
≤ 3 times per month	1,927	<b>0.79</b>	<b>0.65</b>	<b>0.95</b>	1,901	<b>0.65</b>	<b>0.54</b>	<b>0.79</b>	2,086	<b>0.77</b>	<b>0.66</b>	<b>0.89</b>
1–6 times per week	1,272	<b>0.54</b>	<b>0.44</b>	<b>0.66</b>	1,040	<b>0.37</b>	<b>0.30</b>	<b>0.46</b>	966	<b>0.49</b>	<b>0.40</b>	<b>0.59</b>
≥ 1 time per day	293	<b>0.52</b>	<b>0.37</b>	<b>0.72</b>	183	<b>0.41</b>	<b>0.28</b>	<b>0.60</b>	176	0.73	0.50	1.06
<b>Desserts</b>												
Never	431	Reference	–	–	539	Reference	–	–	506	Reference	–	–
≤ 2 times per week	1,816	1.27	0.96	1.68	1,760	1.31	1.01	1.70	1,705	0.92	0.71	1.18
3–4 times per week	1,327	1.11	0.83	1.49	1,231	1.13	0.85	1.48	1,359	0.99	0.76	1.29
≥ 5 times per week	1,406	1.00	0.74	1.33	1,320	1.18	0.89	1.55	1,766	0.83	0.65	1.08
<b>Fast food</b>												
Never	165	Reference	–	–	330	Reference	–	–	561	Reference	–	–
≤ 1 time per month	1,597	1.02	0.65	1.61	2,053	1.04	0.74	1.46	2,761	0.80	0.63	1.01
2–3 times per month	1,429	0.82	0.52	1.30	1,214	0.77	0.54	1.11	1,161	<b>0.62</b>	<b>0.47</b>	<b>0.80</b>
1–6 times per week	1,769	0.78	0.49	1.24	1,238	0.70	0.49	1.07	847	<b>0.49</b>	<b>0.37</b>	<b>0.64</b>
≥ 1 times per day	20	1.26	0.36	4.36	15	<b>0.21</b>	<b>0.06</b>	<b>0.91</b>	6	0.57	0.07	4.09
<b>Fruit and Vegetables</b>												
None	139	Reference	–	–	90	Reference	–	–	79	Reference	–	–
1–2 servings per day	959	1.44	0.94	2.21	895	1.60	0.95	2.71	1,037	1.39	0.81	2.36
3–4 servings per day	1,615	<b>2.73</b>	<b>1.78</b>	<b>4.20</b>	1,556	<b>3.29</b>	<b>1.94</b>	<b>5.56</b>	1,719	<b>3.24</b>	<b>1.91</b>	<b>5.51</b>
≥ 5 servings per day	2,267	<b>5.11</b>	<b>3.30</b>	<b>7.92</b>	2,309	<b>7.07</b>	<b>4.13</b>	<b>15.43</b>	2,501	<b>6.55</b>	<b>3.83</b>	<b>11.20</b>

(Continued)

Table 3. Continued

	Younger (30–46 years)				Middle-Aged (47–56 years)				Older (57–74 years)			
	<i>n</i>	OR	95% CI		<i>n</i>	OR	95% CI		<i>n</i>	OR	95% CI	
Plant protein												
None	1,885	Reference	–	–	1,641	Reference	–	–	1,648	Reference	–	–
1-2 servings per day	1,853	0.96	0.81	1.14	1,824	0.96	0.80	1.14	2,075	1.00	0.85	1.17
3-4 servings per day	866	0.83	0.67	1.03	980	0.95	0.76	1.18	1,146	0.95	0.78	1.15
≥5 servings per day	376	<b>0.66</b>	<b>0.49</b>	<b>0.89</b>	405	0.74	0.55	1.00	467	<b>0.67</b>	<b>0.52</b>	<b>0.87</b>
Whole grains												
None	617	Reference	–	–	500	Reference	–	–	481	Reference	–	–
1-2 servings per day	2,901	1.02	0.81	1.29	3,049	1.16	0.90	1.49	3,257	0.95	0.75	1.21
3-4 servings per day	1,201	0.96	0.73	1.26	1,110	<b>0.74</b>	<b>0.55</b>	<b>0.99</b>	1,355	0.78	0.60	1.02
≥5 servings per day	261	<b>0.59</b>	<b>0.41</b>	<b>0.87</b>	191	<b>0.36</b>	<b>0.23</b>	<b>0.55</b>	243	<b>0.36</b>	<b>0.24</b>	<b>0.52</b>
Refined grains												
None	1,855	Reference	–	–	2,299	Reference	–	–	2,982	Reference	–	–
1-2 servings per day	2,705	<b>0.78</b>	<b>0.66</b>	<b>0.91</b>	2,260	0.88	0.75	1.03	2,097	1.00	0.87	1.14
3-4 servings per day	364	<b>0.61</b>	<b>0.46</b>	<b>0.81</b>	248	0.77	0.55	1.08	214	<b>0.63</b>	<b>0.45</b>	<b>0.88</b>
≥5 servings per day	56	<b>0.45</b>	<b>0.24</b>	<b>0.85</b>	43	0.73	0.33	1.60	43	0.84	0.40	1.76

Note. Bold font indicates significant at  $p < 0.05$ . The reference category for the outcome variable is “male”. All ORs are adjusted for education, income, work, and marital status.

\*Waist circumference  $\geq 88$  cm for females and  $\geq 102$  cm for males.

OR = odds ratios; 95% CI = 95% confidence interval.

Tsai, & Li, 2011). In addition, the inclusion of age categories allowed for a more in-depth and thoughtful analysis that demonstrated differences across the lifespan. This allows for the recognition that not all risk factors are present in all populations (Olivares et al., 2017). For example, those in mid-life are at a greater risk of developing chronic disease and frailty than are younger populations (DeClercq, Duhamel, Theou, & Kehler, 2020; Kelly et al., 2016). This also allows for understanding that decisions related to behavioural health risk factors may be directly influenced by factors such as gender and age, which can provide insight into chronic disease outcomes and inform health promotion and intervention initiatives (Dash et al., 2019; Kelly et al., 2016). The addition of risk factors for specific populations has direct implications for surveillance for improving health interventions and the implementation of effective prevention strategies (Olivares et al., 2017). Current Canadian policies and guidelines for modifiable risk factors for adults do not distinguish among age categories. The findings of this research clearly demonstrate that public health efforts that target all adults (18 years of age and older) as a single homogeneous group do not adequately meet the needs of a diverse population.

Although there is limited literature examining behavioural and metabolic health risk factors for chronic disease using a lifespan approach among males and females, our results support the recently published research from the Australian Health Survey, which also utilized three age categories (21–51, 52–64, and  $\geq 65$ ) (Dash et al., 2019). The Australian Health Survey found that there were differences in adherence to lifestyle behaviours that are protective against the risk of chronic disease between sexes and across age categories (Dash et al., 2019). Likewise, the engagement of Atlantic PATH participants in protective health behaviours varied across age categories (e.g., smoking status or fast food frequency) and between sexes (e.g., consumption of alcohol or fruit/vegetables).

Similar to the Australian Health Survey, we found that females had lower levels of physical activity. However, we observed that the

overall activity levels of females and males increased with age, whereas the Australian study showed fewer adults meeting physical activity guidelines with age (Dash et al., 2019). It is worth noting differences in the age groups and methods of recruitment between the two studies. Nevertheless, differences among countries or within specific regions deserve particular attention for public health and policy development. For example, physical activity levels differ across regions in Canada, with the west coast reporting some of the highest levels of activity. The lowest levels of activity are found on the east coast, including the Atlantic PATH population (Dummer et al., 2018).

Whereas smoking rates among Atlantic PATH participants declined with age, Alam et al. (2019) demonstrate that overall smoking remains a primary risk factor for disease burden in Canada. Another recent Canadian study found that current heavy smokers had an increased risk of chronic disease, and that former heavy smokers had a greater risk than former light smokers (Ng et al., 2020). Specifically, there was an association between current smoking and chronic obstructive respiratory disease, diabetes, lung cancer, myocardial infarction, and stroke among females and an association between current smoking and chronic obstructive respiratory disease, myocardial infarction, and lung cancer among males (Ng et al., 2020).

There were noteworthy findings related to the frequency of alcohol consumption across age groups among Atlantic PATH participants. Whereas younger and middle-aged females were less likely overall to habitually consume alcohol, the frequency of both female and male participants consuming alcohol four or more times a week increased as participants aged. The number of drinks consumed should be examined, as well as the social context of consuming alcohol, because it is well established that the frequency of alcohol consumption with age increases the risk of several chronic diseases (Fernandez-Sola, 2015; Rehm et al., 2017; Shield, Parry, & Rehm, 2013; Smyth et al., 2015), whereas in some situations consuming alcohol may offer social benefits (Dare, Wilkinson, Allsop,

Waters, & McHale, 2014; Public Health Agency of Canada, 2016). A community-based longitudinal survey by Moos, Schutte, Brennan, and Moos (2009) in the United States found that habitual drinking among older adults declined over a 20-year period, as adults entered their seventies and eighties (baseline 55–65 years). However, they also found that among adults 75–85 years of age, more than one quarter of women and nearly half of men were consuming more than two drinks per day. The rates of alcohol consumption among Atlantic PATH participants were also highest among older adults, and among older males in particular. These findings highlight the role that alcohol consumption plays in an aging population, and support recommendations that alcohol guidelines and policies for older adult men should not be set higher than those for women (Moos et al., 2009).

The analysis by age also allowed for some interesting insights into the dietary choices of participants. Health Canada's newly published *Dietary Guidelines for Health Professionals and Policy Makers* represent a shift away from a focus on the number of servings eaten, and towards more generalized recommendations on food choices and eating habits. Although the complete version of Canada's Food Guide has not yet been published, there is a clear emphasis on limiting processed foods that contain excess sodium, sugars, or saturated fats and towards the consumption of plant-based foods including vegetables, fruit, whole grains, and plant-based proteins in order to prevent chronic disease. Interestingly, whereas studies such as the National Health and Nutrition Examination Survey have found that adults eat less protein as they age and are less likely to consume plant-based proteins (Beasley et al., 2020), we found that protein consumption increased as females aged and that plant-based protein consumption increased across all age groups. Some participants were consuming foods that align with the new Canadian guidelines. Consistent with the literature, overall, more females than males engaged in healthier dietary choices (Grzymislawski, Puch, Zawada, & Grzymislawski, 2020; Vari et al., 2016). Also similar to the findings of the Australian Health Survey, we found that more adults consumed fruit and vegetables as they aged, with more females doing this than males suggesting that female participants are continuing to choose healthier dietary choices as they age (Dash et al., 2019).

Although older adults had a higher frequency of desserts/sweets consumption, younger adults reported a higher frequency of consuming snack foods, fast food, and soft drinks which may reflect a generational divide in snack/dessert preferences. The highest rates of sugar-sweetened beverage consumption occurred in the younger age category and decreased with age, which is also in line with the Australian findings. For example, the greatest proportion of participants consuming soft drinks at least once per week were the younger groups, whereas a larger proportion of participants in the older age group reported never consuming soft drinks in the current study. However, across all ages, weekly consumption was higher for males than for females. Sugar-sweetened beverages, including the soft drinks examined in this study, are a well-established source of caloric sweeteners linked to increased risk of chronic disease, including obesity, hypertension, type 2 diabetes, and coronary heart disease (Hu & Malik, 2010; Malik & Hu, 2019; Schwingshackl et al., 2017). Most recently, findings from the French NutriNet Sante cohort demonstrated a positive association with sugar-sweetened beverages and overall cancer risk and breast cancer risk, warranting additional exploration in this area (Chazelas et al., 2019).

The Australian Health Survey reported on combined overweight and obesity categories. When combining the overweight and obese categories in Atlantic PATH, our data were higher in

each of the three age categories, although the age range between the two studies differs slightly. The value found in separating the overweight and obesity categories in these data is best reflected in our female participants. Whereas the obesity rates remain relatively stable among the three age groups, there is a notable increase in female participants who are overweight as they age. This is particularly striking when coupled with the increased abdominal obesity as participants age, despite engaging in positive health behaviours, such as diet and physical activity. The rates of obesity and abdominal obesity among female participants place them at an increased risk for several chronic diseases as they age, including high blood pressure, diabetes, and cancer (Folsom et al., 2000).

The behavioural health risk factors examined are reflected in the high rates of chronic disease and multi-morbidity in Atlantic Canada and among the Atlantic PATH population (Keats et al., 2017). Whereas the prevalence of high blood pressure was higher in male participants across all three age groups, the prevalence of asthma, irritable bowel syndrome, and arthritis was higher across all ages in females. The most striking difference in prevalent chronic conditions was found in participants with arthritis. Given the high rates of multi-morbidity in this cohort, females with arthritis are likely living with multiple chronic conditions, further impacting their quality of life.

Many educational campaigns on risk behaviours and the prevention of chronic disease are implemented by national governments, charities, and non-profit organizations, and those that are local are supported by data and messaging from the national level. The findings of this research from Atlantic Canada highlight the need for considering region-specific campaigns, as well as the clear importance of sex- and age-specific content in order to best meet the needs of an aging population.

We acknowledge that this study has some limitations. There are potential limitations in relying on self-reported data. Two issues related to self-reported data are incomplete questionnaires or missing data, which could contribute to biases. Several participants in the Atlantic PATH cohort were missing data on the risk factors of interest and were excluded from the current analysis (Supplementary Table S1). We acknowledge that some characteristics differ between the included and excluded participants; however, in most cases, the proportions tend to reflect similar patterns. For example, a large majority of participants were living in urban centres, had a college or higher level of education, were employed, had an annual household income between \$25,000 and \$150,000, and were married/living with a partner. Another limitation of self-reported data is under- or over-reporting. For example, the IPAQ is a valid tool used to measure physical activity, but the levels reported may be overestimated. There are also limitations in self-reported dietary data when participants are required to recall past dietary habits over an extended period of time, as well as a possible bias for over-reporting healthy and under-reporting unhealthy dietary options. However, self-reported data are commonly used in longitudinal cohort studies and are supplemented where possible with measured data (e.g., measured anthropometric data). This research represents the baseline period of data collection and is necessarily cross-sectional. The longitudinal nature of the Atlantic PATH cohort will allow us to expand on this work by following health risk factors over time, as well as incident chronic disease outcomes. We will also be able to examine age- and sex-specific similarities and differences across Canada with the regional CanPath cohorts in future research. This study also has several strengths. Although much of the research on health risk factors has primarily focused on sex differences, our study was able to examine both sex differences

and age categories, which allows for a life course approach in considering behaviour and risk for chronic disease. This study also benefits from the inclusion of a large participant base across four Canadian provinces and the assessment of multiple health risk factors at one time point.

## Conclusions

Lifestyle behaviours are recommended for the prevention and management of chronic diseases. The findings of this study, supported by international research, demonstrate the differences in health risk factors between males and females in a Canadian adult population, as well as across age groups. There have been successful public health efforts targeting modifiable risk behaviours, such as anti-smoking campaigns, which are reflected in decreased smoking rates overall (Centers for Disease Control and Prevention, 2016; Durkin, Brennan, & Wakefield, 2012; Golechha, 2016; Health Canada, 2018), and the lower rates of smoking found in younger participants. This study highlights a key opportunity to tailor education efforts and public health interventions to specific populations. Although this study focused on adults, a truly life course approach to the prevention of chronic disease would also include efforts focused on youth and adolescents in order to instill positive lifestyle choices at an early age, which can influence health outcomes in adulthood (Hoare et al., 2018). We recommend that public health efforts in Atlantic Canada account for the role played by sex, gender and age in decision making and risk behaviours, in order to address the high rates of cancer and other chronic diseases in this region.

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