Health Impacts of Climate Change and Air Pollution Exposures on Immigrant, Non-Immigrant, Adolescent and Older Adult Populations in Alberta

by

Brooke T. Sidney

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Epidemiology

School of Public Health
University of Alberta

Abstract

Climate change and air pollution are two critical threats to human health. Various factors can impact a person's vulnerability to these exposures, including low income and a lack of access to high-quality health care. Immigrants have a higher likelihood of experiencing these factors when compared to non-immigrants, while also dealing with various social and cultural changes. My goal was to analyze and highlight the disparity of the health-related impacts of climate change and air pollution exposures on the immigrant population in Alberta. This knowledge is aimed at highlighting the need for clinicians to provide appropriate healthcare options for preventing or treating diseases, inform policymakers, help implement new programs and help immigrants advocate for their health and take action to reduce and/or adapt to these exposures.

In the second chapter, a scoping review methodology was used to examine previous research to determine globally the health-related impacts of climate change and air pollution exposures on immigrants and refugees younger than 18 and 65 years and older. These ages were focused on as they may be more at risk to the impacts of these exposures. Two independent reviewers completed the title/abstract and full-text screening. Three studies fit the criteria and examined excessive temperatures with mortality and respiratory syncytial virus outcomes. One article found that higher temperatures were associated with higher respiratory syncytial virus incidence in refugee children younger than 5 years old. Two articles found that foreign-born and non-US citizens 65 or older were similarly or less susceptible compared to native-born, but younger individuals were more susceptible. Immigrants and refugees are understudied in the literature and often excluded. More focused research on this population is needed, especially among children, adolescents, and older adults and to expand to other health outcomes with climate change and air pollution exposures.

A cross-sectional study was completed for the third chapter. The objective was to investigate and compare the effects of weather (extreme temperatures) and air pollution (wildfire smoke, NO_2, O_3, $PM_{2.5}$) exposures on asthma, cardiovascular outcomes and mental disorders among immigrant (economic, sponsored by family and refugees), total (immigrants and non-immigrants; all ages), adolescent (total

population; ages 12 to 17) and older adult (total population; ages 65 plus) populations in Alberta between 2009-2014. Multivariable logistic regression was completed for all populations. With high temperature exposure there were higher odds of self-reported asthma and cardiovascular outcomes for the total and immigrant populations respectively (Odds ratio (OR) [95% CI], moderate level = 1.34 [1.04-1.72]), high level = 1.58 [1.20-2.07]; low level = 3.15 [1.40-7.07], high level = 2.49 [1.09-5.65]). Immigrants and older immigrants had higher odds of a self-reported cardiovascular outcome with high temperature compared to non-immigrants (OR low level = 3.19 [1.39-7.29], moderate level = 2.69 [1.16-6.28], high level = 3.40 [1.45-7.97]; low level = 2.64 [1.02-6.82], moderate level = 3.48 [1.37-8.79], high level = 3.58 [1.29-9.91]). Older adults were found to have a positive association with low temperature and mental disorders (OR low level = 1.64 [1.00-2.69]). Immigrants and adolescents had higher odds of a self-reported mental disorder with low and high $PM_{2.5}$ exposure levels (OR low level = 2.27 [1.01-5.07]; high level = 2.99 [1.02-8.74]). Immigrants had lower odds of self-reported asthma, cardiovascular outcomes and mental disorders compared to non-immigrants (OR = 0.37 [0.26-0.55] to OR = 0.40 [0.28-0.59]; OR = 0.35 [0.17-0.71]; OR = 0.60 [0.43-0.83] to OR = 0.64 [0.47-0.87]), while adolescent immigrants had lower odds of a self-reported mental disorder (OR = 0.11 [0.02-0.67] to 0.13 [0.02-0.82]). Long-term (10 plus years) and recent immigrants (less than 10 years) had decreased odds of self-reported asthma compared to non-immigrants (OR = 0.39 [0.26-0.59] to OR = 0.45 [0.30-0.68]; OR = 0.25 [0.13-0.49] to OR = 0.27 [0.13-0.56]). Long-term immigrants also had decreased odds of a self-reported mental disorder compared to non-immigrants (OR = 0.65 [0.46-0.91] to OR = 0.69 [0.51-0.95]). Overall, it was found that certain weather and air pollution exposures are associated with health risks, and there are differences between immigrants and non-immigrants and across different age groups. These results can be used to inform policymakers on immigrant health in Canada and hopefully will facilitate a discussion and lead to further research on this understudied topic.

Preface

This thesis is an original work completed by Brooke T. Sidney under the supervision of Dr. Shelby Yamamoto and Dr. Jordana Salma. The research project included in this thesis received ethics approval from the University of Alberta (ID: Pro00121948). Funding was Provided by the Public Health Agency of Canada: Enhanced Surveillance for Chronic Disease Program (2021-HQ-000108).

The second chapter of this thesis has been published as Sidney, BT., Chandras, S., Campbell, SM., Salma, J., Yamamoto, SS. Health-related impacts of climate change and air pollution on older adult, child, and adolescent immigrants and refugees globally: a scoping review. J Public Health [Internet]. 2023. Available from: https://doi.org/10.1007/s10389-023-02103-z. Author contributions are as follows: Brooke T. Sidney had the idea for the article, and Shelby S. Yamamoto helped refine the research question. Sandra M. Campbell performed the literature search. Brooke T. Sidney and Shubham Chandras completed the screening process. Brooke T. Sidney completed the data extraction and drafted the scoping review. Brooke T. Sidney, Shelby S. Yamamoto, Jordana Salma, Shubham Chandras, and Sandra M. Campbell critically revised the work.

Acknowledgements

I respectfully acknowledge that I completed this MSc on Treaty 6 Territory, the traditional land of First Nations and Métis people.

Thank you to my supervisor, Shelby, for your support and guidance throughout every stage of my degree. I feel extremely lucky to have a supervisor who genuinely cares about each student.

Thank you to my committee, Dr. Jordana Salma, for your valuable feedback.

Thank you to the CHEER lab, Sammy Lowe, Ishwar Tiwari, Tianqi Zhao, Niklas Hayden, Sarah Phae, Nandia Shirchindorj, Sachit Gurung and Joey Syer. A special thank you to Shubham Chandras, who was an integral part of my scoping review.

Thank you to my cat Nico, whose zoomies and goofiness kept me smiling throughout stressful times.

Thank you to my soon to be in-laws, Eleanor and Tony. You were a huge help when I applied to this program. I am so happy to be joining your family.

Thank you to my parents for supporting me throughout my undergraduate and graduate degrees, teaching me the importance of education and how lucky I am to be able to pursue this. I would not have been able to get to where I am without you both. Dad, evenings spent practicing multiplication at the kitchen table paid off!

Last but certainly not least, thank you to my fiancée Daniel. For the past 8 years you have supported me throughout every adventure, even if it meant having to be long-distance for over a year. I am so lucky to go through life with someone so supportive and loving. You are my best friend, and I can't wait to marry you.

This research was conducted at the University of Alberta, Edmonton Research Data Centre, a part of the Research Data Centre Network (CRDCN). This service is provided through the support of the University of Alberta, the province of Alberta, the Canadian Foundation for Innovation, the Canadian Institutes of Health Research, the Social Science and Humanity Research Council, and Statistics Canada. All views expressed in this work are my own.

This project was funded by the Public Health Agency of Canada: Enhanced Surveillance for Chronic Disease Program (2021-HQ-000108) and the J Gordin Kaplan Graduate Student Award which gave me

the incredible opportunity to present my research at the 2023 American Public Health Association Expo and Meeting.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1. Background

1.1 Climate Change and Air Pollution

Climate change is a global issue linked to extreme temperatures, changes in precipitation and reduced snow cover among other changes [1]. Canada is warming at over two times the global average, and Northern Canada even more so [2,3]. The annual average land temperature in Canada has increased by approximately 1.7°C and 2.3°C in Northern Canada since 1948 [2]. Canada is expected to continue warming throughout all seasons, but temperature changes have been most prominent in winter [1,2]. In Canada precipitation has also increased, particularly in winter it is predicted that there will be reduced snowfall and more precipitation [2]. This is expected to continue throughout the 21st century [2]. Climate change is due to both natural and anthropogenic activities [4]. Accelerated climate change is primarily caused by anthropogenic activities, such as burning fossil fuels [1]. The oil and gas industry was the most significant contributor to greenhouse gas emissions in Canada in 2022 [5].

The World Health Organization (WHO) defines air pollution as the “contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere” [6(para.1)]. Common outdoor (ambient) air pollutants include fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2) and ozone (O_3), which make up most of the literature on air pollution health-related impacts [7]. Air pollution is a result of human activities including vehicle emissions and power generation and natural emissions such as wildfires, which contain numerous air pollutants, including nitrogen oxides and particulate matter [7,8]. In 2023 wildfires were a catastrophic problem in Canada and impacted the air quality of most of the Northern Hemisphere [9]. Additionally, air pollution can be from primary emissions which release pollutants directly into the air, or secondary emissions where precursors are released that react to form pollutants [7].

1.2 Interactions Between Climate Change and Air Pollution

Climate change and air pollution are interrelated exposures [10]. Climate change can impact air quality through changing various air pollutant processes (e.g. pollutant removal), and worsening chemical reactions in the atmosphere (e.g. ozone creation) [10,11]. This has been seen most recently in large wildfires across the globe in 2023, which may be linked to climate change, and reduced air quality in the surrounding areas [12,13]. Similarly, air pollution can impact climate change. Sulfate particles can reduce temperature while $PM_{2.5}$ can increase the temperature by absorbing heat [10]. These interactions result in

a feedback loop with each worsening each other's effects [10]. Given the influence these exposures have on one another, it is important to look at both.

1.3 Health Impacts of Climate Change and Air Pollution

Both climate change and air pollution can directly or indirectly impact human health and have been associated with various health-related impacts [10]. Climate change and air pollution have been linked to health outcomes such as respiratory diseases (e.g. asthma, chronic obstructive pulmonary disease), mental health problems (e.g. anxiety, depression, post-traumatic stress disorder) and cardiovascular diseases (e.g. heart failure, stroke), among others [14–17].

The WHO has stated that air pollution is one of the largest environmental risks to human health [18]. In 2019 ambient air pollution was linked globally to an estimated 4.2 million deaths, primarily as a result of cardiovascular and respiratory diseases from fine particulate matter exposure [18]. In Canada, despite having better air quality than most countries, nearly a third of Canadians live in locations that do not meet one of the Canadian Ambient Air Quality Standards for one of the analyzed pollutants ($PM_{2.5}$, SO_2, NO_2 and O_3) [19,20]. Air pollution is associated with more than 15,000 premature deaths yearly in Canada, with approximately 1400 of these occurring in Alberta [7,8].

Climate change also presents a significant threat to human health. Climate change can impact human health through three main categories, direct, indirect and human activities [21]. The direct impacts of climate change result from extreme temperatures, floods, and wildfires. Indirect exposures are those that are facilitated through natural systems such as disease vectors or allergens, and human activities include things such as mental stress and food production [21]. It is predicted that climate change will cause 250,000 deaths globally due to malnutrition, malaria, diarrhea and heat stress between 2030 to 2050 [22].

1.4 Populations at Risk

While climate change and air pollution exposures impact the health of humans globally, certain populations are more at risk than others [23]. This can be a result of low income, race and ethnicity, lack of education, poorer health, a lack of access to high-quality healthcare or geographical location [21,24,25]. At risk populations may include immigrants and refugees, particularly adolescents (ages 12-17) and older adults (65 and older). Statistics Canada defines an immigrant as an individual that has been in the past, or currently is a landed immigrant, permanent resident or a Canadian citizen by naturalization and has received permission to reside in Canada from immigration authorities [26]. Refugees are defined as individuals who had to leave their country for safety reasons, such as war or violence [27]. Immigration to Canada presents a lot of stress on individuals as they adapt to their new surroundings [28–30]. There

are also inequalities between immigrants, refugees and non-immigrants in Canada. In the 2016 Canadian census, non-immigrants made an average of $6700 more than immigrants [31]. Immigrants who move to Canada initially tend to be healthier compared to the native-born population [32]. This health advantage declines after arrival over time and is known as the healthy immigrant effect [32]. While this effect has been studied, immigrants are not a homogenous group, and sub-groups may be impacted differently. Refugees commonly experience a traumatic or stressful event before migration, and as a result, often have poorer health upon arrival compared to immigrants [33,34]. Immigrants and refugees are commonly excluded from air pollution and climate change studies because of this effect and unknown prior exposures [35].

Adolescents are at risk to air pollution and climate change (via direct, indirect and human activities) [36,37]. They have little to no control over their surroundings and lifestyle, such as where they live [36]. This can impact the health of adolescents and can increase their risk to climate change and air pollution exposures as compared to adults [36]. Adolescents differ from adults physically, with developing immune systems, anatomy and cognitive ability, making them more vulnerable [36]. Additionally, adolescents are still developing in many ways, including physically, mentally and socially [38]. Adolescents also experience climate anxiety, which encompasses many emotions such as sadness and anger [38]. Overall, this can lead to an increased risk of mental health conditions such as depression and anxiety and respiratory diseases such as asthma [37,39,40]. Adolescent immigrants and refugees experience these same factors, with the added stress of migration, adjustment to a new culture and lack of support [28,29]. As a result, adolescent immigrants and refugees have a higher risk to outcomes such as mental health conditions [39]. Overall, these different experiences can impact adolescent immigrants' and refugees risk to climate change and air pollution exposures compared to non-immigrant and refugee adolescents. Despite this, information regarding the effects of air pollution and climate change exposure on adolescents is an understudied topic [41].

Climate change and air pollution exposures are also a significant threat to the health of older adults [21,42]. This is primarily due to an increased sensitivity to certain factors, such as heat extremes [42]. Older adults also have an increased risk of pre-existing medical conditions (e.g. hypertension, diabetes etc.), which can affect how their body deals with these exposures, making them more susceptible to health-related impacts [21,42,43]. They also may have weakened immune systems, live alone, and have decreased mobility [44]. Exposure to climate change and air pollution exposures can lead to respiratory disease, cardiovascular disease, and mental health conditions [43,45]. Additionally, older adults experience ageism, which is discrimination against an individual based on their age [46,47]. Ageism can lead to social exclusion and a lack of services and supports for aging which can have an impact on health [46,48]. The global human lifespan is predicted to increase over time making health risks in this age group significant [49]. Climate change and air pollution exposures pose a greater threat to

older immigrants and refugees, as they deal with additional migration-related factors such as cultural differences, communication difficulties and social isolation [30,50,51].

1.5 Geographic Variability

While humans are affected by climate change and air pollution exposures globally, the severity differs across varying geographic locations [21,23,52]. This is due to a high degree of spatial and temporal heterogeneity linked to various vulnerability factors [21,24,25]. For example, availability or access to high-quality healthcare varies depending on geographical location, those who live in rural areas may have less access to healthcare compared to those who live in urban areas [21]. Additionally, certain geographical locations have a higher risk of climate change or air pollution exposures [21]. All of this is further complicated by people moving to different geographic locations as their environmental exposures also change [53]. This makes it difficult to estimate their exposures throughout their lifetime [53]. This affects not only immigrants who move to a new country, but also internal migrants who move within Canada [54]. In Canada, between 2018 and 2019 there were approximately 250,000 interprovincial migrants in Canada [54]. Due to this interprovincial migration, their daily climate change and air pollution exposures likely changed [54]. Knowing current and previous lived geographical locations is important when analyzing climate change and air pollution exposures, but the data is not always available.

1.6 Alberta

Climate change and air pollution events have impacted Alberta, including forest fires, extreme temperatures, floods and reduced air quality [55–58]. Notable disasters include the 2016 Fort McMurray wildfires which burned nearly 600,000 hectares of land, cost over $3.5 billion in insured losses and significantly impacted the mental health of those affected by the fires [59]. Following the fire, between May 2016 and March 2017, 29,000 mental health contacts were recorded [59]. This was much higher than the roughly 1000 mental health contacts that were annually recorded before the fire. Contacts remained high at around 15,000 from March 2017 to January 2018 [59]. Another notable disaster was the 2013 Southern Alberta floods which cost $1.7 billion and affected approximately 100,000 people [58]. Higher rates of injuries and mental health problems were seen in areas affected by the flood [58]. Alberta is expected to experience more events in the future, such as heavy precipitation, droughts, forest fires and severe storms [60].

Alberta's climate has changed and is predicted to continue to change over time [61]. From 1950 to 2013, Alberta's average winter temperature has increased by 0.5 to 1°C per decade and the average summer temperature has increased by 0.1 to 0.3°C per decade [61]. Another climate indicator is precipitation. From 1950 to 2013, the percentage of precipitation as snow from September to April decreased by around 2 to 4% per decade, which changed to rain [61]. Alberta is expected to continue to

experience these effects, with fewer cold days and an increase in the number of warm and hot days [61]. These and other changes will not only impact the health of Albertans but also Alberta's agriculture industry and natural resources [61].

The Athabasca oil sands in Alberta is one of the largest oil sands deposits known globally [62]. Industries, such as the Athabasca oil sands region, release high amounts of pollutants into the air and account for a significant amount of emissions within Alberta [63]. This exposure has sparked debate over its impacts on the environment and the health of Albertans [64]. Oil sands collect bitumen which is a thick form of crude oil that has to be diluted to be transported through pipelines [64]. This dilution process involves adding additional toxic chemicals, such as benzo(a)pyrene. A range of health problems can result from human exposure to diluted bitumen [64,65]. It has been found that the Athabasca River contains benzo(a)pyrene, which is associated with birth defects, and organ and genetic damage [64]. Processing oil sands and crude oil also causes metals such as arsenic, nickel and lead to be released into the water bodies [66]. Arsenic, nickel and lead among other elements have been found in the Alberta oil sands region, with Arsenic found in very high concentrations [67,68]. These metals can have an impact on human health, arsenic can cause skin irritations, visceral cancers and cardiovascular disease [66]. Emissions produced by gasoline-powered vehicles also contribute to air pollution in Alberta [69]. Additionally, population growth in Canada increases the need for goods and services which requires fossil fuel energy [70].

1.7 Statement of the Problem

Climate change and air pollution are two related global issues that can affect human health [44]. Both exposures differ temporally and spatially, making it important to assess health-related impacts across various locations and time frames for different populations [24,25]. These exposures impact all humans globally, but certain populations have higher risk, such as immigrants and refugees [23]. This can be due to many different factors, such as low income, lack of education or transferability of educational qualifications, racism and social exclusion due to discrimination [21,71]. Studying immigrants and refugees as a separate group is important as they have different experiences in Canada than non-immigrants and refugees [35]. Additionally, immigration to Alberta is increasing [72]. In the fourth quarter of 2023 31,037 immigrants arrived in Alberta, an approximate 7500 person increase compared to the previous year [72]. While larger cities such as Toronto historically have had higher immigration rates, Alberta's population increase is more recent and the city lacks proper infrastructure to accommodate immigrants. This places further strain on the immigrant and refugee population in Alberta. Given that the immigrant population in Canada is expected to increase to 24.5-30% and in Alberta to 23.6-31.0% by 2036, this is a gap in the literature that needs to be analyzed [73]. Despite these issues, there is a lack of research on the health-related impacts of climate change and air pollution on immigrants in Canada. This

is particularly evident in Alberta, where more than half of emissions result from industrial, manufacturing and construction activities [60].

1.8 Research Aims and Objectives

This research aimed to examine the health impacts of climate change and air pollution exposures on immigrants and non-immigrants living in Alberta. The objectives included:

1. Investigate the current research on climate change and air pollution health impacts on immigrants and refugees globally (children < 18 and older adults $\geq$ 65 years).

2. Investigate and compare the effects of weather and air pollution exposures on certain health outcomes in immigrant (economic, sponsored by family and refugees) and non-immigrant populations in Alberta.

    a. Among Alberta immigrants and non-immigrants, investigate the associations between air pollution exposures (wildfire smoke, NO_2, O_3, $PM_{2.5}$) and asthma, mental disorders (mood disorder, anxiety disorder) and cardiovascular outcomes (heart disease, effects of stroke).

    b. Among Alberta immigrants and non-immigrants, investigate the associations between weather extremes (extreme temperatures) on asthma, mental disorders (mood disorder, anxiety disorder) and cardiovascular outcomes (heart disease, effects of stroke).

References

1. Warren FJ, Lemmen DS. Synthesis. In: Warren FJ, Lemmen DS, editors. Canada in a changing climate: sector perspectives on impacts and adaptation [Internet]. Ottawa, ON: Government of Canada; 2014. p. 1-18. Available from: https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Synthesis_Eng.pdf

2. Zhang X, Flato G, Kirchmeier-Young M, Vincent L, Wan H, Wang X, et al. Changes in temperature and precipitation across Canada. In: Lemmen DS, Bush E, editors. Canada's changing climate report [Internet]. Ottawa, ON: Government of Canada; 2019. p. 112–93. Available from: https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf

3. Lulham N, Warren FJ, Walsh KA, Szwarc J. Canada in a changing climate: synthesis report [Internet]. Ottawa, ON: Government of Canada; 2023. Available from: https://ostrnrcan-dostrncan.canada.ca/handle/1845/271933

4. Warren FJ, Lemmen DS. Chapter 1: Introduction. In: Warren FJ, Lemmen DS, editors. Canada in a changing climate: sector perspectives on impacts and adaptation [Internet]. Ottawa, ON: Government of Canada; 2014. P 19-22. Available from: https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Chapter1-Introduction_Eng.pdf

5. Environment and Climate Change Canada. Greenhouse gas emissions: Canadian environmental sustainability indicators [Internet]. 2024 May. Available from: https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/ghg-emissions/2024/greenhouse-gas-emissions-en.pdf

6. World Health Organization. Air pollution [Internet]. [cited 2023 Jun 8]. Available from: https://www.who.int/health-topics/air-pollution#tab=tab_1

7. Health Canada. Health impacts of air pollution in Canada: estimates of premature deaths and nonfatal outcomes [Internet]. Ottawa, ON; 2021 Mar. Available from: https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/2021-health-effects-indoor-air-pollution/hia-report-eng.pdf

8. Matz CJ, Egyed M, Xi G, Racine J, Pavlovic R, Rittmaster R, et al. Health impact analysis of PM2.5 from wildfire smoke in Canada (2013-2015, 2017-2018). Sci Total Environ [Internet]. 2020 Jul 10;725:138506. Available from: https://pubmed.ncbi.nlm.nih.gov/32302851/

9. Wang Z, Wang Z, Zou Z, Chen X, Wu H, Wang W, et al. Severe global environmental issues caused by Canada's record-breaking wildfires in 2023. Adv Atmos Sci [Internet]. 2023 Nov 17;41:565-71. Available from: https://doi.org/10.1007/s00376-023-3241-0

10. Orru H, Ebi KL, Forsberg B. The interplay of climate change and air pollution on health. Curr Environ Health Rep [Internet]. 2017 Dec;4:504–13. Available from: http://dx.doi.org/10.1007/s40572-017-0168-6

11. Bell ML, Goldberg R, Hogrefe C, Kinney PL, Knowlton K, Lynn B, et al. Climate change, ambient ozone, and health in 50 US cities. Clim Change [Internet]. 2007 Jan 6;82:61–76. Available from: https://doi.org/10.1007/s10584-006-9166-7

12. Wang X, Parisien MA, Taylor SW, Candau JN, Stralberg D, Marshall GA, et al. Projected changes in daily fire spread across Canada over the next century. Environ Res Lett [Internet]. 2017 Feb 2;12:025005. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/aa5835/meta

13. Flannigan MD, Krawchuk MA, de Groot WJ, Mike Wotton B, Gowman LM. Implications of changing climate for global wildland fire. Int. J. Wildland Fire [Internet]. 2009;18:483–507. Available from: http://dx.doi.org/10.1071/WF08187

14. D'Amato G, Cecchi L, D'Amato M, Annesi-Maesano I. Climate change and respiratory diseases. Eur Respir Rev [Internet]. 2014 Jun;23(132):161–9. Available from: https://err.ersjournals.com/content/23/132/161

15. Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. Climate change and mental health: risks, impacts and priority actions. Int J Ment Health Syst [Internet]. 2018 Jun 1;12(28). Available from: http://dx.doi.org/10.1186/s13033-018-0210-6

16. Peters A, Schneider A. Cardiovascular risks of climate change. Nat Rev Cardiol [Internet]. 2021 Nov 9;18:1–2. Available from: https://www.nature.com/articles/s41569-020-00473-5

17. Dominski FH, Lorenzetti Branco JH, Buonanno G, Stabile L, Gameiro da Silva M, Andrade A. Effects of air pollution on health: a mapping review of systematic reviews and meta-analyses. Environ Res [Internet]. 2021 Oct;201:111487. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0013935121007817

18. World Health Organization. Ambient (outdoor) air pollution [Internet]. 2022 Dec 19 [cited 2023 Jan 27]. Available from: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

19. Government of Canada. Canada's air quality [Internet]. 2023 Jun 2 [cited 2023 Aug 10]. Available from: https://www.canada.ca/en/environment-climate-change/campaigns/canadian-environment-week/clean-air-day/air-quality.html

20. Alberta. Canadian ambient air quality standards [Internet]. [cited 2023 Aug 10]. Available from: https://www.alberta.ca/canadian-ambient-air-quality-standards

21. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: impacts, adaptation, and co-benefits. In: Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, editors. Climate change 2014 - impacts, adaptation, and vulnerability: part A: global and sectoral aspects [Internet]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014. p. 709–54. Available from: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf

22. World Health Organization. Climate change [Internet]. [cited 2023 Sept 10]. Available from: https://www.who.int/health-topics/climate-change

23. Hathaway J, Maibach EW. Health implications of climate change: a review of the literature about the perception of the public and health professionals. Curr Environ Health Rep [Internet]. 2018 Feb 8;5:197–204. Available from: http://dx.doi.org/10.1007/s40572-018-0190-3

24. Preston BL, Yuen EJ, Westaway RM. Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. Sustainability Sci [Internet]. 2011 Mar 24;6:177–202. Available from: https://link.springer.com/article/10.1007/s11625-011-0129-1

25. Dias D, Tchepel O. Spatial and temporal dynamics in air pollution exposure assessment. Int J Environ Res Public Health [Internet]. 2018 Mar 20;15(3). Available from: http://dx.doi.org/10.3390/ijerph15030558

26. Statistics Canada. Immigrant [Internet]. 2023. [cited 2024 May 2]. Available from:

https://www23.statcan.gc.ca/imdb/p3Var.pl?Function=Unit&Id=85107

27. Government of Canada. How Canada's refugee system works [Internet]. 2024 Apr 10 [cited 2024 May 2]. Available from: https://www.canada.ca/en/immigration-refugees-citizenship/services/refugees/canada-role.html

28. Ng E, Zhang H. The mental health of immigrants and refugees: Canadian evidence from a nationally linked database [Internet]. 2020 Aug 19;31(8):3-12. Available from: https://pubmed.ncbi.nlm.nih.gov/32816413/

29. Levitt MJ, Lane JD, Levitt J. Immigration stress, social support, and adjustment in the first postmigration year: an intergenerational analysis. Res Hum Dev [Internet]. 2005;2(4):159–77. Available from: https://doi.org/10.1207/s15427617rhd0204_1

30. Mandell N, Borras J, Phonepraseuth J. Strategies and best practices for data literacy education: knowledge synthesis report. 2015. Available from: https://www.niagaraknowledgeexchange.com/wp-content/uploads/sites/2/2018/10/IWYS-Knowledge-Synthesis-Report-Seniors-report-Sept-2018.pdf

31. Government of Canada. Data tables, 2016 census. [Internet]. 2019 Jun 17 [cited 2023 Dec 10]. Available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/dt-td/Rp-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=1&PID=110560&PRID=10&PTYPE=109445&S=0&SHOWALL=0&SUB=999&Temporal=2016,2017&THEME=119&VID=0&VNAMEE=&VNAMEF=

32. Vang ZM, Sigouin J, Flenon A, Gagnon A. Are immigrants healthier than native-born Canadians? a systematic review of the healthy immigrant effect in Canada. Ethn Health [Internet]. 2017;22(3):209–41. Available from: http://dx.doi.org/10.1080/13557858.2016.1246518

33. Lane G, Farag M, White J, Nisbet C, Vatanparast H. Chronic health disparities among refugee and immigrant children in Canada. Appl Physiol Nutr Metab [Internet]. 2018 May 4;43(10):1043–58. Available from: http://dx.doi.org/10.1139/apnm-2017-0407

34. Daynes L. The health impacts of the refugee crisis: a medical charity perspective. Clin Med [Internet]. 2016 Oct;16(5):437–40. Available from: http://dx.doi.org/10.7861/clinmedicine.16-5-437

35. Erickson AC, Christidis T, Pappin A, Brook JR, Crouse DL, Hystad P, et al. Disease assimilation: the mortality impacts of fine particulate matter on immigrants to Canada. Health Rep [Internet]. 2020 Jun 17;31(3):14-26. Available from: https://www.ncbi.nlm.nih.gov/pubmed/32644760

36. Stanberry LR, Thomson MC, James W. Prioritizing the needs of children in a changing climate. PLoS Med [Internet]. 2018 Jul 31;15(7):e1002627. Available from: http://dx.doi.org/10.1371/journal.pmed.1002627

37. Yu W, Weitzman M. Climate change, air pollution, and children's mental health. J Appl Res Child [Internet]. 2021;12(1). Available from: https://digitalcommons.library.tmc.edu/childrenatrisk/vol12/iss1/13/

38. Hickman C, Marks E, Pihkala P, Clayton S, Lewandowski RE, Mayall EE, et al. Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. Lancet Planet Health [Internet]. 2021 Dec;5(12):e863–73. Available from: http://dx.doi.org/10.1016/S2542-5196(21)00278-3

39. Ma T, Moore J, Cleary A. Climate change impacts on the mental health and wellbeing of young people: a scoping review of risk and protective factors. Soc Sci Med [Internet]. 2022 May;301:114888. Available from: http://dx.doi.org/10.1016/j.socscimed.2022.114888

40. Gehring U, Wijga AH, Koppelman GH, Vonk JM, Smit HA, Brunekreef B. Air pollution and the development of asthma from birth until young adulthood. Eur Respir J [Internet]. 2020 Jul;56: 2000147. Available from: http://dx.doi.org/10.1183/13993003.00147-2020

41. Clemens V, von Hirschhausen E, Fegert JM. Report of the intergovernmental panel on climate change: implications for the mental health policy of children and adolescents in Europe-a scoping review. Eur Child Adolesc Psychiatry [Internet]. 2022 May;31:701–13. Available from: http://dx.doi.org/10.1007/s00787-020-01615-3

42. Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med [Internet]. 2009 Jan;51(1):33–7. Available from: http://dx.doi.org/10.1097/JOM.0b013e318193e12e

43. Kriebel-Gasparro A. Climate change: effects on the older adult. J Nurse Pract [Internet]. 2022 Apr ;18(4):372–6. Available from: https://www.sciencedirect.com/science/article/pii/S1555415522000071

44. Akhtar R, Palagiano C. Climate change and air pollution: the impact on human health in developed and developing countries [Internet]. Springer International Publishing; 2018. 430 p. Available from: https://link.springer.com/book/10.1007/978-3-319-61346-8

45. Chang AY, Tan AX, Nadeau KC, Odden MC. Aging hearts in a hotter, more turbulent world: the impacts of climate change on the cardiovascular health of older adults. Curr Cardiol Rep [Internet]. 2022 Apr 19;24:749–60. Available from: http://dx.doi.org/10.1007/s11886-022-01693-6

46. Levy BR, Slade MD, Chang ES, Kannoth S, Wang SY. Ageism amplifies cost and prevalence of health conditions. Gerontologist [Internet]. 2018 Nov 13;60(1):174–81. Available from: https://academic.oup.com/gerontologist/article-pdf/60/1/174/33123535/gny131.pdf

47. World Health Organization. Ageing: ageism [Internet]. 2021 Mar 18 [cited 2024 May 2]. Available from: https://www.who.int/news-room/questions-and-answers/item/ageing-ageism

48. Levy SR, Apriceno M. Ageing: the role of ageism. OBM Geriat [Internet]. 2019 Oct 28;3(4). Available from: https://www.lidsen.com/journals/geriatrics/geriatrics-03-04-083

49. Carnes BA, Staats D, Willcox BJ. Impact of climate change on elder health. J Gerontol A Biol Sci Med Sci [Internet]. 2014 Sep;69(9):1087–91. Available from: http://dx.doi.org/10.1093/gerona/glt159

50. Newbold KB, Filice JK. Health status of older immigrants to Canada. Can J Aging [Internet]. 2006;25(3):305–19. Available from: http://dx.doi.org/10.1353/cja.2007.0009

51. Chowdhury N, Naeem I, Ferdous M, Chowdhury M, Goopy S, Rumana N, et al. Unmet healthcare needs among migrant populations in Canada: exploring the research landscape through a systematic integrative review. J Immigr Minor Health [Internet]. 2021 Apr;23:353–72. Available from: http://dx.doi.org/10.1007/s10903-020-01086-3

52. Hess JJ, Malilay JN, Parkinson AJ. Climate change: the importance of place. Am J Prev Med [Internet]. 2008 Nov;35(5):468–78. Available from: http://dx.doi.org/10.1016/j.amepre.2008.08.024

53. Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. Ambient PM2.5, O_3, and NO_2 exposures and associations with mortality over 16 Years of follow-up in the Canadian Census Health and Environment Cohort (CanCHEC). Environ Health Perspect [Internet]. 2015 Nov 1;123(11):1180–6. Available from: http://dx.doi.org/10.1289/ehp.1409276

54. Chastko K. Internal migration: overview, 2016/2017 to 2018/2019 [Internet]. Statistics Canada; 2021 Jul 14. Available from: https://www150.statcan.gc.ca/n1/pub/91-209-x/2021001/article/00001-

eng.htm

55. Ahmed MR, Hassan QK. Occurrence, area burned, and seasonality trends of forest fires in the natural subregions of Alberta over 1959–2021. Fire [Internet]. 2023 Mar 2;6(3). Available from: https://www.mdpi.com/2571-6255/6/3/96

56. Ejiagha IR, Ahmed MR, Dewan A, Gupta A, Rangelova E, Hassan QK. Urban warming of the two most populated cities in the Canadian province of Alberta, and its influencing factors. Sensors [Internet]. 2022 Apr 9;22(8). Available from: http://dx.doi.org/10.3390/s22082894

57. Bari MA, Kindzierski WB. Evaluation of air quality indicators in Alberta, Canada - an international perspective. Environ Int [Internet]. 2016 Jul-Aug;92–93:119–29. Available from: http://dx.doi.org/10.1016/j.envint.2016.03.021

58. Sahni V, Scott AN, Beliveau M, Varughese M, Dover DC, Talbot J. Public health surveillance response following the southern Alberta floods, 2013. Can J Public Health [Internet]. 2016 mar 1;107(2):e142–8. Available from: http://dx.doi.org/10.17269/cjph.107.5188

59. Mamuji AA, Rozdilsky JL. Wildfire as an increasingly common natural disaster facing Canada: understanding the 2016 Fort McMurray wildfire. Nat Hazards [Internet]. 2019 Sept 25;98:163–80. Available from: https://doi.org/10.1007/s11069-018-3488-4

60. Alberta. Climate change in Alberta [Internet]. [cited 2023 Jun 27]. Available from: https://www.alberta.ca/climate-change-alberta.aspx

61. Hayhoe K, Stoner A. Alberta's climate future: final report [Internet]. ATMOS Research & Consulting; 2019. Available from: https://open.alberta.ca/dataset/89a69583-a11b-4e31-a857-b311ab6563cc/resource/17ce2d24-ba7b-466c-acd9-33a2cf6beb69/download/aep-alberta-climate-report-arc.pdf

62. Tenenbaum DJ. Oil sands development: a health risk worth taking? Environ Health Perspect [Internet]. 2009 Apr 1;117(4):A150-6. Available from: http://dx.doi.org/10.1289/ehp.117-a150

63. Jung K, Chang SX, Ok YS, Arshad MA. Critical loads and H+ budgets of forest soils affected by air pollution from oil sands mining in Alberta, Canada. Atmos Environ [Internet]. 2013 Apr 1;69:56–64. Available from: https://www.sciencedirect.com/science/article/pii/S1352231012011600

64. Finkel ML. The impact of oil sands on the environment and health. Curr Opin Environ Sci Health [Internet]. 2018 Jun;3:52–5. Available from: https://www.sciencedirect.com/science/article/pii/S2468584417300648

65. Government of Canada. Fact sheet: benzo pyrene [Internet]. [cited 2024 Jan 8]. Available from: https://gost.tpsgc-pwgsc.gc.ca/Contfs.aspx?ID=33&lang=eng

66. Ore OT, Adeola AO. Toxic metals in oil sands: review of human health implications, environmental impact, and potential remediation using membrane-based approach. Energ. Ecol. Environ. [Internet]. 2020 Oct 18;6(2):81–91. Available from: https://doi.org/10.1007/s40974-020-00196-w

67. Moncur MC, Paktunc D, Jean Birks S, Ptacek CJ, Welsh B, Thibault Y. Source and distribution of naturally occurring arsenic in groundwater from Alberta's southern oil sands regions. Appl Geochem [Internet]. 2015 Nov;62:171–85. Available from: https://www.sciencedirect.com/science/article/pii/S0883292715000554

68. Huang R, McPhedran KN, Yang L, El-Din MG. Characterization and distribution of metal and nonmetal elements in the Alberta oil sands region of Canada. Chemosphere [Internet]. 2016

Mar;147:218–29. Available from: http://dx.doi.org/10.1016/j.chemosphere.2015.12.099

69. Government of Canada. Air pollution from cars, trucks, vans and SUVs [Internet]. 2017 [cited 2024 May 2]. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/sources/transportation/cars-trucks-vans-suvs.html

70. Government of Canada. Air pollution: drivers and impacts [Internet]. 2024 [cited 2024 May 2]. Available from: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollution-drivers-impacts.html

71. Ferrer I, Brotman S, Koehn S. Unravelling the interconnections of immigration, precarious labour and racism across the life course. J Gerontol Soc Work [Internet]. 2022 Feb 27;65(8):797–821. Available from: http://dx.doi.org/10.1080/01634372.2022.2037805

72. Alberta. Current provincial population estimates [Internet]. [cited 2024 May 2]. Available from: https://www.alberta.ca/population-statistics

73. Malenfant ÉC, Isaac SM. Immigration and Diversity: Population Projections for Canada and its Regions, 2011 to 2036 [Internet]. Statistics Canada; 2017 Jan 25. Available from: https://www150.statcan.gc.ca/n1/en/pub/91-551-x/91-551-x2017001-eng.pdf?st=Ri_b-rZ3

Chapter 2: Health-Related Impacts of Climate Change and Air Pollution on Immigrants and Refugees Globally

Brooke Sidney[1], Shubham Chandras[1], Sandra Campbell[1], Jordana Salma[2] and Shelby S. Yamamoto[1]

J Public Health 2023. https://doi.org/10.1007/s10389-023-02103-z

Received: 12 June 2023 Accepted: 13 September 2023 Published: 14 October 2023

1. School of Public Health, University of Alberta, Edmonton, AB T6G 1C9, Canada; shubhamd@ualberta.ca (S.C.); scampbel@ualberta.ca (S.M.C.); shelby.yamamoto@ualberta.ca (S.S.Y.)

2. Faculty of Nursing, University of Alberta, Edmonton, AB T6G 1C9, Canada; sjordana@ualberta.ca

Abstract

Aim: Climate change and air pollution exposures are global issues impacting human health. This scoping review aims to synthesize evidence on the health-related impacts of climate change and air pollution exposures on immigrant and refugee populations younger than 18 and 65 years and older, and to determine if the impacts are influenced by age, immigrant category, gender, and/or geographical location.

Subject and methods: Databases were searched from inception to July 2022 and included PROSPERO, OVID Medline, OVID EMBASE, Wiley Cochrane Library (CDSR and Central), Proquest Dissertations and Theses Global and SCOPUS. All time frames, languages, and geographic locations were included. Types of evidence sources included were reviews (e.g. scoping, systematic, clinical), books, and descriptive (e.g., ecological) and analytical (e.g. case–control, cross-sectional and cohort) studies.

Results: Three studies fit the criteria. All used secondary data sources, different study designs and analysis approaches and defined immigrants, refugees, and exposures differently. Only climate change exposures (excessive temperatures) were explored, with mortality and respiratory syncytial virus outcomes. Two articles found that foreign-born and non-US citizens 65 years and older were similarly or less susceptible compared to native-born, but younger individuals were more susceptible. The other found that higher temperatures were associated with higher respiratory syncytial virus incidence in refugee children younger than 5 years old. If stratification was done, only sex, age, race, ethnicity, and place of birth were examined.

Conclusions: Immigrants and refugees are understudied in the literature and often excluded. Additional research is needed to determine other exposures and health outcomes for immigrant and refugee populations.

1. Introduction

Climate change and air pollution are interrelated exposures that can directly or indirectly affect human health, including respiratory and cardiovascular diseases [1–4]. The World Health Organization has called climate change the biggest threat to humanity [5]. The acceleration of climate change and ambient air pollution is the result of natural emissions and anthropogenic activities, including fossil fuel consumption [6]. More research is being done on the effects of climate change and air pollution on human health.

Certain populations, including immigrants, may be more susceptible to the effects of these exposures than others [7]. The Intergovernmental Panel on Climate Change defines vulnerability as "the propensity or predisposition to be adversely affected" [8]. Vulnerability can result from low income, structural and racial inequities, lack of education, poor health, and/or a lack of access to high-quality healthcare [8]. Upon relocation, immigrants experience social and cultural changes, adjustments to a new language, have a different diet, and are exposed to different values and ways of life [9]. Refugees adjust to these same changes but also deal with the added stress of fleeing their home country due to fear for their safety, and the negative effect that migrating has on their mental health [9,10]. As a result, refugees have worse health than immigrants and are more vulnerable to certain health outcomes, such as infectious diseases [9]. Overall, these factors can increase levels of vulnerability among the immigrant and refugee populations, and can exacerbate the effects of climate change and air pollution exposures. Immigrants have also been found to be exposed to higher levels of fine particulate matter ($PM_{2.5}$) as they tend to settle in urban areas and specifically in areas with higher levels of exposure [11,12]. Certain age ranges, including those younger than 18 and older than 65 years old may be more susceptible to certain health outcomes due to physiological reasons [13–15]. Adolescents and children may experience additional vulnerability due to factors related to immunity, physiology, and cognitive development [14]. Older adults have an increased risk of pre-existing medical conditions (e.g. hypertension, diabetes, etc.), decreased immune systems, often live alone, and have decreased mobility which can affect how their body deals with these exposures, making them more susceptible to health-related impacts [8,16,17].

Since immigrants and refugees have different experiences than the native-born population, which can impact their health, it is important to include and focus on this population [12]. Immigrants and refugees are understudied, particularly recent immigrants, and tend to be excluded in climate change research such as in large cohort studies focusing on air pollution exposures [12]. This could be due to numerous factors such as a lack of information on prior exposures, reduced access to the health system, and moving within the new country [12,18]. Research can also be more complicated due to a lack of previous known exposures and immigrants and refugees not being captured in databases if they recently immigrated [12]. Additionally, they primarily move to urban areas, which have higher temperatures and

levels of air pollution compared to rural areas [12]. This scoping review aims to examine the literature to determine the health impacts of these exposures on immigrants and refugees, and how it varies among different groups (e.g., age, immigrant category, gender, and/or geographical location). A scoping review was chosen as the field of research on this topic was unknown. While there are studies that focus on the health impacts of climate change and air pollution, it was unclear how or if immigrants have been included in this research topic.

2. Materials and Methods

For this scoping review, framework outlined by the Joanna Briggs Institute Reviewer's Manual was followed [19]. This framework was first proposed in 2005 by Arksey and O'Malley, and was further refined in 2010 by Levac, Colquhoun and O'Brien [20–22]. The PRISMA-S Checklist for scoping reviews was followed [23].

2.1 Research Questions

For this study, we aimed to explore previous research on the health-related impacts of air pollution (e.g., NO_2, O_3 and $PM_{2.5}$) and extreme weather (e.g., wildfires, extreme temperatures and floods) exposures on immigrant and refugee populations. We also examined whether studies explored effects by age group (children and adolescents less than 18 or adults 65 years and older), immigrant category (refugee, economic immigrant, immigrant sponsored by family, other), gender (woman vs man or other) or geographical location (rural vs urban locations). Economic immigrants are those that move for economic opportunities, such as a new job [24]. We define children and adolescents as those younger than 18, and older adults as those 65 years and older. The protocol was filed on open science framework (https://osf.io/wrfah/?view_only=83663 93dbefa45e09d6e22d54ef2ba0c).

For this review, only immigrants and refugees were included. An immigrant was defined as a person who has chosen to leave their country of origin and is or has been a landed immigrant, permanent resident, or citizen through naturalization [25,26]. A refugee was defined as a person who left their country for safety [25]. Weather extremes could include several types of exposures such as wildfires, extreme temperatures, and floods. Ambient air pollution is defined as a mixture of air pollutants from vehicles, industries, and households that people are exposed to outdoors [27]. Air pollution exposures could include NO_2, O_3 and $PM_{2.5}$, among others [27]. Climate change and air pollution exposures were chosen, as complex relationships between them can have an impact on human health independently and synergistically. It is important to look at both exposures, as they may particularly impact immigrant and refugee populations globally. Children, adolescents, and older adults are focused on in this scoping review, as immigrants are not a uniform group; some age groups may be more vulnerable to certain health outcomes.

2.2 Search Methods

A health librarian from the University of Alberta completed a search on six databases using controlled vocabulary (e.g., MeSH, Emtree, etc.) and text word searching. Databases included PROSPERO, OVID Medline, OVID EMBASE, Wiley Cochrane Library (CDSR and Central), Proquest Dissertations and Theses Global, and SCOPUS. Words representing key concepts including “climate change”, “air pollution”, and “immigrants” were searched (Table A1) [28–38]. Searches were restricted to adults 65 years and older, and children and adolescents younger than 18. Databases were searched from inception to July 2022. Records (2378) were exported to Covidence systematic review software, where duplicates (934) were removed, leaving 1444 for level 1 screening [39]. Detailed search strings are available in the supplementary materials.

2.3 Screening

The titles and abstracts of articles were screened using pre-determined questions and completed by two independent reviewers. Articles that completely or partly met the inclusion criteria (answered yes or maybe) proceeded to level 2 screening. The complete articles were then screened based on inclusion and exclusion criteria and were completed by two independent reviewers. Any article that completely met the inclusion criteria (answered yes) was included in the results. If any exclusion criteria were identified, it was rejected. Google Translate was used to translate non-English titles and abstracts for screening. The reference lists of relevant articles were analyzed by browsing for articles that met the inclusion criteria. The types of evidence sources included were reviews (e.g., scoping, systematic, clinical), books, and descriptive (e.g., ecological) and analytical (e.g., case–control, cross-sectional and cohort) studies. All time frames, languages, and geographic locations were included. The studies that focused on any population were considered, as long as immigrants and/or refugees (children and adolescents less than 18 or adults 65 years and older) were also included.

2.4 Data Extraction and Presentation

Data was extracted from each article using Covidence 2.0 data extraction software [39]. Fields recommended by JBI for extraction were used and expanded upon [40]. The full list used for data extraction is provided in the supplementary materials. Data was analyzed narratively.

3. Results

Of the 1444 studies screened at the first stage, 1353 were excluded, leaving 91 for level two full-text screening. Three articles were included in the results (Fig. 2.1). Table 2.1 summarizes the characteristics of the three final included articles. Mercereau et al. analyzed the difference in temperature mortality between those native to France and foreign-born [41]. Taylor et al. had a similar objective, and

explored the risk of heat-related deaths among non-US citizens compared to US citizens [42]. Nyoka et al. looked at the relationship between the incidence of respiratory syncytial virus infections and weather, including temperature in refugee children [43]. All the articles were published within a 2-year period, two published in 2017 and one in 2018. Two articles had similar study length periods, both 10 years, with some overlapping years [41,42]. The shortest study period was 5 years [43]. No air pollution studies were included in the results.

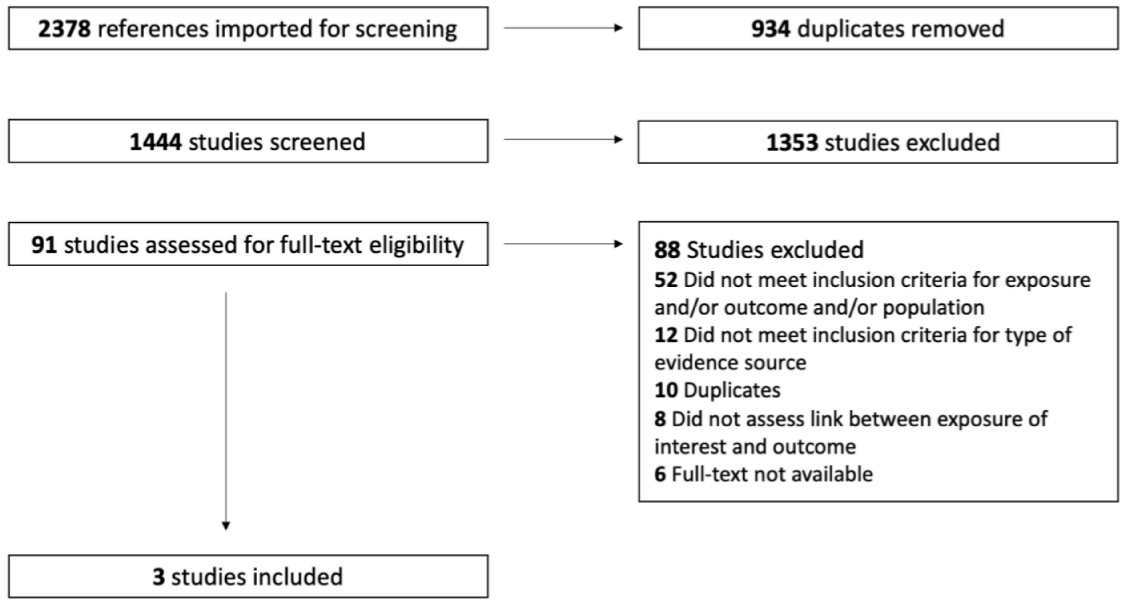

Figure 2.1 PRISMA flow diagram.

Table 2.1 Characteristics of the final studies included

Authors	Years of Study	Country	Population (type, sample size, age categories)	Gender	Study Design	Comparison Group	Primary Exposure Variables	Health Outcomes	Main Findings
[43]	September 2007 - August 2011	Kenya	Refugee, Sample size not specified, ages <5 years old	Gender not specified	Non-gaussian time-series	No comparison group	Temperature (daily mean, minimum and maximum temperature)	Monthly RSV incidence rate	Higher temperatures associated with higher RSV incidence.
[41]	2000-2009	France	Population type not specified (foreign-born), sample size 573,384, all ages, 0-65 (unclear if this category includes those aged 65), 65-85 and >85	Gender not specified	Matched pairs design	Native-born	Heat and cold (Heat wave: at least the 4th day above the 99th percentile of the local temperature distribution, Cold spell: at least the 4th day below the 1st percentile of the local temperature distribution)	Mortality	Similar attributable fraction of deaths in cold/hot temperatures for native-born and foreign-born for ages 65-85 and >85. Foreign and native-born >85 found to be more sensitive to temperatures.

[42]	2005-2014	United States	Population type not specified (non-US citizens), sample size 999, ages <5, 5-17, 18-24, 25-44, 45-64 and ≥ 65	Men and women	Not specified	US citizens	Excessive heat (defined heat related deaths with ICD-10 code X30 [exposure to excessive natural heat] as underlying cause of death)	Mortality	Non-US citizens ≥65 years old had a lower risk of mortality compared to US citizens of the same age. Non-US citizens ages 5-17 had a higher risk compared to US citizens of the same age.

While all studies focused on populations of different ages, two of the articles specifically included those aged 65 and older. Mercereau et al. looked at those aged 65 to 85 and those older than 85, and Taylor et al. those 65 years and older [41,42]. Each study defined immigrants and refugees differently, and none included the length of residence in the adopted country. Taylor et al. used the place of residence to define citizenship, as the citizenship status was not available through the National Vital Statistics System [42]. If a death occurred in the United States, but the residence was recorded as outside of the country, they recorded them as a non-US citizen [42]. It was not specified who was included in the non-US citizen population (e.g., immigrant, refugee). Mercereau et al. used the birthplace of each person to distinguish between those native to France and those foreign-born, obtained from death certificates from the French Epidemiology Center on Medical Causes of Death [41]. Nyoka et al. focused on a refugee population, and recruited from among children who underwent surveillance for viral respiratory illnesses [43]. Data was obtained from surveillance done in the Dadaab refugee camp in Kenya [43]

All articles used secondary data sources, but each employed a different study design and analysis approach. Nyoka et al. conducted a non-Gaussian time-series with generalized linear and additive models, and Mercereau et al. used a matched-pairs design based on birth date, sex, and the place of death with a generalized additive model [41,43]. Taylor et al. did not specify the type of study design, but completed descriptive analysis [42]. Despite these differences, two of the articles examined mortality as the health outcome, while Nyoka et al. focused on monthly respiratory syncytial virus (RSV) incidence rate [41–43]. Additionally, two articles stratified by age, with Taylor et al. also stratifying risk ratios for heat-related deaths by sex (male vs female) race (white vs other) and ethnicity (Hispanic vs non-Hispanic) [41,42]. Mercereau et al. studied the relationship between temperature and mortality, and stratified by birth region and age [41]. Nyoka et al. investigated the association between RSV incidence and climate, but did not present any stratified results [43]. All articles neglected to stratify by immigrant category.

All three studies examined temperature exposures, but each defined them differently. Mercereau et al. defined a heat wave and a cold spell as “at least the 4th day above the 99th or below the 1st percentile of the local temperature distribution” [41]. Taylor et al. did not formally define excessive heat, but used an ICD-10 code (X30) indicative of mortality due to excessive natural heat [42]. Nyoka et al. included the daily mean, minimum, and maximum temperatures [43].

3.1 Study Findings

Nyoka et al. focused on refugee children younger than 5 years old in the Dadaab refugee camp and found that higher temperatures were associated with higher RSV incidence [43]. The other two articles focused on older population ages [41,42]. Mercereau et al. was specifically interested in

adaptation to temperature, and hypothesized that if there was little difference in mortality among foreign-born and native-born, this would be indicative of adaptation [41]. They found that between those aged 65 to 85 and those older than 85, there was little difference in the attributable fraction of deaths with exposure to cold and hot temperatures for native-born and foreign-born populations [41]. Additionally, for both native-born and foreign-born populations, those older than 85 years were found to be more sensitive to temperatures compared to those ages 65 to 85 [41]. The only significant difference found was the attributable fraction of death due to cold between those 65 to 85 who were Southern European-born and their matched native-born counterparts in the continental region of France [41]. The authors reported an estimated mortality rate of 8.8% among those who were Southern European-born, and 5.3% among the native-born populations. It was also found that overall, there was a higher percentage of deaths attributable to cold compared to heat, with those older than 85 affected more than those ages 65 to 85 [41]. Taylor et al. also investigated if non-US citizens had higher heat-related mortality rates compared to US citizens [42]. Non-US citizens ages 65 years and older had a lower risk of heat-related deaths compared to US citizens of the same age [RR = 0.2 (0.1, 0.4)] [42]. It was also found that non-US citizens aged 5 to 17 had a higher risk of heat-related deaths compared to US citizens of the same age (15.6 times more likely). White [RR = 6.2 (5.8, 6.7)] and Hispanic [RR = 3.6 (3.2, 3.9)] non-US citizens were found to be at a higher risk for heat-related death compared to US citizens [42].

4. Discussion

4.1 Health Impacts of Climate Change Exposures in Immigrant Populations

Three articles were included in the results, among two of the articles, it was found that for older foreign-born and non-US citizens (65 and older and 65 to 85) there was little difference or lower risk of mortality when compared to native-born [41,42]. Conversely, mortality from excessive heat exposure among younger non-US citizens ages 18 to 24 was found to be higher [42]. This may be due to younger non-US citizens having higher risk jobs such as farming, compared to older non-US citizens [42]. This is supported by the fact that 19.8% of non-US citizens' place of death was recorded as a farm [42]. It was not certain what led to the difference in older immigrants, with certain factors such as health, and occupation or cultural differences, hypothesized as having a role [42]. A study in France hypothesized that individuals become adapted to weather conditions in their adopted countries, which could also help explain these results [41]. This is contradicted by one significant finding, the attributable fraction of death due to cold in those aged 65 to 85 in the continental region of France was higher in Southern European-born compared to the native-born population [41]. Southern Europe includes countries with warmer climates, such as Greece, Italy, and Spain, which all have mild winters. Comparatively, France has a temperate climate and can have cold winters. This does not support the adaptation of individuals to weather conditions in their adopted countries, it suggests that those born in Southern Europe may not become adapted to colder weather. This suggests that those who move from hot to cold climates may not

have the same adaptation to weather conditions as those who move from cold to hot, or from a similar climate. This was not observed for those ages 65 to 85 born in Maghreb [41]. It was also found that overall more deaths were attributed to cold compared to heat [41]. This may be due to factors such as a lack of education about cold winters resulting in unsuitable winter clothing [44]. It has even been suggested that vitamin D deficiency may also be an issue for those moving from warm to cold climates [44]. Mercereau et al. found that those older than 85 were more affected by cold temperatures than those aged 65 to 85 [41]. This is expected, as older adults may be more susceptible to cold temperatures [45]. Additionally, generally older adults have worse health compared to those who are younger, due to pre-existing medical conditions (e.g., hypertension, diabetes etc.), decreased immune systems, and decreased mobility, which can all increase susceptibility to certain diseases [8,16,17]. Differences were found among study designs, analysis approaches, and in terms of how results were stratified. These differences may be due to the different data sets used, with each article obtaining population data from different sources. If immigrant data is available, it seems that certain factors of interest are not, which limits what can be studied, resulting in a lack of stratified data.

This review identified one study that associated higher RSV incidence in children younger than 5 years old with higher temperatures [43]. It is important to note that overcrowding may also have played a role [46,47]. Crowding issues have led to camps being set up on the perimeters of Dadaab [47]. Other studies have pointed to the detrimental impact of refugee camps on child health, Colosia et al. found that overcrowding was associated with a higher risk of RSV hospitalization for infants and children due to a higher chance of being exposed to the virus through droplets or secretions [48]. Crowded conditions can also lead to other disease outbreaks, as in 2015 when the Dadaab refugee camp experienced a cholera outbreak [49]. Another potential factor is that individuals in refugee camps may experience poor living conditions, malnutrition, and lack of access to appropriate care, which can also increase the incidence of disease [46].

No articles analysing the health-related impacts of air pollution exposures (e.g., NO_2, O_3, and $PM_{2.5}$) on immigrants were included in the results of this scoping review, but still are an important exposure. This may, in part, be due to a lack of pre-immigration exposure data or other missing data, particularly if they recently immigrated [12,42]. A number of studies have looked at air pollution and immigrant health, which showed that immigrants were found to be exposed to higher levels of $PM_{2.5}$ but had lower mortality rates compared to non-immigrants [50–52]. This may be due in part to the screening process that is conducted prior to admission to Canada (healthy immigrant effect) [50–52]. Due to the vulnerability of children, adolescents, and older adults, further research is required to examine the impacts of air pollution on these age-specific migrant populations.

4.2 Limitations

While a comprehensive search was conducted, any articles that did not include the chosen keywords could have been missed. We also did not complete a quality assessment of the evidence, and instead focused on an exploration of the available research focused on climate change, air pollution and older adult, child and adolescent immigrant, and refugee health. Two independent reviewers completed the screening process, though only one completed the data extraction. However, the data extraction table was discussed and vetted by the other authors. While library databases were used to access articles for full-text screening, six full-text studies were not found. Additionally, as populations in low-income countries develop chronic diseases earlier than high-income countries, a broader definition of older adults (e.g., 50 or over) could be warranted. Lastly, there were papers that met most of the screening criteria but were excluded as age ranges were grouped.

5. Conclusions and Gaps in the Literature

This scoping review highlighted potential differences in health impacts related to climate change exposures in immigrant and refugee populations. However, there is a lack of research in this area. As a result of this study, several gaps in the literature were identified, including the lack of stratified results. If results were stratified by age, for example, they tended to be grouped into large age ranges, and key information such as the length of residence was not provided or considered. Data sources might have limited the availability of these factors in these analyses. Immigrant populations are heterogeneous and grouped results might obscure important differences. Vulnerability to climate change and air pollution exposures is probably different in populations 65 years and older and under 18 years old, and should be studied separately [14,16]. Geographical gaps were also found. As exposures vary by geographical region, this is an important gap. Immigrants and refugees were often not the focus of the study, but a subgroup analysis. Many studies that included immigrants also excluded recent immigrants who had been in the country for less than 10 years. Studies tended to focus on temperature-related exposures. Other climate change-related exposures such as floods or wildfires did not appear as frequently in the literature, and none were included in this review. Additionally, given that each paper defined temperature exposures differently, it would be beneficial to establish a standardized definition. No air pollution studies met our inclusion criteria. The health outcomes examined were narrow and focused on mortality. A focus on other health outcomes is needed. These gaps highlight the need for further focused research on immigrant and refugee populations, particularly children, adolescents, and older adults.

Acknowledgements

Author contributions Brooke T. Sidney had the idea for the article, and Shelby S. Yamamoto helped refine the research question. Sandra M. Campbell performed the literature search. Brooke T. Sidney and Shubham Chandras completed the screening process. Brooke T. Sidney completed the data extraction and drafted the scoping review. Brooke T. Sidney, Shelby S. Yamamoto, Jordana Salma, Shubham Chandras, and Sandra M. Campbell critically revised the work.

Funding Provided by the Public Health Agency of Canada: Enhanced Surveillance for Chronic Disease Program (2021-HQ-000108).

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests All authors have no competing interests to declare.

Supplementary Information

The scoping review protocol and detailed search strings (Table A1) are available in Appendix 1.

The full list used for data extraction is provided in Appendix 2.

References

1. D'Amato G, Cecchi L, D'Amato M, Annesi-Maesano I. Climate change and respiratory diseases. Eur Respir Rev [Internet]. 2014 Jun;23(132):161–9. Available from: https://err.ersjournals.com/content/23/132/161

2. Orru H, Ebi KL, Forsberg B. The interplay of climate change and air pollution on health. Curr Environ Health Rep [Internet]. 2017 Dec;4:504–13. Available from: http://dx.doi.org/10.1007/s40572-017-0168-6

3. Peters A, Schneider A. Cardiovascular risks of climate change. Nat Rev Cardiol [Internet]. 2021 Nov 9;18:1–2. Available from: https://www.nature.com/articles/s41569-020-00473-5

4. Dominski FH, Lorenzetti Branco JH, Buonanno G, Stabile L, Gameiro da Silva M, Andrade A. Effects of air pollution on health: a mapping review of systematic reviews and meta-analyses. Environ Res [Internet]. 2021 Oct;201:111487. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0013935121007817

5. World Health Organization. Climate change and health [Internet]. 2021 [cited 2023 Jan 27] . Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

6. Warren FJ, Lemmen DS. Canada in a changing climate: sector perspectives on impacts and adaptation [Internet]. Ottawa, ON: Government of Canada; 2014. 286 p. Available from: https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf

7. Hathaway J, Maibach EW. Health implications of climate change: a review of the literature about the perception of the public and health professionals. Curr Environ Health Rep [Internet]. 2018 Feb 8;5:197–204. Available from: http://dx.doi.org/10.1007/s40572-018-0190-3

8. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: impacts, adaptation, and co-benefits. In: Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, editors. Climate change 2014 - impacts, adaptation, and vulnerability: part A: global and sectoral aspects [Internet]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014. p. 709–54. Available from: https://researchprofiles.canberra.edu.au/en/publications/human-health-impacts-adaptation-and-co-benefits

9. Beiser M. The health of immigrants and refugees in Canada. Can J Public Health [Internet]. 2005 Mar-Apr;96 Suppl 2:S30-44. Available from: https://pubmed.ncbi.nlm.nih.gov/16078554/

10. Lebano A, Hamed S, Bradby H, Gil-Salmerón A, Durá-Ferrandis E, Garcés-Ferrer J, et al. Migrants' and refugees' health status and healthcare in Europe: a scoping literature review. BMC Public Health [Internet]. 2020 Jun 30;20(1). Available from: https://pubmed.ncbi.nlm.nih.gov/32605605/

11. Pinault L, van Donkelaar A, Martin RV. Exposure to fine particulate matter air pollution in Canada. Health Rep [Internet]. 2017 Mar 15;28(3):9–16. Available from: https://pubmed.ncbi.nlm.nih.gov/28295129/

12. Erickson AC, Christidis T, Pappin A, Brook JR, Crouse DL, Hystad P, et al. Disease assimilation: the mortality impacts of fine particulate matter on immigrants to Canada. Health Rep [Internet]. 2020 Jun 17;31(3):14-26. Available from: https://www.ncbi.nlm.nih.gov/pubmed/32644760

13. Carnes BA, Staats D, Willcox BJ. Impact of climate change on elder health. J Gerontol A Biol Sci Med Sci [Internet]. 2014 Sep;69(9):1087–91. Available from: http://dx.doi.org/10.1093/gerona/glt159

14. Stanberry LR, Thomson MC, James W. Prioritizing the needs of children in a changing climate. PLoS Med [Internet]. 2018 Jul 31;15(7):e1002627. Available from: http://dx.doi.org/10.1371/journal.pmed.1002627

15. Yu W, Weitzman M. Climate change, air pollution, and children's mental health. J Appl Res Child [Internet]. 2021;12(1). Available from: https://digitalcommons.library.tmc.edu/childrenatrisk/vol12/iss1/13/

16. Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med [Internet]. 2009 Jan;51(1):33–7. Available from: http://dx.doi.org/10.1097/JOM.0b013e318193e12e

17. Kriebel-Gasparro A. Climate change: effects on the older adult. J Nurse Pract [Internet]. 2022 Apr;18(4):372–6. Available from: https://www.sciencedirect.com/science/article/pii/S1555415522000071

18. Ravichandiran N, Mathews M, Ryan BL. Utilization of healthcare by immigrants in Canada: a cross-sectional analysis of the Canadian community health survey. BMC Prim Care [Internet]. 2022 Apr 6;23(1). Available from: https://pubmed.ncbi.nlm.nih.gov/35387597/

19. Peters MDJ, Godfrey CM, McInerney P, Baldini Soares C, Khalil H, Parker D. The joanna briggs institute reviewers' manual 2015: methodology for JBI scoping reviews [Internet]. The University of Adelaide, South Australia: The Joanna Briggs Institute; 2015. Available from: https://repositorio.usp.br/directbitstream/5e8cac53-d709-4797-971f-263153570eb5/SOARES%2C+C+B+doc+150.pdf

20. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol [Internet]. 2005 Feb23;8(1):19–32. Available from: https://doi.org/10.1080/1364557032000119616

21. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci [Internet]. 2010 Sep 20;5. Available from: https://pubmed.ncbi.nlm.nih.gov/20854677/

22. Daudt HML, van Mossel C, Scott SJ. Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework. BMC Med Res Methodol [Internet]. 2013 Mar 23;13(48). Available from: https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-13-48

23. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med [Internet]. 2018 Oct 2;169(7):467–73. Available from: https://pubmed.ncbi.nlm.nih.gov/30178033/

24. Statistics Canada. Classification of admission category of immigrant [Internet]. 2022 [cited 2023 May 4]. Available from: https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=323293&CVD=323294&CLV=0&MLV=4&D=1

25. Government of Canada. How Canada's refugee system works [Internet]. 2019 [cited 2022 Aug 31]. Available from: https://www.canada.ca/en/immigration-refugees-citizenship/services/refugees/canada-role.html

26. Statistics Canada. Immigrant status of person [Internet]. 2023 [cited 2023 May 4]. Available from: https://www23.statcan.gc.ca/imdb/p3Var.pl?Function=DEC&Id=103339

27. World Health Organization. Ambient (outdoor) air pollution [Internet]. 2022 Dec 19 [cited 2023 Jan 27]. Available from: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

28. Campbell SM. A filter to retrieve studies related to refugees/immigrants from the OVID medline database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2020. Available from: https://docs.google.com/document/d/13CDD4zA_T2nTHO_fAQ-m1vcLr8Nmuw7rnZ2BbXSbO0k/edit

29. Campbell SM. Hedge to retrieve articles related to air pollution in OVID EMBASE [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2021. Available from: https://docs.google.com/document/d/1EbeATCMKWmwzyV79SF97ahnkq4pEedcPLSZkSt-F7W4/edit

30. Campbell SM. Hedge to retrieve articles related to air pollution in OVID medline [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2021. Available from: https://docs.google.com/document/d/1gGY4q7orPUSMhttBBnz5KsOKv5ZCSErkvg-hlBbSorM/edit

31. Campbell SM. Hedge to retrieve articles related to climate change in EBSCO CINAHL [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1BbD7ArMV7wjcYKIoof8ehE_Url0xqDxsSo4_VAwgg9Q/edit#

32. Campbell SM. Hedge to retrieve articles related to climate change in OVID EMBASE [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/17W7bVIeG4xEUKpi3m1tll8oCYtPXTlSJasfMCt-fFNY/edit#

33. Campbell SM. Hedge to retrieve articles related to climate change in OVID medline [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/11s673QzBiO4uqX2TwxukFgPzRYa6sT5Jt47BsFN2yyU/edit#

34. Campbell SM. Hedge to retrieve articles related to air pollution in EBSCO CINAHL [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1OLx0u_a7kChVKUJihLvBWN5nkCxtIANJX2GICrL1v6A/edit

35. Campbell SM. Hedge to retrieve articles related to air pollution in SCOPUS [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1oo3Daq3GWOsjqLhTdBBn2Bfyvk91jX28XhmxUquymbk/edit

36. Campbell SM. A filter to retrieve studies related to refugees/immigrants from the OVID EMBASE database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/19cvUcFhv-n5dzJ-EDaRZA0DzSMZWkicWRMCH9KBu3Nk/edit

37. Campbell SM. A filter to retrieve studies related to refugees/immigrants from the EBSCO CINAHL database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available

from: https://docs.google.com/document/d/1gVj-jQdv8ddWCVmIQgpStoPPoNs6hMWvYDHIgUacEg8/edit

38. Dennett EL, Campbell SM. A hedge to retrieve studies related to climate change from the SCOPUS database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1fVtBDWZE36okUcWzNGOQwYSAVGH69QhWlumaVe88BpI/edit

39. Veritas Health Innovation. Covidence systematic review software [Internet]. Melbourne, Australia; 2023. Available from: https://www.covidence.org/

40. Peters MDJ, Godfrey C, McInerney P, Munn Z, Tricco AC, Khalil, H. Chapter 11: scoping reviews (2020 version). In: Aromataris E MZ, editor. JBI manual for evidence synthesis [Internet]. 2020. Available from: https://synthesismanual.jbi.global. https://doi.org/10.46658/JBIMES-20-12

41. Mercereau L, Todd N, Rey G, Valleron AJ. Comparison of the temperature-mortality relationship in foreign born and native born died in France between 2000 and 2009. Int J Biometeorol [Internet]. 2017 Oct;61(10):1873–84. Available from: https://pubmed.ncbi.nlm.nih.gov/28540492/

42. Taylor EV, Vaidyanathan A, Flanders WD, Murphy M, Spencer M, Noe RS. Differences in heat-related mortality by citizenship status: United States, 2005-2014. Am J Public Health [Internet]. 2018 Apr;108(S2):S131–6. Available from: https://pubmed.ncbi.nlm.nih.gov/29072944/

43. Nyoka R, Omony J, Mwalili SM, Achia TNO, Gichangi A, Mwambi H. Effect of climate on incidence of respiratory syncytial virus infections in a refugee camp in Kenya: a non-gaussian time-series analysis. PLoS One [Internet]. 2017 Jun 1;12(6):e0178323. Available from: https://doi.org/10.1371/journal.pone.0178323

44. Shor E, Roelfs D. Climate shock: moving to colder climates and immigrant mortality. Soc Sci Med [Internet]. 2019 Aug;235:112397. Available from: https://pubmed.ncbi.nlm.nih.gov/31306882/

45. Young AJ, Lee DT. Aging and human cold tolerance. Exp Aging Res [Internet]. 1997 Jan-Mar;23(1):45–67. Available from: https://pubmed.ncbi.nlm.nih.gov/9049612/

46. Ahmed JA, Katz MA, Auko E, Njenga MK, Weinberg M, Kapella BK, et al. Epidemiology of respiratory viral infections in two long-term refugee camps in Kenya, 2007-2010. BMC Infect Dis [Internet]. 2012 Jan 17;12(7). Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-12-7#citeas

47. Somo H, Kurgat A, Kwonyike J. The socio-economic implications of Somali refugees to the host community at the Dadaab refugee camp in Kenya. ASSRJ [Internet]. 2021 Jul 9;8(7):50–70. Available from: https://journals.scholarpublishing.org/index.php/ASSRJ/article/view/10502#:~:text=The%20findings%20show%20that%20Somali,to%20Kenya's%20socio%2Deconomic%20development.

48. Colosia AD, Masaquel A, Hall CB, Barrett AM, Mahadevia PJ, Yogev R. Residential crowding and severe respiratory syncytial virus disease among infants and young children: a systematic literature review. BMC Infect Dis [Internet]. 2012 Apr 20;12:95. Available from: https://pubmed.ncbi.nlm.nih.gov/22520624/#:~:text=Conclusions%3A%20Residential%20crowding%20was%20associated,%2C%20populations%2C%20or%20geographic%20locations.

49. Golicha Q, Shetty S, Nasiblov O, Hussein A, Wainaina E, Obonyo M, et al. Cholera outbreak in Dadaab refugee camp, Kenya - November 2015-June 2016. MMWR Morb Mortal Wkly Rep. 2018 Aug 31;67(34):958–61. Available from: https://www.cdc.gov/mmwr/volumes/67/wr/mm6734a4.htm#:~:text=During%20November%2018%2C%202015%E2%80%93June,a%20shared%20plate%20were%20common.

50. Christidis T, Erickson AC, Pappin AJ, Crouse DL, Pinault LL, Weichenthal SA, et al. Low concentrations of fine particle air pollution and mortality in the Canadian community health survey cohort. Environ Health [Internet]. 2019 Oct 10;18(1):84. Available from: https://pubmed.ncbi.nlm.nih.gov/31601202/

51. Pappin AJ, Christidis T, Pinault LL, Crouse DL, Brook JR, Erickson A, et al. Examining the shape of the association between low levels of fine particulate matter and mortality across three cycles of the Canadian census health and environment cohort. Environ Health Perspect [Internet]. 2019 Oct;127(10):107008. Available from: https://pubmed.ncbi.nlm.nih.gov/31638837/

52. Brauer M, Brook JR, Christidis T, Chu Y, Crouse DL, Erickson A, et al. Mortality–air pollution associations in low-exposure environments (MAPLE): phase 1. Res Rep Health Eff Inst [Internet]. 2019;203:1-87 Nov 1. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7334864/

Chapter 3: Health Impacts of Climate Change and Air Pollution on Immigrants and Non-Immigrants in Alberta

Brooke T. Sidney[1], Jordana Salma[2], Joey Syer[1], Shelby S. Yamamoto[1]

1. School of Public Health, University of Alberta, Edmonton, AB T6G 1C9, Canada; shelby.yamamoto@ualberta.ca; syer@ualberta.ca

2. Faculty of Nursing, University of Alberta, Edmonton, AB T6G 1C9, Canada; sjordana@ualberta.ca

Abstract

Climate change and air pollution are global issues that can have an impact on human health and is an understudied topic of research. This cross-sectional study examined the associations between weather and air pollution exposures and asthma, cardiovascular outcomes (heart disease and stroke effects), and mental disorders (mood and anxiety disorder) in immigrant (economic, sponsored by family and refugees; all ages), total (immigrants and non-immigrants; all ages), adolescent (total population; ages 12 to 17) and older adult (total population; ages 65 plus) populations in Alberta. Weather exposures included annual variables for extreme temperatures (high, low etc.), and air pollution exposures included annual variables for wildfire smoke exposure, NO_2, O_3 and $PM_{2.5}$. Exposure variables were categorized into quartiles (very low, low, moderate, and high exposure levels or very small, small, medium and large).

With high temperature exposure, higher odds of self-reported asthma were found for the total population (Odds ratio (OR) [95% CI], moderate level = 1.34 [1.04-1.72]), high level = 1.58 [1.20-2.07]) and higher odds of self-reported cardiovascular outcomes for the immigrant population (low level = 3.15 [1.40-7.07], high level 2.49 [1.09-5.65]). Immigrants and older immigrants were found to have higher odds of a self-reported cardiovascular outcome with high temperature compared to non-immigrants (OR low level = 3.19 [1.39-7.29], moderate level = 2.69 [1.16-6.28], high level = 3.40 [1.45-7.97]; low level = 2.64 [1.02-6.82], moderate level = 3.48 [1.37-8.79], high level = 3.58 [1.29-9.91]). Among older adults, a positive association between low temperature and self-reported mental disorders was found (OR low level = 1.64 [1.00-2.69]). Immigrants and adolescents were found to have a positive association with fine particulate matter exposure and mental disorders (OR low level = 2.27 [1.01-5.07]; high level = 2.99 [1.02-8.74]). For other exposures, mixed results were found.

For high temperature exposure, previous studies have found that high temperatures are associated with asthma and cardiovascular outcomes, but limited research has been completed on older immigrants. Limited research has also been completed among older adults on the association between low temperature and mental disorders, but anxiety disorders have been found to occur less frequently in older adults compared to younger individuals. For adolescents, the results found between fine particulate

matter exposure and mental disorders are consistent with previous studies. Comparatively, for immigrants the results differ from the literature, immigrants in Canada have been found to have a lower prevalence of mood and anxiety disorders. Going forward, immigrant specific studies on the impact of climate change and air pollution exposures on health outcomes, particularly for adolescents and older adults, should be conducted and stratified by age, sex, geographical location (urban, rural), world area of birth and immigrant category.

1. Introduction

1.1 Climate Change and Air Pollution

Climate change and air pollution are two closely related global issues. Climate change has been called “one of the defining challenges of the 21st century” [1(p11)]. In Canada, the effects of climate change are seen in changes in the temperature, precipitation and snow cover, which can result in droughts and wildfires [2]. These effects are worsening over time, and are expected to continue throughout the 21st century [2]. Since 1948 Canada has increased in temperature by 1.7°C, with more prominent changes observed in winter [2]. While climate change is the result of natural and anthropogenic activities, accelerated climate change is mainly due to anthropogenic activities like burning fossil fuels [2]. Air pollution commonly refers to $PM_{2.5}$, NO_2 and O_3, with many studies analyzing the adverse impact of these pollutants on human health [3]. Similar to climate change, it is caused by various natural and human activities, such as wildfires and vehicle emissions [3,4]. Climate change and air pollution are interrelated exposures, meaning each can affect the other [5]. As a result, it is important to look at the health impacts of both exposures.

1.2 Climate Change, Weather and Air Pollution in Alberta

Average temperatures vary depending on the location and season in Alberta, with a daily average temperature in Edmonton between 1991 and 2020 ranging from -11°C in December to 16.2 °C in July [6]. Air quality also varies across the province and is impacted by the oil sands industry and wildfires [7,8]. Alberta has a history of extreme wildfires, including the 2016 Fort McMurray wildfires, which burned nearly 600,000 hectares of land and cost over $3.5 billion in insured losses [9]. Albertans are exposed to numerous air pollutants from these sources including nitrogen dioxide (NO_2), ozone (O_3) and fine particulate matter ($PM_{2.5}$) [10].

The severity of the impact of climate change and air pollution exposure on human health differs geographically [11]. This is due to a high degree of spatial and temporal heterogeneity linked to vulnerability factors, such as access to high-quality and specialized healthcare [11–13]. Additionally, certain geographic locations have higher pollutant concentrations [11]. Alberta specifically has experienced climate change and air pollution events such as extreme temperatures, flooding, wildfires and poor air quality [14–17]. Limited research looking at the associations between these exposures and health impacts has been completed in Alberta. It is expected that Alberta will experience more events in the future, making it critical to further understand the impact of these exposures on the health of those living in Alberta [18].

1.3 Health Impacts of Climate Change and Air Pollution Exposures

Climate change and air pollution are interrelated exposures that can directly or indirectly impact human health [5]. Globally, ambient air pollution was associated with approximately 4.2 million deaths in 2019 [19]. In Canada alone, air pollution is associated with more than 15,000 premature deaths per year [3]. Climate change could cause 250,000 deaths between 2030 to 2050 due to various effects such as extreme heat, in 2022 more than 60,000 deaths were linked to extreme heat in Europe [19–21]. Previous studies have found that climate change-related exposures such as extreme temperatures, and air pollutants such as O_3 are also directly and indirectly associated with morbidity due to asthma, cardiovascular outcomes and mental disorders [2]. Between 2015 and 2020, asthma impacted an average of 8.9% of the Canadian population ages 12 or older [22]. Mental disorders are a growing problem in Canada. More than 18% of Canadians 15 and older were diagnostically considered to have a mood, anxiety or substance use disorder in 2022, but this was likely impacted by COVID-19 [23]. Additionally, the amount of people with a mood or anxiety disorder has increased by approximately 0.5-4% from 2012 to 2022 [23]. Cardiovascular outcomes are another key health issue in Canada, with heart disease being the second most common cause of death [24].

1.4 At-Risk Populations

Certain populations are at higher risk to the effects of these exposures compared to others [25]. Immigrants and refugees, particularly adolescents and older adults, may experience exacerbated risks from these exposures due to factors such as low income, racial inequities and lack of access to high-quality health care, among others [11,26]. Immigrants tend to reside in urban areas, which have higher levels of $PM_{2.5}$, thus impacting their exposure levels [27]. While initially immigrants that move to Canada tend to be healthier compared to those born in Canada, their health declines over time to match that of the host population [28]. This is known as the healthy immigrant effect, but immigrants are not a homogenous group, and sub-groups may be impacted differently [28]. Comparatively, refugees often have poor health compared to immigrants upon arrival as they commonly go through a traumatic event before migration [29,30]. There is limited research looking at these exposure outcome associations among immigrants and refugees. Immigrants are commonly excluded due to the healthy immigrant effect and unknown past exposures [31]. Refugees are also commonly excluded, including refugees involves ethical challenges as they are in a position with unequal power and have likely come from a previous situation of poverty and violence [32]. It is important to focus on immigrants and refugees as they make up a significant portion of the Canadian population. Approximately 37,000 refugee claims were accepted by the Immigration and Refugee Board of Canada between January and December 2023 [33]. The immigrant population in Canada is increasing and it is estimated that by 2036, immigrants and second-generation individuals in Canada will make up one in every two people [34].

Adolescents and older adults may also experience higher risks to the effects of these exposures [35,36]. Adolescents have different immune responses, anatomy and cognitive abilities compared to adults which can impact their risk [35]. Older adults may have pre-existing medical conditions, less robust immune systems and can experience ageism, making them more susceptible to health-related impacts from these exposures [37,38]. Additionally, older adults are more likely to suffer from certain conditions, such as heart disease compared to those who are younger. It is important to look at older adults as it is predicted that by 2046 older adults (ages 65 plus) will make up 20% of the Canadian population, an approximate increase of 6% since 2020 [39].

1.5 Statement of the Problem and Objectives

Climate change and air pollution exposures are global problems that can have local health impacts in Canada [2]. It is important to look at higher risk populations, such as immigrants, older adults and adolescents as they have different lived experiences and tend to be understudied in the literature [25,31]. It is also important to focus on locations such as Alberta, which has a large oil production industry that can contribute to climate change and air pollution problems regionally. Thus, the objectives of this study were to examine and compare the effects of climate change extremes (extreme temperatures) and air pollution exposures (NO_2, O_3, $PM_{2.5}$, wildfire smoke) on certain health outcomes (asthma, mental disorders and cardiovascular outcomes) in immigrants (economic, sponsored by family and refugees; all ages), total (immigrants and non-immigrants; all ages), adolescent (total population; ages 12 to 17) and older adult (total population; ages 65 plus) populations in Alberta.

2. Methods

2.1 Study Design, Population, and Location

A cross-sectional study was completed using data from Alberta, Canada between 2009 to 2014. As of the 2021 Canadian census, the province of Alberta has a population of 4,262,635 people [40]. Two major cities in Alberta, Calgary and Edmonton, make up just over half of the population, with 2,317,683 people [41]. There are 1,772,670 private dwellings in Alberta, with an average household size of 2.6 people [40]. The average income after taxes for individuals is $50,200 [40]. The total population (ages 12 to 85 plus), adolescents (ages 12-17), older adults (65 plus) and immigrants (less than or equal to 17 to 80 plus) who resided in Alberta were included in this study. The average age in Alberta is 39 years old [40]. As of 2021, those older than 85 made up 1.7 % of the Alberta population, older adults ages 65 plus made up 14.8%, individuals ages 15 to 64 made up 66.2% and individuals ages 0 to 14 made up 19% [40]. Immigrants comprised 23% of the population in Alberta in 2021, with the most common age at immigration between 25 to 44 years old at 46% [40]. The number of immigrants in Canada is expected to grow over the years, with an estimated 24.5-30% by 2036 [34]. By 2046, it is estimated that Alberta's

population will increase to nearly 6.4 million people, with approximately 54% of this increase due to the migration of immigrants [39]. Among Immigrants in Canada, 55.9% were economic, 28.5% were sponsored by family, 14.7% were refugees, and 0.99% were classified as other [40]. Economic immigrants move for economic opportunities such as a job, and other immigrants are admitted based on humanitarian reasons, public policy or another admission category not listed [42,43]. Alberta's most densely populated area is the Edmonton-Calgary Corridor, which includes nearly 77% of the population [39]. In the past ten years, 86% of immigrants who moved to Alberta settled in this area [39]. Ethics was obtained from the University of Alberta Health Research Ethics Board (Pro00121948).

2.2 Health and Sociodemographic Data

The outcomes of interest included asthma, cardiovascular outcomes, and mental disorders. These outcomes have been previously linked to climate change and air pollution exposures [44–46]. Cardiovascular outcomes included heart disease and stroke effects. Mental disorders included mood and anxiety disorders. Initially, health outcomes were intended to be analyzed individually, but due to low counts, were grouped into these broader categories. Health outcome data (2009-2014) was self-reported and obtained from the Canadian Community Health Survey (CCHS) via the Statistics Canada Research Data Centre (RDC) [47]. The RDC is a secure location to access and use Statistics Canada microdata and was started in 2000 [48,49]. As of 2024, there are 33 locations across Canada [49]. The CCHS is a voluntary annual sample survey with a cross-sectional design and stratified sample [47]. It was started in 2001 and gathers health information from Canadians for health surveillance and population health research [47]. While initially the CCHS was conducted every 2 years, it was changed to annually in 2007 [47]. From 2009 to 2014 it used three sampling frames, area frame (from the Labour Force Survey), telephone numbers and random digit dialling [47]. Up to 2022, the CCHS questioned Canadians ages 12 and older [47]. The CCHS excludes individuals who live on reserves and other aboriginal settlements, full-time members of the Canadian Forces, the institutionalized population and individuals living in the Quebec health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James [47]. Only CCHS individuals who gave permission to share their survey information with provincial and federal ministries of health and have their responses linked to administrative data were included [50]. Variables used from the CCHS include age, household income (all sources), geographical location (urban or rural), sex (male or female), marital status, BMI, household size, cultural/racial background, education level, self-perceived health, self-perceived mental health, high blood pressure status, diabetes status, smoking status, sense of belonging to community, asthma status, heart disease status, stroke effects status, mood disorder status, anxiety disorder status and length of residence in Canada.

CCHS data was linked to the Longitudinal Immigration Database (IMDB) integrated permanent and non-permanent resident file [50,51]. The IMDB is an annual census survey with a longitudinal design [51]. It was started in 1980 to gather data on the immigration program in Canada [51]. The IMDB

integrated permanent and non-permanent resident file dataset joins person-level data from the Immigrant Landing File, the Non-Permanent Resident File and the T1 Family File [52]. It only includes non-permanent residents who later became permanent residents since 1980 and filed a tax return since 1982 [52]. The Immigrant Landing File is an administrative census of immigrants who arrived in Canada since 1980 and includes sociodemographic information [50]. While the IMDB contains information as far back as 1952, IMDB data from 1980 to 2014 is available to be linked to the CCHS [53]. The IMDB dataset was accessed in the RDC and used to obtain additional individual-level immigrant data on immigrants in Alberta. The IMDB integrated the permanent and non-permanent resident files, which was used as it contained the most relevant variables for the population of interest. While no variables were directly used from the IMDB due to a high amount of missing data and correlation issues, a variable to identify immigrants (economic, sponsored by family, refugees) and non-immigrants was created using IMDB data. More information on these variables can be found in Table A3.

2.3 Weather and Air Pollution Exposures

2.3.1 Weather Exposures

Climate metrics were obtained from the Canadian Urban Environmental Health Research Consortium (CANUE) and included annual variables for high, low, average, average daily minimum, average daily maximum temperatures and the annual average of the difference between minimum and maximum temperature (Celsius), also known as the diurnal temperature range (DTR) for Alberta from 2009 to 2014 [54]. This data was created using base data obtained from the Canadian Forest Service of Natural Resources Canada and interpolating for all postal code locations in Canada from 1983 to 2015 [55]. This was done using Australian National University Spline (ANULSPLIN) climate modeling software, which uses thin plate smoothing splines for interpolation [55–57]. Thin plate smoothing splines can be described as a “non-parametric, multi-dimensional curve fitting technique for application to noisy multi-variate data” [58(para.2)]. This is especially useful for climate metric data as there is a lack of data in remote locations [58]. Data is available annually and is linked to annual postal code files [55]. This data was linked to the CCHS and IMDB based on the postal code. As climate metrics were not linear, transformations were applied and eventually categorized as quartiles: very low, low, moderate and high exposure levels (Table 3.1). DTR was categorized as quartiles: very small, small, medium and large (Table 3.1). More information on the weather exposure variables can be found in Table A3.

Table 3.1 Categories for annual weather and air pollution exposure variables.

	Exposure categories			
	Very low	**Low**	**Moderate**	**High**
High temperature (Celsius)	min to 30.73	30.74 to 31.87	32.88 to 33.08	33.09 to max

Low temperature (Celsius)	min to -33.16	-34.44 to -33.17	-34.45 to -35.97	-35.98 to max
Average temperature (Celsius)	min to 2.83	2.84 to 3.31	3.32 to 4.02	4.03 to max
Average daily maximum temperature (Celsius)	min to 8.77	8.78 to 9.17	9.18 to 10.16	10.17 to max
Average daily minimum temperature (Celsius)	min to -2.05	-2.06 to -2.52	-2.53 to -3.10	-3.11 to max
Average wildfire smoke ($PM_{2.5}$ $\mu g/m^3$)	min to 6.59	6.60 to 7.14	7.15 to 7.74	7.75 to max
Average $PM_{2.5}$ ($\mu g/m^3$)	min to 6.75	6.77 to 8.09	8.19 to 10.17	10.31 to max
Average NO_2 (ppb)	min to 6.92	7.07 to 11.62	11.74 to 15.31	15.71 to max
Average O_3 (ppb)	min to 19.94	20.23 to 22.83	22.90 to 26.55	26.56 to max
	Exposure categories			
	Very Small	**Small**	**Medium**	**Large**
Average diurnal temperature range (Celsius)	min to 11.59	11.60 to 12.00	12.01 to 12.53	12.54 to max

Sources: Canadian Urban Environmental Health Research Consortium [54] and National Air Pollution Surveillance Program [59].

2.3.2 Air Pollution Exposures

Wildfire smoke exposure ($PM_{2.5}$) data was also obtained from CANUE and included annual smoke exposure ($PM_{2.5}$ - annual average concentration in $\mu g/m^3$) from 2010-2014, which is a measure of wildfire smoke [54]. Data from 2009 was not available as collection did not start until 2010. While wildfire smoke is a combination of various air pollutants that are common to other sources, in this data $PM_{2.5}$ from wildfire smoke was the target exposure [60]. This variable was generated by the Environmental Health Services of the BC Centre for Disease Control using a random forest machine learning model called the Canadian Optimized Statistical Smoke Model (CanOSSEM) [61]. It estimated $PM_{2.5}$ concentrations at a 5

km by 5 km spatial resolution using predictor variables specific to wildfire smoke obtained from various sources [61]. After a wildfire event or when new data is available, CanOSSEM is retrained and new estimates generated [61]. Data is linked to annual postal code files and is available annually or monthly [61]. As wildfire smoke exposure data was not linear, transformations were applied and categorized into quartiles: very low, low, moderate and high exposure levels (Table 3.1).

Exposure data for the annual mean concentrations of NO_2, O_3 and $PM_{2.5}$ were obtained from the National Air Pollution Surveillance (NAPS) Program from 2009-2014 [59]. A health geographer mapped the spatial distribution of the NAPS variables using ArcGIS® Pro version 2.7 (Esri, Redlands, CA, USA). NAPS data was linked to postal codes by assigning the closest observation to each using ArcMap software version 10.7. The NAPS program started in 1969 and is "the main source of ambient air quality data in Canada" [62(para.1)]. NO_2 (ppb), O_3 (ppb) and $PM_{2.5}$ ($\mu g/m^3$) data are available as hourly or annual average concentrations [62]. Only annual observations with nine or more months of data were included. As NO_2, O_3 and $PM_{2.5}$ were not linear, transformations were applied and categorized into quartiles: very low, low, moderate and high exposure levels (Table 3.1). NO_2, O_3 and $PM_{2.5}$ were chosen as air pollution variables as they are criteria air pollutants included in the Air Quality Health Index, and previous research has shown links to health impacts in humans [10,63].

In sensitivity analyses, ground-level $PM_{2.5}$ exposures between 1998 to 2021 from geographically weighted regression models from CANUE were used, although these were focused primarily on urban areas [64]. The most recent version (version 5) was used, which extended the available data to 2021. These estimates were determined from Aerosol Optical Depth retrievals, including NASA, MODIS, MISR and SeaWIFS and the GEOS-Chem chemical transport model [64]. Data is calibrated to global ground-based observations with geographically weighted regression [64]. Geographically weighted regression is a spatial regression technique that assigns exposures based on distance to the air pollutant monitoring stations [65]. Data was linked to annual postal code files [64]. More information on the air pollution exposure variables can be found in Table A3.

2.4 Statistical Analysis

All analysis was completed in STATA MP/18 in the RDC. Individual-level data was used to analyze the health impacts of weather and air pollution exposures on immigrants in Alberta. Adolescents (ages 12-17) and older adults (ages 65 plus) immigrants were also of interest in this study, but due to low counts could not be analyzed separately by age group. Age stratification of the total population across Alberta was conducted.

2.4.1 Sample Size of Prevalence in Population

The estimated sample size needed to estimate asthma prevalence among those ages 12 plus is 64, based on a margin of error of 0.05 and a prevalence of 8.93% [22]. The estimated sample size needed to estimate the prevalence of mood disorders among those ages 12 plus is 71, based on a margin of error of 0.05 and a prevalence of 10.04% [66]. The calculation can be found in Appendix 4.

2.4.2 Variable Selection and Data Linkage

In the case of similar variables across the IMDB and CCHS databases, the CCHS variable was chosen, as it included the total population (immigrants and non-immigrants). Variables in the CCHS were also checked for consistency across years as variable names, categories and definitions may have changed or been dropped. Not all CCHS variables were available for all years, which also affected variable selection.

The pooled approach was used with the CCHS data, each year (2009-2014) was combined at the micro-data level and then examined as one population [67]. CCHS data was merged with exposure data using the postal code, to the IMDB link keys file using the sample ID and person ID and then to the IMDB data using the IMDB ID. NAPS data only included latitude and longitude coordinates, which were converted to postal codes using ArcMap software (version 10.7). A variable was created to identify immigrants and non-immigrants. To capture available immigrants in the dataset, immigrants from both the CCHS and IMDB were included. Some individuals were classified as immigrants in the CCHS but were not included in the IMDB as they likely predated the IMDB. A small number of participants in the IMDB who answered “no” to a CCHS immigrant question were also included.

2.4.3 Descriptive Statistics

Descriptive statistics were conducted. Duplicates were explored and identified in the CCHS database. In these cases, the most recent CCHS data for each individual was kept and the other dropped. The distribution, frequency, range, and central tendency (mean, median, mode) from 2009 to 2014 were examined in tabular and graphical formats. Missing data and outliers were explored. Any implausible observations were recoded to be missing. All drinking variables were dropped due to a high amount of missing observations. IMDB variables (immigrant category, world area of birth, and official language) were also dropped due to a high amount of missing observations among the immigrant population, and high correlation with other variables among the total (immigrant, non-immigrant) population. Numbers were weighted and suppressed to meet the confidentiality requirements of Statistics Canada.

2.4.4 Multivariable Logistic Regression

2.4.4.1 Total Population

Variables were selected *a priori.* Collinearity and multicollinearity among the selected variables were checked. High correlations were found between population type (immigrant, non-immigrant) and all IMDB variables (official language, immigration category and world area of birth), population type and length of residence variable. High correlations were also found between cultural/racial background and the length of residence in Canada. As such, population type and cultural/racial background were kept and the other variables were dropped. Final model variables included age, sex, population type (immigrant, non-immigrant), geographical location (urban or rural) [68–71], marital status [72–74], high blood pressure [75–78], diabetes [75,76,78], smoking [72,76–80], cultural/racial background [72,76,78,79], education [72,73,77,79], household income [72,75,79], BMI [72,75–77,79–81], self-perceived health [82–84], self-perceived mental health [82–84], sense of belonging to the community [85,86] and household size [87]. Self-reported high blood pressure and diabetes were only included in cardiovascular models [77]. Self-perceived mental health was only included in mental disorder models. Effect modification by population type (immigrant, non-immigrant) and age (ages 12 to 17 and 65plus) was also examined. The interaction term population type and high temperature was retained in the cardiovascular model for the total population. The linearity assumption was examined between each outcome and continuous variable (age, household income, all exposure variables) and transformations (natural log, categorization) were applied as necessary. Model fit was examined using Pearson's chi-square test, and calibration curves. All models were weighted using pweight (sampling weight) to account for the CCHS sampling scheme. Sensitivity analyses were completed for all models using geographically weighted regression models for $PM_{2.5}$ data. Age-stratified models were also run for the total population, including adolescents (ages 12-17 years) and older adults (65 years plus). Cardiovascular outcomes were not examined for adolescents. Effect modification for older adults was examined and the interaction term population type and high temperature was retained only in the cardiovascular model. Due to the smaller sample size of adolescents available, interaction terms were not included.

2.4.4.2 Immigrant Population

For models that included only the immigrant population, the same variables were included, where possible. Due to low counts, some variable categories were combined. Immigrant models also included the length of residence in Canada (less than 10 years [recent immigrant] or 10 plus years [long-term immigrant]). The immigration category and official language variables were dropped due to extensive missingness. Bootstrap estimates were examined, but given the sample size, were not reported. Age-stratified models were not run for the immigrant population due to sample size issues. Multi-level logistic regression was planned for both the total and immigrant analyses, but due to sample and cluster size issues, was not performed.

3. Results

3.2 Descriptive Summary

3.2.1 Population and Health Outcomes

The weighted sample size for the total population across Alberta, Canada from 2009 to 2014 was 14,620,000. Most individuals were between the ages of 18 to 49 years old, the mean age was 41.96 years, and the percentage of males (50.6%) to females (49.4%) was fairly even. Immigrants made up ~23% of the population, with ~8% residing in Canada for less than 10 years, and ~15% for 10 plus years. Nearly 80% of individuals were white, ~90% of individuals lived in an urban location and ~36% of individuals had a household income between no income to $69,999 per year. Among the total population, ~8% reported having asthma, ~4% a cardiovascular outcome and ~10% a mental disorder.

Effects among adolescents (ages 12-17) and older adults (65 plus) in the total population were also examined. For the adolescent population across Alberta, Canada from 2009 to 2014 the weighted sample size was 1,254,000. The percentage of males (49.4%) to females (50.6%) was also fairly even. Around 12% of adolescents were immigrants, and ~73% of all adolescents were white. Over 90% lived in an urban location, and ~29% had a household income between no income to $69,999 per year. For the adolescent population, ~12% had asthma and ~6% had a mental disorder. For older adults across Alberta, Canada from 2009 to 2014 the weighted sample size was 1,833,000. There was a slightly higher percentage of females (54.7%) than males (45.3%). Around 29% of the older adult population were older immigrants, and nearly 90% of all older adults were white. More than 90% of older adults lived in an urban location, and ~70% had a household income between no income to $69,999 per year. Among older adults, ~8% reported they had asthma, ~19% a cardiovascular outcome, and ~9% a mental disorder.

For the immigrant population across Alberta, Canada from 2009 to 2014 the weighted sample size was 3,384,000. The percentage of males (49.5%) to females (50.47%) was fairly even. Most were between 18 to 49 years old (mean age: 45.28 years). Approximately 36% resided in Canada for less than 10 years, and nearly 70% had lived in the country for 10 plus years. Most immigrants (~57%) were born in Southern Asia/Eastern Asia/Oceania or other Asia and were economic immigrants (~55%), ~63% of immigrants spoke English, French or both. Only ~36% of immigrants were white, with ~97% living in an urban location and ~46% reporting a household income between no income to $69,999 per year. Among immigrants, ~4% reported having asthma, ~4% a cardiovascular outcome and ~6% a mental disorder. A descriptive summary of health outcomes and characteristics is presented in Table 3.2.

Table 3.2 Descriptive summary of health outcomes and characteristics for all populations, 2009-2014.

Population characteristics[3]	**Total population (%)**	**Total adolescent population (%)**	**Total older population (%)**	**Immigrant population (%)**
Weighted sample size	n = 14,620,000	n = 1,254,000	n = 1,833,000	n = 3,384,000
Health Outcomes				
Asthma				
Yes	8.39	12.24	7.65	3.90
No	91.61	87.76	92.35	96.10
Cardiovascular outcome				
Yes	4.17	-	18.72	4.48
No	95.83	-	81.28	95.52
Heart disease				
Yes	3.45	-	15.89	3.82
No	96.55	-	84.11	96.18
Stroke effects				
Yes	0.99	-	4.32	1.01
No	99.01	-	95.68	98.99
Mental disorder				
Yes	10.23	6.46	8.63	5.66
No	89.77	93.54	91.37	94.34
Mood disorder				
Yes	7.54	4.16	6.46	4.50
No	92.46	95.84	93.55	95.50
Anxiety disorder				
Yes	5.68	4.39	3.78	2.70
No	94.32	95.61	96.22	97.30
Categorical characteristics				
Age				
12 to 17	8.58	-	-	4.43
18 to 49	56.88	-	-	58.65
50 to 64	22.00	-	-	21.43
65+	12.54	-	-	15.49
Sex				
Male	50.64	49.36	45.28	49.53
Female	49.36	50.64	54.72	50.47
Cultural/racial background				
White	79.70	73.42	89.78	35.71
Other[1]	20.30	26.58	10.22	64.29
Geographical location				
Urban	93.54	91.95	91.54	97.25
Rural	6.46	8.05	8.46	2.75
Population type				
Non-immigrant	76.88	87.94	71.29	-
Immigrant	23.22	12.06	28.71	-
Marital status				
Married/common law	58.38	-	64.61	68.14
Widowed/separated/divorced/single/never married	41.62	-	35.39	31.86
Household size				
Less than or equal to 3 people	64.94	24.56	94.44	57.83

Greater than 3 people	35.06	75.44	5.57	42.17
Household income				
No income-$69,999	36.11	28.96	69.79	45.58
$70,000 plus	63.89	71.04	30.21	54.42
Sense of belonging to the community (regrouped)				
Very strong/somewhat strong	63.81	-	-	68.24
Somewhat weak/very weak	36.19	-	-	31.76
Sense of belonging to the community				
Very strong	15.84	19.66	25.54	-
Somewhat strong	47.97	55.67	48.56	-
Somewhat weak	26.97	19.98	18.75	-
Very weak	9.22	4.69	7.15	-
Education (regrouped)				
Secondary school graduation or less	37.47	-	-	30.62
Some post-secondary/post-secondary grad	62.53	-	-	69.38
Education				
Less than secondary school graduation	17.77	-	26.88	-
Secondary school graduation	19.71	-	16.42	-
Some post-secondary	5.97	-	4.01	-
Post-secondary graduation	56.55	-	52.70	-
Self-perceived health				
Excellent/very good/good	90.32	95.35	80.09	90.60
Fair/poor	9.68	4.65	19.91	9.40
Self-perceived mental health				
Excellent/very good/good	95.09	97.14	94.29	95.66
Fair/poor	4.91	2.86	5.71	4.34
BMI (regrouped)				
Normal weight	45.12	62.18	-	49.53
Underweight/overweight/obese	54.88	37.82	-	50.47
BMI				
Underweight	4.13	-	2.56	-
Normal weight	45.12	-	39.12	-
Overweight	33.28	-	39.66	-
Obese	17.47	-	18.67	-
High blood pressure				
Yes	15.03	-	48.68	16.93
No	84.97	-	51.32	83.07
Diabetes				
Yes	5.09	-	15.39	7.01
No	94.92	-	84.61	92.99
Smoking type (regrouped)				
Daily/occasionally	20.44	7.75	-	14.31
Not at all	79.56	92.25	-	85.69
Smoking type				
Daily	15.56	-	8.95	-
Occasionally	4.88	-	1.31	-
Not at all	79.56	-	89.74	-
Length of residence in Canada				
Less than 10 years (recent immigrant)	7.96	-	-	36.25
10 plus years (long-term immigrant)	15.02	-	-	68.36
Non-immigrant	77.02	-	-	0
World area of birth				

Europe/United States or other miscellaneous	-	-	-	21.21
Africa and the Middle East	-	-	-	13.69
Southern Asia/Eastern Asia/Oceania and other Asia	-	-	-	56.72
South and Central America	-	-	-	8.38
Official Language				
English and/or French	-	-	-	62.95
Neither English nor French	-	-	-	37.05
Immigration category				
Economic	-	-	-	54.93
Sponsored by family	-	-	-	28.72
Refugee or other[2]	-	-	-	16.35
Continuous characteristics	**N**	**Mean**	**Linearized Standard error**	**Minimum - Maximum**
Total population (n = 14,620,000)				
Age	14,620,000	41.96	0.19	12 - 85+
Household income	13,012,000	108,400	1296	<= 10,000 - 500,000+
Adolescent population (n = 1,254,000)				
Household income	1,051,000	122,160	4239	<= 40,000-200,000+
Older adult population (n = 1,833,000)				
Household income	1,589,000	64,230	1713	<= 15,000 - 150,000+
Immigrant population (n = 3,384,000)				
Age	3,384,000	45.28	0.4336	<= 17-80+
Household income	3,037,000	94,080	2606	<= 18,000 - 250,000+
Length of time in Canada (years)	3,339,000	21.15	0.4418	0 - 60+

Source: Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].
1 Other included Black, Asian, Arab/West Asian, Latin American and multiple or other races.
2 This category includes public policy or humanitarian and compassionate grounds or any immigrant that does not fall into the categories listed [43].
3 Percentages excluded and replaced with "-" if the variable was not used in the model for that population.

3.2.2 Exposures

The median of the average temperature across Alberta between 2009 to 2014 was 3.37°C. The median of the highest temperatures was 32.21°C and lowest temperatures -34.21°C. The median for average DTR was 12.14°C, average daily maximum temperature 9.24°C and average daily minimum temperature -2.51°C. The medians for average $PM_{2.5}$, NO_2 and O_3 across Alberta from 2009 to 2014 were 6.80 µg/m3, 6.23 ppb and 26.30 ppb, respectively. The median for average wildfire smoke exposure was 7.31 µg/m^3. A descriptive summary of all exposures is presented in Tables 3.3 and A5. Figures 3.1 to 3.4 show the average daily temperature exposures, average $PM_{2.5}$, NO_2 and O_3 concentrations from 2009 to 2014 across Alberta.

Table 3.3 Descriptive summary of weather and air pollution exposures, 2009-2014.

Weather exposures						
Year	**High temperature (Celsius)**	**Low temperature (Celsius)**	**Average temperature (Celsius)**	**Average daily maximum temperature (Celsius)**	**Average daily minimum temperature (Celsius)**	**Average diurnal temperature range (Celsius)**
Median (IQR)						
2009	33.22 (32.98 to 33.43)	-36.54 (-40.13 to -33.55)	2.54 (2.34 to 3.42)	9.00 (8.78 to 9.93)	-3.89 (-4.09 to -3.08)	12.92 (12.85 to 13.00)
2010	31.12 (30.85 to 31.62)	-32.02 (-32.76 to -30.83)	3.47 (3.30 to 4.31)	9.29 (9.04 to 10.41)	-2.30 (-2.44 to -1.79)	11.78 (11.47 to 12.18)
2011	31.02 (30.72 to 31.31)	-35.36 (-35.64 to -32.57)	3.35 (3.21 to 3.81)	9.23 (9.06 to 9.85)	-2.51 (-2.66 to -2.23)	11.86 (11.71 to 12.10)
2012	32.17 (30.67 to 32.41)	-34.36 (-34.64 to -34.09)	3.67 (3.50 to 4.60)	9.39 (9.16 to 10.88)	-2.05 (-2.17 to -1.68)	11.91 (11.33 to 12.55)
2013	32.52 (32.29 to 33.58)	-34.14 (-34.78 to -33.06)	3.34 (3.15 to 4.22)	9.23 (9.03 to 10.52)	-2.54 (-2.72 to -2.07)	12.06 (11.73 to 12.60)
2014	31.15 (30.58 to 32.14)	-35.48 (-35.85 to -34.35)	3.21 (3.05 to 3.90)	8.86 (8.70 to 9.87)	-2.44 (-2.61 to -2.09)	11.73 (11.27 to 11.98)
2009 to 2014	32.21 (30.95 to 33.20)	-34.21 (-35.78 to -33.11)	3.37 (2.98 to 3.94)	9.24 (8.88 to 10.08)	-2.51 (-3.11 to -2.08)	12.14 (11.66 to 12.83)
Minimum and maximum temperature range						
2009	25.85 to 36.40	-44.04 to -31.80	-2.24 to 5.37	2.63 to 11.94	-7.45 to -1.20	9.74 to 13.95
2010	24.71 to 36.67	-40.37 to -28.34	0.04 to 5.85	5.37 to 11.97	-5.46 to -0.26	9.67 to 13.18
2011	24.14 to 36.53	-40.81 to -30.93	-0.92 to 5.7	4.22 to 11.91	-6.41 to -0.44	9.86 to 13.17

2012	26.41 to 36.61	-40.66 to -32.71	-0.86 to 6.84	4.11 to 13.56	-6.33 to 0.12	9.94 to 13.84
2013	28.72 to 36.33	-42.05 to -32.62	-2.06 to 6.43	3.05 to 13.03	-7.16 to -0.18	9.90 to 13.51
2014	27.25 to 36.73	-43.99 to -31.26	-2.52 to 5.81	2.67 to 12.08	-7.71 to -0.45	10.31 to 13.49
2009 to 2014	24.14 to 36.73	-44.04 to -28.34	-2.52 to 6.84	2.63 to 13.56	-7.17 to 0.12	9.67 to 13.95

Air pollution exposures				
Year	**Average $PM_{2.5}$ ($\mu g/m^3$)**	**Average NO_2 (ppb)**	**Average O_3 (ppb)**	**Average wildfire smoke ($PM_{2.5}$ $\mu g/m^3$)**
		Median (IQR)		
2009	4.54 (3.94 to 7.26)	6.06 (4.34 to 12.00)	25.41 (22.77 to 30.40)	-
2010	8.81 (4.89 to 10.07)	7.02 (4.62 to 12.20)	24.89 (20.81 to 28.34)	8.43 (7.73 to 8.89)
2011	6.70 (4.10 to 9.52)	6.13 (3.79 to 11.15)	28.45 (23.07 to 31.93)	7.12 (6.39 to 7.31)
2012	6.77 (5.10 to 8.41)	6.22 (3.65 to 9.35)	26.03 (22.45 to 29.46)	7.32 (6.87 to 7.74)
2013	6.79 (4.27 to 7.53)	6.18 (3.73 to 10.11)	27.51 (22.27 to 29.79)	6.56 (6.32 to 7.13)
2014	7.10 (5.58 to 8.19)	6.19 (3.92 to 10.48)	25.66 (21.21 to 28.43)	7.56 (6.77 to 7.88)
2009 to 2014	6.80 (4.75 to 8.40)	6.23 (3.91 to 10.94)	26.30 (22.08 to 29.55)	7.31 (6.76 to 7.77)
		Minimum and maximum range		

2009	2.32 to 12.71	0.99 to 21.84	18.09 to 42.43	-
2010	2.77 to 16.38	0.93 to 21.02	16.15 to 42.11	6.00 to 12.86
2011	1.71 to 13.86	0.97 to 16.04	19.65 to 44.58	5.24 to 11.12
2012	2.48 to 11.56	0.87 to 16.19	18.37 to 36.92	5.75 to 10.06
2013	2.26 to 11.21	0.71 to 18.07	17.92 to 35.70	5.17 to 8.25
2014	2.81 to 11.21	0.80 to 18.89	8.27 to 34.94	5.36 to 9.10
2009 to 2014	1.26 to 16.67	0.71 to 30.48	8.27 to 44.57	5.17 to 12.86

Sources: Canadian Urban Environmental Health Research Consortium [54] and National Air Pollution Surveillance Program [59].

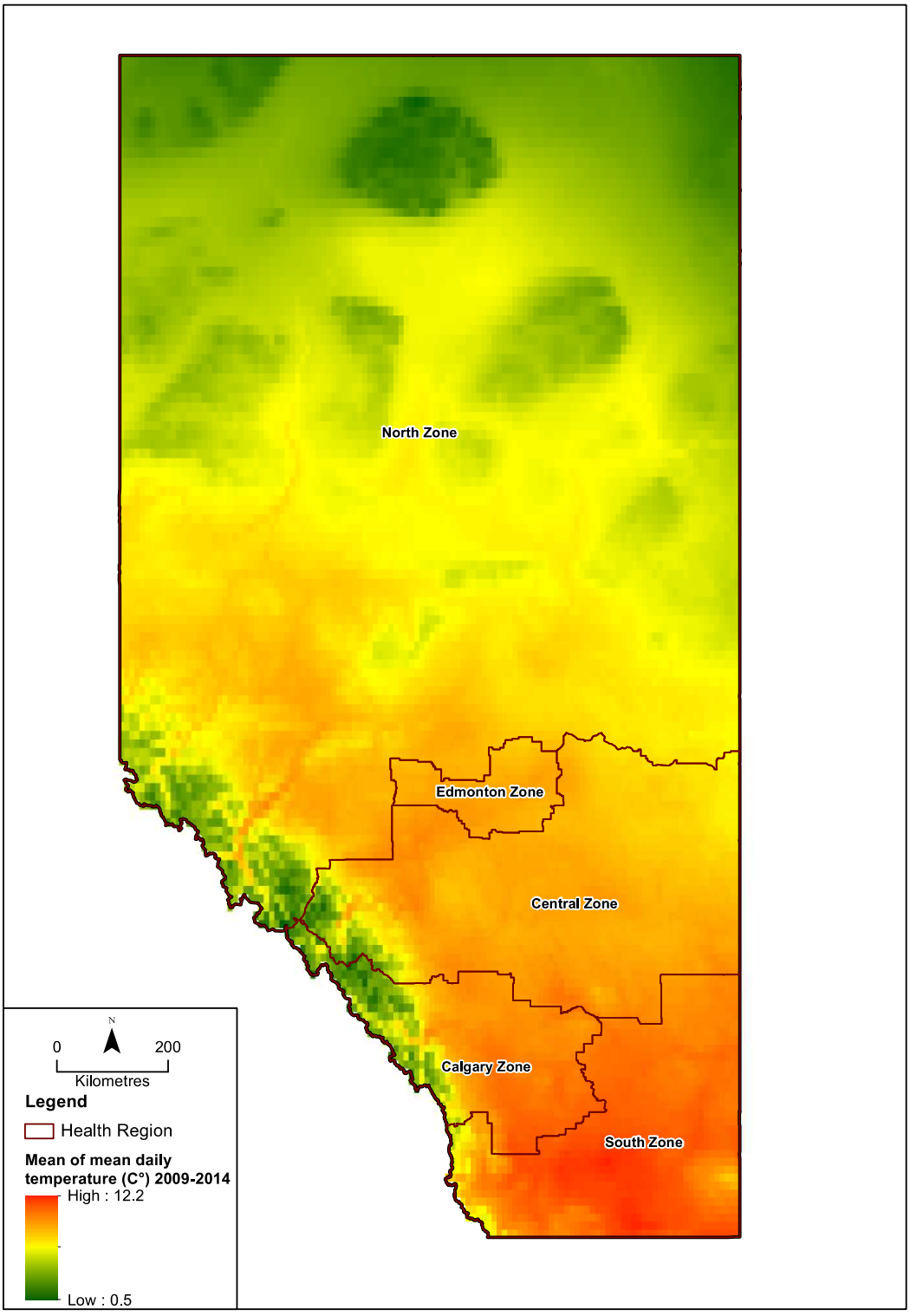

Figure 3.1 Exposure map for mean of mean daily temperature from 2009 to 2014. Note: A spatial resolution of 10 KM was used. *CANUE, DMTI, ESRI, HERE, Garming, USGS, Intermap, INCREMENT P, NRCan, ESRI Japan, METI, Esri China (Hong Kong), ESRI Korea, ESRI (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community.*

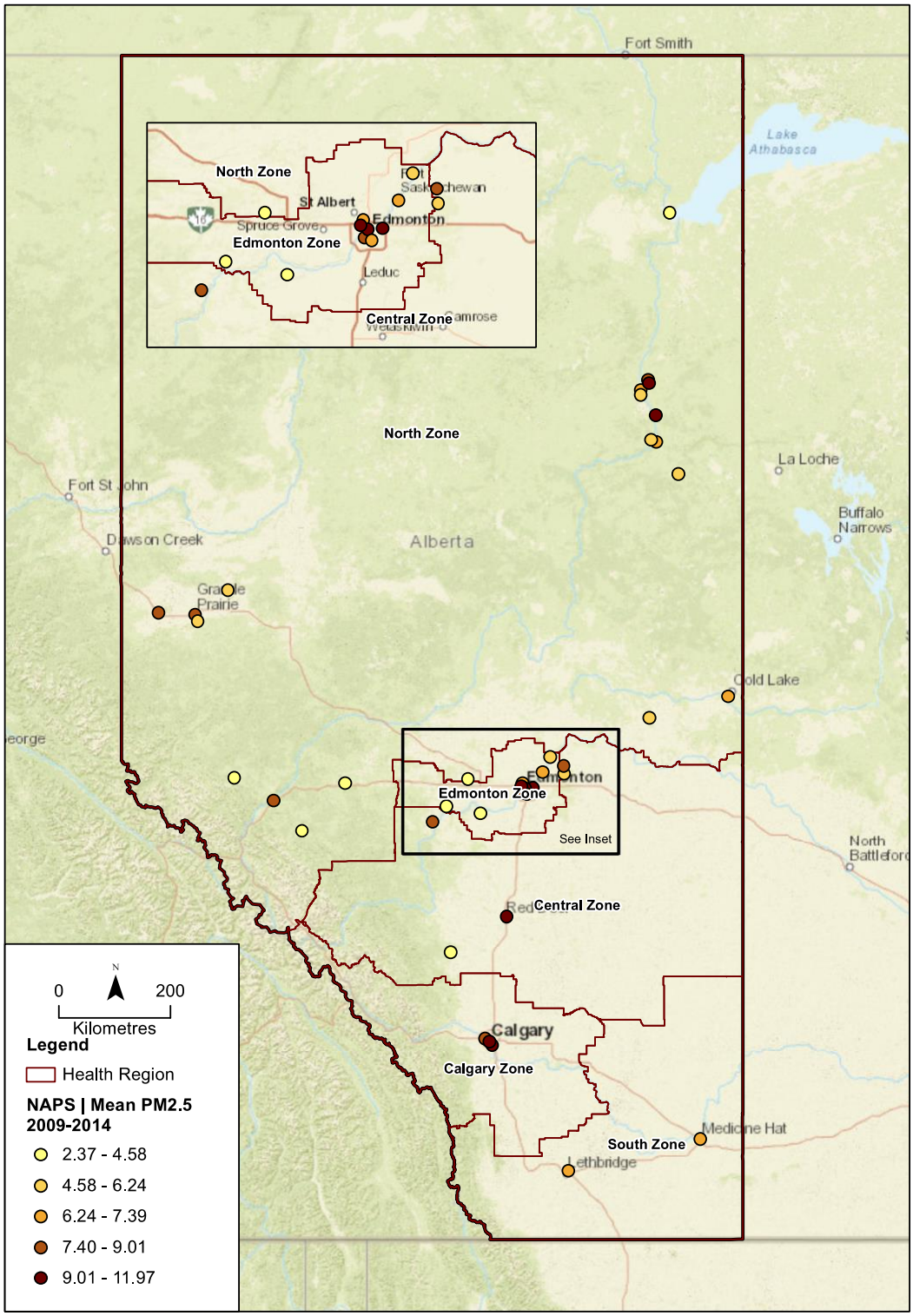

Figure 3.2 Exposure map for mean $PM_{2.5}$ from 2009 to 2014 in Alberta, Canada. Some NAPS stations did not have observations for all years. *CANUE, DMTI, ESRI, HERE, Garming, USGS, Intermap, INCREMENT P, NRCan, ESRI Japan, METI, Esri China (Hong Kong), ESRI Korea, ESRI (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community.*

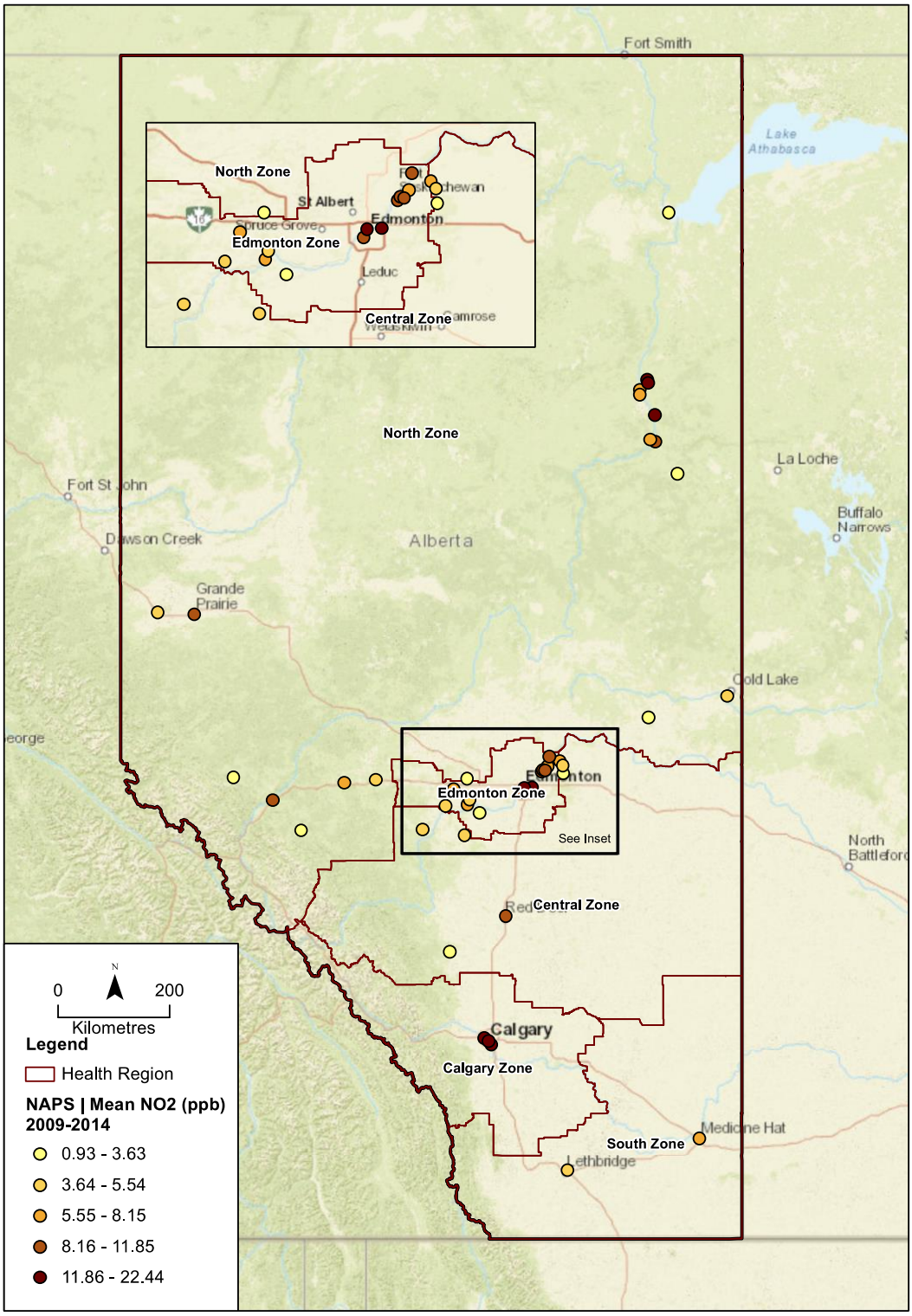

Figure 3.3 Exposure map for mean NO_2 from 2009 to 2014 in Alberta, Canada. Some NAPS stations did not have observations for all years. *CANUE, DMTI, ESRI, HERE, Garming, USGS, Intermap, INCREMENT P, NRCan, ESRI Japan, METI, Esri China (Hong Kong), ESRI Korea, ESRI (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community.*

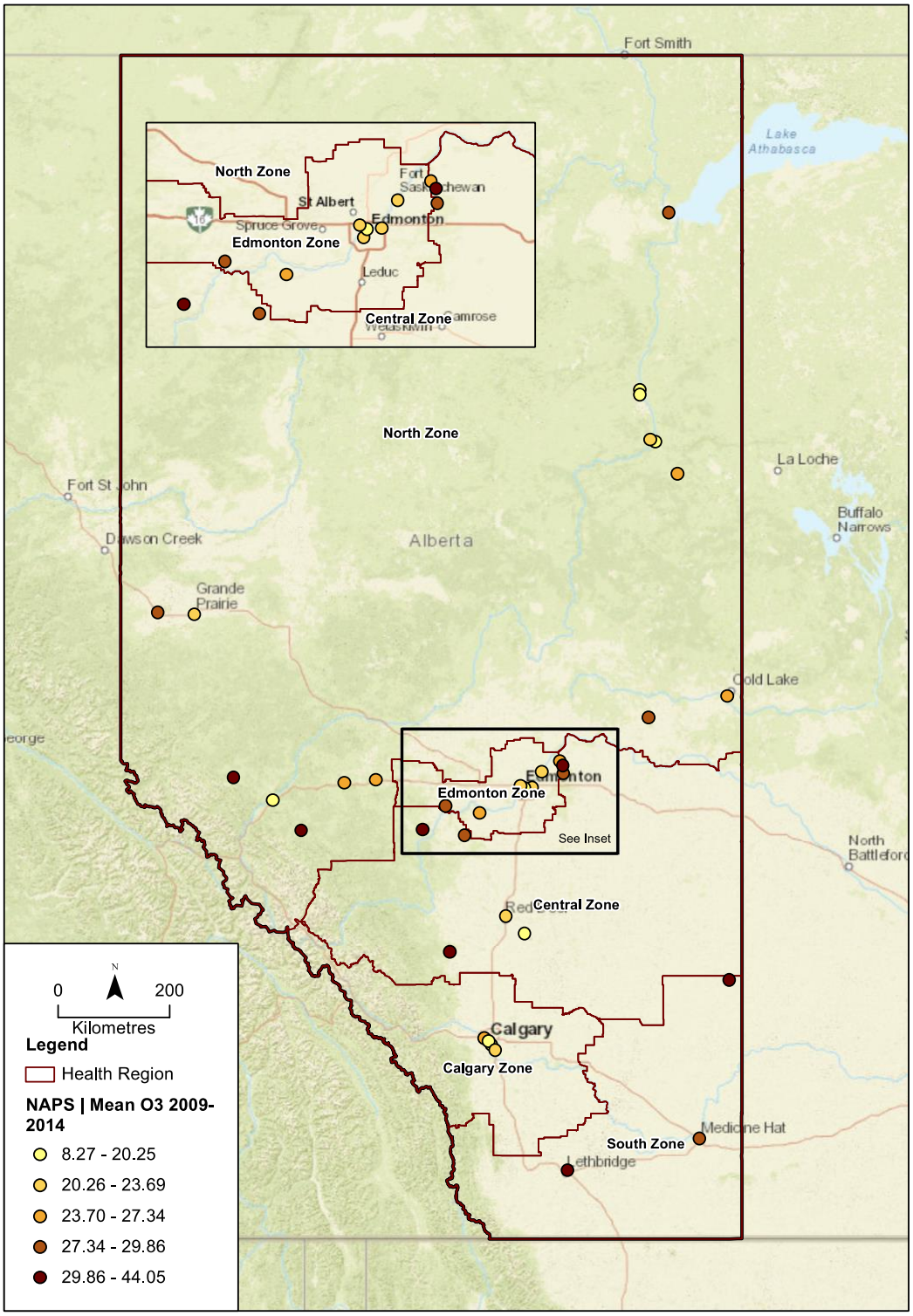

Figure 3.4 Exposure map for mean O_3 from 2009 to 2014 in Alberta, Canada. Some NAPS stations did not have observations for all years. *CANUE, DMTI, ESRI, HERE, Garming, USGS, Intermap, INCREMENT P, NRCan, ESRI Japan, METI, Esri China (Hong Kong), ESRI Korea, ESRI (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community.*

3.3 Associations with Weather Exposures

3.3.1 High Temperature

3.3.1.1 Total Population

Exposure to the highest temperatures (annually) between 2009 and 2014 was subdivided into quartiles: Very low (min to 30.73°C), low (30.74°C to 31.87°C), moderate (32.88 to 33.08°C), and high (33.09°C to max). For the total population, increasing exposure quartile indicated increasingly higher odds of having asthma (Table 3.4). For those classified as having moderate and high quartiles of exposure, the estimated odds of having asthma were 1.34 and 1.58 times higher, respectively, compared to those classified as having very low exposure. Conversely, cardiovascular outcomes appeared to show the opposite trend. Those classified in the highest quartile were less likely to report having cardiovascular outcomes (OR=0.69, 95%CI: 0.49-0.99) compared to those in the lowest quartile. No significant associations were observed with mental disorders. Among the adolescent and older adult populations, no significant results or obvious trends were observed for asthma or mental disorders. Cardiovascular outcomes for the total adolescent population were not examined as this is typically less of a health concern in this age group [88]. Additional results for other exposures, outcomes, and populations that were not significant are presented in Tables A6.1 to A6.3.

Table 3.4 Adjusted logistic model associations for quartiles of exposure to highest annual temperatures (2009 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**
Asthma	Very low (min to 30.73)	Reference			
	Low (30.74 to 31.87)	1.18 (0.92-1.50)	1.23 (0.68-2.25)	1.36 (0.79-2.33)	1.69 (0.75-3.78)
	Moderate (32.88 to 33.08)	**1.34*** (1.04-1.72)	0.92 (0.48-1.76)	1.61 (0.98-2.62)	2.12 (0.97-4.61)
	High (33.09 to max)	**1.58**** (1.20-2.07)	1.26 (0.64-2.46)	1.12 (0.68-1.86)	2.13 (0.83-5.52)
Cardiovascular	Very low (min to 30.73)	Reference			
	Low (30.74 to 31.87)	1.01 (0.71-1.43)	-	1.11 (0.66-1.87)	**3.15**** (1.40-7.08)
	Moderate (32.88 to 33.08)	0.80 (0.56-1.14)	-	0.67 (0.42-1.07)	2.15 (0.96-4.8)
	High (33.09 to max)	**0.69*** (0.49-0.99)	-	0.78 (0.48-1.26)	**2.49*** (1.09-5.65)
Population x high temperature	Very low & non-immigrant	Reference			
	Low & immigrant	**3.19****	-	**2.64***	-

(interaction term – cardiovascular)		(1.39-7.29)		(1.02-6.82)	
	Moderate & immigrant	**2.69*** (1.16-6.28)	-	**3.48*** (1.37-8.79)	-
	High & immigrant	**3.40*** (1.45-7.97)	-	**3.58*** (1.29-9.91)	-
Mental disorders	Very low (min to 30.73)	Reference			
	Low (30.74 to 31.87)	0.93 (0.74-1.18)	1.23 (0.51-2.97)	0.98 (0.58-1.65)	0.85 (0.43-1.70)
	Moderate (32.88 to 33.08)	1.12 (0.87-1.43)	1.30 (0.53-3.19)	1.38 (0.83-2.28)	0.90 (0.40-2.01)
	High (33.09 to max)	0.88 (0.68-1.13)	0.70 (0.27-1.82)	0.73 (0.40-1.32)	0.56 (0.23-1.34)

***p<0.001, **p<0.01, *p<0.05
Sources: Canadian Urban Environmental Health Research Consortium [54] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].
1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.
2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI and corresponding exposure. Mental disorder models were also adjusted for self-perceived mental health.
3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

3.3.1.2 Immigrant Population

We also observed significant associations with some quartiles of high temperature exposures among the immigrant population (Table 3.4). Quartiles of low (OR=3.15, 95%CI: 1.40-7.08) and high (OR=2.49, 95%CI: 1.09-5.65) temperature exposures were associated with significantly increased odds of having a cardiovascular outcome. No significant associations were observed with asthma and mental disorders.

We also examined interactions between quartiles of high temperature exposure and immigrant status in our total population models (Table 3.4). Significant interactions were observed across all quartiles of exposure and immigrant status for cardiovascular outcomes. This indicates potential differences in the associations between high temperature and the reporting of cardiovascular outcomes by population (immigrant vs non-immigrant). An interaction term was also included in the older adult population models. Similar results were also observed for cardiovascular outcomes, indicating potential effect modification among older adults by immigrant status.

3.3.2 Low Temperature and Daily Minimum Temperature

3.3.2.1 Total Population

Low temperature is the annual single lowest temperature to which individuals were exposed. The daily minimum temperature is the annual average of all daily minimum temperatures. Exposure to the lowest temperatures (annually) between 2009 to 2014 was subdivided into quartiles: very low (min to -33.16°C), low (-34.44°C to -33.17°C), moderate (-34.45°C to -35.97°C) and high (-35.98°C to max). For the total population, the low temperature quartile was not significantly associated with self-reported asthma and mental disorders, except the moderate and high quartiles respectively (Table 3.5). For those classified as having moderate exposure, the estimated odds of having self-reported asthma was 0.71 times lower compared to those classified as having very low exposure. For those with high exposure, the estimated odds of having a self-reported mental disorder was 0.78 times lower compared to those with very low exposure. For the total population, there were no obvious trends among exposure levels for all outcomes, and no significant results were seen for self-reported cardiovascular outcomes.

For adolescents classified as having moderate exposure, the estimated odds of having self-reported asthma was 0.49 times lower compared to those classified as having very low exposure. For the adolescent population, self-reported asthma had no obvious trends among exposure levels. However, increasing exposure quartiles indicated increasingly higher odds of having a self-reported mental disorder, but this was not statistically significant. For older adults classified as having low exposure, the estimated odds of having a self-reported mental disorder was 1.64 times higher compared to those classified as having very low exposure. The older adult population appeared to show decreasing trends for all outcomes with higher exposures, but no statistically significant results were observed for self-reported asthma and cardiovascular outcomes.

Table 3.5 Adjusted logistic model associations for quartiles of exposure to lowest annual temperatures (2009 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**
Asthma	Very low (min to -33.16)	Reference			
	Low (-33.17 to -34.44)	0.98 (0.77-1.25)	0.71 (0.39-1.30)	1.29 (0.82-2.03)	1.89 (0.93-3.84)
	Moderate (-34.45 to -35.97)	**0.71**** (0.56-0.90)	**0.49*** (0.27-0.90)	1.10 (0.64-1.90)	1.27 (0.59-2.73)
	High (-35.98 to max)	0.87 (0.66-1.16)	0.59 (0.32-1.09)	1.03 (0.58-1.82)	1.56 (0.68-3.6)
Cardiovascular	Very low (min to -33.16)	Reference			
	Low (-33.17 to -34.44)	0.79 (0.6-1.06)	-	0.82 (0.57-1.18)	0.80 (0.43-1.48)
	Moderate (-34.45 to -35.97)	0.74 (0.54-1.01)	-	0.69 (0.45-1.05)	0.75 (0.38-1.49)

	High (-35.98 to max)	0.92 (0.67-1.26)	-	0.67 (0.44-1.03)	1.18 (0.54-2.56)
Mental disorders	Very low (min to -33.16)	Reference			
	Low (-33.17 to -34.44)	0.91 (0.71-1.16)	0.44 (0.16-1.20)	**1.64*** (1.001-2.69)	1.05 (0.55-1.99)
	Moderate (-34.45 to -35.97)	1.02 (0.81-1.29)	0.98 (0.42-2.30)	1.15 (0.70-1.89)	1.35 (0.72-2.44)
	High (-35.98 to max)	**0.78*** (0.62-0.98)	1.22 (0.50-3.02)	0.80 (0.46-1.37)	0.85 (0.43-1.68)

***p<0.001, **p<0.01, *p<0.05
Sources: Canadian Urban Environmental Health Research Consortium [54] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].
1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.
2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI and corresponding exposure. Mental disorder models were also adjusted for self-perceived mental health.
3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

Exposure to the average daily minimum temperature (annually) between 2009 to 2014 was subdivided into quartiles: very low (min to -2.05°C), low (-2.06 to -2.52°C), moderate (-2.53 to -3.10), and high (-3.11 to max). Only mental disorder models showed significant results (Table 3.6). Increasing exposure quartile indicated increasingly lower odds of having a self-reported mental disorder for the total and older populations. Among the total population, for those classified as having high exposure, the estimated odds of having a self-reported mental disorder was 0.72 times lower compared to those classified as having very low exposure. For the total older population, for those classified as having high exposure, the estimated odds of having a self-reported mental disorder was 0.52 times lower compared to those classified as having very low exposure. No significant associations or obvious trends were observed for self-reported asthma and cardiovascular outcomes with the total and older adult populations. No significant associations or obvious trends were observed for all outcomes among the adolescent population.

Table 3.6 Adjusted logistic model associations for quartiles of exposure to annual average daily minimum temperatures (2009 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**

Asthma	Very low (min to -2.05)	Reference			
	Low (-2.06 to -2.52)	0.92 (0.72-1.17)	0.69 (0.38-1.26)	1.54 (0.97-2.43)	0.93 (0.46-1.88)
	Moderate (-2.53 to -3.10)	0.88 (0.69-1.13)	0.96 (0.53-1.75)	1.59 (0.95-2.66)	1.50 (0.72-3.14)
	High (-3.11 to max)	0.99 (0.74-1.33)	0.71 (0.39-1.30)	1.31 (0.75-2.27)	1.73 (0.54-5.52)
Cardiovascular	Very low (min to -2.05)	Reference			
	Low (-2.06 to -2.52)	0.97 (0.73-1.29)	-	0.92 (0.64-1.34)	0.65 (0.35-1.22)
	Moderate (-2.53 to -3.10)	1.06 (0.79-1.43)	-	0.91 (0.61-1.35)	1.35 (0.70-2.61)
	High (-3.11 to max)	0.96 (0.70-1.31)	-	0.77 (0.51-1.17)	1.20 (0.56-2.58)
Mental disorders	Very low (min to -2.05)	Reference			
	Low (-2.06 to -2.52)	1.19 (0.94-1.51)	1.17 (0.52-2.65)	1.12 (0.72-1.75)	1.63 (0.78-3.39)
	Moderate (-2.53 to -3.10)	1.03 (0.81-1.31)	1.36 (0.59-3.11)	0.86 (0.50-1.46)	1.41 (0.61-3.25)
	High (-3.11 to max)	**0.72**** (0.56-0.92)	1.18 (0.47-2.97)	**0.52*** (0.29-0.92)	1.14 (0.49-2.65)

***p<0.001, **p<0.01, *p<0.05

Sources: Canadian Urban Environmental Health Research Consortium [54] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].

1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI and corresponding exposure. Mental disorder models were also adjusted for self-perceived mental health.

3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

3.3.2.2 Immigrant Population

No significant results for annual lowest temperature or average daily minimum temperature exposures were found for the immigrant population (Tables 3.5 and 3.6). No obvious trends were seen across low temperature exposure levels. For annual average daily minimum temperature, increasing exposure quartile indicated increasingly higher odds of having self-reported asthma. Comparatively, increasing exposure quartiles appeared to indicate lower odds of having a self-reported mental disorder. For cardiovascular outcomes, there were no obvious trends across exposure levels.

3.3.3 Average Diurnal Temperature Range

3.3.3.1 Total Population

Exposure to the DTR (annual average) between 2009 and 2014 was subdivided into quartile ranges: very small (min to 11.59°C), small (11.60 to 12.00°C), medium (12.01 to 12.53°C), and large (12.54°C to max). DTR had negative associations with self-reported mental disorders for the total and older populations (Table 3.7). For the total population, those exposed to a large DTR, the estimated odds of having a self-reported mental disorder was 0.71 times lower compared to exposed to a very small DTR. Among older adults, for those exposed to a large DTR, the estimated odds of having a self-reported mental disorder was 0.48 times lower compared to those exposed to a very small DTR. For both populations DTR had no obvious trends among self-reported mental disorder exposure quartiles. No significant associations or obvious trends were seen for self-reported asthma and cardiovascular outcomes for the total and older adult populations. No significant associations were observed for all outcomes with the adolescent population but increasing exposure quartile indicated decreasingly lower odds of having a self-reported mental disorder.

Table 3.7 Adjusted logistic model associations for quartiles of exposure to annual average diurnal temperature range (2009 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**
Asthma	Very small (min to 11.59)	Reference			
	Small (11.60 to 12.00)	0.97 (0.75-1.25)	1.22 (0.61-2.44)	1.08 (0.64-1.80)	1.54 (0.78-3.04)
	Medium (12.01 to 12.53)	0.89 (0.69-1.15)	1.47 (0.77-2.80)	0.63 (0.39-1.04)	**0.46*** (0.22-0.95)
	Large (12.54 to max)	1.11 (0.85-1.45)	1.38 (0.69-2.77)	0.82 (0.51-1.33)	0.96 (0.38-2.39)
Cardiovascular outcome	Very small (min to 11.59)	Reference			
	Small (11.60 to 12.00)	0.90 (0.67-1.22)	-	0.97 (0.66-1.44)	1.61 (0.80-3.22)
	Medium (12.01 to 12.53)	1.05 (0.77-1.43)	-	1.28 (0.83-1.97)	1.09 (0.56-2.15)
	Large (12.54 to max)	0.87 (0.64-1.2)	-	0.87 (0.58-1.32)	1.34 (0.68-2.65)
Mental disorders	Very small (min to 11.59)	Reference			
	Small (11.60 to 12.00)	0.93 (0.72-1.19)	1.32 (0.53-3.26)	0.89 (0.55-1.45)	0.89 (0.45-1.76)
	Medium (12.01 to 12.53)	0.96 (0.75-1.24)	1.12 (0.48-2.59)	0.93 (0.57-1.50)	0.92 (0.43-1.98)
	Large (12.54 to max)	**0.71**** (0.55-0.91)	0.40 (0.15-1.06)	**0.48**** (0.27-0.83)	**0.42*** (0.19-0.91)

***p<0.001, **p<0.01, *p<0.05

Sources: Canadian Urban Environmental Health Research Consortium [54] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].
1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.
2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI and corresponding exposure. Mental disorder models were also adjusted for self-perceived mental health.
3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

3.3.3.2 Immigrant Population

Significant associations with some quartiles of DTR were also observed when analyses were stratified by immigrant status (Table 3.7). For the immigrant population, those exposed to a medium DTR, the estimated odds of having self-reported asthma was 0.46 times lower compared to those exposed to a very small DTR. For those exposed to a large DTR, the estimated odds of having a self-reported mental disorder was 0.42 times lower compared to those exposed to a very small DTR. There was no obvious trend among DTR quartiles for self-reported asthma or mental disorders. There was no obvious trend or significant results among DTR quartiles for self-reported cardiovascular outcomes.

3.4 Associations with Air Pollution Exposures

3.4.1 Wildfire Smoke

3.4.1.1 Total Population

Exposure to wildfire smoke (annual average) between 2010 and 2014 was subdivided into quartiles: very low (min to 6.59 μg/m^3), low (6.60 to 7.14 μg/m^3), moderate (7.15 to 7.74 μg/m^3), and high (7.75 μg/m^3 to max). For the total population, increasing exposure quartiles indicated increasingly higher odds of having self-reported asthma. For those classified as having low exposure, the estimated odds of self-reported asthma was 0.73 times lower compared to those classified as having very low exposure. Among the total population, no significant associations or obvious trends were observed for self-reported cardiovascular outcomes. For self-reported mental disorders among the total population, increasing exposure quartile indicated increasingly higher odds.

Among the adolescent population, no significant associations or obvious trends were observed for self-reported asthma and mental disorders. Among the older adult population, no significant associations were observed for all outcomes, and no obvious trends were observed for self-reported asthma. For self-reported cardiovascular outcomes among older adults, increasing exposure quartile

indicated decreasingly lower odds. Comparatively, for self-reported mental disorders among older adults, increasing exposure quartile indicated increasingly higher odds.

Table 3.8 Adjusted logistic model associations for quartiles of exposure to annual average wildfire smoke (2010 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**
Asthma	Very low (min to 6.59)	Reference			
	Low (6.60 to 7.14)	**0.73*** (0.56-0.97)	0.62 (0.32-1.21)	0.87 (0.49-1.55)	1.05 (0.44-2.52)
	Moderate (7.15 to 7.74)	0.78 (0.59-1.02)	0.59 (0.30-1.14)	0.80 (0.46-1.37)	0.66 (0.31-1.37)
	High (7.75 to max)	0.82 (0.62-1.08)	1.00 (0.51-1.96)	0.82 (0.49-1.40)	0.75 (0.32-1.75)
Cardiovascular outcome	Very low (min to 6.59)	Reference			
	Low (6.60 to 7.14)	1.17 (0.83-1.64)	-	1.43 (0.90-2.28)	1.19 (0.52-2.73)
	Moderate (7.15 to 7.74)	0.97 (0.69-1.37)	-	1.28 (0.82-1.99)	1.25 (0.62-2.54)
	High (7.75 to max)	1.18 (0.84-1.68)	-	1.13 (0.72-1.76)	1.03 (0.45-2.35)
Mental disorders	Very low (min to 6.59)	Reference			
	Low (6.60 to 7.14)	0.99 (0.76-1.28)	1.40 (0.47-4.15)	0.82 (0.45-1.49)	0.98 (0.45-2.14)
	Moderate (7.15 to 7.74)	1.01 (0.77-1.32)	2.02 (0.74-5.53)	0.96 (0.56-1.65)	1.06 (0.54-2.09)
	High (7.75 to max)	1.12 (0.84-1.48)	0.99 (0.33-2.94)	1.09 (0.65-1.85)	1.94 (0.80-4.68)

***p<0.001, **p<0.01, *p<0.05

Sources: Canadian Urban Environmental Health Research Consortium [54] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].

1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, corresponding exposure and average temperature. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models self-perceived mental health.

2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI, corresponding exposure and average temperature. Mental disorder models were also adjusted for self-perceived mental health.

3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada, corresponding exposure and average temperature. Cardiovascular models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

3.4.1.2 Immigrant Population

No significant associations with quartiles of wildfire smoke were found for the immigrant population. Self-reported asthma and cardiovascular outcome models had no obvious trends among exposure quartiles. Increasing exposure quartiles indicated increasingly higher odds of having a self-reported mental disorder.

3.4.2 Ozone

3.4.2.1 Total Population

Exposure to O_3 (annual average) between 2009 and 2014 was subdivided into quartiles: very low (min to 19.94 ppb), low (20.23 to 22.83 ppb), moderate (22.90 to 26.55 ppb), and high (26.56 ppb to max). Exposure to O_3 was associated with cardiovascular outcomes for the total and older populations (Table 3.9). Among the total population, for those classified as having moderate exposure, the estimated odds of having a self-reported cardiovascular outcome was 0.71 times lower compared to those classified as having very low exposure. For older adults classified as having moderate exposure, the estimated odds of a self-reported cardiovascular outcome was 0.67 times lower compared to those classified as having very low exposure. O_3 exposure showed no obvious trends for cardiovascular outcome exposure quartiles for the total and older populations. Among the total and older adult populations, no significant associations were observed for self-reported asthma and mental disorders. Among the total population for self-reported asthma, increasing exposure quartile indicated increasingly higher odds. Comparatively, among the total population for self-reported mental disorders, increasing exposure quartile indicated decreasingly lower odds. For the older adult population, no obvious trends were seen for self-reported asthma, but for self-reported mental disorders, increasing exposure quartile indicated increasingly higher odds. No significant associations or obvious trends were observed for self-reported asthma with the adolescent population. For self-reported mental disorders among the adolescent population no significant associations were found but increasing exposure quartile indicated decreasingly lower odds.

Table 3.9 Adjusted logistic model associations for quartiles of exposure to annual average ozone concentrations (2009 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**
Asthma	Very low (min to 19.94)	Reference			
	Low (20.23 to 22.83)	0.80 (0.62-1.04)	0.89 (0.45-1.76)	0.88 (0.52-1.48)	**0.34*** (0.13-0.89)
	Moderate (22.90 to 26.55)	0.91 (0.70-1.19)	0.87 (0.46-1.65)	1.26 (0.73-2.15)	0.73 (0.28-1.92)
	High (26.56 to max)	1.05 (0.81-1.36)	1.13 (0.54-2.39)	1.05 (0.63-1.77)	1.07 (0.46-2.49)
	Very low	Reference			

Cardiovascular outcome	(min to 19.94)				
	Low (20.23 to 22.83)	0.96 (0.70-1.31)	-	0.82 (0.53-1.27)	0.76 (0.39-1.51)
	Moderate (22.90 to 26.55)	**0.71*** (0.52-0.97)	-	**0.67*** (0.45-0.99)	1.20 (0.65-2.21)
	High (26.56 to max)	0.86 (0.63-1.16)	-	0.83 (0.56-1.22)	0.90 (0.40-1.99)
Mental disorders	Very low (min to 19.94)	Reference			
	Low (20.23 to 22.83)	1.06 (0.81-1.37)	2.53 (0.97-6.60)	0.76 (0.43-1.33)	1.31 (0.55-3.10)
	Moderate (22.90 to 26.55)	0.96 (0.72-1.28)	1.80 (0.72-4.49)	0.86 (0.50-1.49)	1.23 (0.46-3.30)
	High (26.56 to max)	0.93 (0.73-1.19)	0.79 (0.28-2.28)	1.04 (0.65-1.65)	0.83 (0.41-1.70)

***p<0.001, **p<0.01, *p<0.05

Sources: National Air Pollution Surveillance Program [59] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].

1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, corresponding exposure and average temperature. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI, corresponding exposure and average temperature. Mental disorder models were also adjusted for self-perceived mental health.

3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada, corresponding exposure and average temperature. Cardiovascular models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

3.4.2.2 Immigrant Population

When analyses were stratified by immigrant status (Table 3.9), for those classified as having low O_3 exposure, the estimated odds of self-reported asthma was 0.34 times lower compared to those classified as having very low exposure. Among the immigrant population, increasing exposure quartiles indicated increasingly higher odds of having self-reported asthma. No significant associations or obvious trends were seen for self-reported cardiovascular outcomes. While no significant associations were found for self-reported mental disorders, increasing exposure quartile indicated decreasingly lower odds.

3.4.3 Fine Particulate Matter ($PM_{2.5}$)

3.4.3.1 Total Population

Exposure to $PM_{2.5}$ (annual average) between 2009 and 2014 was subdivided into quartiles: very low (min to 6.75 µg/m^3), low (6.77 to 8.09 µg/m^3), moderate (8.19 to 10.17 µg/m^3), and high (10.31 µg/m^3 to max). Exposure to $PM_{2.5}$ showed varying associations with mental disorders for the adolescent and older populations (Table 3.10). For older adults classified as having high exposure, the estimated odds of a self-reported mental disorder was 0.54 times lower compared to those classified as having very low

exposure. There was no obvious trend among exposure quartiles for self-reported mental disorders. Conversely, for adolescents classified as having high exposure, the estimated odds of a self-reported mental disorder was 2.99 times higher compared to those with very low exposure. For the adolescent population, increasing exposure quartile indicated increasingly higher odds of having a self-reported mental disorder. The older adult and adolescent populations had no obvious trends and no significant associations for self-reported asthma. With the older adult population, increasing exposure quartiles indicated decreasing odds of having a self-reported cardiovascular outcome, but no significant results were seen. For the total population, no significant results or obvious trends were seen for self-reported cardiovascular outcomes and mental disorders. For self-reported asthma among the total population, no significant results were seen but increasing exposure quartile indicated decreasingly lower odds.

Table 3.10 Adjusted logistic model associations for quartiles of exposure to annual average PM2.5 concentrations (2009 to 2014) and health outcomes.

Outcome	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population adolescent OR (95% CI)[2]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[3]**
Asthma	Very low (min to 6.75)	Reference			
	Low (6.77 to 8.09)	1.00 (0.76-1.31)	0.80 (0.38-1.68)	0.81 (0.48-1.35)	1.01 (0.35-2.90)
	Moderate (8.19 to 10.17)	0.97 (0.74-1.28)	0.74 (0.38-1.43)	0.64 (0.38-1.08)	0.66 (0.28-1.58)
	High (10.31 to max)	0.84 (0.64-1.10)	0.94 (0.48-1.83)	0.76 (0.45-1.30)	0.44 (0.18-1.08)
Cardiovascular outcome	Very low (min to 6.75)	Reference			
	Low (6.77 to 8.09)	1.10 (0.78-1.54)	-	1.04 (0.68-1.59)	1.23 (0.55-2.75)
	Moderate (8.19 to 10.17)	0.87 (0.63-1.19)	-	0.96 (0.66-1.40)	1.16 (0.57-2.37)
	High (10.31 to max)	1.18 (0.84-1.67)	-	0.93 (0.61-1.43)	0.87 (0.40-1.91)
Mental disorders	Very low (min to 6.75)	Reference			
	Low (6.77 to 8.09)	0.97 (0.74-1.26)	1.94 (0.62-6.02)	0.65 (0.38-1.09)	**2.27*** (1.01-5.07)
	Moderate (8.19 to 10.17)	0.83 (0.64-1.06)	2.05 (0.74-5.70)	1.09 (0.68-1.74)	1.57 (0.68-3.62)
	High (10.31 to max)	0.85 (0.66-1.10)	**2.99*** (1.02-8.74)	**0.54*** (0.34-0.87)	1.33 (0.60-2.92)

***p<0.001, **p<0.01, *p<0.05

Sources: National Air Pollution Surveillance Program [59] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [47,50,51].

1 Adjusted for age, household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, corresponding exposure and average temperature. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

2 Adjusted for household income, geographical location (urban or rural), population type (immigrants or non-immigrants), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI, corresponding exposure and average temperature. Mental disorder models were also adjusted for self-perceived mental health.
3 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status, length of residence in Canada, corresponding exposure and average temperature. Cardiovascular models were also adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

3.4.3.2 Immigrant Population

For the immigrant population statistically significant results were only seen for self-reported mental disorders. For those classified as having low $PM_{2.5}$ exposure, the estimated odds of a self-reported mental disorder was 2.27 times higher compared to those with very low exposure among immigrants (Table 3.10). Increasing exposure quartiles indicated decreasing odds of having a self-reported mental disorder. For all outcomes, increasing exposure quartiles were associated with decreasing odds.

3.5 Other Associations: Comparisons Across Populations

In models for the total, older adult and adolescent populations, population type (immigrant, non-immigrant) was included (Table A7). Immigrants among the total population, adolescent immigrants and older adult immigrants had decreased odds of self-reported asthma and mental disorders compared to non-immigrants. Results were not significant for self-reported mental disorders with older immigrants, and self-reported asthma with older and adolescent immigrants. For self-reported cardiovascular outcomes, among the total population, immigrants showed decreased odds compared to non-immigrants, but only one result was statistically significant. Comparatively, older immigrants were found to have increased odds of a self-reported cardiovascular outcome, only one result was statistically significant result and had decreased odds.

A length of residence in Canada (less than 10 years [recent immigrant], 10 plus years [long-term immigrant]) variable was included in models for the immigrant population. This variable looked at the associations between health outcomes and the length of residence in Canada (Table A8). Recent and long-term immigrants had lower odds of self-reported asthma and mental disorders compared to non-immigrants. For self-reported mental disorders, only long-term immigrants showed significant results. The estimated odds of a self-reported cardiovascular outcome trended higher for each additional year lived in Canada, but the results were not significant.

3.6 Sensitivity Analysis

A sensitivity analysis was completed with CANUE geographically weighted regression $PM_{2.5}$ data (Table A9). Self-reported asthma, cardiovascular outcomes and mental disorder results for the total population and self-reported asthma results for the adolescent population follow a similar trend to the main analysis, but some odds ratios showed different results. For all outcomes among the immigrant and older adult and self-reported mental disorders among the adolescent population, results tended to differ from those presented above.

3.7 Model Fit

Certain models fit well for Pearson's chi-square goodness-of-fit test and the calibration curve tests. This included self-reported cardiovascular outcomes (total, immigrants, older adults [except high temperature model], sensitivity analysis [total and older adults]), self-reported mental disorders (total, adolescents [daily minimum temperature, DTR and O_3], older adults [except high temperature model]) and self-reported asthma (total [except DTR and NO_2 models], older adults [daily minimum and maximum temperature, wildfire smoke, O_3 and $PM_{2.5}$]). Some models only fit well according to the Pearson's chi-square goodness of fit test. These included self-reported asthma models (adolescents, older adults [high, low and average temperature], immigrants [low, daily maximum, daily minimum and average temperature and NO_2 and O_3], sensitivity analyses [total, adolescents and older adults]), and self-reported mental disorder models (sensitivity analysis [total, immigrant and older adults]). Other models only fit well according to the calibration curve, these included self-reported asthma models (total and older adults [DTR and NO_2]), self-reported cardiovascular outcomes (older adults [high temperature], sensitivity analysis [immigrant] and self-reported mental disorders (adolescents [except for daily minimum temperature, DTR and O_3], older adults [high temperature], immigrants). Other models fit poorly for both tests, these included self-reported asthma models (immigrants [high temperature, DTR, $PM_{2.5}$ and wildfire smoke], sensitivity analysis [immigrants]) and self-reported mental disorder models (sensitivity analysis [adolescents]).

4. Discussion

4.2 Summary of Findings

This study analyzed the associations between weather, air pollution exposures and self-reported asthma, cardiovascular outcomes, and mental disorders in immigrant, total, adolescent and older adult populations in Alberta. Exposures that had the largest impact on health outcomes in this study were high temperature, low temperature, and $PM_{2.5}$ (quartile) exposures. Higher odds of self-reported asthma and cardiovascular outcomes were found with high temperature exposure for the total (immigrants and non-immigrants) and immigrant populations, respectively, while older adults were found to have a positive

association with low temperature and mental disorders. Immigrants and adolescents were likewise found to have a positive association with $PM_{2.5}$ exposure and mental disorders. High temperature, low temperature, daily minimum temperature, DTR, wildfire smoke, O_3 and $PM_{2.5}$ (quartile) exposures were negatively associated with health outcomes. Other significant weather and air pollution associations were not observed. Differences were observed between immigrants and non-immigrants, but not in the way expected. Immigrants were found to have statistically significant lower odds of self-reported asthma, cardiovascular outcomes and mental disorders compared to non-immigrants. Adolescent immigrants had statistically significant lower odds of self-reported mental disorders compared to non-immigrant adolescents. Older immigrants had statistically significant lower odds of self-reported cardiovascular outcomes compared to non-immigrant older adults. When looking at the impact of exposures other than high temperature, these associations changed for the total and older populations. Immigrants and older immigrants were found to have higher odds of a self-reported cardiovascular outcome with all exposures other than high temperature compared to non-immigrants. For immigrants the length of residence in Canada also had an impact on health outcomes: both long-term and recent immigrants had decreased odds of self-reported asthma compared to non-immigrants. Long-term immigrants also had decreased odds of a self-reported mental disorder compared to non-immigrants.

4.3 Weather Exposures

4.3.1 High Temperature

4.3.1.1 Total Population

Higher temperatures were positively associated with self-reported asthma, but not with self-reported cardiovascular outcomes or mental disorders among the total population. The estimated odds of self-reported asthma was higher for individuals categorized as having moderate and high exposure to high temperatures compared to individuals categorized as having very low exposure. These results align with previous studies, which have found that people who experience extreme heat events had a higher risk of asthma hospital visits, hospitalizations and asthma attacks [89–91]. When there is extreme heat, people may not have access to air conditioning or other methods used to cool down. According to Statistics Canada, an estimated 39% of Canadians do not have household air conditioning, leaving many at risk to the health impacts of high temperatures [92]. Physiologically, high temperatures (and other extreme temperatures) can affect those with asthma by causing bronchoconstriction, which is when the bronchial tubes narrow [93,94]. Despite the plausibility of these results, there seem to be inconsistencies in the literature. One study found that higher daily temperature was associated with a lower risk of asthma [95]. Overall, exposure to high temperature appears to exacerbate asthma, and from this study, increases the odds of self-reported asthma among the total population [89–91].

Comparatively, the estimated odds of a self-reported cardiovascular outcome was lower for individuals categorized as having high exposure to high temperature compared to individuals categorized as having very low exposure. Although other exposure levels were not significant, there was a trend of decreasing odds with higher exposure levels. These results are inconsistent with the literature findings, previous studies have found that exposure to extreme heat is associated with a higher risk of cardiovascular outcomes and higher rates of cardiovascular mortality [96–98]. High temperature has been found to be associated with cardiovascular-related emergency department visits, hospitalizations and hospital admissions in other studies [99,100]. One study found that there was a 2.1% increase in cardiovascular disease-related mortality for each 1°C increase in temperature [101]. Physiologically, high temperatures can impact cardiovascular outcomes by increasing blood pressure and viscosity and elevating heart rate [102]. It is important to note that these studies have been conducted in different countries (United States, Iran), so geographical and climatic differences might help to explain these inconsistencies [97,98,100]. Additionally, some studies look at high temperatures and others look at extreme heat or heat waves. Temperature is different among various geographical locations, and as there is no standard definition for extreme heat, this definition may be tailored to average meteorological conditions at that geographical location. This also may help explain the differences found among studies. Two high temperature variables were used in this study: the annual highest temperature recorded at each postal code in Alberta, and the annual average of the daily maximum temperature in each postal code in Alberta. Environment and Climate Change Canada defines a heat wave (also commonly called extreme heat event) as three plus days in a row when the maximum temperature is at or above 32°C [103]. This definition was not applied to this study as three or more consecutive days of ≥ 32°C is typically rare in most of Alberta. Additionally, while this study looked at cardiovascular outcomes (heart disease and stroke effects), other studies included other cardiovascular outcomes such as cardiovascular mortality and cardiovascular-related hospital admissions, [97,100].

These results could also be due to differences in behaviour at lower and higher exposure levels. With less extreme high temperatures, individuals may not change their behaviour due to perceived lower risk. Cardiovascular outcomes more frequently affect older adults, who are more likely to limit their time outdoors, especially with higher temperatures. Different results may have been seen with asthma in this study, as younger individuals are also affected and are more likely to go outdoors, even with high temperatures as they have obligations such as school or work.

4.3.1.2 Immigrant Population

Comparatively, for immigrants, high temperature was positively associated with self-reported asthma and cardiovascular outcomes, but results were only significant for the latter. For the immigrant population, the estimated odds of a self-reported cardiovascular outcome was higher for individuals at all categories of high temperature exposure (low, moderate, high) compared to individuals categorized as

having very low exposure. Interestingly, the low exposure category was significant and was associated with the highest odds. This result is not fully expected with high temperature, as based on the literature, immigrants were found to have a lower relative risk for cardiovascular mortality if they moved to a comparable climate [104]. It has been found that immigrants who moved from warm to cold climates had a higher relative risk for cardiovascular mortality compared to the native-born population [104]. These results were based on a review study with additional meta-regression that collected and compared numerous studies, destination countries included Canada, the United States, Sweden, Switzerland among others and origin countries included Mexico, Argentina, Algeria, Morocco among others [104]. For immigrant populations, it has been found that the temperature difference between the destination and origin countries impacts cardiovascular mortality [104]. In recent years, the majority of immigrants who came to Canada are from India, which primarily has a tropical climate [105]. While heat waves are impacting Canada and India, there are differences in the type of heat. Canada has a continental climate with very cold winters, hot summers and overall is fairly dry. This means immigrants from India and other tropical climates are exposed to a vastly different climate upon moving to Canada, even if there are comparable hot temperatures. Additionally, during that same year immigrants likely experienced colder weather in Alberta which also may have impacted the results seen. Due to this climate difference, immigrants may not be knowledgeable on how to cope with the heat in Alberta compared to their home country. This may include not knowing where the nearest cooling centre is (e.g. public library, community centre, shopping mall etc.), not understanding that homes built for cold climates retain heat (insulation reduces heat loss to outside) and being unaware of urban heat islands [106,107]. An urban heat island is a temperature increase in certain areas of a city [108]. Additionally, immigrants are not a homogenous group and there are likely differences between immigrant categories (economic, sponsored by family and refugees), but this was not able to be explored. Our results may differ from the literature as the world area of birth variable also could not be included due to correlation issues. Cultural/racial background and the length of residence in the country immigrated to are similarly important variables. While they were adjusted for, stratification by these variables could not be completed due to sample size issues [109,110]. Future research that stratifies on these variables is likely warranted.

4.3.1.3 Immigrant and Non-Immigrant Comparison

An interaction term was included in the high temperature model for the total and older adult populations, testing the effect of population type (immigrant, non-immigrant) and high temperature exposure. It was found that for the total immigrant population and older immigrants, the estimated odds of a self-reported cardiovascular outcome was increased for individuals categorized as having low, moderate and high exposure to high temperature compared to non-immigrant and older-non-immigrant individuals categorized as having very low exposure. The odds increased with increasing exposure levels. It is known that generally, older adults are more susceptible to the effects of heatwaves compared to younger individuals as the ability to thermoregulate decreases with age [111,112]. Older adults may also

have chronic conditions that impact the body's ability to deal with extreme heat [112]. As previously mentioned, cultural/racial background, length of residence in the country immigrated to and world area of birth are likely important variables to examine [109,110]. Additionally, the inability of immigrants to properly cope with the heat in Alberta may also have had an impact on these results.

4.3.2 Low temperature and Daily Minimum Temperature

4.3.2.1 Total Population

For the total and adolescent populations, the estimated odds of self-reported asthma was lower for individuals categorized as having moderate exposure to low temperature compared to individuals categorized as having very low exposure. The results for low temperature differ across studies in the literature, but it has been found that cold air is hard on the lungs for individuals with asthma [113]. Previous studies found that extreme cold is associated with an increased risk of asthma hospital admissions, hospital visits, and asthma attacks [91,114–116]. There are, however, inconsistencies in the literature. One study found that asthma incidence in adults was not impacted by temperature [115]. Additionally, one meta-analysis study that looked at 13 countries found that winter was positively associated with an increased risk of asthma, while another focused on New York, USA found that there was no change in asthma hospital admissions in the winter, only after cold spells [115,117]. It is important to note that some of these studies were completed in countries that have inconsistent indoor heating (e.g China, Chile), with some likely relying on firewood or a simple stove [118,119]. The results found in this study and the USA may be due to differences in behavior between the winter and summer seasons [117]. With extreme cold in Canada, most people limit their time outdoors and have access to heated spaces. This means that despite there being colder temperatures outside, it is likely that individuals have lower overall exposure compared to hotter temperatures. Additionally, in most studies, the duration of time spent outdoors by individuals is unknown. These factors may help to explain the decreased odds observed when individuals are exposed to low temperatures in this study. Some studies have also examined the association between asthma and vitamin D deficiency, a common deficiency in cold climates due to the limited time spent outdoors in the winter compared to summer [120–122]. This association is still being explored but may be a factor in observed associations in the literature. Overall, while low temperatures, similar to high temperature, have been found in the literature to exacerbate asthma, it does not appear to increase the odds of self-reported asthma in the total population in this study.

For adolescents, the estimated odds of self-reported asthma was lower for individuals categorized as having moderate exposure to low temperatures compared to individuals categorized as having very low exposure. Children (ages less than 12) have been found to have higher odds of asthma as the temperature drops [115]. Limited research focused on extreme temperature and asthma seems to

have been done in adolescents. Most research tends to focus on infants and children and positive associations have been found between cold spells and childhood asthma and asthma-related hospital admissions [123,124]. Once again, most of these studies focused on countries with inconsistent indoor heating, such as China. There also could be differences between adolescents and children, as adolescents may spend less time outdoors, behave and dress differently when they are outside and have different exposure to low temperatures compared to children. In Canada, indoor heated recreation and social spaces (e.g. recreation centres, libraries) are widely available, which adolescents likely frequent during the winter, reducing their exposure to low temperatures. As a result, adolescents should be considered as a separate age group. No studies were found examining the association between extreme cold and asthma for adolescents. Overall, low temperature does not appear to be positively associated with higher odds of self-reported asthma for adolescents in this study.

Low temperature and daily minimum temperature had similar associations with mental disorders in the total population. The estimated odds of having a self-reported mental disorder was lower for individuals in the high exposure quartile compared to individuals in the very low exposure quartile with respect to low temperatures and daily minimum temperatures. There are limited studies examining the association between mental disorders and extreme cold. The association between extreme heat and mental disorders seems to be more frequently studied. It has been found that extreme heat is positively associated with emergency room visits related to mental and behavioral disorders [125–127]. Results for extreme cold are less conclusive. One study in Toronto, Canada found no significant associations between cold temperatures and mental and behaviour disorder (including mood disorders) emergency room admissions [127]. Another study in New York, United States, found that extreme cold was positively associated with emergency room visits related to mental and behaviour disorders [128]. These results may differ due to characteristics such as race and age [128]. The physiological mechanism by which extreme temperatures may impact mental disorders has not been fully determined. It has been suggested mental health may be impacted by the behaviours that extreme temperatures cause, such as a lack of sleep, irritability and a decline in cognitive capacity, as these can cause mood changes and an increase in stress and anxiety levels [128,129]. Additionally, those with mental disorders may not take precautionary actions to limit their exposure to extreme temperatures [128]. Over long periods, this may be a factor in triggering the development of new cases of mental illness or worsening existing cases [129]. More research is needed to fully determine the impact of low temperatures on mental disorders, but from this study, it does not appear to be a major factor.

For older adults, low temperature and daily minimum temperature had similar associations with mental disorders. For both exposures, there was a trend of decreasing odds from low to high exposure quartiles for low temperatures. Additionally, for each exposure the estimated odds of having a self-reported mental disorder was higher for individuals categorized as having low exposure and lower for

individuals categorized as having high exposure compared to individuals categorized as having very low exposure. These associations appear to be less studied in older adults.

The literature on mental disorders in older adults is not consistent and the prevalence varies globally [130]. It has been found that anxiety disorders occur less frequently in older adults compared to those who are younger [131]. This may be due to underdiagnosis and earlier death for those with anxiety disorders [130]. It is important to note that this can also vary among different types of anxiety disorders [132]. Limited research appears to have been done on extreme temperatures and mental disorders among older adults. It has been found that cold weather can have a negative impact on mental health as individuals likely spend less time outside, increasing social isolation [133]. This effect is amplified for poor, non-white and older adults (65 plus) [133,134]. Older adults have the added difficulty of navigating outside with poor weather conditions, such as ice and snow which make walking more difficult and dangerous [134]. Overall, our results indicate that among older adults, more extreme low temperature and daily minimum temperature exposures are associated with lower odds of having a self-reported mental disorder. These results may be impacted by the fact that the duration spent outside is unknown, and less time may be spent outdoors when temperatures are colder.

4.3.2.2 Immigrant Population

No statistically significant results for low temperature or daily minimum temperature exposures were found for the immigrant population. Increasingly higher odds of self-reported asthma were seen for immigrants with higher daily minimum temperature exposure levels. Comparatively, decreasingly lower odds of self-reported mental disorders were seen for immigrants with higher daily minimum temperature exposure levels. This suggests that there may be a positive association between lower temperatures and self-reported asthma for the immigrant population. While the total population results did not align with previous findings of an increased risk of asthma hospital admissions and visits with extreme cold, those for the immigrant population do [91,114,115]. This could be due to the inability of immigrants to adapt to their new environment and mitigate risk.

4.3.3 Diurnal Temperature Range

4.3.3.1 Total Population

For the total and older populations, the estimated odds of having a self-reported mental disorder was lower and significant for individuals categorized as being exposed to larger DTRs compared to individuals categorized as exposed to a very small DTR. Greater DTR indicates a larger difference between the daily minimum and maximum temperatures. Differences in behaviour for individuals exposed to larger or smaller DTRs may impact these results. Large DTRs have been found to have an impact on

human health, but limited research has examined this relationship with mental disorders, or mental health [135]. One study found that there was an increase in daily schizophrenia hospital admissions with a larger DTR [136]. More research is needed to fully understand the impact of DTR on mental disorders.

4.3.3.2 Immigrant Population

For the immigrant population, the estimated odds of having self-reported asthma was lower for individuals exposed to moderate DTRs compared to individuals exposed to a very small DTR. This is contrary to previous literature findings. DTR has been found to primarily have an impact on asthma, COPD and respiratory tract infections [135]. This does not appear to hold true for the immigrant population in this study. Previous research has also found higher asthma rates in those from developed countries [137,138]. This is known as the nativity effect where certain countries have lower or higher rates of certain diseases such as asthma [139]. Another study found that when the population analyzed had a larger number of refugees, larger DTR was a risk factor for respiratory health events [140]. It is important to note that in this study DTR was not examined by season, and instead looked at annually. Overall, limited research seems to have been completed on the association between DTR and asthma for immigrants and refugees.

The estimated odds of a self-reported mental disorder was also lower for immigrants exposed to larger DTRs compared to individuals exposed to a very small DTR. Similar to the total population, limited research on immigrants has been conducted on the association between DTR and mental disorders. Despite this, results are consistent with studies that have analyzed the prevalence of mental disorders in immigrants without focusing on the impact of DTR. In Canada, immigrants were found to have a lower prevalence of mood and anxiety disorders compared to non-immigrant adults, children and youth [141,142]. Other studies in the United States have found similar results, but have reported that findings differ by race and ethnicity [143,144]. Comparatively, refugees have been found to have a higher risk of experiencing mental disorders such as depression and anxiety due to previous traumatic events [145]. The lower odds of self-reported mental disorders for immigrants in this study may be impacted by other factors such as stigmatization, cultural, religious, or language differences, age at immigration and affluence before immigration [138,146]. As previously mentioned, immigrants are not a homogenous group and there are likely differences among economic immigrants, immigrants sponsored by family, and refugees, this was not able to be analyzed in this study.

4.4 Air Pollution Exposures

4.4.1 Wildfire Smoke

4.4.1.1 Total Population

For the total population, the estimated odds of self-reported asthma was decreased for individuals categorized as having low wildfire smoke exposure compared to individuals categorized as having very low exposure. The estimated odds did not vary much between wildfire smoke exposure levels (low, moderate and high), which differs from findings that have been previously reported. Research in Canada has found that wildfire smoke exposure is associated with an increased risk of asthma-related physician visits [147,148]. Studies outside of Canada have also found that wildfire smoke exposure is associated with an increased risk of asthma morbidity and hospital admissions [149–151]. Another study observed interactions around wildfire smoke, with findings indicating effects as worse for females compared to males and for adults compared to children [152]. Wildfire smoke can affect the lower respiratory tract through numerous mechanisms, including decreasing lung function and increasing oxidative stress, which can increase asthma symptoms [153]. In this study, hospital admissions and morbidity were not examined, and instead analyzed self-reports of asthma. It is also important to note that past wildfire smoke exposure was not known in this study. While limited research has been done on this topic, among firefighters, cumulative woodsmoke exposure was positively associated with a decrease in lung function [154]. Overall, the literature indicates that asthma is impacted by wildfire smoke exposure, though positive associations with self-reported asthma were not observed in this study.

4.4.1.2 Immigrant Population

While no significant results for wildfire smoke exposure were seen among immigrants, the odds of a self-reported mental disorder were increased for individuals categorized as having higher wildfire smoke exposure. This is consistent with previous research in other countries indicating associations with an increased risk of asthma morbidity and hospital admissions, though these findings are not necessarily specific to immigrants [149–151]. Further research in this area is needed.

4.4.2 Ozone

4.4.2.1 Total Population

For the total and older populations, the estimated odds of having a self-reported cardiovascular outcome was lower for individuals categorized as having moderate O_3 exposure compared to individuals categorized as having very low exposure. Other studies have found that O_3 exposure is associated with overall cardiovascular mortality, ischaemic heart disease mortality, and cardiovascular-related hospital admissions [155,156]. Short-term controlled exposure to O_3 has been associated with cardiovascular effects [157,158]. While many studies have been completed in China, one study in Canada found that O_3 exposure was positively associated with cardiovascular mortality [63]. This association was found to be stronger in older adults (ages 65 plus) compared to those who were younger [155]. Older adults have

been found to have an increased incidence of congestive heart failure with long-term O_3 exposure, and O_3 exposure for those older than 65 is associated with a higher risk of cardiovascular-related hospitalization [159,160]. More research is needed to determine the physiological effects of O_3 on cardiovascular outcomes, but it is suggested that O_3 impacts inflammation, fibrinolysis endothelial function pathways, platelet activation and increases blood pressure [161,162].

In this study, O_3 exposure was found to have protective effects for self-reported cardiovascular outcomes among the total and older adult populations. This may be due to population differences compared to other studies. Data from O_3 monitor stations are sparser in rural locations in Alberta, so estimates may be coarser than those from urban locations. Canada also has significantly lower O_3 concentrations compared to certain countries such as the United States, which report positive associations between O_3 and cardiovascular diseases [159]. The average annual O_3 concentration in Phoenix, United States was 47.83 ppb between 2009 to 2014, while the annual O_3 average concentration recorded in Alberta, Canada was 26.13 ppb for the same time frame [163]. Additionally, the amount of time an individual spends outdoors was not considered in this study. Older adults may spend less time outside, meaning they have a lower O_3 exposure which could help to explain the protective effect that was observed [164]. Past O_3 exposure for the total population was not known. Individuals could have moved to Alberta from a different province or country, and their current O_3 exposure may be very different from their past exposure.

4.4.2.2 Immigrant Population

Among immigrants, the estimated odds of having self-reported asthma was lower for individuals categorized as having low exposure compared to individuals categorized as having very low exposure. Although other exposure levels were not significant, the estimated odds of having self-reported asthma tended to increase with higher O_3 exposure levels. This is consistent with other studies, as it has been found that O_3 exposure is associated with asthma emergency department visits and mortality [165–168]. One study reported a negative association between low and moderate O_3 exposure levels and asthma hospital visits [169]. This is consistent with the O_3 low and moderate exposure results found in this study. High levels of O_3 are known to worsen asthma symptoms, particularly in younger and older populations, and may play a role in the development of asthma [169,170]. While higher odds of self-reported asthma were seen in the adolescent and older adult non-immigrant populations with categories of higher O_3 exposure, results did not reach statistical significance. Physiologically, O_3 affects asthma through the formation of secondary oxidation products that activate airway epithelium and create pro-inflammatory and immune factors [171–173]. Overall, this causes airway inflammation, which lowers lung function [171,172]. Results may be impacted by the nativity effect, the healthy immigrant effect, and changes in outdoor behaviours [139]. Season may be an important effect modifier as O_3 concentrations are typically higher during the summer, though this study focused on annual average O_3 concentrations. Again, past

O_3 exposure was not known and O_3 concentrations that immigrants were exposed to in Alberta from 2009 to 2014 may not reflect their past exposures. It has been found that among young healthy individuals in California, cumulative exposure to O_3 over an individual's lifetime had an impact on airway injury and lower/upper respiratory symptoms [174]. It has also been found that long-term O_3 exposure is significantly associated with reduced lung function [175].

4.4.3 Particulate Matter 2.5

4.4.3.1 Total Population

We observed different associations for high $PM_{2.5}$ exposure and mental disorders among older adults and adolescents. For older adults, the estimated odds of a self-reported mental disorder was lower among those categorized as having high exposure to $PM_{2.5}$. This is not consistent with most findings. For older adults, $PM_{2.5}$ has been positively associated with depression and anxiety symptoms and non-specific perceived stress, which can lead to psychiatric disorders. [176–180]. Air pollution can lead to these changes by affecting the brain through mechanisms such as inflammation, oxidative stress, neurotransmitter receptor changes and necrosis or apoptosis [181]. There are inconsistencies in the literature, other studies have reported negative associations or that air pollution is not linked to depressive symptoms or major depressive episodes [182,183]. Similar to O_3 exposure, the protective effects seen in this study could be due to population differences compared to other studies. $PM_{2.5}$ concentration was also collected from the same data source (NAPS) as O_3, as previously mentioned rural estimates may be coarser than those from urban locations. Additionally, time spent outdoors by individuals and past $PM_{2.5}$ exposure was not known. As mentioned previously, behavioral changes may impact these results. Older adults likely spend less time outdoors, lowering their $PM_{2.5}$ exposure.

For adolescents, the estimated odds of a self-reported mental disorder was higher for individuals categorized as having high exposure to $PM_{2.5}$ compared to individuals categorized as having very low exposure. A trend of increasing odds with categories of increasing $PM_{2.5}$ exposure levels was seen but was not significant. This is consistent with other reported results. One study in Canada found that same-day and one-day lagged exposure to $PM_{2.5}$ was associated with a higher risk of mental disorder emergency department visits for those ages 8 to 24 years old, among those previously diagnosed [184]. Another study found that $PM_{2.5}$ exposure at age 12 was associated with major depressive disorder at age 18 [185]. It has also been suggested that exposure to air pollution can impact cognitive health in children, and may lead to other diseases later in life [186]. Mechanisms previously mentioned may explain this relationship in adolescents, which could also be compounded by additional physical, mental and social development occurring at this stage [187]. These results emphasize the importance of limiting adolescent exposure to air pollutants such as $PM_{2.5}$. Increasing adolescent exposure to green spaces like parks and

gardens can have a positive impact on health [186,188,189]. Green spaces generally have lower $PM_{2.5}$ levels, compared to surrounding areas, and are associated with numerous positive impacts on mental health, such as reduced stress and improved mood [190–192]. Similar to O_3 exposure, past $PM_{2.5}$ exposure for the adolescent and older adult populations was not known.

4.4.3.2 Immigrant Population

For immigrants, the estimated odds of having a self-reported mental disorder is higher for individuals categorized as having low $PM_{2.5}$ exposure compared to individuals categorized as having very low exposure. A trend of decreasing odds with increasing categories of exposure was also seen, but lacked statistical significance. These results are inconsistent with what is known about the prevalence of mental disorders in immigrants. In Canada, immigrants have been found to have a lower prevalence of mood and anxiety disorders compared to non-immigrants [141,142]. It has been found that this association is impacted by immigration category, with refugees being "significantly more likely to report experiencing emotional problems and high levels of stress compared to family class immigrants" [193 (p24)]. Duration of residence, country of origin, and ethnicity may be important to consider in future studies as has been seen with other health outcomes among immigrants [109,110]. Previous $PM_{2.5}$ exposure for the immigrant population was not known. This is particularly important as immigrants in this study came from a variety of countries with some known to have higher $PM_{2.5}$ concentrations compared to Canada. Approximately 57% of immigrants in this study came from Southern Asia, Eastern Asia, Oceania or other Asia. From April 2014 to April 2015, the annual average $PM_{2.5}$ concentration in China across 190 cities was 57 ± 18 $\mu g/m^3$, comparatively the annual average for Alberta in 2014 was 7.10 $\mu g/m^3$ [194]. This indicates that while this study examined Alberta $PM_{2.5}$ concentrations, past exposure could have had an impact on the results.

4.5 Immigrant and Non-Immigrant Health Outcome Comparison

Further comparisons by population type (immigrant, non-immigrant) and length of residence in Canada were also conducted. The purpose was to explore differences between immigrants compared to non-immigrants and recent/long-term immigrants compared to non-immigrants in terms of asthma, cardiovascular outcomes, and mental disorder outcomes. It was found that the sex distribution was fairly even between male and female immigrants in this study. Despite this, men may be more likely to migrate to Canada for work compared to females and bring their families over after settling [195,196].

4.5.1 Asthma

The estimated odds of having self-reported asthma was lower for immigrants compared to non-immigrants. Similar results were found for adolescent and older adult immigrants but were not statistically

significant. This aligns with previous research, which found that first-generation immigrants have a lower prevalence of asthma compared to second-generation immigrants and those who are native-born [137,138,197]. Place of birth, length of residence, the healthy migrant effect and other characteristics such as affluence status may play a role in these findings [139].

It was found that for both recent and long-term immigrants, the estimated odds of having self-reported asthma was also lower compared to non-immigrants. Additionally, long-term immigrants had lower odds of having self-reported asthma compared to non-immigrants than recent immigrants compared to non-immigrants. Previous studies have also found that immigrants are less likely to have asthma compared non-immigrants in Canada [198-200].

4.5.2 Cardiovascular Outcomes

The estimated odds of a self-reported cardiovascular outcome were statistically significant and lower for immigrants compared to non-immigrants in selected models. This result is consistent with the main literature findings. Immigrants have been observed to have a lower risk of cardiovascular diseases, such as stroke and ischemic heart disease compared to the host population [201]. The incidence of cardiovascular events varies among Canadian immigrants from different countries, ethnicities, and length of residence in the host country [109,110,202]. For example, one study examined immigrants from China, India and the Philippines who moved to Canada and found that ischemic heart disease was higher among South Asian women compared to non-immigrants [203]. Another study found that immigrants who moved to a country with a colder climate from a country with a warmer climate had higher rates of cardiovascular mortality [104]. This is potentially due to various factors, including physiological (reduced vitamin D levels) and behavioral (limited physical activity) [104]. Results from this study may, in part, reflect different immigration policies in North America, as in Western Europe it has been found that immigrants were at a higher risk or equal risk for ischemic heart disease or stroke compared to the host population [201]. Immigrants are not a homogenous group. To fully understand the risk of cardiovascular outcomes for immigrants it is important to look at other distinctions between immigrant groups (world area of birth, ethnicity, duration of residence, age, sex, education).

For older immigrants, the estimated odds of having a self-reported cardiovascular outcome was lower compared to older non-immigrants in a select model. While recent immigrants are normally found to be healthier than the general population, this could also be true of older immigrant adults as well [110,204]. In terms of the length of residence in Canada, the estimated odds of having a self-reported cardiovascular outcome appeared to be higher for each additional year lived in Canada, indicating the presence of the healthy immigrant effect, but results were not statistically significant [199].

4.5.3 Mental Disorders

For all immigrants and adolescent immigrants the estimated odds of having a self-reported mental disorder was lower compared to non-immigrants. For older immigrants the estimated odds of a self-reported mental disorder was also lower compared to older non-immigrants, but was not statistically significant. This is consistent with the literature in Canada and the United States. Immigrants have been found to have a lower prevalence of mood and anxiety disorders compared to non-immigrants in these countries [141–144], but it is important to note that these results can differ by race and ethnicity [143,144].

For long-term immigrants, the estimated odds of having a self-reported mental disorder was also lower compared to non-immigrants. This is consistent with other results that have found immigrants are less likely to have mental health problems and have a lower prevalence of mood and anxiety disorders compared to non-immigrants for adults, youth, and children [28,141,142]. While results were not statistically significant for recent immigrants, their odds were also lower than that of long-term immigrants. These results are consistent with the healthy immigrant effect. One Canadian study reported that immigrants had better mental health compared to non-immigrants almost 20 years after immigrating [205]. Comparatively, another Canadian study found that recent Canadian immigrants had a health advantage, but that long-term immigrants did not [206]. Results regarding the healthy immigrant effect and mental health are still being explored as most studies have focused on physical health [207]. Longitudinal studies are needed to further analyze this association.

4.6 Strengths and Limitations

One strength of this study is that it used the Canadian Community Health Survey, which used random sampling, which strengthens the generalizability of these findings. Additionally, this study had good geographical coverage (study area is province-wide) and included a large number of participants overall. This study also included immigrants, which are a commonly excluded population. These findings can help to guide Canadian policymakers about future health considerations for immigrant populations.

This study has some limitations, including a smaller sample size in terms of the number of immigrants, older adults, and adolescents. The sample size was limited to those in Alberta. For immigrants, this limited our ability to further stratify by age, sex, geographical location (urban or rural), immigrant category (economic, sponsored, refugee), or world area of birth. Certain behavioral factors that may have impacted these reported outcomes could not be analyzed in this study due to data limitations, such as drinking status. Additionally, temperature and air pollutant exposures are estimated exposures. Depending on the amount of time spent outdoors or indoors, these exposures may vary for individuals. We also lacked exposure histories, which arguably could be a more important consideration in terms of self-reported health outcomes than current exposures. Additionally, due to correlation issues, we were not

able to include world area of birth, official language spoken, immigration category, and length of residence in Canada simultaneously in any of the models. Transnational migration could also have an impact, as immigrants may move to Canada but travel elsewhere for health treatments, including back to their home countries [208, 209].

Certain biases could not be avoided, such as volunteer bias, as the Canadian Community Health Survey is a voluntary survey. Non-response bias is also potentially an issue as those who are healthier may be more motivated/able to participate. Exclusion bias may also be a concern: only individuals who were selected and allowed their responses to be used further were included in this study. This study may also be impacted by recall bias. The CCHS is a self-reported cross-sectional survey, and is a very long survey so not all respondents may accurately recall certain information. Selection bias is also a concern as the Longitudinal Immigration Database only includes those who file tax returns [52]. Residual confounding may also be a concern as some key variables might have been missed.

5. Conclusion

This study found that weather and air pollution exposures may be associated with selected health outcomes. High temperature had a positive association with self-reported asthma and cardiovascular outcomes among the total and immigrant populations, respectively. This is important as Canada's temperature has risen 1.7° since 1948 and is predicted to continue to rise [2]. Low temperature was negatively associated with self-reported asthma in the total and adolescent populations, and self-reported mental disorders in the total population. Similarly, daily minimum temperature had negative associations with self-reported mental disorders in the total and older adult populations. Comparatively, low temperature was positively associated with self-reported mental disorders in older adults. Less conclusive research has been done on the effects of low temperature, particularly for mental disorders. DTR was negatively associated with self-reported asthma in immigrants, and self-reported mental disorders in the total, older adult, and immigrant populations. While limited research has been conducted on the association between DTR and mental disorders, large DTRs have been found to have an impact on human health [135]. DTR has also been found to have an impact on asthma, COPD and respiratory tract infections [135]. For air pollutants, $PM_{2.5}$ exposure was positively associated with self-reported mental disorders in adolescents and immigrants, and negatively associated with this same outcome in older adults. While these results are consistent with previous literature for adolescents, this is not the case for immigrants and older adults. O_3 exposure was negatively associated with self-reported cardiovascular outcomes for the total and older populations, and asthma in immigrants. These results are inconsistent with previous findings but may be affected by behavioral factors. For wildfire smoke, there was a negative association with self-reported asthma in the total population, which was not expected. Immigrants had

lower odds of self-reported asthma, cardiovascular outcomes and mental disorders compared to non-immigrants, indicating the presence of the healthy migrant effect.

Despite these findings, this does not mean that these health outcomes are not a concern among immigrants. The length of residence immigrants had spent in Canada also had an impact on outcomes, Long-term immigrants had higher odds of self-reported asthma and cardiovascular outcomes compared to recent immigrants. This indicates that while immigrants appear to have lower odds of these self-reported outcomes compared to non-immigrants, their health declines with longer residence in Alberta, Canada. Differences across populations and exposures also suggest the need to consider these effects in future studies. These results indicate the need for more immigrant-specific studies regarding weather and air pollution exposures.

Author contributions: Conceptualization and methodology, B.T.S and S.S.Y.; data management and cleaning, B.T.S.; spatial analysis and exposure assignment, B.T.S and J.R.S.; Statistical analysis, B.T.S.; thesis draft, B.T.S.; editing, J.S and S.S.Y.; supervision, S.S.Y

References

1. Bush E, Flato G. Chapter 1: about this report. In: Bush E, Lemmen DS, editors. Canada's changing climate report [Internet]. Ottawa, ON: Government of Canada; 2019. p. 7–23. Available from: https://changingclimate.ca/site/assets/uploads/sites/2/2018/11/CCCR_Chapter1-About-this-Report.pdf

2. Zhang X, Flato G, Kirchmeier-Young M, Vincent L, Wan H, Wang X, et al. Temperature and precipitation across Canada. In: Lemmen DS, Bush E, editors. Canada's changing climate report [Internet]. Ottawa, ON: Government of Canada; 2019. p. 112–93. Available from: https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf

3. Health Canada. Health impacts of air pollution in Canada: estimates of premature deaths and nonfatal outcomes [Internet]. Ottawa, ON; 2021 Mar. Available from: https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/2021-health-effects-indoor-air-pollution/hia-report-eng.pdf

4. Matz CJ, Egyed M, Xi G, Racine J, Pavlovic R, Rittmaster R, et al. Health impact analysis of PM2.5 from wildfire smoke in Canada (2013-2015, 2017-2018). Sci Total Environ [Internet]. 2020 Jul 10;725:138506. Available from: https://pubmed.ncbi.nlm.nih.gov/32302851/

5. Orru H, Ebi KL, Forsberg B. The interplay of climate change and air pollution on health. Curr Environ Health Rep [Internet]. 2017 Dec;4:504–13. Available from: http://dx.doi.org/10.1007/s40572-017-0168-6

6. Government of Canada. Canadian climate normals 1991-2020 data [Internet]. 2024 [cited 2024 Apr 15]. Available from: https://climate.weather.gc.ca/climate_normals/results_1991_2020_e.html?searchType=stnProv&lstProvince=AB&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=281000000&dispBack=0

7. Brook JR, Cober SG, Freemark M, Harner T, Li SM, Liggio J, et al. Advances in science and applications of air pollution monitoring: a case study on oil sands monitoring targeting ecosystem protection. J Air Waste Manag Assoc [Internet]. 2019 May 24;69(6):661–709. Available from: http://dx.doi.org/10.1080/10962247.2019.1607689

8. Schneider SR, Lee K, Santos G, Abbatt JPD. Air quality data approach for defining wildfire influence: impacts on $PM_{2.5}$, NO_2, CO, and O_3 in western Canadian cities. Environ Sci Technol [Internet]. 2021 Oct 5;55(20):13709–17. Available from: http://dx.doi.org/10.1021/acs.est.1c04042

9. Mamuji AA, Rozdilsky JL. Wildfire as an increasingly common natural disaster facing Canada: understanding the 2016 Fort McMurray wildfire. Nat Hazards [Internet]. 2019 Sept 25;98:163–80. Available from: https://doi.org/10.1007/s11069-018-3488-4

10. Alberta. Air quality and health [Internet]. [cited 2024 Feb 10]. Available from: https://www.alberta.ca/air-quality-and-health.aspx

11. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: impacts, adaptation, and co-benefits. In: Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, editor. Climate change 2014 - impacts, adaptation, and vulnerability: part A: global and sectoral aspects [Internet]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014 [cited 2022 Jun 27]. p.

709–54. Available from: https://researchprofiles.canberra.edu.au/en/publications/human-health-impacts-adaptation-and-co-benefits

12. Preston BL, Yuen EJ, Westaway RM. Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. Sustainability Sci [Internet]. 2011 Mar 24;6:177–202. Available from: https://link.springer.com/article/10.1007/s11625-011-0129-1

13. Dias D, Tchepel O. Spatial and temporal dynamics in air pollution exposure assessment. Int J Environ Res Public Health [Internet]. 2018 Mar 20;15(3). Available from: http://dx.doi.org/10.3390/ijerph15030558

14. Ahmed MR, Hassan QK. Occurrence, area burned, and seasonality trends of forest fires in the natural subregions of Alberta over 1959–2021. Fire [Internet]. 2023 Mar 2;6(3). Available from: https://www.mdpi.com/2571-6255/6/3/96

15. Ejiagha IR, Ahmed MR, Dewan A, Gupta A, Rangelova E, Hassan QK. Urban warming of the two most populated cities in the Canadian province of Alberta, and its influencing factors. Sensors [Internet]. 2022 Apr 9;22(8). Available from: http://dx.doi.org/10.3390/s22082894

16. Bari MA, Kindzierski WB. Evaluation of air quality indicators in Alberta, Canada - an international perspective. Environ Int [Internet]. 2016 Jul-Aug;92–93:119–29. Available from: http://dx.doi.org/10.1016/j.envint.2016.03.021

17. Sahni V, Scott AN, Beliveau M, Varughese M, Dover DC, Talbot J. Public health surveillance response following the southern Alberta floods, 2013. Can J Public Health [Internet]. 2016 mar 1;107(2):e142–8. Available from: http://dx.doi.org/10.17269/cjph.107.5188

18. Alberta. Climate change in Alberta [Internet]. [cited 2023 Nov 1]. Available from: https://www.alberta.ca/climate-change-alberta.aspx

19. World Health Organization. Ambient (outdoor) air pollution [Internet]. 2022 Dec 19 [cited 2023 Jan 27]. Available from: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

20. World Health Organization. Climate change [Internet]. [cited 2024 Jan 10]. Available from: https://www.who.int/health-topics/climate-change

21. Kerry V, Sayeed S. Advancing the climate change and health nexus: The 2024 Agenda. PLOS Glob Public Health [Internet]. 2024 Mar 28;4(3):e0003008. Available from: http://dx.doi.org/10.1371/journal.pgph.0003008

22. Statistics Canada. Asthma, by age group [Internet]. 2023 Nov 6 [cited 2024 Jan 15]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009608&pickMembers%5B0%5D=1.10&pickMembers%5B1%5D=3.1&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2020&referencePeriods=20150101%2C20200101

23. Statistics Canada. Mental disorders in Canada, 2022 [Internet]. 2023 Sept 22 [cited 2024 Jan 15]. Available from: https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2023053-eng.htm

24. Government of Canada. Heart disease in Canada [Internet]. 2022 Jul 28 [cited 2024 Jan 15]. Available from: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html

25. Hathaway J, Maibach EW. Health implications of climate change: a review of the literature about the perception of the public and health professionals. Curr Environ Health Rep [Internet]. 2018 Feb 8;5:197–204. Available from: http://dx.doi.org/10.1007/s40572-018-0190-3

26. Benevolenza MA, DeRigne L. The impact of climate change and natural disasters on vulnerable populations: a systematic review of literature. J Hum Behav Soc Environ [Internet]. 2019;29(2):266–81. Available from: https://doi.org/10.1080/10911359.2018.1527739

27. Pinault L, van Donkelaar A, Martin RV. Exposure to fine particulate matter air pollution in Canada. Health Rep [Internet]. 2017 Mar 15;28(3):9–16. Available from: https://pubmed.ncbi.nlm.nih.gov/28295129/

28. Vang ZM, Sigouin J, Flenon A, Gagnon A. Are immigrants healthier than native-born Canadians? a systematic review of the healthy immigrant effect in Canada. Ethn Health [Internet]. 2016 Nov 3;22(3):209–41. Available from: http://dx.doi.org/10.1080/13557858.2016.1246518

29. Lane G, Farag M, White J, Nisbet C, Vatanparast H. Chronic health disparities among refugee and immigrant children in Canada. Appl Physiol Nutr Metab [Internet]. 2018 Oct;43(10):1043–58. Available from: http://dx.doi.org/10.1139/apnm-2017-0407

30. Daynes L. The health impacts of the refugee crisis: a medical charity perspective. Clin Med [Internet]. 2016 Oct;16(5):437–40. Available from: http://dx.doi.org/10.7861/clinmedicine.16-5-437

31. Erickson AC, Christidis T, Pappin A, Brook JR, Crouse DL, Hystad P, et al. Disease assimilation: the mortality impacts of fine particulate matter on immigrants to Canada. Health Rep [Internet]. 2020 Jun 17;31(3):14-26. Available from: https://www.ncbi.nlm.nih.gov/pubmed/32644760

32. Müller-Funk L. Research with refugees in fragile political contexts: how ethical reflections impact methodological choices. J Refug Stud [Internet]. 2021 Aug 25;34(2):2308–32. Available from: https://academic.oup.com/jrs/article-pdf/34/2/2308/39903775/feaa013.pdf

33. Immigration, Refugee Board of Canada. Claims by country of alleged persecution - 2023 [Internet]. 2023 [cited 2024 May 1]. Available from: https://www.irb-cisr.gc.ca/en/statistics/protection/Pages/RPDStat2023.aspx

34. Morency JD, Malenfant ÉC, MacIsaac S. Immigration and diversity: population projections for Canada and its regions, 2011 to 2036 [Internet]. Statistics Canada; 2017 Jan 25. Available from: https://www150.statcan.gc.ca/n1/en/pub/91-551-x/91-551-x2017001-eng.pdf?st=Ri_b-rZ3

35. Stanberry LR, Thomson MC, James W. Prioritizing the needs of children in a changing climate. PLoS Med [Internet]. 2018 Jul 31;15(7):e1002627. Available from: http://dx.doi.org/10.1371/journal.pmed.1002627

36. Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med [Internet]. 2009 Jan;51(1):33–7. Available from: http://dx.doi.org/10.1097/JOM.0b013e318193e12e

37. Kriebel-Gasparro A. Climate change: effects on the older adult. J Nurse Pract [Internet]. 2022 Apr;18(4):372–6. Available from: https://www.sciencedirect.com/science/article/pii/S1555415522000071

38. Levy SR, Apriceno M. Ageing: the role of ageism. OBM Geriat [Internet]. 2019 Oct 28;3(4). Available from: https://www.lidsen.com/journals/geriatrics/geriatrics-03-04-083

39. Alberta. Population projections: Alberta and census divisions, 2021– 2046 [Internet]. 2021 Jul 2. Available from: https://open.alberta.ca/dataset/90a09f08-c52c-43bd-b48a-fda5187273b9/resource/9b48e997-92b0-4b74-82d2-017443049790/download/2021-2046-alberta-population-projections.pdf

40. Statistics Canada. Census profile, 2021 census of population: profile table [Internet]. 2022 [cited 2024 Mar 14]. Available from: https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=Alberta&DGUIDlist=2021A000248&GENDERlist=1,2,3&STATISTIClist=1&HEADERlist=0

41. Statistics Canada. Population and dwelling counts: Canada and census subdivisions (municipalities) [Internet]. 2022 Feb 9 [cited 2024 Mar 14]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810000201

42. Statistics Canada. Classification of admission category [Internet]. [cited 2024 Mar 15] Available from: https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=323293&CVD=323294&CLV=0&MLV=4&D=1

43. Statistics Canada. Classification of admission category: 4 – other immigrant [Internet]. [cited 2024 Mar 15]. Available from: https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=323293&CVD=323294&CPV=4&CST=10102023&CLV=1&MLV=4

44. Cianconi P, Betrò S, Janiri L. The impact of climate change on mental health: a systematic descriptive review. Front Psychiatry [Internet]. 2020 Mar 6;11:74. Available from: https://pubmed.ncbi.nlm.nih.gov/32210846/

45. Rocque RJ, Beaudoin C, Ndjaboue R, Cameron L, Poirier-Bergeron L, Poulin-Rheault RA, et al. Health effects of climate change: an overview of systematic reviews. BMJ Open [Internet]. 2021 Jun 9;11(6):e046333. Available from: http://dx.doi.org/10.1136/bmjopen-2020-046333

46. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: a review. Front Public Health [Internet]. 2020 Feb 19;8:14. Available from: http://dx.doi.org/10.3389/fpubh.2020.00014

47. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29 [cited 2024 Mar 10]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

48. Government of Canada. About the access - RDC [Internet]. 2023 Dec 29 [cited 2024 Mar 10]. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/about

49. Canadian Research Data Centre Network. About the Canadian research data centre network [Internet]. [cited 2024 Mar 10]. Available from: https://crdcn.ca/about/about-crdcn/

50. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2022 Dec 2 [cited 2024 Mar 11]. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb

51. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2024 Jan 19 [cited 2024 Mar 11]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

52. Statistics Canada. Longitudinal immigration database (IMDB) technical report, 2021 [Internet]. 2022 Dec. Available from: https://www150.statcan.gc.ca/n1/en/pub/11-633-x/11-633-x2022009-eng.pdf?st=uHw5aNzK

53. Ng E, Zhang H. The mental health of immigrants and refugees: Canadian evidence from a nationally linked database [Internet]. 2020 Aug 19;31(8):3-12. Available from: https://pubmed.ncbi.nlm.nih.gov/32816413/

54. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

55. The Canadian Urban Environmental Health Research Consortium. Canue metadata - weather climate metrics [Internet]. 2024 Mar 29. Available from: https://www.canuedata.ca/tmp/CANUE_METADATA_WTHNRC_A_YY.pdf

56. Wahba G, Wendelberger J. Some new mathematical methods for variational objective analysis using splines and cross validation. Mon Weather Rev [Internet]. 1980 Aug 1;108(8):1122–43. Available from: https://journals.ametsoc.org/view/journals/mwre/108/8/1520-0493_1980_108_1122_snmmfv_2_0_co_2.xml

57. Hutcbinson MF, Biscbof RJ. A new method for estimating the spatial distribution of mean seasonal and annual rainfall applied to the Hunter Valley, New South Wales. Aust Met Mag [Internet]. 1983; 31(3):1979-184. Available from: https://epic.awi.de/id/eprint/29862/1/Hut1983a.pdf

58. Government of Canada. Regional, national and international climate modeling [Internet]. 2020 Dec 8 [cited 2024 Mar 15]. Available from: https://cfs.nrcan.gc.ca/projects/3

59. Government of Canada. National air pollution surveillance program [Internet]. 2022 Apr 28 [cited 2024 Mar 15]. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

60. World Health Organization. Wildfires [Internet]. [cited 2024 Mar 20]. Available from: https://www.who.int/health-topics/wildfires

61. The Canadian Urban Environmental Health Research Consortium. Canue metadata - air quality smoke exposure (PM2.5 v2) [Internet]. 2024 Mar 29. Available from: https://www.canuedata.ca/tmp/CANUE_METADATA_AQSMK_AVB_YY.pdf

62. Government of Canada. National air pollution surveillance (NAPS) program [Internet]. 2019 Nov 28 [cited 2024 Mar 15]. Available from: https://open.canada.ca/data/en/dataset/1b36a356-defd-4813-acea-47bc3abd859b

63. Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. Ambient PM2.5, O_3, and NO_2 exposures and associations with mortality over 16 Years of follow-up in the Canadian census health and environment cohort (CanCHEC). Environ Health Perspect [Internet]. 2015 Nov 1;123(11):1180–6. Available from: http://dx.doi.org/10.1289/ehp.1409276

64. The Canadian Urban Environmental Health Research Consortium. Canue metadata - air quality fine particulate matter (PM2.5 v5) [Internet]. 2024 Mar 29. Available from: https://www.canuedata.ca/tmp/CANUE_METADATA_PM25DALE_A_YY.pdf

65. Brunsdon C, Fotheringham S, Charlton M. Geographically weighted regression. J Royal Statistical Soc D [Internet]. 1998 Sept;47(3):431–43. Available from: https://onlinelibrary.wiley.com/doi/10.1111/1467-9884.00145

66. Statistics Canada. Table 13-10-0096-18 Mood disorders, by age group [Internet]. 2023 [cited 2024 Mar 22]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009618&pickMembers%5B0%5D=1.10&pickMembers%5B1%5D=3.1&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2022&referencePeriods=20150101%2C20220101

67. Thomas S, Wannell B. Combining cycles of the Canadian community health survey. Health Rep [Internet]. 2009 Mar;20(1):53–8. Available from: https://www.ncbi.nlm.nih.gov/pubmed/19388369

68. Nuotio J, Vähämurto L, Pahkala K, Magnussen CG, Hutri-Kähönen N, Kähönen M, et al. CVD risk factors and surrogate markers - urban-rural differences. Scand J Public Health [Internet]. 2020 Nov;48(7):752–61. Available from: http://dx.doi.org/10.1177/1403494819869816

69. Weich S, Twigg L, Lewis G. Rural/non-rural differences in rates of common mental disorders in Britain: prospective multilevel cohort study. Br J Psychiatry [Internet]. 2006 Jan 2;188(1):51–7. Available from: http://dx.doi.org/10.1192/bjp.bp.105.008714

70. Diala CC, Muntaner C. Mood and anxiety disorders among rural, urban, and metropolitan residents in the United States. Community Ment Health J [Internet]. 2003 Jun;39(3):239–52. Available from: http://dx.doi.org/10.1023/a:1023342307323

71. Jie Y, Isa Z, Jie X, Ju ZL, Ismail NH. Urban vs. rural factors that affect adult asthma. In: Whitacre DM, editor. Reviews of environmental contamination and toxicology volume 226 [Internet]. New York, NY: Springer New York; 2013. p. 33–63. Available from: https://doi.org/10.1007/978-1-4614-6898-1_2

72. Hayes RB, Lim C, Zhang Y, Cromar K, Shao Y, Reynolds HR, et al. PM2.5 air pollution and cause-specific cardiovascular disease mortality. Int J Epidemiol [Internet]. 2020 Feb 1;49(1):25–35. Available from: http://dx.doi.org/10.1093/ije/dyz114

73. Martins SS, Ko J, Kuwabara S, Clarke D, Alexandre P, Zandi P, et al. The relationship of adult mental disorders to socioeconomic status, race/ethnicity, marital status, and urbanicity of residence. In: Eaton WW, editor. Public mental health [Internet]. USA: Oxford University Press;2012 Jul. p 151-197. Available from: https://academic.oup.com/book/7515

74. Christidis T, Erickson AC, Pappin AJ, Crouse DL, Pinault LL, Weichenthal SA, et al. Low concentrations of fine particle air pollution and mortality in the Canadian community health survey cohort. Environ Health [Internet]. 2019 Oct 10;18(84). Available from: http://dx.doi.org/10.1186/s12940-019-0518-y

75. Tanuseputro P, Manuel DG, Leung M, Nguyen K, Johansen H. Risk factors for cardiovascular disease in Canada. Can J Cardiol [Internet]. 2003 Oct;19(11):1249–59. Available from: https://www.ncbi.nlm.nih.gov/pubmed/14571310

76. Bays HE, Taub PR, Epstein E, Michos ED, Ferraro RA, Bailey AL, et al. Ten things to know about ten cardiovascular disease risk factors. Am J Prev Cardiol [Internet]. 2021 Mar;5:100149. Available from: http://dx.doi.org/10.1016/j.ajpc.2021.100149

77. Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. Lancet [Internet]. 2020 Mar 7;395(10226):795–808. Available from: http://dx.doi.org/10.1016/S0140-6736(19)32008-2

78. Bakolis I, Hammoud R, Stewart R, Beevers S, Dajnak D, MacCrimmon S, et al. Mental health consequences of urban air pollution: prospective population-based longitudinal survey. Soc

Psychiatry Psychiatr Epidemiol [Internet]. 2020 Oct 24;56:1587–99. Available from: http://dx.doi.org/10.1007/s00127-020-01966-x

79. Dong GH, Zhang P, Sun B, Zhang L, Chen X, Ma N, et al. Long-term exposure to ambient air pollution and respiratory disease mortality in Shenyang, China: a 12-year population-based retrospective cohort study. Respiration [Internet]. 2012;84(5):360–8. Available from: http://dx.doi.org/10.1159/000332930

80. Toskala E, Kennedy DW. Asthma risk factors. Int Forum Allergy Rhinol [Internet]. 2015 Sep;5(Suppl 1):S11-6. Available from: http://dx.doi.org/10.1002/alr.21557

81. Scott KM, McGee MA, Wells JE, Oakley Browne MA. Obesity and mental disorders in the adult general population. J Psychosom Res [Internet]. 2008 Jan;64(1):97–105. Available from: http://dx.doi.org/10.1016/j.jpsychores.2007.09.006

82. Ko Y, Boo S. Self-perceived health versus actual cardiovascular disease risks. Jpn J Nurs Sci [Internet]. 2015 Jun 23;13(1):65–74. Available from: http://dx.doi.org/10.1111/jjns.12087

83. Bonner WIA, Weiler R, Orisatoki R, Lu X, Andkhoie M, Ramsay D, et al. Determinants of self-perceived health for Canadians aged 40 and older and policy implications. Int J Equity Health [Internet]. 2017 Jun 6;16(94). Available from: http://dx.doi.org/10.1186/s12939-017-0595-x

84. Jylhä M. What is self-rated health and why does it predict mortality? towards a unified conceptual model. Soc Sci Med [Internet]. 2009 Aug;69(3):307–16. Available from: http://dx.doi.org/10.1016/j.socscimed.2009.05.013

85. Renwick KA, Sanmartin C, Dasgupta K, Berrang-Ford L, Ross N. The influence of low social support and living alone on premature mortality among aging Canadians. Can J Public Health [Internet]. 2020 Mar 13;111:594–605. Available from: http://dx.doi.org/10.17269/s41997-020-00310-9

86. Kitchen P, Williams A, Chowhan J. Sense of community belonging and health in Canada: a regional analysis. Soc Indic Res [Internet]. 2011 Mar 26;107:103–26. Available from: https://doi.org/10.1007/s11205-011-9830-9

87. McLeod CB, Lavis JN, Mustard CA, Stoddart GL. Income inequality, household income, and health status in Canada: a prospective cohort study. Am J Public Health [Internet]. 2003 Aug;93(8):1287–93. Available from: http://dx.doi.org/10.2105/ajph.93.8.1287

88. Rodgers JL, Jones J, Bolleddu SI, Vanthenapalli S, Rodgers LE, Shah K, et al. Cardiovascular risks associated with gender and aging. J Cardiovasc Dev Dis [Internet]. 2019 Apr 27;6(2). Available from: http://dx.doi.org/10.3390/jcdd6020019

89. Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. Environ Health [Internet]. 2016 Apr 27;15(57). Available from: http://dx.doi.org/10.1186/s12940-016-0142-z

90. Deng S, Han A, Jin S, Wang S, Zheng J, Jalaludin BB, et al. Effect of extreme temperatures on asthma hospital visits: modification by event characteristics and healthy behaviors. Environ Res [Internet]. 2023 Jun 1;226:115679. Available from: http://dx.doi.org/10.1016/j.envres.2023.115679

91. Han A, Deng S, Yu J, Zhang Y, Jalaludin B, Huang C. Asthma triggered by extreme temperatures: from epidemiological evidence to biological plausibility. Environ Res [Internet]. 2023 Jan 1;216(Pt 2):114489. Available from: http://dx.doi.org/10.1016/j.envres.2022.114489

92. Quick M and Tjepkema M. The prevalence of household air conditioning in Canada. Health rep [Internet]. 2023 Jul 19;34(7). Available from: https://www150.statcan.gc.ca/n1/pub/82-003-x/2023007/article/00002-eng.htm

93. Deng L, Ma P, Wu Y, Ma Y, Yang X, Li Y, et al. High and low temperatures aggravate airway inflammation of asthma: evidence in a mouse model. Environ Pollut [Internet]. 2020 Jan;256:113433. Available from: http://dx.doi.org/10.1016/j.envpol.2019.113433

94. Alberta. Wheezing or bronchoconstriction: care instructions [Internet]. 2022 Nov 13 [2024 Mar 24]. Available from: https://myhealth.alberta.ca/Health/aftercareinformation/pages/conditions.aspx?hwid=bo1026

95. Sohail H, Kollanus V, Tiittanen P, Schneider A, Lanki T. Heat, Heatwaves and cardiorespiratory hospital admissions in Helsinki, Finland. Int J Environ Res Public Health [Internet]. 2020 Oct 28;17(21). Available from: http://dx.doi.org/10.3390/ijerph17217892

96. Chaseling GK, Iglesies-Grau J, Juneau M, Nigam A, Kaiser D, Gagnon D. Extreme heat and cardiovascular health: what a cardiovascular health professional should know. Can J Cardiol [Internet]. 2021 Nov 17;37(11):1828–36. Available from: http://dx.doi.org/10.1016/j.cjca.2021.08.008

97. Khatana SAM, Werner RM, Groeneveld PW. Association of extreme heat and cardiovascular mortality in the United States: a county-level longitudinal analysis from 2008 to 2017. Circulation [Internet]. 2022 Jul 21;146(3):249–61. Available from: http://dx.doi.org/10.1161/CIRCULATIONAHA.122.060746

98. Mohammadi D, Zare Zadeh M, Zare Sakhvidi MJ. Short-term exposure to extreme temperature and risk of hospital admission due to cardiovascular diseases. Int J Environ Health Res [Internet]. 2021 Sept 5;31(3):344–54. Available from: http://dx.doi.org/10.1080/09603123.2019.1663496

99. Cicci KR, Maltby A, Clemens KK, Vicedo-Cabrera AM, Gunz AC, Lavigne É, et al. High temperatures and cardiovascular-related morbidity: a scoping review. Int J Environ Res Public Health [Internet]. 2022 Sep 7;19(18). Available from: http://dx.doi.org/10.3390/ijerph191811243

100. Lin S, Luo M, Walker RJ, Liu X, Hwang SA, Chinery R. Extreme high temperatures and hospital admissions for respiratory and cardiovascular diseases. Epidemiology [Internet]. 2009 Sept;20(5):738–46. Available from: http://dx.doi.org/10.1097/EDE.0b013e3181ad5522

101. Liu J, Varghese BM, Hansen A, Zhang Y, Driscoll T, Morgan G, et al. Heat exposure and cardiovascular health outcomes: a systematic review and meta-analysis. Lancet Planet Health [Internet]. 2022 Jun;6(6):e484–95. Available from: http://dx.doi.org/10.1016/S2542-5196(22)00117-6

102. Gostimirovic M, Novakovic R, Rajkovic J, Djokic V, Terzic D, Putnik S, et al. The influence of climate change on human cardiovascular function. Arch Environ Occup Health [Internet]. 2020 Mar 23;75(7):406–14. Available from: http://dx.doi.org/10.1080/19338244.2020.1742079

103. Government of Canada. Communicating the health risks of extreme heat events [Internet]. 2020 [cited 2024 Mar 25]. Available from: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/climate-change-health/communicating-health-risks-extreme-heat-events-toolkit-public-health-emergency-management-officials-health-canada-2011.html

104. Shor E, Roelfs D. Climate shock: moving to colder climates and immigrant mortality. Soc Sci Med [Internet]. 2019 Aug;235:112397. Available from: https://pubmed.ncbi.nlm.nih.gov/31306882/

105. Government of Canada. Immigrants make up the largest share of the population in over 150 years and continue to shape who we are as Canadians [Internet]. 2022 Oct 26 [cited 2024 Mar 17]. Available from: https://www150.statcan.gc.ca/n1/daily-quotidien/221026/dq221026a-eng.htm

106. Alberta. Extreme heat [Internet]. [cited 2024 Mar 25]. Available from: https://www.alberta.ca/extreme-heat

107. Government of Canada. Keeping the heat in - section 2: how your house works [Internet]. 2023 [cited 2024 Mar 25]. Available from: https://natural-resources.canada.ca/energy-efficiency/homes/make-your-home-more-energy-efficient/keeping-the-heat/section-2-how-your-house-works/15630

108. Santamouris M. Chapter 3 – urban heat island and local climate change. In: Santamouris M, editor. Minimizing energy consumption, energy poverty and global and local climate change in the built environment: innovating to zero: causalities and impacts in a zero concept world [Internet]. Elsevier; 2019. p. 65-102. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9780128114179000039?via%3Dihub

109. Sebastian SA, Avanthika C, Jhaveri S, Carrera KG, Camacho L GP, Balasubramanian R. The risk of cardiovascular disease among immigrants in Canada. Cureus [Internet]. 2022 Feb 16;14(2):e22300. Available from: http://dx.doi.org/10.7759/cureus.22300

110. Tu JV, Chu A, Rezai MR, Guo H, Maclagan LC, Austin PC, et al. The incidence of major cardiovascular events in immigrants to Ontario, Canada: the CANHEART immigrant study. Circulation [Internet]. 2015 Aug 31;132(16):1549–59. Available from: http://dx.doi.org/10.1161/CIRCULATIONAHA.115.015345

111. Kenny GP, Yardley J, Brown C, Sigal RJ, Jay O. Heat stress in older individuals and patients with common chronic diseases. CMAJ [Internet]. 2010 Jul 13;182(10):1053–60. Available from: http://dx.doi.org/10.1503/cmaj.081050

112. Meade RD, Akerman AP, Notley SR, McGinn R, Poirier P, Gosselin P, et al. Physiological factors characterizing heat-vulnerable older adults: a narrative review. Environ Int [Internet]. 2020 Nov;144:105909. Available from: http://dx.doi.org/10.1016/j.envint.2020.105909

113. D'Amato M, Molino A, Calabrese G, Cecchi L, Annesi-Maesano I, D'Amato G. The impact of cold on the respiratory tract and its consequences to respiratory health. Clin Transl Allergy [Internet]. 2018 May 30;8(20). Available from: http://dx.doi.org/10.1186/s13601-018-0208-9

114. Chen Y, Kong D, Fu J, Zhang Y, Zhao Y, Liu Y, et al. Increased hospital admissions for asthma from short-term exposure to cold spells in Beijing, China. Int J Hyg Environ Health [Internet]. 2021 Sept;238:113839. Available from: http://dx.doi.org/10.1016/j.ijheh.2021.113839

115. Cong X, Xu X, Zhang Y, Wang Q, Xu L, Huo X. Temperature drop and the risk of asthma: a systematic review and meta-analysis. Environ Sci Pollut Res Int [Internet]. 2017 Aug 13;24:22535–46. Available from: http://dx.doi.org/10.1007/s11356-017-9914-4

116. Gautier C, Charpin D. Environmental triggers and avoidance in the management of asthma. J Asthma Allergy [Internet]. 2017 Mar 7;10:47–56. Available from: http://dx.doi.org/10.2147/JAA.S121276

117. Fitzgerald EF, Pantea C, Lin S. Cold spells and the risk of hospitalization for asthma: New York, USA 1991-2006. Lung [Internet]. 2014 Oct 11;192:947–54. Available from: http://dx.doi.org/10.1007/s00408-014-9645-y

118. Zhu L, Liao H, Hou B, Cheng L, Li H. The status of household heating in northern China: a field survey in towns and villages. Environ Sci Pollut Res Int [Internet]. 2020 Feb 27;27:16145–58. Available from: http://dx.doi.org/10.1007/s11356-020-08077-9

119. Muñoz-Fierro J, Bobadilla-Moreno A, Pérez-Fargallo A. Residential heating use profiles in central-southern Chile. In: Marín-Restrepo L, Pérez-Fargallo A, Piderit-Moreno MB, Trebilcock-Kelly M, Wegertseder-Martínez P, editors. Removing barriers to environmental comfort in the global south [Internet]. Cham: Springer International Publishing; 2023. p. 401–14. Available from: https://doi.org/10.1007/978-3-031-24208-3_28

120. Andújar-Espinosa R, Salinero-González L, Illán-Gómez F, Castilla-Martínez M, Hu-Yang C, Ruiz-López FJ. Effect of vitamin D supplementation on asthma control in patients with vitamin D deficiency: the ACVID randomised clinical trial. Thorax [Internet]. 2021 Nov 5;76:126–33. Available from: http://dx.doi.org/10.1136/thoraxjnl-2019-213936

121. Ogeyingbo OD, Ahmed R, Gyawali M, Venkatesan N, Bhandari R, Botleroo RA, et al. The relationship between vitamin D and asthma exacerbation. Cureus [Internet]. 2021 Aug 18;13(8):e17279. Available from: http://dx.doi.org/10.7759/cureus.17279

122. Schwalfenberg GK, Genuis SJ, Hiltz MN. Addressing vitamin D deficiency in Canada: a public health innovation whose time has come. Public Health [Internet]. 2010 Jun;124(6):350–9. Available from: http://dx.doi.org/10.1016/j.puhe.2010.03.003

123. Liu X, He Y, Tang C, Wei Q, Xu Z, Yi W, et al. Association between cold spells and childhood asthma in Hefei, an analysis based on different definitions and characteristics. Environ Res [Internet]. 2021 Apr;195:110738. Available from: http://dx.doi.org/10.1016/j.envres.2021.110738

124. Guo Y, Jiang F, Peng L, Zhang J, Geng F, Xu J, et al. The association between cold spells and pediatric outpatient visits for asthma in Shanghai, China. PLoS One [Internet]. 2012 Jul 25;7(7):e42232. Available from: http://dx.doi.org/10.1371/journal.pone.0042232

125. Yoo EH, Eum Y, Roberts JE, Gao Q, Chen K. Association between extreme temperatures and emergency room visits related to mental disorders: a multi-region time-series study in New York, USA. Sci Total Environ [Internet]. 2021 Oct 20;792:148246. Available from: http://dx.doi.org/10.1016/j.scitotenv.2021.148246

126. Lavigne E, Maltby A, Côté JN, Weinberger KR, Hebbern C, Vicedo-Cabrera AM, et al. The effect modification of extreme temperatures on mental and behavior disorders by environmental factors and individual-level characteristics in Canada. Environ Res [Internet]. 2023 Feb 15;219:114999. Available from: http://dx.doi.org/10.1016/j.envres.2022.114999

127. Wang X, Lavigne E, Ouellette-kuntz H, Chen BE. Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. J Affect Disord [Internet]. 2014 Feb;155:154–61. Available from: http://dx.doi.org/10.1016/j.jad.2013.10.042

128. Yoo EH, Eum Y, Gao Q, Chen K. Effect of extreme temperatures on daily emergency room visits for mental disorders. Environ Sci Pollut Res Int [Internet]. 2021 Mar 22;28:39243–56. Available from: http://dx.doi.org/10.1007/s11356-021-12887-w

129. Rony MKK, Alamgir HM. High temperatures on mental health: recognizing the association and the need for proactive strategies-a perspective. Health Sci Rep [Internet]. 2023 Dec 4;6(12):e1729. Available from: http://dx.doi.org/10.1002/hsr2.1729

130. Petrova NN, Khvostikova DA. Prevalence, structure, and risk factors for mental disorders in older people. Adv Gerontol [Internet]. 2021 Dec 9;11:409–15. Available from: https://doi.org/10.1134/S2079057021040093

131. Schuurmans J, van Balkom A. Late-life anxiety disorders: a review. Curr Psychiatry Rep [Internet]. 2011 May 3;13:267–73. Available from: http://dx.doi.org/10.1007/s11920-011-0204-4

132. Skoog I. Psychiatric disorders in the elderly. Can J Psychiatry [Internet]. 2011 Jul 1;56(7):387–97. Available from: http://dx.doi.org/10.1177/070674371105600702

133. Vachuska K. Cold weather isolation is worse in poor and non-white neighborhoods in the United States. Prev Med Rep [Internet]. 2023;38:102541. Available from: http://dx.doi.org/10.1016/j.pmedr.2023.102541

134. Clarke PJ, Yan T, Keusch F, Gallagher NA. The impact of weather on mobility and participation in older U.S. adults. Am J Public Health [Internet]. 2015 Jun 5;105(7):1489–94. Available from: http://dx.doi.org/10.2105/AJPH.2015.302582

135. Cheng J, Xu Z, Zhu R, Wang X, Jin L, Song J, et al. Impact of diurnal temperature range on human health: a systematic review. Int J Biometeorol [Internet]. 2014 Feb 18;58:2011–24. Available from: http://dx.doi.org/10.1007/s00484-014-0797-5

136. Zhao D, Zhang X, Xie M, Cheng J, Zhang H, Wang S, et al. Is greater temperature change within a day associated with increased emergency admissions for schizophrenia? Sci Total Environ [Internet]. 2016 Oct 1;566–567:1545–51. Available from: http://dx.doi.org/10.1016/j.scitotenv.2016.06.045

137. Cabieses B, Uphoff E, Pinart M, Antó JM, Wright J. A systematic review on the development of asthma and allergic diseases in relation to international immigration: the leading role of the environment confirmed. PLoS One [Internet]. 2014 Aug 20;9(8):e105347. Available from: http://dx.doi.org/10.1371/journal.pone.0105347

138. Tham EH, Loo EXL, Zhu Y, Shek LPC. Effects of migration on allergic diseases. Int Arch Allergy Immunol [Internet]. 2019;178(2):128–40. Available from: http://dx.doi.org/10.1159/000494129

139. Iqbal S, Oraka E, Chew GL, Flanders WD. Association between birthplace and current asthma: the role of environment and acculturation. Am J Public Health [Internet]. 2014 Feb;104(Suppl 1):S175-82. Available from: http://dx.doi.org/10.2105/AJPH.2013.301509

140. Tilstra MH, Nielsen CC, Tiwari I, Jones CA, Vargas AO, Quemerais B, et al. Exploring socio-environmental effects on community health in Edmonton, Canada to understand older adult and immigrant risk in a changing climate. Urban Climate [Internet]. 2022 Jul;44:101225. Available from: http://www.sciencedirect.com/science/article/pii/S2212095522001432

141. Gadermann AM, Gagné Petteni M, Janus M, Puyat JH, Guhn M, Georgiades K. Prevalence of mental health disorders among immigrant, refugee, and nonimmigrant children and youth in British Columbia, Canada. JAMA Netw Open [Internet]. 2022 Feb 15;5(2):e2144934. Available from: http://dx.doi.org/10.1001/jamanetworkopen.2021.44934

142. Nwoke CN, Okpalauwaekwe U, Bwala H. Mental health professional consultations and the prevalence of mood and anxiety disorders among immigrants: multilevel analysis of the Canadian community health survey. JMIR Ment Health [Internet]. 2020 Sep 16;7(9):e19168. Available from: http://dx.doi.org/10.2196/19168

143. Alegría M, Álvarez K, DiMarzio K. Immigration and mental health. Curr Epidemiol Rep [Internet]. 2017 Apr 22;4:145–55. Available from: http://dx.doi.org/10.1007/s40471-017-0111-2

144. Breslau J, Borges G, Hagar Y, Tancredi D, Gilman S. Immigration to the USA and risk for mood and anxiety disorders: variation by origin and age at immigration. Psychol Med [Internet]. 2009 Jul;39(7):1117–27. Available from: https://pubmed.ncbi.nlm.nih.gov/19000338/

145. Hameed S, Sadiq A, Din AU. The increased vulnerability of refugee population to mental health disorders. Kans J Med [Internet]. 2018 Feb 28;11(1):1–12. Available from: https://www.ncbi.nlm.nih.gov/pubmed/29844851

146. Salami B, Salma J, Hegadoren K. Access and utilization of mental health services for immigrants and refugees: perspectives of immigrant service providers. Int J Ment Health Nurs [Internet]. 2019 Feb;28(1):152–61. Available from: http://dx.doi.org/10.1111/inm.12512

147. Yao J, Eyamie J, Henderson SB. Evaluation of a spatially resolved forest fire smoke model for population-based epidemiologic exposure assessment. J Expo Sci Environ Epidemiol [Internet]. 2014 Oct 8;26:233–40. Available from: http://dx.doi.org/10.1038/jes.2014.67

148. Mahsin MD, Cabaj J, Saini V. Respiratory and cardiovascular condition-related physician visits associated with wildfire smoke exposure in Calgary, Canada, in 2015: a population-based study. Int J Epidemiol [Internet]. 2022 Feb;51(1):166–78. Available from: http://dx.doi.org/10.1093/ije/dyab206

149. Gan RW, Liu J, Ford B, O'Dell K, Vaidyanathan A, Wilson A, et al. The association between wildfire smoke exposure and asthma-specific medical care utilization in Oregon during the 2013 wildfire season. J Expo Sci Environ Epidemiol [Internet]. 2020 Feb 12;30:618–28. Available from: http://dx.doi.org/10.1038/s41370-020-0210-x

150. Martin KL, Hanigan IC, Morgan GG, Henderson SB, Johnston FH. Air pollution from bushfires and their association with hospital admissions in Sydney, Newcastle and Wollongong, Australia 1994-2007. Aust N Z J Public Health [Internet]. 2013 Jun;37(3):238–43. Available from: http://dx.doi.org/10.1111/1753-6405.12065

151. Delfino RJ, Brummel S, Wu J, Stern H, Ostro B, Lipsett M, et al. The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003. Occup Environ Med [Internet]. 2008 Nov 18;66(3):189–97. Available from: http://dx.doi.org/10.1136/oem.2008.041376

152. Kondo MC, De Roos AJ, White LS, Heilman WE, Mockrin MH, Gross-Davis CA, et al. Meta-analysis of heterogeneity in the effects of wildfire smoke exposure on respiratory health in North America. Int J Environ Res Public Health [Internet]. 2019 Mar 18;16(6):960. Available from: http://dx.doi.org/10.3390/ijerph16060960

153. Noah TL, Worden CP, Rebuli ME, Jaspers I. The effects of wildfire smoke on asthma and allergy. Curr Allergy Asthma Rep [Internet]. 2023 May 12;23:375–87. Available from: http://dx.doi.org/10.1007/s11882-023-01090-1

154. Adetona O, Hall DB, Naeher LP. Lung function changes in wildland firefighters working at prescribed burns. Inhal Toxicol [Internet]. 2011;23(13):835–41. Available from: http://dx.doi.org/10.3109/08958378.2011.617790

155. Niu Y, Zhou Y, Chen R, Yin P, Meng X, Wang W, et al. Long-term exposure to ozone and cardiovascular mortality in China: a nationwide cohort study. Lancet Planet Health [Internet]. 2022 Jun;6(6):e496–503. Available from: http://dx.doi.org/10.1016/S2542-5196(22)00093-6

156. Jiang Y, Huang J, Li G, Wang W, Wang K, Wang J, et al. Ozone pollution and hospital admissions for cardiovascular events. Eur Heart J [Internet]. 2023 May 7;44(18):1622–32. Available from: http://dx.doi.org/10.1093/eurheartj/ehad091

157. Devlin RB, Duncan KE, Jardim M, Schmitt MT, Rappold AG, Diaz-Sanchez D. Controlled exposure of healthy young volunteers to ozone causes cardiovascular effects. Circulation [Internet]. 2012 Jul 3;126(1):104–11. Available from: http://dx.doi.org/10.1161/CIRCULATIONAHA.112.094359

158. Gong H Jr, Wong R, Sarma RJ, Linn WS, Sullivan ED, Shamoo DA, et al. Cardiovascular effects of ozone exposure in human volunteers. Am J Respir Crit Care Med [Internet]. 1998 Aug;158(2):538–46. Available from: http://dx.doi.org/10.1164/ajrccm.158.2.9709034

159. Jin T, Di Q, Réquia WJ, Danesh Yazdi M, Castro E, Ma T, et al. Associations between long-term air pollution exposure and the incidence of cardiovascular diseases among American older adults. Environ Int [Internet]. 2022 Dec;170:107594. Available from: http://dx.doi.org/10.1016/j.envint.2022.107594

160. Koken PJM, Piver WT, Ye F, Elixhauser A, Olsen LM, Portier CJ. Temperature, air pollution, and hospitalization for cardiovascular diseases among elderly people in Denver. Environ Health Perspect [Internet]. 2003 Aug 1;111(10):1312–7. Available from: https://ehp.niehs.nih.gov/doi/abs/10.1289/ehp.5957

161. Mirowsky JE, Carraway MS, Dhingra R, Tong H, Neas L, Diaz-Sanchez D, et al. Ozone exposure is associated with acute changes in inflammation, fibrinolysis, and endothelial cell function in coronary artery disease patients. Environ Health [Internet]. 2017 Nov 21;16(126). Available from: http://dx.doi.org/10.1186/s12940-017-0335-0

162. Day DB, Xiang J, Mo J, Li F, Chung M, Gong J, et al. Association of ozone exposure with cardiorespiratory pathophysiologic mechanisms in healthy adults. JAMA Intern Med [Internet]. 2017 Sept 1;177(9):1344–53. Available from: http://dx.doi.org/10.1001/jamainternmed.2017.2842

163. Government of Canada. International comparison of urban air quality [Internet]. 2016 Dec 21 [cited 2024 Apr 29]. Available from: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/international-comparison-urban-air-quality.html

164. Kerr J, Marshall S, Godbole S, Neukam S, Crist K, Wasilenko K, et al. The relationship between outdoor activity and health in older adults using GPS. Int J Environ Res Public Health [Internet]. 2012 Dec 10;9(12):4615–25. Available from: http://dx.doi.org/10.3390/ijerph9124615

165. Mar TF, Koenig JQ. Relationship between visits to emergency departments for asthma and ozone exposure in greater Seattle, Washington. Ann Allergy Asthma Immunol [Internet]. 2009 Dec;103(6):474–9. Available from: http://dx.doi.org/10.1016/S1081-1206(10)60263-3

166. Stieb DM, Szyszkowicz M, Rowe BH, Leech JA. Air pollution and emergency department visits for cardiac and respiratory conditions: a multi-city time-series analysis. Environ Health [Internet]. 2009 Jun 10;8(25). Available from: http://dx.doi.org/10.1186/1476-069X-8-25

167. Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987-2000. JAMA [Internet]. 2004 Nov 17;292(19):2372–8. Available from: http://dx.doi.org/10.1001/jama.292.19.2372

168. Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J, et al. Acute effects of ozone on mortality from the “air pollution and health: a European approach” project. Am J Respir Crit Care Med [Internet]. 2004 Nov 15;170(10):1080–7. Available from: http://dx.doi.org/10.1164/rccm.200403-333OC

169. Lee S, Lee M. Low-to-moderate atmospheric ozone levels are negatively correlated with hospital visits by asthma patients. Medicine [Internet]. 2022 Nov 11;101(45):e31737. Available from: http://dx.doi.org/10.1097/MD.0000000000031737

170. Gryech I, Ghogho M, Mahraoui C, Kobbane A. An Exploration of features impacting respiratory diseases in urban areas. Int J Environ Res Public Health [Internet]. 2022 Mar 6;19(5):3095. Available from: http://dx.doi.org/10.3390/ijerph19053095

171. Mumby S, Chung KF, Adcock IM. Transcriptional effects of ozone and impact on airway inflammation. Front Immunol [Internet]. 2019 Jul 10;10(1610). Available from: http://dx.doi.org/10.3389/fimmu.2019.01610

172. Seltzer J, Bigby BG, Stulbarg M, Holtzman MJ, Nadel JA, Ueki IF, et al. O3-induced change in bronchial reactivity to methacholine and airway inflammation in humans. J Appl Physiol [Internet]. 1986 Apr 1;60(4):1321–6. Available from: http://dx.doi.org/10.1152/jappl.1986.60.4.1321

173. Mudway IS, Kelly FJ. Ozone and the lung: a sensitive issue. Mol Aspects Med [Internet]. 2000;21(1–2):1–48. Available from: http://dx.doi.org/10.1016/s0098-2997(00)00003-0

174. Arjomandi M, Tager IB, Bastaki M, Chen C, Holland N, Balmes JR. Is there an association between lifetime cumulative exposure and acute pulmonary responses to ozone? J Occup Environ Med [Internet]. 2008 Mar;50(3):341–9. Available from: http://dx.doi.org/10.1097/JOM.0b013e318162f5eb

175. Wang M, Aaron CP, Madrigano J, Hoffman EA, Angelini E, Yang J, et al. Association between long-term exposure to ambient air pollution and change in quantitatively assessed emphysema and lung function. JAMA [Internet]. 2019 Aug 13;322(6):546–56. Available from: http://dx.doi.org/10.1001/jama.2019.10255

176. Pun VC, Manjourides J, Suh H. Association of ambient air pollution with depressive and anxiety symptoms in older adults: results from the NSHAP study. Environ Health Perspect [Internet]. 2017 Mar;125(3):342–8. Available from: https://ehp.niehs.nih.gov/doi/full/10.1289/EHP494

177. Nobile F, Forastiere A, Michelozzi P, Forastiere F, Stafoggia M. Long-term exposure to air pollution and incidence of mental disorders. a large longitudinal cohort study of adults within an urban area. Environ Int [Internet]. 2023 Nov;181:108302. Available from: http://dx.doi.org/10.1016/j.envint.2023.108302

178. Zhou Y, Liu J. Air pollution and mental health of older adults in China. Sustain Sci Pract Policy [Internet]. 2020 Jan 28;12(3):950. Available from: https://www.mdpi.com/2071-1050/12/3/950

179. Power MC, Kioumourtzoglou MA, Hart JE, Okereke OI, Laden F, Weisskopf MG. The relation between past exposure to fine particulate air pollution and prevalent anxiety: observational cohort study. BMJ [Internet]. 2015 Mar 24;350:h1111. Available from: http://dx.doi.org/10.1136/bmj.h1111

180. Mehta AJ, Kubzansky LD, Coull BA, Kloog I, Koutrakis P, Sparrow D, et al. Associations between air pollution and perceived stress: the Veterans administration normative aging study. Environ Health [Internet]. 2015 Jan 27;14(10). Available from: http://dx.doi.org/10.1186/1476-069X-14-10

181. Zundel CG, Ryan P, Brokamp C, Heeter A, Huang Y, Strawn JR, et al. Air pollution, depressive and anxiety disorders, and brain effects: a systematic review. Neurotoxicology [Internet]. 2022 Dec;93:272–300. Available from: http://dx.doi.org/10.1016/j.neuro.2022.10.011

182. Wang Y, Eliot MN, Koutrakis P, Gryparis A, Schwartz JD, Coull BA, et al. Ambient air pollution and depressive symptoms in older adults: results from the MOBILIZE Boston study. Environ Health

Perspect [Internet]. 2014 Jun;122(6):553–8. Available from: https://ehp.niehs.nih.gov/doi/10.1289/ehp.1205909

183. Dores AK, Fick GH, MacMaster FP, Williams JVA, Bulloch AGM, Patten SB. Outdoor air pollution and depression in Canada: a population-based cross-sectional study from 2011 to 2016. Int J Environ Res Public Health [Internet]. 2021 Mar 2;18(5):2450. Available from: http://dx.doi.org/10.3390/ijerph18052450

184. Szyszkowicz M, Zemek R, Colman I, Gardner W, Kousha T, Smith-Doiron M. Air pollution and emergency department visits for mental disorders among youth. Int J Environ Res Public Health [Internet]. 2020 Jun 12;17(12):4190. Available from: http://dx.doi.org/10.3390/ijerph17124190

185. Roberts S, Arseneault L, Barratt B, Beevers S, Danese A, Odgers CL, et al. Exploration of NO2 and PM2.5 air pollution and mental health problems using high-resolution data in London-based children from a UK longitudinal cohort study. Psychiatry Res [Internet]. 2019 Feb;272:8–17. Available from: http://dx.doi.org/10.1016/j.psychres.2018.12.050

186. Roche IV, Ubalde-Lopez M, Daher C, Nieuwenhuijsen M, Gascon M. The health-related and learning performance effects of air pollution and other urban-related environmental factors on school-age children and adolescents-a scoping review of systematic reviews. Curr Environ Health Rep [Internet]. 2024 Feb 19;11:300-16. Available from: http://dx.doi.org/10.1007/s40572-024-00431-0

187. Hickman C, Marks E, Pihkala P, Clayton S, Lewandowski RE, Mayall EE, et al. Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. Lancet Planet Health [Internet]. 2021 Dec;5(12):e863–73. Available from: http://dx.doi.org/10.1016/S2542-5196(21)00278-3

188. Zhang Y, Mavoa S, Zhao J, Raphael D, Smith M. The association between green space and adolescents' mental well-being: a systematic review. Int J Environ Res Public Health [Internet]. 2020 Sept 11;17(18):6640. Available from: http://dx.doi.org/10.3390/ijerph17186640

189. Crouse DL, Pinault L, Christidis T, Lavigne E, Thomson EM, Villeneuve PJ. Residential greenness and indicators of stress and mental well-being in a Canadian national-level survey. Environ Res [Internet]. 2021 Jan;192:110267. Available from: http://dx.doi.org/10.1016/j.envres.2020.110267

190. van den Berg AE, Maas J, Verheij RA, Groenewegen PP. Green space as a buffer between stressful life events and health. Soc Sci Med [Internet]. 2010 Apr;70(8):1203–10. Available from: http://dx.doi.org/10.1016/j.socscimed.2010.01.002

191. Li D, Deal B, Zhou X, Slavenas M, Sullivan WC. Moving beyond the neighborhood: daily exposure to nature and adolescents' mood. Landsc Urban Plan [Internet]. 2018 May;173:33–43. Available from: https://www.sciencedirect.com/science/article/pii/S0169204618300318

192. Chen Y, Ke X, Min M, Zhang Y, Dai Y, Tang L. Do we need more urban green space to alleviate PM2.5 pollution? a case study in Wuhan, China. Land [Internet]. 2022 May 25;11(6):776. Available from: https://www.mdpi.com/2073-445X/11/6/776

193. Robert AM, Gilkinson T. Mental health and well-being of recent immigrants in Canada: evidence from the longitudinal survey of immigrants to Canada [Internet]. Citizenship and Immigration Canada; 2012 Nov. Available from: https://www.canada.ca/content/dam/ircc/migration/ircc/english/pdf/research-stats/mental-health.pdf

194. Zhang YL, Cao F. Fine particulate matter (PM 2.5) in China at a city level. Sci Rep [Internet]. 2015 Oct 15;5(14884). Available from: http://dx.doi.org/10.1038/srep14884

195. Government of Canada. Gender-based analysis plus [Internet]. 2023 [cited 2024 Jul 2]. Available from: https://www.canada.ca/en/immigration-refugees-citizenship/corporate/publications-manuals/departmental-performance-reports/2023/gender-based-analysis-plus.html

196. Yilma M, Regassa N. Gender differentials in internal migration decisions: the case of Dilla Town, Southern Ethiopia. Kontakt [Internet]. 2019 Sep 18;21(3):312–9. Available from: http://dx.doi.org/10.32725/kont.2019.026

197. Radhakrishnan D, Guttmann A, To T, Reisman JJ, Knight BD, Mojaverian N, et al. Generational patterns of asthma incidence among immigrants to Canada over two decades. a population-based cohort study. Ann Am Thorac Soc [Internet]. 2019 Feb;16(2):248–57. Available from: http://dx.doi.org/10.1513/AnnalsATS.201803-187OC

198. Siddiqi A, Ornelas IJ, Quinn K, Zuberi D, Nguyen QC. Societal context and the production of immigrant status-based health inequalities: a comparative study of the United States and Canada. J Public Health Policy [Internet]. 2013 Feb 28;34(2):330–44. Available from: http://dx.doi.org/10.1057/jphp.2013.7

199. Newbold KB. Chronic conditions and the healthy immigrant effect: evidence from Canadian immigrants. J Ethn Migr Stud [Internet]. 2006 Jul;32(5):765–84. Available from: https://doi.org/10.1080/13691830600704149

200. Philipneri A, Hanna S, Mandhane PJ, Georgiades K. Association of immigrant generational status with asthma. Can J Public Health [Internet]. 2019 Apr 8;110:462–71. Available from: http://dx.doi.org/10.17269/s41997-019-00201-8

201. Sohail QZ, Chu A, Rezai MR, Donovan LR, Ko DT, Tu JV. The risk of ischemic heart disease and stroke among immigrant populations: a systematic review. Can J Cardiol [Internet]. 2015 Sept;31(9):1160–8. Available from: http://dx.doi.org/10.1016/j.cjca.2015.04.027

202. Chiu M, Austin PC, Manuel DG, Tu JV. Cardiovascular risk factor profiles of recent immigrants vs long-term residents of Ontario: a multi-ethnic study. Can J Cardiol [Internet]. 2012 Jan-Feb;28(1):20–6. Available from: http://dx.doi.org/10.1016/j.cjca.2011.06.002

203. Omariba DWR. Immigration, ethnicity, and avoidable mortality in Canada, 1991-2006. Ethn Health [Internet]. 2015 Jan 8;20(4):409–36. Available from: http://dx.doi.org/10.1080/13557858.2014.995155

204. Saposnik G, Redelmeier DA, Lu H, Fuller-Thomson E, Lonn E, Ray JG. Myocardial infarction associated with recency of immigration to Ontario. QJM [Internet]. 2010 Apr;103(4):253–8. Available from: http://dx.doi.org/10.1093/qjmed/hcq006

205. Ali J. Mental health of Canada's immigrants. Health Rep [Internet]. 2002 Jul 4;13. Available from: https://www150.statcan.gc.ca/n1/en/pub/82-003-s/2002001/pdf/82-003-s2002006-eng.pdf?st=czXoq5gx

206. Wu Z, Schimmele CM. The Healthy migrant effect on depression: variation over time? CSP [Internet]. 2005;32(2):271–95. Available from: https://journals.library.ualberta.ca/csp/index.php/csp/article/view/15950

207. Elshahat S, Moffat T, Newbold KB. Understanding the healthy immigrant effect in the context of mental health challenges: a systematic critical review. J Immigr Minor Health [Internet]. 2022 Nov 22;24:1564–79. Available from: http://dx.doi.org/10.1007/s10903-021-01313-5

208. Wang L, Kwak MJ. Immigration, barriers to healthcare and transnational ties: A case study of South Korean immigrants in Toronto, Canada. Soc Sci Med [Internet]. 2015 May;133:340–8. Available from: http://dx.doi.org/10.1016/j.socscimed.2014.11.039

209. Villa-Torres L, González-Vázquez T, Fleming PJ, González-González EL, Infante-Xibille C, Chavez R, et al. Transnationalism and health: A systematic literature review on the use of transnationalism in the study of the health practices and behaviors of migrants. Soc Sci Med [Internet]. 2017 Jun;183:70–9. Available from: http://dx.doi.org/10.1016/j.socscimed.2017.04.048

Chapter 4: Conclusions

Climate change and air pollution are global issues that can directly or indirectly impact human health [1]. The health effects of climate change and air pollution in Canada have been observed in terms of changes in temperature, wildfires, and air quality [2,3]. In Alberta, one of the top oil-producing provinces in Canada, less research in this area has been conducted. Certain populations, such as immigrants and refugees, may experience different health risks from these exposures compared to non-immigrants due to unique factors such as social and cultural changes [4,5]. Despite this, immigrants and refugees are a commonly excluded population from climate change and health studies [6]. Similarly, adolescents and older adults also may experience higher health risks as a result of behavioural and physiological differences compared to the general population [7–9]. This research focused on exploring the understudied health-related impacts of climate change and air pollution exposures in immigrant (economic, sponsored by family and refugees; all ages), total (immigrants and non-immigrants; all ages), adolescent (total population; ages 12 to 17) and older adult (total population; ages 65 plus) populations in Alberta.

1. Summary of Thesis Findings

A scoping review was completed (Chapter 2) to synthesize evidence on the health-related impacts of climate change (e.g. extreme temperatures and floods) and air pollution (e.g., NO_2, O_3, and $PM_{2.5}$) exposures on immigrant and refugee populations (<18 and 65+), and to determine if these impacts are influenced by age, immigrant category, gender, and/or geographical location. Very few articles focusing on this topic were found (n=3). Only excessive temperatures with mortality and respiratory syncytial virus outcomes were examined in these populations [10–12]. Two of the studies focused on older adults and found that foreign-born and non-US citizens 65 years and older were similarly or less susceptible compared to native-born, but that younger individuals were more susceptible [10,11]. The other study focused on refugee children younger than five and found that higher temperatures were associated with higher respiratory syncytial virus incidence [12]. No articles analyzed the health-related impacts of air pollutants (e.g., NO_2, O_3, and $PM_{2.5}$). Additionally, limited stratified results were presented. One article stratified the population by age and birth region, and another stratified by age, sex, race and ethnicity [10,11]. This emphasized a critical gap in terms of immigrant and refugee-focused climate change and health research, particularly in children, adolescents, and older adults. A recommendation to emerge from this review is the need to investigate a broader set of exposures and outcomes and present stratified results by key factors such as age, sex, birth region, race, ethnicity, immigrant category, and geographical location.

Chapter 3 aimed to start addressing the gaps identified in the scoping review. A cross-sectional study that analyzed the health impacts of weather and air pollution exposures on immigrant (economic, sponsored by family and refugees; all ages), total (immigrants and non-immigrants; all ages), adolescent (total population; ages 12 to 17) and older adult (total population; ages 65 plus) populations in Alberta was completed. Canada's temperature has been and is continuing to rise, with a 1.7°C increase since 1948 [3]. Alberta's summer temperature has risen each decade from 1950 to 2013 by 0.1 to 0.3°C and It is predicted that Alberta will continue to experience a higher number of warm and hot days, and fewer cold days [14–18]. This study found that weather and air pollution exposures were associated with health impacts in Alberta. High temperature (quartile) was associated with increased odds of self-reported asthma for the total (immigrant and non-immigrant) population. Results also indicated that immigrants are differentially impacted by high temperature exposures. High temperature was associated with increased odds of a self-reported cardiovascular outcome in the immigrant population, but decreased odds in the total population in this study. It was also found that older immigrants had increased odds of a self-reported cardiovascular outcome with high temperature exposure compared to older non-immigrants. Most of these results are consistent with previous studies, which found that high temperatures were associated with asthma and cardiovascular outcomes [19,20]. The majority of immigrants overall who come to Canada are from a tropical climate, and previous studies have found migration from a hot to cold climate is associated with a higher relative risk of cardiovascular mortality compared to non-immigrant populations [21,22]. Variations and differences in some of our results may also have been affected by our inability to stratify by country of birth and immigrant status due smaller sample sizes.

Comparatively, low temperature was associated with a decreased odds of self-reported asthma for the total and adolescent population. Low temperatures have been found to exacerbate asthma in previous studies [23,24]. For the total population, low temperature was associated with decreased odds of a self-reported mental disorder for those classified as having high exposure. For older adults low temperature was associated with increased odds of a self-reported mental disorder for those classified as having low exposure. Conversely, lower daily minimum temperature and greater diurnal temperature range exposures among older adults and the total population were associated with decreased odds of a self-reported mental disorder. Immigrants also had decreased odds of a self-reported mental disorder with exposure to greater diurnal temperature ranges. Previous studies on low temperature and mental disorders are not conclusive, but the results found here suggest a greater impact on older adults compared to the total population. Generally, older adults have a higher risk of health outcomes with exposure to extreme temperatures, both high and low [25]. The high and low temperature findings in this study may be impacted by the fact that the amount of time individuals spent outdoors was unknown, and that many studies have different definitions for extreme temperature exposures.

Several associations between air pollutants and different health outcomes were found. Adolescents and immigrants were found to have increased odds of a self-reported mental disorder with $PM_{2.5}$ exposure, while older adults had decreased odds. For adolescents, these results are consistent with previous studies. It has been found that $PM_{2.5}$ exposure is associated with a higher risk of mental disorder emergency department visits [26,27]. Gadermann et al. found that immigrants actually had a lower prevalence of mood and anxiety disorders compared to non-immigrants in their study [28–32]. Prior studies also report that immigrants are more likely to consult a psychiatrist, so while they may have a lower prevalence of mental disorders, symptom severity among those that report these conditions may be worse than non-immigrants. Comparatively, for older adults, our results are not consistent with previous studies. Prior research has found that $PM_{2.5}$ exposure is associated with depression and anxiety symptoms and non-specific perceived stress in older adults, which can lead to psychiatric disorders [33–35].

Exposure to O_3 was found to have decreased odds of a self-reported cardiovascular outcome among the total and older adult populations, which is inconsistent with other findings [36–38]. In this study, these results may be impacted by the fact that older adults may spend less time outdoors and have lower O_3 exposure. Comparatively those of working age must be outdoors often to commute and work. Consistently, the total population was also found to have decreased odds of self-reported asthma with wildfire smoke exposure. Wildfire smoke has been found to be associated with increased risk of asthma morbidity and hospital admissions [39].

More generally, it was found that health outcomes differed across populations (immigrants vs. non-immigrants). Immigrants were found to have decreased odds of asthma, cardiovascular outcomes and mental disorders compared to non-immigrants. It was also found that the length of residence in Canada had an impact on outcomes among immigrants. Long-term immigrants (10 plus years in Canada) were found to have higher odds of self-reported asthma and cardiovascular outcomes compared to recent immigrants (less than 10 years in Canada). Asthma and cardiovascular outcomes results align with the healthy immigrant effect, where after immigrants arrive in Canada, their rates of disease converge with that of the general population over time [26,27,40–45]. For mental disorders, immigrants were found to have decreased odds with increased years residing in Canada. These results are consistent with other studies, which have found that immigrants had a lower prevalence of mood and anxiety disorders compared to non-immigrants [8]. This could be a result of immigrants becoming settled and being able to access to healthcare.

2. Gaps in the Literature and Contributions

Results from Chapter 3 were generally consistent with previous findings on the health impacts of climate change and air pollution exposures. Limited research has been done on immigrants and

adolescents regarding the health impacts of weather and air pollution exposures (particularly low temperature impact on mental disorders), which this study aimed to explore. While initially Chapter 3 intended to address certain knowledge gaps identified in the Chapter 2 scoping review (stratification of immigrants by age, immigrant category, gender and geographical location), data limitations allowed us to address only some of these gaps. It was found that Alberta immigrant-specific health data is limited, particularly at the provincial level.

Building on the gaps identified in the scoping review, we undertook a study to explore the health impacts of weather and air pollution specifically in immigrant, older adult, and adolescent populations. No Canadian studies were identified in the scoping review. Very few focused on immigrant health in older adults and adolescents. No studies were found that focused on air pollution exposures. In this study, we explored associations with several air pollutants (NO_2, O_3 and $PM_{2.5}$), and found a positive association with $PM_{2.5}$ and mental disorders among adolescents in the total population (immigrants and non-immigrants). While we were not able to specifically report findings related to adolescent immigrants, they were included in the total adolescent population. While children are at risk for various outcomes, adolescents are an important age group to consider due to differences in terms of immune system maturity and anatomy, as compared to adults [46]. Positive associations with other outcomes were also found: high temperature was associated with self-reported asthma among the total population and self-reported cardiovascular outcomes among immigrants and low temperature was associated with mental disorders among all older adults. Differences between immigrants and non-immigrants in terms of the prevalence of health outcomes were also noted, specifically length of residence in Canada. While data limitations restricted further immigrant-specific analyses, these findings contribute to this understudied topic in Canada and globally.

3. Recommendations and Next Steps

Climate change and air pollution exposures are impacting health. Canada is expected to continue to warm, which can lead to changes in the frequency and intensity of weather extremes [3]. Parts of Canada also experience poor air quality, including Alberta, home to the Athabasca oil sands, which is responsible for the release of several pollutants of concern for health [46]. Geographical regions experience these impacts differently and amplify various factors that can impact risk (e.g. healthcare access). This makes it important for researchers to consider effects across different geographical areas. More specifically, exposures and health impacts vary across Canada, which need to be considered in current and future research. Future studies comparing immigrant population risks across the Canadian Prairie provinces (Alberta, Saskatchewan and Manitoba) could be conducted.

Certain populations, such as immigrants, may experience different risks from climate change and air pollution exposures compared to non-immigrants, though little research has focused on this population to date. With immigration to Canada expected to increase, this is an important knowledge gap. This is particularly important for adolescent and older adult immigrants, who have additional factors that that may compound risks. Further research on immigrants stratified by age, sex, world area of birth and immigration category is needed to fully understand and compare risks. Given a sufficient sample size, stratification by various characteristics could be explored. This could also allow a multi-level analysis to be completed, which would account for cluster variations. Additionally, a longer time frame could be examined. While the CCHS and IMDB can only be linked up to 2014, years before 2009 up to 2014 could be examined.

4. Conclusion

The goal of this work was to contribute to the limited research on the impact of climate change and air pollution exposures on immigrants. Research on immigrants, specifically adolescents and older adults within Canada, is particularly limited. We found that certain key exposures are associated with health risks among immigrant, total, adolescent and older adult populations in Alberta, emphasizing the need for further research in this area. Further research is also needed to more fully explore these impacts temporally and spatially.

References

1. Orru H, Ebi KL, Forsberg B. The interplay of climate change and air pollution on health. Curr Environ Health Rep [Internet]. 2017 Dec;4:504–13. Available from: http://dx.doi.org/10.1007/s40572-017-0168-6

2. Government of Canada. Canada's air quality [Internet]. 2023 [cited 2024 Mar 27]. Available from: https://www.canada.ca/en/environment-climate-change/campaigns/canadian-environment-week/clean-air-day/air-quality.html

3. Zhang X, Flato G, Kirchmeier-Young M, Vincent L, Wan H, Wang X, et al. Temperature and precipitation across Canada. In: Lemmen DS, Bush E, editors. Canada's changing climate report [Internet]. Ottawa, ON: Government of Canada; 2019. p. 112–93. Available from: https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf

4. Preston BL, Yuen EJ, Westaway RM. Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. Sustainability Sci [Internet]. 2011 Mar 24;6:177–202. Available from: https://link.springer.com/article/10.1007/s11625-011-0129-1

5. Beiser M. The health of immigrants and refugees in Canada. Can J Public Health [Internet]. 2005 Mar-Apr;96 Suppl 2:S30-44. Available from: https://pubmed.ncbi.nlm.nih.gov/16078554/

6. Erickson AC, Christidis T, Pappin A, Brook JR, Crouse DL, Hystad P, et al. Disease assimilation: the mortality impacts of fine particulate matter on immigrants to Canada. Health Rep [Internet]. 2020 Jun 17;31(3):14-26. Available from: https://www.ncbi.nlm.nih.gov/pubmed/32644760

7. Carnes BA, Staats D, Willcox BJ. Impact of climate change on elder health. J Gerontol A Biol Sci Med Sci [Internet]. 2014 Sep;69(9):1087–91. Available from: http://dx.doi.org/10.1093/gerona/glt159

8. Stanberry LR, Thomson MC, James W. Prioritizing the needs of children in a changing climate. PLoS Med [Internet]. 2018 Jul 31;15(7):e1002627. Available from: http://dx.doi.org/10.1371/journal.pmed.1002627

9. Yu W, Weitzman M. Climate change, air pollution, and children's mental health. J Appl Res Child [Internet]. 2021;12(1). Available from: https://digitalcommons.library.tmc.edu/childrenatrisk/vol12/iss1/13/

10. Taylor EV, Vaidyanathan A, Flanders WD, Murphy M, Spencer M, Noe RS. Differences in heat-related mortality by citizenship status: United States, 2005–2014. Am J Public Health [Internet]. 2018 Apr;108(S2):S131–6. Available from: https://pubmed.ncbi.nlm.nih.gov/29072944/

11. Mercereau L, Todd N, Rey G, Valleron AJ. Comparison of the temperature-mortality relationship in foreign born and native born died in France between 2000 and 2009. Int J Biometeorol [Internet]. 2017 Oct;61(10):1873–84. Available from: https://pubmed.ncbi.nlm.nih.gov/28540492/

12. Nyoka R, Omony J, Mwalili SM, Achia TNO, Gichangi A, Mwambi H. Effect of climate on incidence of respiratory syncytial virus infections in a refugee camp in Kenya: A non-gaussian time-series analysis. PLoS One [Internet]. 2017 Jun 1;12(6):e0178323. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0178323

13. Hayhoe K, Stoner A. Alberta's climate future: final report [Internet]. ATMOS Research & Consulting; 2019. Available from: https://open.alberta.ca/dataset/89a69583-a11b-4e31-a857-b311ab6563cc/resource/17ce2d24-ba7b-466c-acd9-33a2cf6beb69/download/aep-alberta-climate-report-arc.pdf

14. Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. Environ Health [Internet]. 2016 Apr 27;15:57. Available from: https://ehjournal.biomedcentral.com/articles/10.1186/s12940-016-0142-z#citeas

15. Deng S, Han A, Jin S, Wang S, Zheng J, Jalaludin BB, et al. Effect of extreme temperatures on asthma hospital visits: modification by event characteristics and healthy behaviors. Environ Res [Internet]. 2023 Jun 1;226:115679. Available from: https://pubmed.ncbi.nlm.nih.gov/36913996/

16. Chaseling GK, Iglesies-Grau J, Juneau M, Nigam A, Kaiser D, Gagnon D. Extreme heat and cardiovascular health: what a cardiovascular health professional should know. Can J Cardiol [Internet]. 2021 Nov;37(11):1828–36. Available from: https://pubmed.ncbi.nlm.nih.gov/34802857/

17. Khatana SAM, Werner RM, Groeneveld PW. Association of extreme heat and cardiovascular mortality in the United States: a county-level longitudinal analysis from 2008 to 2017. Circulation [Internet]. 2022 Jul 21;146(3):249–61. Available from: https://www.ahajournals.org/doi/full/10.1161/CIRCULATIONAHA.122.060746

18. Mohammadi D, Zare Zadeh M, Zare Sakhvidi MJ. Short-term exposure to extreme temperature and risk of hospital admission due to cardiovascular diseases. Int J Environ Health Res [Internet]. 2021 Apr;31(3):344–54. Available from: https://pubmed.ncbi.nlm.nih.gov/33615930/

19. Government of Canada. Immigrants make up the largest share of the population in over 150 years and continue to shape who we are as Canadians [Internet]. 2022 [cited 2024 Mar 29]. Available from: https://www150.statcan.gc.ca/n1/daily-quotidien/221026/dq221026a-eng.htm

20. Shor E, Roelfs D. Climate shock: moving to colder climates and immigrant mortality. Soc Sci Med [Internet]. 2019 Aug;235:112397. Available from: https://pubmed.ncbi.nlm.nih.gov/31306882/

21. Han A, Deng S, Yu J, Zhang Y, Jalaludin B, Huang C. Asthma triggered by extreme temperatures: from epidemiological evidence to biological plausibility. Environ Res [Internet]. 2023 Jan 1;216(Pt 2):114489. Available from: https://pubmed.ncbi.nlm.nih.gov/36208788/

22. Gautier C, Charpin D. Environmental triggers and avoidance in the management of asthma. J Asthma Allergy [Internet]. 2017 Mar 7;10:47–56. Available from: https://pubmed.ncbi.nlm.nih.gov/28331347/

23. Kenny GP, Yardley J, Brown C, Sigal RJ, Jay O. Heat stress in older individuals and patients with common chronic diseases. CMAJ [Internet]. 2010 Jul 13;182(10):1053–60. Available from: https://pubmed.ncbi.nlm.nih.gov/19703915/

24. Meade RD, Akerman AP, Notley SR, McGinn R, Poirier P, Gosselin P, et al. Physiological factors characterizing heat-vulnerable older adults: a narrative review. Environ Int [Internet]. 2020 Nov;144:105909. Available from: https://www.sciencedirect.com/science/article/pii/S016041202031864X

25. Szyszkowicz M, Zemek R, Colman I, Gardner W, Kousha T, Smith-Doiron M. Air pollution and emergency department visits for mental disorders among youth. Int J Environ Res Public Health [Internet]. 2020 Jun 12;17(12). Available from: http://dx.doi.org/10.3390/ijerph17124190

26. Gadermann AM, Gagné Petteni M, Janus M, Puyat JH, Guhn M, Georgiades K. Prevalence of mental health disorders among immigrant, refugee, and nonimmigrant children and youth in British Columbia, Canada. JAMA Netw Open [Internet]. 2022 Feb 1;5(2):e2144934. Available from: https://pubmed.ncbi.nlm.nih.gov/35166784/

27. Nwoke CN, Okpalauwaekwe U, Bwala H. Mental health professional consultations and the prevalence of mood and anxiety disorders among immigrants: multilevel analysis of the Canadian

community health survey. JMIR Ment Health [Internet]. 2020 Sep 16;7(9):e19168. Available from: https://pubmed.ncbi.nlm.nih.gov/32801115/

28. Pun VC, Manjourides J, Suh H. Association of ambient air pollution with depressive and anxiety symptoms in older adults: results from the NSHAP study. Environ Health Perspect [Internet]. 2017 Mar;125(3):342–8. Available from: https://pubmed.ncbi.nlm.nih.gov/27517877/

29. Nobile F, Forastiere A, Michelozzi P, Forastiere F, Stafoggia M. Long-term exposure to air pollution and incidence of mental disorders. a large longitudinal cohort study of adults within an urban area. Environ Int [Internet]. 2023 Nov;181:108302. Available from: https://pubmed.ncbi.nlm.nih.gov/37944432/

30. Zhou Y, Liu J. Air pollution and mental health of older adults in China. Sustain Sci Pract Policy [Internet]. 2020 Jan 28;12(3). Available from: https://www.mdpi.com/2071-1050/12/3/950

31. Power MC, Kioumourtzoglou MA, Hart JE, Okereke OI, Laden F, Weisskopf MG. The relation between past exposure to fine particulate air pollution and prevalent anxiety: observational cohort study. BMJ [Internet]. 2015 Mar 24;350:h1111. Available from: https://pubmed.ncbi.nlm.nih.gov/25810495/

32. Mehta AJ, Kubzansky LD, Coull BA, Kloog I, Koutrakis P, Sparrow D, et al. Associations between air pollution and perceived stress: the veterans administration normative aging study. Environ Health [Internet]. 2015 Jan 27;14:10. Available from: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-14-10#citeas

33. Niu Y, Zhou Y, Chen R, Yin P, Meng X, Wang W, et al. Long-term exposure to ozone and cardiovascular mortality in China: a nationwide cohort study. Lancet Planet Health [Internet]. 2022 Jun;6(6):e496–503. Available from: https://pubmed.ncbi.nlm.nih.gov/35709807/

34. Jiang Y, Huang J, Li G, Wang W, Wang K, Wang J, et al. Ozone pollution and hospital admissions for cardiovascular events. Eur Heart J [Internet]. 2023 May 7;44(18):1622–32. Available from: https://academic.oup.com/eurheartj/article/44/18/1622/7070974

35. Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. Ambient PM2.5, O_3, and NO_2 exposures and associations with mortality over 16 Years of follow-up in the Canadian Census Health and Environment Cohort (CanCHEC). Environ Health Perspect [Internet]. 2015 Nov 1;123(11):1180–6. Available from: http://dx.doi.org/10.1289/ehp.1409276

36. Gan RW, Liu J, Ford B, O'Dell K, Vaidyanathan A, Wilson A, et al. The association between wildfire smoke exposure and asthma-specific medical care utilization in Oregon during the 2013 wildfire season. J Expo Sci Environ Epidemiol [Internet]. 2020 Jul;30(4):618–28. Available from: https://pubmed.ncbi.nlm.nih.gov/32051501/

37. Martin KL, Hanigan IC, Morgan GG, Henderson SB, Johnston FH. Air pollution from bushfires and their association with hospital admissions in Sydney, Newcastle and Wollongong, Australia 1994-2007. Aust N Z J Public Health [Internet]. 2013 Jun;37(3):238–43. Available from: https://pubmed.ncbi.nlm.nih.gov/23731106/

38. Delfino RJ, Brummel S, Wu J, Stern H, Ostro B, Lipsett M, et al. The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003. Occup Environ Med [Internet]. 2009 Mar;66(3):189–97. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4176821/

39. Vang ZM, Sigouin J, Flenon A, Gagnon A. Are immigrants healthier than native-born Canadians? a systematic review of the healthy immigrant effect in Canada. Ethn Health [Internet]. 2017 Jun;22(3):209–41. Available from:

https://pubmed.ncbi.nlm.nih.gov/27809589/#:~:text=Objectives%3A%20Immigrants%20are%20typically%20healthier,healthy%20immigrant%20effect%20(HIE).

40. Breslau J, Borges G, Hagar Y, Tancredi D, Gilman S. Immigration to the USA and risk for mood and anxiety disorders: variation by origin and age at immigration. Psychol Med [Internet]. 2009 Jul;39(7):1117–27. Available from: https://pubmed.ncbi.nlm.nih.gov/19000338/

41. Alegría M, Álvarez K, DiMarzio K. Immigration and mental health. Curr Epidemiol Rep [Internet]. 2017 Jun;4(2):145–55. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5966037/

42. Sohail QZ, Chu A, Rezai MR, Donovan LR, Ko DT, Tu JV. The risk of ischemic heart disease and stroke among immigrant populations: a systematic review. Can J Cardiol [Internet]. 2015 Sep;31(9):1160–8. Available from: https://pubmed.ncbi.nlm.nih.gov/26195229/#:~:text=When%20duration%20of%20residence%20was,long%2Dterm%20residents%20of%20Canada.

43. Cabieses B, Uphoff E, Pinart M, Antó JM, Wright J. A systematic review on the development of asthma and allergic diseases in relation to international immigration: the leading role of the environment confirmed. PLoS On [Internet]. 2014 Aug 20;9(8):e105347. Available from: https://pubmed.ncbi.nlm.nih.gov/25141011/

44. Tham EH, Loo EXL, Zhu Y, Shek LPC. Effects of migration on allergic diseases. Int Arch Allergy Immunol [Internet]. 2019;178(2):128–40. Available from: https://pubmed.ncbi.nlm.nih.gov/30466080/

45. Radhakrishnan D, Guttmann A, To T, Reisman JJ, Knight BD, Mojaverian N, et al. Generational patterns of asthma incidence among immigrants to Canada over two decades. a population-based cohort study. Ann Am Thorac Soc [Internet]. 2019 Feb;16(2):248–57. Available from: https://pubmed.ncbi.nlm.nih.gov/30395726/

46. Jung K, Chang SX, Ok YS, Arshad MA. Critical loads and H+ budgets of forest soils affected by air pollution from oil sands mining in Alberta, Canada. Atmos Environ [Internet]. 2013 Apr 1;69:56–64. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1352231012011600

Bibliography

Adetona O, Hall DB, Naeher LP. Lung function changes in wildland firefighters working at prescribed burns. Inhal Toxicol [Internet]. 2011;23(13):835–41. Available from: http://dx.doi.org/10.3109/08958378.2011.617790

Ahmed JA, Katz MA, Auko E, Njenga MK, Weinberg M, Kapella BK, et al. Epidemiology of respiratory viral infections in two long-term refugee camps in Kenya, 2007-2010. BMC Infect Dis [Internet]. 2012 Jan 17;12(7). Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-12-7#citeas

Ahmed MR, Hassan QK. Occurrence, area burned, and seasonality trends of forest fires in the natural subregions of Alberta over 1959–2021. Fire [Internet]. 2023 Mar 2;6(3). Available from: https://www.mdpi.com/2571-6255/6/3/96

Akhtar R, Palagiano C. Climate change and air pollution: the impact on human health in developed and developing countries [Internet]. Springer International Publishing; 2018. 430 p. Available from: https://link.springer.com/book/10.1007/978-3-319-61346-8

Alberta. Population projections: Alberta and census divisions, 2021– 2046 [Internet]. 2021 Jul 2. Available from: https://open.alberta.ca/dataset/90a09f08-c52c-43bd-b48a-fda5187273b9/resource/9b48e997-92b0-4b74-82d2-017443049790/download/2021-2046-alberta-population-projections.pdf

Alberta. Wheezing or bronchoconstriction: care instructions [Internet]. 2022 Nov 13 [2024 Mar 24]. Available from: https://myhealth.alberta.ca/Health/aftercareinformation/pages/conditions.aspx?hwid=bo1026

Alberta. Climate change in Alberta [Internet]. [cited 2023 Jun 27]. Available from: https://www.alberta.ca/climate-change-alberta.aspx

Alberta. Canadian ambient air quality standards [Internet]. [cited 2023 Aug 10]. Available from: https://www.alberta.ca/canadian-ambient-air-quality-standards

Alberta. Current provincial population estimates [Internet]. [cited 2024 May 2]. Available from: https://www.alberta.ca/population-statistics

Alberta. Extreme heat [Internet]. [cited 2024 Mar 25]. Available from: https://www.alberta.ca/extreme-heat

Alberta. Air quality and health [Internet]. [cited 2024 Feb 10]. Available from: https://www.alberta.ca/air-quality-and-health.aspx

Alegría M, Álvarez K, DiMarzio K. Immigration and mental health. Curr Epidemiol Rep [Internet]. 2017 Apr 22;4:145–55. Available from: http://dx.doi.org/10.1007/s40471-017-0111-2

Ali J. Mental health of Canada's immigrants. Health Rep [Internet]. 2002 Jul 4;13. Available from: https://www150.statcan.gc.ca/n1/en/pub/82-003-s/2002001/pdf/82-003-s2002006-eng.pdf?st=czXoq5gx

Andújar-Espinosa R, Salinero-González L, Illán-Gómez F, Castilla-Martínez M, Hu-Yang C, Ruiz-López FJ. Effect of vitamin D supplementation on asthma control in patients with vitamin D deficiency: the ACVID randomised clinical trial. Thorax [Internet]. 2021 Nov 5;76:126–33. Available from: http://dx.doi.org/10.1136/thoraxjnl-2019-213936

Arjomandi M, Tager IB, Bastaki M, Chen C, Holland N, Balmes JR. Is there an association between lifetime cumulative exposure and acute pulmonary responses to ozone? J Occup Environ Med [Internet]. 2008 Mar;50(3):341–9. Available from: http://dx.doi.org/10.1097/JOM.0b013e318162f5eb

Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol [Internet]. 2005 Feb23;8(1):19–32. Available from: https://doi.org/10.1080/1364557032000119616

Bakolis I, Hammoud R, Stewart R, Beevers S, Dajnak D, MacCrimmon S, et al. Mental health consequences of urban air pollution: prospective population-based longitudinal survey. Soc Psychiatry Psychiatr Epidemiol [Internet]. 2020 Oct 24;56:1587–99. Available from: http://dx.doi.org/10.1007/s00127-020-01966-x

Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med [Internet]. 2009 Jan;51(1):33–7. Available from: http://dx.doi.org/10.1097/JOM.0b013e318193e12e

Bari MA, Kindzierski WB. Evaluation of air quality indicators in Alberta, Canada - an international perspective. Environ Int [Internet]. 2016 Jul-Aug;92–93:119–29. Available from: http://dx.doi.org/10.1016/j.envint.2016.03.021

Bays HE, Taub PR, Epstein E, Michos ED, Ferraro RA, Bailey AL, et al. Ten things to know about ten cardiovascular disease risk factors. Am J Prev Cardiol [Internet]. 2021 Mar;5:100149. Available from: http://dx.doi.org/10.1016/j.ajpc.2021.100149

Beiser M. The health of immigrants and refugees in Canada. Can J Public Health [Internet]. 2005 Mar-Apr;96 Suppl 2:S30-44. Available from: https://pubmed.ncbi.nlm.nih.gov/16078554/

Bell ML, Goldberg R, Hogrefe C, Kinney PL, Knowlton K, Lynn B, et al. Climate change, ambient ozone, and health in 50 US cities. Clim Change [Internet]. 2007 Jan 6;82:61–76. Available from: https://doi.org/10.1007/s10584-006-9166-7

Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987-2000. JAMA [Internet]. 2004 Nov 17;292(19):2372–8. Available from: http://dx.doi.org/10.1001/jama.292.19.2372

Benevolenza MA, DeRigne L. The impact of climate change and natural disasters on vulnerable populations: a systematic review of literature. J Hum Behav Soc Environ [Internet]. 2019;29(2):266–81. Available from: https://doi.org/10.1080/10911359.2018.1527739

Bonner WIA, Weiler R, Orisatoki R, Lu X, Andkhoie M, Ramsay D, et al. Determinants of self-perceived health for Canadians aged 40 and older and policy implications. Int J Equity Health [Internet]. 2017 Jun 6;16(94). Available from: http://dx.doi.org/10.1186/s12939-017-0595-x

Brauer M, Brook JR, Christidis T, Chu Y, Crouse DL, Erickson A, et al. Mortality–air pollution associations in low-exposure environments (MAPLE): phase 1. Res Rep Health Eff Inst [Internet]. 2019;203:1-87 Nov 1

Breslau J, Borges G, Hagar Y, Tancredi D, Gilman S. Immigration to the USA and risk for mood and anxiety disorders: variation by origin and age at immigration. Psychol Med [Internet]. 2009 Jul;39(7):1117–27. Available from: https://pubmed.ncbi.nlm.nih.gov/19000338/

Brook JR, Cober SG, Freemark M, Harner T, Li SM, Liggio J, et al. Advances in science and applications of air pollution monitoring: a case study on oil sands monitoring targeting ecosystem protection. J Air Waste Manag Assoc [Internet]. 2019 May 24;69(6):661–709. Available from: http://dx.doi.org/10.1080/10962247.2019.1607689

Brunsdon C, Fotheringham S, Charlton M. Geographically weighted regression. J Royal Statistical Soc D

[Internet]. 1998 Sept;47(3):431–43. Available from: https://onlinelibrary.wiley.com/doi/10.1111/1467-9884.00145

Bush E, Flato G. Chapter 1: about this report. In: Bush E, Lemmen DS, editors. Canada's changing climate report [Internet]. Ottawa, ON: Government of Canada; 2019. p. 7–23. Available from: https://changingclimate.ca/site/assets/uploads/sites/2/2018/11/CCCR_Chapter1-About-this-Report.pdf

Cabieses B, Uphoff E, Pinart M, Antó JM, Wright J. A systematic review on the development of asthma and allergic diseases in relation to international immigration: the leading role of the environment confirmed. PLoS One [Internet]. 2014 Aug 20;9(8):e105347. Available from: http://dx.doi.org/10.1371/journal.pone.0105347

Campbell SM. A filter to retrieve studies related to refugees/immigrants from the OVID medline database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2020. Available from: https://docs.google.com/document/d/13CDD4zA_T2nTHO_fAQ-m1vcLr8Nmuw7rnZ2BbXSbO0k/edit

Campbell SM. Hedge to retrieve articles related to air pollution in OVID EMBASE [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2021. Available from: https://docs.google.com/document/d/1EbeATCMKWmwzyV79SF97ahnkq4pEedcPLSZkSt-F7W4/edit

Campbell SM. Hedge to retrieve articles related to air pollution in OVID medline [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2021. Available from: https://docs.google.com/document/d/1gGY4q7orPUSMhttBBnz5KsOKv5ZCSErkvg-hlBbSorM/edit

Campbell SM. Hedge to retrieve articles related to climate change in EBSCO CINAHL [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1BbD7ArMV7wjcYKIoof8ehE_Url0xqDxsSo4_VAwgg9Q/edit#

Campbell SM. Hedge to retrieve articles related to climate change in OVID EMBASE [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from:

https://docs.google.com/document/d/17W7bVIeG4xEUKpi3m1tll8oCYtPXTlSJasfMCt-fFNY/edit#

Campbell SM. A filter to retrieve studies related to refugees/immigrants from the OVID EMBASE database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/19cvUcFhv-n5dzJ-EDaRZA0DzSMZWkicWRMCH9KBu3Nk/edit

Campbell SM. Hedge to retrieve articles related to climate change in OVID medline [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/11s673QzBiO4uqX2TwxukFgPzRYa6sT5Jt47BsFN2yyU/edit#

Campbell SM. A filter to retrieve studies related to refugees/immigrants from the EBSCO CINAHL database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1gVj-jQdv8ddWCVmIQgpStoPPoNs6hMWvYDHIgUacEg8/edit

Campbell SM. Hedge to retrieve articles related to air pollution in EBSCO CINAHL [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1OLx0u_a7kChVKUJihLvBWN5nkCxtIANJX2GICrL1v6A/edit

Campbell SM. Hedge to retrieve articles related to air pollution in SCOPUS [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1oo3Daq3GWOsjqLhTdBBn2Bfyvk91jX28XhmxUquymbk/edit

Canadian Research Data Centre Network. About the Canadian research data centre network [Internet]. [cited 2024 Mar 10]. Available from: https://crdcn.ca/about/about-crdcn/

Carnes BA, Staats D, Willcox BJ. Impact of climate change on elder health. J Gerontol A Biol Sci Med Sci [Internet]. 2014 Sep;69(9):1087–91. Available from: http://dx.doi.org/10.1093/gerona/glt159

Chang AY, Tan AX, Nadeau KC, Odden MC. Aging hearts in a hotter, more turbulent world: the impacts of climate change on the cardiovascular health of older adults. Curr Cardiol Rep [Internet]. 2022 Apr 19;24:749–60. Available from: http://dx.doi.org/10.1007/s11886-022-01693-6

Chaseling GK, Iglesies-Grau J, Juneau M, Nigam A, Kaiser D, Gagnon D. Extreme heat and cardiovascular health: what a cardiovascular health professional should know. Can J Cardiol [Internet]. 2021 Nov 17;37(11):1828–36. Available from: http://dx.doi.org/10.1016/j.cjca.2021.08.008

Chastko K. Internal migration: overview, 2016/2017 to 2018/2019 [Internet]. Statistics Canada; 2021 Jul 14. Available from: https://www150.statcan.gc.ca/n1/pub/91-209-x/2021001/article/00001-eng.htm

Chen Y, Ke X, Min M, Zhang Y, Dai Y, Tang L. Do we need more urban green space to alleviate PM2.5 pollution? a case study in Wuhan, China. Land [Internet]. 2022 May 25;11(6):776. Available from: https://www.mdpi.com/2073-445X/11/6/776

Chen Y, Kong D, Fu J, Zhang Y, Zhao Y, Liu Y, et al. Increased hospital admissions for asthma from short-term exposure to cold spells in Beijing, China. Int J Hyg Environ Health [Internet]. 2021 Sept;238:113839. Available from: http://dx.doi.org/10.1016/j.ijheh.2021.113839

Cheng J, Xu Z, Zhu R, Wang X, Jin L, Song J, et al. Impact of diurnal temperature range on human health: a systematic review. Int J Biometeorol [Internet]. 2014 Feb 18;58:2011–24. Available from: http://dx.doi.org/10.1007/s00484-014-0797-5

Chiu M, Austin PC, Manuel DG, Tu JV. Cardiovascular risk factor profiles of recent immigrants vs long-term residents of Ontario: a multi-ethnic study. Can J Cardiol [Internet]. 2012 Jan-Feb;28(1):20–6. Available from: http://dx.doi.org/10.1016/j.cjca.2011.06.002

Chowdhury N, Naeem I, Ferdous M, Chowdhury M, Goopy S, Rumana N, et al. Unmet healthcare needs among migrant populations in Canada: exploring the research landscape through a systematic integrative review. J Immigr Minor Health [Internet]. 2021 Apr;23:353–72. Available from: http://dx.doi.org/10.1007/s10903-020-01086-3

Christidis T, Erickson AC, Pappin AJ, Crouse DL, Pinault LL, Weichenthal SA, et al. Low concentrations of fine particle air pollution and mortality in the Canadian community health survey cohort. Environ Health [Internet]. 2019 Oct 10;18(1):84. Available from: https://pubmed.ncbi.nlm.nih.gov/31601202/

Cianconi P, Betrò S, Janiri L. The impact of climate change on mental health: a systematic descriptive

review. Front Psychiatry [Internet]. 2020 Mar 6;11:74. Available from: https://pubmed.ncbi.nlm.nih.gov/32210846/

Cicci KR, Maltby A, Clemens KK, Vicedo-Cabrera AM, Gunz AC, Lavigne É, et al. High temperatures and cardiovascular-related morbidity: a scoping review. Int J Environ Res Public Health [Internet]. 2022 Sep 7;19(18). Available from: http://dx.doi.org/10.3390/ijerph191811243

Clarke PJ, Yan T, Keusch F, Gallagher NA. The impact of weather on mobility and participation in older U.S. adults. Am J Public Health [Internet]. 2015 Jun 5;105(7):1489–94. Available from: http://dx.doi.org/10.2105/AJPH.2015.302582

Clemens V, von Hirschhausen E, Fegert JM. Report of the intergovernmental panel on climate change: implications for the mental health policy of children and adolescents in Europe-a scoping review. Eur Child Adolesc Psychiatry [Internet]. 2022 May;31:701–13. Available from: http://dx.doi.org/10.1007/s00787-020-01615-3

Colosia AD, Masaquel A, Hall CB, Barrett AM, Mahadevia PJ, Yogev R. Residential crowding and severe respiratory syncytial virus disease among infants and young children: a systematic literature review. BMC Infect Dis [Internet]. 2012 Apr 20;12:95. Available from: https://pubmed.ncbi.nlm.nih.gov/22520624/#:~:text=Conclusions%3A%20Residential%20crowding%20was%20associated,%2C%20populations%2C%20or%20geographic%20locations.

Cong X, Xu X, Zhang Y, Wang Q, Xu L, Huo X. Temperature drop and the risk of asthma: a systematic review and meta-analysis. Environ Sci Pollut Res Int [Internet]. 2017 Aug 13;24:22535–46. Available from: http://dx.doi.org/10.1007/s11356-017-9914-4

Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. Ambient PM2.5, O_3, and NO_2 exposures and associations with mortality over 16 Years of follow-up in the Canadian Census Health and Environment Cohort (CanCHEC). Environ Health Perspect [Internet]. 2015 Nov 1;123(11):1180–6. Available from: http://dx.doi.org/10.1289/ehp.1409276

Crouse DL, Pinault L, Christidis T, Lavigne E, Thomson EM, Villeneuve PJ. Residential greenness and indicators of stress and mental well-being in a Canadian national-level survey. Environ Res [Internet]. 2021 Jan;192:110267. Available from: http://dx.doi.org/10.1016/j.envres.2020.110267

D'Amato G, Cecchi L, D'Amato M, Annesi-Maesano I. Climate change and respiratory diseases. Eur

Respir Rev [Internet]. 2014 Jun;23(132):161–9. Available from: https://err.ersjournals.com/content/23/132/161

D'Amato M, Molino A, Calabrese G, Cecchi L, Annesi-Maesano I, D'Amato G. The impact of cold on the respiratory tract and its consequences to respiratory health. Clin Transl Allergy [Internet]. 2018 May 30;8(20). Available from: http://dx.doi.org/10.1186/s13601-018-0208-9

Daudt HML, van Mossel C, Scott SJ. Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework. BMC Med Res Methodol [Internet]. 2013 Mar 23;13(48). Available from: https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-13-48

Day DB, Xiang J, Mo J, Li F, Chung M, Gong J, et al. Association of ozone exposure with cardiorespiratory pathophysiologic mechanisms in healthy adults. JAMA Intern Med [Internet]. 2017 Sept 1;177(9):1344–53. Available from: http://dx.doi.org/10.1001/jamainternmed.2017.2842

Daynes L. The health impacts of the refugee crisis: a medical charity perspective. Clin Med [Internet]. 2016 Oct;16(5):437–40. Available from: http://dx.doi.org/10.7861/clinmedicine.16-5-437

Delfino RJ, Brummel S, Wu J, Stern H, Ostro B, Lipsett M, et al. The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003. Occup Environ Med [Internet]. 2008 Nov 18;66(3):189–97. Available from: http://dx.doi.org/10.1136/oem.2008.041376

Deng L, Ma P, Wu Y, Ma Y, Yang X, Li Y, et al. High and low temperatures aggravate airway inflammation of asthma: evidence in a mouse model. Environ Pollut [Internet]. 2020 Jan;256:113433. Available from: http://dx.doi.org/10.1016/j.envpol.2019.113433

Deng S, Han A, Jin S, Wang S, Zheng J, Jalaludin BB, et al. Effect of extreme temperatures on asthma hospital visits: modification by event characteristics and healthy behaviors. Environ Res [Internet]. 2023 Jun 1;226:115679. Available from: http://dx.doi.org/10.1016/j.envres.2023.115679

Dennett EL, Campbell SM. A hedge to retrieve studies related to climate change from the SCOPUS database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1fVtBDWZE36okUcWzNGOQwYSAVGH69QhWlumaVe88B

pl/edit

Devlin RB, Duncan KE, Jardim M, Schmitt MT, Rappold AG, Diaz-Sanchez D. Controlled exposure of healthy young volunteers to ozone causes cardiovascular effects. Circulation [Internet]. 2012 Jul 3;126(1):104–11. Available from: http://dx.doi.org/10.1161/CIRCULATIONAHA.112.094359

Diala CC, Muntaner C. Mood and anxiety disorders among rural, urban, and metropolitan residents in the United States. Community Ment Health J [Internet]. 2003 Jun;39(3):239–52. Available from: http://dx.doi.org/10.1023/a:1023342307323

Dias D, Tchepel O. Spatial and temporal dynamics in air pollution exposure assessment. Int J Environ Res Public Health [Internet]. 2018 Mar 20;15(3). Available from: http://dx.doi.org/10.3390/ijerph15030558

Dominski FH, Lorenzetti Branco JH, Buonanno G, Stabile L, Gameiro da Silva M, Andrade A. Effects of air pollution on health: a mapping review of systematic reviews and meta-analyses. Environ Res [Internet]. 2021 Oct;201:111487. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0013935121007817

Dong GH, Zhang P, Sun B, Zhang L, Chen X, Ma N, et al. Long-term exposure to ambient air pollution and respiratory disease mortality in Shenyang, China: a 12-year population-based retrospective cohort study. Respiration [Internet]. 2012;84(5):360–8. Available from: http://dx.doi.org/10.1159/000332930

Dores AK, Fick GH, MacMaster FP, Williams JVA, Bulloch AGM, Patten SB. Outdoor air pollution and depression in Canada: a population-based cross-sectional study from 2011 to 2016. Int J Environ Res Public Health [Internet]. 2021 Mar 2;18(5):2450. Available from: http://dx.doi.org/10.3390/ijerph18052450

Ejiagha IR, Ahmed MR, Dewan A, Gupta A, Rangelova E, Hassan QK. Urban warming of the two most populated cities in the Canadian province of Alberta, and its influencing factors. Sensors [Internet]. 2022 Apr 9;22(8). Available from: http://dx.doi.org/10.3390/s22082894

Elshahat S, Moffat T, Newbold KB. Understanding the healthy immigrant effect in the context of mental health challenges: a systematic critical review. J Immigr Minor Health [Internet]. 2022 Nov 22;24:1564–79. Available from: http://dx.doi.org/10.1007/s10903-021-01313-5

Environment and Climate Change Canada. Greenhouse gas emissions: Canadian environmental sustainability indicators [Internet]. 2024 May. Available from: https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/ghg-emissions/2024/greenhouse-gas-emissions-en.pdf

Erickson AC, Christidis T, Pappin A, Brook JR, Crouse DL, Hystad P, et al. Disease assimilation: the mortality impacts of fine particulate matter on immigrants to Canada. Health Rep [Internet]. 2020 Jun 17;31(3):14-26. Available from: https://www.ncbi.nlm.nih.gov/pubmed/32644760

Ferrer I, Brotman S, Koehn S. Unravelling the interconnections of immigration, precarious labour and racism across the life course. J Gerontol Soc Work [Internet]. 2022 Feb 27;65(8):797–821. Available from: http://dx.doi.org/10.1080/01634372.2022.2037805

Finkel ML. The impact of oil sands on the environment and health. Curr Opin Environ Sci Health [Internet]. 2018 Jun;3:52–5. Available from: https://www.sciencedirect.com/science/article/pii/S2468584417300648

Fitzgerald EF, Pantea C, Lin S. Cold spells and the risk of hospitalization for asthma: New York, USA 1991-2006. Lung [Internet]. 2014 Oct 11;192:947–54. Available from: http://dx.doi.org/10.1007/s00408-014-9645-y

Flannigan MD, Krawchuk MA, de Groot WJ, Mike Wotton B, Gowman LM. Implications of changing climate for global wildland fire**.** Int. J. Wildland Fire [Internet]. 2009;18:483–507. Available from: http://dx.doi.org/10.1071/WF08187

Gadermann AM, Gagné Petteni M, Janus M, Puyat JH, Guhn M, Georgiades K. Prevalence of mental health disorders among immigrant, refugee, and nonimmigrant children and youth in British Columbia, Canada. JAMA Netw Open [Internet]. 2022 Feb 15;5(2):e2144934. Available from: http://dx.doi.org/10.1001/jamanetworkopen.2021.44934

Gan RW, Liu J, Ford B, O'Dell K, Vaidyanathan A, Wilson A, et al. The association between wildfire smoke exposure and asthma-specific medical care utilization in Oregon during the 2013 wildfire season. J Expo Sci Environ Epidemiol [Internet]. 2020 Feb 12;30:618–28. Available from: http://dx.doi.org/10.1038/s41370-020-0210-x

Gautier C, Charpin D. Environmental triggers and avoidance in the management of asthma. J Asthma

Allergy [Internet]. 2017 Mar 7;10:47–56. Available from: https://pubmed.ncbi.nlm.nih.gov/28331347/

Gehring U, Wijga AH, Koppelman GH, Vonk JM, Smit HA, Brunekreef B. Air pollution and the development of asthma from birth until young adulthood. Eur Respir J [Internet]. 2020 Jul;56: 2000147. Available from: http://dx.doi.org/10.1183/13993003.00147-2020

Golicha Q, Shetty S, Nasiblov O, Hussein A, Wainaina E, Obonyo M, et al. Cholera outbreak in Dadaab refugee camp, Kenya - November 2015-June 2016. MMWR Morb Mortal Wkly Rep. 2018 Aug 31;67(34):958–61. Available from: https://www.cdc.gov/mmwr/volumes/67/wr/mm6734a4.htm#:~:text=During%20November%2018%2C%202015%E2%80%93June,a%20shared%20plate%20were%20common.

Gong H Jr, Wong R, Sarma RJ, Linn WS, Sullivan ED, Shamoo DA, et al. Cardiovascular effects of ozone exposure in human volunteers. Am J Respir Crit Care Med [Internet]. 1998 Aug;158(2):538–46. Available from: http://dx.doi.org/10.1164/ajrccm.158.2.9709034

Gostimirovic M, Novakovic R, Rajkovic J, Djokic V, Terzic D, Putnik S, et al. The influence of climate change on human cardiovascular function. Arch Environ Occup Health [Internet]. 2020 Mar 23;75(7):406–14. Available from: http://dx.doi.org/10.1080/19338244.2020.1742079

Government of Canada. Air pollution from cars, trucks, vans and SUVs [Internet]. 2017 [cited 2024 May 2]. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/sources/transportation/cars-trucks-vans-suvs.html

Government of Canada. International comparison of urban air quality [Internet]. 2016 Dec 21 [cited 2024 Apr 29]. Available from: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/international-comparison-urban-air-quality.html

Government of Canada. Data tables, 2016 census. [Internet]. 2019 Jun 17 [cited 2023 Dec 10]. Available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/dt-td/Rp-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=1&PID=110560&PRID=10&PTYPE=109445&S=0&SHOWALL=0&SUB=999&Temporal=2016,2017&THEME=119&VID=0&VNAMEE=&VNAMEF=

Government of Canada. National air pollution surveillance (NAPS) program [Internet]. 2019 Nov 28 [cited

2024 Mar 15]. Available from: https://open.canada.ca/data/en/dataset/1b36a356-defd-4813-acea-47bc3abd859b

Government of Canada. How Canada's refugee system works [Internet]. 2019 [cited 2022 Aug 31]. Available from: https://www.canada.ca/en/immigration-refugees-citizenship/services/refugees/canada-role.html

Government of Canada. Regional, national and international climate modeling [Internet]. 2020 Dec 8 [cited 2024 Mar 15]. Available from: https://cfs.nrcan.gc.ca/projects/3

Government of Canada. Communicating the health risks of extreme heat events [Internet]. 2020 [cited 2024 Mar 25]. Available from: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/climate-change-health/communicating-health-risks-extreme-heat-events-toolkit-public-health-emergency-management-officials-health-canada-2011.html

Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

Government of Canada. Heart disease in Canada [Internet]. 2022 Jul 28 [cited 2024 Jan 15]. Available from: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html

Government of Canada. Immigrants make up the largest share of the population in over 150 years and continue to shape who we are as Canadians [Internet]. 2022 Oct 26 [cited 2024 Mar 17].

Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2022 Dec 2 [cited 2024 Mar 11]. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb

Government of Canada. Gender-based analysis plus [Internet]. 2023 [cited 2024 Jul 2]. Available from: https://www.canada.ca/en/immigration-refugees-citizenship/corporate/publications-manuals/departmental-performance-reports/2023/gender-based-analysis-plus.html

Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29 [cited 2024 Mar 10]. Available from:

https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

Available from: https://www150.statcan.gc.ca/n1/daily-quotidien/221026/dq221026a-eng.htm

Government of Canada. About the access - RDC [Internet]. 2023 Dec 29 [cited 2024 Mar 10]. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/about

Government of Canada. Canada's air quality [Internet]. 2023 [cited 2024 Mar 27]. Available from: https://www.canada.ca/en/environment-climate-change/campaigns/canadian-environment-week/clean-air-day/air-quality.html

Government of Canada. Keeping the heat in - section 2: how your house works [Internet]. 2023 [cited 2024 Mar 25]. Available from: https://natural-resources.canada.ca/energy-efficiency/homes/make-your-home-more-energy-efficient/keeping-the-heat/section-2-how-your-house-works/15630

Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2024 Jan 19 [cited 2024 Mar 11]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

Government of Canada. Air pollution: drivers and impacts [Internet]. 2024 [cited 2024 May 2]. Available from: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollution-drivers-impacts.html

Government of Canada. Canadian climate normals 1991-2020 data [Internet]. 2024 [cited 2024 Apr 15]. Available from: https://climate.weather.gc.ca/climate_normals/results_1991_2020_e.html?searchType=stnProv&lstProvince=AB&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=281000000&dispBack=0

Government of Canada. Fact sheet: benzo pyrene [Internet]. [cited 2024 Jan 8]. Available from: https://gost.tpsgc-pwgsc.gc.ca/Contfs.aspx?ID=33&lang=eng

Gryech I, Ghogho M, Mahraoui C, Kobbane A. An Exploration of features impacting respiratory diseases in urban areas. Int J Environ Res Public Health [Internet]. 2022 Mar 6;19(5):3095. Available from: http://dx.doi.org/10.3390/ijerph19053095

Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J, et al. Acute effects of ozone on mortality from the "air pollution and health: a European approach" project. Am J Respir Crit

Care Med [Internet]. 2004 Nov 15;170(10):1080–7. Available from: http://dx.doi.org/10.1164/rccm.200403-333OC

Guo Y, Jiang F, Peng L, Zhang J, Geng F, Xu J, et al. The association between cold spells and pediatric outpatient visits for asthma in Shanghai, China. PLoS One [Internet]. 2012 Jul 25;7(7):e42232. Available from: http://dx.doi.org/10.1371/journal.pone.0042232

Hameed S, Sadiq A, Din AU. The increased vulnerability of refugee population to mental health disorders. Kans J Med [Internet]. 2018 Feb 28;11(1):1–12. Available from: https://www.ncbi.nlm.nih.gov/pubmed/29844851

Han A, Deng S, Yu J, Zhang Y, Jalaludin B, Huang C. Asthma triggered by extreme temperatures: from epidemiological evidence to biological plausibility. Environ Res [Internet]. 2023 Jan 1;216(Pt 2):114489. Available from: https://pubmed.ncbi.nlm.nih.gov/36208788/

Hathaway J, Maibach EW. Health implications of climate change: a review of the literature about the perception of the public and health professionals. Curr Environ Health Rep [Internet]. 2018 Feb 8;5:197–204. Available from: http://dx.doi.org/10.1007/s40572-018-0190-3

Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. Climate change and mental health: risks, impacts and priority actions. Int J Ment Health Syst [Internet]. 2018 Jun 1;12(28). Available from: http://dx.doi.org/10.1186/s13033-018-0210-6

Hayes RB, Lim C, Zhang Y, Cromar K, Shao Y, Reynolds HR, et al. PM2.5 air pollution and cause-specific cardiovascular disease mortality. Int J Epidemiol [Internet]. 2020 Feb 1;49(1):25–35. Available from: http://dx.doi.org/10.1093/ije/dyz114

Hayhoe K, Stoner A. Alberta's climate future: final report [Internet]. ATMOS Research & Consulting; 2019. Available from: https://open.alberta.ca/dataset/89a69583-a11b-4e31-a857-b311ab6563cc/resource/17ce2d24-ba7b-466c-acd9-33a2cf6beb69/download/aep-alberta-climate-report-arc.pdf

Health Canada. Health impacts of air pollution in Canada: estimates of premature deaths and nonfatal outcomes [Internet]. Ottawa, ON; 2021 Mar. Available from: https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/2021-health-effects-indoor-air-pollution/hia-report-eng.pdf

Hess JJ, Malilay JN, Parkinson AJ. Climate change: the importance of place. Am J Prev Med [Internet]. 2008 Nov;35(5):468–78. Available from: http://dx.doi.org/10.1016/j.amepre.2008.08.024

Hickman C, Marks E, Pihkala P, Clayton S, Lewandowski RE, Mayall EE, et al. Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. Lancet Planet Health [Internet]. 2021 Dec;5(12):e863–73. Available from: http://dx.doi.org/10.1016/S2542-5196(21)00278-3

Huang R, McPhedran KN, Yang L, El-Din MG. Characterization and distribution of metal and nonmetal elements in the Alberta oil sands region of Canada. Chemosphere [Internet]. 2016 Mar;147:218–29. Available from: http://dx.doi.org/10.1016/j.chemosphere.2015.12.099

Hutcbinson MF, Biscbof RJ. A new method for estimating the spatial distribution of mean seasonal and annual rainfall applied to the Hunter Valley, New South Wales. Aust Met Mag [Internet]. 1983; 31(3):1979-184. Available from: https://epic.awi.de/id/eprint/29862/1/Hut1983a.pdf

Immigration, Refugee Board of Canada. Claims by country of alleged persecution - 2023 [Internet]. 2023 [cited 2024 May 1]. Available from: https://www.irb-cisr.gc.ca/en/statistics/protection/Pages/RPDStat2023.aspx

Iqbal S, Oraka E, Chew GL, Flanders WD. Association between birthplace and current asthma: the role of environment and acculturation. Am J Public Health [Internet]. 2014 Feb;104(Suppl 1):S175-82. Available from: http://dx.doi.org/10.2105/AJPH.2013.301509

Jiang Y, Huang J, Li G, Wang W, Wang K, Wang J, et al. Ozone pollution and hospital admissions for cardiovascular events. Eur Heart J [Internet]. 2023 May 7;44(18):1622–32. Available from: http://dx.doi.org/10.1093/eurheartj/ehad091

Jie Y, Isa Z, Jie X, Ju ZL, Ismail NH. Urban vs. rural factors that affect adult asthma. In: Whitacre DM, editor. Reviews of environmental contamination and toxicology volume 226 [Internet]. New York, NY: Springer New York; 2013. p. 33–63. Available from: https://doi.org/10.1007/978-1-4614-6898-1_2

Jin T, Di Q, Réquia WJ, Danesh Yazdi M, Castro E, Ma T, et al. Associations between long-term air pollution exposure and the incidence of cardiovascular diseases among American older adults. Environ Int [Internet]. 2022 Dec;170:107594. Available from:

http://dx.doi.org/10.1016/j.envint.2022.107594

Jung K, Chang SX, Ok YS, Arshad MA. Critical loads and H+ budgets of forest soils affected by air pollution from oil sands mining in Alberta, Canada. Atmos Environ [Internet]. 2013 Apr 1;69:56–64. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1352231012011600

Jylhä M. What is self-rated health and why does it predict mortality? towards a unified conceptual model. Soc Sci Med [Internet]. 2009 Aug;69(3):307–16. Available from: http://dx.doi.org/10.1016/j.socscimed.2009.05.013

Kenny GP, Yardley J, Brown C, Sigal RJ, Jay O. Heat stress in older individuals and patients with common chronic diseases. CMAJ [Internet]. 2010 Jul 13;182(10):1053–60. Available from: http://dx.doi.org/10.1503/cmaj.081050

Kerr J, Marshall S, Godbole S, Neukam S, Crist K, Wasilenko K, et al. The relationship between outdoor activity and health in older adults using GPS. Int J Environ Res Public Health [Internet]. 2012 Dec 10;9(12):4615–25. Available from: http://dx.doi.org/10.3390/ijerph9124615

Kerry V, Sayeed S. Advancing the climate change and health nexus: The 2024 Agenda. PLOS Glob Public Health [Internet]. 2024 Mar 28;4(3):e0003008. Available from: http://dx.doi.org/10.1371/journal.pgph.0003008

Khatana SAM, Werner RM, Groeneveld PW. Association of extreme heat and cardiovascular mortality in the United States: a county-level longitudinal analysis from 2008 to 2017. Circulation [Internet]. 2022 Jul 21;146(3):249–61. Available from: http://dx.doi.org/10.1161/CIRCULATIONAHA.122.060746

Kitchen P, Williams A, Chowhan J. Sense of community belonging and health in Canada: a regional analysis. Soc Indic Res [Internet]. 2011 Mar 26;107:103–26. Available from: https://doi.org/10.1007/s11205-011-9830-9

Ko Y, Boo S. Self-perceived health versus actual cardiovascular disease risks. Jpn J Nurs Sci [Internet]. 2015 Jun 23;13(1):65–74. Available from: http://dx.doi.org/10.1111/jjns.12087

Koken PJM, Piver WT, Ye F, Elixhauser A, Olsen LM, Portier CJ. Temperature, air pollution, and hospitalization for cardiovascular diseases among elderly people in Denver. Environ Health Perspect [Internet]. 2003 Aug 1;111(10):1312–7. Available from:

https://ehp.niehs.nih.gov/doi/abs/10.1289/ehp.5957

Kondo MC, De Roos AJ, White LS, Heilman WE, Mockrin MH, Gross-Davis CA, et al. Meta-analysis of heterogeneity in the effects of wildfire smoke exposure on respiratory health in North America. Int J Environ Res Public Health [Internet]. 2019 Mar 18;16(6):960. Available from: http://dx.doi.org/10.3390/ijerph16060960

Kriebel-Gasparro A. Climate change: effects on the older adult. J Nurse Pract [Internet]. 2022 Apr ;18(4):372–6. Available from: https://www.sciencedirect.com/science/article/pii/S1555415522000071

Lane G, Farag M, White J, Nisbet C, Vatanparast H. Chronic health disparities among refugee and immigrant children in Canada. Appl Physiol Nutr Metab [Internet]. 2018 Oct;43(10):1043–58. Available from: http://dx.doi.org/10.1139/apnm-2017-0407

Lavigne E, Maltby A, Côté JN, Weinberger KR, Hebbern C, Vicedo-Cabrera AM, et al. The effect modification of extreme temperatures on mental and behavior disorders by environmental factors and individual-level characteristics in Canada. Environ Res [Internet]. 2023 Feb 15;219:114999. Available from: http://dx.doi.org/10.1016/j.envres.2022.114999

Lebano A, Hamed S, Bradby H, Gil-Salmerón A, Durá-Ferrandis E, Garcés-Ferrer J, et al. Migrants' and refugees' health status and healthcare in Europe: a scoping literature review. BMC Public Health [Internet]. 2020 Jun 30;20(1). Available from: https://pubmed.ncbi.nlm.nih.gov/32605605/

Lee S, Lee M. Low-to-moderate atmospheric ozone levels are negatively correlated with hospital visits by asthma patients. Medicine [Internet]. 2022 Nov 11;101(45):e31737. Available from: http://dx.doi.org/10.1097/MD.0000000000031737

Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci [Internet]. 2010 Sep 20;5. Available from: https://pubmed.ncbi.nlm.nih.gov/20854677/

Levitt MJ, Lane JD, Levitt J. Immigration stress, social support, and adjustment in the first postmigration year: an intergenerational analysis. Res Hum Dev [Internet]. 2005;2(4):159–77. Available from: https://doi.org/10.1207/s15427617rhd0204_1

Levy BR, Slade MD, Chang ES, Kannoth S, Wang SY. Ageism amplifies cost and prevalence of health conditions. Gerontologist [Internet]. 2018 Nov 13;60(1):174–81. Available from:

https://academic.oup.com/gerontologist/article-pdf/60/1/174/33123535/gny131.pdf

Levy SR, Apriceno M. Ageing: the role of ageism. OBM Geriat [Internet]. 2019 Oct 28;3(4). Available from: https://www.lidsen.com/journals/geriatrics/geriatrics-03-04-083

Li D, Deal B, Zhou X, Slavenas M, Sullivan WC. Moving beyond the neighborhood: daily exposure to nature and adolescents' mood. Landsc Urban Plan [Internet]. 2018 May;173:33–43. Available from: https://www.sciencedirect.com/science/article/pii/S0169204618300318

Lin S, Luo M, Walker RJ, Liu X, Hwang SA, Chinery R. Extreme high temperatures and hospital admissions for respiratory and cardiovascular diseases. Epidemiology [Internet]. 2009 Sept;20(5):738–46. Available from: http://dx.doi.org/10.1097/EDE.0b013e3181ad5522

Liu J, Varghese BM, Hansen A, Zhang Y, Driscoll T, Morgan G, et al. Heat exposure and cardiovascular health outcomes: a systematic review and meta-analysis. Lancet Planet Health [Internet]. 2022 Jun;6(6):e484–95. Available from: http://dx.doi.org/10.1016/S2542-5196(22)00117-6

Liu X, He Y, Tang C, Wei Q, Xu Z, Yi W, et al. Association between cold spells and childhood asthma in Hefei, an analysis based on different definitions and characteristics. Environ Res [Internet]. 2021 Apr;195:110738. Available from: http://dx.doi.org/10.1016/j.envres.2021.110738

Lulham N, Warren FJ, Walsh KA, Szwarc J. Canada in a changing climate: synthesis report [Internet]. Ottawa, ON: Government of Canada; 2023. Available from: https://ostrnrcan-dostrncan.canada.ca/handle/1845/271933

Ma T, Moore J, Cleary A. Climate change impacts on the mental health and wellbeing of young people: a scoping review of risk and protective factors. Soc Sci Med [Internet]. 2022 May;301:114888. Available from: http://dx.doi.org/10.1016/j.socscimed.2022.114888

Mahsin MD, Cabaj J, Saini V. Respiratory and cardiovascular condition-related physician visits associated with wildfire smoke exposure in Calgary, Canada, in 2015: a population-based study. Int J Epidemiol [Internet]. 2022 Feb;51(1):166–78. Available from: http://dx.doi.org/10.1093/ije/dyab206

Mamuji AA, Rozdilsky JL. Wildfire as an increasingly common natural disaster facing Canada: understanding the 2016 Fort McMurray wildfire. Nat Hazards [Internet]. 2019 Sept 25;98:163–80. Available from: https://doi.org/10.1007/s11069-018-3488-4

Mandell N, Borras J, Phonepraseuth J. Strategies and best practices for data literacy education: knowledge synthesis report. 2015. Available from: https://www.niagaraknowledgeexchange.com/wp-content/uploads/sites/2/2018/10/IWYS-Knowledge-Synthesis-Report-Seniors-report-Sept-2018.pdf

Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: a review. Front Public Health [Internet]. 2020 Feb 19;8:14. Available from: http://dx.doi.org/10.3389/fpubh.2020.00014

Mar TF, Koenig JQ. Relationship between visits to emergency departments for asthma and ozone exposure in greater Seattle, Washington. Ann Allergy Asthma Immunol [Internet]. 2009 Dec;103(6):474–9. Available from: http://dx.doi.org/10.1016/S1081-1206(10)60263-3

Martin KL, Hanigan IC, Morgan GG, Henderson SB, Johnston FH. Air pollution from bushfires and their association with hospital admissions in Sydney, Newcastle and Wollongong, Australia 1994-2007. Aust N Z J Public Health [Internet]. 2013 Jun;37(3):238–43. Available from: https://pubmed.ncbi.nlm.nih.gov/23731106/

Martins SS, Ko J, Kuwabara S, Clarke D, Alexandre P, Zandi P, et al. The relationship of adult mental disorders to socioeconomic status, race/ethnicity, marital status, and urbanicity of residence. In: Eaton WW, editor. Public mental health [Internet]. USA: Oxford University Press;2012 Jul. p 151-197. Available from: https://academic.oup.com/book/7515

Matz CJ, Egyed M, Xi G, Racine J, Pavlovic R, Rittmaster R, et al. Health impact analysis of PM2.5 from wildfire smoke in Canada (2013-2015, 2017-2018). Sci Total Environ [Internet]. 2020 Jul 10;725:138506. Available from: https://pubmed.ncbi.nlm.nih.gov/32302851/

McLeod CB, Lavis JN, Mustard CA, Stoddart GL. Income inequality, household income, and health status in Canada: a prospective cohort study. Am J Public Health [Internet]. 2003 Aug;93(8):1287–93. Available from: http://dx.doi.org/10.2105/ajph.93.8.1287

Meade RD, Akerman AP, Notley SR, McGinn R, Poirier P, Gosselin P, et al. Physiological factors characterizing heat-vulnerable older adults: a narrative review. Environ Int [Internet]. 2020 Nov;144:105909. Available from: http://dx.doi.org/10.1016/j.envint.2020.105909

Mehta AJ, Kubzansky LD, Coull BA, Kloog I, Koutrakis P, Sparrow D, et al. Associations between air

pollution and perceived stress: the Veterans administration normative aging study. Environ Health [Internet]. 2015 Jan 27;14(10). Available from: http://dx.doi.org/10.1186/1476-069X-14-10

Mercereau L, Todd N, Rey G, Valleron AJ. Comparison of the temperature-mortality relationship in foreign born and native born died in France between 2000 and 2009. Int J Biometeorol [Internet]. 2017 Oct;61(10):1873–84. Available from: https://pubmed.ncbi.nlm.nih.gov/28540492/

Mirowsky JE, Carraway MS, Dhingra R, Tong H, Neas L, Diaz-Sanchez D, et al. Ozone exposure is associated with acute changes in inflammation, fibrinolysis, and endothelial cell function in coronary artery disease patients. Environ Health [Internet]. 2017 Nov 21;16(126). Available from: http://dx.doi.org/10.1186/s12940-017-0335-0

Mohammadi D, Zare Zadeh M, Zare Sakhvidi MJ. Short-term exposure to extreme temperature and risk of hospital admission due to cardiovascular diseases. Int J Environ Health Res [Internet]. 2021 Apr;31(3):344–54. Available from: https://pubmed.ncbi.nlm.nih.gov/33615930/

Moncur MC, Paktunc D, Jean Birks S, Ptacek CJ, Welsh B, Thibault Y. Source and distribution of naturally occurring arsenic in groundwater from Alberta's southern oil sands regions. Appl Geochem [Internet]. 2015 Nov;62:171–85. Available from: https://www.sciencedirect.com/science/article/pii/S0883292715000554

Morency JD, Malenfant ÉC, MacIsaac S. Immigration and diversity: population projections for Canada and its regions, 2011 to 2036 [Internet]. Statistics Canada; 2017 Jan 25. Available from: https://www150.statcan.gc.ca/n1/en/pub/91-551-x/91-551-x2017001-eng.pdf?st=Ri_b-rZ3

Mudway IS, Kelly FJ. Ozone and the lung: a sensitive issue. Mol Aspects Med [Internet]. 2000;21(1–2):1–48. Available from: http://dx.doi.org/10.1016/s0098-2997(00)00003-0

Müller-Funk L. Research with refugees in fragile political contexts: how ethical reflections impact methodological choices. J Refug Stud [Internet]. 2021 Aug 25;34(2):2308–32. Available from: https://academic.oup.com/jrs/article-pdf/34/2/2308/39903775/feaa013.pdf

Mumby S, Chung KF, Adcock IM. Transcriptional effects of ozone and impact on airway inflammation. Front Immunol [Internet]. 2019 Jul 10;10(1610). Available from: http://dx.doi.org/10.3389/fimmu.2019.01610

Muñoz-Fierro J, Bobadilla-Moreno A, Pérez-Fargallo A. Residential heating use profiles in central-

southern Chile. In: Marín-Restrepo L, Pérez-Fargallo A, Piderit-Moreno MB, Trebilcock-Kelly M, Wegertseder-Martínez P, editors. Removing barriers to environmental comfort in the global south [Internet]. Cham: Springer International Publishing; 2023. p. 401–14. Available from: https://doi.org/10.1007/978-3-031-24208-3_28

Newbold KB. Chronic conditions and the healthy immigrant effect: evidence from Canadian immigrants. J Ethn Migr Stud [Internet]. 2006 Jul;32(5):765–84. Available from: https://doi.org/10.1080/13691830600704149

Newbold KB, Filice JK. Health status of older immigrants to Canada. Can J Aging [Internet]. 2006;25(3):305–19. Available from: http://dx.doi.org/10.1353/cja.2007.0009

Ng E, Zhang H. The mental health of immigrants and refugees: Canadian evidence from a nationally linked database [Internet]. 2020 Aug 19;31(8):3-12. Available from: https://pubmed.ncbi.nlm.nih.gov/32816413/

Niu Y, Zhou Y, Chen R, Yin P, Meng X, Wang W, et al. Long-term exposure to ozone and cardiovascular mortality in China: a nationwide cohort study. Lancet Planet Health [Internet]. 2022 Jun;6(6):e496–503. Available from: http://dx.doi.org/10.1016/S2542-5196(22)00093-6

Noah TL, Worden CP, Rebuli ME, Jaspers I. The effects of wildfire smoke on asthma and allergy. Curr Allergy Asthma Rep [Internet]. 2023 May 12;23:375–87. Available from: http://dx.doi.org/10.1007/s11882-023-01090-1

Nobile F, Forastiere A, Michelozzi P, Forastiere F, Stafoggia M. Long-term exposure to air pollution and incidence of mental disorders. a large longitudinal cohort study of adults within an urban area. Environ Int [Internet]. 2023 Nov;181:108302. Available from: http://dx.doi.org/10.1016/j.envint.2023.108302

Nuotio J, Vähämurto L, Pahkala K, Magnussen CG, Hutri-Kähönen N, Kähönen M, et al. CVD risk factors and surrogate markers - urban-rural differences. Scand J Public Health [Internet]. 2020 Nov;48(7):752–61. Available from: http://dx.doi.org/10.1177/1403494819869816

Nwoke CN, Okpalauwaekwe U, Bwala H. Mental health professional consultations and the prevalence of mood and anxiety disorders among immigrants: multilevel analysis of the Canadian community health survey. JMIR Ment Health [Internet]. 2020 Sep 16;7(9):e19168. Available from:

http://dx.doi.org/10.2196/19168

Nyoka R, Omony J, Mwalili SM, Achia TNO, Gichangi A, Mwambi H. Effect of climate on incidence of respiratory syncytial virus infections in a refugee camp in Kenya: A non-gaussian time-series analysis. PLoS One [Internet]. 2017 Jun 1;12(6):e0178323. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0178323

Ogeyingbo OD, Ahmed R, Gyawali M, Venkatesan N, Bhandari R, Botleroo RA, et al. The relationship between vitamin D and asthma exacerbation. Cureus [Internet]. 2021 Aug 18;13(8):e17279. Available from: http://dx.doi.org/10.7759/cureus.17279

Omariba DWR. Immigration, ethnicity, and avoidable mortality in Canada, 1991-2006. Ethn Health [Internet]. 2015 Jan 8;20(4):409–36. Available from: http://dx.doi.org/10.1080/13557858.2014.995155

Ore OT, Adeola AO. Toxic metals in oil sands: review of human health implications, environmental impact, and potential remediation using membrane-based approach. Energ. Ecol. Environ. [Internet]. 2020 Oct 18;6(2):81–91. Available from: https://doi.org/10.1007/s40974-020-00196-w

Orru H, Ebi KL, Forsberg B. The interplay of climate change and air pollution on health. Curr Environ Health Rep [Internet]. 2017 Dec;4:504–13. Available from: http://dx.doi.org/10.1007/s40572-017-0168-6

Pappin AJ, Christidis T, Pinault LL, Crouse DL, Brook JR, Erickson A, et al. Examining the shape of the association between low levels of fine particulate matter and mortality across three cycles of the Canadian census health and environment cohort. Environ Health Perspect [Internet]. 2019 Oct;127(10):107008. Available from: https://pubmed.ncbi.nlm.nih.gov/31638837/

Peters MDJ, Godfrey CM, McInerney P, Baldini Soares C, Khalil H, Parker D. The joanna briggs institute reviewers' manual 2015: methodology for JBI scoping reviews [Internet]. The University of Adelaide, South Australia: The Joanna Briggs Institute; 2015. Available from: https://repositorio.usp.br/directbitstream/5e8cac53-d709-4797-971f-263153570eb5/SOARES%2C+C+B+doc+150.pdf

Peters A, Schneider A. Cardiovascular risks of climate change. Nat Rev Cardiol [Internet]. 2021 Nov 9;18:1–2. Available from: https://www.nature.com/articles/s41569-020-00473-5

Peters MDJ, Godfrey C, McInerney P, Munn Z, Tricco AC, Khalil, H. Chapter 11: scoping reviews (2020 version). In: Aromataris E MZ, editor. JBI manual for evidence synthesis [Internet]. 2020. Available from: https://synthesismanual.jbi.global. https://doi.org/10.46658/JBIMES-20-12

Petrova NN, Khvostikova DA. Prevalence, structure, and risk factors for mental disorders in older people. Adv Gerontol [Internet]. 2021 Dec 9;11:409–15. Available from: https://doi.org/10.1134/S2079057021040093

Philipneri A, Hanna S, Mandhane PJ, Georgiades K. Association of immigrant generational status with asthma. Can J Public Health [Internet]. 2019 Apr 8;110:462–71. Available from: http://dx.doi.org/10.17269/s41997-019-00201-8

Pinault L, van Donkelaar A, Martin RV. Exposure to fine particulate matter air pollution in Canada. Health Rep [Internet]. 2017 Mar 15;28(3):9–16. Available from: https://pubmed.ncbi.nlm.nih.gov/28295129/

Power MC, Kioumourtzoglou MA, Hart JE, Okereke OI, Laden F, Weisskopf MG. The relation between past exposure to fine particulate air pollution and prevalent anxiety: observational cohort study. BMJ [Internet]. 2015 Mar 24;350:h1111. Available from: http://dx.doi.org/10.1136/bmj.h1111

Preston BL, Yuen EJ, Westaway RM. Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. Sustainability Sci [Internet]. 2011 Mar 24;6:177–202. Available from: https://link.springer.com/article/10.1007/s11625-011-0129-1

Pun VC, Manjourides J, Suh H. Association of ambient air pollution with depressive and anxiety symptoms in older adults: results from the NSHAP study. Environ Health Perspect [Internet]. 2017 Mar;125(3):342–8. Available from: https://pubmed.ncbi.nlm.nih.gov/27517877/

Quick M and Tjepkema M. The prevalence of household air conditioning in Canada. Health rep [Internet]. 2023 Jul 19;34(7). Available from: https://www150.statcan.gc.ca/n1/pub/82-003-x/2023007/article/00002-eng.htm

Radhakrishnan D, Guttmann A, To T, Reisman JJ, Knight BD, Mojaverian N, et al. Generational patterns of asthma incidence among immigrants to Canada over two decades. a population-based cohort study. Ann Am Thorac Soc [Internet]. 2019 Feb;16(2):248–57. Available from: https://pubmed.ncbi.nlm.nih.gov/30395726/

Ravichandiran N, Mathews M, Ryan BL. Utilization of healthcare by immigrants in Canada: a cross-sectional analysis of the Canadian community health survey. BMC Prim Care [Internet]. 2022 Apr 6;23(1). Available from: https://pubmed.ncbi.nlm.nih.gov/35387597/

Renwick KA, Sanmartin C, Dasgupta K, Berrang-Ford L, Ross N. The influence of low social support and living alone on premature mortality among aging Canadians. Can J Public Health [Internet]. 2020 Mar 13;111:594–605. Available from: http://dx.doi.org/10.17269/s41997-020-00310-9

Robert AM, Gilkinson T. Mental health and well-being of recent immigrants in Canada: evidence from the longitudinal survey of immigrants to Canada [Internet]. Citizenship and Immigration Canada; 2012 Nov. Available from: https://www.canada.ca/content/dam/ircc/migration/ircc/english/pdf/research-stats/mental-health.pdf

Roberts S, Arseneault L, Barratt B, Beevers S, Danese A, Odgers CL, et al. Exploration of NO2 and PM2.5 air pollution and mental health problems using high-resolution data in London-based children from a UK longitudinal cohort study. Psychiatry Res [Internet]. 2019 Feb;272:8–17. Available from: http://dx.doi.org/10.1016/j.psychres.2018.12.050

Roche IV, Ubalde-Lopez M, Daher C, Nieuwenhuijsen M, Gascon M. The health-related and learning performance effects of air pollution and other urban-related environmental factors on school-age children and adolescents-a scoping review of systematic reviews. Curr Environ Health Rep [Internet]. 2024 Feb 19;11:300-16. Available from: http://dx.doi.org/10.1007/s40572-024-00431-0

Rocque RJ, Beaudoin C, Ndjaboue R, Cameron L, Poirier-Bergeron L, Poulin-Rheault RA, et al. Health effects of climate change: an overview of systematic reviews. BMJ Open [Internet]. 2021 Jun 9;11(6):e046333. Available from: http://dx.doi.org/10.1136/bmjopen-2020-046333

Rodgers JL, Jones J, Bolleddu SI, Vanthenapalli S, Rodgers LE, Shah K, et al. Cardiovascular risks associated with gender and aging. J Cardiovasc Dev Dis [Internet]. 2019 Apr 27;6(2). Available from: http://dx.doi.org/10.3390/jcdd6020019

Rony MKK, Alamgir HM. High temperatures on mental health: recognizing the association and the need for proactive strategies-a perspective. Health Sci Rep [Internet]. 2023 Dec 4;6(12):e1729. Available from: http://dx.doi.org/10.1002/hsr2.1729

Sahni V, Scott AN, Beliveau M, Varughese M, Dover DC, Talbot J. Public health surveillance response

following the southern Alberta floods, 2013. Can J Public Health [Internet]. 2016 mar 1;107(2):e142–8. Available from: http://dx.doi.org/10.17269/cjph.107.5188

Salami B, Salma J, Hegadoren K. Access and utilization of mental health services for immigrants and refugees: perspectives of immigrant service providers. Int J Ment Health Nurs [Internet]. 2019 Feb;28(1):152–61. Available from: http://dx.doi.org/10.1111/inm.12512

Santamouris M. Chapter 3 – urban heat island and local climate change. In: Santamouris M, editor. Minimizing energy consumption, energy poverty and global and local climate change in the built environment: innovating to zero: causalities and impacts in a zero concept world [Internet]. Elsevier; 2019. p. 65-102. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9780128114179000039?via%3Dihub

Saposnik G, Redelmeier DA, Lu H, Fuller-Thomson E, Lonn E, Ray JG. Myocardial infarction associated with recency of immigration to Ontario. QJM [Internet]. 2010 Apr;103(4):253–8. Available from: http://dx.doi.org/10.1093/qjmed/hcq006

Schneider SR, Lee K, Santos G, Abbatt JPD. Air quality data approach for defining wildfire influence: impacts on $PM_{2.5}$, NO_2, CO, and O_3 in western Canadian cities. Environ Sci Technol [Internet]. 2021 Oct 5;55(20):13709–17. Available from: http://dx.doi.org/10.1021/acs.est.1c04042

Schuurmans J, van Balkom A. Late-life anxiety disorders: a review. Curr Psychiatry Rep [Internet]. 2011 May 3;13:267–73. Available from: http://dx.doi.org/10.1007/s11920-011-0204-4

Schwalfenberg GK, Genuis SJ, Hiltz MN. Addressing vitamin D deficiency in Canada: a public health innovation whose time has come. Public Health [Internet]. 2010 Jun;124(6):350–9. Available from: http://dx.doi.org/10.1016/j.puhe.2010.03.003

Scott KM, McGee MA, Wells JE, Oakley Browne MA. Obesity and mental disorders in the adult general population. J Psychosom Res [Internet]. 2008 Jan;64(1):97–105. Available from: http://dx.doi.org/10.1016/j.jpsychores.2007.09.006

Sebastian SA, Avanthika C, Jhaveri S, Carrera KG, Camacho L GP, Balasubramanian R. The risk of cardiovascular disease among immigrants in Canada. Cureus [Internet]. 2022 Feb 16;14(2):e22300. Available from: http://dx.doi.org/10.7759/cureus.22300

Seltzer J, Bigby BG, Stulbarg M, Holtzman MJ, Nadel JA, Ueki IF, et al. O3-induced change in bronchial

reactivity to methacholine and airway inflammation in humans. J Appl Physiol [Internet]. 1986 Apr 1;60(4):1321–6. Available from: http://dx.doi.org/10.1152/jappl.1986.60.4.1321

Shor E, Roelfs D. Climate shock: moving to colder climates and immigrant mortality. Soc Sci Med [Internet]. 2019 Aug;235:112397. Available from: https://pubmed.ncbi.nlm.nih.gov/31306882/

Siddiqi A, Ornelas IJ, Quinn K, Zuberi D, Nguyen QC. Societal context and the production of immigrant status-based health inequalities: a comparative study of the United States and Canada. J Public Health Policy [Internet]. 2013 Feb 28;34(2):330–44. Available from: http://dx.doi.org/10.1057/jphp.2013.7

Skoog I. Psychiatric disorders in the elderly. Can J Psychiatry [Internet]. 2011 Jul 1;56(7):387–97. Available from: http://dx.doi.org/10.1177/070674371105600702

Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: impacts, adaptation, and co-benefits. In: Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, editors. Climate change 2014 - impacts, adaptation, and vulnerability: part A: global and sectoral aspects [Internet]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014. p. 709–54. Available from: https://researchprofiles.canberra.edu.au/en/publications/human-health-impacts-adaptation-and-co-benefits

Sohail H, Kollanus V, Tiittanen P, Schneider A, Lanki T. Heat, Heatwaves and cardiorespiratory hospital admissions in Helsinki, Finland. Int J Environ Res Public Health [Internet]. 2020 Oct 28;17(21). Available from: http://dx.doi.org/10.3390/ijerph17217892

Sohail QZ, Chu A, Rezai MR, Donovan LR, Ko DT, Tu JV. The risk of ischemic heart disease and stroke among immigrant populations: a systematic review. Can J Cardiol [Internet]. 2015 Sept;31(9):1160–8. Available from: http://dx.doi.org/10.1016/j.cjca.2015.04.027

Somo H, Kurgat A, Kwonyike J. The socio-economic implications of Somali refugees to the host community at the Dadaab refugee camp in Kenya. ASSRJ [Internet]. 2021 Jul 9;8(7):50–70. Available from: https://journals.scholarpublishing.org/index.php/ASSRJ/article/view/10502#:~:text=The%20finding

s%20show%20that%20Somali,to%20Kenya's%20socio%2Deconomic%20development.

Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. Environ Health [Internet]. 2016 Apr 27;15(57). Available from: http://dx.doi.org/10.1186/s12940-016-0142-z

Stanberry LR, Thomson MC, James W. Prioritizing the needs of children in a changing climate. PLoS Med [Internet]. 2018 Jul 31;15(7):e1002627. Available from: http://dx.doi.org/10.1371/journal.pmed.1002627

Statistics Canada. Population and dwelling counts: Canada and census subdivisions (municipalities) [Internet]. 2022 Feb 9 [cited 2024 Mar 14]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810000201

Statistics Canada. Longitudinal immigration database (IMDB) technical report, 2021 [Internet]. 2022 Dec. Available from: https://www150.statcan.gc.ca/n1/en/pub/11-633-x/11-633-x2022009-eng.pdf?st=uHw5aNzK

Statistics Canada. Classification of admission category of immigrant [Internet]. 2022 [cited 2023 May 4]. Available from: https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=323293&CVD=323294&CLV=0&MLV=4&D=1

Statistics Canada. Census profile, 2021 census of population: profile table [Internet]. 2022 [cited 2024 Mar 14]. Available from: https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=Alberta&DGUIDlist=2021A000248&GENDERlist=1,2,3&STATISTIClist=1&HEADERlist=0

Statistics Canada. Mental disorders in Canada, 2022 [Internet]. 2023 Sept 22 [cited 2024 Jan 15]. Available from: https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2023053-eng.htm

Statistics Canada. Immigrant [Internet]. 2023. [cited 2024 May 2]. Available from: https://www23.statcan.gc.ca/imdb/p3Var.pl?Function=Unit&Id=85107

Statistics Canada. Immigrant status of person [Internet]. 2023. Available from: https://www23.statcan.gc.ca/imdb/p3Var.pl?Function=DEC&Id=103339

Statistics Canada. Table 13-10-0096-18 Mood disorders, by age group [Internet]. 2023. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009618&pickMembers%5B0%5D=1.10&pickMembers%5B1%5D=3.1&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2022&referencePeriods=20150101%2C20220101

Statistics Canada. Table 13-10-0096-08 asthma, by age group [Internet]. 2023. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009608&pickMembers%5B0%5D=1.10&pickMembers%5B1%5D=3.1&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2022&referencePeriods=20150101%2C20220101

Statistics Canada. Classification of admission category: 4 – other immigrant [Internet]. [cited 2024 Mar 15]. Available from: https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=323293&CVD=323294&CPV=4&CST=10102023&CLV=1&MLV=4

Stieb DM, Szyszkowicz M, Rowe BH, Leech JA. Air pollution and emergency department visits for cardiac and respiratory conditions: a multi-city time-series analysis. Environ Health [Internet]. 2009 Jun 10;8(25). Available from: http://dx.doi.org/10.1186/1476-069X-8-25

Szyszkowicz M, Zemek R, Colman I, Gardner W, Kousha T, Smith-Doiron M. Air pollution and emergency department visits for mental disorders among youth. Int J Environ Res Public Health [Internet]. 2020 Jun 12;17(12):4190. Available from: http://dx.doi.org/10.3390/ijerph17124190

Tanuseputro P, Manuel DG, Leung M, Nguyen K, Johansen H. Risk factors for cardiovascular disease in Canada. Can J Cardiol [Internet]. 2003 Oct;19(11):1249–59. Available from: https://www.ncbi.nlm.nih.gov/pubmed/14571310

Taylor EV, Vaidyanathan A, Flanders WD, Murphy M, Spencer M, Noe RS. Differences in heat-related mortality by citizenship status: United States, 2005–2014. Am J Public Health [Internet]. 2018 Apr;108(S2):S131–6. Available from: https://pubmed.ncbi.nlm.nih.gov/29072944/

Tenenbaum DJ. Oil sands development: a health risk worth taking? Environ Health Perspect [Internet]. 2009 Apr 1;117(4):A150-6. Available from: http://dx.doi.org/10.1289/ehp.117-a150

Tham EH, Loo EXL, Zhu Y, Shek LPC. Effects of migration on allergic diseases. Int Arch Allergy Immunol [Internet]. 2019;178(2):128–40. Available from: http://dx.doi.org/10.1159/000494129

The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

The Canadian Urban Environmental Health Research Consortium. Canue metadata - air quality fine particulate matter (PM2.5 v5) [Internet]. 2024 Mar 29. Available from: https://www.canuedata.ca/tmp/CANUE_METADATA_PM25DALE_A_YY.pdf

The Canadian Urban Environmental Health Research Consortium. Canue metadata - air quality smoke exposure (PM2.5 v2) [Internet]. 2024 Mar 29. Available from: https://www.canuedata.ca/tmp/CANUE_METADATA_AQSMK_AVB_YY.pdf

The Canadian Urban Environmental Health Research Consortium. Canue metadata - weather climate metrics [Internet]. 2024 Mar 29. Available from: https://www.canuedata.ca/tmp/CANUE_METADATA_WTHNRC_A_YY.pdf

Thomas S, Wannell B. Combining cycles of the Canadian community health survey. Health Rep [Internet]. 2009 Mar;20(1):53–8. Available from: https://www.ncbi.nlm.nih.gov/pubmed/19388369

Tilstra MH, Nielsen CC, Tiwari I, Jones CA, Vargas AO, Quemerais B, et al. Exploring socio-environmental effects on community health in Edmonton, Canada to understand older adult and immigrant risk in a changing climate. Urban Climate [Internet]. 2022 Jul;44:101225. Available from: http://www.sciencedirect.com/science/article/pii/S2212095522001432

Toskala E, Kennedy DW. Asthma risk factors. Int Forum Allergy Rhinol [Internet]. 2015 Sep;5(Suppl 1):S11-6. Available from: http://dx.doi.org/10.1002/alr.21557

Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med [Internet]. 2018 Oct 2;169(7):467–73. Available from: https://pubmed.ncbi.nlm.nih.gov/30178033/

Tu JV, Chu A, Rezai MR, Guo H, Maclagan LC, Austin PC, et al. The incidence of major cardiovascular events in immigrants to Ontario, Canada: the CANHEART immigrant study. Circulation [Internet]. 2015 Aug 31;132(16):1549–59. Available from: http://dx.doi.org/10.1161/CIRCULATIONAHA.115.015345

Vachuska K. Cold weather isolation is worse in poor and non-white neighborhoods in the United States. Prev Med Rep [Internet]. 2023;38:102541. Available from:

http://dx.doi.org/10.1016/j.pmedr.2023.102541

van den Berg AE, Maas J, Verheij RA, Groenewegen PP. Green space as a buffer between stressful life events and health. Soc Sci Med [Internet]. 2010 Apr;70(8):1203–10. Available from: http://dx.doi.org/10.1016/j.socscimed.2010.01.002

Vang ZM, Sigouin J, Flenon A, Gagnon A. Are immigrants healthier than native-born Canadians? a systematic review of the healthy immigrant effect in Canada. Ethn Health [Internet]. 2017 Jun;22(3):209–41. Available from:

Veritas Health Innovation. Covidence systematic review software [Internet]. Melbourne, Australia; 2023. Available from: https://www.covidence.org/

Villa-Torres L, González-Vázquez T, Fleming PJ, González-González EL, Infante-Xibille C, Chavez R, et al. Transnationalism and health: A systematic literature review on the use of transnationalism in the study of the health practices and behaviors of migrants. Soc Sci Med [Internet]. 2017 Jun;183:70–9. Available from: http://dx.doi.org/10.1016/j.socscimed.2017.04.048

Wahba G, Wendelberger J. Some new mathematical methods for variational objective analysis using splines and cross validation. Mon Weather Rev [Internet]. 1980 Aug 1;108(8):1122–43. Available from: https://journals.ametsoc.org/view/journals/mwre/108/8/1520-0493_1980_108_1122_snmmfv_2_0_co_2.xml

Wang X, Lavigne E, Ouellette-kuntz H, Chen BE. Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. J Affect Disord [Internet]. 2014 Feb;155:154–61. Available from: http://dx.doi.org/10.1016/j.jad.2013.10.042

Wang Y, Eliot MN, Koutrakis P, Gryparis A, Schwartz JD, Coull BA, et al. Ambient air pollution and depressive symptoms in older adults: results from the MOBILIZE Boston study. Environ Health Perspect [Internet]. 2014 Jun;122(6):553–8. Available from: https://ehp.niehs.nih.gov/doi/10.1289/ehp.1205909

Wang L, Kwak MJ. Immigration, barriers to healthcare and transnational ties: A case study of South Korean immigrants in Toronto, Canada. Soc Sci Med [Internet]. 2015 May;133:340–8. Available from: http://dx.doi.org/10.1016/j.socscimed.2014.11.039

Wang X, Parisien MA, Taylor SW, Candau JN, Stralberg D, Marshall GA, et al. Projected changes in daily fire spread across Canada over the next century. Environ Res Lett [Internet]. 2017 Feb 2;12:025005. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/aa5835/meta

Wang M, Aaron CP, Madrigano J, Hoffman EA, Angelini E, Yang J, et al. Association between long-term exposure to ambient air pollution and change in quantitatively assessed emphysema and lung function. JAMA [Internet]. 2019 Aug 13;322(6):546–56. Available from: http://dx.doi.org/10.1001/jama.2019.10255

Wang Z, Wang Z, Zou Z, Chen X, Wu H, Wang W, et al. Severe global environmental issues caused by Canada's record-breaking wildfires in 2023. Adv Atmos Sci [Internet]. 2023 Nov 17;41:565-71. Available from: https://doi.org/10.1007/s00376-023-3241-0

Warren FJ, Lemmen DS. Canada in a changing climate: sector perspectives on impacts and adaptation [Internet]. Ottawa, ON: Government of Canada; 2014. 286 p. Available from: https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf

Warren FJ, Lemmen DS. Chapter 1: Introduction. In: Warren FJ, Lemmen DS, editors. Canada in a changing climate: sector perspectives on impacts and adaptation [Internet]. Ottawa, ON: Government of Canada; 2014. P 19-22. Available from: https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Chapter1-Introduction_Eng.pdf

Warren FJ, Lemmen DS. Synthesis. In: Warren FJ, Lemmen DS, editors. Canada in a changing climate: sector perspectives on impacts and adaptation [Internet]. Ottawa, ON: Government of Canada; 2014. p. 1-18. Available from: https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Synthesis_Eng.pdf

Weich S, Twigg L, Lewis G. Rural/non-rural differences in rates of common mental disorders in Britain: prospective multilevel cohort study. Br J Psychiatry [Internet]. 2006 Jan 2;188(1):51–7. Available from: http://dx.doi.org/10.1192/bjp.bp.105.008714

World Health Organization. Ageing: ageism [Internet]. 2021 Mar 18 [cited 2024 May 2]. Available from: https://www.who.int/news-room/questions-and-answers/item/ageing-ageism

World Health Organization. Climate change and health [Internet]. 2021 [cited 2023 Jan 27] . Available

from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

World Health Organization. Ambient (outdoor) air pollution [Internet]. 2022 Dec 19 [cited 2023 Jan 27]. Available from: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

World Health Organization. Wildfires [Internet]. [cited 2024 Mar 20]. Available from: https://www.who.int/health-topics/wildfires

World Health Organization. Air pollution [Internet]. [cited 2023 Jun 8]. Available from: https://www.who.int/health-topics/air-pollution#tab=tab_1

World Health Organization. Climate change [Internet]. [cited 2023 Sept 10]. Available from: https://www.who.int/health-topics/climate-change

Wu Z, Schimmele CM. The Healthy migrant effect on depression: variation over time? CSP [Internet]. 2005;32(2):271–95. Available from: https://journals.library.ualberta.ca/csp/index.php/csp/article/view/15950

Yao J, Eyamie J, Henderson SB. Evaluation of a spatially resolved forest fire smoke model for population-based epidemiologic exposure assessment. J Expo Sci Environ Epidemiol [Internet]. 2014 Oct 8;26:233–40. Available from: http://dx.doi.org/10.1038/jes.2014.67

Yilma M, Regassa N. Gender differentials in internal migration decisions: the case of Dilla Town, Southern Ethiopia. Kontakt [Internet]. 2019 Sep 18;21(3):312–9. Available from: http://dx.doi.org/10.32725/kont.2019.026

Yoo EH, Eum Y, Gao Q, Chen K. Effect of extreme temperatures on daily emergency room visits for mental disorders. Environ Sci Pollut Res Int [Internet]. 2021 Mar 22;28:39243–56. Available from: http://dx.doi.org/10.1007/s11356-021-12887-w

Yoo EH, Eum Y, Roberts JE, Gao Q, Chen K. Association between extreme temperatures and emergency room visits related to mental disorders: a multi-region time-series study in New York, USA. Sci Total Environ [Internet]. 2021 Oct 20;792:148246. Available from: http://dx.doi.org/10.1016/j.scitotenv.2021.148246

Young AJ, Lee DT. Aging and human cold tolerance. Exp Aging Res [Internet]. 1997 Jan-Mar;23(1):45–67. Available from: https://pubmed.ncbi.nlm.nih.gov/9049612/

Yu W, Weitzman M. Climate change, air pollution, and children's mental health. J Appl Res Child [Internet]. 2021;12(1). Available from: https://digitalcommons.library.tmc.edu/childrenatrisk/vol12/iss1/13/

Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. Lancet [Internet]. 2020 Mar 7;395(10226):795–808. Available from: http://dx.doi.org/10.1016/S0140-6736(19)32008-2

Zhang X, Flato G, Kirchmeier-Young M, Vincent L, Wan H, Wang X, et al. Changes in temperature and precipitation across Canada. In: Lemmen DS, Bush E, editors. Canada's changing climate report [Internet]. Ottawa, ON: Government of Canada; 2019. p. 112–93. Available from: https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf

Zhang Y, Mavoa S, Zhao J, Raphael D, Smith M. The association between green space and adolescents' mental well-being: a systematic review. Int J Environ Res Public Health [Internet]. 2020 Sept 11;17(18):6640. Available from: http://dx.doi.org/10.3390/ijerph17186640

Zhang YL, Cao F. Fine particulate matter (PM 2.5) in China at a city level. Sci Rep [Internet]. 2015 Oct 15;5(14884). Available from: http://dx.doi.org/10.1038/srep14884

Zhao D, Zhang X, Xie M, Cheng J, Zhang H, Wang S, et al. Is greater temperature change within a day associated with increased emergency admissions for schizophrenia? Sci Total Environ [Internet]. 2016 Oct 1;566–567:1545–51. Available from: http://dx.doi.org/10.1016/j.scitotenv.2016.06.045

Zhou Y, Liu J. Air pollution and mental health of older adults in China. Sustain Sci Pract Policy [Internet]. 2020 Jan 28;12(3):950. Available from: https://www.mdpi.com/2071-1050/12/3/950

Zhu L, Liao H, Hou B, Cheng L, Li H. The status of household heating in northern China: a field survey in towns and villages. Environ Sci Pollut Res Int [Internet]. 2020 Feb 27;27:16145–58. Available from: http://dx.doi.org/10.1007/s11356-020-08077-9

Zundel CG, Ryan P, Brokamp C, Heeter A, Huang Y, Strawn JR, et al. Air pollution, depressive and anxiety disorders, and brain effects: a systematic review. Neurotoxicology [Internet]. 2022 Dec;93:272–300. Available from: http://dx.doi.org/10.1016/j.neuro.2022.10.011

Appendices

Appendix 1: Protocol and Detailed Search Strings for Scoping Review

Health-Related Impacts of Climate Change and Air Pollution on Immigrants Globally: A Scoping Review Protocol

Introduction

Globally, human health is influenced by climate change and air pollution exposures. However, certain populations, such as immigrants, may be more vulnerable than others [1]. After immigrating, the health of immigrants tends to decline over time, known as the healthy migrant effect [2]. For example, immigrants are more likely than native-born Canadians to experience socio-economic challenges such as unemployment, poverty, a lack of access to basic services and decreased support from their community [3]. Immigrants also experience social, cultural and environmental changes, such as adjustment to a new language, diet, climate and new values and ways of life [3,4]. Additionally, certain age groups of immigrants may be more vulnerable than others [5]**.** Children under the age of 18 have different immune responses, anatomy and cognitive ability compared to adults, and as a result, may be more vulnerable to the direct and indirect effects of air pollution and climate change exposures [6,7]. Adults over the age of 65 also tend to have weaker immune systems, poor physiological reserves and slow metabolism, among other factors, which may make them more vulnerable [8]. These factors can increase vulnerability among older and younger immigrant populations, putting immigrants at higher risk for health-related impacts of climate change and air pollution exposures, such as respiratory (asthma, bronchitis, rhinitis), cardiovascular (stroke, ischaemic heart disease) and mental health problems (anxiety, depression, post-traumatic stress disorder) among others [9-11]. Given that the immigrant population in Canada is expected to increase to 24.5-30% between 2011 and 2036, this is a gap in the literature that needs to be analyzed [12,13].

Objective

This scoping review aims to examine previous research to determine the health-related impacts of climate change and air pollution exposures on immigrant populations.

Research Questions

1. Within existing literature, what health-related impacts of air pollution (e.g., NO_2, O_3 and $PM_{2.5}$) and climate change (e.g., wildfires, extreme temperatures and floods) exposures on immigrant populations (children <18 years or older adults $\geq$65 years) have been reported globally?

2. Within existing literature, do the impacts of these exposures on immigrants vary by age group (children <18 years or older adults ≥65 years), immigrant category (refugee, economic immigrant, immigrant sponsored by family, other), gender (woman vs man) or geographical location (rural vs urban locations)?

Methods

In this scoping review, the framework outlined in the Joanna Briggs Institute Reviewer's Manual will be followed [14]. This includes determining the research question and relevant studies, selecting the study, charting the data and reporting the results [14]. This framework was first proposed by Arksey and O'Malley in 2005, and refined further by Levac, Colquhoun and O'Brien in 2010 [15,16]. Additionally, the PRISMA extension for scoping review guidelines will be followed [17]. The reference lists of relevant articles will also be analyzed for articles that meet the inclusion criteria. The screening process will be done independently by two different reviewers, with conflicts resolved by consensus.

Search Methods

A search will be executed by an expert searcher/health librarian (SC) on the following databases: PROSPERO, OVID Medline, OVID EMBASE, Wiley Cochrane Library (CDSR and Central), Proquest Dissertations and Theses Global and SCOPUS using controlled vocabulary (eg: MeSH, Emtree, etc) and filters will be applied for the key concepts "climate change" [18–21], "air pollution" [22–25], and "immigrants" [26-28]. Searches will be limited to adults 65 years and older and children and adolescents younger than 18. Databases will be searched from inception to July, 2022. Results (2378) will be exported to COVIDENCE review management software, where duplicates (934) will be removed. Detailed search strings are available in Table A1.

Screening

Restrictions

- An age restriction will be placed on the population of interest. Immigrants between the ages of 18 and 64 will not be included.
- No language restrictions.
- No time frame restrictions.

- No geographical restrictions

Level 1 screening

- The titles and abstracts will be screened using predetermined questions and completed by 2 independent reviewers.

- Articles that completely or partly meet the inclusion criteria (answered yes or maybe) will proceed to level 2 screening.

- If any of the exclusion criteria are identified it will not proceed to level 2 screening and be confirmed by a second independent reviewer.

- Google translate will be used to translate non-English titles and abstracts for screening.

Level 2 screening

- The complete articles will be screened based on inclusion and exclusion criteria.

- Any articles that completely meet the inclusion criteria (answered yes) will be included in the results.

Inclusion criteria

- Types of evidence source: reviews (scoping, systematic, clinical), books, descriptive (case report, case series and ecological studies) and analytical (case-control, cross-sectional and cohort studies) studies.

- Time frame: All time frames will be included.

- Population: Any population as long as immigrants (children <18 years or older adults ≥65 years) are included.

    - Immigrant is defined as a person who has chosen to leave their country of origin and is or has been a landed immigrant, permanent resident, or a citizen through naturalization [29,30].

    - Refugee is defined as a person who left their country for safety [30].

- Geography: All research globally will be included.

- Languages: All languages will be included.

- All research that focuses on the health-related impacts of climate change and air pollution exposures on immigrant populations.

    - Climate change is defined as a change in climate that lasts for a prolonged period, usually decades or longer, and can be a result of natural forces or anthropogenic changes [31].

    - Ambient air pollution is defined by the World Health Organization as a mixture of air pollutants from vehicles, industries and households that people are exposed to outdoors [32].

Exclusion criteria

- Types of evidence source: letters, articles without peer-reviews, editorials, case studies/reports, theses, dissertations, and grey literature.

- Time frame: No time frames will be excluded.

- Population: Populations that do not include immigrants (children <18 years or older adults ≥65 years) as a primary focus or as a subgroup.

- Geography: No research will be excluded based on location.

- Languages: No languages will be excluded.

- Research that examines the health of immigrant populations unrelated to climate change and air pollution exposures.

- Research that examines climate change and air pollution exposures in a topic unrelated to health.

Screening questions

Level 1 screening will include answering the following questions for each title and/or abstract:

1. Does the research focus on immigrant populations (children <18 years or older adults ≥65 years)?
    - Yes
    - No
    - Maybe

2. Does the research focus on exposure to climate change and/or air pollution variables?
    - Yes
    - No
    - Maybe

3. Does the research focus on the health-related impacts of climate change and/or air pollution exposures?
    - Yes
    - No
    - Maybe

Level 2 screening will include answering the following questions for each complete article:

1. Does the research focus on immigrant populations (children <18 years or older adults ≥65 years)?
    - Yes
    - No

2. Does the research focus on exposure to climate change and/or air pollution variables?
    - Yes
    - No

3. Does the research focus on the health-related impacts of climate change and/or air pollution exposures?
    - Yes
    - No

Data collection and analysis

Software

For this scoping review, Covidence will be used to manage the article results and remove duplicates.

Data Extraction

The following data will be extracted from each article using Covidence data extraction 2.0. Fields recommended by JBI for extraction were used and expanded upon [33]. Additional fields may be added if necessary.

1. Author(s)
2. Title
3. Year of publication
4. Journal
5. Objective
6. Country that study was conducted in
7. Setting (Rural or urban)
8. Study population
9. Sample size
10. Gender (male or female)
11. Age breakdown
12. Data source (primary or secondary)
13. Immigrant category (refugee, economic immigrant, immigrant sponsored by family, other)
14. Length of residence (less than 10 years or greater than or equal to 10 years)
15. Study design
16. Type of analyses
17. Climate and air pollution exposure variable(s)
18. How climate and air pollution exposure variables were defined
19. Health outcome(s)
20. How health outcomes were measured
21. Did the study look at age/gender/immigrant category differences?
22. If yes to 19, what were the interactions and results?
23. Key findings on health-related impacts of climate change and air pollution exposures

Presentation

Data that is extracted will be presented in a table, and the research questions will be addressed. Data will be analyzed narratively.

References

1. Hathaway J, Maibach EW. Health implications of climate change: a review of the literature about the perception of the public and health professionals. Curr Environ Health Rep [Internet]. 2018 Feb 8;5:197–204. Available from: http://dx.doi.org/10.1007/s40572-018-0190-3

2. Vang ZM, Sigouin J, Flenon A, Gagnon A. Are immigrants healthier than native-born Canadians? a systematic review of the healthy immigrant effect in Canada. Ethn Health [Internet]. 2017;22(3):209–41. Available from: http://dx.doi.org/10.1080/13557858.2016.1246518

3. Beiser M. The health of immigrants and refugees in Canada. Can J Public Health [Internet]. 2005 Mar-Apr;96 Suppl 2:S30-44. Available from: https://pubmed.ncbi.nlm.nih.gov/16078554/

4. Shor E, Roelfs D. Climate shock: moving to colder climates and immigrant mortality. Soc Sci Med [Internet]. 2019 Aug;235:112397. Available from: https://pubmed.ncbi.nlm.nih.gov/31306882/

5. Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. J Occup Environ Med [Internet]. 2009 Jan;51(1):33–7. Available from: http://dx.doi.org/10.1097/JOM.0b013e318193e12e

6. Stanberry LR, Thomson MC, James W. Prioritizing the needs of children in a changing climate. PLoS Med [Internet]. 2018 Jul 31;15(7):e1002627. Available from: http://dx.doi.org/10.1371/journal.pmed.1002627

7. Yu W, Weitzman M. Climate change, air pollution, and children's mental health. J Appl Res Child [Internet]. 2021;12(1). Available from: https://digitalcommons.library.tmc.edu/childrenatrisk/vol12/iss1/13/

8. Carnes BA, Staats D, Willcox BJ. Impact of climate change on elder health. J Gerontol A Biol Sci Med Sci [Internet]. 2014 Sep;69(9):1087–91. Available from: http://dx.doi.org/10.1093/gerona/glt159

9. Orru H, Ebi KL, Forsberg B. The interplay of climate change and air pollution on health. Curr Environ Health Rep [Internet]. 2017 Dec;4:504–13. Available from: http://dx.doi.org/10.1007/s40572-017-0168-6

10. Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. Climate change and mental health: risks, impacts and priority actions. Int J Ment Health Syst [Internet]. 2018 Jun 1;12(28). Available from: http://dx.doi.org/10.1186/s13033-018-0210-6

11. Khraishah H, Alahmad B, Ostergard RL Jr, AlAshqar A, Albaghdadi M, Vellanki N, et al. Climate change and cardiovascular disease: implications for global health. Nat Rev Cardiol [Internet]. 2022 Jun 7;19:798-812. Available from: http://dx.doi.org/10.1038/s41569-022-00720-x

12. Government of Canada, Canada S. Population Projections for Canada and its Regions, 2011 to 2036 [Internet]. 2017 [cited 2022 Jun 8]. Available from: https://www150.statcan.gc.ca/n1/pub/91-551-x/91-551-x2017001-eng.htm

13. Government of Canada. Census profile, 2016 census [Internet]. 2017. Available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/Page.cfm?Lang=E&Geo1=PR&Code1=48&Geo2=&Code2=&SearchText=Alberta&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=48&type=0

14. Peters MDJ, Godfrey CM, McInerney P, Baldini Soares C, Khalil H, Parker D. The joanna briggs institute reviewers' manual 2015: methodology for JBI scoping reviews [Internet]. The University of Adelaide, South Australia: The Joanna Briggs Institute; 2015. Available from:

https://repositorio.usp.br/directbitstream/5e8cac53-d709-4797-971f-263153570eb5/SOARES%2C+C+B+doc+150.pdf

15. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol [Internet]. 2005 Feb23;8(1):19–32. Available from: https://doi.org/10.1080/1364557032000119616

16. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci [Internet]. 2010 Sep 20;5. Available from: https://pubmed.ncbi.nlm.nih.gov/20854677/

17. Rethlefsen ML, Kirtley S, Waffenschmidt S, Ayala AP, Moher D, Page MJ, et al. PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews. Syst Rev [Internet]. 2021 Jan 26;10(39). Available from: http://dx.doi.org/10.1186/s13643-020-01542-z

18. Campbell SM. Hedge to retrieve articles related to climate change in OVID medline [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/11s673QzBiO4uqX2TwxukFgPzRYa6sT5Jt47BsFN2yyU/edit#

19. Campbell SM. Hedge to retrieve articles related to climate change in OVID EMBASE [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/17W7bVIeG4xEUKpi3m1tll8oCYtPXTlSJasfMCt-fFNY/edit#

20. Campbell SM. Hedge to retrieve articles related to climate change in EBSCO CINAHL [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1BbD7ArMV7wjcYKIoof8ehE_Url0xqDxsSo4_VAwgg9Q/edit#

21. Dennett EL, Campbell SM. A hedge to retrieve studies related to climate change from the SCOPUS database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1fVtBDWZE36okUcWzNGOQwYSAVGH69QhWlumaVe88BpI/edit

22. Campbell SM. Hedge to retrieve articles related to air pollution in OVID medline [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2021. Available from: https://docs.google.com/document/d/1gGY4q7orPUSMhttBBnz5KsOKv5ZCSErkvg-hlBbSorM/edit

23. Campbell SM. Hedge to retrieve articles related to air pollution in OVID EMBASE [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2021. Available from: https://docs.google.com/document/d/1EbeATCMKWmwzyV79SF97ahnkq4pEedcPLSZkSt-F7W4/edit

24. Campbell SM. Hedge to retrieve articles related to air pollution in EBSCO CINAHL [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1OLx0u_a7kChVKUJihLvBWN5nkCxtIANJX2GICrL1v6A/edit

25. Campbell SM. Hedge to retrieve articles related to air pollution in SCOPUS [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1oo3Daq3GWOsjqLhTdBBn2Bfyvk91jX28XhmxUquymbk/edit

26. Campbell SM. A filter to retrieve studies related to refugees/immigrants from the OVID medline database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2020. Available from: https://docs.google.com/document/d/13CDD4zA_T2nTHO_fAQ-m1vcLr8Nmuw7rnZ2BbXSbO0k/edit

27. Campbell SM. A filter to retrieve studies related to refugees/immigrants from the OVID EMBASE database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available

from: https://docs.google.com/document/d/19cvUcFhv-n5dzJ-EDaRZA0DzSMZWkicWRMCH9KBu3Nk/edit

28. Campbell SM. A filter to retrieve studies related to refugees/immigrants from the EBSCO CINAHL database [Internet]. John W. Scott Health Sciences Library, University of Alberta; 2022. Available from: https://docs.google.com/document/d/1gVj-jQdv8ddWCVmIQgpStoPPoNs6hMWvYDHIgUacEg8/edit

29. Statistics Canada. Immigrant status of person [Internet]. 2023. Available from: https://www23.statcan.gc.ca/imdb/p3Var.pl?Function=DEC&Id=103339

30. Government of Canada. How Canada's refugee system works [Internet]. 2024. Available from: https://www.canada.ca/en/immigration-refugees-citizenship/services/refugees/canada-role.html

31. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: impacts, adaptation, and co-benefits. In: Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, editors. Climate change 2014 - impacts, adaptation, and vulnerability: part A: global and sectoral aspects [Internet]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014. p. 709–54. Available from: https://researchprofiles.canberra.edu.au/en/publications/human-health-impacts-adaptation-and-co-benefits

32. World Health Organization. Ambient air pollution [Internet]. Available from: https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/ambient-air-pollution

33. Peters A, Schneider A. Cardiovascular risks of climate change. Nat Rev Cardiol [Internet]. 2021 Nov 9;18:1–2. Available from: https://www.nature.com/articles/s41569-020-00473-5

Table A1 Detailed Search Strings

Ovid MEDLINE(R) ALL <1946 to July 08, 2022>

#	Search Statement	Results
1	carbon cycle/ or carbon sequestration/ or climate change/ or global warming/ or droughts/ or El Nino-Southern Oscillation/ or floods/ or greenhouse effect/ or Hot Temperature/ or ("Arctic amplification" or "Arctic shrinkage" or "carbon footprint" or "carbon offset*" or "carbon sequestration" or "carbon sink" or "carbon sinks" or (chlorofluorocarbon* adj2 (release or concentration* or atmosphere*)) or (climate adj2 (change* or model?ing or predict* or resilience or sensitivity)) or deglaciation or desertification or "natural disaster*" or drought or (earth adj2 warming) or El Nino or La Nina or "emissions reduc*" or "emissions trading" or flood* or ((glacial or galcier) adj3 (retreat* or melt*)) or "global radiation" or "global temperature*" or "global warming" or "greenhouse effect" or "greenhouse gas" or "heat wave*" or hurricane* or "ice cap melt*" or "ice mass loss*" or "Kyoto Protocol" or "landslide*" or "land slide*" or "mudslide*" or "mud slide*" or (ozone adj2 hole) or "Paris Accord" or "permafrost melt*" or "polar amplification" or "polar ice melt*" or "sea ice shrinkage" or "sea level rise*" or "sea surface warming" or "storm surge*" or "thermohaline circulation" or ((extreme or severe or destructive) adj2 (temperature* or weather* or storm* or hail or wind*)) or tornado* or typhoon* or wildfire* or "wild fire*").mp.	263091
2	exp Air Pollution/ or Traffic-Related Pollution/ or greenhouse gases/ or stratospheric ozone/ or ((gases/ or ammonia/ or carbon dioxide/ or carbon monoxide/ or chlorine/ or greenhouse gases/ or hydrogen sulfide/ or nitrogen/ or nitrogen oxides/ or nitrogen dioxide/ or nitrous oxide/ or ozone/ or sulfur dioxide/ or carbon monoxide*.mp. or hydrogen sulfide*.mp. or hydrogen sulphide*.mp. or H2S.mp. or nitrogen oxide*.mp. or volatile organic*.mp. or voc.mp. or nox.mp. or sulfur dioxide*.mp. or SO2.mp. or sulfur oxide*.mp. or sulphur dioxide*.mp. or sulphur oxide*.mp.) and (exp Pollution/ or pollut*.mp. or emit*.mp. or emission*.mp. or contaminat*.mp. or decontaminat*.mp.)) or ((air or atmospher*) adj3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)).mp. or ((gas or gases) adj3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)).mp. or (acid* adj3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)).mp. or afterburning.mp. or biogas.mp. or (burning adj3 fossil fuel*).mp. or ((chimney or stack) adj3 height).mp. or dust.mp. or fallout.mp. or fall out.mp. or flaring.mp. or fly ash.mp. or electrosmog.mp. or (greenhouse adj3 (gas or effect or effects or gases or emission*)).mp. or incineration.mp. or odor.mp. or odour.mp. or olfactory pollution.mp. or particulate*.mp. or smog.mp. or smoke.mp. or soot.mp. or sick building syndrome.mp. or vapo?r recovery system*.mp. or ((industrial or automobile* or traffic or freeway or highway or roadway or motorway or diesel or vehicle* or diesel or truck or trucks or lorry or lorries or taxi or taxis or tailpipe* or roadside* or "road side*" or autobus* or bus or buses) adj3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	363940
3	1 or 2	600176
4	exp "Emigration and Immigration"/	26029
5	exp Refugee Camps/	267
6	exp "Emigrants and Immigrants"/ or Refugees/ or (immigrant* or immigration or emigrant*	94131

	or emigration or refugee* or "asylum seeker*" or asylee* or "displaced person*" or "displaced people" or "incomer*" or "in comer*" or "new comer*" or newcomer* or (migrant* not "internal migra*") or resettler*).mp.	
7	4 or 5 or 6	94131
8	3 and 7 [(climate change OR air pollution) AND immigrants]	2120
9	exp Animals/ not (exp Animals/ and Humans/)	5025514
10	(sheep or sheep or ovine or pig or piglets or pigs or porcine or dog or dogs or canine or cat or cats or kitten* or feline or rabbit* or rodent* or mice or mouse or rat or rats or murine or bird or birds or fish or fishes).mp.	5104397
11	(sheep or sheep or ovine or pig or piglets or pigs or porcine or dog or dogs or canine or cat or cats or kitten* or feline or rabbit* or rodent* or mice or mouse or rat or rats or murine or bird or birds or fish or fishes).mp. and (exp humans/ or (human or humans).ti,ab,kw.)	1529565
12	10 not 11	3574832
13	9 or 12	5275881
14	8 not 13	1700
15	limit 14 to "all aged (65 and over)" or limit 14 to "all child (0 to 18 years)"	414
16	exp Child/ or "Congenital, Hereditary, and Neonatal Diseases and Abnormalities"/ or exp infant/ or adolescent/ or exp pediatrics/ or child, abandoned/ or exp child, exceptional/ or child, orphaned/ or child, unwanted/ or minors/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre-term or preterm* or premature birth* or NICU or preschool* or pre-school* or kindergarten* or kindergarden* or elementary school* or nursery school* or (day care* not adult*) or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or pre-pubesc* or prepubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn.	4959530
17	exp Geriatrics/ or exp Aged/ or Health Services for the Aged/ or Senior Centers/ or (elders or elderly or geriatric* or "gerontolog* old age" or (seniors not "high school") or (older adj3 (adult*or person* or people or man or men or woman or women)) or centenarian* or nonagenarian* or octogenarian* or septuagenarian* or sexagenarian* or dottering or decrepit or tottering or overaged or "oldest old" or supercentenarian*).mp.	3537660
18	16 or 17	7776213
19	1 and 7 and 18	265
20	15 or 19	516
21	remove duplicates from 20	515

Embase <1974 to 2022 July 08>

#	Search Statement	Results

1	exp carbon cycle/ or exp carbon footprint/ or exp carbon sequestration/ or exp climate change/ or exp global warming/ or exp desertification/ or exp deglaciation/ or exp drought/ or exp El Nino/ or exp flooding/ or exp greenhouse effect/ or high temperature/ or exp sea level rise/ or exp sea surface temperature/ or exp storm surge/ or severe weather/ or "cold wave (weather)"/ or extreme weather/ or heat wave/ or hurricane/ or "storm (weather)"/ or tornado/ or wildfire/ or ("Arctic amplification" or "Arctic shrinkage" or "carbon footprint" or "carbon offset*" or "carbon sequestration" or "carbon sink" or "carbon sinks" or (chlorofluorocarbon* adj2 (release or concentration* or atmosphere*)) or (climate adj2 (change* or model?ing or predict* or resilience or sensitivity)) or deglaciation or desertification or "natural disaster*" or drought or (earth adj2 warming) or "emissions reduc*" or "emissions trading" or flood* or ((glacial or glacier) adj3 (retreat* or melt*)) or "global radiation" or "global temperature*" or "global warming" or "greenhouse effect" or "greenhouse gas" or "heat wave*" or hurricane* or "ice cap melt*" or "ice mass loss*" or "Kyoto Protocol" or "landslide*" or "land slide*" or "mudslide*" or "mud slide*" or (ozone adj2 hole) or "Paris Accord" or "permafrost melt*" or "polar amplification" or "polar ice melt*" or "sea ice shrinkage" or "sea level rise*" or "sea surface warming" or "storm surge*" or "thermohaline circulation" or ((extreme or severe or destructive) adj2 (temperature* or weather* or storm* or hail or wind*)) or tornado* or typhoon* or wildfire* or "wild fire*").mp. or (("El Nino" or "La Nina").mp. not spanish.lg.)	201178
2	((exp air pollution/ or traffic pollution/ or (gas/ or ammonia/ or "gases, fumes, vapors and related phenomena"/ or carbon dioxide/ or carbon monoxide/ or chlorine dioxide/ or exp metal oxide/ or nitric oxide/ or nitrogen dioxide/ or nitrogen oxide/ or nitrous oxide/ or sulfur dioxide/ or sulfur oxide/ or (carbon dioxide* or carbon monoxide* or hydrogen sulfide* or hydrogen sulphide* or H2S or nitrogen oxide* or peroxyacetylnitrate or volatile organic* or voc or nox or sulfur dioxide* or SO2 or sulfur oxide* or sulphur dioxide* or sulphur oxide*).mp.)) and (exp Pollution/ or (pollut* or emit* or emission* or contaminat* or decontaminat*).mp.)) or ((air or atmospher*) adj3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)).mp. or ((gas or gases) adj3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)).mp. or (acid* adj3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)).mp. or afterburning.mp. or biogas.mp. or (burning adj3 fossil fuel*).mp. or ((chimney or stack) adj3 height).mp. or dust.mp. or fallout.mp. or fall out.mp. or flaring.mp. or fly ash.mp. or electrosmog.mp. or (greenhouse adj3 (gas or effect or effects or gases or emission*)).mp. or incineration.mp. or odor.mp. or odour.mp. or olfactory pollution.mp. or particulate*.mp. or smog.mp. or smoke.mp. or soot.mp. or "sick building syndrome".mp. or vapo?r recovery system*.mp. or ((industrial or automobile* or traffic or freeway* or highway* or roadway* or motorway* or diesel or vehicle* or truck or trucks or lorry or lorries or taxi or taxis or tailpipe* or roadside* or "road side*" or autobus* or bus or buses) adj3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]	533677
3	exp refugee camp/ or exp refugee/ or Immigrant/ or Emigrant/ or (immigrant* or immigration or emigrant* or emigration or refugee* or "asylum seeker*" or asylee* or "displaced person*" or "displaced people" or "incomer*" or "in comer*" or "new comer*" or newcomer* or resettler*).mp. or ((exp migrant/ or migrant*.mp.) not internal*.mp.)	92295
4	1 or 2	686180
5	3 and 4	2357
6	limit 5 to (embryo <first trimester> or infant <to one year> or child <unspecified age> or	286

	preschool child <1 to 6 years> or school child <7 to 12 years> or adolescent <13 to 17 years>)	
7	5	2357
8	limit 7 to aged <65+ years>	165
9	6 or 8	396
10	juvenile/ or exp adolescent/ or exp child/ or exp postnatal development/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre term or preterm* or premature birth or NICU or preschool* or pre school* or kindergarten* or elementary school* or nursery school* or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or prepubesc* or pre pubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn.	5207454
11	exp geriatrics/ or aged/ or aged hospital patient/ or exp elderly care/ or frail elderly/ or gerontology/ or institutionalized elderly/ or very elderly/ or ("aging in place" or elders or elderly or geriatric* or gerodontic* or gerontol* or old age or (seniors not "high school") or (older adj3 (adult* or person* or people or man or men or woman or women)) or centenarian* or nonagenarian* or octogenarian* or septuagenarian* or sexagenarian* or dottering or decrepit or tottering or overaged or "oldest old" or supercentenarian*).mp.	3626113
12	10 or 11	8307342
13	5 and 12	601
14	9 or 13	601
15	remove duplicates from 14	595

EBSCO CINAHL Plus Full Text
Search Modes: Search all my search terms.
Search History

#	Query	Results
S1	(MH "Climate Change+") OR (MH "Sea Level Rise") OR (MH "Greenhouse Effect") OR (MH "Carbon Footprint") OR (MH "Natural Disasters+") OR(MH "Extreme Weather") OR (MH "Wildfires") or ("Arctic amplification" or "Arctic shrinkage" or "carbon footprint" or "carbon offset*" or "carbon sequestration" or "carbon sink" or "carbon sinks" or (chlorofluorocarbon* N2 (release or concentration* or atmosphere*)) or (climate N2 (change* or model* or predict* or resilience or sensitivity)) or deglaciation or desertification or "natural disaster*" or drought or (earth N2 warming) or "emissions reduc*" or "emissions trading" or flood* or ((glacial or glacier) n3 (retreat* or melt*)) or "global radiation" or "global temperature*" or "global warming" or "greenhouse effect" or "greenhouse gas" or "heat wave*" or hurricane* or "ice cap melt*" or "ice mass loss*" or "Kyoto Protocol" or "landslide*" or "land slide*" or "mudslide*" or "mud slide*" or (ozone N2 hole) or "Paris Accord" or "permafrost melt*" or "polar amplification" or "polar ice melt*" or "sea ice	27,014

	shrinkage" or "sea level rise*" or "sea surface warming" or "storm surge*" or "thermohaline circulation" or ((extreme or severe or destructive) N2 (temperature* or weather* or storm* or hail or wind*)) or tornado* or typhoon* or wildfire* or "wild fire*")	
S2	(MH "Air Pollution") OR (MH "Air Pollution, Indoor") OR (MH "Motor Vehicle Emissions") OR (MH "Dust") OR (MH "Microparticles") OR (MH "Smog") OR (MH "Smoke") OR (MH "Traffic Pollution+") OR (MH "Particulate Matter") OR (MH "Air Pollutants") OR (MH "Air Pollutants, Environmental") OR (MH "Air Pollutants, Occupational") OR (MH "Air Pollutants, Radioactive") or (((carbon monoxide* or hydrogen sulfide* or hydrogen sulphide* or H2S or nitrogen oxide* or volatile organic* or voc or nox or sulfur dioxide* or sulfur oxide* or sulphur dioxide* or sulphur oxide*) and (pollut* or emit* or emission* or contaminat* or decontaminat*)) or ((air or atmospher*) N/3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)) or ((gas or gases) N/3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)) or (acid* N/3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)) or afterburning or biogas or (burning adj3 fossil fuel*) or ((chimney or stack) N/3 height) or dust or fallout or fall out or flaring or fly ash or electrosmog or (greenhouse N/3 (gas or effect or effects or gases or emission*)) or incineration or odor or odour or olfactory pollution or particulate* or smog or smoke or soot or sick building syndrome or vapo?r recovery system* or ((industrial or automobile* or traffic or freeway or highway or roadway or motorway or diesel or vehicle*) N/3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)))	45,407
S3	S1 OR S2	71,423
S4	(MH "Refugees+") OR (MH "Immigrants") OR (MH "Undocumented Immigrants")	25,094
S5	(MH "Emigration and Immigration") OR (MH "Relocation") OR (MH "Transients and Migrants")	14,334
S6	(immigrant* or immigration or emigrant* or emigration or refugee* or "asylum seeker*" or asylee* or "displaced person*" or "displaced people" or "incomer*" or "in comer*" or "new comer*" or newcomer* or (migrant* not "internal migrant*") or resettler*)	46,368
S7	S4 OR S5 OR S6	48,122
S8	S3 AND S7	830
S9	S3 AND S7 [**Narrow by SubjectAge:** - all child]	189
S10	S3 AND S7 [**Narrow by SubjectAge:** - aged: 65+ years]	116
S11	S9 OR S10	273

SCOPUS Searched July 12, 2022 Result = 839

((TITLE-ABS-KEY (immigrant* OR immigration OR emigrant* OR emigration OR refugee* OR {asylum seeker*} OR asylee* OR {displaced person*} OR {displaced people} OR "incomer*" OR {in comer*} OR {new comer*} OR newcomer* OR migrant* OR resettler*)) AND (TITLE-ABS-KEY (elders OR elderly OR geriatric* OR {old age} OR {senior citizens} OR {older adult*} OR

centenarian* OR nonagenarian* OR octogenarian* OR septuagenarian* OR sexagenarian* OR dottering OR (decrepit W/3 (person OR persons OR people OR patient*)) OR tottering OR overaged OR {oldest old} OR pediatric* OR paediatric* OR child* OR grandchild* OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat* OR pre-term OR preterm* OR {premature birth*} OR nicu OR preschool* OR pre-school* OR kindergarten* OR kindergarden* OR {elementary school*} OR {nursery school*} OR {day care*} OR daycare* OR schoolchild* OR toddler* OR boy OR boys OR girl* OR {middle school*} OR pubescen* OR juvenile* OR teen* OR youth* OR {high school*} OR adolesc* OR pre-pubesc* OR prepubesc*)) AND ((TITLE-ABS-KEY ("Arctic amplification" OR "Arctic shrinkage" OR "carbon footprint" OR "carbon offset*" OR "carbon sequestration" OR "carbon sink" OR "carbon sinks" OR (chlorofluorocarbon* W/2 (release OR concentration* OR atmosphere*)) OR (climate W/2 (change* OR model?ing OR predict* OR resilience OR sensitivity)) OR deglaciation OR desertification OR "natural disaster*" OR drought OR (earth W/2 warming) OR "El Nino" OR "La Nina" OR "emissions reduc*" OR "emissions trading" OR flood* OR ((glacial OR galcier) W/3 (retreat* OR melt*)) OR "global radiation" OR "global temperature*" OR "global warming" OR "greenhouse effect" OR "greenhouse gas" OR "heat wave*" OR hurricane* OR "ice cap melt*" OR "ice mass loss*" OR "Kyoto Protocol" OR "landslide*" OR "land slide*" OR "mudslide*" OR "mud slide*" OR (ozone W/2 hole) OR "Paris Accord" OR "permafrost melt*" OR "polar amplification" OR "polar ice melt*" OR "sea ice shrinkage" OR "sea level rise*" OR "sea surface warming" OR "storm surge*" OR "thermohaline circulation" OR ((extreme OR severe OR destructive) W/2 (temperature* OR weather* OR storm* OR hail OR wind*)) OR tornado* OR typhoon* OR wildfire* OR "wild fire*")) OR (TITLE-ABS-KEY ((("carbon monoxide*" OR "hydrogen sulfide*" OR "hydrogen sulphide*" OR h2s OR "nitrogen oxide*" OR "volatile organic*" OR voc OR nox OR "sulfur dioxide*" OR so2 OR "sulfur oxide*" OR "sulphur dioxide*" OR "sulphur oxide*") AND (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*))) OR TITLE-ABS-KEY (((air OR atmospher*) W/3 (pollut* OR quality OR wast* OR contamin* OR emission* OR immission* OR effluent* OR acidification OR contaminat* OR degrad* OR decontaminat* OR purif* OR restor*))) OR TITLE-ABS-KEY (((gas OR gases) W/3 (toxic* OR noxious OR releas* OR purifi* OR scrub* OR emit* OR waste* OR vapo?r)) OR (acid* W/3 (deposition* OR rain* OR snow OR fog OR mist OR precipitation OR hail OR sleet)) OR afterburning OR biogas OR (burning W/3 "fossil fuel*")) OR TITLE-ABS-KEY (((chimney OR stack) W/3 height) OR dust OR fallout OR "fall out" OR flaring OR "fly ash" OR electrosmog OR (greenhouse W/3 (gas OR effect OR effects OR gases OR emission*)) OR incineration OR odor OR odour OR "olfactory pollution" OR particulate* OR smog OR smoke OR soot OR "sick building syndrome" OR "vapor recovery system*" OR "vapour recovery system*" OR ((industrial OR automobile* OR traffic OR freeway OR highway OR roadway OR motorway OR diesel OR vehicle* OR diesel OR truck OR trucks OR lorry OR lorries OR taxi OR taxis OR tailpipe* OR roadside* OR "road side*" OR autobus* OR bus OR buses) W/3 (exhaust* OR emission* OR emit* OR fume OR fumes OR vapor* OR vapour*)))))) AND NOT (TITLE-ABS-KEY ("internal migrat*" OR "internal migrant*" OR pine OR pines OR tree OR trees OR pollen OR plant OR plants OR "range expansion" OR "species" OR bird OR birds OR phytoplankton OR oak OR treeline OR vegetation OR shrub OR shrubs OR fish OR larvae OR eel* OR salmon* OR rat OR rats OR diptera OR dogfish* OR redhead* OR knot OR knots OR "marine migration" OR squirrel* OR mullet* OR prawn* OR waterfowl))

PROQuest Dissertations and Theses Full Text Searched July 12, 2022

Search1 Result =39

noft((("carbon monoxide*" OR "hydrogen sulfide*" OR "hydrogen sulphide*" OR h2s OR "nitrogen oxide*" OR "volatile organic*" OR voc OR nox OR "sulfur dioxide*" OR so2 OR "sulfur oxide*" OR "sulphur dioxide*" OR "sulphur oxide*") AND (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*)) OR ((air OR atmospher*) NEAR/3 (pollut* OR quality OR wast* OR contamin* OR emission* OR immission* OR effluent* OR acidification OR contaminat* OR degrad* OR decontaminat* OR purif* OR restor*)) OR ((gas OR gases) NEAR/3 (toxic* OR noxious OR releas* OR purifi* OR scrub* OR emit* OR waste* OR vapor OR vapour)) OR (acid* NEAR/3 (deposition* OR rain* OR snow OR fog OR mist OR precipitation OR hail OR sleet)) OR afterburning OR biogas OR (burning NEAR/3 "fossil fuel*") OR ((chimney OR stack) NEAR/3 height) OR dust OR fallout OR "fall out" OR flaring OR "fly ash" OR

electrosmog OR (greenhouse NEAR/3 (gas OR effect OR effects OR gases OR emission*)) OR incineration OR odor OR odour OR "olfactory pollution" OR particulate* OR smog OR smoke OR soot OR "sick building syndrome" OR "vapor recovery system*" OR "vapour recovery system*" OR ((industrial OR automobile* OR traffic OR freeway OR highway OR roadway OR motorway OR diesel OR vehicle* OR diesel OR truck OR trucks OR lorry OR lorries OR taxi OR taxis OR tailpipe* OR roadside* OR "road side*" OR autobus* OR bus OR buses) NEAR/3 (exhaust* OR emission* OR emit* OR fume OR fumes OR vapor* OR vapour*))) AND noft((immigrant* OR immigration OR emigrant* OR emigration OR refugee* OR "asylum seeker* " OR asylee* OR "displaced person* " OR "displaced people " OR "incomer*" OR "in comer* " OR "new comer* " OR newcomer* OR migrant* OR resettler*) AND (elders OR elderly OR geriatric* OR "old age " OR "senior citizens " OR "older adult* " OR centenarian* OR nonagenarian* OR octogenarian* OR septuagenarian* OR sexagenarian* OR dottering OR (decrepit NEAR/3 (person OR persons OR people OR patient*)) OR tottering OR overaged OR "oldest old " OR pediatric* OR paediatric* OR child* OR grandchild* OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat* OR pre-term OR preterm* OR "premature birth* " OR nicu OR preschool* OR pre-school* OR kindergarten* OR kindergarden* OR "elementary school* " OR "nursery school* " OR "day care* " OR daycare* OR schoolchild* OR toddler* OR boy OR boys OR girl* OR "middle school* " OR pubescen* OR juvenile* OR teen* OR youth* OR "high school* " OR adolesc* OR pre-pubesc* OR prepubesc*)) NOT noft((("internal migrat*" OR "internal migrant*" OR pine OR pines OR tree OR trees OR pollen OR plant OR plants OR "range expansion" OR "species" OR bird OR birds OR phytoplankton OR oak OR treeline OR vegetation OR shrub OR shrubs OR fish OR larvae OR eel* OR salmon* OR rat OR rats OR diptera OR dogfish* OR redhead* OR knot OR knots OR "marine migration" OR squirrel* OR mullet* OR prawn* OR waterfowl)))

Search 2 Results =103

noft(("Arctic amplification" OR "Arctic shrinkage" OR "carbon footprint" OR "carbon offset*" OR "carbon sequestration" OR "carbon sink" OR "carbon sinks" OR (chlorofluorocarbon* N/2 (release OR concentration* OR atmosphere*))) OR (climate N/2 (change* OR model* OR predict* OR resilience OR sensitivity)) OR deglaciation OR desertification OR "natural disaster*" OR drought OR (earth N/2 warming) OR "El Nino" OR "La Nina" OR "emissions reduc*" OR "emissions trading" OR flood* OR ((glacial OR glacier) N/3 (retreat* OR melt*)) OR "global radiation" OR "global temperature*" OR "global warming" OR "greenhouse effect" OR "greenhouse gas" OR "heat wave*" OR hurricane* OR "ice cap melt*" OR "ice mass loss*" OR "Kyoto Protocol" OR "landslide*" OR "land slide*" OR "mudslide*" OR "mud slide*" OR (ozone N/2 hole) OR "Paris Accord" OR "permafrost melt*" OR "polar amplification" OR "polar ice melt*" OR "sea ice shrinkage" OR "sea level rise*" OR "sea surface warming" OR "storm surge*" OR "thermohaline circulation" OR ((extreme OR severe OR destructive) N/2 (temperature* OR weather* OR storm* OR hail OR wind*)) OR tornado* OR typhoon* OR wildfire* OR "wild fire*") AND noft((immigrant* OR immigration OR emigrant* OR emigration OR refugee* OR "asylum seeker* " OR asylee* OR "displaced person* " OR "displaced people " OR "incomer*" OR "in comer* " OR "new comer* " OR newcomer* OR migrant* OR resettler*) AND (elders OR elderly OR geriatric* OR "old age " OR "senior citizens " OR "older adult* " OR centenarian* OR nonagenarian* OR octogenarian* OR septuagenarian* OR sexagenarian* OR dottering OR (decrepit NEAR/3 (person OR persons OR people OR patient*)) OR tottering OR overaged OR "oldest old " OR pediatric* OR paediatric* OR child* OR grandchild* OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat* OR pre-term OR preterm* OR "premature birth* " OR nicu OR preschool* OR pre-school* OR kindergarten* OR kindergarden* OR "elementary school* " OR "nursery school* " OR "day care* " OR daycare* OR schoolchild* OR toddler* OR boy OR boys OR girl* OR "middle school* " OR pubescen* OR juvenile* OR teen* OR youth* OR "high school* " OR adolesc* OR pre-pubesc* OR prepubesc*)) NOT noft(((("internal migrat*" OR "internal migrant*" OR pine OR pines OR tree OR trees OR pollen OR plant OR plants OR "range expansion" OR "species" OR bird OR birds OR phytoplankton OR oak OR treeline OR vegetation OR shrub OR shrubs OR fish OR larvae OR eel* OR salmon* OR rat OR rats OR diptera OR dogfish* OR redhead* OR knot OR knots OR "marine migration" OR squirrel* OR mullet* OR prawn* OR waterfowl)))

Cochrane Library Searched July 12, 2022

ID	Search	Hits
#1	((((("carbon monoxide" OR "hydrogen sulfide" OR "hydrogen sulphide*" OR h2s OR "nitrogen oxide*" OR "volatile organic" OR voc OR nox OR "sulfur dioxide" OR so2 OR "sulfur oxide" OR "sulphur dioxide" OR "sulphur oxide") AND (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*)) OR ((air OR atmospher*) NEAR 3 (pollut* OR quality OR wast* OR contamin* OR emission* OR immission* OR effluent* OR acidification OR contaminat* OR degrad* OR decontaminat* OR purif* OR restor*)) OR ((gas OR gases) NEAR 3 (toxic* OR noxious OR releas* OR purifi* OR scrub* OR emit* OR waste* OR vapor OR vapour)) OR (acid* NEAR 3 (deposition* OR rain* OR snow OR fog OR mist OR precipitation OR hail OR sleet)) OR afterburning OR biogas OR (burning NEAR 3 "fossil fuel*") OR ((chimney OR stack) NEAR 3 height) OR dust OR fallout OR "fall out" OR flaring OR "fly ash" OR electrosmog OR (greenhouse NEAR 3 (gas OR effect OR effects OR gases OR emission*)) OR incineration OR odor OR odour OR "olfactory pollution" OR particulate* OR smog OR smoke OR soot OR "sick building syndrome" OR "vapor recovery system*" OR "vapour recovery system*" OR ((industrial OR automobile* OR traffic OR freeway OR highway OR roadway OR motorway OR diesel OR vehicle* OR diesel OR truck OR trucks OR lorry OR lorries OR taxi OR taxis OR tailpipe* OR roadside* OR "road side*" OR autobus* OR bus OR buses) NEAR 3 (exhaust* OR emission* OR emit* OR fume OR fumes OR vapor* OR vapour*))))):ti,ab,kw	10060
#2	((("Arctic amplification" OR "Arctic shrinkage" OR "carbon footprint" OR "carbon offset*" OR "carbon sequestration" OR "carbon sink" OR "carbon sinks" OR (chlorofluorocarbon* Near 2 (release OR concentration* OR atmosphere*))) OR (climate Near 2 (change* OR model* OR predict* OR resilience OR sensitivity)) OR deglaciation OR desertification OR "natural disaster" OR drought OR (earth Near 2 warming) OR "El Nino" OR "La Nina" OR "emissions reduction" OR "emissions trading" OR flood* OR ((glacial OR glacier) Near 3 (retreat* OR melt*)) OR "global radiation" OR "global temperature*" OR "global warming" OR "greenhouse effect" OR "greenhouse gas" OR "heat wave*" OR hurricane* OR "ice cap melt" OR "ice mass loss*" OR "Kyoto Protocol" OR "landslide" OR "land slide" OR "mudslide" OR "mud slide" OR (ozone Near 2 hole) OR "Paris Accord" OR "permafrost melt" OR "polar amplification" OR "polar ice melt" OR "sea ice shrinkage" OR "sea level rise" OR "sea surface warming" OR "storm surge" OR "thermohaline circulation" OR ((extreme OR severe OR destructive) Near 2 (temperature* OR weather* OR storm* OR hail OR wind*)) OR tornado* OR typhoon* OR wildfire* OR "wild fire*")):ti,ab,kw	1172
#3	#1 or #2	11202
#4	((immigrant* OR immigration OR emigrant* OR emigration OR refugee* OR "asylum seeker" OR asylee* OR "displaced person" OR "displaced people" OR "incomer*" OR "in comer " OR "new comer" OR newcomer* OR migrant* OR resettler*)):ti,ab,kw	1900
#5	((elders OR elderly OR geriatric* OR "old age " OR "senior citizens " OR "older adult* " OR centenarian* OR nonagenarian* OR octogenarian* OR septuagenarian* OR sexagenarian* OR dottering OR tottering OR overaged OR "oldest old " OR pediatric* OR paediatric* OR child* OR grandchild* OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat* OR pre-term OR preterm* OR "premature birth* " OR nicu OR preschool* OR pre-school* OR kindergarten* OR kindergarden* OR "elementary school* " OR "nursery school* " OR "day care* " OR daycare* OR schoolchild* OR toddler* OR boy OR boys OR girl* OR "middle school* " OR pubescen* OR juvenile* OR teen* OR youth* OR "high school* " OR adolesc* OR pre-pubesc* OR prepubesc*)):ti,ab,kw	390634
#6	"decrepit person" or "decrepit persons" or "decrepit people" or "decrepit patient"	0
#7	#5 or #6	390634

#8 #3 and #4 and #7 11

PROSPERO Searched July 12, 2022 Results =3

Line	Search for	Hits
#1	"carbon monoxide" OR "hydrogen sulfide" OR "hydrogen sulphide*" OR h2s OR "nitrogen oxide*" OR "volatile organic" OR voc OR nox OR "sulfur dioxide" OR so2 OR "sulfur oxide" OR "sulphur dioxide" OR "sulphur oxide"	516
#2	pollut* OR emit* OR emission* OR contaminat* OR decontaminat*	3003
#3	#1 AND #2	236
#4	(air OR atmospher*):TI,KW	459
#5	(pollut* OR quality OR wast* OR contamin* OR emission* OR immission* OR effluent* OR acidification OR contaminat* OR degrad* OR decontaminat* OR purif* OR restor*):TI,KW	6522
#6	#4 AND #5	349
#7	(gas OR gases):TI,KW	69
#8	(toxic* OR noxious OR releas* OR purifi* OR scrub* OR emit* OR waste* OR vapor OR vapour):TI,KW	886
#9	#7 AND #8	4
#10	(acid*):TI,KW	1620
#11	(deposition* OR rain* OR snow OR fog OR mist OR precipitation OR hail OR sleet):TI,KW	51
#12	#10 AND #114	
#13	(afterburning OR biogas):TI,KW	0
#14	(burning and "fossil fuel*"):TI,KW	0
#15	(chimney height or stack height):TI,KW	0
#16	(dust OR fallout OR "fall out" OR flaring OR "fly ash" OR electrosmog):TI,KW	37
#17	(greenhouse):TI,KW	4
#18	(incineration OR odor OR odour OR "olfactory pollution" OR particulate* OR smog OR smoke OR soot OR "sick building syndrome" OR "vapor recovery system*" OR "vapour recovery system*"):TI,KW	217
#19	(industrial OR automobile* OR traffic OR freeway OR highway OR roadway OR motorway OR diesel OR vehicle* OR diesel OR truck OR trucks OR lorry OR lorries OR taxi OR taxis OR tailpipe* OR roadside* OR "road side*" OR autobus* OR bus OR buses):TI,KW	242
#20	(exhaust* OR emission* OR emit* OR fume OR fumes OR vapor* OR vapour):TI,KW	251
#21	#19 AND #20	6
#22	("Arctic amplification" OR "Arctic shrinkage" OR "carbon footprint" OR "carbon offset*" OR "carbon sequestration" OR "carbon sink" OR "carbon sinks"):TI,KW	13
#23(	chlorofluorocarbon*):TI,KW	0
#24	("climate change" or "climate model" or "climate predict*" or "climate resilience" or "climate senstivity"):TI,KW	112
#25	(deglaciation OR desertification OR "natural disaster" OR drought):TI,KW	38
#26	("El Nino" OR "La Nina" OR "emissions reduction" OR "emissions trading" OR flood*):TI,KW	18
#27	("earth warming"):TI,KW	0
#28	("glac* retreat*" or "glac* melt*"):TI,KW	0
#29	("global radiation" OR "global temperature*" OR "global warming" OR "greenhouse effect" OR "greenhouse gas" OR "heat wave*" OR hurricane* OR "ice cap melt" OR "ice mass loss*" OR "Kyoto Protocol" OR "landslide" OR "land slide" OR "mudslide" OR "mud slide"):TI,KW	38
#30	("Paris Accord" OR "permafrost melt" OR "polar amplification" OR "polar ice melt" OR "sea ice shrinkage" OR "sea level rise" OR "sea surface warming" OR "storm surge" OR "thermohaline circulation"):TI,KW	1

#31 ("ozone hole"):TI,KW 0
#32 ("extreme weather" or "extreme heat" or "extreme storm*" or "extreme hail" or "extreme wind*" or "severe heat*" or "severe storm*" or "severe hail" or "sever temperature" or "destructive weather" or "destructive storm*" or "destructive temperature*" or "destructive hail"):TI,KW 16
#33 (tornado* OR typhoon* OR wildfire* OR "wild fire*"):TI,KW 17
#34 #3 OR #6 OR #9 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 748
#35 (immigrant* OR immigration OR emigrant* OR emigration OR refugee* OR "asylum seeker" OR asylee* OR "displaced person" OR "displaced people" OR "incomer*" OR "in comer " OR "new comer" OR newcomer* OR migrant* OR resettler*):TI,KW 613
#36 #34 AND #35 3

Appendix 2: Extraction Template for Scoping Review

1. Author(s)
2. Title
3. Year of publication
4. Journal
5. Objective
6. Country that study was conducted in
7. Setting (Rural or urban)
8. Study population
9. Sample size
10. Gender (male or female)
11. Age breakdown
12. Data source (primary or secondary)
13. Immigrant category (refugee, economic immigrant, immigrant sponsored by family, other)
14. Length of residence (less than 10 years or greater than or equal to 10 years)
15. Study design
16. Type of analyses
17. Climate and air pollution exposure variable(s)
18. How climate and air pollution exposure variables were defined
19. Health outcome(s)
20. How health outcomes were measured
21. Did the study look at age/gender/immigrant category differences?
22. If yes to 19, what were the interactions and results?
23. Key findings on health-related impacts of climate change and air pollution exposures

Appendix 3 Data Dictionary for Exposures, Characteristics and Health Outcomes

Table A3 Further information on variables used in the analysis

Variable	Variable label	Data source	Spatial distribution	Years	Variable type	Categories	Reference group
Exposure variables							
High temperature	Annual highest temperature (Celsius)	CANUE	Estimated using ANUSPLIN modelling at postal code level (completed by CANUE)	2009 to 2014	Categorical	0 = min to 30.73 1 = 30.74 to 31.87 2 = 31.88 to 33.08 3 = 33.09 to max	0 (mildest temps)
Low temperature	Annual lowest temperature (Celsius)	CANUE	Estimated using ANUSPLIN modelling at postal code level (completed by CANUE)	2009 to 2014	Categorical	0 = -35.98 to max 1 = -35.97 to -34.45 2 = -34.44 to -33.17 3 = min to -33.16	3 (mildest temps)
Average temperature	Annual average temperature (Celsius)	CANUE	Estimated using ANUSPLIN modelling at postal code level (completed by CANUE)	2009 to 2014	Categorical	0 = min to 2.83 1 = 2.84 to 3.31 2 = 3.32 to 4.02 3 = 4.03 to max	3 (mildest temps)
Average daily maximum temperature	Annual average of daily maximum temperature (Celsius)	CANUE	Estimated using ANUSPLIN modelling at postal code level	2009 to 2014	Categorical	0 = min to 8.77 1 = 8.78 to 9.17 2 = 9.18 to 10.16 3 = 10.17 to max	0 (mildest temps)

			(completed by CANUE)				
Average daily minimum temperature	Annual average of daily minimum temperature (Celsius)	CANUE	Estimated using ANUSPLIN modelling at postal code level (completed by CANUE)	2009 to 2014	Categorical	0 = -3.11 to max 1 = -3.10 to -2.53 2 = -2.52 to -2.06 3 = min to -2.05	3 (mildest temp)
Average diurnal temperature range	Annual average of difference between maximum and minimum temperatures (Celsius)	CANUE	Estimated using ANUSPLIN modelling at postal code level (completed by CANUE)	2009 to 2014	Categorical	0 = min to 11.59 1 = 11.60 to 12.00 2 = 12.01 to 12.53 3 = 12.54 to max	0 (smallest difference between minimum and maximum temperature = mildest temps)
Average $PM_{2.5}$ (sensitivity analysis data)	Annual average PM2.5 Concentration ($\mu g/m^3$)	CANUE	Estimated using geographically weighted regression (completed by CANUE)	2009 to 2014	Categorical	1 = min to 6.40 2 = 6.50 to 7.50 3 = 7.60 to 8.90 4 = 9.00 to max	1 (lowest exposure)
Average wildfire smoke	Annual average concentration ($\mu g/m^3$)	CANUE	Estimated using Canadian Optimized Statistical Smoke Model (completed by CANUE)	2010 to 2014	Categorical	0 = min to 6.59 1 = 6.60 to 7.14 2 = 7.15 to 7.74 3 = 7.75 to max	0 (lowest exposure)
Average NO_2	Annual mean level of pollutant (unit ppb) calculated from sufficient	NAPS	Assigned closest observation to each individual	2009 to 2014	Categorical	0 =min to 6.92 1 = 7.07 to 11.62 2 = 11.74 to 15.31 3 = 15.71 to max	0 (lowest exposure)

	days months >=9)		using ArcMap				
Average O_3	Annual mean level of pollutant (unit ppb) calculated from sufficient days of data months >=9)	NAPS	Assigned closest observation to each individual using ArcMap	2009 to 2014	Categorical	0 = min to 19.94 1 = 20.23 to 22.83 2 = 22.90 to 26.55 3 = 26.56 to max	0 (lowest exposure)
Average $PM_{2.5}$	Annual mean level of pollutant ($\mu g/m^3$) calculated from sufficient days of data months >=9	NAPS	Assigned closest observation to each individual using ArcMap	2009 to 2014	Categorical	0 = min to 6.75 1 = 6.77 to 8.09 2 = 8.19 to 10.17 3 = 10.31 to max	0 (lowest exposure)
Characteristics							
Age	Age of individual (years)	CCHS	Postal code	2009 to 2014	Continuous	-	-
Household income	household income best estimate	CCHS	Postal code	2009 to 2014	Continuous	-	-
Length of residence	Length of time resided in Canada (years)	CCHS	Postal code	2009 to 2014	Continuous	-	-
Age	Age of individual (years)	Generated using CCHS data	Postal code	2009 to 2014	Categorical	1 = 12 to 17 2 = 18 to 49 3 = 50 to 64 4 = 65+	2
Household income	household income best estimate	Generated using CCHS data	Postal code	2009 to 2014	Categorical	1 = no income to $69,999 2 = $70,000 to $100,00+	2
Length of residence	Length of time resided in Canada (years)	Generated using CCHS data	Postal code	2009 to 2014	Categorical	1 = <10 years in Canada 2 = 10+ years in Canada	0 for total population models, 1 for

						0 = non-immigrant	immigrant models
Geographical location	Whether the individual lives in an urban or rural location	CCHS	Postal code	2009 to 2014	Categorical	1 = urban 2 = rural	1
Sex	Whether the individual is male or female	CCHS	Postal code	2009 to 2014	Categorical	1 = male 2 = female	1
Marital status	Marital status of the individual	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = married/common law 2 = widowed/separated/divorced/single/never married	1
BMI	Body Mass Index (measure of body weight)	CCHS	Postal code	2009 to 2014	Categorical	1 = underweight 2 = normal weight 3 = overweight 4 = obese	2
BMI (regrouped)	Body Mass Index (measure of body weight)	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = normal weight 2 = underweight/ overweight/obese	1
Household size	Number of individuals residing in one household	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = <= 3 people 2 = > 3 people	1
Cultural/racial background	Cultural/racial background of individual	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = White 2 = other (Black, Asian, Arab, West Asian, Latin American, multiple races or other race)	1
Education	Highest level of education obtained	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = less than secondary school graduation 2 = secondary school, gra, no post-secondary 3 = some post-secondary education	4

						4 = post-secondary certification/diploma or university degree	
Education (regrouped)	Highest level of education obtained	CCHS	Postal code	2009 to 2014	Categorical	1 = secondary school graduation or less 2 = some post-secondary/post-secondary grad	2
Self-perceived health	How an individual perceives their own health status	CCHS	Postal code	2009 to 2014	Categorical	1 = excellent/very good/good 2 = fair/poor	1
Self-perceived mental health	How an individual perceives their own mental health status	CCHS	Postal code	2009 to 2014	Categorical	1 = excellent/very good/good 2 = fair/poor	1
High blood pressure	Whether the individual has high blood pressure or not	CCHS	Postal code	2009 to 2014	Categorical	1 = yes 2 = no	2
Diabetes	Whether the individual has diabetes or not	CCHS	Postal code	2009 to 2014	Categorical	1 = yes 2 = no	2
Smoking status	If and how often the individual smokes	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = daily 2 = occasionally 3 = not at all	3
Smoking status (regrouped)	If and how often the individual smokes	CCHS	Postal code	2009 to 2014	Categorical	1 = daily/occasionally 2 = not at all	2
Sense of belonging to the community	Whether the individual feel s like they belong to the community	CCHS	Postal code	2009 to 2014	Categorical	1 = very strong 2 = somewhat strong 3 = somewhat weak 4 = very weak	1

Sense of belonging to the community (regrouped)	Whether the individual feel s like they belong to the community	Regrouped CCHS variable	Postal code	2009 to 2014	Categorical	1 = very strong/somewhat strong 2 = somewhat weak/very weak	1
Population type	Whether the individual is an immigrant or not	Generated using CCHS and IMDB variables	Postal code	2009 to 2014	Categorical	0 = non-immigrant 1 = immigrant	0
Health outcomes							
Heart disease	Whether the individual has heart disease	CCHS	Postal code	2009 to 2014	Categorical	1 = yes 2 = no	-
Stroke effects	Whether the individual suffers from the effects of a stroke	CCHS	Postal code	2009 to 2014	Categorical	1 = yes 2 = no	-
Mood disorder	Whether the individual has a mood disorder	CCHS	Postal code	2009 to 2014	Categorical	1 = yes 2 = no	-
Anxiety disorder	Whether the individual has an anxiety disorder	CCHS	Postal code	2009 to 2014	Categorical	1 = yes 2 = no	-
Asthma	Whether the individual has asthma	CCHS	Postal code	2009 to 2014	Categorical	0 = no 1 = yes	-
Cardiovascular outcome	Whether the individual has heart disease and/or suffers from the effects of a stroke	Generated using CCHS variable	Postal code	2009 to 2014	Categorical	0 = no 1 = yes	-
Mental disorder	Whether the individual has a mood disorder	Generated using CCHS variable	Postal code	2009 to 2014	Categorical	0 = no 1 = yes	-

	and/or anxiety disorder						

Sources: The Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2], Canadian Community Health Survey [3] and Longitudinal Immigration Database [4].

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

Appendix 4 Sample Size Estimation: Population Prevalence

The required sample size for this study was calculated using the sample size calculation formula for a cross-sectional study [1-4].

$$n = \frac{z^2 * p\ (1-p)}{d^2}$$

n = sample size

z = standard normal variate (95% desired level of confidence) = 1.96

p = expected prevalence

-prevalence of asthma (Alberta 2015 to 2020 ages 12+): 8.93% [5]

-prevalence of asthma (Alberta 2015 to 2020 ages 12 to 17): 12.72% [5]

-prevalence of asthma (Alberta 2015 to 2020 ages 65+) 7.72% [5]

-prevalence of mood disorder (Alberta 2015 to 2022 ages 12+): 10.04% [6]

-prevalence of mood disorder (Alberta 2015 to 2022 ages 12 to 17): 6.78% [6]

-prevalence of mood disorder (Alberta 2015 to 2022 ages 65+): 7.13% [6]

d = margin of error = 0.05

For asthma ages 12+, a minimum sample size of ~64 is needed, for ages 12 to 17 a minimum of ~87 is needed and for ages 65 plus a minimum of ~56. For mood disorders ages 12+ a minimum sample size of ~71 is needed, for ages 12 to 17 of ~50 is needed and for ages 65+ a minimum of ~52 is needed.

References

1. Pourhoseingholi MA, Vahedi M, Rahimzadeh M. Sample size calculation in medical studies. Gastroenterol Hepatol Bed Bench [Internet]. 2013;6(1):14–17. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4017493/

2. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med [Internet]. 2013 Apr-Jun;35(2);121–126. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3775042/

3. Sapra RL. How to calculate an adequate sample size? In: Nundy S, Kakar A, Bhutta ZA, editors. How to practice academic medicine and publish from developing countries? a practical guide [Internet]. Singapore: Springer Nature Singapore; 2022. p. 81–93. Available from: https://link.springer.com/book/10.1007/978-981-16-5248-6

4. Charan J, Kaur R, Bhardwaj P, et al. Sample size calculation in medical research: a primer. Ann Natl Acad Med Sci [Internet]. 2021 Apr; 57(2):74–80. Available from: https://www.researchgate.net/publication/350836701_Sample_Size_Calculation_in_Medical_Research_A_Primer

5. Statistics Canada. Table 13-10-0096-08 asthma, by age group [Internet]. 2023. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009608&pickMembers%5B0%5D=1.10&pickMembers%5B1%5D=3.1&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2022&referencePeriods=20150101%2C20220101

6. Statistics Canada. Table 13-10-0096-18 Mood disorders, by age group [Internet]. 2023. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009618&pickMembers%5B0%5D=1.10&pickMembers%5B1%5D=3.1&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2022&referencePeriods=20150101%2C20220101

Appendix 5 Exposure Descriptive Summary

Table A5 Descriptive summary of annual weather and air pollution exposures

Continuous characteristics	Mean	Linearized Standard error
Total population (n = 14,620,000)		
High temperature (Celsius)	31.68	0.0153
Low temperature (Celsius)	-34.49	0.0224
Average temperature (Celsius)	3.51	0.0086
Average daily minimum temperature (Celsius)	-2.52	0.0082
Average daily maximum temperature (Celsius)	9.54	0.0102
Average diurnal temperature range (Celsius)	12.06	0.007
Average NO_2 (ppb)	13.36	0.0504
Average O_3 (ppb)	22.70	0.0403
Average $PM_{2.5}$ ($\mu g/m^3$)	9.08	0.0315
Average wildfire smoke ($\mu g/m^3$)	7.37	0.0109
Adolescent population (n = 1,254,000)		
High temperature (Celsius)	31.89	0.0443
Low temperature (Celsius)	-34.61	0.0795
Average temperature (Celsius)	3.47	0.0254
Average daily minimum temperature (Celsius)	-2.57	0.0247
Average daily maximum temperature (Celsius)	9.52	0.0298
Average diurnal temperature range (Celsius)	12.09	0.0207
Average NO_2 (ppb)	13.43	0.1538
Average O_3 (ppb)	22.6	0.1193
Average $PM_{2.5}$ ($\mu g/m^3$)	9.11	0.0905
Average wildfire smoke ($\mu g/m^3$)	7.4	0.0338
Older adult population (n = 1,833,000)		
High temperature (Celsius)	31.91	0.0278
Low temperature (Celsius)	-34.53	0.0484
Average temperature (Celsius)	3.56	0.0158
Average daily minimum temperature (Celsius)	-2.47	0.0153
Average daily maximum temperature (Celsius)	9.59	0.0187
Average diurnal temperature range (Celsius)	12.06	0.013
Average NO_2 (ppb)	13.14	0.0995
Average O_3 (ppb)	22.95	0.0784
Average $PM_{2.5}$ ($\mu g/m^3$)	8.95	0.0577
Average wildfire smoke ($\mu g/m^3$)	7.35	0.0218
Immigrant population (n = 3,384,000)		
High temperature (Celsius)	31.82	0.0313
Low temperature (Celsius)	-34.26	0.0514
Average temperature (Celsius)	3.6	0.0181
Average daily minimum temperature (Celsius)	-2.43	0.0164
Average daily maximum temperature (Celsius)	9.63	0.0227
Average diurnal temperature range (Celsius)	12.05	0.0162
Average NO_2 (ppb)	14.32	0.1028
Average O_3 (ppb)	22.18	0.092
Average $PM_{2.5}$ ($\mu g/m^3$)	9.41	0.0711
Average wildfire smoke ($\mu g/m^3$)	7.41	0.0251

Sources: Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [3,4,5].

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

5. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imd

Appendix 6 Weather and Air Pollution Results

Table A6.1 Adjusted logistic model results for weather and air pollution exposures and asthma

Exposure type	Exposure level	Total population OR (95% CI)[1]	Total population adolescent OR (95% CI)[2]	Total population older adults OR (95% CI)[1]	Immigrant population OR (95% CI)[3]
Average temperature (Celsius)	Very low (min to 2.83)	0.93 (0.69-1.25)	0.78 (0.42-1.43)	1.25 (0.73-2.16)	1.54 (0.72-3.30)
	Low (2.84 to 3.31)	1.02 (0.80-1.3)	0.76 (0.42-1.38)	1.33 (0.83-2.12)	1.97 (0.91-4.28)
	Moderate (3.32 to 4.02)	0.84 (0.66-1.07)	1.01 (0.56-1.83)	1.47 (0.93-2.35)	1.25 (0.64-2.48)
	High (4.03 to max)	Reference			
Average daily maximum temperature (Celsius)[4]	Very low (min to 8.77)	Reference			
	Low (8.78 to 9.17)	1.28 (0.99-1.66)	0.86 (0.44-1.65)	1.46 (0.88-2.44)	1.55 (0.77-3.12)
	Moderate (9.18 to 10.16)	0.99 (0.78-1.26)	1.43 (0.78-2.62)	1.33 (0.79-2.24)	1.00 (0.45-2.21)
	High (10.17 to max)	1.14 (0.89-1.46)	1.10 (0.59-2.03)	1.02 (0.61-1.69)	0.88 (0.43-1.80)
Average NO_2 (ppb)	Very low (min to 6.92)	Reference			
	Low (7.07 to 11.62)	0.80 (0.62-1.03)	0.71 (0.38-1.32)	0.87 (0.52-1.46)	0.95 (0.38-2.37)
	Moderate (11.74 to 15.31)	0.97 (0.74-1.27)	0.59 (0.29-1.22)	1.30 (0.78-2.17)	0.64 (0.26-1.58)
	High (15.71 to max)	1.08 (0.83-1.41)	0.88 (0.46-1.69)	0.86 (0.51-1.45)	0.83 (0.34-2.07)

Sources: Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [3,4,5].
1 Adjusted for age, household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level, BMI and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.
2 Adjusted for household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, BMI and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.
3 Adjusted for household income, geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, BMI, length of residence in Canada and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.
4 The average daily maximum temperature is the annual average of all daily maximum temperatures individuals were exposed to. High temperature is the annual single highest temperature that individuals were exposed to.

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

5. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb

Table A6.2 Adjusted logistic model results for weather and air pollution exposures and cardiovascular outcomes

Exposure type	**Exposure level**	**Total population OR (95% CI)[1]**	**Total population older adults OR (95% CI)[1]**	**Immigrant population OR (95% CI)[2]**
Average temperature (Celsius)	Very low (min to 2.83)	0.94 (0.69-1.28)	0.74 (0.48-1.13)	1.07 (0.52-2.2)
	Low (2.84 to 3.31)	1.01 (0.75-1.37)	0.90 (0.60-1.36)	1.08 (0.55-2.11)
	Moderate (3.32 to 4.02)	0.94 (0.71-1.26)	0.84 (0.58-1.22)	0.84 (0.44-1.59)
	High (4.03 to max)	Reference		
Average daily maximum temperature (Celsius)[3]	Very low (min to 8.77)	Reference		
	Low (8.78 to 9.17)	0.88 (0.63-1.23)	1.27 (0.83-1.94)	1.27 (0.51-3.12)
	Moderate (9.18 to 10.16)	0.91 (0.65-1.28)	1.28 (0.85-1.93)	0.94 (0.39-2.26)
	High (10.17 to max)	0.91 (0.65-1.26)	1.37 (0.90-2.08)	1.01 (0.42-2.46)
Average NO_2 (ppb)	Very low (min to 6.92)	Reference		
	Low (7.07 to 11.62)	0.78 (0.57-1.08)	0.77 (0.51-1.15)	0.99 (0.38-2.57)
	Moderate (11.74 to 15.31)	0.83 (0.60-1.15)	0.82 (0.54-1.25)	1.45 (0.67-3.15)
	High (15.71 to max)	1.19 (0.87-1.63)	1.21 (0.80-1.83)	1.53 (0.69-3.38)

Sources: Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [3,4,5].

1 Adjusted for age, household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, high blood pressure, diabetes and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.

2 Adjusted for household income, geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI, high blood pressure, diabetes, length of residence in Canada and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.

3 The average daily maximum temperature is the annual average of all daily maximum temperatures individuals were exposed to. High temperature is the annual single highest temperature that individuals were exposed to.

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

5. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb

Table A6.3 Adjusted logistic model results for weather and air pollution exposures and mental disorders

Exposure type	Exposure level	Total population OR (95% CI)[1]	Total population adolescent OR (95% CI)[2]	Total population older adults OR (95% CI)[1]	Immigrant population OR (95% CI)[3]
Average temperature (Celsius)	Very low (min to 2.83)	0.80 (0.63-1.02)	1.73 (0.69-4.32)	0.70 (0.39-1.25)	1.46 (0.67-3.18)
	Low (2.84 to 3.31)	0.96 (0.76-1.22)	1.45 (0.58-3.61)	1.35 (0.85-2.16)	1.36 (0.58-3.18)
	Moderate (3.32 to 4.02)	1.16 (0.91-1.47)	1.13 (0.49-2.62)	1.32 (0.83-2.11)	2.17 (0.97-4.88)
	High (4.03 to max)	Reference			
Average daily maximum temperature (Celsius)[4]	Very low (min to 8.77)	Reference			
	Low (8.78 to 9.17)	0.94 (0.73-1.21)	1.64 (0.60-4.53)	1.29 (0.75-2.23)	0.95 (0.45-2.01)
	Moderate (9.18 to 10.16)	0.92 (0.73-1.17)	0.83 (0.32-2.16)	1.61 (0.95-2.72)	0.97 (0.51-1.84)
	High (10.17 to max)	0.95 (0.74-1.21)	0.87 (0.35-2.19)	0.99 (0.58-1.69)	0.66 (0.29-1.51)
Average NO_2 (ppb)	Very low (min to 6.92)	Reference			
	Low (7.07 to 11.62)	1.09 (0.82-1.44)	1.32 (0.47-3.73)	0.65 (0.38-1.13)	1.63 (0.51-5.19)
	Moderate (11.74 to 15.31)	0.98 (0.76-1.27)	1.20 (0.40-3.58)	0.78 (0.49-1.27)	1.85 (0.83-4.11)
	High (15.71 to max)	0.95 (0.72-1.24)	1.36 (0.46-4.05)	0.73 (0.44-1.22)	1.46 (0.65-3.25)

Sources: Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [3,4,5].

1 Adjusted for age, household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, marital status, household size, cultural/racial background, self-perceived health, self-perceived mental health, sense of belonging to the community, smoking type, education level, BMI and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.

2 Adjusted for household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, self-perceived mental health, sense of belonging to the community, smoking type, BMI and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.

3 Adjusted for household income, geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, self-perceived mental health, sense of belonging to the community, smoking type and BMI, length of residence in Canada and corresponding exposure. NO_2 exposure models were also adjusted for average temperature.

4 The average daily maximum temperature is the annual average of all daily maximum temperatures individuals were exposed to. High temperature is the annual single highest temperature that individuals were exposed to.

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

5. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb

Appendix 7 Immigrant Compared to Non-Immigrant Results

Table A7 Adjusted logistic model results for health outcomes and immigrants compared to non-immigrants

Model	**Health outcome**	**Total population immigrants OR (95% CI)[1]**	**Adolescent immigrants OR (95% CI)[2]**	**Older adult immigrants OR (95% CI)[1]**
High temperature (Celsius)[3]	Asthma	**0.38*** ** (0.26-0.55)	0.42 (0.15-1.19)	0.91 (0.55-1.49)
	Cardiovascular outcome	**0.35** ** (0.17-0.71)	-	**0.42*** (0.19-0.93)
	Mental disorder	**0.64** ** (0.47-0.87)	**0.12*** (0.02-0.71)	0.84 (0.53-1.34)
Low temperature (Celsius)[4]	Asthma	**0.37*** ** (0.26-0.55)	0.39 (0.13-1.17)	0.91 (0.55-1.50)
	Cardiovascular outcome	0.87 (0.65-1.16)	-	1.05 (0.75-1.47)
	Mental disorder	**0.63** ** (0.46-0.85)	**0.12*** (0.02-0.76)	0.83 (0.52-1.32)
Average temperature (Celsius)	Asthma	**0.38*** ** (0.26-0.55)	0.40 (0.14-1.19)	0.91 (0.55-1.50)
	Cardiovascular outcome	0.87 (0.65-1.16)	-	1.05 (0.75-1.47)
	Mental disorder	**0.63** ** (0.46-0.85)	**0.13*** (0.02-0.74)	0.81 (0.50-1.31)
Average daily maximum temperature (Celsius)[3]	Asthma	**0.38*** ** (0.26-0.55)	0.41 (0.14-1.18)	0.91 (0.55-1.50)
	Cardiovascular outcome	0.88 (0.66-1.17)	-	1.06 (0.76-1.48)
	Mental disorder	**0.64** ** (0.47-0.87)	**0.12*** (0.02-0.72)	0.81 (0.50-1.31)
Average daily minimum temperature (Celsius)[4]	Asthma	**0.38*** ** (0.26-0.55)	0.43 (0.15-1.24)	0.90 (0.54-1.49)
	Cardiovascular outcome	0.88 (0.66-1.17)	-	1.05 (0.76-1.47)
	Mental disorder	**0.62** ** (0.46-0.84)	**0.12*** (0.02-0.74)	0.81 (0.50-1.31)
Average diurnal temperature range (Celsius)	Asthma	**0.38*** ** (0.26-0.55)	0.41 (0.14-1.18)	0.91 (0.55-1.49)
	Cardiovascular outcome	0.87 (0.66-1.17)	-	1.05 (0.75-1.47)
	Mental disorder	**0.64** ** (0.47-0.87)	**0.13*** (0.02-0.77)	0.82 (0.51-1.32)
Average $PM_{2.5}$ ($\mu g/m^3$)	Asthma	**0.38*** ** (0.26-0.55)	0.41 (0.14-1.20)	0.91 (0.55-1.50)
	Cardiovascular outcome	0.87 (0.65-1.16)	-	1.05 (0.75-1.46)
	Mental disorder	**0.63** ** (0.46-0.86)	**0.11*** (0.02-0.71)	0.81 (0.50-1.31)
Average NO_2 (ppb)	Asthma	**0.38*** ** (0.26-0.55)	0.41 (0.14-1.23)	0.90 (0.54-1.52)
	Cardiovascular outcome	0.85 (0.64-1.14)	-	1.02 (0.72-1.43)
	Mental disorder	**0.63** ** (0.46-0.85)	**0.13*** (0.02-0.78)	0.81 (0.50-1.31)
Average O_3 (ppb)	Asthma	**0.38*** ** (0.26-0.55)	0.41 (0.14-1.22)	0.92 (0.55-1.52)

	Cardiovascular outcome	0.86 (0.64-1.14)	-	1.03 (0.74-1.45)
	Mental disorder	**0.63**** (0.46-0.85)	**0.11*** (0.02-0.67)	0.80 (0.49-1.31)
Average wildfire smoke ($PM_{2.5}$ $\mu g/m^3$)[5]	Asthma	**0.40***** (0.28-0.59)	0.33 (0.09-1.21)	0.88 (0.51-1.50)
	Cardiovascular outcome	0.82 (0.60-1.12)	-	1.02 (0.71-1.47)
	Mental disorder	**0.60**** (0.43-0.83)	**0.13*** (0.02-0.82)	0.79 (0.47-1.31)

***p<0.001, **p<0.01, *p<0.05

Sources: Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [3,4,5].

1 Adjusted for age, household income, geographical location (urban or rural), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level and BMI, and corresponding exposure. $PM_{2.5}$, O_3, NO_2 and wildfire smoke exposure models were also adjusted for average temperature, cardiovascular outcome models were adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health.

2 Adjusted for household income, geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI and corresponding exposure. $PM_{2.5}$, O_3, NO_2 and wildfire smoke exposure models were also adjusted for average temperature, and mental disorder models were adjusted for self-perceived mental health.

3 High temperature is the annual single highest temperature that individuals were exposed to. The average daily maximum temperature is the annual average of all daily maximum temperatures individuals were exposed to.

4 Low temperature is the annual single lowest temperature that individuals were exposed to. The average daily minimum temperature is the annual average of all daily minimum temperatures individuals were exposed to.

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

5. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imd

Appendix 8 Length of Residence in Canada Results

Table A8 Adjusted logistic model results for length of residence and health outcomes

Exposure model	**Health outcome**	**Immigrant population OR (95% CI)[1]**	**Length of residence in Canada**	**Total population Immigrant variables OR (95% CI)[1,2]**
High temperature (Celsius)[6]	Asthma[3]	1.04 (0.48 – 2.26)	< 10 years	**0.27*** ** (0.13-0.55)
			≥ 10 years	**0.40*** ** (0.26-0.60)
	Cardiovascular outcome[4]	1.01 (0.99-1.03)	< 10 years	0.66 (0.23-1.84)
			≥ 10 years	0.90 (0.67-1.20)
	Mental disorder[5]	0.91 (0.59-1.39)	< 10 years	0.52 (0.25-1.08)
			≥ 10 years	**0.69*** (0.50-0.94)
Low temperature (Celsius)[7]	Asthma	1.05 (0.48-2.32)	< 10 years	**0.27*** ** (0.13-0.56
			≥ 10 years	**0.39*** ** (0.26-0.59)
	Cardiovascular outcome	1.09 (0.84-1.41)	< 10 years	0.65 (0.23-1.82)
			≥ 10 years	0.89 (0.67-1.19)
	Mental disorder	0.93 (0.62-1.40)	< 10 years	0.51 (0.24-1.05)
			≥ 10 years	**0.67*** (0.49-0.92)
Average temperature (Celsius)	Asthma	1.10 (0.50-2.44)	< 10 years	**0.27*** ** (0.13-0.55)
			≥ 10 years	**0.39*** ** (0.26-0.60)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.65 (0.23-1.84)
			≥ 10 years	0.90 (0.67-1.20)
	Mental disorder	0.91 (0.60-1.37)	< 10 years	0.51 (0.25-1.05)
			≥ 10 years	**0.67*** (0.49-0.92)
Average daily maximum temperature (Celsius)[6]	Asthma	1.11 (0.50-2.48)	< 10 years	**0.27*** ** (0.13-0.56)
			≥ 10 years	**0.39*** ** (0.26-0.59)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.66 (0.23-1.85)
			≥ 10 years	0.90 (0.67-1.21)

	Mental disorder	0.91 (0.60-1.37)	< 10 years	0.52 (0.25-1.08)
			≥ 10 years	**0.69*** (0.50-0.94)
Average daily minimum temperature (Celsius)[7]	Asthma	1.06 (0.48-2.35)	< 10 years	**0.27***** (0.13-0.56)
			≥ 10 years	**0.40***** (0.26-0.60)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.65 (0.23-1.85)
			≥ 10 years	0.90 (0.67-1.20)
	Mental disorder	0.91 (0.61-1.38)	< 10 years	0.50 (0.24-1.05)
			≥ 10 years	**0.67*** (0.49-0.91)
Average diurnal temperature range (Celsius)	Asthma	1.09 (0.50-2.37)	< 10 years	**0.27***** (0.13-0.56)
			≥ 10 years	**0.39***** (0.26-0.60)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.65 (0.23-1.85)
			≥ 10 years	0.90 (0.67-1.20)
	Mental disorder	0.90 (0.60-1.36)	< 10 years	0.52 (0.25-1.08)
			≥ 10 years	**0.69*** (0.50-0.94)
Average $PM_{2.5}$ ($\mu g/m^3$)	Asthma	1.08 (0.49-2.40)	< 10 years	**0.27***** (0.13-0.55)
			≥ 10 years	**0.40***** (0.26-0.60)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.67 (0.24-1.88)
			≥ 10 years	0.89 (0.67-1.20)
	Mental disorder	0.91 (0.60-1.37)	< 10 years	0.51 (0.25-1.06)
			≥ 10 years	**0.69*** (0.51-0.95)
Average NO_2 (ppb)	Asthma	1.11 (0.49-2.49)	< 10 years	**0.27***** (0.13-0.55)
			≥ 10 years	**0.39***** (0.26-0.59)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.62 (0.22-1.77)
			≥ 10 years	0.88 (0.66-1.18)
	Mental disorder	0.90 (0.60-1.34)	< 10 years	0.51 (0.25-1.06)
			≥ 10 years	**0.68*** (0.50-0.93)
Average O_3 (ppb)	Asthma	1.04 (0.47-2.31)	< 10 years	**0.26***** (0.13-0.55)

			≥ 10 years	**0.39*** ** (0.26-0.60)
	Cardiovascular outcome	1.01 (0.99-1.03)	< 10 years	0.64 (0.22-1.81)
			≥ 10 years	0.88 (0.66-1.18)
	Mental disorder	0.90 (0.60-1.35)	< 10 years	0.52 (0.25-1.08)
			≥ 10 years	**0.68*** (0.50-0.93)
Average wildfire smoke ($PM_{2.5}$ $\mu g/m^3$)	Asthma	0.88 (0.39-2.02)	< 10 years	**0.25*** ** (0.13-0.49)
			≥ 10 years	**0.45*** ** (0.30-0.68)
	Cardiovascular outcome	1.02 (1.00-1.04)	< 10 years	0.37 (0.11-1.28)
			≥ 10 years	0.86 (0.62-1.18)
	Mental disorder	0.97 (0.61-1.54)	< 10 years	0.45 (0.20-1.02)
			≥ 10 years	**0.65*** (0.46-0.91)

***p<0.001, **p<0.01, *p<0.05

Sources: Canadian Urban Environmental Health Research Consortium [1], National Air Pollution Surveillance Program [2] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [3,4,5].

1 Adjusted for age, sex, marital status, household size, self-perceived health, sense of belonging to the community, cultural/racial background, education level, BMI, household income, geographical location (urban or rural), smoking status and length of residence in Canada. $PM_{2.5}$, O_3, NO_2 and wildfire smoke exposure models were also adjusted for average temperature, cardiovascular outcome models were adjusted for high blood pressure and diabetes, and mental disorder models were adjusted for self-perceived mental health. Results are for immigrants who have been in Canada for 10 plus years compared to those who have been in Canada for less than 10 years.

2 These models are for the total population, using similar variables to the immigrant models. In some cases, immigrant models included variables that were recategorized due to cell size issues.

3 Total population asthma models used a categorical length of residence variable.

4 Total population cardiovascular outcome models used a continuous length of residence variable.

5 Total population mental disorder models used the natural log of the continuous length of residence variable.

6 High temperature is the annual single highest temperature that individuals were exposed to. The average daily maximum temperature is the annual average of all daily maximum temperatures individuals were exposed to.

7 Low temperature is the annual single lowest temperature that individuals were exposed to. The average daily minimum temperature is the annual average of all daily minimum temperatures individuals were exposed to.

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. National air pollution surveillance program. 2022. Available from: https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html

3. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

4. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

5. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb

Appendix 9 Sensitivity Analysis Results

Table A9 Sensitivity analysis for all populations and outcomes

Exposure type and outcome	Exposure level	Total population OR (95% CI)[1]	Total population adolescent OR (95% CI)[2]	Total population older adults OR (95% CI)[1]	Immigrant population OR (95% CI)[3]
$PM_{2.5}$ V5 (µg/m^3), asthma	Very low	Reference			
	Low	1.17 (0.90-1.50)	1.03 (0.56-1.88)	1.08 (0.65-1.77)	0.81 (0.35-1.90)
	Medium	1.17 (0.89-1.53)	0.83 (0.45-1.55)	0.83 (0.51-1.35)	0.53 (0.24-1.19)
	High	0.95 (0.71-1.26)	1.28 (0.66-2.46)	0.66 (0.39-1.12)	0.60 (0.22-1.66)
$PM_{2.5}$ V5 (µg/m^3), cardiovascular outcomes	Very low	Reference			
	Low	1.00 (0.73-1.36)	-	1.18 (0.78-1.78)	1.02 (0.43-2.45)
	Medium	1.01 (0.75-1.35)	-	1.10 (0.77-1.57)	1.27 (0.61-2.63)
	High	1.09 (0.78-1.51)	-	1.25 (0.82-1.92)	1.00 (0.48-2.10)
$PM_{2.5}$ V5 (µg/m^3), mental disorders	Very low	Reference			
	Low	1.03 (0.78-1.35)	0.75 (0.27-2.05)	1.17 (0.69-1.99)	0.96 (0.31-2.98)
	Medium	0.77 (0.58-1.01)	0.61 (0.24-1.56)	0.95 (0.57-1.57)	0.90 (0.28-2.89)
	High	0.79 (0.58-1.07)	0.56 (0.20-1.60)	1.17 (0.70-1.95)	1.01 (0.30-3.45)

Sources: Canadian Urban Environmental Health Research Consortium [1] and the Canadian Community Health Survey linked to Longitudinal Immigration Database [2,3,4].

1 Adjusted for age, household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, marital status, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type, education level, BMI, average temperature and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes and mental disorder models were adjusted for self-perceived mental health.

2 Adjusted for household income, population type (immigrants or non-immigrants), geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI, average temperature and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes and mental disorder models were adjusted for self-perceived mental health.

3 Adjusted for household income, geographical location (urban or rural), sex, household size, cultural/racial background, self-perceived health, sense of belonging to the community, smoking type and BMI, length of residence in Canada, average temperature and corresponding exposure. Cardiovascular outcome models were also adjusted for high blood pressure and diabetes and mental disorder models were adjusted for self-perceived mental health.

References

1. The Canadian Urban Environmental Health Research Consortium. [Internet]. Available from: https://canue.ca/

2. Government of Canada. Canadian community health survey - annual component (CCHS) [Internet]. 2023 Dec 29. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226

3. Government of Canada. Longitudinal immigration database (IMDB) [Internet]. 2021. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5057

4. Government of Canada. Linkage of the Canadian community health survey (2003-2014) to the longitudinal immigration database (1980-2013) [Internet]. 2018. Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cencchs-imdb