RESEARCH ARTICLE

Identity and COVID-19 in Canada: Gender, ethnicity, and minority status

Roland Pongou[1], Bright Opoku Ahinkorah[2], Marie Christelle Mabeu[3], Arunika Agarwal[4], Stéphanie Maltais[5,6], Aissata Boubacar Moumouni[1], Sanni Yaya[5,7] *

1 Department of Economics, Faculty of Social Sciences, University of Ottawa, Ottawa, Ontario, Canada, **2** School of Public Health, Faculty of Health, University of Technology Sydney, Ultimo, NSW, Australia, **3** Department of Economics, Stanford University, Stanford, California, United States of America, **4** Department of Global Health and Population, Harvard T.H. Chan School of Public Health, Boston, MA, United States of America, **5** School of International Development and Global Studies, Faculty of Social Sciences, University of Ottawa, Ottawa, Ontario, Canada, **6** The Public Health Agency of Canada (PHAC), Ottawa, Ontario, Canada, **7** The George Institute for Global Health, Imperial College London, London, United Kingdom

* sanni.yaya@uOttawa.ca

Abstract

Background

During the COVID-19 pandemic, growing evidence from the United States, the United Kingdom, and China has demonstrated the unequal social and economic burden of this health crisis. Yet, in Canada, studies assessing the socioeconomic and demographic determinants of COVID-19, and how these determinants vary by gender and ethnic minority status, remain scarce. As new strains of COVID-19 emerge, it is important to understand the disparities to be able to initiate policies and interventions that target and prioritise the most at-risk sub-populations.

Aim

The objective of this study is to assess the socioeconomic and demographic factors associated with COVID-19-related symptoms in Canada, and how these determinants vary by identity factors including gender and visible minority status.

Methods

We implemented an online survey and collected a nationally representative sample of 2,829 individual responses. The original data collected via the SurveyMonkey platform were analysed using a cross-sectional study. The outcome variables were COVID-19-related symptoms among respondents and their household members. The exposure variables were socioeconomic and demographic factors including gender and ethnicity as well as age, province, minority status, level of education, total annual income in 2019, and number of household members. Descriptive statistics, chi-square tests, and multivariable logistic regression analyses were performed to test the associations. The results were presented as adjusted odds ratios (aORs) at $p < 0.05$ and a 95% confidence interval.

Data Availability Statement: The survey data cannot be shared publicly as they hold potentially attributable sensitive information regarding the participants. It would therefore be unethical to

Results

We found that the odds of having COVID-19-related symptoms were higher among respondents who belong to mixed race [aOR = 2.77; CI = 1.18–6.48] and among those who lived in provinces other than Ontario and Quebec [aOR = 1.88; CI = 1.08–3.28]. There were no significant differences in COVID-19 symptoms between males and females, however, we did find a significant association between the province, ethnicity, and reported COVID-19 symptoms for female respondents but not for males. The likelihood of having COVID-19-related symptoms was also lower among respondents whose total income was $100,000 or more in 2019 [aOR = 0.18; CI = 0.07–0.45], and among those aged 45–64 [aOR = 0.63; CI = 0.41–0.98] and 65–84 [aOR = 0.42; CI = 0.28–0.64]. These latter associations were stronger among non-visible minorities. Among visible minorities, being black or of the mixed race and living in Alberta were associated with higher odds of COVID-19-related symptoms.

Conclusion

We conclude that ethnicity, age, total income in 2019, and province were significantly associated with experiencing COVID-19 symptoms in Canada. The significance of these determinants varied by gender and minority status. Considering our findings, it will be prudent to have COVID-19 mitigation strategies including screening, testing, and other prevention policies targeted toward the vulnerable populations. These strategies should also be designed to be specific to each gender category and ethnic group, and to account for minority status.

Introduction

The first case of the novel Coronavirus, also known as SARS-CoV-2 or COVID-19, was reported in Wuhan, Hubei Province in China in December 2019 [1]. In a few days, on January 13, 2020, Thailand, reported the first case of COVID-19 [2]. Subsequently, the disease spread to multiple countries, and by January 30, 2020, the World Health Organization (WHO) declared COVID-19 a public health emergency of international concern [3]. Thereafter, the spread of the disease led to the WHO declaring it a global pandemic [4]. Canada was not spared of this pandemic, and since its start, the country has recorded more than 3.5 million cases and more than 37,000 deaths [5].

COVID-19 spreads through human contact or respiratory droplets [2]. According to the WHO, the most common symptoms of COVID-19 are fever, dry cough, and tiredness [3, 7]. Other less common symptoms include aches and pains, headaches, a rash on skin, or discolouration of fingers or toes, loss of smell and taste, sore throat, conjunctivitis, and diarrhoea [6, 7]. These symptoms are expected to be developed within 1–14 days after infection; however, the average incubation time is 5–6 days after infection [6]. In severe cases, it could cause pneumonia, respiratory failure, septic shock, or multiple organ dysfunction or failure [6]. The WHO also identifies difficulty breathing or shortness of breath, chest pain or pressure, and loss of speech or movement as some of the serious symptoms of COVID-19 that require immediate medical attention [7].

In countries such as the United States (U.S), a number of studies demonstrate that racial/ethnic minorities and individuals from segregated areas and low-income backgrounds are more likely to become infected and die from COVID-19 [8–12]. Moreover, other important

socio-demographic and biological characteristics including age, gender, and presence of underlying chronic non-communicable problems (e.g., cardiovascular diseases, hypertension, diabetes, obesity, and chronic obstructive pulmonary disease) increase people's risk of COVID-19 infection and death [13, 14].

Concerning Canada, studies assessing the socio-economic determinants of COVID outcomes, and how they vary by identity factors such as gender and ethnic minority status, remain scarce. This is likely due to limited individual-level data on socio-economic characteristics and their relationship with COVID outcomes, which has prevented a systematic assessment of the socioeconomic and demographic determinants of COVID-19 outcomes in this country. Nevertheless, a few studies exist. For instance, Lapointe-Shaw et al. conducted a syndromic analysis of COVID-19 symptoms in Canada, which found that the prevalence of reporting a combination of fever with cough or shortness of breath is higher among visible minorities [15]. Relatedly, St-Denis' study revealed that being a female, older age, and having lower income were associated with a greater risk of exposure [16]; however, their scope was limited to socio-demographic determinants of occupational risk of exposure to COVID-19. Another study found that being a female and having lower education exacerbated infection risk inequities [17]. Similarly, Wu et al.'s study of the level and predictors of COVID-19 symptoms among the Canadian population revealed that 8% of Canadians reported that they and/or one or more household members experienced COVID-19 symptoms and that the risk of COVID-19 symptoms was higher among younger adults and visible minorities [18]. Our study further builds upon the findings of Wu et al. [18], with the difference in the time periods of the two studies, as well as looking more closely at gender and ethnic disparities in the prevalence of COVID-19 symptoms. We analyse how the socioeconomic and demographic determinants of COVID-19 symptoms differ by gender and visible minority status in Canada.

Identity factors including race and gender both have been found to be significant determinants of COVID-19 outcomes, especially in the U.S. A higher prevalence of non-communicable diseases such as diabetes, hypertension, and cardiovascular diseases and low socio-economic status are some of the factors that are found to be associated with a higher prevalence of COVID-19 in the Afro-American population in the U.S. [19–21]. Similarly, COVID-19 infection and related mortality have gender differences as well. Earlier studies have found higher infection among males than females [22, 23], however, there are other studies which have reported females to be more susceptible than males [24, 25]. There are several genetic, hormonal, and epigenetic factors that influence the difference in infection rates between sexes [26]. More clinical and population-level data from large-scale studies in other countries are needed to make informed conclusions about the gender and ethnicity differences in COVID-19 symptoms, infections, and mortality.

By analysing the socioeconomic and demographic determinants of COVID-19 symptoms and examining how these determinants vary by gender identity and visible minority status in Canada, findings from our study would add to the current state of knowledge of the epidemiology of this virus. COVID-19 policies have significantly varied over time and across regions within Canada; because these policies are likely to affect individuals and population subgroups differently [27, 28], the determinants of COVID-19 symptoms can be expected to vary across gender and ethnic groups. Our study is necessary because it is likely to illuminate the demographic nuances peculiar to the Canadian population during pandemics. Also, as new strains of the COVID-19 emerge, it is important to understand the demographic disparities to be able to implement policies and interventions that target and prioritise the most at-risk subpopulations.

Materials and methods

Study design and data collection

Using a cross-sectional study design, we collected data via an online SurveyMonkey platform with portals on the University of Ottawa website available in French and English (https://socialsciences.uottawa.ca/research/covid19-survey). The survey was based on the COVID-19 Symptoms & Social Distancing Web Survey designed by Canning et al. [29]. The study involves three waves of data collection. However, for this paper, we have used data from the first wave that was collected between July and October 2020. The survey questionnaire collected demographic information, recent work experiences, loss of income, experiencing symptoms of COVID-19, mental health conditions, and social distancing behaviour. For data collection, we shared the survey on various social networks and encouraged the snowball method. We also shared the University of Ottawa's Web links via sponsored posts on Facebook in English and French via the University's institutional account. Respondents were sampled online using convenience sampling and snowballing. The questionnaire was available in both English and French. The median time respondents spent completing the survey was around 8 minutes for the French survey and around 7 minutes for the English survey. We collected 3,225 individual responses in English and 1,650 in French for a total of 4,875 across Canada. However, for this paper, only respondents who had complete information on reported COVID-19 symptoms and that of members of their households were considered. Hence, a sample size of 2,829 individual respondents was considered for this study.

Outcome variables

Two outcome variables were considered for the analysis. The first outcome variable was COVID-19 symptoms among respondents. To derive this outcome variable, we used questions in which respondents were asked if they had experienced any of the following symptoms in the past 2 weeks: fever, dry cough, shortness of breath, decreased sense of smell/taste, and other flu-like symptoms. The responses were "yes", "no" and "don't know". Respondents who mentioned that they had experienced at least one of these symptoms were regarded as those experiencing COVID-19 symptoms, and the remaining were categorized as experiencing no COVID-19 symptoms. The second outcome variable was COVID-19 symptoms among either respondent or a household member. This variable was derived from two questions: 1. Has anyone else in your household besides yourself experienced any of the following symptoms in the past 2 weeks? 2. Have you experienced any of the following symptoms in the past 2 weeks? The responses were "yes", "no" and "don't know". The symptoms were those listed above. COVID-19 symptoms among respondents or household members were obtained from affirmative responses provided by respondents of their experience or the experience of a household member of at least one of the symptoms and otherwise were categorized as no COVID-19 symptoms among respondents or household members.

Exposure variables

Eight variables were considered as exposures in this study. These were gender (female and male), age (18–44, 45–64, 65–84, and 85 years and above), province (Quebec, Ontario, British Columbia, and other), race (white, black, mixed race, other-aboriginal/indigenous, Asian, Latin American, Arab, and other race), belongs to a visible minority group (no and yes), highest level of education, total personal income in 2019, and number of household members. The highest level of education was coded as high school or less, college, and postgraduate. Total income in 2019 was coded as less than $20,000, $20,000 to less than $50,000, $50,000 to less

than $100,000, and $100,000 or more. The number of household members was divided into three categories—1, 2–3, and 4 or more. The choice of these variables was based on their associations with reported COVID-19 symptoms in previous studies [18, 29].

Statistical analysis

Stata version 14 was used to clean the data, recode variables, and analyse the data. Both descriptive (frequencies and percentages) and inferential (chi-square test of independence and multivariate logistic regression) analyses were carried out. Frequencies and percentages were first used to describe the socio-demographic characteristics of the respondents and present the proportions of reported COVID-19 symptoms among the respondents and their household members. Next, the chi-square test of independence was used to show the difference in reported COVID-19 symptoms among the respondents and their household members across the socio-demographic characteristics of the respondents. Statistical significance was obtained at a 95% confidence interval. Finally, multivariable logistic regression was employed to examine the socio-demographic characteristics associated with reported COVID-19 symptoms among the respondents only and with symptoms reported by respondents or a household member. We estimated four different models. Model 1 had gender and age of respondents as exposure variables. In Model 2, province, race, and visible minority group were added to the variables in Model 1 as controls. In Model 3, the highest level of education and total income in 2019 were added to the variables in Model 2 as controls. In the final model (Model 4), all the socioeconomic and demographic characteristics were included. To assess whether the socioeconomic and demographic determinants of the likelihood of self-reporting COVID-19 symptoms differ by gender and visible minority status, we implemented our most conservative multivariable regression analysis (Model 4) separately by gender and visible minority status. The results were presented as adjusted odds ratios (aOR) at 95% confidence interval. Model fitness was checked using Pseudo R-squared goodness of fit test, with the highest value indicating the best fit model. Since the survey sample was not representative of the general population, both descriptive statistics and regression results used weights that were generated using the distributions of gender, age, and province from the Demographic Estimations program at StatCan to have national representativeness and correct imbalances between the survey sample and the population. We computed a sampling weight for each sex-age-province group. Specifically, for each sex-age-province group, the weight is equivalent to the ratio of the share (probability of selection) of this group in the 2016 census and the share of the same group in the survey sample. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines to report our results.

Ethical considerations

Ethics approval was obtained from the Office of Research Ethics and Integrity of the University of Ottawa (S-06-20-5911). The survey was open only to residents of Canada over the age of 18. Respondents had to give signed written consent forms after reading the introduction script. The sensitive questions could be skipped by the participants. The analytical dataset did not include any personal identifiers.

Results

Socioeconomic and demographic characteristics of respondents

This section of the results provides information on the socioeconomic and demographic characteristics of respondents. Of the 2,829 respondents in this study, 51.05% were females, and

Table 1. Descriptive statistics on socio-demographic characteristics of respondents.

Variables	Unweighted Frequency	Weighted Frequency	Weighted Percentage
Gender			
Female	2225	1444	51.05
Male	604	1384	48.95
Age group			
18–44	1145	1277	45.15
45–64	865	941	33.25
65–84	807	555	19.61
85 years and above	12	56	1.99
Province			
Alberta	1280	319	11.29
British Columbia	935	392	13.85
Ontario	959	1098	38.83
Quebec	145	640	22.61
Other	210	379	13.41
Race			
White	2529	2418	85.49
Black	79	90	3.18
Mixed race	73	133	4.70
Other	148	187	6.62
Minority group			
No	91.02	2478	87.58
Yes	254	351	12.42
Highest level of education			
High school or less	355	391	13.83
College	1787	1838	64.97
Postgraduate	687	600	21.20
Total income in 2019			
Less than $20,000	630	666	23.55
$20,000 to less than $50,000	1015	878	31.03
$50,000 to less than $100,000	969	1002	35.42
$100,000 or more	215	283	10.00
Number of household members			
1	574	547	19.33
2–3	1657	1639	57.94
4 or more	598	643	22.73
Total sample size		**2829**	**100.00**

NB: Race: Other includes Manitoba, New Brunswick, Newfoundland and Labrador, Northwest territories, Nova scotia, Nunavut, Prince Edward Island, Saskatchewan and Yukon

45.15% were aged 18–44 (Table 1). About 38.83% of the respondents were from the Ontario Province, and the majority of the respondents (85.49%) classified themselves as whites. More than one in ten respondents belonged to a minority group. With respect to educational level, most of the respondents had a college education (64.97%), followed by those with postgraduate education (21.20%). About 35% alluded to receiving a total income of between $50,000 to less than $100,000 in 2019. Concerning the number of household members, the majority (58%) of the respondents indicated that they belonged to a 2–3-member household, followed by those in four or more members' households (22.73%).

Prevalence of reported COVID-19 symptoms

This section provides information on the prevalence of reported COVID-19 symptoms during the period in which the data were collected. Of the 2,829 respondents included in the analysis, 13.38% had experienced at least one COVID-19 symptom. Dry cough was the most common symptom experienced by the respondents (7.65%) (see Fig 1). Approximately 16.82% of the respondents reported that they or at least a member of their household had COVID-19 symptoms. Relatedly, dry cough was the most common symptom experienced by respondents or by members of their households (7.62%) (see Fig 2).

Distribution of COVID-19 symptoms across the socioeconomic and demographic characteristics of respondents

Table 2 shows the distribution of COVID-19 symptoms across the socioeconomic and demographic characteristics of the respondents. The findings showed a statistically significant association between age, ethnicity, province of residence, and total income in 2019 and reporting of COVID-19 symptoms among respondents. With respect to the reporting of COVID-19 symptoms among respondents or a household member, the findings showed statistically significant associations with age, ethnicity, province, highest level of education, total income in 2019, and number of household members.
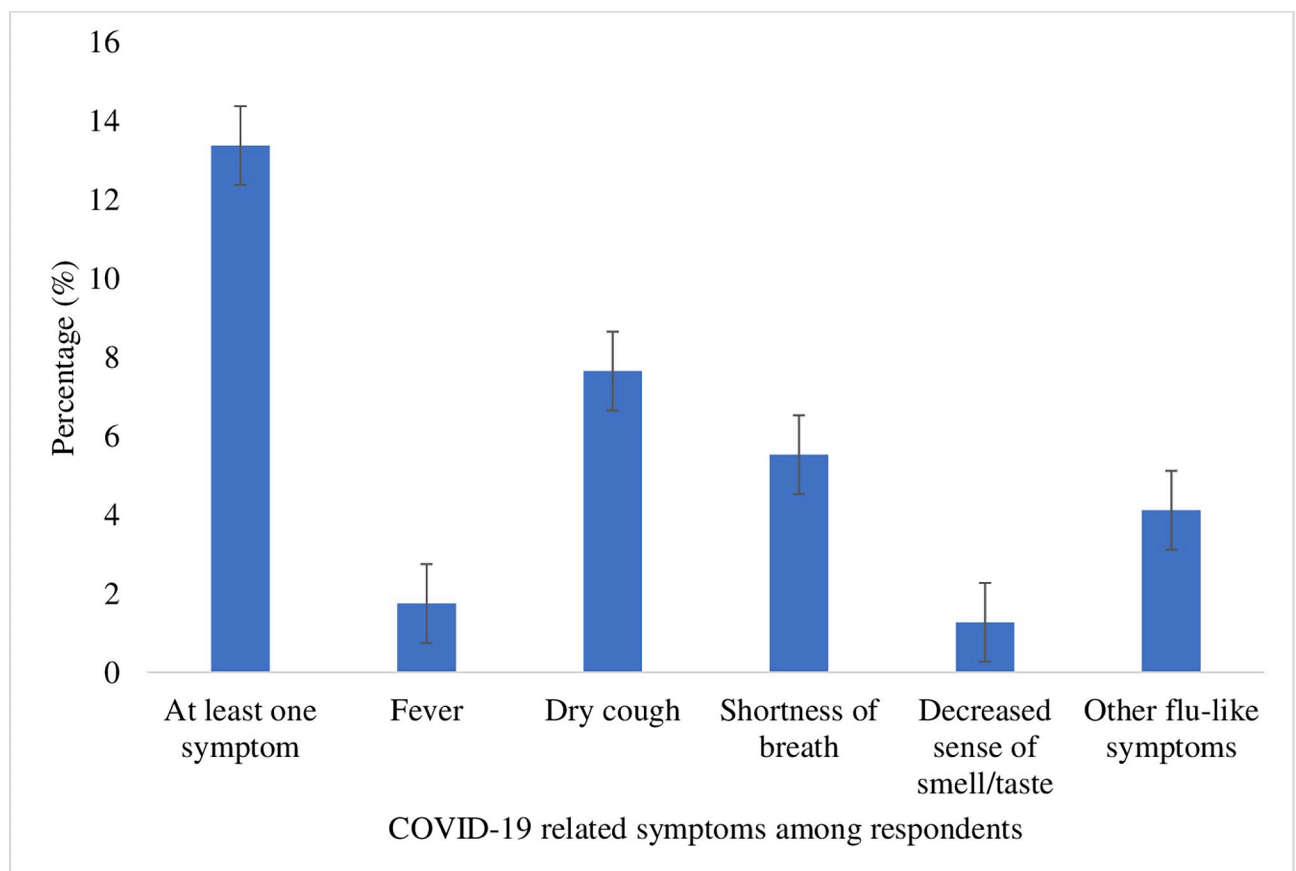

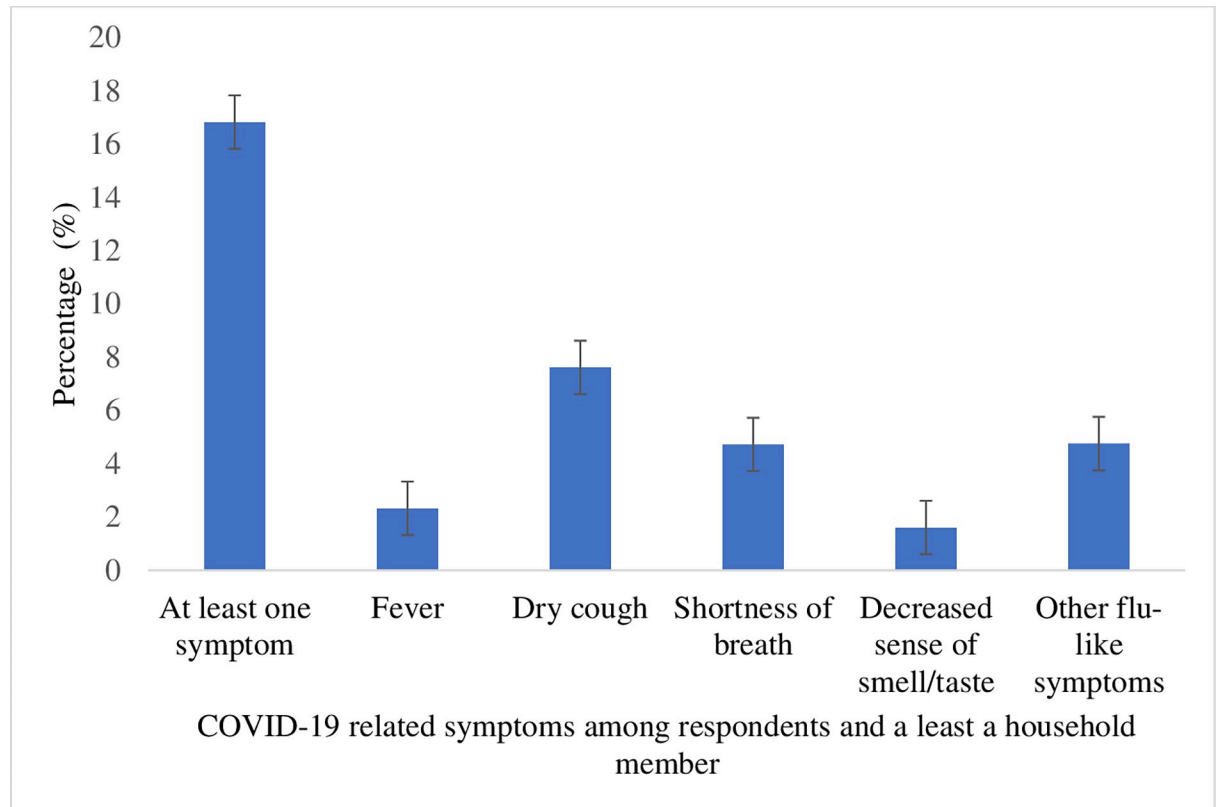**Fig 1. Prevalence of self-reported COVID-19 symptoms among respondents.**

https://doi.org/10.1371/journal.pgph.0001156.g001

Fig 2. Prevalence of self-reported COVID-19 symptoms among respondents and a least a household member.

Socioeconomic and demographic determinants of COVID-19 symptoms among respondents

This section reports the results of the binary logistic regressions; it highlights the socioeconomic and demographic characteristics of respondents who were more likely to report COVID-19 symptoms. Table 3 presents the results of the association between socioeconomic and demographic characteristics and COVID-19 symptoms among respondents in the past 2 weeks. The analysis revealed that respondents aged 45–64 [aOR = 0.63; CI = 0.41–0.98] and 65–84 [aOR = 0.42; CI = 0.28–0.64] had lower odds of reporting COVID-19 symptoms compared to those aged 18–44. Respondents who lived in "other" provinces (than Alberta, British Columbia, and Ontario) [aOR = 1.88; CI = 1.08–3.28] were more likely to report COVID-19 symptoms compared to those who lived in Quebec. In the same vein, respondents who belonged to mixed race [aOR = 2.77; CI = 1.18–6.48] were more likely to report COVID-19 symptoms compared to whites. The likelihood of reporting COVID-19 symptoms was lower among respondents whose total income was $100,000 or more in 2019 compared to those whose total income was less than $20,000 in 2019 [aOR = 0.18; CI = 0.07–0.45].

Socioeconomic and demographic determinants of COVID-19 symptoms among respondents and household members

This section reports the results of the binary logistic regressions that analyse the socioeconomic and demographic factors associated with COVID-19 symptoms among respondents or household members in the past 2 weeks. The results are presented in Table 4. Compared to respondents aged

Table 2. Distribution of COVID-19 symptoms across socio-demographic factors of respondents.

Variables	COVID-19 symptoms among respondents only in the past 2 weeks	p-value	COVID-19 symptoms among respondent or their household members in the past 2 weeks	p-value
	Yes (%)		Yes (%)	
Gender		0.986		0.164
Female	11.97		16.70	
Male	14.85		16.96	
Age		<0.001		<0.001
18–44	18.09		23.06	
45–64	10.33		12.81	
65–84	9.07		9.79	
85 years and above	0		11.69	
Province		0.074		0.003
Alberta	16.32		20.27	
British Columbia	7.62		10.34	
Ontario	12.23		15.28	
Quebec	12.46		16.34	
Other	21.75		25.91	
Race		0.046		0.036
White	13.03		16.32	
Black	15.68		18.92	
Mixed race	25.11		30.93	
Other	8.50		12.29	
Minority group		0.309		0.610
No	13.56		17.04	
Yes	12.14		15.33	
Highest level of education		0.156		0.020
High school or less	14.82		16.03	
College	12.04		15.57	
Postgraduate	16.55		21.19	
Total income in 2019		0.001		0.006
Less than $20,000	15.01		17.67	
$20,000 to less than $50,000	16.47		19.68	
$50,000 to less than $100,000	12.32		16.63	
$100,000 or more	3.71		6.66	
Number of household members		0.304		<0.001
1	12.45		13.35	
2–3	14.38		17.43	
4 or more	11.62		18.23	

*P-values obtained from chi-square test

https://doi.org/10.1371/journal.pgph.0001156.t002

18–44, those aged 45–64 [aOR = 0.57; CI = 0.38–0.85] and 65–84 [aOR = 0.35; CI = 0.24–0.53] were less likely to report that they or at least a member of their households experienced COVID-19 symptoms. In addition, respondents with an income of at least $100,000 were less likely to report that they or at least a member of their households experienced COVID-19 symptoms compared to those with income less than $20,000 [aOR = 30; CI = 0.13–0.67].

Table 3. Binary logistic regression results on the socio-demographic factors associated with COVID-19 symptoms.

Variables	Respondents only having COVID-19 symptoms in the past 2 weeks			
	aOR [95%CI]; Model 1	aOR [95%CI]; Model 2	aOR [95%CI]; Model 3	aOR [95%CI]; Model 4
Gender				
Female	Reference	Reference	Reference	Reference
Male	1.22[0.85–1.76]	1.22[0.85–1.75]	1.35[0.93–1.94]	1.30[0.91–1.86]
Age				
18–44	Reference	Reference	Reference	Reference
45–64	0.52**[0.34–0.80]	0.51**[0.33–0.79]	0.65[0.42–1.01]	0.63*[0.41–0.98]
65–84	0.45***[0.31–0.67]	0.45***[0.30–0.67]	0.45***[0.30–0.68]	0.42***[0.28–0.64]
85 years and above	-	-	-	-
Province				
Quebec		Reference	Reference	Reference
British Columbia		0.57[0.31–1.04]	0.62[0.33–1.14]	0.61[0.33–1.14]
Ontario		0.97[0.68–1.40]	1.07[0.73–1.55]	1.08[0.74–1.57]
Alberta		1.28[0.63–2.58]	1.69[0.83–3.44]	1.67[0.83–3.40]
Other		1.92*[1.09–3.35]	1.88*[1.07–3.29]	1.88*[1.08–3.28]
Race				
White		Reference	Reference	Reference
Black		1.42[0.41–4.94]	1.68[0.50–5.68]	1.82[0.55–6.03]
Mixed race		2.18[0.85–5.61]	2.63*[1.14–6.10]	2.77*[1.18–6.48]
Other		0.67[0.22–2.09]	0.71[0.25–2.07]	0.75[0.27–2.13]
Minority group				
No		Reference	Reference	Reference
Yes		0.63[0.27–1.51]	0.51[0.23–1.15]	0.52[0.23–1.16]
Highest level of education				
High school or less			Reference	Reference
College			1.00[0.56–1.79]	0.96[0.54–1.71]
Postgraduate			1.53[0.78–3.01]	1.45[0.73–2.86]
Total income in 2019				
Less than $20,000			Reference	Reference
$20,000 to less than $50,000			1.16[0.71–1.89]	1.13[0.69–1.85]
$50,000 to less than $100,000			0.75[0.45–1.26]	0.75[0.45–1.25]
$100,000 or more			0.12***[0.07–0.43]	0.18***[0.07–0.45]
Number of household members				
1				Reference
2–3				1.03[0.66–1.60]
4 or more				0.74[0.43–1.27]
Pseudo R-squared	0.020	0.045	0.069	0.071

Exponentiated coefficients; 95% confidence intervals in brackets

aOR adjusted odds ratios

CI Confidence Interval

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

https://doi.org/10.1371/journal.pgph.0001156.t003

Table 4. Binary logistic regression results on the socio-demographic factors associated with COVID-19 symptoms.

Variables	Respondents or a household member having COVID-19 rsymptoms in the past 2 weeks			
	AOR [95%CI] Model 1	AOR [95%CI] Model 2	AOR [95%CI] Model 3	AOR [95%CI] Model 4
Gender				
Female	Reference	Reference	Reference	Reference
Male	0.99 [0.70–1.39]	0.98[0.70–1.37]	1.06[0.75–1.49]	1.07 [0.76–1.49]
Age				
18–44	Reference	Reference	Reference	Reference
45–64	0.49***[0.34–0.71]	0.48***[0.32–0.70]	0.57**[0.38–0.84]	0.57**[0.38–0.85]
65–84	0.36***[0.25–0.51]	0.36***[0.25–0.52]	0.35***[0.24–0.51]	0.35***[0.24–0.53]
85 years and above	0.44 [0.05–3.57]	0.36 [0.05–2.52]	0.31[0.05–1.94]	0.33 [0.05–2.14]
Province				
Quebec		Reference	Reference	Reference
British Columbia		0.57*[0.33–0.99]	0.63[0.36–1.09]	0.62[0.36–1.08]
Ontario		0.90 [0.65–1.25]	0.97[0.69–1.37]	0.96[0.69–1.36]
Alberta		1.20 [0.64–2.23]	1.47[0.78–2.77]	1.47 [0.79–2.74]
Other		1.75* [1.04–2.94]	1.72*[1.01–2.92]	1.68 [0.99–2.84]
Ethnic groups				
White		Reference	Reference	Reference
Black		1.46[0.48–4.43]	1.68 [0.57–4.96]	1.70 [0.58–4.95]
Mixed race		2.26[0.88–5.77]	2.65*[0.1.13–6.26]	2.19 [1.12–6.19]
Other		0.82[0.33–2.06]	0.90[0.37–2.17]	0.90[0.37–2.19]
Minority group				
No		Reference	Reference	Reference
Yes		0.60 [0.28–1.30]	0.51[0.24–1.06]	0.50 [0.24–1.05]
Highest level of education				
High school or less			Reference	Reference
College			1.13[0.65–1.94]	1.13[0.65–1.95]
Postgraduate			1.66[0.89–3.10]	1.68[0.89–3.15]
Total income in 2019				
Less than $20,000			Reference	Reference
$20,000 to less than $50,000			1.23 [0.79–1.92]	1.22[0.78–1.92]
$50,000 to less than $100,000			0.93 [0.59–1.49]	0.93[0.58–1.48]
$100,000 or more			0.31**[0.14–0.69]	0.30* [0.13–0.67]
Number of household members				
1				Reference
2–3				1.23 [0.79–1.92]
4 or more				1.21 [0.73–1.99]
Pseudo R-squared	0.026	0.050	0.066	0.067

Exponentiated coefficients; 95% confidence intervals in brackets

aOR adjusted odds ratios; CI Confidence Interval

* $p < 0.05$

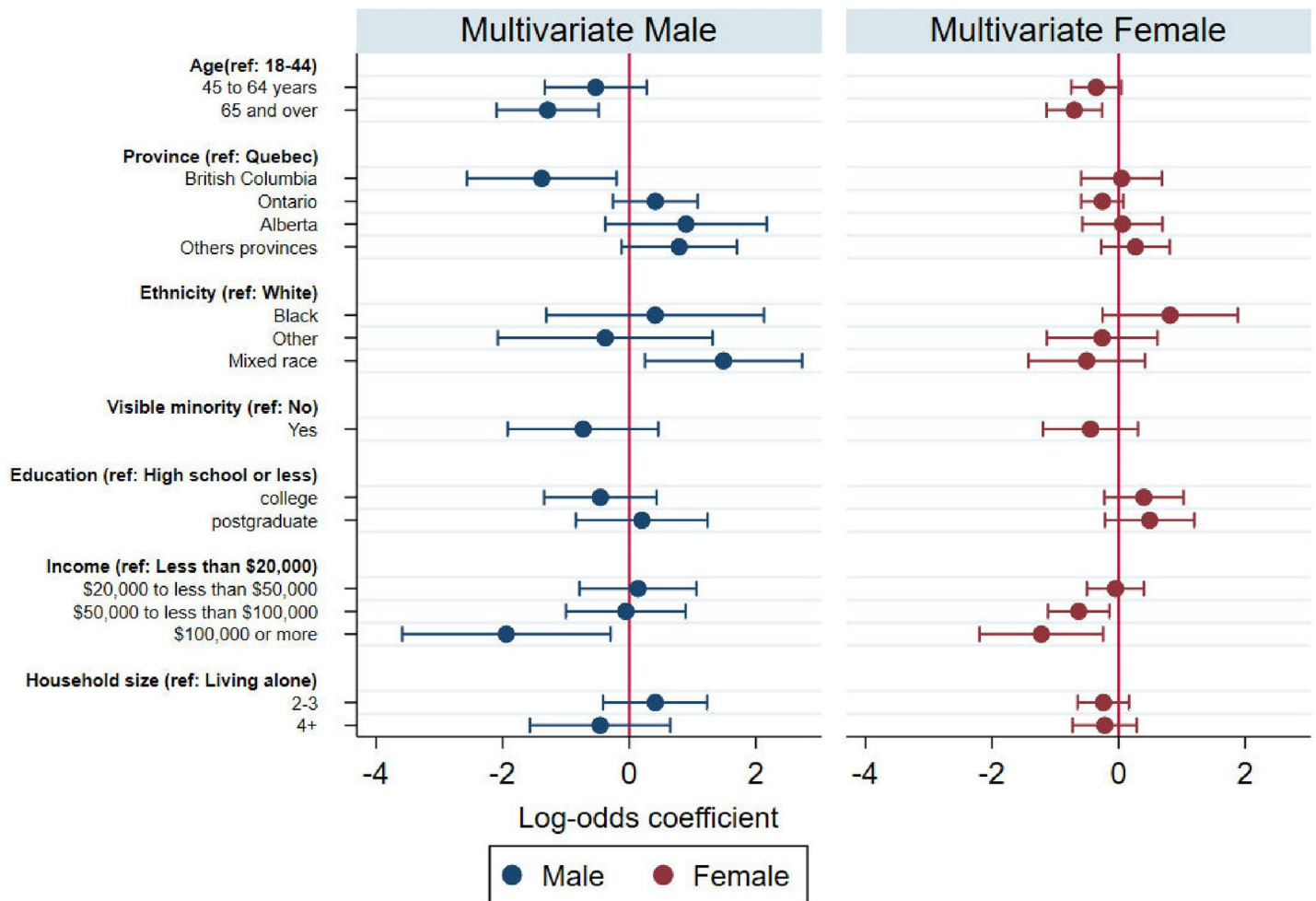** $p < 0.01$

*** $p < 0.001$

Fig 3. Socio-demographic factors associated with self-reported COVID-19 symptoms disaggregated by gender.

The role of gender: Socioeconomic and demographic factors associated with COVID-19 symptoms disaggregated by gender identity

Fig 3 presents the multivariate logistic regression results of the association between socioeconomic and demographic characteristics and self-reported COVID-19 symptoms disaggregated by gender identity. The results revealed that after controlling for other factors men from mixed race were significantly more likely to report experiencing COVID-19 symptoms while this was not the case for women from mixed race. We also observed that residents of British Columbia were significantly less likely to report COVID-19 symptoms, but this is only true for men and not for women. Additionally, while being black is not significantly associated with the likelihood of self-reporting COVID-19 for both men and women, the size of the odd ratio suggests that Black men and Black women have higher odds of reporting COVID-19 symptoms, but the effect is more pronounced for Black women.

Fig 4 presents the results of the association between socioeconomic and demographic characteristics and reporting of COVID-19 symptoms among respondents and at least a household member disaggregated by gender. The results revealed that both older men and women were less likely to report that they or at least a member of their households experienced COVID-19
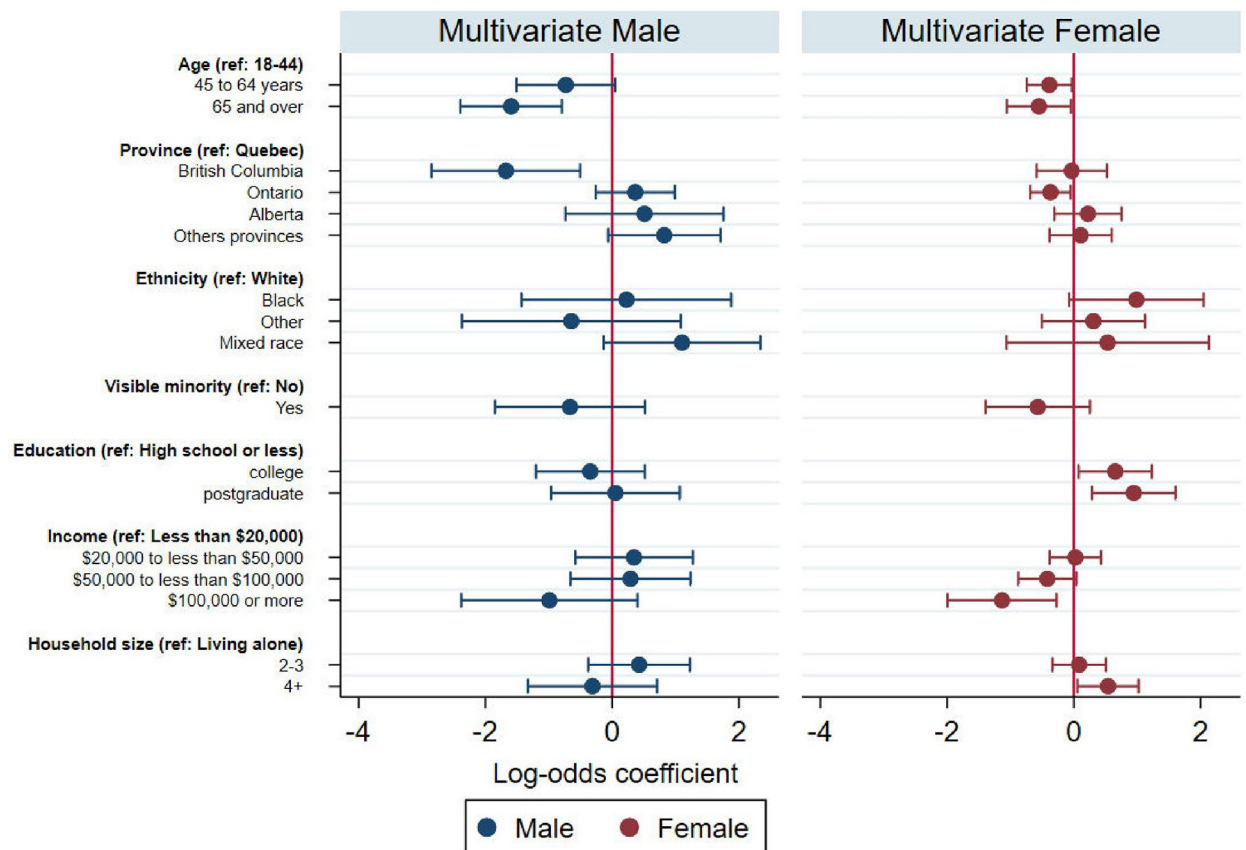
Fig 4. Socio-demographic factors associated with COVID-19 symptoms among respondents and household members by gender.

symptoms compared to younger men and women. While men who lived in British Columbia were significantly less likely report that they or at least a member of their households experienced COVID-19 symptoms compared to those who lived in Quebec, females who lived in Ontario were significantly less likely to report that they or at least a member of their households experienced COVID-19 symptoms compared to those who lived in Quebec. Highest level of education and number of people in a household was a significant predictor of experience of COVID-19 symptoms among female respondents, but this was not the case for male respondents.

The role of minority status: Socioeconomic and demographic factors associated with COVID-19 symptoms disaggregated by visible minority status

This section highlights the socioeconomic and demographic factors associated with self-reported COVID-19 symptoms disaggregated by minority status. Fig 5 reports the multivariate logistic regression examining the socioeconomic and demographic factors associated with self-reported COVID-19 symptoms among respondents. The analysis revealed that in both visible minorities and non-visible minorities, respondents who earned $100,000 or more were less likely to report that they experienced COVID-19 symptoms, but this association tended to be higher among non-visible minorities. In addition, within visible minorities, respondents who were black or mixed race or living in Alberta had higher odds of presenting COVID-19 symptoms. By comparison, among the non-visible minorities, male respondents and those living in
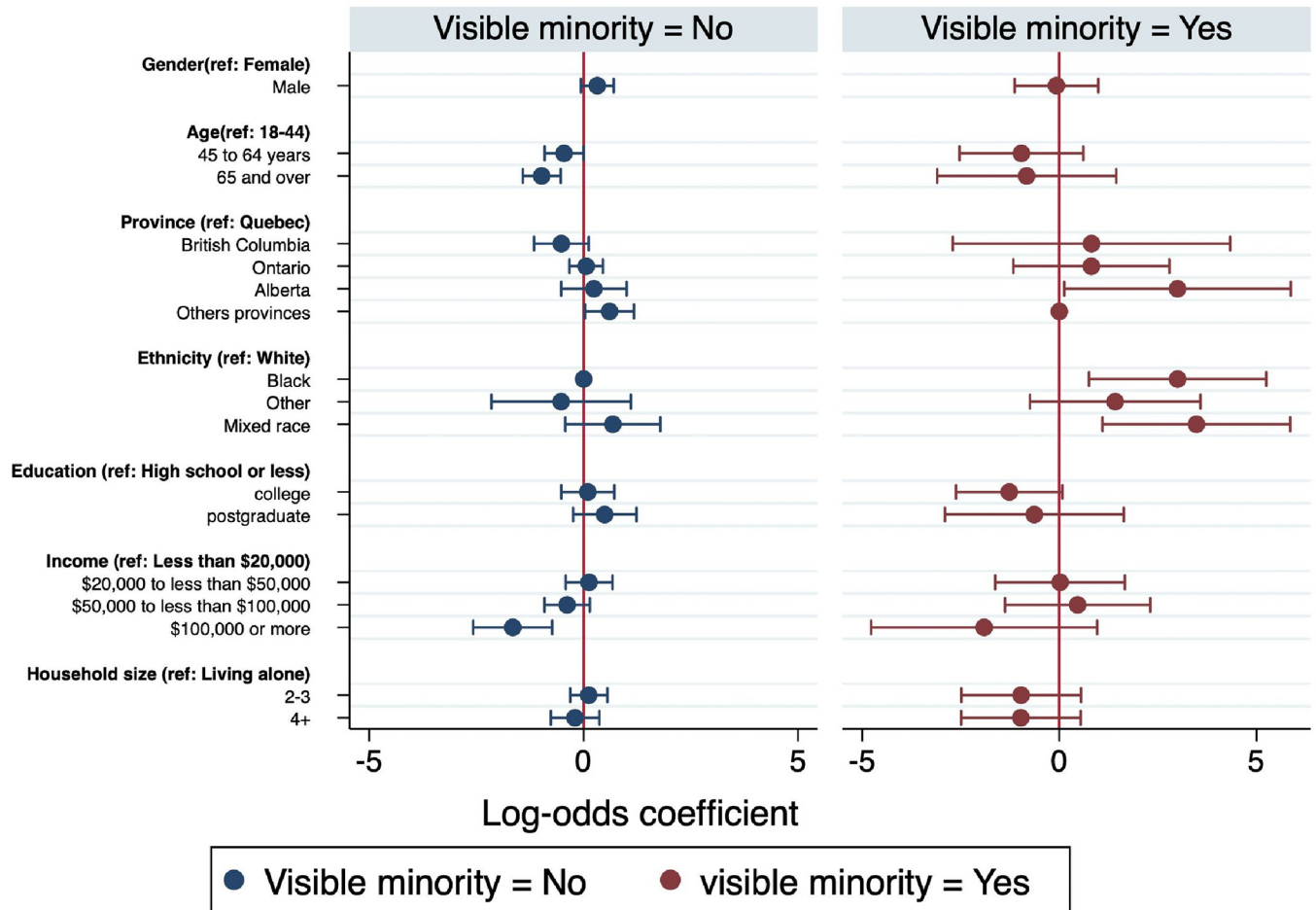
Fig 5. Socio-demographic factors associated with COVID-19 symptoms among respondents and household members by visible minority.

provinces other than Alberta, Ontario, and British Columbia were more likely to report they experienced COVID-19 symptoms, while those who were older were less likely to present COVID-19 symptoms.

Fig 6 presents the socioeconomic and demographic factors associated with self-reported COVID-19 symptoms among respondents and at least a member of their household disaggregated by visible minority status. The analysis revealed that among respondents who were from a visible minority group, those who were older and those who earned $100,000 or more were less likely to report that they or at least a member of their households experienced COVID-19 symptoms. These associations were less strong among non-visible minorities. In addition, among respondents who were of visible minority, those who lived in Alberta and those of the black, mixed, and other race were more likely to report that they or at least a member of their households experienced COVID-19 symptoms.

Discussions

Our analyses assessed the socioeconomic and demographic factors associated with the reporting of COVID-19 symptoms in Canada, and how these determinants varied by gender and
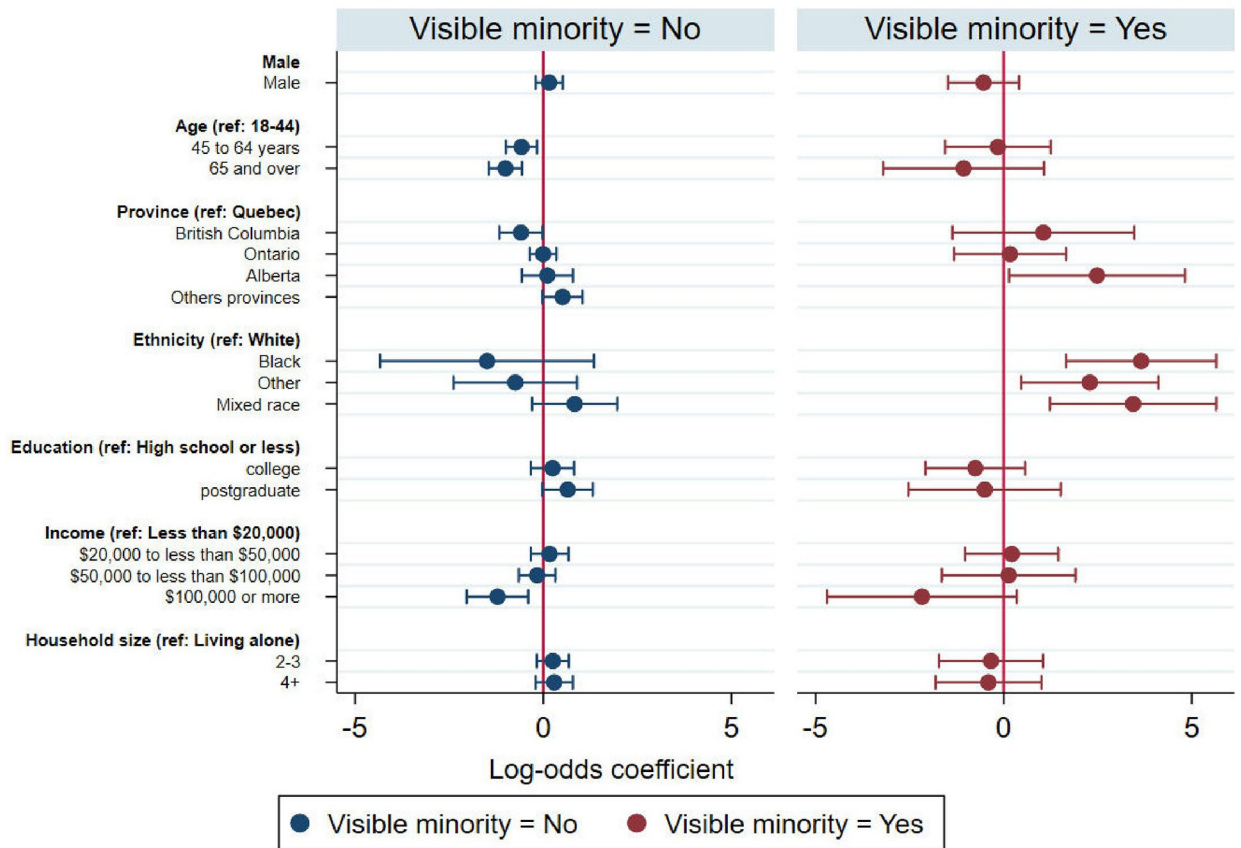
Fig 6. Socio-demographic factors associated with COVID-19 symptoms among respondents and at least a member of the household disaggregated by visible minority.

https://doi.org/10.1371/journal.pgph.0001156.g006

visible minority status. Overall, the prevalence of self-reported COVID-19 symptoms was relatively higher at the individual level (12.3%) compared to COVID-19 symptoms self-reported among household members (6.9%). This is higher than the 8% that was reported by Wu et al. [18] and higher than the 1.6% COVID symptoms reported in Lapointe-Shaw et al.'s study [15]. Although Canada has fared relatively well in terms of the number of cases and deaths due to COVID-19 when compared to other developed countries, especially its neighbour, the U.S., the distribution of the cases and deaths within Canada was not homogenous. There were interprovincial differences in self-reported COVID-19 symptoms in our study. Respondents residing in "other" provinces (than Alberta, British Columbia, and Ontario) had greater likelihood of reporting COVID-19 symptoms compared to those residing in Quebec. Also, as with other health, social, and economic issues, COVID-19 disproportionately affected the vulnerable populations in Canada [30]. There are a number of studies elucidating the inequities in COVID-19 cases and deaths, and the disproportionate burden born by the marginalized population in countries most affected by the COVID-19 pandemic such as the U.S., the UK, Italy, and France [31–34].

The prevalence of self-reported COVID-19 symptoms was higher among the younger age groups. The age distribution of COVID-19 symptoms is in line with related studies from the United States and Brazil [35, 36]. As noted in other countries, the severity of the infection was quite low in younger age groups [37, 38]. Compared to respondents aged 18–44, reporting of COVID-19 symptoms was lower among respondents aged 45–84 and lower for at least a

member of their households. Our findings corroborate those of Wu et al. who found the reported symptoms of COVID-19 lower among older adults than any other age group [18]. Plausibly, it could be a limitation of our study (probably sampling bias) in which only those older adults who participated in the survey were healthier, living in a residence, and had access to the internet. Consequently, the observed lower odds of reporting COVID-19 symptoms among older adults (i.e., age 65+) is reflective of a significant limitation of our study; that is, the lack of representation of persons in nursing and long-term care homes that are inhabiting majority of the Canadian older people, and where COVID-19 cases and deaths have been the highest [39]. As contended by Graham [40], older adults often report symptoms such as dizziness and confusion which are also symptoms of COVID-19; however, our study did not consider dizziness and confusion as COVID symptoms. Another explanation for lower reporting of COVID-19 symptoms among older adults could be because of their health behaviour, which is usually preventive and cautious [41].

In contrast to the findings of a syndromic analysis that found no significant difference in reported symptoms of COVID-19 across income groups in Canada [15], we found significant association between income levels of individuals and their reporting of COVID-19 symptoms. Per our study, the risk of reporting symptoms reduced significantly with increasing income. This finding corroborates a similar study by Mena et al. that showed a strong association between socioeconomic status and the risk of COVID-19 symptoms, incidence, and mortality in Chile [42]. People belonging to lower-income groups are usually employed in low-paying essential jobs, where working from home is not an option, and thus are at a higher risk of getting infected [43, 44].

Consistent with previous studies [45, 46], we found larger household size to be significantly associated with higher odds of reporting COVID-19 symptoms among household members. This finding reflects the compounded risk emanating from having more household inhabitants. Large household size makes it difficult to observe social distancing protocols and reduces the possibility of self-isolation when a household member gets sick or is infected [47, 48].

Males and females had an equal prevalence of experiencing COVID-19 symptoms. Related studies have found that, while men and women show comparable odds of experiencing COVID-19 symptoms [49, 50], men with COVID-19 are more at risk for poorer outcomes and death [50]. Besides typical male-female differences [51, 52], processes unique to COVID-19 probably play a role in this mortality disparity [53]. Male-female characteristics and unique COVID-19 processes may also explain the discrepancies in the socioeconomic and demographic factors determining COVID-19 symptoms by gender. The province of residence and ethnicity were significantly associated with self-reported COVID-19 symptoms among female respondents but not among male respondents in our study. When the analysis was disaggregated by gender, we found that males who lived in British Columbia were less likely to self-report COVID-19 symptoms compared to those who lived in Quebec. Among females, province was not a significant factor associated with self-reported COVID-19 symptoms. Evidence shows that Ontario and Quebec, which are the two most populous provinces had reported the highest infection and cases of COVID-19 [49]. Hence, stringent preventive measures were instituted in these two provinces compared to the other provinces.

Our results also revealed that among male respondents, those from mixed race were significantly more likely to report experiencing COVID-19 symptoms while this was not the case for women from mixed race. This racial disparity is corroborated by the findings of a systematic review conducted among adults in the UK and the U.S. [53]. Similarly, our findings are consistent with a related study conducted in the U.S. [54]. There are multiple reasons for the observed racial and sex disparities, most of which the present study does not directly account for. For instance, our findings may be explained by masculinity norms that permeate mixed-

race populations [54]. Masculinity ideals that are upheld by men of mixed race are negatively correlated with their adherence to COVID-19 preventive measures; hence, significantly increasing their risk of reporting more COVID-19 symptoms. Additionally, Black men and Black women have higher odds of reporting COVID-19 symptoms, but the effect is more pronounced for Black women. This result is consistent with previous studies [55–59]. Primarily, the result may be due to structural factors from occupation and access to healthcare [54]. In the U.S., Frye [55] noted that there is an overrepresentation of black women working as nurse assistants and home health aides. Such essential occupations exacerbate black women's risk of reporting COVID-19 symptoms.

Analyses disaggregated by minority status showed that higher income was associated with lower odds of reporting COVID-19 symptoms both among visible minorities and non-visible minorities, but this association tended to be stronger among non-visible minorities. Among visible minorities, respondents of the black or mixed race were more likely to experience COVID-19 symptoms. These findings complement studies that found that racial and ethnic minority groups have disproportionally higher rates of developing COVID-19 illness [60]. Individuals from historically marginalised racial and ethnic groups have been found to suffer disproportionately from frequent and severe medical disorders that increase their risk of experiencing COVID-19 symptoms [61]. We complement this existing literature by documenting disparities in COVID-19 symptoms among visible minority ethnic groups. We also found that age was significantly associated with COVID-19 self-reported symptoms among non-visible minorities. Older respondents were less likely to present COVID-19 symptoms. This could be explained by the fact that Canadian seniors were more concerned about their health and took more precautions than younger individuals [62]. Our analysis however suggests that this was more likely to be the case among non-visible minorities.

Overall the findings indicate that some sub-populations including individuals from low-income earners, older adults, those of the mixed race, and those who lived in "other" provinces (than Alberta, British Columbia, and Ontario) were at high risk of reporting COVID-19 symptoms. The socioeconomic and demographic determinants of COVID-19 symptoms also varied by gender and visible minority status. The analysis implies that it is imperative to strengthen current preventive interventions in vulnerable sub-populations.

Strengths and limitations

Our study substantiates other studies conducted in Canada that established an association between socioeconomic and demographic factors and COVID-19 symptoms at the individual and household levels. Moreover, the sample used for this study is nationally representative and facilitates the generalisability of the findings to the larger Canadian population. Nevertheless, our findings should be interpreted while taking into consideration some limitations. The study design was cross-sectional and as such, causality cannot be easily established. Also, this study used self-reported data, hence, it is likely that there may have been some recall bias. Additionally, respondents were sampled online using convenience and snowballing, which can induce noise to our results. Moreover, internet-based surveys usually have sampling bias. We tried to overcome this limitation by our sample. Finally, a large share of the older population of Canada is unlikely to complete a survey on a web platform. These include nursing home residents and those with chronic health issues or disabilities.

Conclusion

Our findings suggest that COVID-19 mitigation strategies including screening, testing, and containment should focus on the vulnerable populations (i.e., low-income earners, older

adults, those of the mixed race, and those who lived in provinces other than Alberta, British Columbia, and Ontario). The socioeconomic and demographic determinants of COVID-19 symptoms vary by identity factors including gender and visible minority status in Canada. The analysis suggests that mitigation strategies should be designed to be specific to each gender category, ethnic group, and minority status in Canada.

Author Contributions

Conceptualization: Roland Pongou, Sanni Yaya.

Formal analysis: Roland Pongou, Bright Opoku Ahinkorah, Marie Christelle Mabeu, Sanni Yaya.

Funding acquisition: Roland Pongou, Sanni Yaya.

Investigation: Stéphanie Maltais.

Methodology: Arunika Agarwal, Sanni Yaya.

Project administration: Roland Pongou.

Supervision: Sanni Yaya.

Validation: Stéphanie Maltais, Sanni Yaya.

Writing – original draft: Roland Pongou, Bright Opoku Ahinkorah, Sanni Yaya.

Writing – review & editing: Roland Pongou, Bright Opoku Ahinkorah, Marie Christelle Mabeu, Arunika Agarwal, Stéphanie Maltais, Aissata Boubacar Moumouni, Sanni Yaya.

References

1. Xu B, Gutierrez B, Mekaru S, Sewalk K, Goodwin L, Loskill A, et al. Epidemiological data from the COVID-19 outbreak, real-time case information. Scientific data. 2020 Mar 24; 7(1):1–6.

2. Hui DS, Azhar EI, Madani TA, Ntoumi F, Kock R, Dar O, et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China. International journal of infectious diseases. 2020 Feb 1; 91:264–6. https://doi.org/10.1016/j.ijid.2020.01.009 PMID: 31953166

3. Hamzah FB, Lau C, Nazri H, Ligot DV, Lee G, Tan CL, et al. CoronaTracker: worldwide COVID-19 outbreak data analysis and prediction. Bull World Health Organ. 2020 Mar; 1(32).

4. Raza A, Talha M, e Zaman S, Khan A, Awais M. Knowledge, Attitude and Practice Regarding Personal Hygiene and Awareness about COVID-19 among School Children of Government Primary School Haider Abad Town Sargodha.

5. Elflein J. Coronavirus (COVID-19) in Canada—Statistics & Facts. [Internet]. April, 2022. Retrieved: https://www.statista.com/topics/6192/coronavirus-covid-19-in-canada/#dossierKeyfigures. (accessed April 5, 2022).

6. Roser M, Ritchie H, Ortiz-Ospina E, Hasell J. Coronavirus disease (COVID-19)–Statistics and research. Our World in data. 2020 Mar; 4.

7. World Health Organization. Coronavirus [Internet]. 2020 Retrieved: https://www.who.int/health-topics/coronavirus#tab=tab_3 (accessed June 6, 2021).

8. Alcendor DJ. Racial disparities-associated COVID-19 mortality among minority populations in the US. Journal of clinical medicine. 2020 Aug; 9(8):2442. https://doi.org/10.3390/jcm9082442 PMID: 32751633

9. Hooper MW, Nápoles AM, Pérez-Stable EJ. COVID-19 and racial/ethnic disparities. Jama. 2020 Jun 23; 323(24):2466–7. https://doi.org/10.1001/jama.2020.8598 PMID: 32391864

10. Rentsch CT, Kidwai-Khan F, Tate JP, Park LS, King JT Jr, Skanderson M, et al. Patterns of COVID-19 testing and mortality by race and ethnicity among United States veterans: A nationwide cohort study. PLoS medicine. 2020 Sep 22; 17(9):e1003379.

11. Debnam Guzman J, Mabeu MC, Pongou R. Identity during a Crisis: COVID-19 and Ethnic Divisions in the United States. InAEA Papers and Proceedings 2022 May (Vol. 112, pp. 319–24).

12. Pongou R, Tchuente G, Tondji JB. Laissez-faire, social networks, and race in a pandemic. InAEA Papers and Proceedings 2022 May (Vol. 112, pp. 325–29).

13. Wei Y, Lu Y, Xia L, Yuan X, Li G, Li X, et al. Analysis of 2019 novel coronavirus infection and clinical characteristics of outpatients: An epidemiological study from a fever clinic in Wuhan, China. Journal of Medical Virology. 2020 Nov; 92(11):2758–67. https://doi.org/10.1002/jmv.26175 PMID: 32544281

14. Unim B, Palmieri L, Noce CL, Brusaferro S, Onder G. Prevalence of COVID-19-related symptoms by age group. Aging Clinical and Experimental Research. 2021 Apr; 33(4):1145–7. https://doi.org/10.1007/s40520-021-01809-y PMID: 33650071

15. Lapointe-Shaw L, Rader B, Astley CM, Hawkins JB, Bhatia D, Schatten WJ, et al. Web and phone-based COVID-19 syndromic surveillance in Canada: A cross-sectional study. PloS one. 2020 Oct 2; 15 (10):e0239886. https://doi.org/10.1371/journal.pone.0239886 PMID: 33006990

16. St-Denis X. Sociodemographic determinants of occupational risks of exposure to COVID-19 in Canada. Canadian Review of Sociology/Revue canadienne de sociologie. 2020 Aug; 57(3):399–452. https://doi.org/10.1111/cars.12288 PMID: 32662245

17. Baylis P, Beauregard PL, Connolly M, Fortin N, Green DA, Cubillos PG, et al. The Distribution of COVID-19 Related Risks. National Bureau of Economic Research; 2020 Oct 5.

18. Wu DC, Jha P, Lam T, Brown P, Gelband H, Nagelkerke N, et al Action to Beat Coronavirus in Canada/Action pour Battre le Coronavirus (Ab-C) Study Group. Predictors of self-reported symptoms and testing for COVID-19 in Canada using a nationally representative survey. PloS one. 2020 Oct 21; 15(10):e0240778.

19. Garg S, Kim L, Whitaker M, O'Halloran A, Cummings C, Holstein R, et al. Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019—COVID-NET, 14 states, March 1–30, 2020. MMWR Morb Mortal Weekly Rep. (2020) 69:458–64. https://doi.org/10.15585/mmwr.mm6915e3 PMID: 32298251

20. Dowd JB, Aiello AE. Socioeconomic differentials in immune response. Epidemiology. 2009 Nov; 20 (6):902–8. https://doi.org/10.1097/EDE.0b013e3181bb5302 PMID: 19797966

21. Adler NE. Socioeconomic inequalities in health. No easy solution. J Am Med Assoc. (1993) 269:3140–5. https://doi.org/10.1001/jama.269.24.3140 PMID: 8505817

22. Li L, Huang T, Wang Y, Wang Z, Liang Y, Huang T, et al. COVID-19 patients' clinical characteristics, discharge rate, and fatality rate of meta-analysis. J Med Virol. 92:577–83. https://doi.org/10.1002/jmv.25757 PMID: 32162702

23. Jin J-M, Bai P, He W, Wu F, Liu X-F, Han D-M, et al. Gender differences in patients with COVID-19: focus on severity and mortality. Front Public Health. (2020) 8:152. https://doi.org/10.3389/fpubh.2020.00152 PMID: 32411652

24. Lian J, Jin X, Hao S, Cai H, Zhang S, Zheng L, et al. Analysis of epidemiological and clinical features in older patients with corona virus disease 2019 (COVID-19) out of Wuhan. Clin Infect Dis. (2020) 382: ciaa242. https://doi.org/10.1093/cid/ciaa242 PMID: 32211844

25. Korean Society of Infectious Diseases Korean Society of Pediatric Infectious Diseases Korean Society of Epidemiology Korean Society for Antimicrobial Therapy Korean Society for Healthcare-associated Infection Control and Prevention Korea Centers for Disease Control and Prevention. Report on the epidemiological features of coronavirus disease 2019 (COVID-19) outbreak in the Republic of Korea from January 19 to March 2, 2020. J Korean Med Sci. (2020) 35:e112. https://doi.org/10.3346/jkms.2020.35.e112 PMID: 32174069

26. Scully EP, Haverfield J, Ursin RL, Tannenbaum C, Klein SL. Considering how biological sex impacts immune responses and COVID-19 outcomes. Nat Rev Immunol. (2020) 20:442–7. https://doi.org/10.1038/s41577-020-0348-8 PMID: 32528136

27. Pongou R, Ahinkorah BO, Maltais S, Mabeu MC, Agarwal A, Yaya S. Psychological distress during the COVID-19 pandemic in Canada. Plos one. 2022 Nov 17; 17(11):e0277238. https://doi.org/10.1371/journal.pone.0277238 PMID: 36395148

28. Pongou R, Ahinkorah BO, Mabeu MC, Agarwal A, Maltais S, Yaya S. Examining the association between reported COVID-19 symptoms and testing for COVID-19 in Canada: a cross-sectional survey. BMJ open. 2022 Mar 1; 12(3):e056229. https://doi.org/10.1136/bmjopen-2021-056229 PMID: 35246421

29. Canning D, Karra M, Dayalu R, Guo M, Bloom DE. The association between age, COVID-19 symptoms, and social distancing behavior in the United States. MedRxiv. 2020 Jan 1. https://doi.org/10.1101/2020.04.19.20065219 PMID: 32511621

30. Social inequalities in COVID-19 mortality by area- and individual-level characteristics in Canada, January to July/August 2020. 2021 July 7. https://health-infobase.canada.ca/covid-19/inequalities-deaths/technical-report.html (accessed: August 2o, 2021).

31.   Wilder JM. The disproportionate impact of COVID-19 on racial and ethnic minorities in the United States. Clinical Infectious Diseases. 2021 Feb 15; 72(4):707–9. https://doi.org/10.1093/cid/ciaa959 PMID: 32648581

32.   Meer N, Qureshi K, Kasstan B, Hill S. The social determinants of Covid 19 and BAME disproportionality. Discover Society website. April. 2020; 30:2020.

33.   Nurchis MC, Pascucci D, Sapienza M, Villani L, D'ambrosio F, Castrini F, et al. Impact of the burden of COVID-19 in Italy: results of disability-adjusted life years (DALYs) and productivity loss. International journal of environmental research and public health. 2020 Jan; 17(12):4233. https://doi.org/10.3390/ijerph17124233 PMID: 32545827

34.   Roche B, Garchitorena A, Roiz D. The impact of lockdown strategies targeting age groups on the burden of COVID-19 in France. Epidemics. 2020 Dec 1; 33:100424. https://doi.org/10.1016/j.epidem.2020.100424 PMID: 33285420

35.   Yang W, Kandula S, Huynh M, Greene SK, Van Wye G, Li W, et al. Estimating the infection-fatality risk of SARS-CoV-2 in New York City during the spring 2020 pandemic wave: a model-based analysis. The Lancet Infectious Diseases. 2021 Feb 1; 21(2):203–12. https://doi.org/10.1016/S1473-3099(20)30769-6 PMID: 33091374

36.   Menezes AM, Victora CG, Hartwig FP, Silveira MF, Horta BL, Barros AJ, et al. High prevalence of symptoms among Brazilian subjects with antibodies against SARS-CoV-2: a nationwide household survey. medRxiv. 2020 Jan 1.

37.   Maragakis LL. Coronavirus and COVID-19: Younger adults are at risk, too. Johns Hopkins Medicine. 2020 Apr.

38.   Bosman J, Mervosh S. As virus surges, younger people account for 'disturbing'number of cases. The New York Times. 2020 Jun 25.

39.   Canadian Life and Health Insurance Association. CLHIA report on long-term care policy: Improving the accessibility, quality and sustainability of long-term care in Canada. 2014. https://www.clhia.ca/web/clhia_lp4w_lnd_webstation.nsf/page/3C342451F891CF1D85257A240044F961/$file/LTC_Policy_Paper_1_EN.pdf.

40.   Graham J. Seniors with COVID show unusual symptoms, doctors say. CNN Health. 2020 Apr 23 [Cited 2020 May 13]. https://www.cnn.com/2020/04/23/health/seniors-elderly-coronavirus-symptoms-wellness-partner/index.htmll.

41.   Chen LK. Older adults and COVID-19 pandemic: Resilience matters. Archives of gerontology and geriatrics. 2020 Jul; 89:104124. https://doi.org/10.1016/j.archger.2020.104124 PMID: 32474351

42.   Mena GE, Martinez PP, Mahmud AS, Marquet PA, Buckee CO, Santillana M. Socioeconomic status determines COVID-19 incidence and related mortality in Santiago, Chile. Science. 2021 May 28; 372 (6545).

43.   Deng Z, Morissette R, Messacar D. Running the economy remotely: Potential for working from home during and after COVID-19.

44.   Statistics Canada. 2020. "Labour Force Survey, April 2020." *The Daily*. Ottawa: Statistics Canada. https://www150.statcan.gc.ca/n1/daily-quotidien/200508/dq200508a-eng.htm

45.   Lu FS, Nguyen AT, Link NB, Davis JT, Chinazzi M, Xiong X, et al. Estimating the cumulative incidence of COVID-19 in the United States using four complementary approaches. medRxiv. 2020 Jan 1. https://doi.org/10.1101/2020.04.18.20070821 PMID: 32587997

46.   Cloutier L, Merindol N, Pépin G, Marcoux-Huard C, Vasil PA, Houle C, et al. Asymptomatic carriers of COVID-19 in a confined adult community population in Quebec: A cross-sectional study. American journal of infection control. 2021 Jan 1; 49(1):120–2. https://doi.org/10.1016/j.ajic.2020.08.015 PMID: 32835745

47.   Federgruen A, Naha S. Crowding effects dominate demographic attributes in COVID-19 cases. International Journal of Infectious Diseases. 2021 Jan 1; 102:509–16. https://doi.org/10.1016/j.ijid.2020.10.063 PMID: 33217575

48.   Yang F, Aitken N. "People Living in Apartments and Larger Households Were at Higher Risk of Dying from COVID-19 during the First Wave of the Pandemic." Ottawa: Statistics Canada (Catalogue no. 45280001). 2021, April 13.

49.   Detsky AS, Bogoch II. COVID-19 in Canada: experience and response. Jama. 2020 Aug 25. https://doi.org/10.1001/jama.2020.14033 PMID: 32790824

50.   DESA U. Leaving no-one behind: The imperative of inclusive development. 2016 report on the World Social Situation. New York, NY: UN. Retrieved from https://www.un.org/esa/socdev/rwss/2016/full-report.Pdf. 2016.

51.   Pongou R. Sex differences in early-age mortality: The preconception origins hypothesis. Demography. 2015 Dec 1; 52(6):2053–6. https://doi.org/10.1007/s13524-015-0441-y PMID: 26527470

52. Pongou R. Why is infant mortality higher in boys than in girls? A new hypothesis based on preconception environment and evidence from a large sample of twins. Demography. 2013 Apr 1; 50(2):421–44. https://doi.org/10.1007/s13524-012-0161-5 PMID: 23151996

53. Sze S, Pan D, Nevill CR, Gray LJ, Martin CA, Nazareth J, et al. Ethnicity and clinical outcomes in COVID-19: a systematic review and meta-analysis. EClinicalMedicine. 2020; 29: 100630. PubMed Abstract| Publisher Full Text| Free Full Text. 2020. https://doi.org/10.1016/j.eclinm.2020.100630 PMID: 33200120

54. Rushovich T, Boulicault M, Chen JT, Danielsen AC, Tarrant A, Richardson SS, et al. Sex disparities in COVID-19 mortality vary across US racial groups. Journal of General Internal Medicine. 2021 Jun; 36 (6):1696–701. https://doi.org/10.1007/s11606-021-06699-4 PMID: 33818679

55. Frye J. On the frontlines at work and at home: The disproportionate economic effects of the coronavirus pandemic on women of color. Center for American Progress. 2020 Apr; 23.

56. Hawkins D. Differential occupational risk for COVID-19 and other infection exposure according to race and ethnicity. American journal of industrial medicine. 2020 Sep; 63(9):817–20. https://doi.org/10.1002/ajim.23145 PMID: 32539166

57. Ahmed MM, Sayed AM, El Abd D, Fares S, Said MSM, Elsayed Sedik Ebrahim E. Gender Difference in Perceived Symptoms and Laboratory Investigations in Suspected and Confirmed COVID-19 Cases: A Retrospective Study. J Prim Care Community Health. 2021 Jan-Dec; 12:21501327211039718. https://doi.org/10.1177/21501327211039718 PMID: 34407661; PMCID: PMC8381412.

58. Jin JM, Bai P, He W, Wu F, Liu XF, Han DM, et al. Gender Differences in Patients With COVID-19: Focus on Severity and Mortality. Front Public Health. 2020 Apr 29; 8:152. https://doi.org/10.3389/fpubh.2020.00152 PMID: 32411652; PMCID: PMC7201103.

59. Niessen A, Teirlinck AC, McDonald SA, van der Hoek W, van Gageldonk-Lafeber R; RIVM COVID-19 epidemiology, surveillance group, Knol MJ. Sex differences in COVID-19 mortality in the Netherlands. Infection. 2022 Jun; 50(3):709–717. https://doi.org/10.1007/s15010-021-01744-0 Epub 2022 Feb 9. PMID: 35138581; PMCID: PMC9151564.

60. Acosta AM, Garg S, Pham H, Whitaker M, Anglin O, O'Halloran A, et al. Racial and Ethnic Disparities in Rates of COVID-19-Associated Hospitalization, Intensive Care Unit Admission, and In-Hospital Death in the United States From March 2020 to February 2021. JAMA Netw Open. 2021 Oct 1; 4(10): e2130479. https://doi.org/10.1001/jamanetworkopen.2021.30479 PMID: 34673962; PMCID: PMC8531997.

61. StatCan 2021. [Internet] https://www150.statcan.gc.ca/n1/pub/75-006-x/2021001/article/00008-eng.htm

62. The American Medical Association. 2022 [Internet] https://www.ama-assn.org/delivering-care/health-equity/why-race-ethnicity-can-help-determine-covid-19-severity-risk.