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Role of Temperature on Health Outcomes for People with Schizophrenia Spectrum Disorders

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Abstract

Rising ambient temperatures and more frequent temperature extremes are increasingly recognized as important determinants of health, particularly for people with schizophrenia spectrum disorders (SSD) who are vulnerable to heat- and cold-related risks. This thesis first reviews evidence on how ambient and extreme air temperatures are associated with SSD-related health outcomes. Extreme heat was consistently linked to higher risks of emergency department (ED) visits, hospitalizations, and mortality. A few studies also linked extreme cold with increased outpatient visits and hospital admissions. Ambient and diurnal temperature range effects were smaller and heterogeneous, and apparent and seasonal metrics suggested additional risks that vary by sociodemographic and regional factors. Next, we examined the short-term effects of extreme temperature on ED visits among people with SSD in Ontario, Canada, using a time-stratified case-crossover design with conditional Poisson and distributed lag non-linear regression models. Extreme heat was associated with a lower risk of mental health ED visits, but a higher risk of non-mental health ED visits. Extreme cold was associated with a lower risk of non-mental health ED visits and was not associated with mental health ED visits.

Keywords

Schizophrenia spectrum disorders, extreme temperature, heat and cold exposure, climate-related health impacts, health service utilization, emergency department utilization, case-crossover design, distributed lag models.

Summary for Lay Audience

As the climate warms and extreme temperatures become more common, research shows higher risks of death, heart and lung problems, and mental health crises, particularly in vulnerable groups. People with schizophrenia spectrum disorders (SSD) already face serious health challenges, including physical illnesses and difficulties regulating body temperature, which may make them especially sensitive to heat and cold. This work reviews existing studies on temperature and SSD, then focuses on how extreme temperatures are linked to emergency department (ED) use for both mental and physical health reasons among people with SSD in Ontario, Canada.

I systematically reviewed all published studies that looked at how temperature affects the health of people with SSD. I searched three major medical databases, screened nearly 3,600 records, and ultimately included 37 studies from around the world. These studies used different ways of measuring temperature (for example, heat waves, cold spells, and day-to-day temperature changes) and examined outcomes such as emergency visits, hospital admissions, and deaths. Overall, the review found that extreme heat, and to a lesser extent extreme cold, were often linked to higher use of health services and poorer health outcomes for people with SSD.

In the second part of the study, I used health records and weather data from across Ontario to see how very hot and very cold days affect ED visits among people with SSD. Each person was compared to themselves on different days, which helps separate the effect of temperature from their usual health service use patterns. The study included over 116,000 people with SSD and more than 160,000 ED visits in 2019 and separately looked at visits for mental health and non-mental health reasons. Daily temperature, air pollution, and humidity were linked to each person's home address, and advanced statistical models were used to track how temperature affects ED visits over several days. The results show that extreme heat was followed by fewer ED visits for mental health reasons but more ED visits for non-mental health reasons. During periods of extreme cold, there were fewer ED visits for non-mental health reasons and no effect on ED visits for mental health reasons.

Co-Authorship Statement

This thesis includes two integrated articles, which will be submitted for publication in peer-reviewed journals. The co-author details for each article are presented below.

Chapter 2: Patel D., Wilk P, Rana Bhatt D., Anderson K.K., Rotenberg M.

Diya Patel was involved in conception and design of the study, the literature search, study screening and selection, data extraction, risk of bias assessment, analysis, and interpretation of data, writing the first and subsequent drafts of the paper. Dr. Piotr Wilk was involved in the interpretation of data, and critical revision of the article. Deepmala Rana Bhatt was involved in study screening, data extraction and risk of bias. Dr. Kelly K. Anderson was involved in the conception and design of the study, and interpretation of data and critical revision of the article. Dr. Martin Rotenberg was involved in the conception and design of the study, interpretation of data and critical revision of the article.

Chapter 3: Patel D., Wilk P., Lam M., Anderson K.K, Rotenberg M.

Diya Patel was involved in the conception and design of the study, data acquisition and curation, coding and statistical analysis of data, and writing the first and subsequent drafts of the paper. Dr. Piotr Wilk was involved in designing the study, data acquisition, and interpretation of data, and critical revision of the article. Melody Lam was involved in data acquisition. Dr. Kelly K. Anderson acquired funding and was involved in the conception and design of the study, data acquisition, provided guidance on data analysis, and interpretation of data, and critical revision of the article. Dr. Martin Rotenberg was involved in the conception and design of the study, data acquisition, provided guidance on data analysis, and interpretation of data and critical revision of the article.

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Chapter 1

1. Introduction

1.1 Thesis Overview

Over the past four decades, a growing body of research has supported an association between environmental factors – such as air pollution, green space, and ambient temperature – and population health.[1,2] In particular, numerous studies have examined how variations in environmental temperature can influence outcomes in people with mental disorders.[3] Deviations from typical temperature ranges, especially during extreme heat or cold events, have been shown to negatively impact health, with disproportionately adverse effects observed in vulnerable populations, including those with psychiatric conditions.[4] Numerous studies, including a systematic review and meta-analysis, have shown that people with mental illness have higher mortality and morbidity, higher hospital admissions, and overall detrimental mental health outcomes during extreme heat events.[4,5] Among these, schizophrenia spectrum disorders have received considerable attention due to their complex symptomatology and susceptibility to environmental stressors.[6]

In the following chapter, background information on different types of environmental temperature, and overview of schizophrenia spectrum disorders will be provided. Additionally, the effects of temperature on schizophrenia spectrum disorders will be introduced in this chapter.

1.2 Global Temperature

The global average temperature has progressively increased due to elevated carbon-dioxide emissions, and is estimated to increase by 2.6ºC to 4.8ºC by the end of the century if current emission trends persist.[7]

This rise in temperature leads to more frequent and intense rainfall events, increased variability in weather patterns, and long-term rise in terrestrial precipitation.[8,9] The direct effects of this climate change are diverse, and may include heat stress, floods, drought, and more frequent extreme weather events.[7] Indirectly, these climatic shifts have had an impact on human health through factors such as spread of disease vectors, food insecurity, and displacement, and has also led to detrimental mental health impacts.[7]

Environmental temperature can be divided into two categories: ambient and extreme temperature. The following sections will define these temperature categories in more detail and explore their respective impacts on population health.

1.2.1 Ambient Temperature

Ambient temperatures have received increased attention amidst the global climate crisis. Defined as the average air temperature in surrounding air, ambient temperature can be quantified through many derived indicators such as daily mean temperature, diurnal temperature range, or apparent temperature.[10] Variability in ambient temperatures has been linked to numerous health outcomes, from acute mortality to longer-term impacts on chronic disease progression.[11,12] Although the present background does not provide an exhaustive list, some of the most commonly studied outcomes will be discussed in the following sections.

1.2.2 Types of Ambient Temperature Indicators

Mean temperature is one of the most widely used indicators of ambient air temperature. It is calculated as the average of observed temperatures within a defined period.[13] The majority of studies use daily mean temperature, but longer periods of time such as seasonal or annual temperature have also been used.[14,15] Another commonly used measure is diurnal temperature range, defined as the difference between the daily maximum and daily minimum temperatures.[16] This measure is mainly used in studies that are exploring urban heat island dynamics, or short-term thermal stress.[17] In addition to these direct measures, composite measures such as apparent temperature may better represent perceived temperature, as they integrate ambient temperature and atmospheric humidity.[18] Some formulations also include solar radiation and wind speed.[19] Collectively, mean temperature, diurnal temperature range, and apparent temperature each measure distinct dimensions of thermal exposure and provide insight into associations between temperature and human health outcomes.

1.2.3 Ambient Temperature Related Health Outcomes

Ambient temperature has been examined in relation to a wide range of health outcomes, reflecting its broad physiological and systemic impacts on human health. One of the most consistently documented outcomes is excess mortality. Globally, an estimated 9.4% of annual deaths are attributable to non-optimal temperature with the majority of this burden driven by cold exposure.[5] Hot temperatures account for less than 1% of temperature-related deaths worldwide, while the remainder are cold-related.[5] Non-optimal temperatures account for more than 2.5% of all deaths in high-income countries and over 3.0% in middle-income countries.[20] Substantial regional variation has also been observed, with excess mortality rates nearly twice as high in Eastern Europe and Sub-Saharan Africa compared with Latin America, the Caribbean, and South-Eastern Asia.[5,21,22] Sub-Saharan Africa experiences the highest cold-related excess mortality, whereas Eastern Europe has the highest heat-related mortality.[5] Temporally, excess cold-related deaths have declined over recent decades, while heat-related excess mortality has increased.[5]

Beyond mortality, non-optimal temperatures have been linked to increased risk of cardiovascular and respiratory morbidity, including myocardial infarction, acute aortic dissection, and cardiorespiratory disease, particularly at lower ambient temperatures and during short-term temperature changes.[23–25] Ambient temperature has also been inversely associated with blood pressure,[26,27] and higher temperatures may exacerbate respiratory symptoms indirectly through increased concentrations of fine particulate matter.[28] Geographic factors further modify these relationships, with lower risks of myocardial infarction observed at higher latitudes, consistent with long-term adaption to cooler climates.[23]

Changes in mental health outcomes have also been reported with non-optimal ambient temperatures, with the majority of literature focusing on health service use and mortality outcomes. Both heat and cold temperatures increase mortality rates and health service usage.[3,29] However, factors such as availability of caregivers and care, community treatment centers, and income all moderate this relationship.[29]

1.3 Extreme Temperature

Extreme temperature events are established once the temperature crosses above an upper or lower threshold of historical temperature measurements.[30] Through thermoregulation, the body carefully maintains a core temperature of 37ºC to ensure proper physiological function.[31] To counteract heat accumulation, the body uses heat dissipation mechanisms such as sweating and peripheral vasodilation.[31] Similarly, to counteract cold stress, defense mechanisms such as increased thermogenesis (shivering) and peripheral vasoconstriction are used.[32]

1.3.1 The Effects of Heat Stress

The majority of the adverse health outcomes associated with extreme temperatures are often a result of the temperature overwhelming the body's thermoregulatory systems.[33] Responses to heat accumulation can range from milder conditions such as heat rashes and cramps to more serious conditions such as heat exhaustion or heat strokes.[31] In addition, periods of extreme heat increase the occurrence and exacerbate underlying illnesses and organ injuries.[31] Multiple studies have shown increased adverse health outcomes, including mortality, for people with ischemic heart disease, cardiac dysrhythmia, asthma and chronic obstructive pulmonary diseases, hyperglycemia, and kidney failure during extreme heat events.[31,34,35]

1.3.2 The Effects of Cold Stress

Cold stress introduces unique detrimental health effects. Interestingly, cold stress significantly lowers an individual's strength, power and balance, primarily due to decline in deep body and muscle temperature, and cardiovascular and metabolic changes.[36] Cold exposure can also activate physiological stress-response pathways, induce inflammatory changes, and alter neurotransmitter and hormonal regulation (e.g., norepinephrine and cortisol), which may adversely affect mood, cognition, and vulnerability to psychiatric symptom exacerbation.[37] Several studies have also revealed that cold stress is inversely related to cancer incidence and mortality.[38] The underlying mechanism is thought to be altered gene expression due to the exposure to cold stress which influences cancer progression.[38] Additionally, prolonged exposure to extreme low temperatures increases overall health risk and mortality for people with respiratory diseases, circulatory diseases, cardiovascular disease, and mental health illnesses.[39–42]

1.3.3 Mental Health Outcomes

Several adverse mental health outcomes have been associated with extreme temperature events. The majority of prior research explores the excess risk of suicide associated with extreme weather events.[3,43,44] Evidence also suggests that extreme temperature may also lead to increases in hospital admissions, outpatient care, and ER visits for bipolar disorder, depression, and schizophrenia, among other mental disorders.[43,45] Beyond mental health there is evidence that temperature extremes may impact other brain health or neurological conditions such as severity of stroke, migraines, multiple sclerosis, Parkinson's disease and sleep disorders.[46,47]

1.3.4 Vulnerable Groups

Risks associated with extreme temperature exposure are higher for vulnerable groups such as outdoor occupational groups (e.g. construction workers, firefighters, agriculture workers), people aged over 65 years, young children and pregnant women, athletes, people living in lower income households, some communities of colour, and people with pre-existing physical and mental health conditions.[31,48]

1.4 Schizophrenia Spectrum Disorders

SSDs encompass a broader classification that include schizophrenia along with related psychotic conditions such as schizoaffective disorder, delusional disorder, schizophreniform disorder, and schizotypal personality disorder, which are characterized by varying degrees of psychosis and functional impairment.[49]

1.4.1 Diagnostic Criteria

According to the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5), some of the core symptoms of schizophrenia are positive symptoms, negative symptoms, and cognitive deficits.[50] Positive symptoms comprise of delusions, hallucinations, disorganized speech and motor behavior, and negative symptoms include apathy, flat affect, and withdrawal from social relationships.[51] At least two or more of the preceding symptoms must be present for a significant portion of 1-month period or longer (and at least one must be delusions, hallucinations, or disorganization). Additionally, continuous signs of disturbance must persist for at least 6 months, and there must be impairment in one or more major areas of functioning (work, interpersonal relations, or self-care).[52] Due to these debilitating symptoms, these disorders are one of the leading causes of disability.[53]

1.4.2 Risk Factors

The onset of schizophrenia is typically in early adulthood, with a median onset age of 25 years.[54] The prevalence of schizophrenia increases by age, peaking at the age of 20.5 years.[54] However, several studies suggest the etiology of this disease begins early in neurodevelopment.[52] Increased rates of adversity in utero (e.g. maternal starvation, infection, insufficient neonatal vitamin D), obstetric complications (e.g. preterm birth and preeclampsia), and early disrupted neurodevelopment, such as altered ectodermal development and mild cognitive motor impairments, all contribute to the heightened risk of developing SSD.[52,55] In addition to prenatal and neurodevelopmental factors, other socio-environmental elements such as winter birth, childhood trauma, urban living, migration, and cannabis use are all important to SSD risk pathways.[55,56] For example, studies on birth seasonality have found excess of schizophrenia births during the winter and early spring months.[57] Other studies suggest the overall risk associated with developing schizophrenia is 2.9 times higher among migrant groups, which is greater than most other socioenvironmental risk factors.[54] Similarly, cannabis doubles the risk of developing SSDs in vulnerable populations, through interactions with the dopamine neurotransmitter system.[58] There is also a large genetic component to schizophrenia, where studies show heritability is estimated to be around 80%.[59]

1.4.3 Health-Related Outcomes

People with schizophrenia experience a broad range of adverse health-related outcomes, including elevated all-cause mortality and a substantial reduction in life expectancy compared with the general population.[60,61] Cardiovascular disease, respiratory illness, infections, and metabolic disorders all contribute to the excess mortality, and these conditions are also temperature-sensitive.[62–65] Cardiometabolic disease is also a major concern for people with schizophrenia.[66] Compared to the rest of the population, those with schizophrenia have a substantially increased risk of death from ischemic heart disease, stroke, and diabetes.[62,66] In addition, many people face significant burden from comorbid psychiatric conditions, have poorer quality of life, and experience greater health care inequalities.[67–69]

1.4.4 Internal Temperature and Regulation

Several studies have noted differences in core temperatures and thermoregulation in people with SSD compared to the general population. A study exploring circadian core temperatures found that people with SSD have an earlier peak temperature, higher hourly morning peak temperatures, and drastically lower core temperatures in the evening after 5:00 PM.[70] In addition, a study by Shiloh et al, suggests people with SSD have exaggerated increases in core temperature during transitory infectious and inflammatory processes.[71] Studies on thermoregulation suggest SSD is associated with wider temperature differentials, failure to adapt to heat stress, and comparatively higher body temperature under cold stress.[65] All of these studies demonstrate the vulnerability of people with SSD to temperature changes in the environment.

1.4.5 Temperature and Schizophrenia

People with schizophrenia exhibit impaired heat tolerance, which may be exacerbated by antipsychotic medications that disrupt thermoregulatory responses.[72] Particularly first-generation agents and second-generation agents are known to impair thermoregulatory processes, and people with schizophrenia maintained on antipsychotics have shown impaired heat tolerance when exposed to high temperatures.[72] Cold exposure may also pose unique challenges. Antipsychotics can affect peripheral responses to temperature, and studies suggest people receiving chronic antipsychotic treatment may be more prone to hypothermia and impaired temperature regulation in cold environments.[73]

Social determinants of health also may shape the vulnerability of people with SSD to temperature extremes. People with SSD experience disproportionately high rates of housing instability and homelessness, which can increase exposure to extreme temperatures and limit access to climate-controlled environments.[74,75] Economic disadvantage may also restrict the ability to afford or use air conditioning or adequate heating during extreme weather events.[74,76] Cognitive and functional impairments such as disorganization, and impaired judgment, may interfere with risk perception and engagement in protective behavior during periods of environmental stress. Collectively, these social vulnerabilities likely interact with pharmacological and physiological factors to heighten temperature-related health risks among people with SSD.

1.5 Current Thesis

1.5.1 Rationale

SSDs are relatively rare conditions,[77,78] yet they account for significant disability and costs.[79] The largest burden from schizophrenia is during the most productive years of a person's life, specifically between the ages of 25 and 54 years.[59] For each person diagnosed with schizophrenia at age 25, the total lifetime cost to the economy is approximately $3.8 million or $92,000 per year.[80] In Canada, a high frequency of inpatient admissions accounts for the large proportion of the total cost of SSD.[79] In addition to the economic burden, evidence suggests people with SSD are vulnerable to temperature through physiological, pharmacological, and social mechanisms.

Yet, there is a significant lack of studies exploring the health outcomes among people with SSD associated with ambient and extreme temperatures, especially from a Canadian context. Additionally, extreme cold temperatures have rarely been a focus in this body of literature, and there is limited knowledge of the effects of both extreme heat and extreme cold temperatures, on the use of acute physical and mental health care services among people with SSD.

1.5.2 Objectives

This thesis will examine the association of ambient and extreme air temperature on the health outcomes for people with SSD. The main objectives of this thesis are to:

i) Review the current literature on the effect of ambient and extreme temperatures on both physical and mental health outcomes among people with SSD (Chapter 2).

ii) Examine the association between extreme temperature events and the use of emergency department (ED) services for mental health and non-mental health reasons among people with SSD in Ontario (Chapter 3).

Chapter 2

2. The Effect of Ambient and Extreme Air Temperature for People with Schizophrenia Spectrum Disorders: A Systematic Review and Meta-Analysis

2.1 Background

The rising global temperature will have a significant impact on human health. Long-term exposure to changing temperatures due to climate change can increase the spread of infectious diseases and increase the risk of adverse health outcomes.[3] Extreme cold temperatures can cause hypothermia and frostbite, and may worsen cardiovascular and respiratory conditions.[24] Extreme heat can lead to exhaustion, dehydration, and heatstroke, particularly in vulnerable populations such as older adults, children, and those with chronic illnesses.[19,22,23] In addition, temperature can affect mental health – prolonged heatwaves have been linked to higher levels of stress, anxiety, aggression, and sleep disturbances, and even increased rates of depression.[32,33]

Many systematic reviews and meta-analyses have examined the relationship between ambient air temperature and broad categories of mental and behavioral disorders, such as mood disorders, substance misuse, anxiety disorders, and dementia. A 2023 review of 114 studies by Thompson et al. found evidence linking elevated ambient and extreme temperatures with worsening mental health outcomes.[58] In particular, each 1ºC increase in mean monthly temperature was associated with a 1.5% increase in suicide incidence, and heatwaves significantly increased mental health-related hospital visits.[58] Another meta-analysis of 53 studies by Lui et al. found each 1ºC increase in temperature increased mental health-related mortality by 2.2% and morbidity by 0.9%, with heatwaves leading to increased numbers of hospitalizations for mood- and substance-related disorders.[59] Among older adults, each 1ºC rise in temperature led to a 1.4% increase in mental health hospital admissions.[81] In addition, heatwave effects increased admissions by 27%, and extreme heat and cold exposure may be associated with declines in cognitive function and an increased risk of adverse health outcomes for various mental and neurological conditions.[81] Despite this growing body of evidence, there is no review to date that has specifically explored the effects of ambient or extreme temperatures on schizophrenia spectrum disorders (SSD), leaving a gap in understanding how this vulnerable population is affected.

People with SSD may be more vulnerable to ambient and extreme temperatures due to a combination of physiological, clinical, and social determinants. Antipsychotic medications, which are essential to SSD management, can impair thermoregulation by altering sweating, heat dissipation, and core temperature control, making those with SSD less able to physiologically adapt to heat exposure.[6,72,82] Additionally, comorbid health conditions such as cardiovascular disease, metabolic syndrome or renal issues - which occur at elevated rates among people with SSD - may worsen vulnerability to dehydration, heat or cold induced strain, and general physiological stress.[6,83] Social factors such as higher levels of inadequate housing among people with SSD can increase exposure to cold environments and exacerbate cold-related risks.[84] Collectively, these factors contribute to the increased risk observed in this population during periods of extreme heat or cold.

The objective of this study was to perform a systematic review and meta-analysis of the literature on the association between extreme and ambient air temperature and health outcomes for people with SSD.

2.2 Methods

This systematic review was pre-registered with PROSPERO (Protocol # CRD42024572794). We followed the PRISMA reporting guidelines for systematic reviews and meta-analyses, and the checklist can be found in Appendix 2.1.

2.2.1 Search Strategy and Study Selection

We conducted an electronic literature search using the MEDLINE, Embase, and PsycInfo databases in July 2024. The search strategy primarily focused on the two concepts (i) temperature and (ii) SSD, and used a combination of keywords and controlled vocabulary specific to each database (Appendix 2.2). No restrictions were placed on the date of publication;

however, the search was limited to articles published in English. Additional relevant articles were identified by forward and backward citation tracing of included articles.

Study screening was performed using Covidence, and title and abstract screening were done by a single reviewer (DP). Studies that evaluated the effects of closed environment (i.e. indoor) temperature changes, other systematic reviews and meta-analyses, narrative reviews, and case reports were excluded at this stage of the screening. Full-text review was performed in duplicate by two independent reviewers (DP and DRB). Studies were included if they examined: (i) any clinical or service-related health outcome; (ii) ambient or extreme air temperature; (iii) among people with SSD, diagnosed using standardized criteria such as ICD or DSM; (iv) relative to a moderate temperature or general population comparison group. All geographic regions and study designs were included, where observational studies were more expected over randomized control trials. Studies which included people with other mental disorders, without providing stratum-specific estimates for SSD, were excluded.

2.2.2 Data Extraction

A data extraction table was created to facilitate the comparison of information across the included studies. We extracted data on the following study characteristics: title, author(s), year of publication, country, study sample, study design, sample size, age range, type of temperature measurement, outcomes, and the type and the value of any reported effect estimates. Data were extracted by one reviewer (DP) independently and verified by the second reviewer (DRB).

2.2.3 Risk of Bias

One reviewer (DP) assessed the risk of bias in included studies, followed by verification by the second reviewer (DRB). To the best of our knowledge, there is no validated scale developed to assess the risk of bias for time-series or case-crossover study designs. Therefore, risk of bias was assessed using the CLARITY cohort study tool. In addition to core CLARITY domains, study-specific considerations, including control of environmental confounders, and consideration of temporal or lag effects, were evaluated to ensure appropriate assessment of methodological quality in the context of temperature-health research.

The included studies were evaluated for risk of bias using the modified CLARITY tool, and the following characteristics were considered:

- Selection of source population: Was the selection of exposed and non-exposed groups drawn from the same population?
- Assessment of exposure: Can we be confident in the assessment of the exposure?
- Assessment of outcome: Can we be confident in the assessment of the outcome?
- Outcome absent at start of the study: Can we be confident that the outcome of interest was not present at the start of the study?
- Inclusion of confounding factors
- Missing data
- Control of environmental factors: Were other environmental factors considered and controlled for in the statistical model?
- Consideration of temporal or lag effects: Were temporal or lag trends included in the statistical model?

Disagreements between the reviewers were resolved by discussion, with the involvement of a co-author (KKA) where needed.

2.2.4 Data Synthesis and Meta-Analyses

Findings from all included studies were summarized using a narrative synthesis. Studies which presented suitable data for quantitative synthesis were included in a random-effects meta-analysis when at least four studies reported sufficient and comparable data for a given exposure-outcome pairing. In studies that used the same cohort, the most recent one was used, unless an earlier study was considered higher quality based on risk of bias assessment. Due to the diverse range of temperature indicators, the data were divided by the type of temperature exposure: extreme heat, ambient heat, diurnal temperature range, extreme cold, and others.

Measures of effect for each meta-analysis were converted to risk ratios (RRs), as hazard ratios and odds ratios were assumed to approximate the RR due to low incidence of the outcome. [4,85] Percent change was transformed using the equation: RR = 1+ (PC/100). For studies that provided estimates per increment in exposure, the estimates were standardized to increases per

10 ºC using the equation: RR (per increase in 10 units) = $[RR(\text{per c units})]^{10/c}$, where c is the reported increment in degrees Celsius.[86] In studies that stratified estimates by lagged temperature exposure, only estimates from 0, 1 or 0-1 days were included, as these lag periods were most consistently reported across studies. For the meta-analysis, all effect estimates were transformed to the natural log scale for pooling and then exponentiated back to relative risks (RRs) for presentation in the forest plots and summary results.

Results of the meta-analyses were summarized using forest plots. Between- study heterogeneity was assessed using the I^2 statistic, with values of 25%, 50%, and 75% indicating a low, medium, and high level of heterogeneity, respectively.[87] Publication bias was assessed through visual inspection of funnel plots and Egger's regression test for small-study effects.[87] All meta-analyses were conducted in RStudio 4.4.0 using the *metafor* package.[88] The findings are presented as RRs with corresponding 95% intervals.

2.3 Results

2.3.1 Search Results

Our electronic search identified a total of 3599 records, of which 3595 citations were found through database searching and four were found through citation tracing. Of the 3599 records, 2343 studies remained after duplicates were removed. After title and abstract screening, we excluded 2276 citations as they were not within the scope of this review. A total of 158 full-text studies were assessed for eligibility, and 121 studies were excluded due to the following reasons: did not report clinical or service-related outcomes (n = 12); were case studies or newspaper articles (n = 43); outdoor temperature was not the main exposure of interest (n = 54); or study population did not include people with SSD or did not differentiate people with SSD from other mental disorders (n = 12). In total, 37 studies were eligible for inclusion in this review. The full results of the literature search and study screening are presented in the PRISMA flow chart (Figure 2.1).

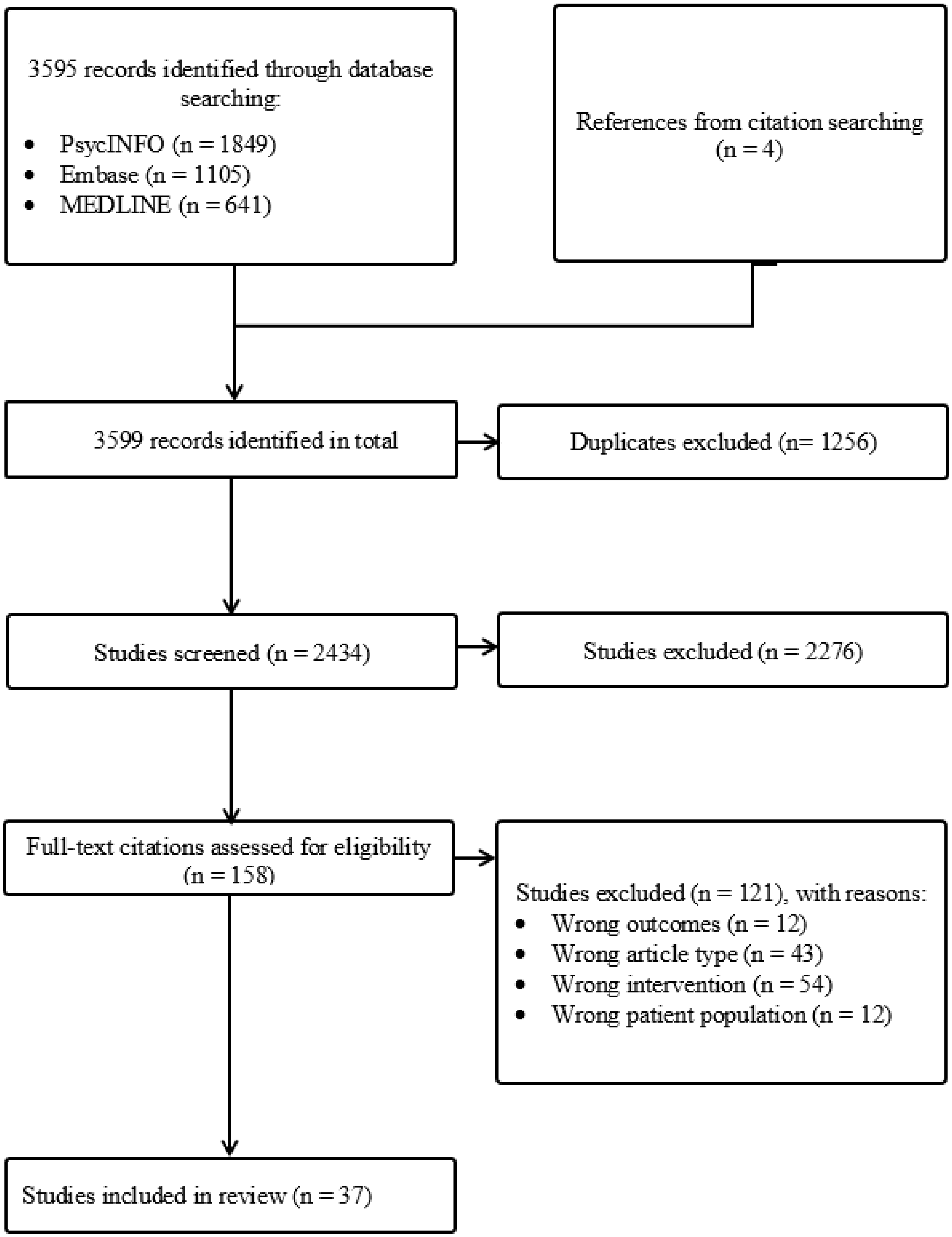

Figure 2.1 Prisma flowchart.

2.3.2 Study Characteristics

The characteristics of the included studies can be found in Tables 2.1 and 2.2, and a comprehensive summary of the included articles can be found in Appendix 2.3.

Of the 37 studies, 24 were published within the past five years, while the earliest studies date back to 1992. Most studies used either a time-series, or a case-crossover study design. The sample sizes ranged from 269 to 9.9 million (Tables 2.1 and 2.2). Eleven of the studies were conducted in North America (4 in Canada, 7 in USA) and seventeen in Asia (14 in China, 1 each in Taiwan, Israel, and Vietnam). Six were carried out in Europe (2 in Switzerland, 1 each in Greece, UK, Finland, and England) and 3 in Australia.

2.3.2.1 Ambient Temperature

A total of 25 studies examined associations between ambient temperature and SSD-related outcomes, including onset of schizophrenia, incidence, hospital admissions, and emergency room visits. Three studies used apparent temperature, with two looking at the association with emergency department visits and one with hospital admissions. Five studies focused on diurnal temperature range, all analyzing its effects on hospital admissions for schizophrenia and other mental disorders. Nine studies assessed ambient heat, including six focused on hospital admissions, one on emergency department visits, one on incidence of schizophrenia, and one on the risk of schizophrenia onset. Two studies considered both high and low temperatures, both analyzing hospital admissions for schizophrenia. In addition, five studies analyzed seasonal temperature patterns in relation to daily hospital admissions for heat or cold related illnesses, or for schizophrenia-related hospitalizations. One study applied projected temperature scenarios to estimate the future burden of schizophrenia-related emergency department visits.

2.3.2.2 Extreme Temperature

12 studies measured the influence of extreme temperatures on SSD-related health outcomes. A total of five studies measured both high and low extreme, and two analyzed their relationship to daily number of emergency department visits for mental health reasons, two for

hospital admissions for schizophrenia, and one for outpatient visits. Only one study explored cold spells and their relation to hospital admissions for schizophrenia, while six measured extreme heat.

Table 2.1 Characteristics of ambient temperature studies included in the review.

Citation	Country	Year	Type of Temperature	Age Range	Main Outcome	Study Design	SSD Sample Size	Study Period	Sample Source
Asimakopoulos, Lampros et al.	Greece	2021	Ambient temperature - seasonal	all	Hospital admissions for mental disorders	Time-series	269	2013 to 2019	General Hospital of Katerini
Aydin-Ghormoz, Heather et al.	USA	2022	Ambient temperature - seasonal	5+	Hospitalization for hot or cold related illness	Ecological time-series	12272393	2005 to 2019	SPARCS
Bundo, Marvin et al.	Switzerland	2021	Ambient temperature - heat only	all	Hospital admissions for mental disorders	Time-stratified case-crossover	275079	1973 to 2017	University Psychiatric Hospital
Bundo, Marvin et al.	Switzerland	2020	Ambient temperature - heat only	all	Hospital admissions for mental disorders	Time-series	71931	1973 to 2010	University Hospital of Psychiatry and Psychotherapy in Bern
Cohen, Gali et al.	USA	2024	Ambient temperature - diurnal temperature range	all	Hospital admissions for mental and behavioural disorders	Case-crossover	211973	1995 to 2014	SPARCS
Crank, Peter et al.	USA	2023	Ambient temperature - both	all	Hospital admissions for schizophrenia	Time-series	3287	2006 to 2014	Maricopa County Department of Public Health

Gupta, Sunjai et al.	United Kingdom	1992	Ambient temperature - heat only	15 to 54	Incidence of Schizophrenia	Retrospective cohort	NA-	1979 to 187	IPSS and DOSMD
Jahan, Shafkat et al.	Australia	2021	Ambient temperature - seasonal	all	Hospital admissions for schizophrenia	Time-series	38306	1996 to 2015	Queensland Health Department
Jahan, Shafkat et al.	Australia	2021	Ambient temperature - monthly	all	Hospital admissions for schizophrenia	Time-series	132088	1996 to 2015	Queensland Health Department
Komulainen, Kaisla	Finland	2022	Ambient temperature - heat only	10 to 27	Onset of schizophrenia from childhood to young adult	Prospective cohort	365482	1990 to 1995	Care Register for Health Care
Min, Minet al.	China	2019	Ambient temperature - apparent temperature	all	Emergency room visits for mental disorders	Time-series	8438	2014 to 2017	Hospital Medical Records
Niu, Yan-Linet al.	China	2024	Ambient temperature - projected	all	Emergency department visits for mental disorders	Time-series	16606	2016 to 2018	Beijing Municipal Health Commission
Nori-Sarma, Amruta et al.	USA	2022	Ambient temperature - heat only	18+	Emergency department visits for mental disorders	Case-crossover	2243395	2010 to 2019	OptumsLabs Data Warehouse

Pan, Rubing et al.	China	2022	Ambient temperature - diurnal temperature range	all	Hospital admissions for schizophrenia	Time-series	53376	2005 to 2019	Hefei Fourth People's Hospital
Qiu, Xinye et al.	USA	2022	Ambient temperature - both	65+	Hospital admissions for psychosis	Time-stratified case-crossover	165572	2000 to 2016	Medicare
Shiloh, Roni et al.	Israel	2005	Ambient temperature - seasonal	18+	Hospital admissions for psychosis	Time-series	33614	1981 to 1991	Tel-Aviv Hospital Records
Sung, Tzu-I et al.	Taiwan	2011	Ambient temperature - diurnal temperature range	all	Hospital admissions for schizophrenia	Retrospective cohort	64388	1996 to 2007	National Health Insurance Research Database
Takei, Noriyoshi et al.	England	1992	Ambient temperature - seasonal	all	Hospital admissions for psychosis	Retrospective observational	17770	1976 to 1986	Medical Health Enquiry Data
Tang, Chao et al.	China	2021	Ambient temperature - heat only	all	Hospital admissions for schizophrenia	Case-crossover	21169	2005 to 2019	AMHC
Tupinier Martin, Frederic et al.	Canada	2024	Ambient temperature - heat only	18+	Hospital admissions for psychosis	Time-stratified case-crossover	30649	2001 to 2019	QICDSS

Wang, S et al.	China	2018	Ambient temperature - heat only	all	Hospital admissions for schizophrenia	Time-series	17744	2005 to 2014	AMHC
Yi, Weizhuo et al.	China	2019	Ambient temperature - apparent temperature	all	Hospital admissions for schizophrenia	Time-series	36607	2005 to 2014	AMHC
Zhao, Desheng et al.	China	2017	Ambient temperature - diurnal temperature range	all	Hospital admissions for schizophrenia	Time-series	18417	2005 to 2014	AMHC
Zhao, Desheng et al.	China	2016	Ambient temperature - diurnal temperature range	all	Hospital admissions for schizophrenia	Time-series	36607	2005 to 2014	AMHC
Zhou, Qian et al.	China	2024	Ambient temperature - heat only	all	Hospital admissions for schizophrenia	Time-series	10420	2013 to 2020	Guangxi Zhuang Autonomous Regions Brain Hospital

Abbreviations: SPARCS, New York Statewide and Planning Research and Cooperative System; IPSS, International Pilot Study of Schizophrenia; DOSMD, Determinants of Outcome of Severe Mental Disorders; AMHC, Anhui Mental Health Center; QICDSS, Quebec's Integrated Chronic Disease Surveillance System.

Table 2.2 Characteristics of extreme temperature studies included in the review.

Citation	Country	Year	Type of Temperature	Age Range	Main Outcome	Study Design	SSD Sample Size	Study Period	Sample Source
Bark, Nigel et al.	USA	1998	Extreme temperature - heat only	all	Mortality	Retrospective ecological	28512	1971 to 1984	New York State Hospitals
Dang, Tran Ngoc et al.	Vietnam	2022	Extreme temperature - heat only	all	Hospital admissions for mental and behavioural disorders	Time-series	NA-	2017 to 2019	Ho Chi Minh City Mental Health Hospital
Hansen, Alana et al.	Australia	2008	Extreme temperature - heat only	15+	Hospital admissions for mental and behavioural disorders, and mortality	Time-series	4629	1993 to 2006	Integrated South Australian Activity Collection
He, Yangyang et al.	China	2022	Extreme temperature - cold only	all	Hospital admissions for schizophrenia	Time-series	11005	2013 to 2019	Hefei Fourth People's Hospital
Lavigne, Eric et al.	Canada	2023	Extreme temperature - both	all	Emergency department visits for mental and behavioural disorders	Case-crossover	9958037	2004 to 2020	NACRS
Lee, Michael et al.	Canada	2023	Extreme temperature - heat only	18+	Mortality	Case-crossover	8138	2021 to 2012	British Columbia's COVID-19 Data Library

Liu, Jintao et al.	China	2022	Extreme temperature - heat only	all	Hospital admissions for schizophrenia	Time-series	5779	2014 to 2020	Jining Psychiatric Hospital
Pan, Rubing et al.	China	2019	Extreme temperature - both	all	Hospital admissions for schizophrenia	Time-series	36607	2005 to 2014	AMHC
Pan, Rubing et al.	China	2020	Extreme temperature - both	all	Hospital admissions for schizophrenia	Time-series	36607	2005 to 2014	AMHC
Wang, Xiang et al.	Canada	2014	Extreme temperature - both	all	Emergency room visits for mental disorders	Time-series	46765	2002 to 2010	NACRS
Yoo, Eun-Hye et al.	USA	2021	Extreme temperature - heat only	all	Emergency room visits for mental disorders	Time-series	2893794	2009 to 2016	SPARCS
Zhang, Shiyu et al.	China	2020	Extreme temperature - both	all	Outpatient visits	Case-crossover	400	2013 to 2018	Hospital Medical Records

Abbreviations: NACRS, National Ambulatory Care Reporting System; AMHC, Anhui Mental Health Center, SPARCS; New York Statewide and Planning Research and Cooperative System.

2.3.3 Risk of Bias

The results of the risk of bias assessment are summarized in Figure 2.2, and detailed ratings are provided in Appendix 2.4. All studies were assessed as having low risk of bias for the domains related to outcome assessment and confirmation that the outcome was not present at baseline. This was largely due to the standardized classification of outcomes, most of which were identified using diagnostic codes or health administrative data.

Nearly all studies had a low risk level of bias for assessment of exposure, with the exception of two. In contrast, approximately a third of the studies had an intermediate or high risk of bias when evaluating control of environmental confounding factors, as they did not include variables such as air pressure, humidity, or air pollutants in their models. One third of the studies were rated as having a high risk of bias in the domain related to temporal or lag adjustment, as they did not account for the delayed effects of the temperature exposure. Furthermore, around half of the studies did not report information on the extent of missing data.

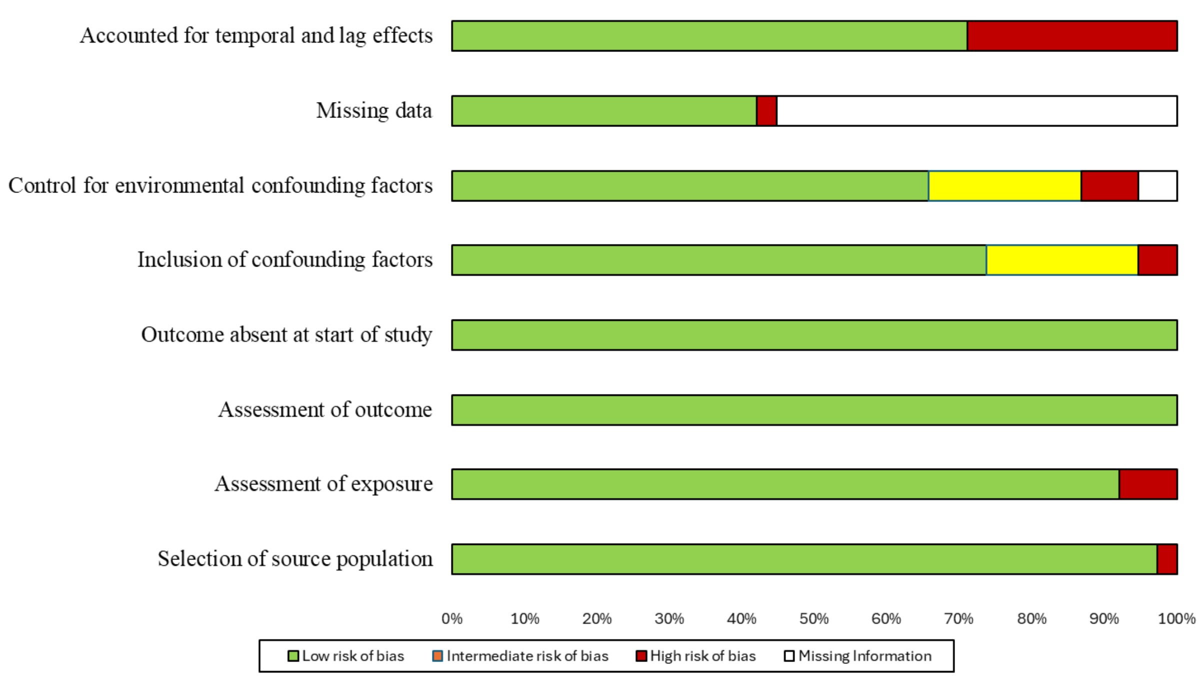

Figure 2.2 Risk of bias assessment summary.

2.3.4 Data Synthesis

For data synthesis, we grouped the studies according to the temperature exposure metric used. We classified exposures into five groups: extreme temperature, ambient temperature, diurnal temperature range, and other temperature indices. Results are summarized within each exposure group, with meta-analysis estimates reported where there were sufficient data to enable pooling of estimates.

2.3.4.1 Extreme Temperature Outcomes

The impact of extreme temperature was evaluated across five outcome categories: emergency department (ED) visits (3 studies), mortality (2 studies), outpatient visits (1 study), and hospital admissions (6 studies).[89–100] Overall, extreme heat was consistently associated with a higher risk of ED visits among people with SSD. The three studies examining ED visits reported cumulative estimates over varying lag periods, with cumulative risk estimates ranging from 4% to 149%.[89,90,93] Notably, the study with the highest cumulative effect also observed the strongest single-day association at lag 0, corresponding to a 9.7% increase in ED visits.[93] Similarly, extreme heat was associated with an increase in mortality.[94,95] However, findings for outpatient visits were mixed. In a multi-city study conducted in China, extreme heat was associated with outpatient visits in Zhaoqing but not in Shenzhen or Huizhou, suggesting potential regional effect modification.[96]

Three studies assessed extreme cold exposure. Collectively, they found that extreme cold temperature was significantly associated with increased outpatient visits after a delay, as well as higher rates of hospital admissions. [91,92,96]

Figure 2.3 shows the meta-analysis of the 4 studies examining the relationship between extreme heat and hospital admissions.[97–100] It showed an elevated risk of hospitalization among people with SSD during extreme heat (RR 1.22; 95% CI 1.04, 1.43). However, heterogeneity was high (I^2 = 85.3%; Figure 2.4), and both the funnel plot and Egger's test ($p<0.0001$) indicated possible publication bias or small-study effects.

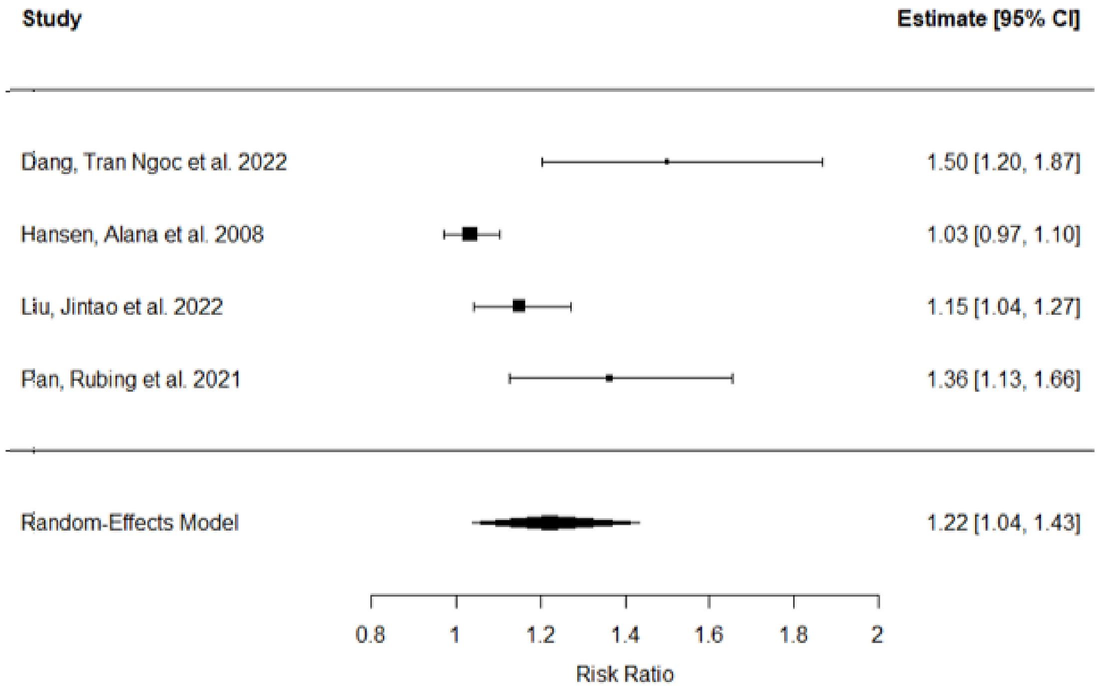

Figure 2.3 Results of a log-transformed random effects meta-analysis (REML) of the studies exploring the association between extreme heat and hospital admissions.

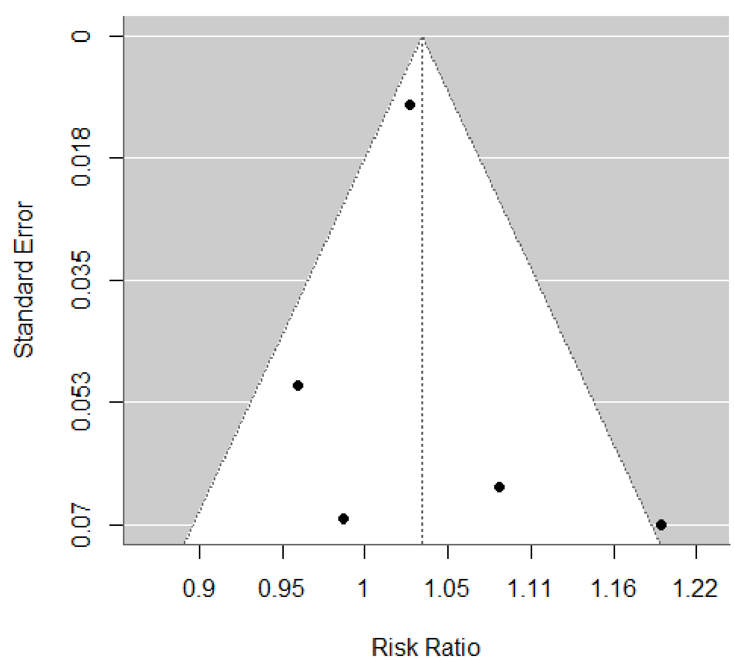

Figure 2.4 Results of the funnel plot of the studies exploring the association between extreme heat and hospital admissions.

2.3.4.2 Ambient Temperature Outcomes

Ambient temperature estimates were reported as incidence rate ratios, or per-degree increases (often 10ºC), or percentile-based comparisons to a reference temperature (such as minimum risk temperature or the 50th percentile of temperature). Two meta-analyses were conducted, one with estimates using per degree increases, and the other with percentile-based comparisons to a reference temperature.

In the first meta-analysis (Figure 2.5), which included 4 studies, ambient temperature increases of 10ºC were not associated with a change in hospital admissions among people with SSD (RR 1.03; 95% CI 0.99,1.07). [101–104] There was a high degree of statistical heterogeneity (I^2 = 85.9%). The funnel plot (Figure 2.6) showed some asymmetry, which is suggestive of publication bias, however Egger's test suggested there was no significant effect ($p = 0.06$) of publication bias on the results of the meta-analysis.

The findings from the second meta-analysis, shown in Figure 2.7, also suggest that the risk of hospital admissions in people with SSD is similar during ambient increases in temperature, relative to the normal range of temperature (RR 1.04; 95% CI 0.99,1.09).[105–108] There was high overall heterogeneity (I^2 = 61.6%; Figure 2.8), and the funnel plot asymmetry in Figure 2.8, suggests some potential publication bias, however Egger's test ($p = 0.36$) suggests little effect of publication bias on the results of the meta-analysis.

Three studies were not included in the meta-analyses because they examined different outcomes. These studies reported associations between increased ambient temperatures and a higher risk of ED visits (n=1), as well as higher risk of SSD onset from childhood through adulthood (n=2).[109–111]

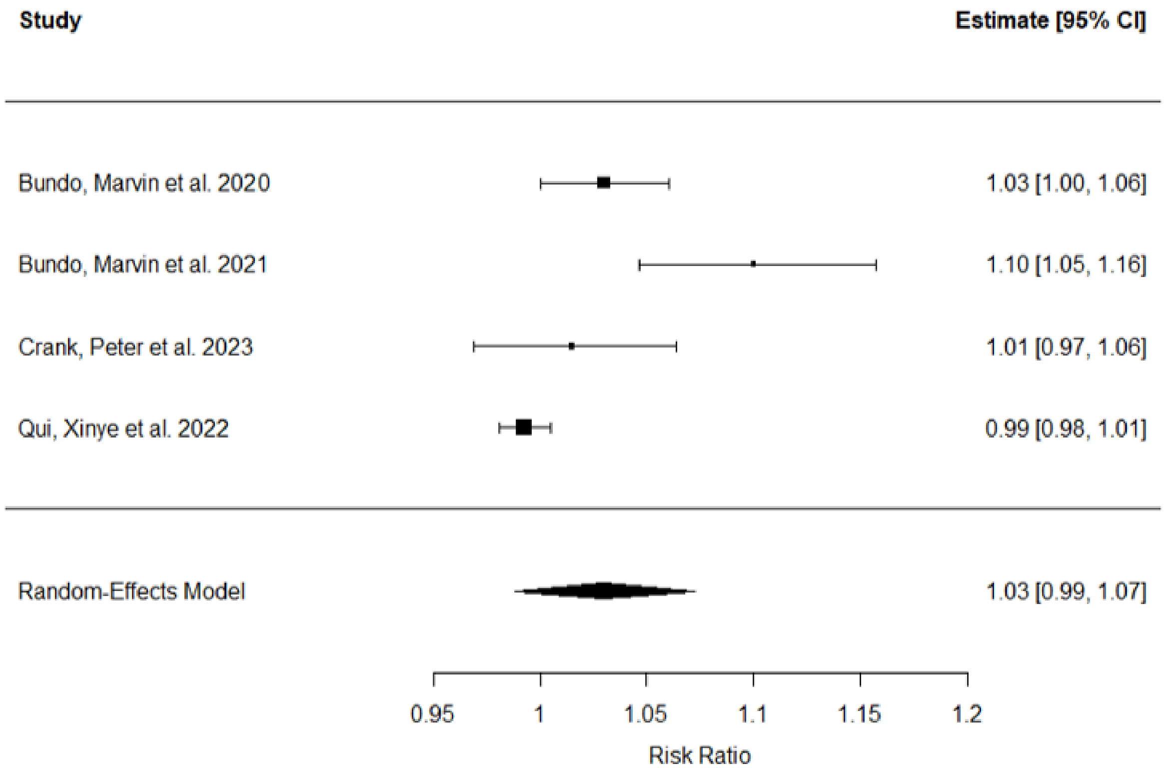

Figure 2.6 Results of a log-transformed random effects meta-analysis (REML) of the studies exploring the association between ambient heat and hospital admissions per increase in 10ºC.

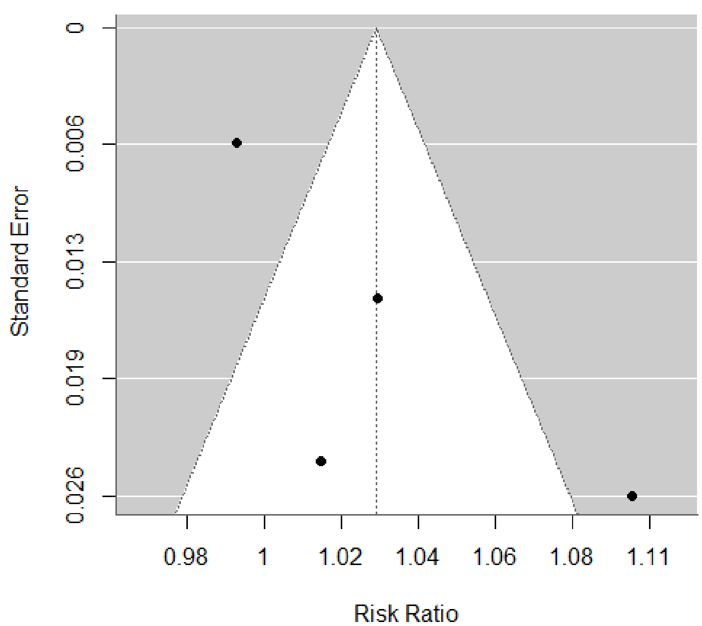

Figure 2.5 Results of the funnel plot of the studies exploring the association between ambient heat and hospital admissions per increase in 10ºC.

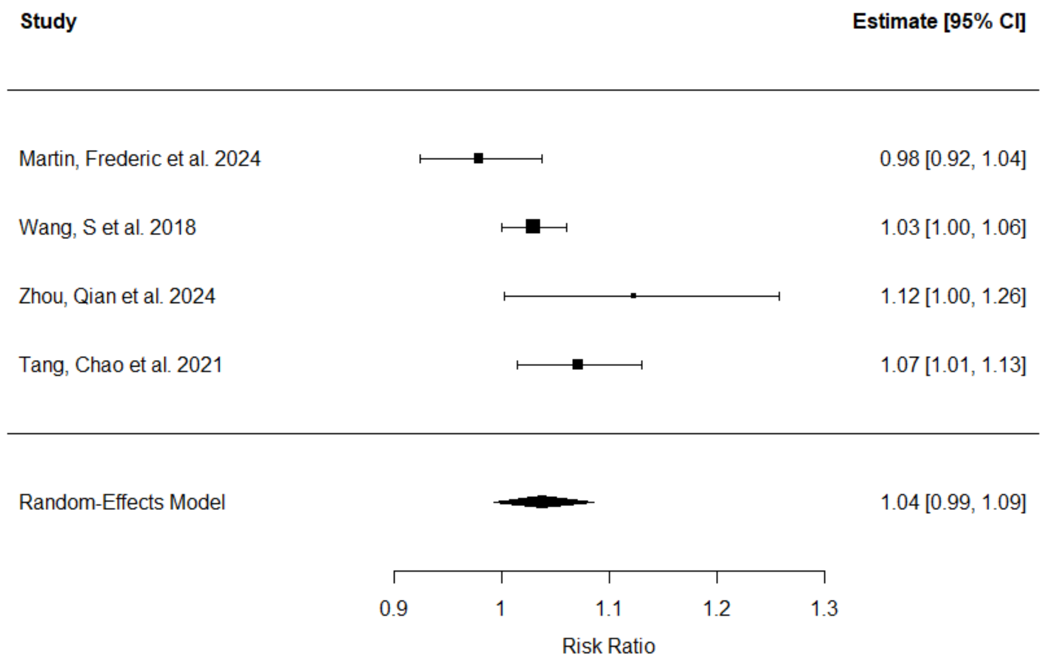

Figure 2.8 Results of a log-transformed random effects meta-analysis (REML) of the studies exploring the association between ambient heat and hospital admissions of a percentile compared to a reference temperature.

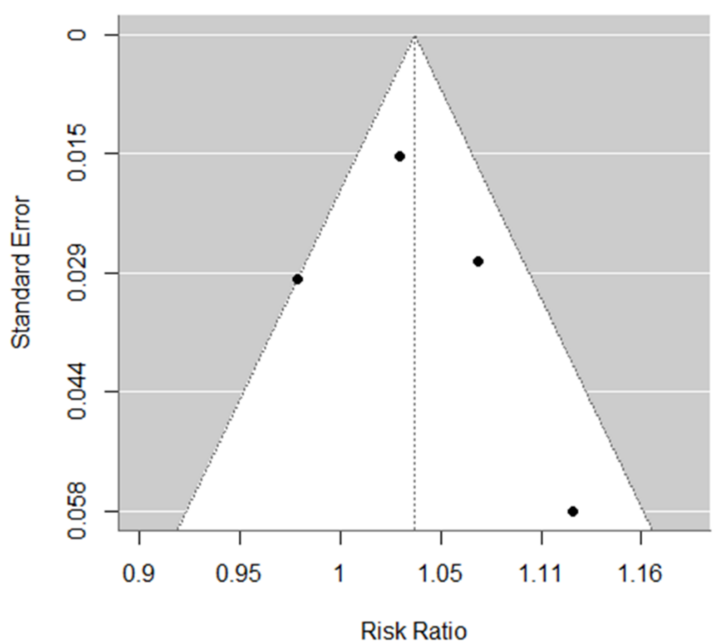

Figure 2.7 Results of the funnel plot of the studies exploring the association between ambient heat and hospital admissions of a percentile compared to a reference temperature.

2.3.4.3 Diurnal Temperature Range Outcomes

All five studies using diurnal temperature range as the temperature metric to evaluate associations with hospital admissions were incorporated in a meta-analysis. As shown in Figure 2.9, the risk of daily hospital admissions for people with SSD shows no statistically significant association with elevated diurnal temperature range (RR 1.04; 95% CI 0.98, 1.09). There was considerable heterogeneity (I^2 = 45.1%), and the Egger's test (p = 0.60) and funnel plot (Figure 2.10) did not suggest evidence of publication bias or small study effects. Also, several studies reported diurnal temperature range had significant delayed effects on hospital admissions. [112,113]

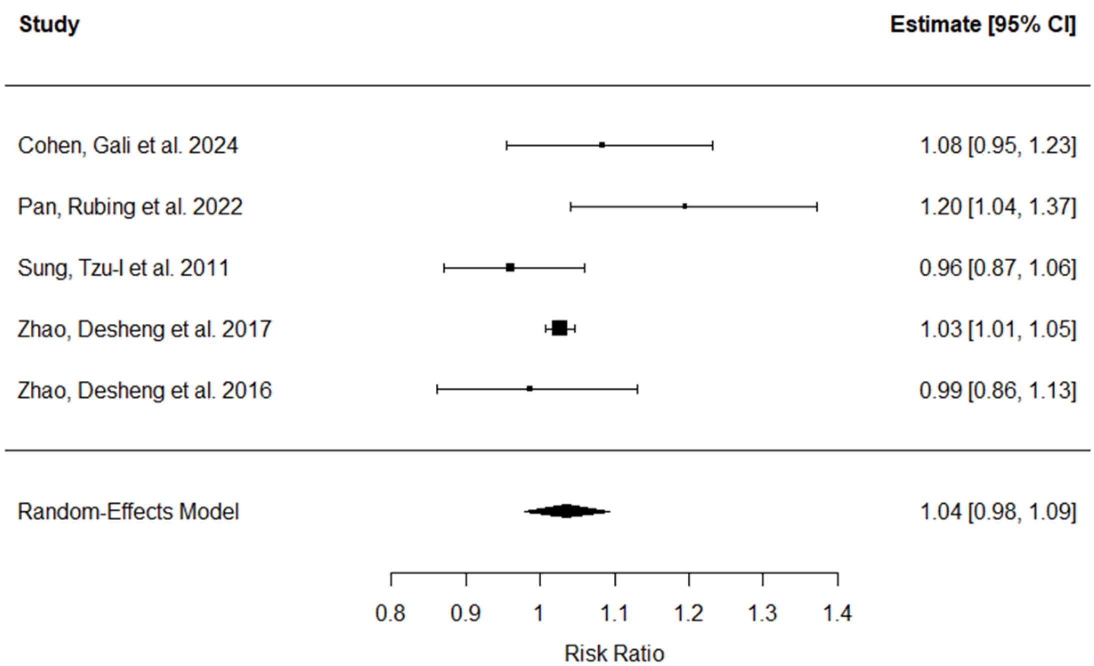

Figure 2.9 Results of a log transformed random effects meta-analysis (REML) of the studies exploring the association between diurnal temperature range and hospital admissions, compared at 99th percentile to 50th percentile.

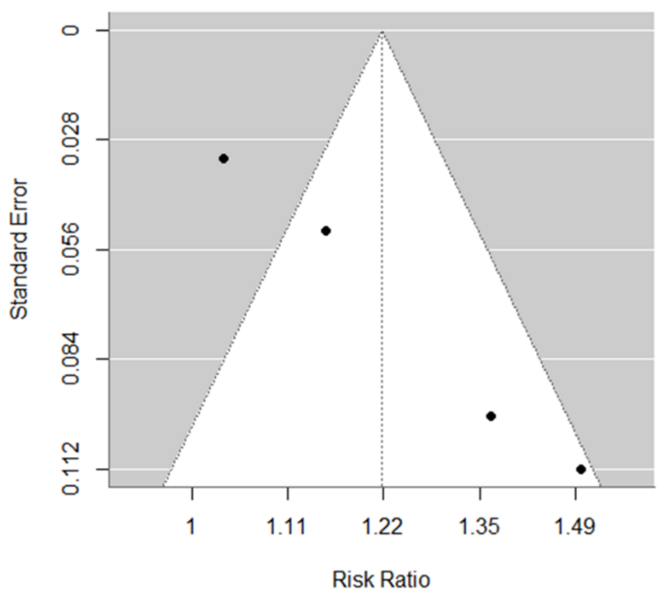

Figure 2.10 Results of the funnel plot of the studies exploring the association between diurnal temperature range and hospital admissions, compared at 99th percentile to 50th percentile.

2.3.4.4 Other Temperature Metric Outcomes

Several studies in this review reported outcomes using apparent temperature, seasonal temperature patterns, monthly temperature patterns, projected temperature, and temperature-related illnesses.[15,18,114–118] Only two studies use apparent temperature as the exposure metric.[18,118] Together, they found that higher apparent temperatures were associated with higher same-day and cumulative risk of ED visits and hospital admissions.[18,118] In contrast, lower apparent temperatures were not associated with ED visits but were linked to higher hospital admission risk.[18,118] Seasonal and monthly analyses showed temperature variation among the months was associated with a higher risk of hospital admissions; some studies observed peaks in winter, other in summer.[15,114–117] Additionally, people with SSD experienced higher rates of heat- and cold-related illnesses, and projections based on modelled temperatures suggest elevated ED visits during periods of extreme low and high temperatures.[119,120]

2.4 Discussion

To our knowledge, there is no prior systematic review that has specifically focused on the impact of temperature on health outcomes among people with SSD. Our systematic review provides a synthesis of the evidence on the effects of ambient and extreme air temperature exposures on various health outcomes among people with SSD, with a majority of studies focused on the effects of ambient or extreme heat on hospital admissions and mortality.

Extreme temperature was consistently associated with higher acute healthcare utilization. Heat exposure was linked to increased ED visits and mortality, and the meta-analysis indicated a 22% increase in hospital admissions (RR 1.22; 95% CI 1.04, 1.43, $I^2 = 85.3\%$). Cold exposure was associated with delayed increases in outpatient visits and hospital admissions. Ambient temperature effects were less pronounced, with meta-analyses showing no significant association with hospital admissions. Though, increases in ambient temperature were associated with higher ED visits and higher risk of SSD onset from childhood through adulthood. Diurnal temperature range showed no significant associations with hospital admissions, but some studies suggest evidence of delayed effects. Other temperature metrics, including apparent temperature, seasonal and monthly patterns, projected temperatures, and temperature-related illnesses, reinforced the sensitivity of people with SSD to environmental variability. Apparent temperature was linked to higher risk of ED visits and hospital admissions at higher temperatures, whereas lower apparent temperature primarily affected hospital admissions. Peaks in hospital admissions varied by season and region, and a modelling study predicted increased ED visits during periods of extreme heat or cold.

Some of the studies in this literature review have performed subgroup analyses, suggesting temperature effects may be higher among unmarried males, non-white populations, and certain age groups, though age-specific effects were inconsistent across studies. Differences in risk between subgroups may be due to sex and structural inequalities in their environment.[121,122] Additionally, regional differences were observed across cities suggesting local climate, healthcare infrastructure, and population adaption may modify temperature-related risk.[123,124]

Previous systematic reviews found associations between high ambient temperature and mental health outcomes for a wide range of mental illnesses, including schizophrenia[4,43,125] A study by Liu et al. found with every increase in 1ºC, there was a 0.2% increase in mental health-related mortality.[4] In addition, a review by Li et al. found the top 99th percentile of temperature to be associated with a 7% higher risk of onset for schizophrenia.[125] Interestingly, a study by Thompson et al. found that the risk of hospitalization for people with schizophrenia was not significantly elevated on heat wave days, however the risk of mortality was more than doubled.[43] The findings from the present study add to this body of evidence and suggests that there may be an increased risk of hospitalization and mortality during periods of extreme heat, although further evidence is needed to strengthen this conclusion.

Though the underlying etiology is not fully understood, there are a few potential biological mechanisms that could explain the association between extreme temperature and increased risk of hospital admissions among people with SSD. Firstly, impaired heat tolerance is an effect of antipsychotic medication, as studies suggest that antipsychotic medication may impair thermal homeostasis.[82] First- and second-generation antipsychotics can impair sweating, alter vasodilation, and reduce thirst perception through anticholinergic and dopaminergic blockade.[126] Prior studies have shown that people with SSD tend to have reduced heat tolerance and high risk of heat-related illness.[6,72,127] These biological mechanisms may explain how increases in temperature may have an amplified effect on people with SSD. In addition, people with SSD have higher risks of economic marginalization, social isolation, unstable housing, limited financial resources, and barriers to accessing cooling facilities or medical care.[6] These social factors increase the risk of exposure during extreme weather events, which may have downstream impacts on the risk of hospitalization or mortality.

It is important to note that not all studies reported significant associations between temperature and SSD-related outcomes. A previous meta-analysis notes high levels of heterogeneity across regions and study designs, suggesting differences in climatic conditions, population characteristics, and methodological approaches may contribute to the inconsistency in observed associations between temperature and SSD-related outcomes.[43] Some studies found minimal or inconsistent temperature effects after additional environmental variables, such as air pressure or humidity, are controlled for.[101,128] This suggests the effect of temperature are not uniform among people with SSD, but depend on the local climate and social context.

There was notable heterogeneity in study variables and methodologies. For example, even within the same ambient temperature metric, there were two methods to report effect sizes – measures based on increases per 10ºC and percentile-based estimates above a specified threshold. There is no agreement on the shape of the relationship between temperature and health outcomes, however it is suggested it follows a non-linear pattern as the shape of the exposure-response curve varies by region, population or study period.[129,130] Additionally, due to the absence of standardization, various temperature metrics exist, such as apparent temperature, diurnal temperature range, heat waves, or extreme heat, often with region-specific cut-offs or modified definitions. We found significant heterogeneity in the effect estimates of the included studies, which may be due to differences in temperature measurement, in addition to other factors such as differences in social environment, population characteristics, or study location.

A key strength of our review was the inclusion of a broad range of health outcomes for people with SSD, which has not been explored previously. We also looked at a comprehensive range of temperature metrics such as diurnal temperature range, apparent temperature, and projected temperature, which have not been covered in previous meta-analyses. Additionally, we modified the CLARITY risk of bias tool to better capture important methodological details for time-series and case-crossover studies, which addressed the limitations of prior risk of bias assessments in this domain and provided a more tailored approach.

2.4.1 Limitations of Included Studies

Studies included in this review were mainly single-city studies, with few multi-city studies identified in the literature. Multi-city studies are better able to capture region-specific climatic, demographic, and socioeconomic factors, which improve the validity of the effect estimates. They also provide greater statistical power to detect associations and effect modification by regional characteristics such as population variability, mental health resources, or baseline climate.[96,108] Therefore, multi-city studies allow for a more robust approach to understanding how temperature affects health outcomes across diverse regions.

Across the included studies, substantial heterogeneity in exposure definitions (e.g., temperature metrics), lag structure, and outcome ascertainment were observed, limiting comparability of findings. Most studies used ecological time-series designs, which do not account for individual-level vulnerabilities such as housing quality, medication use, illness severity, or age; in contrast, case-crossover approaches use within-person comparison. Additionally, all studies used outdoor temperature, which may not reflect exposure for those spending most time indoors.

The majority of the studies were conducted in China, Canada, USA, and several countries in Europe. Although this geographical distribution reflects data availability and research capacity, it also limits the generalizability of the findings to global populations. Low or middle-income countries often experience greater temperature variability, fewer adaptive resources, and higher vulnerability to environmental stressors.[131] Additionally, differences in healthcare infrastructure, housing, and access to mental health care services would not be as variable across studies conducted primarily in high-income settings. Therefore, it is important to expand research efforts to include diverse climatic and socioeconomic contexts to build a more comprehensive understanding of temperature-related health outcomes for SSD populations worldwide.

2.4.2 Limitations of the Review

This review had several limitations that should be considered when interpreting the findings. First, the limited number of studies evaluating cold temperature exposure restricted our ability to quantitatively assess cold-related effects among people with SSD. Second, the exclusion of non-English publications may have resulted in the omission of relevant international studies and increased the risk of publication bias, as null findings are more likely to be published in non-English journals, potentially narrowing the evidence base. Finally, substantial heterogeneity in exposure metrics, outcome definitions, lag structures, and analytical methods across studies restricted the scope of quantitative synthesis and prevented the estimation of pooled effects across all temperature and health outcome categories.

2.5 Conclusions

In summary, this review and meta-analysis of 37 studies highlight the impacts of ambient and extreme air temperature on health outcomes among people with SSD. The meta-analysis suggests a significant increase in hospital admissions associated with extreme heat exposure. However, there remains a lack of research examining the longer-term effects, cold temperature exposures, populations in low- and middle-income countries, and other forms of health service use such as ED visits. Addressing these gaps through multi-city designs and including information on local adaptive and contextual factors will be important to better understanding temperature-related vulnerability in this population and informing targeted prevention strategies.

Chapter 3

3. The Effect of Extreme Temperatures on Emergency Department Visits for People with Schizophrenia Spectrum Disorders: a case-crossover study

3.1 Introduction

Globally, the life time-prevalence of schizophrenia spectrum disorders (SSD) is estimated to be between 0.4% to 0.8%, and yet they account for significant disability and substantial societal and health system costs [78,79] SSDs encompass a spectrum of diagnoses which include schizophrenia, schizoaffective disorder, schizophreniform disorders as well as other related disorders.[132] They are typically characterized by delusions, hallucinations, disordered thinking, apathy, and cognitive deficits.[53] The underlying psychopathological mechanisms are largely unknown, however, there are several risk factors that are known to contribute to the onset or recurrence of this illness.[133] Prior research has shown that SSDs are not only shaped by genetics, but environmental exposures like prenatal infections, obstetric complications, childhood adversity, migration and ethnic marginalization, and urbanicity. [134]

Climate-related exposures are an emerging research domain. Largely, the studies from this domain have explored the relationship between extreme heat and schizophrenia. They have found extreme heat and heatwaves have been associated with acute increases in psychiatric emergency department (ED) visits, hospital admissions, and suicide. [3,43,109] A large multi-region study in the U.S. found that days of extreme heat were associated with higher rates of mental health-related ED visits overall, including specific disorders such as schizophrenia.[109] Similarly, another 45-year time-series study from Bern, Switzerland reported each 10ºC increase in temperature corresponded to a 10% increase in hospitalizations for schizophrenia.[102] Another study found that both extreme heat and cold were linked to higher risk of mental-health related outpatient visits, including schizophrenia,[96] although evidence on the effects of extreme cold is limited.

There is a lack of studies exploring the association between both temperature extremes and health service use among people with SSD, especially in the Canadian context. Furthermore, there is limited knowledge on the effects of both extreme heat and extreme cold temperatures on the use of acute physical and mental health care services among people with SSD. The purpose of this study was to examine the association between extreme temperature events (both hot and cold) and the use of ED services for physical and mental health reasons among people with SSD in Ontario. The primary objectives of the study were to:

1. Examine the association between extreme heat events and both mental health and non-mental health-related ED visits among people with SSD.

2. Examine the association between extreme cold events and both mental health and non-mental health-related ED visits among people with SSD.

As a secondary objective, we used stratified analyses to explore effect modification by health region, sex, and age in the association between extreme weather events and ED visits among people with SSD.

We hypothesized that extreme heat events would be associated with higher use of ED services and that extreme cold events may introduce delays in seeking outpatient services leading to a delayed increase in the use of ED services.

3.2 Methods

3.2.1 Study Design

We employed a time-stratified case-crossover study design to assess- short term association between extreme temperature and ED visits among people with SSD using health administrative databases in Ontario, Canada.[135] This study design accounts for time-invariant confounding by comparing each person who experiences the event (a 'case day') to themselves during selected control periods, such that the individual effectively serves as their own control.[136] For this study, the control period was chosen to be same day of the week within the same month as the case day, this accounts for differences in health service usage during weekdays and weekend periods.[89,96,137] An individuals' case days were excluded from their control period, resulting in between 1 to 4 matched control days per case.[138,139] Each set of case and control days were assigned to a unique stratum, ensuring that only one case day and its corresponding control days were included per stratum.[137,139] Strata containing only case days were excluded from the analysis, as they do not contribute to the model. [137,139]

3.2.2 Health Administrative Data Sources

This study used population-based health administrative data from Ontario, Canada, held by ICES (formerly known as the Institute for Clinical Evaluative Sciences). The following databases were linked using unique encoded identifiers and analyzed at ICES:

- *The Registered Persons Database (RPDB):* This population-based database includes information on every person registered for the publicly funded Ontario Health Insurance Plan (OHIP).[140] The data available include unique health card number, sex, date of birth, and residential address. It is maintained by the Ontario Ministry of Health (MOH).
- *Ontario Health Insurance Plan (OHIP) Claims Database*: This database includes information on all billing claims made by physicians for insured services in Ontario. Around 95% of Ontario physicians are covered by this database.[141] It includes information such as type of incurred service provided, diagnostic information, the physician who provided the service, the patient who received the service, and service fee code.[142]
- *National Ambulatory Care Reporting System (NACRS)*: This database captures information on emergency department visits, reason for the visit, and other ambulatory care services (e.g., day surgeries, outpatient clinic visits, dialysis, cardiac catheterization, and oncology) for hospital-based and community-based ambulatory care.[143]
- *Ontario Mental Health Reporting System (OMHRS)*: This database collects information on hospitalizations occurring in designated adult psychiatry beds starting from October 2005. CIHI constructs the databases using the Resident Assessment Instrument–Mental Health (RAI-MH©), and admission and discharge events. It includes information about mental and physical health, social supports, service use, and outcomes[144,141]
- *Canadian Institute of Health Information's Discharge Abstract Database (CIHI-DAD):* This database was developed in 1963, and it includes all patient-level administrative, clinical, and

demographic information on hospital discharges.[145] All hospitalizations not reported to OMHRS are included in DAD.

- *Ontario Marginalization Index (ON-Marg)*: The ON-Marg is an area-level marginalization indicator that is derived from census data and includes four marginalization factors: households and dwellings, material resources, age and labour force, and racialized and newcomer populations. Data are available for both small area level and larger geographies.[146]

3.2.3 Meteorological Data

Meteorological data were obtained from the DAYMET database. This database is a product of daily meteorological observations that are interpolated and extrapolated by computer algorithms and software to produced daily weather parameters.[147] On a 1km x 1km gridded surface, parameters such as daily surface mean and maximum temperature, humidity, and particulate matter 2.5 ($PM_{2.5}$) were collected.[147] Daily mean temperature was calculated by the average of daily maximum and minimum temperatures and then selected as the exposure index. All temperature and air quality metrics were linked at the FSA-level.

3.2.4 Temperature Exposure

As our exposure, we chose to use extreme temperature, where extreme heat is classified as the top 97.5th percentile temperature and extreme cold was classified as top 2.5th percentile temperature, as done in previous studies.[89,148,149] The temperatures percentiles were calculated using the full period of temperature data from January 1st to December 31st, 2019 in Ontario. Temperature exposure, $PM_{2.5}$, and humidity was assigned based on a person's residential Forward Sortation Area (FSA) on the date of the ED visit.

3.2.5 Setting

The study took place in Ontario, a Central Canadian province with a population of about 14 million people.[150] The climate is considered as continental, where temperatures can range from humid in the south, to sub-arctic in the north.[151] Many regions have cold winters and warm summers, but temperatures often vary considerably from region to region due to the large geographic area of Ontario (e.g. mean temperature of 2.32ºC in the North East and 8.22ºC in

Toronto).[151] For health system planning, Ontario is divided into 6 different health regions: West, Central, Toronto, East, North East, and North West, as shown in Figure 3.1.[152] FSAs that spanned multiple health regions were reassigned entirely to the single health region containing the largest portion of those FSAs.

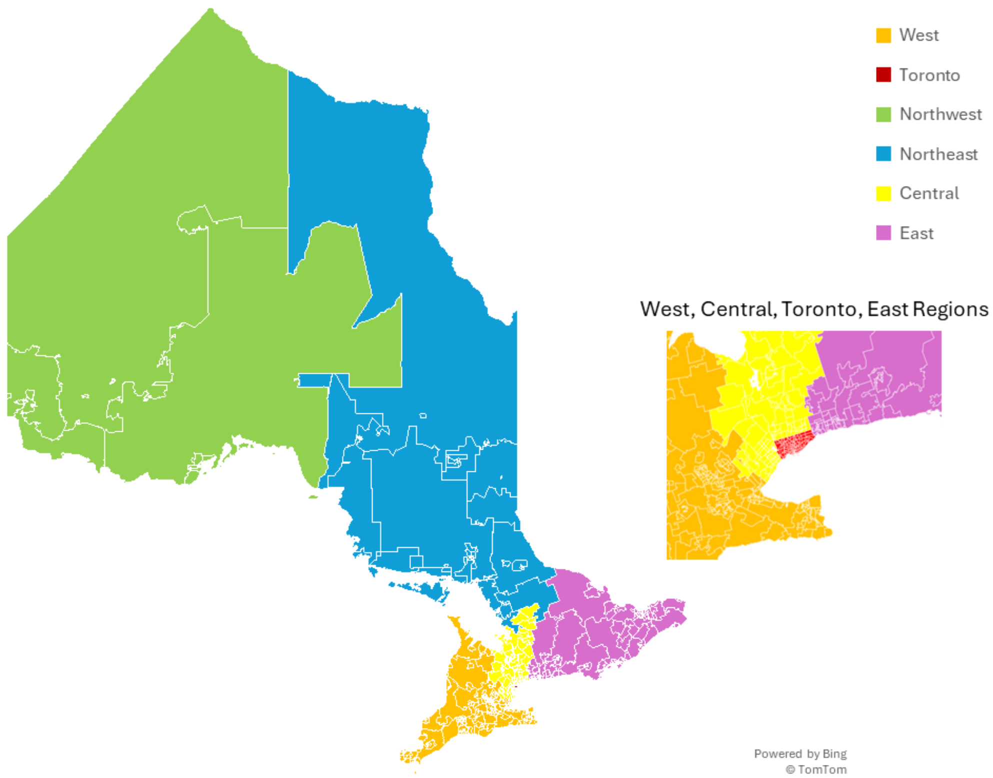

Figure 3.1 Map of six health regions of Ontario.

3.2.6 Study Population and Cohort

The study cohort included all people aged 14 years and older who had an index diagnosis of SSD between January 1, 2014, to December 31, 2018. People were followed from January 1st to December 31st , 2019. The cohort, therefore, represents prevalent cases identified during the accrual window.

To be identified as a case of SSD, people must have met at least one of the following criteria:

1) A discharge diagnosis of schizophrenia, schizoaffective disorder, or unspecified psychosis from an inpatient hospitalization in DAD.

2) A Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) Axis 1 discharge diagnosis of schizophrenia, schizoaffective disorder, or unspecified psychosis from a psychiatric admission in OMHRS (DSM-IV code 295 and 298).
3) At least two OHIP billing claims with a diagnostic code for schizophrenia, schizoaffective disorder, or unspecified psychosis (ICD-9 code 295 and 298; ICD-10 code F20, F25, or F29) in a 24-month period.

This algorithm has been validated through comparison to information abstracted directly from medical charts and has a sensitivity of 93.9%, with a specificity of 50.0%.[153] The positive predictive value is 62.1%, with a higher negative predictive value of 90.4%.[153]

People older than 105 or younger than 14 on the index date (January 1st, 2019) were excluded from the cohort. Individuals were excluded if their death was on or before the January 1, 2019, or if they lived in an FSA not included in the DAYMET data. Non-residents of Ontario and those not eligible for OHIP on January 1st, 2019 were excluded to improve continuity of the data.

3.2.7 Outcomes

ED visits for mental health and non-mental health reasons were chosen as the outcomes of interest. We extracted ED admissions from the NACRS database that occurred between January 1, 2019 and December 31, 2019. All ED visits, planned visits, and ED transfer visits, were included, regardless of whether they resulted in a subsequent hospital visit or not.

The outcome variable was then separated into ED visits for mental health reasons (MH-ED) if their main diagnosis was classified under ICD10 codes F06 to F99. All other ED visits were classified as ED visits for non-mental health reasons (Non-MH-ED). The cases were aggregated by ICES Key Number (IKN), and date. Then the top 10% of MH-ED (users with >74 cases per year) and Non-MH-ED (users with >107 cases per year) users were removed from the analytical cohort to reduce the influence of extreme utilization patterns on our analysis. This threshold was chosen because a prior study in Ontario defined high system users as the top 10% of ED users.[154] Finally, all ED counts were converted to binary, such that if a person has multiple visits on the same day, they were counted as a single ED visit for that day.

3.2.8 Demographic Variables

We obtained information on the sociodemographic characteristics of the sample – including age, sex and health region– from RPBD. Additionally, median income, rurality, health region, Charlson Comorbidity Index (CCI), year of cohort entry, and neighborhood-level marginalization indicators were all obtained. From CIHI-DAD databases, CCI was used as an index for presence and summary of physical comorbidity.[155] This index assigns weighted scores to 17 chronic conditions, which are summed to produce an overall comorbidity score; with higher scores indicating greater comorbidity burden.[156] In this study, we categorized the CCI as 0, 1, 2 and 3+. Neighborhood-level marginalization variables were obtained from ON-Marg. We obtained information on the households and dwellings dimension with captures housing and material disadvantage, the age and labor force dimension with reflects demographics and economic dependency, and the racialized and newcomer populations dimension which represents structural marginalization related to race and immigration. We used categories with scores divided into quintiles based on provincial distribution, where quintile 1 represents the least marginalized stratum and quintile 6 represents the most marginalized. All descriptive variables were assessed at index date, with the exception of marginalization indices which were assessed at census date.

3.2.9 Statistical Analyses

The descriptive characteristics of the analytic sample were summarized using counts and percentages per category. Daily temperature, assessed across all cases and control days during the study period, was summarized using minimum, maximum, mean, median, and the 2.5th and 97.5th percentiles, calculated overall for the province and stratified by region.

The relationship between daily mean temperature and MH-ED and Non-MH-ED visits for people with schizophrenia is lagged across specific timeframes, and is best characterized by a non-linear exposure-response curve.[157–159] To capture this, we used a time-stratified case-crossover design that compares temperature on each case day with temperature on matched control days for the same individual, and modelled this association using a conditional-Poisson regression combined with a distributed lag non-linear model (DLNM).[129] The DLNM is built by combining the temperature lag functions to create a bi-dimensional "cross-basis" matrix which allows estimate of the non-linear effects of temperature and morbidity across specific lag periods.[129] Akaike information criterion (AIC) was used to determine best model fits, where a lower AIC value indicates an improvement in model fit, and the outcome of mental health ED visits and non-mental health ED visits were fit as separate models.[160,161]

The model for mental health ED visits and temperature was fit as follows:

$$Y_{t,l} \sim Poisson(\mu_{t,l})$$

$$log(\mu_t) = \alpha + cb(T_{t,l}) + ns(PM_{t,l}, df = 2) + \beta RH_{t,l}$$

$Y_{t,l}$ is the expected daily number of mental health ED visits on day t; α is the intercept; *cb()* is the cross-basis function for temperature (daily mean average); *ns()* is the natural cubic spline function for $PM_{2.5}$, β is the vector coefficient for relative humidity, separately. According to the AIC, a lag of 4 days, 2 degrees of freedom (df) for the exposure-response dimension, along with 3 df for the lag dimension were used for the cross-basis function.

The model for non-mental health ED visits and temperature was fit as:

$$Y_{t,l} \sim Poisson(\mu_{t,l})$$

$$log(\mu_t) = \alpha + cb(T_{t,l}) + \beta PM_{t,l} + \beta RH_{t,l}$$

Where $Y_{t,l}$ is the expected daily number of non-mental health ED visits on day t; α is the intercept; cb () is the cross-basis function for temperature (daily mean average); β is the vector coefficient for $PM_{2.5}$ and relative humidity, separately. A lag of 6 days, 4 df for the exposure-response dimension, along with 5 df for the lag dimension were used for the cross-basis function, as selected by the AIC.

After the models were fit, we plotted the associations between MH-ED visits and Non-MH-ED visits. To quantify the effects of extreme temperature on MH-ED visits and Non-MH-ED visits, we calculated relative risks (RRs) by specific temperature percentiles (97.5% for heat and 2.5% for cold) relative to the province-wide median (7.53ºC). Delayed effects were also considered to investigate specific days (lag 0 to lag 4 or 6) and cumulative lag days (lag 0-1, lag 0-4 or lag 0-6).

Additionally, we conducted subgroup analyses stratified by health region (West, Central, Toronto, East, North West, and North East, shown in Figure 3.1), administrative sex (female and male), and age to explore effect modification in the observed associations. The age strata were defined based on Jeffery Arnett's work on emerging adulthood and Erik Erikson's stages of psychosocial development: 14-29 years old, 30-49 years old, and 50 years or older.[162,163]

All statistical analyses were conducted in R software (version 4.4.2).[164] Packages *gnm* and *dlnm* were used to fit the conditional Poisson regression with DLNMs.[165,166]

3.3 Results

3.3.1 Descriptive Analyses

A total of 117,367 people with SSD were identified in this study. 809 people from 5 FSAs in Beamsville, the Cochrane district, Lake Superior North Shore district, North Western Ontario, and Sioux Lookout were excluded due to a lack of temperature data, resulting in a final cohort of 116,558. Their demographic and neighborhood characteristics by health region and for the province overall are summarized in Appendix 3.1. From this cohort, the analytic sample for the case-crossover analysis comprised of 166,747 ED visits, after excluding visits from 19 high-service users. Of these, 48,607 were MH-ED visits, and 118,140 were Non-MH-ED visits. The demographic and neighborhood characteristics of the analytic sample are summarized in Table 3.1, and the health region-specific breakdowns of MH-ED visits and Non-MH-ED visit characteristics are summarized in Appendix 3.2, and Appendix 3.3, respectively. A study flow diagram can be found in Appendix 3.4.

Overall, a greater proportion of people aged 50 years and older (39.7%) had ED visits compared to the rest of the analytic cohort. Additionally, those aged 50 years and older accounted for a larger share of Non-MH-ED visits (46.8%), whereas those aged 30-49 years accounted for a larger share of MH-ED visits (43.6%). Males (55.3%) had more ED visits when compared to females. A substantial proportion of people with ED visits lived in neighborhoods with median household incomes below $25,000. Only about 7% of the analytic cohort lived in rural areas, and approximately 8% of the cohort lived in the North East and North West health regions. A large share of the analytic cohort fell within the highest marginalization categories for the household and dwellings index (47.1%) and the racialized and newcomer populations index (24.0%), whereas the age and labor force index showed a nearly uniform distribution across categories.

The top 10 reasons for MH-ED visits and Non-MH-ED visits are listed in Tables 3.2 and 3.3 respectively. Unspecified schizophrenia was the most common reason for MH-ED visits, whereas other and unspecified abdominal pain was the leading cause of Non-MH-ED visits.

Table 3.4 shows notable temperature differences across health regions. The North West (minimum: -34.74ºC) and North East (minimum: -32.65ºC) regions experienced the lowest temperatures, whereas the West region had the highest (maximum: 29.21ºC). Mean temperatures across most regions were comparable, except for the substantially lower averages observed in the North West (mean: 2.32 ºC) and North East (mean: 3.17 ºC).

Table 3.1 Descriptive characteristics of the analytical cohort at index date.

		Mental Health ED visits, n (%)	Non-Mental Health ED visits, n (%)	Total Cohort, n (%)
Age (years)	14-29	16425 (33.79)	24626 (20.84)	41051 (24.62)
	30-49	21205 (43.63)	38211 (32.34)	59416 (35.63)
	50+	10977 (22.58)	55303 (46.81)	66280 (39.75)
Sex	F	18769 (38.61)	55818 (47.25)	74587 (44.73)
	M	29838 (61.39)	62322 (52.75)	92160 (55.27)
Income	Missing	1018 (2.09)	1736 (1.47)	2754 (1.65)
	<25k	20242 (41.64)	49676 (42.05)	69918 (41.93)
	25k to 50k	10533 (21.67)	25354 (21.46)	35887 (21.52)
	50k to 75k	7185 (14.78)	17048 (14.43)	24233 (14.53)
	75k to 100k	5202 (10.70)	13470 (11.40)	18672 (11.20)
	100k+	4427 (9.11)	10856 (9.19)	15283 (9.17)
Rurality	Urban	46072 (94.78)	109124 (92.37)	155196 (93.07)
	Rural	2535 (5.22)	9016 (7.63)	11551 (6.93)
Health Region	West	13464 (27.70)	35789 (30.29)	49253 (29.54)
	Central	8212 (16.89)	19593 (16.58)	27805 (16.67)
	Toronto	14345 (29.51)	31174 (26.39)	45519 (27.30)
	East	8604 (17.70)	22090 (18.70)	30694 (18.41)
	North East	2795 (5.75)	6874 (5.82)	9669 (5.80)
	North West	1187 (2.44)	2620 (2.22)	3807 (2.28)
Charlson Comorbidity Index	0	41997 (86.40)	82524 (69.85)	124521 (74.68)
	1	3767 (7.75)	13806 (11.69)	17573 (10.54)
	2	1402 (2.88)	8042 (6.81)	9444 (5.66)
	3+	1441 (2.96)	13768 (11.65)	15209 (9.12)
Year of Cohort Entry	2014	21659 (44.56)	51052 (43.21)	72711 (43.61)
	2015	7416 (15.26)	18471 (15.63)	25887 (15.52)
	2016	6481 (13.33)	16787 (14.21)	23268 (13.95)
	2017	6969 (14.34)	17042 (14.43)	24011 (14.40)
	2018	6082 (12.51)	14788 (12.52)	20870 (12.52)

Households and Dwellings Score	Missing	1321 (2.72)	2457 (2.08)	3778 (2.27)
	1 (lowest)	4308 (8.86)	9135 (7.73)	13443 (8.06)
	2	4646 (9.56)	11550 (9.78)	16196 (9.71)
	3	5603 (11.53)	14925 (12.63)	20528 (12.31)
	4	9581 (19.71)	24666 (20.88)	34247 (20.54)
	5 (highest)	23148 (47.62)	55407 (46.90)	78555 (47.11)
Age and Labour Force Score	Missing	1321 (2.72)	2457 (2.08)	3778 (2.27)
	1 (lowest)	11626 (23.92)	24244 (20.52)	35870 (21.51)
	2	9722 (20.00)	22019 (18.64)	31741 (19.04)
	3	9241 (19.01)	21188 (17.93)	30429 (18.25)
	4	7812 (16.07)	20036 (16.96)	27848 (16.70)
	5 (highest)	8885 (18.28)	28196 (23.87)	37081 (22.24)
Racialized Newcomer and Populations	Missing	1321 (2.72)	2457 (2.08)	3778 (2.27)
	1 (lowest)	5940 (12.22)	17954 (15.20)	23894 (14.33)
	2	7176 (14.76)	19720 (16.69)	26896 (16.13)
	3	9921 (20.41)	23974 (20.29)	33895 (20.33)
	4	11587 (23.84)	26639 (22.55)	38226 (22.92)
	5 (highest)	12662 (26.05)	27396 (23.19)	40058 (24.02)

Table 3.2 Top 10 primary diagnoses leading to mental health ED visits.

Rank	Type	ICD10 code
1	Schizophrenia, unspecified	F20.9
2	Unspecified psychosis not due to substance or known physiological condition	F29.0
3	Acute stress reaction	F43.0
4	Anxiety disorder, unspecified	F41.9
5	Alcohol abuse, uncomplicated	F10.0
6	Major depressive disorder, single episode, unspecified	F32.9
7	Schizoaffective disorder, unspecified	F25.9
8	Bipolar disorder, unspecified	F31.9
9	Other psychoactive substance abuse, uncomplicated	F19.1
10	Adjustment disorder, unspecified	F43.2

Table 3.3 Top 10 primary diagnoses leading to non-mental health ED visits.

Rank	Type	ICD10 code
1	Other and unspecified abdominal pain	R10.4
2	Low self-esteem	R45.8
3	Chest pain, unspecified	R07.4
4	Problems related to care provider dependency	Z76.0
5	Urinary tract infection, site not specified	N39.0
6	Pneumonia, unspecified organism	J18.9
7	Chronic obstructive pulmonary disease w (acute) exacerbation	J44.1
8	Neoplastic (malignant) related fatigue	R53.0
9	Cellulitis of right axilla	L03.11
10	Low back pain	M54.5

Table 3.4 Temperature Distribution of Ontario and its health regions in 2019.

	Minimum (ºC)	Median (ºC)	Mean (ºC)	Maximum (ºC)	Bottom 2.5% (ºC)	Top 97.5% (ºC)
West	-20.87	8.12	8.11	29.21	-11.84	24.41
Central	-23.57	7.41	7.17	28.1	-13.49	24.07
Toronto	-18.68	8.32	8.22	28.14	-11.11	24.6
East	-24.07	7.35	6.22	27.79	-16.36	23.53
North East	-32.65	4.18	3.17	25.58	-21.8	21.14
North West	-34.74	3.53	2.32	24.73	-24.98	20.7
Total	-34.74	7.53	7.09	29.21	-15.17	24.12

3.3.2 Extreme Temperature and Mental Health Emergency Department Visits

Table 3.5 presents the lag-specific and cumulative RRs (95% CIs) for the association between extreme heat and cold and MH-ED visits. Figures 3.2, 3.3, and 3.4 further illustrate these relationships through a 3D contour plot, corresponding overall exposure–response curve, and lag-specific curves, respectively. During extreme heat, significantly lower single-day risk of MH-ED visits were observed at lag 0 (RR 0.86; 95% CI 0.80, 0.92), lag 1 (RR 0.96; 95% CI 0.93, 0.99), and lag 4 (RR 0.94; 95% CI 0.89, 0.99). There was a 3% single-day increase (95% CI 1.00, 1.06) in risk of MH-ED visits two days after extreme heat exposure, however, the confidence intervals include the possibility of a null effect. Cumulatively, there was a consistently lower risk of MH-ED visits across all lag periods, reaching a 20% lower risk by lag period 0-4. Extreme cold was not significantly associated with MH-ED visits any individual or cumulative lag.

Table 3.5 Extreme heat (97.5th percentile) and cold (2.5th percentile) effects on Ontario-wide MH-ED visits with a reference to 7.53ºC (median).

	Extreme Heat (P97.5)	Extreme Cold (P2.5)
Single-day effects, RR (95% CI)		
lag0	0.86 (0.80, 0.92)*	1.01 (0.96, 1.07)
lag1	0.96 (0.93, 0.99)*	0.99 (0.96, 1.02)
lag2	1.03 (1.00, 1.06)	0.98 (0.95, 1.02)
lag3	1.01 (0.98, 1.04)	0.98 (0.95, 1.01)
lag4	0.94 (0.89, 0.99)*	0.99 (0.94, 1.04)
Cumulative effects, RR (95% CI)		
lag0-0	0.86 (0.80, 0.92)*	1.01 (0.96, 1.07)
lag0-1	0.82 (0.75, 0.91)*	1.01 (0.94, 1.09)
lag0-2	0.85 (0.76, 0.93)*	0.99 (0.91, 1.08)
lag0-3	0.85 (0.77, 0.95)*	0.97 (0.87, 1.08)
lag0-4	0.80 (0.71, 0.91)*	0.96 (0.84, 1.09)

* p-value ≤ 0.05

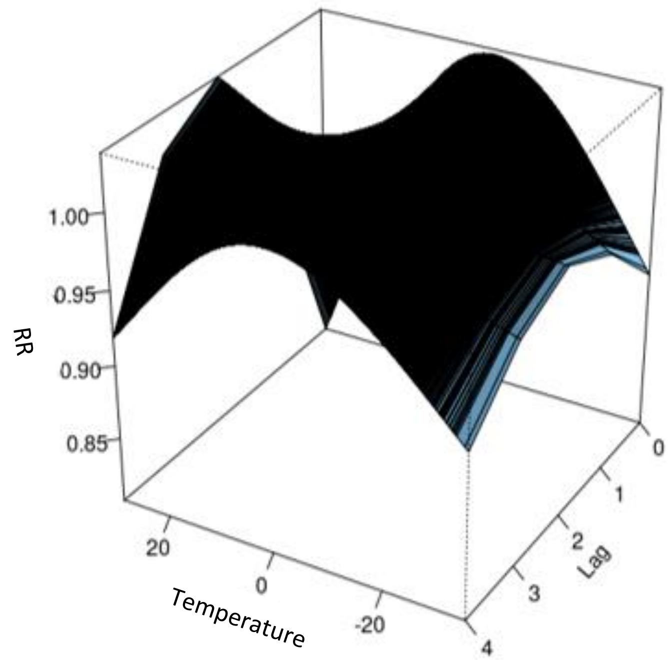

Figure 3.2 Three-dimensional graph of RR for MH-ED visits along with average temperature and lag, with reference to 7.53ºC.

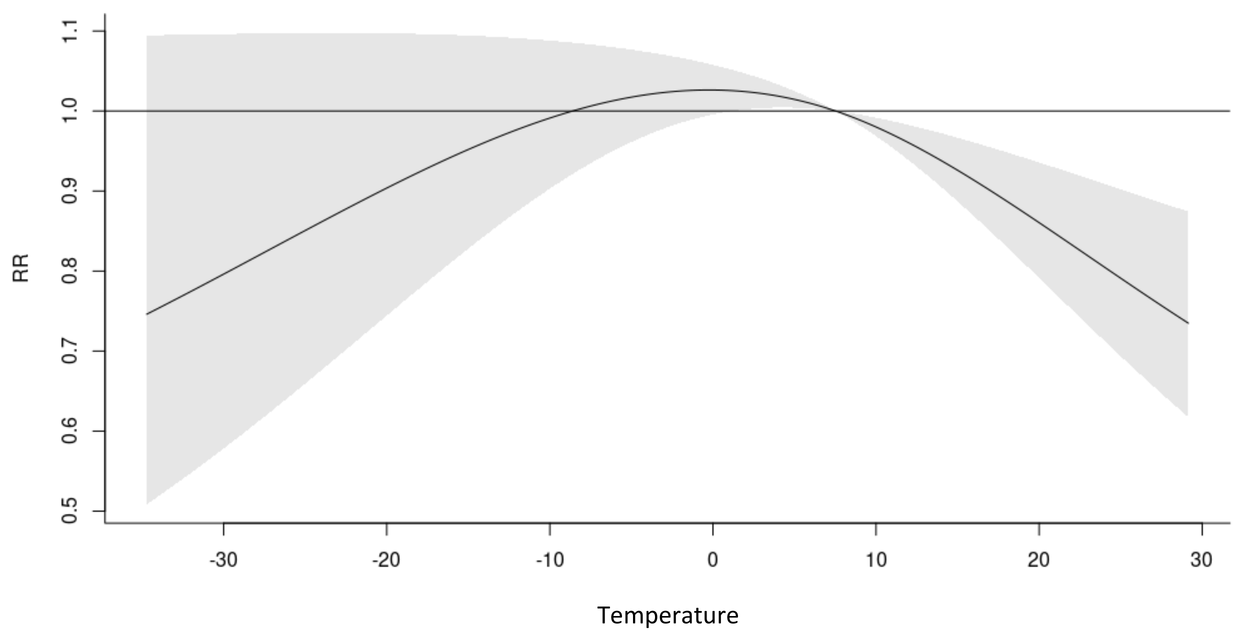

Figure 3.3 Overall effects of exposure-response associations between average temperature and RR for MH-ED visits for people with SSD, with reference to 7.53ºC.

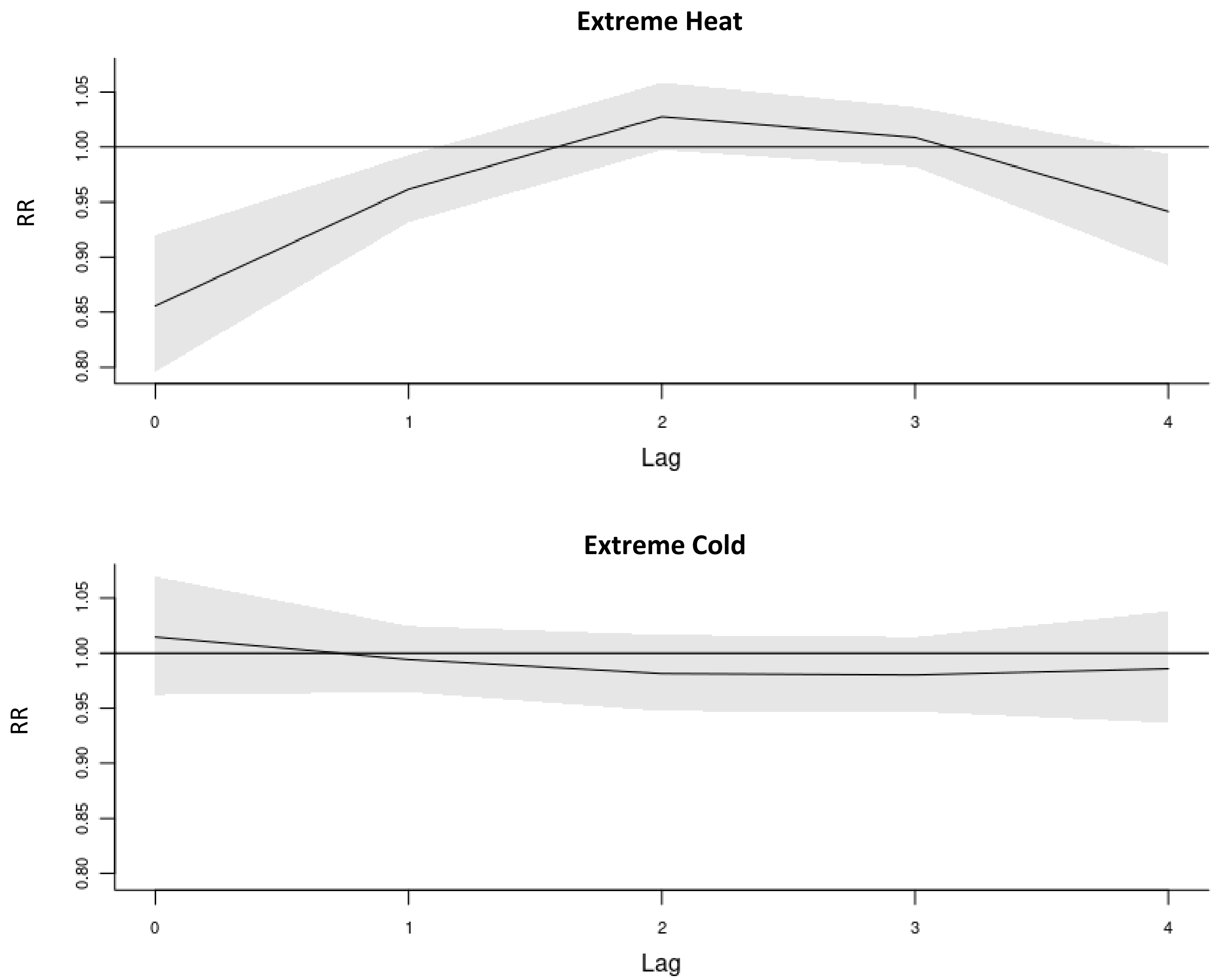

Figure 3.4 Lag-specific effects of the association between average temperature and MH-ED visits at 97.5% (24.12ºC) for extreme heat and 2.5% (-15.17ºC) for extreme cold, with reference to 7.53ºC.

3.3.3 Subgroup Analyses for Mental Health Emergency Department Visits

The lag-specific and cumulative RRs for the subgroup analyses stratified by health region, sex, and age are presented in Tables 3.6 through 3.9, and Figures 3.5 through 3.7 show the corresponding overall exposure-response curves stratified by health region, sex, and age.

3.3.3.1 Health Region

When stratified by health region, a significantly lower risk of MH-ED visits was observed on lag day 0 for Toronto (RR 0.83; 95% CI 0.72, 0.96), North East (RR 0.66; 95% CI 0.52, 0.85), and North West (RR 0.70; 95% CI 0.49, 0.99), followed by a non-significant increase in risk before decreasing again. For the North East region, there was a significant increase in single-day risk on lag days 3 (RR 1.12; 95% CI 1.02, 1.23) and 4 (RR 1.19; 95% CI 1.00, 1.43). Toronto, East and North East had significantly lower cumulative risk of MH-ED visits, with the lowest risk during lag period 0-4 for Toronto (RR 0.73; 95% CI 0.57, 0.93) and East (RR 0.73; 95% CI 0.57, 0.93), and lag period 0-3 for North East (RR 0.62; 95% CI 0.43, 0.89). Extreme heat was not associated with MH-ED visits for West and Central health regions.

For extreme cold exposure, the North West region had 49% higher risk of MH-ED visits on lag day 0 (RR 1.49; 95% CI 1.04, 2.13) followed by a decrease in risk. The East health region had significantly lower risks of MH-ED visits at lag 0 to 1 and lag 3 to 4, with the lowest risk at lag 0 (RR 0.87; 95% CI 0.77, 1.00). Additionally, significantly lower cumulative effects were observed for this health region, with the lowest effect during lag 0-4 (RR 0.60, 95% CI 0.44, 0.82). Extreme cold exposure was not significantly associated with MH-ED visits in West, Central, Toronto, and North East regions.

Table 3.6 Extreme heat (97.5th percentile) effects MH-ED visits with a reference to 7.53ºC (median) in each health region.

	West	Central	Toronto	East	North East	North West
Single-day effects, RR (95% CI)						
lag0	0.89 (0.77, 1.02)	0.89 (0.74, 1.07)	0.83 (0.72, 0.96)*	0.85 (0.72, 1.01)	0.66 (0.52, 0.85)*	0.70 (0.49, 0.99)*
lag1	0.99 (0.93, 1.05)	1.02 (0.94, 1.10)	0.95 (0.89, 1.01)	0.93 (0.87, 1.01)	0.83 (0.75, 0.93)*	0.88 (0.75, 1.04)
lag2	1.05 (0.99, 1.12)	1.09 (1.01, 1.18)*	1.02 (0.96, 1.08)	0.98 (0.92, 1.06)	1.00 (0.90, 1.11)	1.02 (0.87, 1.20)
lag3	1.04 (0.98, 1.09)	1.05 (0.98, 1.12)	1.00 (0.94, 1.05)	0.96 (0.91, 1.03)	1.12 (1.02, 1.23)	1.02 (0.89, 1.17)
lag4	0.97 (0.87, 1.07)	0.94 (0.82, 1.07)	0.91 (0.82, 1.02)	0.91 (0.80, 1.02)	1.19 (1.00, 1.43)	0.93 (0.72, 1.21)
Cumulative effects, RR (95% CI)						
lag0-0	0.89 (0.77, 1.02)	0.89 (0.74, 1.07)	0.83 (0.72, 0.96)*	0.85 (0.72, 1.01)	0.66 (0.52, 0.85)*	0.70 (0.49, 0.99)*
lag0-1	0.88 (0.73, 1.06)	0.91 (0.71, 1.16)	0.79 (0.65, 0.95)*	0.80 (0.63, 1.00)	0.55 (0.40, 0.77)*	0.61 (0.38, 1.00)
lag0-2	0.93 (0.76, 1.13)	0.99 (0.77, 1.28)	0.80 (0.66, 0.98)*	0.78 (0.62, 1.00)	0.55 (0.39, 0.79)*	0.63 (0.38, 1.05)
lag0-3	0.96 (0.78, 1.18)	1.04 (0.80, 1.34)	0.80 (0.65, 0.98)*	0.75 (0.59, 0.97)*	0.62 (0.43, 0.89)*	0.64 (0.37, 1.10)
lag0-4	0.93 (0.73, 1.19)	0.98 (0.72, 1.33)	0.73 (0.57, 0.93)*	0.68 (0.51, 0.92)*	0.74 (0.48, 1.13)	0.60 (0.32, 1.13)

* p-value ≤ 0.05

Table 3.7 Extreme cold (2.5th percentile) effects on MH-ED visits with a reference to 7.53ºC (median) in each health region.

	West	Central	Toronto	East	North East	North West
Single-day effects, RR (95% CI)						
lag0	1.00 (0.91, 1.09)	1.04 (0.92, 1.18)	1.03 (0.95, 1.13)	0.87 (0.77, 1.00)	1.05 (0.82, 1.35)	1.49 (1.04, 2.13)*
lag1	1.01 (0.96, 1.07)	1.04 (0.97, 1.12)	1.00 (0.95, 1.05)	0.91 (0.85, 0.98)*	1.02 (0.90, 1.15)	1.08 (0.88, 1.32)
lag2	1.03 (0.96, 1.10)	1.03 (0.95, 1.13)	0.99 (0.93, 1.05)	0.93 (0.86, 1.01)	0.99 (0.86, 1.14)	0.86 (0.68, 1.09)
lag3	1.03 (0.96, 1.10)	1.02 (0.94, 1.11)	1.00 (0.94, 1.07)	0.92 (0.85, 0.99)*	0.98 (0.85, 1.13)	0.79 (0.62, 1.00)
lag4	1.03 (0.94, 1.12)	1.00 (0.89, 1.13)	1.04 (0.95, 1.13)	0.88 (0.78, 1.00)	0.97 (0.78, 1.21)	0.79 (0.56, 1.11)
Cumulative effects, RR (95% CI)						
lag0-0	1.00 (0.91, 1.09)	1.04 (0.92, 1.18)	1.03 (0.95, 1.13)	0.87 (0.77, 1.00)	1.05 (0.82, 1.35)	1.49 (1.04, 2.13)*
lag0-1	1.01 (0.89, 1.15)	1.08 (0.91, 1.29)	1.03 (0.91, 1.17)	0.80 (0.67, 0.96)*	1.07 (0.76, 1.51)	1.61 (0.97, 2.67)
lag0-2	1.04 (0.88, 1.22)	1.12 (0.91, 1.38)	1.02 (0.87, 1.19)	0.74 (0.60, 0.92)*	1.06 (0.73, 1.55)	1.38 (0.76, 2.52)
lag0-3	1.06 (0.87, 1.30)	1.14 (0.89, 1.47)	1.02 (0.84, 1.24)	0.68 (0.53, 0.88)*	1.04 (0.67, 1.60)	1.09 (0.53, 2.24)
lag0-4	1.09 (0.85, 1.40)	1.14 (0.83, 1.57)	1.06 (0.84, 1.34)	0.60 (0.44, 0.82)*	1.00 (0.58, 1.73)	0.86 (0.35, 2.12)

* p-value ≤ 0.05

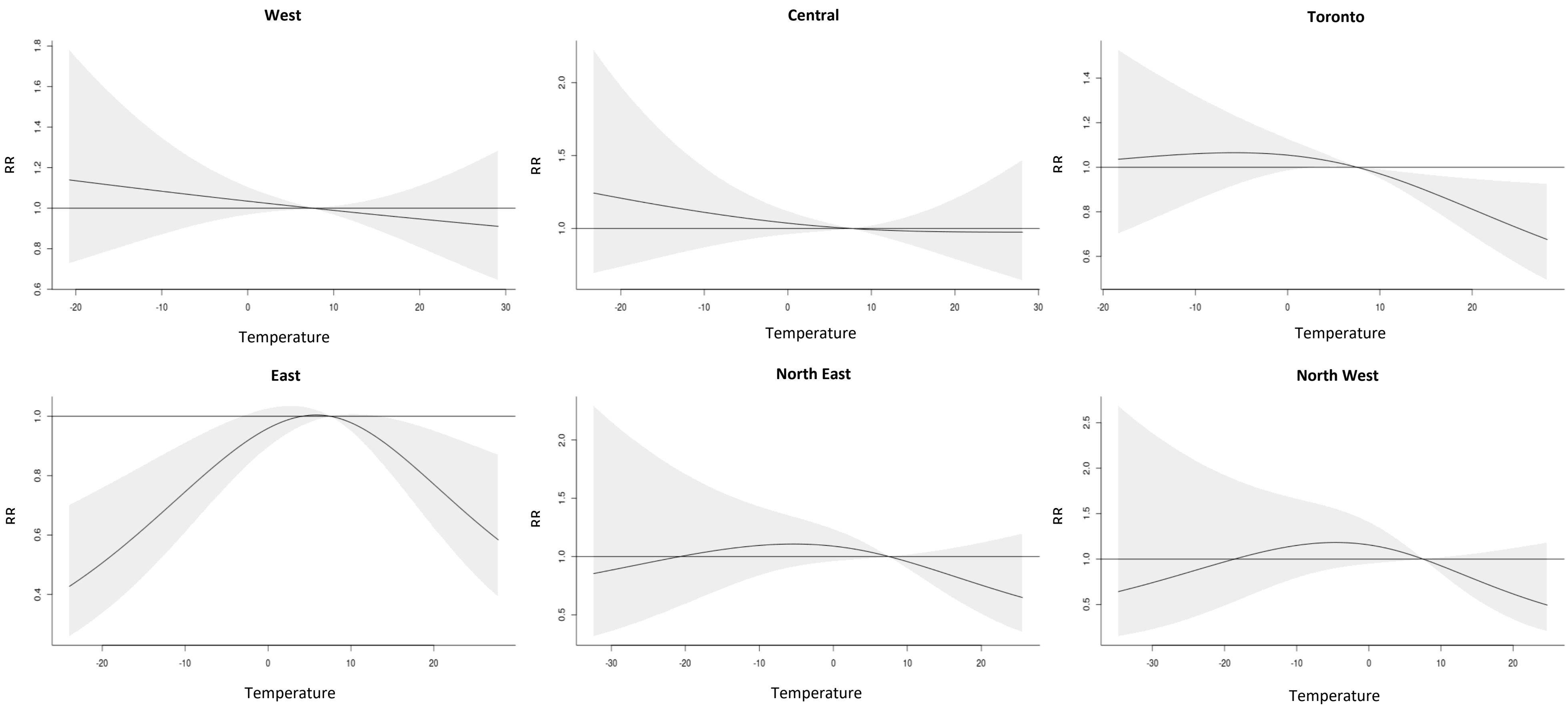

Figure 3.5 Overall effects of exposure-response associations between average temperature and RR for MH-ED visits for people with SSD, with reference to 7.53ºC and stratified by health region.

3.3.3.2 Administrative Sex

When stratified by administrative sex, single-day effects were suggestive of lower risk for females during extreme heat exposure on lag 0 (RR: 0.89; 95% CI 0.79, 1.00) and lag 1 (RR: 0.95; 95% CI 0.91, 1.00), although both estimates include the possibility of a null effect. There was also a suggestive cumulative decrease in the risk of MH-ED visits from lag period 0-1(RR 0.85 95% CI; 0.73, 0.99) to the lowest risk estimate at lag 0-3 (RR 0.85 95% CI; 0.72, 1.00). For males, exposure to extreme heat lowered risk of MH-ED visits by 19% (RR 0.81; 95% CI 0.74, 0.89) on the day of exposure followed by an 8% (RR 1.08; 95% CI 1.04, 1.12) and a suggestive 3% (RR 1.03; 95% CI 1.00, 1.07) higher risk on lag day 2 and 3, respectively. The cumulative effects of extreme heat on men show consistently lower risk of MH-ED visits, with the lowest effect observed on lag 0-4 (RR 0.80; 95% CI 0.68, 0.94).

Extreme cold exposure was associated with lower single-day and cumulative MH-ED risk in females from lag 1 (RR 0.93; 95% CI 0.89, 0.98) to lag 3 (RR 0.95; 95% CI 0.90, 1.00), and lag 0-2 (RR 0.83; 95% CI 0.72, 0.96) to lag 0-4 (RR 0.78; 95% CI 0.63, 0.97). No effects of extreme cold on MH-ED visits were observed for males.

Table 3.8 Extreme heat (97.5th percentile) and cold (2.5th percentile) effects on Ontario-wide MH-ED visits with a reference to 7.53ºC, stratified by sex.

	Extreme Heat (P97.5)		Extreme Cold (P2.5)	
	Female	Male	Female	Male
Single-day effects, RR (95% CI)				
lag0	0.89 (0.79, 1.00)	0.81 (0.74, 0.89)*	0.96 (0.88, 1.04)	1.05 (0.99, 1.13)
lag1	0.95 (0.91, 1.00)	0.98 (0.94, 1.02)	0.93 (0.89, 0.98)*	1.03 (0.99, 1.07)
lag2	1.00 (0.95, 1.05)	1.08 (1.04, 1.12)*	0.93 (0.88, 0.98)*	1.01 (0.97, 1.06)
lag3	1.00 (0.96, 1.04)	1.03 (1.00, 1.07)	0.95 (0.90, 1.00)	1.00 (0.96, 1.05)
lag4	0.98 (0.90, 1.06)	0.90 (0.84, 0.97)*	0.99 (0.91, 1.08)	1.00 (0.94, 1.07)
Cumulative effects, RR (95% CI)				
lag0-0	0.89 (0.79, 1.00)	0.81 (0.74, 0.89)*	0.96 (0.88, 1.04)	1.05 (0.99, 1.13)
lag0-1	0.85 (0.73, 0.99)*	0.79 (0.70, 0.90)*	0.89 (0.79, 1.01)	1.08 (0.98, 1.19)
lag0-2	0.85 (0.72, 1.00)	0.86 (0.75, 0.97)*	0.83 (0.72, 0.96)*	1.09 (0.98, 1.23)
lag0-3	0.85 (0.72, 1.00)	0.88 (0.77, 1.01)	0.79 (0.66, 0.94)*	1.10 (0.96, 1.26)
lag0-4	0.83 (0.68, 1.01)	0.80 (0.68, 0.94)*	0.78 (0.63, 0.97)*	1.10 (0.93, 1.30)

* p-value ≤ 0.05

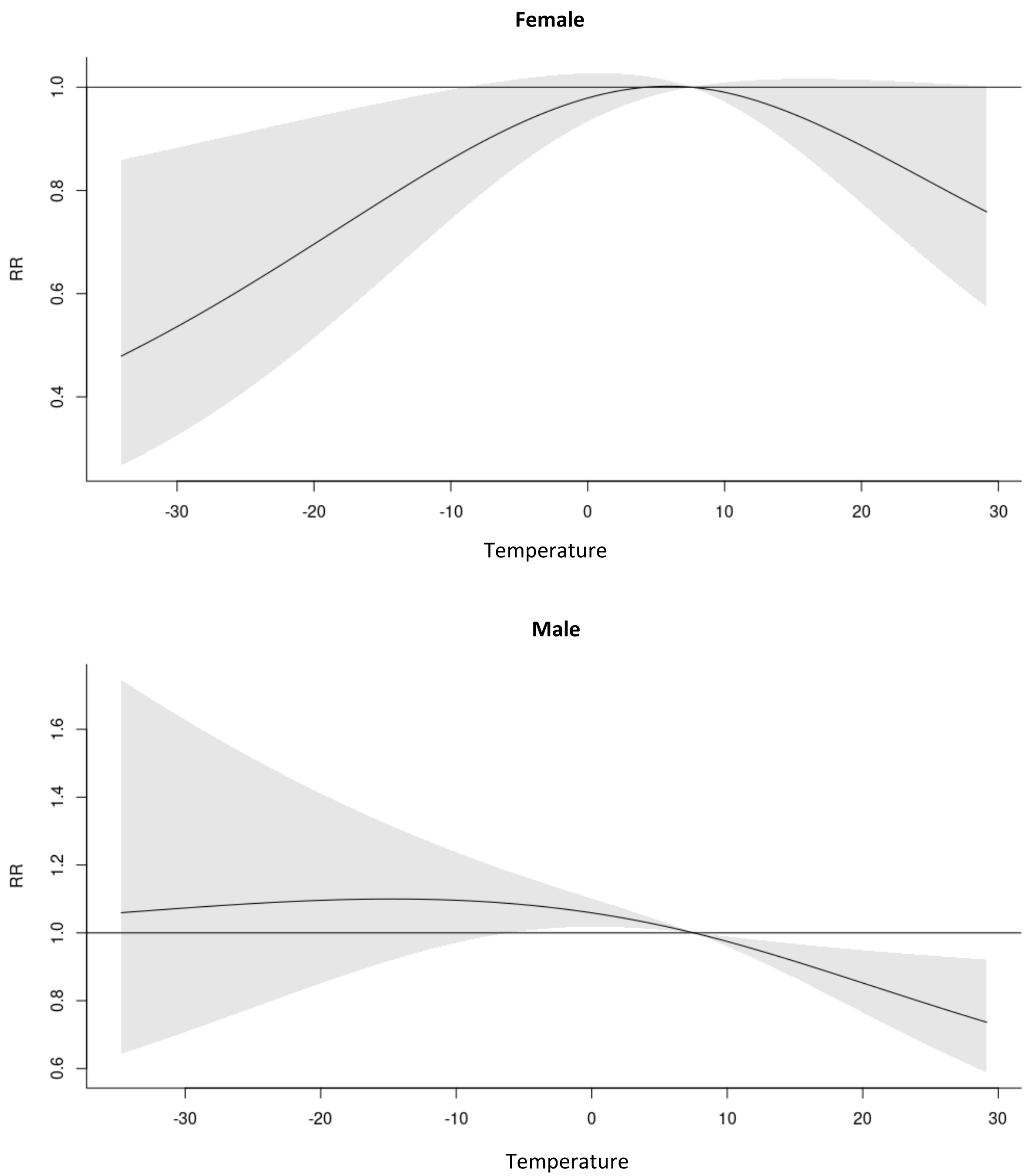

Figure 3.6 Overall effects of exposure-response associations between average temperature and RR for MH-ED visits for people with SSD, with reference to 7.53ºC and stratified by sex.

3.3.3.3 Age

When stratified by age, exposure to extreme heat lowered the risk of MH-ED visits for all age groups on the day of the exposure (14 to 29 years: RR 0.87; CI 95% 0.77, 0.98; 30 to 49 years: RR 0.86; 95% CI 0.77, 0.96; 50+ years: RR 0.80; 95% CI 0.69, 0.93). Cumulatively lowered risk of MH-ED visits was observed for age group 14 to 29 years from lag 0-1 (RR 0.83; CI 95% 0.70, 0.98) to lag 0-2 (RR 0.84 CI 95% 0.70, 0.98). For the two other age groups, they both had significantly lower cumulative risks on lag 0-1 (30 to 49 years: RR 0.84; 95% CI 0.72, 0.97; 50+ years: RR 0.79; 95% CI 0.64, 0.96) and lag 0-4 (30 to 49 years: RR 0.81; 95% CI 0.67, 0.98; 50+ years: RR 0.75; 95% CI 0.58, 0.97). No significant effects were observed between extreme cold and MH-ED visits for any age group.

Table 3.9 Extreme heat (97.5th percentile) and cold (2.5th percentile) effects on Ontario-wide MH-ED visits with a reference to 7.53ºC (median), stratified by age.

	Extreme Heat (P97.5)			Extreme Cold (P2.5)		
	14 to 29 years	30 to 49 years	50+ years	14 to 29 years	30 to 49 years	50+ years
Single-day effects, RR (95% CI)						
lag0	0.87 (0.77, 0.98)*	0.86 (0.77, 0.96)*	0.80 (0.69, 0.93)*	1.00 (0.91, 1.10)	1.01 (0.93, 1.10)	1.05 (0.94, 1.17)
lag1	0.95 (0.90, 1.01)	0.97 (0.92, 1.02)	0.98 (0.92, 1.04)	1.00 (0.95, 1.06)	0.97 (0.93, 1.02)	1.02 (0.96, 1.09)
lag2	1.01 (0.96, 1.07)	1.03 (0.99, 1.08)	1.08 (1.02, 1.15)*	1.01 (0.95, 1.07)	0.94 (0.90, 1.00)	1.01 (0.94, 1.09)
lag3	1.02 (0.97, 1.07)	1.01 (0.97, 1.05)	1.02 (0.96, 1.08)	1.01 (0.95, 1.07)	0.95 (0.90, 1.00)	1.02 (0.95, 1.10)
lag4	1.00 (0.91, 1.09)	0.93 (0.86, 1.01)	0.87 (0.78, 0.97)*	1.01 (0.93, 1.11)	0.96 (0.89, 1.04)	1.04 (0.93, 1.16)
Cumulative effects, RR (95% CI)						
lag0-0	0.87 (0.77, 0.98)*	0.86 (0.77, 0.96)*	0.80 (0.69, 0.93)*	1.00 (0.91, 1.10)	1.01 (0.93, 1.10)	1.05 (0.94, 1.17)
lag0-1	0.83 (0.70, 0.98)*	0.84 (0.72, 0.97)*	0.79 (0.64, 0.96)*	1.00 (0.88, 1.14)	0.98 (0.88, 1.10)	1.07 (0.91, 1.25)
lag0-2	0.84 (0.70, 0.99)*	0.86 (0.74, 1.01)	0.85 (0.69, 1.05)	1.01 (0.87, 1.18)	0.93 (0.81, 1.06)	1.09 (0.90, 1.31)
lag0-3	0.85 (0.71, 1.02)	0.87 (0.74, 1.02)	0.87 (0.70, 1.07)	1.02 (0.85, 1.23)	0.88 (0.74, 1.03)	1.11 (0.88, 1.39)
lag0-4	0.85 (0.69, 1.05)	0.81 (0.67, 0.98)*	0.75 (0.58, 0.97)*	1.03 (0.82, 1.30)	0.84 (0.69, 1.03)	1.15 (0.87, 1.53)

* p-value ≤ 0.05

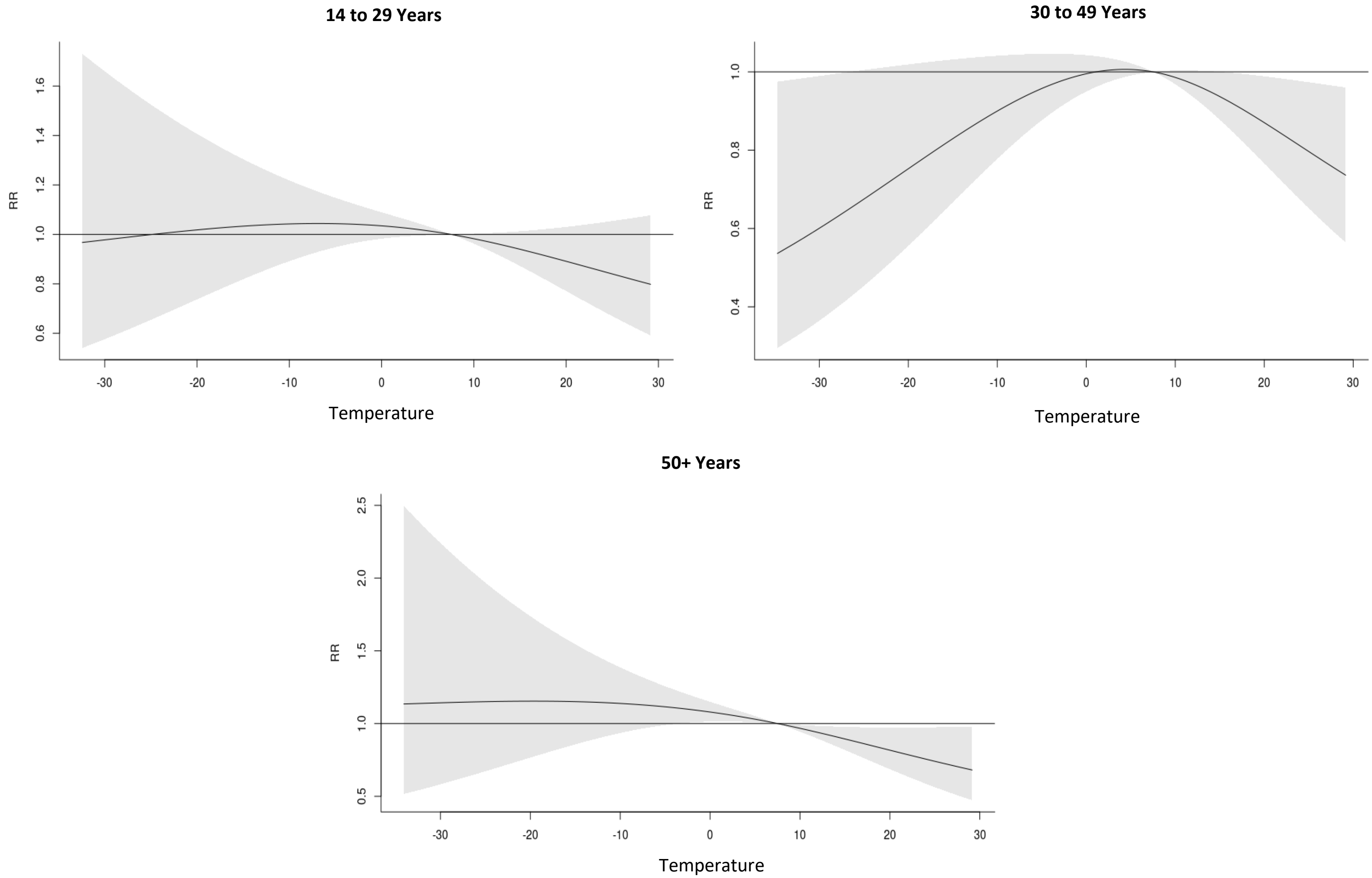

Figure 3.7 Overall effects of exposure-response associations between average temperature and RR for MH-ED visits for people with SSD, with reference to 7.53ºC and stratified by age.

3.3.4 Extreme Temperature and Emergency Department Visits for Non-Mental Health Reasons

Table 3.10 presents the lag-specific and cumulative RRs for the associations of extreme heat and cold with Non-MH-ED visits among people with SSD. Figures 3.8, 3.9, 3.10 show the 3D contour plot, overall exposure-response curve, and lag-specific curves for the association between temperature and Non-MH-ED visits. Extreme heat was associated with suggestive higher risk of Non-MH-ED visits on the day of exposure (RR 1.05; 95% CI 1.00, 1.11) and at lag 6 (RR 1.05; 95% CI 1.01, 1.08). In contrast, lower risk of Non-MH-ED visits was observed on lag days 4 and 5 (RR 0.96; 95% CI 0.93, 0.99). Cumulative heat effects suggest a small elevation of risk during lag periods 0-2 (RR 1.08; 95% CI 1.00, 1.17) and 0-3 (RR 1.09; 95% CI 1.00, 1.19), though they were no longer elevated when longer lag periods were considered.

Extreme cold exposure was associated with a lower risk in Non-MH-ED visits on the day of exposure (RR 0.91; 95% CI 0.88, 0.95). Single-day cold effects on later lags were largely null. Cumulative cold effects consistently indicated lower risk of ED visits from lag 0-1 (RR 0.90; 95% CI 0.88, 0.95) to lag 0-3 (RR 0.90; 95% CI 0.83, 0.98), with estimates approaching null as the lag window increased.

Table 3.10 Extreme heat (97.5th percentile) and cold (2.5th percentile) effects on Ontario-wide *Non-MH-ED* visits with a reference to 7.53ºC (median).

	Extreme Heat (P97.5)	Extreme Cold (P2.5)
Single-day effects, RR (95% CI)		
lag0	1.05 (1.00, 1.11)	0.91 (0.88, 0.95)*
lag1	1.01 (0.98, 1.05)	0.99 (0.96, 1.02)
lag2	1.01 (0.99, 1.03)	1.01 (0.98, 1.03)
lag3	1.01 (0.98, 1.04)	0.99 (0.96, 1.02)
lag4	0.96 (0.93, 0.99)*	1.01 (0.98, 1.05)
lag5	0.96 (0.93, 0.99)*	1.03 (1.00, 1.06)
lag6	1.05 (1.01, 1.08)*	1.00 (0.97, 1.04)
Cumulative effects, RR (95% CI)		
lag0-0	1.05 (1.00, 1.11)	0.91 (0.88, 0.95)*
lag0-1	1.07 (0.99, 1.15)	0.90 (0.86, 0.95)*
lag0-2	1.08 (1.00, 1.17)	0.91 (0.85, 0.97)*
lag0-3	1.09 (1.00, 1.19)	0.90 (0.83, 0.98)*
lag0-4	1.04 (0.95, 1.15)	0.91 (0.82, 1.01)
lag0-5	1.00 (0.89, 1.12)	0.94 (0.83, 1.06)
lag0-6	1.05 (0.93, 1.19)	0.94 (0.83, 1.07)

* p-value ≤ 0.05

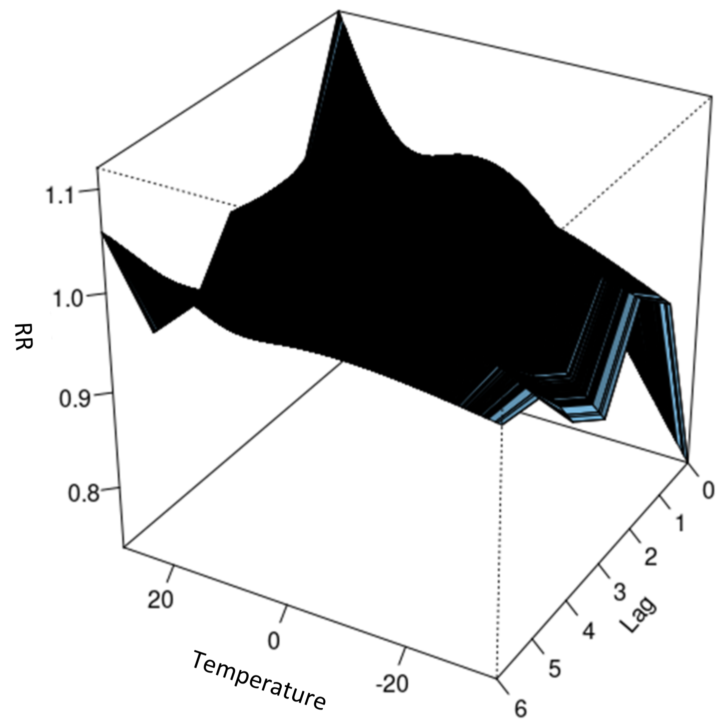

Figure 3.8 Three-dimensional graph of RR for Non-MH-ED visits along with average temperature and lag, with reference to 7.53ºC.

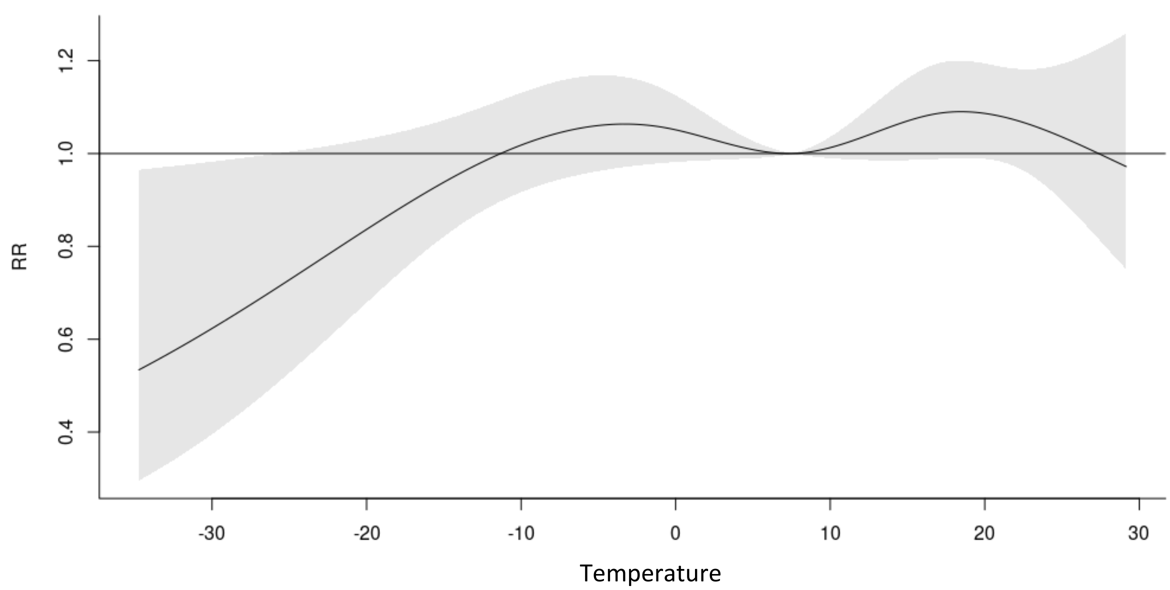

Figure 3.9 Overall effects of exposure-response associations between average temperature and RR for Non-MH-ED visits for people with SSD, with reference to 7.53ºC.

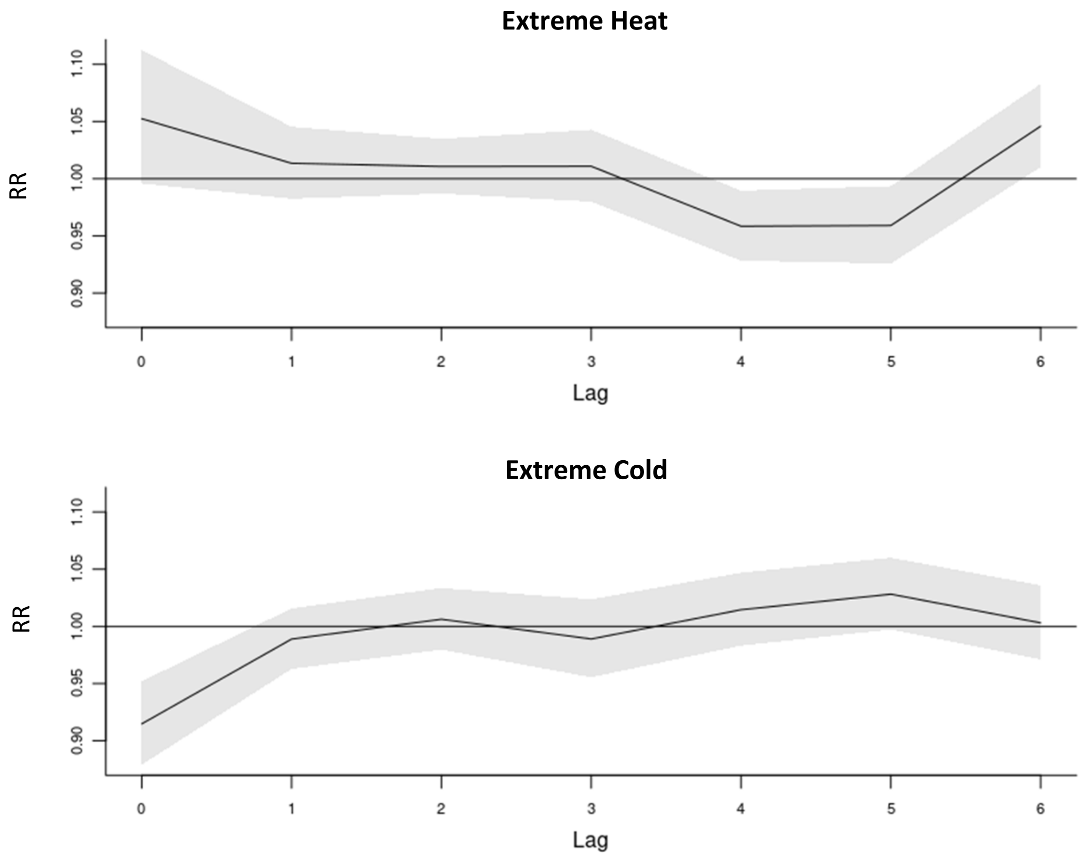

Figure 3.10 Lag-specific effects of the association between average temperature and Non-MH-ED visits at 97.5% (24.12ºC) for extreme heat and 2.5% (-15.17ºC) for extreme cold, with reference to 7.53ºC.

3.3.5 Subgroup Analyses for Non-Mental Health Emergency Department Visits

The lag-specific and cumulative results of the subgroup analyses for health region, sex and age are reported in Tables 3.11 through 3.14, and the overall exposure-response curves are presented in Figures 3.11 through 3.13.

3.3.5.1 Health Region

For single-day effects of extreme heat, a higher risk of Non-MH-ED visits occurred on the day of exposure (RR 1.16; 95% CI 1.01, 1.33) for the Central health region. This was followed by gradual decreases in effect with the lowest risk for Non-MH-ED visits at lag 4 (RR 0.91; 95% CI 0.84, 0.98). Similarly, a lower risk of Non-MH-ED visit was observed at lag 4 (RR 0.91; 95% CI 0.86, 0.97) for Toronto. At longer lags, specifically at lag 6, a higher risk of Non-MH-ED visits was observed in the West (RR 1.08; 95% CI 1.01, 1.15) and Central (RR 1.11; 95% CI 1.03, 1.18) health regions. Cumulative heat effects showed a higher risk of Non-MH-ED visits through lag 0-2 (RR 1.24; 95% CI 1.02, 1.50). In the East region, cumulative risk was suggestively higher at lag 0-3 (RR 1.21; 95% CI 1.00, 1.47). No associations between extreme heat and Non-MH-ED visits were noted for North West or North East regions.

Extreme cold was generally associated with lower Non-MH-ED visit risk on the day of exposure for the West (RR 0.88; 95% CI 0.83, 0.94), Central (RR 0.90; 95% CI 0.82, 0.99), and North West (RR 0.70; 95% CI 0.52, 0.94) regions. Cumulative cold effects were observed for the West and Central health regions with the lowest cumulative risk of Non-MH-ED visits through lag period 0-4 (West: RR 0.80; 95% CI 0.66, 0.97; Central: RR 0.76; 95% CI 0.58, 0.99). No associations between extreme cold and Non-MH-ED visits were observed for East, Toronto, and North East regions.

Table 3.11 Extreme heat (97.5th percentile) effects on Non-MH-ED visits with a reference to 7.53ºC (median) in each health region.

	West	Central	Toronto	East	North East	North West
Single-day effects, RR (95% CI)						
lag0	1.01 (0.92, 1.11)	1.16 (1.01, 1.33)*	1.05 (0.94, 1.18)	1.09 (0.96, 1.24)	0.99 (0.81, 1.21)	1.11 (0.82, 1.49)
lag1	1.03 (0.97, 1.09)	1.06 (0.98, 1.15)	0.99 (0.93, 1.05)	1.03 (0.96, 1.10)	1.06 (0.94, 1.20)	0.99 (0.81, 1.22)
lag2	1.03 (0.99, 1.07)	1.00 (0.95, 1.06)	0.98 (0.94, 1.03)	1.03 (0.98, 1.09)	1.07 (0.97, 1.18)	1.02 (0.87, 1.20)
lag3	1.00 (0.95, 1.06)	0.96 (0.89, 1.04)	0.98 (0.93, 1.05)	1.04 (0.97, 1.12)	1.02 (0.91, 1.16)	1.06 (0.87, 1.29)
lag4	0.97 (0.91, 1.02)	0.91 (0.84, 0.98)*	0.91 (0.86, 0.97)*	0.96 (0.90, 1.04)	0.98 (0.87, 1.11)	0.89 (0.74, 1.08)
lag5	0.99 (0.93, 1.05)	0.93 (0.85, 1.01)	0.94 (0.87, 1.00)	0.96 (0.88, 1.04)	0.96 (0.84, 1.10)	0.83 (0.67, 1.04)
lag6	1.08 (1.01, 1.15)*	1.05 (0.96, 1.14)	1.11 (1.03, 1.18)*	1.07 (0.99, 1.16)	0.94 (0.82, 1.08)	0.98 (0.78, 1.23)
Cumulative effects, RR (95% CI)						
lag0-0	1.01 (0.92, 1.11)	1.16 (1.01, 1.33)*	1.05 (0.94, 1.18)	1.09 (0.96, 1.24)	0.99 (0.81, 1.21)	1.11 (0.82, 1.49)
lag0-1	1.04 (0.91, 1.18)	1.23 (1.03, 1.47)*	1.04 (0.90, 1.20)	1.12 (0.95, 1.32)	1.05 (0.81, 1.38)	1.10 (0.73, 1.67)
lag0-2	1.07 (0.93, 1.23)	1.24 (1.02, 1.50)*	1.02 (0.88, 1.20)	1.16 (0.97, 1.39)	1.13 (0.83, 1.54)	1.13 (0.69, 1.84)
lag0-3	1.07 (0.92, 1.25)	1.19 (0.96, 1.47)	1.01 (0.85, 1.19)	1.21 (1.00, 1.47)	1.16 (0.82, 1.64)	1.20 (0.69, 2.08)
lag0-4	1.03 (0.87, 1.23)	1.08 (0.85, 1.38)	0.92 (0.76, 1.11)	1.17 (0.94, 1.46)	1.14 (0.77, 1.70)	1.07 (0.57, 2.00)
lag0-5	1.02 (0.83, 1.25)	1.01 (0.76, 1.33)	0.86 (0.69, 1.08)	1.12 (0.87, 1.44)	1.10 (0.69, 1.74)	0.89 (0.43, 1.85)
lag0-6	1.10 (0.88, 1.38)	1.05 (0.77, 1.44)	0.95 (0.75, 1.21)	1.20 (0.91, 1.58)	1.03 (0.62, 1.72)	0.87 (0.38, 1.98)

* p-value ≤ 0.05

Table 3.12 Extreme cold (2.5th percentile) effects on Non-MH-ED visits with a reference to 7.53ºC (median) in each health region.

	West	Central	Toronto	East	North East	North West
Single-day effects, RR (95% CI)						
lag0	0.88 (0.83, 0.94)*	0.90 (0.82, 0.99)*	0.95 (0.88, 1.02)	0.96 (0.88, 1.06)	1.02 (0.84, 1.25)	0.70 (0.52, 0.94)*
lag1	0.96 (0.92, 1.01)	0.94 (0.88, 1.00)	0.98 (0.93, 1.03)	1.03 (0.97, 1.09)	0.96 (0.86, 1.07)	0.97 (0.80, 1.19)
lag2	0.98 (0.93, 1.03)	0.96 (0.89, 1.03)	0.97 (0.91, 1.02)	1.01 (0.95, 1.08)	0.96 (0.86, 1.07)	1.12 (0.90, 1.39)
lag3	0.96 (0.90, 1.02)	0.97 (0.89, 1.05)	0.94 (0.88, 1.01)	0.98 (0.90, 1.06)	1.00 (0.87, 1.15)	1.09 (0.85, 1.41)
lag4	0.99 (0.94, 1.05)	0.98 (0.90, 1.06)	0.97 (0.91, 1.03)	1.04 (0.97, 1.13)	1.02 (0.89, 1.17)	1.11 (0.87, 1.40)
lag5	1.03 (0.98, 1.08)	0.98 (0.91, 1.05)	1.00 (0.94, 1.06)	1.07 (0.99, 1.14)	1.03 (0.90, 1.17)	1.08 (0.86, 1.35)
lag6	1.03 (0.98, 1.09)	0.96 (0.89, 1.04)	1.00 (0.95, 1.06)	0.98 (0.91, 1.06)	1.03 (0.90, 1.17)	0.98 (0.79, 1.23)
Cumulative effects, RR (95% CI)						
lag0-0	0.88 (0.83, 0.94)*	0.90 (0.82, 0.99)*	0.95 (0.88, 1.02)	0.96 (0.88, 1.06)	1.02 (0.84, 1.25)	0.70 (0.52, 0.94)*
lag0-1	0.85 (0.78, 0.93)*	0.84 (0.74, 0.95)*	0.93 (0.84, 1.02)	0.99 (0.87, 1.12)	0.98 (0.77, 1.25)	0.68 (0.47, 1.00)
lag0-2	0.84 (0.74, 0.94)*	0.80 (0.68, 0.95)*	0.89 (0.79, 1.01)	1.00 (0.86, 1.16)	0.94 (0.71, 1.24)	0.76 (0.46, 1.26)
lag0-3	0.80 (0.68, 0.94)*	0.78 (0.63, 0.96)*	0.84 (0.71, 1.00)	0.98 (0.81, 1.19)	0.94 (0.67, 1.32)	0.83 (0.43, 1.61)
lag0-4	0.80 (0.66, 0.97)*	0.76 (0.58, 0.99)*	0.82 (0.66, 1.00)	1.02 (0.80, 1.30)	0.96 (0.64, 1.44)	0.92 (0.41, 2.08)
lag0-5	0.82 (0.65, 1.03)	0.74 (0.54, 1.01)	0.82 (0.64, 1.04)	1.09 (0.82, 1.44)	0.98 (0.61, 1.59)	1.00 (0.39, 2.55)
lag0-6	0.85 (0.66, 1.09)	0.71 (0.51, 1.00)	0.82 (0.63, 1.06)	1.07 (0.79, 1.46)	1.01 (0.60, 1.70)	0.98 (0.36, 2.66)

* p-value ≤ 0.05

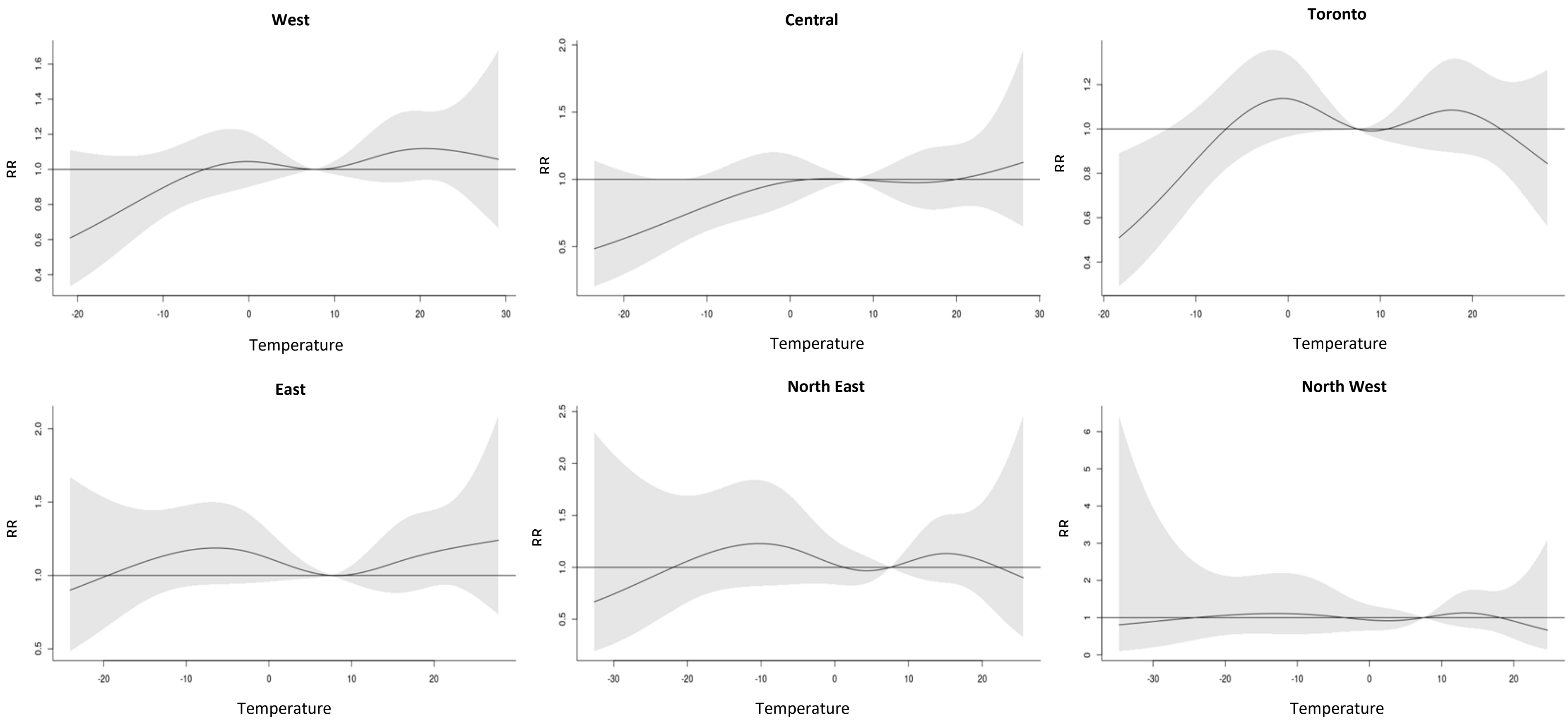

Figure 3.11 Overall effects of exposure-response associations between average temperature and RR for Non-MH-ED visits for people with SSD, with reference to 7.53ºC and stratified by health region.

3.3.5.2 Administrative Sex

When stratified by administrative sex, both males (RR 1.06; 95% CI 1.01, 1.12) and females (RR 1.06; 95% CI 1.01, 1.11) had a higher Non-MH-ED visit risk on lag 6 during extreme heat. Cumulatively higher risk effects of extreme heat were observed for females through lag 0-3 (RR 1.14; 95% CI 1.01, 1.29). For males, a significantly lower risk of Non-MH-ED visits was observed on the day of cold exposure (RR 0.88; 95% CI 0.84, 0.93). To add, cumulative effects of extreme cold were observed in males through lag 3 (RR 0.89; 95% CI 0.81, 0.98), where a lower risk of Non-MH-ED visits was observed. No association between extreme cold and Non-MH-ED visits were found for females.

Table 3.13 Extreme heat (97.5th percentile) and cold (2.5th percentile) effects on Ontario-wide Non-MH-ED visits with a reference to 7.53ºC, stratified by sex.

	Extreme Heat (P97.5)		Extreme Cold (P2.5)	
	Female	Male	Female	Male
Single day effects, RR (95% CI)				
lag0	1.06 (0.98, 1.15)	1.05 (0.98, 1.14)	0.96 (0.91, 1.02)	0.88 (0.84, 0.93)*
lag1	1.03 (0.99, 1.08)	1.00 (0.96, 1.04)	1.00 (0.97, 1.04)	0.99 (0.95, 1.02)
lag2	1.02 (0.99, 1.06)	1.02 (0.98, 1.05)	1.01 (0.97, 1.05)	1.02 (0.99, 1.06)
lag3	1.01 (0.97, 1.06)	1.04 (0.99, 1.08)	0.99 (0.94, 1.04)	1.01 (0.96, 1.06)
lag4	0.99 (0.95, 1.04)	0.93 (0.89, 0.98)*	0.99 (0.95, 1.04)	1.03 (0.98, 1.07)
lag5	1.00 (0.95, 1.05)	0.92 (0.88, 0.97)*	1.01 (0.97, 1.06)	1.02 (0.98, 1.07)
lag6	1.06 (1.01, 1.12)*	1.06 (1.01, 1.11)*	1.02 (0.97, 1.07)	0.98 (0.94, 1.02)
Cumulative effects, RR (95% CI)				
lag0-0	1.06 (0.98, 1.15)	1.05 (0.98, 1.14)	0.96 (0.91, 1.02)	0.88 (0.84, 0.93)*
lag0-1	1.10 (0.99, 1.22)	1.05 (0.95, 1.16)	0.97 (0.89, 1.04)	0.87 (0.81, 0.94)*
lag0-2	1.12 (1.00, 1.26)	1.07 (0.96, 1.19)	0.97 (0.88, 1.07)	0.89 (0.81, 0.98)*
lag0-3	1.14 (1.01, 1.29)*	1.11 (0.98, 1.25)	0.96 (0.85, 1.08)	0.90 (0.80, 1.01)
lag0-4	1.13 (0.98, 1.30)	1.04 (0.91, 1.18)	0.95 (0.82, 1.11)	0.92 (0.80, 1.07)
lag0-5	1.13 (0.96, 1.33)	0.95 (0.81, 1.11)	0.96 (0.81, 1.15)	0.95 (0.80, 1.12)
lag0-6	1.20 (1.00, 1.44)	1.01 (0.85, 1.19)	0.99 (0.81, 1.19)	0.93 (0.77, 1.11)

* p-value ≤ 0.05

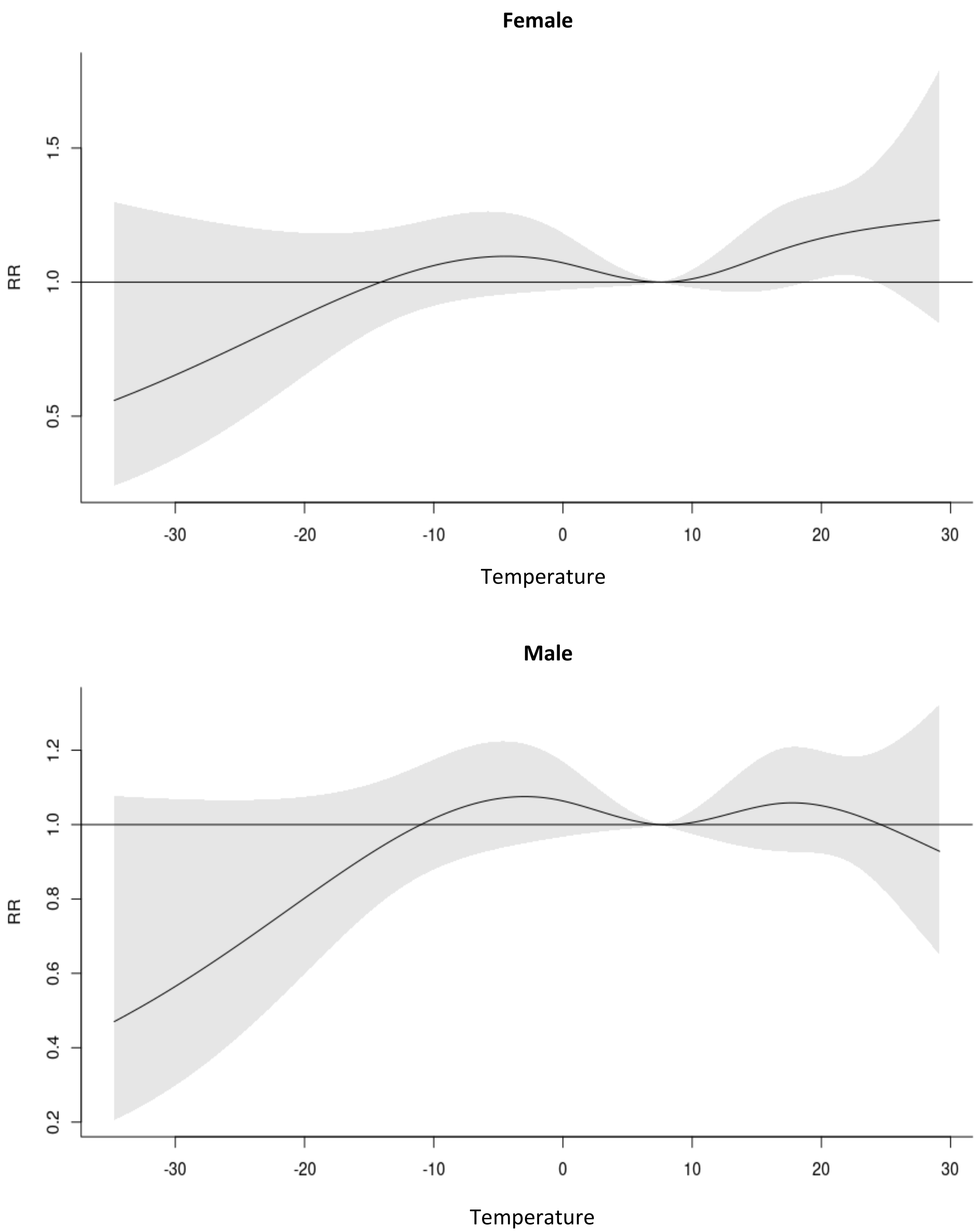

Figure 3.12 Overall effects of exposure-response associations between average temperature and RR for Non-MH-ED visits for people with SSD, with reference to 7.53ºC and stratified by sex.

3.3.5.3 Age

During extreme heat exposure, people aged 50+ years had a higher single-day risk of Non-MH-ED visits from lag 0 (RR 1.11; 95% CI 1.02, 1.20) to lag 3 (RR 1.03; 95% CI 1.00, 1.07), and a suggestive higher risk again on lag 6 (RR 1.06; 95% CI 1.00, 1.11). Additionally, this age group experienced higher cumulative risk of Non-MH-ED visits through lag 0-6 (RR 1.24; 95% CI 1.04, 1.49). People in the 14 to 29 years age group experienced suggestively lower single-day Non-MH-ED visit risk on lag 4 (RR 0.94; 95% CI 0.87, 1.00). No association between extreme heat and Non-MH-ED visits were observed for people in the 30 to 49 years age group.

For extreme cold exposure, people aged 50+ had lower risk of Non-MH-ED visits on the day of the exposure (RR 0.89; 95% CI 0.84, 0.94). Cumulatively lower risks were observed through lag 0-4 (RR 0.84; 95% CI 0.72, 0.98) for this age group, followed by attenuation of effect. No associations between extreme cold and Non-MH-ED visits were observed for people in the 14 to 29 years age group and 30 to 49 years age group.

Table 3.14 Extreme heat (97.5th percentile) and cold (2.5th percentile) effects on Ontario-wide Non-MH-ED visits with a reference to 7.53ºC (median), stratified by age.

	Extreme Heat (P97.5)			Extreme Cold (P2.5)		
	14 to 29 years	30 to 49 years	50+ years	14 to 29 years	30 to 49 years	50+ years
Single day effects, RR (95% CI)						
lag0	0.96 (0.85, 1.08)	1.03 (0.94, 1.14)	1.11 (1.02, 1.20)*	0.95 (0.87, 1.04)	0.95 (0.88, 1.01)	0.89 (0.84, 0.94)*
lag1	1.03 (0.96, 1.10)	0.97 (0.92, 1.02)	1.07 (1.02, 1.12)*	0.99 (0.93, 1.05)	1.00 (0.95, 1.05)	0.98 (0.94, 1.02)
lag2	1.04 (0.98, 1.09)	0.98 (0.94, 1.03)	1.03 (1.00, 1.07)	1.02 (0.96, 1.08)	1.01 (0.96, 1.05)	1.00 (0.96, 1.04)
lag3	0.98 (0.91, 1.05)	1.03 (0.98, 1.09)	1.00 (0.95, 1.05)	1.03 (0.96, 1.11)	0.99 (0.93, 1.05)	0.97 (0.92, 1.02)
lag4	0.94 (0.87, 1.00)	0.98 (0.93, 1.04)	0.97 (0.93, 1.02)	1.01 (0.95, 1.08)	1.01 (0.95, 1.07)	0.99 (0.95, 1.04)
lag5	0.96 (0.89, 1.04)	0.97 (0.91, 1.04)	0.99 (0.94, 1.04)	0.99 (0.93, 1.06)	1.01 (0.96, 1.07)	1.02 (0.98, 1.07)
lag6	1.06 (0.99, 1.15)	1.06 (0.99, 1.13)	1.06 (1.00, 1.11)	0.99 (0.92, 1.06)	0.98 (0.92, 1.03)	1.02 (0.97, 1.07)
Cumulative effects, RR (95% CI)						
lag0-0	0.96 (0.85, 1.08)	1.03 (0.94, 1.14)	1.11 (1.02, 1.20)*	0.95 (0.87, 1.04)	0.95 (0.88, 1.01)	0.89 (0.84, 0.94)*
lag0-1	0.98 (0.84, 1.15)	1.00 (0.88, 1.13)	1.18 (1.07, 1.31)*	0.94 (0.84, 1.05)	0.95 (0.86, 1.04)	0.87 (0.80, 0.94)*
lag0-2	1.02 (0.86, 1.21)	0.98 (0.86, 1.13)	1.22 (1.09, 1.37)*	0.96 (0.83, 1.10)	0.95 (0.85, 1.07)	0.87 (0.79, 0.96)*
lag0-3	1.00 (0.83, 1.20)	1.02 (0.87, 1.18)	1.22 (1.08, 1.38)*	0.98 (0.82, 1.18)	0.94 (0.81, 1.09)	0.84 (0.75, 0.95)*
lag0-4	0.93 (0.75, 1.15)	1.00 (0.84, 1.19)	1.19 (1.03, 1.37)*	1.00 (0.80, 1.24)	0.95 (0.79, 1.14)	0.84 (0.72, 0.98)*
lag0-5	0.90 (0.70, 1.15)	0.97 (0.79, 1.19)	1.18 (1.00, 1.39)	0.99 (0.76, 1.28)	0.96 (0.78, 1.19)	0.86 (0.72, 1.02)
lag0-6	0.95 (0.73, 1.25)	1.03 (0.82, 1.28)	1.24 (1.04, 1.49)*	0.98 (0.74, 1.30)	0.94 (0.74, 1.18)	0.87 (0.72, 1.06)

* p-value ≤ 0.05

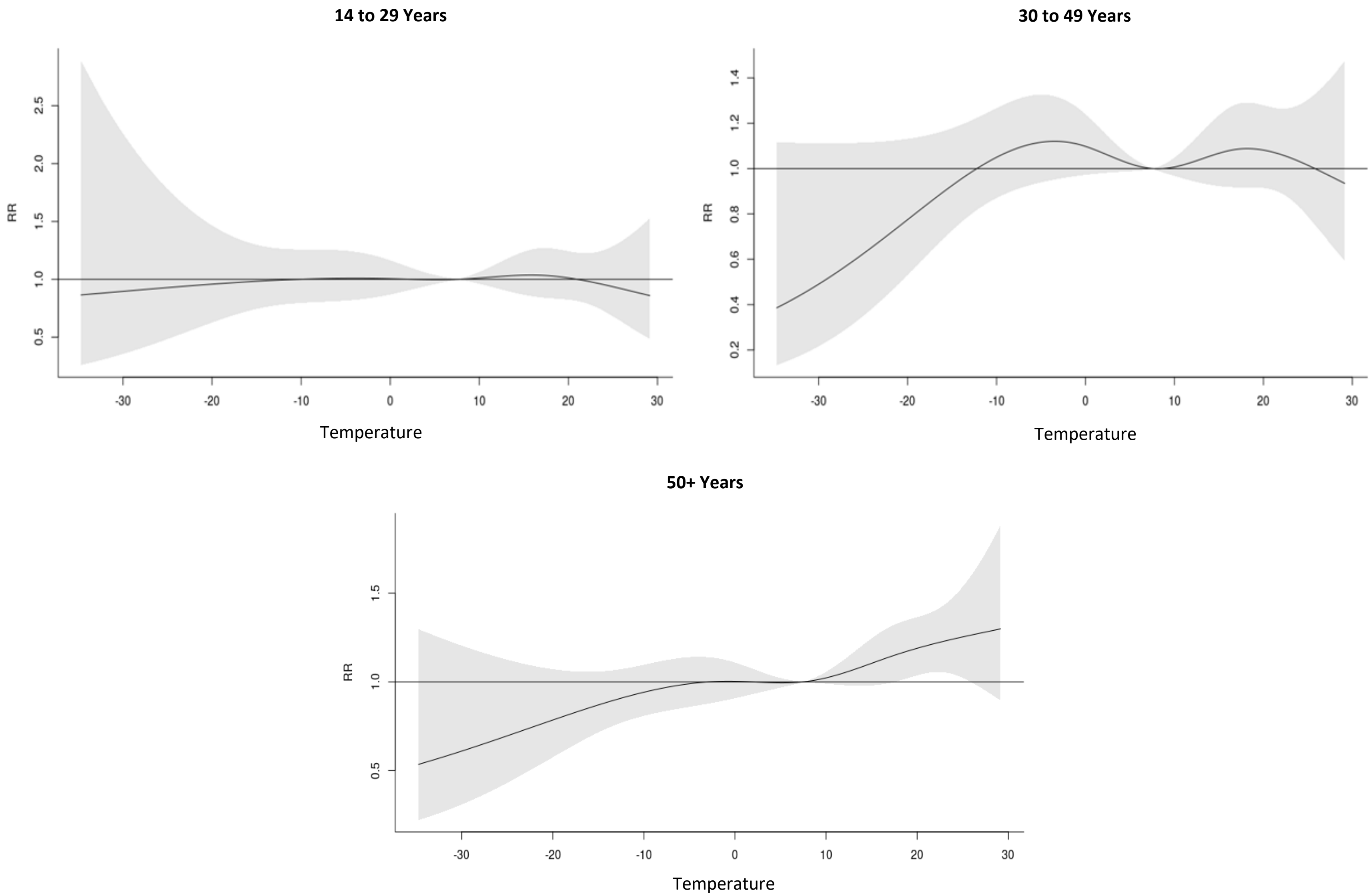

Figure 3.13 Overall effects of exposure-response associations between average temperature and RR for Non-MH-ED visits for people with SSD, with reference to 7.53°C and stratified by age.

3.4 Discussion

This study examined the impact of extreme heat and cold on emergency department (ED) visits for both mental health-related (MH-ED) and non-mental health-related (Non-MH-ED) reasons among people with SSD. Extreme heat was consistently associated with a lower MH-ED visit risk, especially on the day of exposure, and this effect persisted across cumulative lag periods. However, we found little evidence of an association between extreme cold and MH-ED visits. For Non-MH-ED visits, extreme heat was associated with small increases in risk at short lags, whereas extreme cold was associated with reduced risk, particularly over short cumulative lag windows.

In stratified analysis, patterns differed between MH-ED and Non-MH-ED visits. For MH-ED visits, extreme heat was generally associated with lower risks across most health regions, with larger decreases observed in Toronto and the Northern regions, and similar lower risks were observed across sex and age strata, particularly at short cumulative lags. In contrast, Non-MH-ED visits showed a different pattern, with higher risks during periods of extreme heat, with stronger effects observed among Central and East regions, among older adults (50+ years), and among females. Extreme cold showed patterns of lower risk of Non-MH-ED visits on the day of exposure and over short cumulative lag periods among Central and West regions, among males, and among those aged over 50 years.

Compared with prior studies, the overall association observed in this study differs in both direction and magnitude, particularly for mental health-related emergency visits. [89,90,109] Several studies have reported a higher risk of mental health-related ED visits, including schizophrenia, with effects observed on the same day of exposure and at short lags. [103,109,167] However, in our study, we observed null or lower risk of MH-ED visits during extreme heat. A study in Toronto found higher single-day risks for schizophrenia ED visits during lag 0 to lag 5 during extreme heat, however we observed lower risk of MH-ED visits.[93] These variations in effect may reflect differences in methodologies, as our study used province-wide data and a case-crossover study design which allows for within-person comparisons that control for individual-level confounders, whereas the Toronto study used an ecological time-series approach limited to a single city. For Non-MH-ED visits, our findings of modestly higher risks during extreme heat is consistent with evidence from broader literature that high temperature exposure is associated with increased acute care utilization for non-mental health outcomes.[4]

We found generally lower risks of Non-MH-ED visits and no association with MH-ED visits during extreme cold temperatures, which is a novel finding given that few prior studies have focused on the effect of extreme cold on ED visits for schizophrenia. A study by Lavigne et al. found that over 0-5 day lag period, extreme cold exposure was associated with a cumulative 1.9% lower risk of ED visits for schizophrenia in Ontario and Alberta, which is consistent with our results.

Descriptive patterns in our stratified analyses broadly align with epidemiological evidence that the impacts of extreme temperature on emergency department utilization can differ across region, sex, and age. Some studies exploring MH-ED visits have reported high heat-related risk estimates among men compared to women, suggesting sex-based differences in vulnerability or health care utilization patterns during heat exposure.[109] Research also indicates that age may be an important factor in temperature-health relationships, although the data are largely mixed.[107] Differences in ED use between regions could be due to factors such as differences in baseline climates, regional socioeconomic factors, variation in health-service access, or differences in demographic composition by region.[168,169]

The physiological vulnerability of people with SSD to temperature extremes may differ from the general population because of impairments in thermoregulation and medication effects. SSDs have been linked with impaired heat tolerance and altered core temperature responses, which can disrupt sweating and heat dissipation.[72] Additionally, antipsychotics such as haloperidol, clozapine, and zuclopenthixol can blunt heat-loss and perceived thermal stress, increasing the risk of complications during extreme temperature events.[65,72,83]

Despite physiological risk, behavioral adaptation may alter observed healthcare utilization patterns in people with SSD. During extreme heat, those with serious mental illness may be more likely to stay in climate-controlled environments which could potentially reduce the likelihood of psychiatric crises leading to emergency visits.[6,170] Adaptive behaviors (avoiding heat exposure, limiting outdoor activity) combined with public health heat warnings may contribute to attenuated or lower MH-ED visits during heat waves.[6]

Another possible explanation is related to the disproportionate burden of social and housing instability among people with SSD. Limited access to stable housing and inadequate cooling or heating may increase exposure to extreme temperature while also reducing capacity to manage environmental stressors.[6] These structural factors may additionally create barriers to accessing emergency care during periods of extreme weather, such as challenges related transportation or care coordination.[6] As a result, reduced emergency department utilization during extreme temperatures may reflect constrained access to services rather than reduced need for care.[6]

For non-mental health emergency visits, mechanisms may align more closely with the broader temperature-health literature. Extreme heat is known to exacerbate chronic physical conditions such as having substantially elevated prevalence of metabolic syndrome, obesity, diabetes, and cardiovascular disease, which are highly prevalent among people with SSD.[171] These effects can worsen physiological stress during and shortly after heat exposure and may increase the likelihood of Non-MH-ED visits.

Lastly, behavioral and system dynamics, including changes in care-seeking behavior, mobility limitations, and access barriers during temperature extremes, may influence observed patterns. People with more severe manifestations of SSD may be more likely to postpone emergency care during uncomfortable or hazardous weather and rely on alternate support, which would suppress ED visit counts even when underlying distress or physical symptoms are present.[29] Together, these physiological, behavioral, and healthcare system factors help contextualize why extreme temperature may alter ED visits patterns for people with SSD.

3.4.1 Strengths

This study had several strengths. To our knowledge, this is the first study in Canada to examine the relationship between extreme heat and cold and both mental health and non-mental health ED visits in a large, validated SSD cohort in Ontario. It also captures immediate and delayed effects of extreme temperature. We further explored the association across strata of health region, sex, and age, noting that patterns across health regions have rarely been examined in existing literature. Also, we used a case-crossover study design which is well suited for assessing the relationship between short-term varying environmental temperatures and acute health events, and it also has the advantage of controlling for time-invariant risk factors.[136,172] The quality of our temperature and $PM_{2.5}$ data was assigned at FSA-level which allows for more precise exposure assessment and thereby reduces exposure misclassification. These results were based on models chosen for their best overall fit, determined after conducting multiple exploratory analyses with varied degrees of freedom for the exposure and lag functions, as well as the length of the lag period.

3.4.2 Limitations

This study also had several limitations. Five FSAs in the North East region of Ontario were excluded due to a lack of temperature data, which may affect the regional representation of our findings. Additionally, the study period was limited to a single year, limiting our ability to capture annual variability in temperature patterns and health service use, including unusually hot or cold years, and reduces the generalizability of the results to other years, or long-term trends. We were also unable to control for other air pollution factors such as NO2, O3, access to green space, and wildfire smoke exposure, and we did not account for holiday periods, which have been shown to influence the relationship between extreme temperature and ED visits.

Several important individual-level factors could not be accounted for, including housing type or quality, access to air conditioning, medication type or dose, comorbid physical or mental health conditions, and the availability of supportive services, which may confound or modify temperature-related risks. Additionally, exposure was based on daily mean temperature from the DAYMET database, which may not fully capture localized microclimates such as urban heat islands, particularly in large metropolitan area such as Toronto. As a result, true temperature exposure in densely built environments may have been underestimated. More broadly, individual-level exposure was not captured, which is important for individuals spending most of their time indoors. In addition, we used the province-wide median as a reference for all model estimates, which may not reflect baseline differences across health region, or population subgroups by administrative sex or age.

3.5 Conclusions

This study identified significantly lower single-day and cumulative MH-ED visits but suggestive evidence of a moderately higher risk of Non-MH-ED visits during extreme heat among people with SSD. For extreme cold exposure, only a lower risk of Non-MH-ED visits was observed, and little evidence suggested an association between extreme cold and MH-ED visits. Stratified analyses further indicated that observed associations were not uniform across health regions, sex, and age. Reduced MH-ED visits may reflect barriers to service access rather than decreased clinical need, while differences in health care use patterns may be influenced by a combination of physiological, behavioral, and health system factors. These findings highlight the need for further research on the impact of extreme temperature events on health service use in Canada, and emphasize the importance of providing regionally targeted interventions, timely support services, and tailored public health messaging for people with SSD during periods of extreme weather events.

3.6 Acknowledgement

The data used in this current study was accessed through ICES, which is an independent non-profit institute funded annually by the Ontario Ministry of Health (MOH) and the Ministry of Long-Term Care (MLTC). As a prescribed entity under Ontario's privacy legislation, ICES is authorized to collect and use health care data for purposes related to health system analysis, evaluation, and decision support. Access to these data is strictly governed by policies and procedures approved by the Information and Privacy Commissioner of Ontario, ensuring secure and compliant data use.

Chapter 4

4. Integrated Discussion

The following chapter synthesizes the findings of Chapters 2 and 3 by linking the broader evidence from the systematic review and meta-analysis of temperature-related health outcomes in people with schizophrenia spectrum disorder (SSD) with the empirical assessment of extreme temperature impacts on emergency department (ED) use among people with SSD in Ontario. Additionally, key results and factors that may influence them are discussed. Finally, this chapter outlines the implications of these findings for future research and highlights key questions that remain unanswered in this emerging field.

4.1 Key Findings

The objectives of this thesis were twofold: first, to use systematic review methods to synthesize the existing evidence on the effects of extreme and ambient temperature on SSD-related health outcomes; and second, to extend this evidence base by examining the impact of extreme temperatures on ED visits among people with SSD using Ontario health administrative data linked to temperature data. The systematic review and meta-analysis in Chapter 2 synthesized the existing literature and identified key gaps in knowledge regarding temperature-related health risks in this population, most notably a relative absence of evidence on the effects of cold temperatures. Building on these findings, Chapter 3 employed a time-stratified case-crossover design to assess the association between extreme temperature and ED visits among people with SSD in Ontario.

Taken together, findings from the systematic review and meta-analyses (Chapter 2) and the population-based case-crossover analysis in Ontario (Chapter 3) provide a picture of how extreme temperatures are associated with health service use among people with SSD. While the broader literature generally reports higher risk of ED visits, hospital admissions, and mortality during periods of extreme heat, the results from the Ontario cohort indicate more complex, outcome-specific patterns for ED visits.

In Chapter 2, extreme heat was consistently associated with higher risks of ED visits and mortality among people with SSD, and meta-analytic evidence suggests an elevated risk of hospital admissions during heat events, despite substantial heterogeneity across studies. In contrast, findings for ambient temperature were largely null for hospital admissions, and results varied by exposure metric and reference temperature. Extreme cold exposure was less frequently studied but was generally associated with delayed increases in outpatient visits and hospital admissions.

In comparison, the Ontario-based case-crossover study in Chapter 3 revealed that extreme heat was associated with lower short-term risks of mental health-related (MH-ED) visits, with consistent cumulative reductions observed across lag periods. For non-mental health ED (Non-MH-ED) visits, extreme heat was associated with small increases in risk on the day of exposure and shorter cumulative lag windows, but the effect reduced when longer lag windows were considered. Extreme cold was generally associated with lower risks for Non-MH-ED visits, with estimates approaching null as lag periods increased. These findings diverge from the predominant direction of associations reported in Chapter 2 and suggest that observed ED utilization patterns during extreme temperature may be influenced by factors beyond immediate physiological risk.

Stratified analyses in Chapter 3 further highlighted heterogeneity in estimated associations across health regions, age groups, and administrative sex, although these analyses were descriptive. Notably, older adults with SSD showed more consistent increases in Non-MH-ED visits during extreme heat, which aligns with evidence from the studies in Chapter 2, indicating heightened vulnerability among older populations.

Integrating evidence from both chapters shows the relationship between extreme temperature and healthcare utilization among people with SSD is complex and outcome-dependent. While extreme temperatures are associated with adverse outcomes in people with SSD, short-term reductions in risk of ED visits may reflect changes in care-seeking behaviour and access rather than reductions in underlying risk. These findings highlight the importance of interpreting temperature-health associations within the broader context of health care systems, social vulnerability, and behavioural responses.

4.2 Results in Context

The results of this thesis should be interpreted within the broader context of established literature on temperature-related health effects and the unique clinical and social characteristics of people with SSD.

One potential mechanism underlying the observed lower risk in MH-ED visits during periods of extreme heat relates to behavioral adaptation and public health responses. Heat warnings and targeted messaging can lead people to engage in preventative behaviors such as increased hydration, greater use of cooling environments, and avoidance of unnecessary travel, which may delay or reduce non-urgent ED presentation. [173,174] In addition to behavioral responses, illness-related and comorbidity factors may further influence how people with SSD experience and respond to temperature extremes. Symptoms of SSD such as cognitive disorganization, poor concentration, or psychosis may limit recognition of environmental risk and timely engagement with care.[175–177] Also, comorbidities are common among people with SSD.[178] Comorbidities (e.g. substance use) can further influence an individual's ability to sense and respond to their environment leading to delays in care-seeking or avoidance of ED use during extreme temperatures. [175–177]

Similarly, short-term decreases in ED visits during extreme cold may reflect barriers to mobility and access rather than protective effects of cold exposure.[6] Especially in Canada, adverse winter conditions can make travel difficult and uncomfortable, particularly for people with SSD who may have restricted access to transportation, unstable housing, or limited social support.[6,179] As a result, individuals may postpone or avoid ED care leading to observed lower risk of ED visits during extreme cold temperatures.

For people with SSD, social and structural vulnerabilities may further shape observed utilization patterns. Disproportionate exposure to housing instability, limited access to climate-controlled environments, and fewer social supports can increase susceptibility to thermal stress while also reducing the ability to seek timely emergency care.[6] These intersecting vulnerabilities may lead to unmet healthcare needs that are not fully captured by ED visit counts, particularly in the short-term.

Biologically, people with SSD have impaired thermoregulation, which is further exacerbated by antipsychotic medications such as haloperidol, clozapine, and zuclopenthixol.[65,72,83] Many commonly prescribed antipsychotics possess anticholinergic properties, which inhibit acetylcholine signaling and disrupt key thermoregulatory processes, including sweat gland activation which rely on these signaling pathways.[83,126] These medications can also alter vasodilation, reduce thirst perception, and blunt physiological responses to thermal stress, increasing susceptibility to heat- and cold-related complications.[126] Moreover, co-occurring conditions common in SSD, including metabolic syndrome, obesity, diabetes, and cardiovascular disease, can exacerbate physiological stress during extreme temperature events, further increasing the likelihood of health service use.[171] Impaired responses to environmental stressors may lead to increases in underlying psychological strain that are not immediately reflected in ED visits, particularly if symptoms are nonspecific, poorly recognized, or delayed in presentation.[65,175]

Overall, these results reinforce the importance of interpreting temperature-health associations in people with SSD in consideration with behavioral responses, healthcare access, illness-related factors, and structural vulnerability.

4.3 Policy Implications

The findings of this thesis suggest that observed healthcare utilization may not fully reflect physiological vulnerability alone but also the influence of social and structural factors, such as housing instability, social isolation, and access to healthcare, which affect adaptive capacity. Heat-health advisory teams should support the development of integrated strategies that combine temperature-health response plans with mental health services, supportive housing programs, and proactive community outreach. Additionally, stratified analyses in Chapter 3 suggest policies may need to target subpopulations, particularly older adults with SSD, who showed more consistent increases in Non-MH-ED visits during heat events.

4.4 Future Directions

Building on the current findings, future research should focus on identifying the pathways through which temperature extremes affect people with SSD, extend this work by examining temperature-health associations among people with SSD using studies that more explicitly integrate clinical, social, and healthcare system factors. In addition, further multi-city and multi-region studies could shed light on how climatic, socioeconomic, and healthcare factors modify temperature-related risks.

At the individual level, further research should explore vulnerability factors such as age, sex, comorbidities, antipsychotic medication use, and social determinants like housing instability and social isolation, which may amplify exposure and susceptibility to temperature extremes. Equally important is the need for studies in low- and middle-income countries, where differences in healthcare access and environmental conditions could influence observed effects.

Finally, future work that explicitly evaluates adaptation and mitigation measures, such as heat warning systems, cold weather alerts, community outreach programs, and supportive housing interventions, would be valuable for understanding how public health responses shape healthcare utilization patterns among people with SSD. It would also help in the development of targeted interventions, tailored public health messaging, and improved access to cooling or heating resources for people with SSD.

4.5 Conclusions

This thesis found that ambient and extreme temperatures significantly impact health outcomes among people with SSD. The systematic review and meta-analysis indicated that extreme temperatures are associated with increased health service use. Building on this evidence, the case-crossover study demonstrated lower risks of MH-ED visits during extreme heat but suggestive of higher risk of Non-MH-ED visits. Lower risks of Non-MH-ED were observed during extreme cold exposure, but no association was observed between extreme cold and MH-ED visits. Taken together, these findings likely reflect a combination of behavioral adaptation, delayed care, and unmet need within a population already facing substantial clinical and social vulnerability. This highlights the need for future research and public health responses that account for environmental exposure, social conditions, and healthcare system dynamics in the context of a changing climate.

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Appendices

Appendix 2.1 Prisma Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	
	23b	Discuss any limitations of the evidence included in the review.	
	23c	Discuss any limitations of the review processes used.	
	23d	Discuss implications of the results for practice, policy, and future research.	
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

Appendix 2.2 Search Strategy

Concept	MEDLINE	EMBASE	PsycINFO	Keywords
SSD	exp “schizophrenia spectrum/ OR schizoid disorders/ OR schizoaffective disorder”/	Exp schizophrenia spectrum/ OR schizoid disorders/ OR schizoaffective disorder”/ /	exp schizophrenia spectrum disorders and other psychotic disorders /	(Psychosis OR psychotic OR schizophreni* OR schizophrenia spectrum disorder* OR schizoid disorder* OR schizoaffective disorder).
Temperature	exp temperature/ OR air temperature/ OR extreme temperature/ OR ambient air temperature/	exp temperature/ OR air temperature/ OR extreme temperature/ OR ambient air temperature/	exp temperature/ OR air temperature/ OR extreme temperature/ OR ambient air temperature/	(temperature* OR air temperature OR ambient temperature* OR extreme temperature).
Results	**630**	**1105**	**1862**	**Total: 3597**
			TOTAL AFTER REMOVING DUPLICATES:	**3156**

Appendix 2.3 Mock Extraction Table.

Title	**Author**	**Year of Publication**	**Country**	**Study Sample**	**Study Design**	**Sample Size**	**Age Range**	**Type of Temperature Measurement**	**Outcomes**	**Type of Effect**	**Value of Effect**

Appendix 2.4 Results of Risk of Bias Assessment

Country	Year	Selection of source population	Assessment of exposure	Assessment of outcome	Outcome absent at start of study	Inclusion of confounding factors	Control for environmental confounding factors	Missing data	Accounted for temporal and lag effects
Greece	2021	low	low	low	low	low	low	missing	high
USA	2022	low	high	low	low	intermediate	intermediate	low	high
USA	1998	low	low	low	low	intermediate	intermediate	missing	high
Switzerland	2021	low	low	low	low	low	intermediate	missing	low
Switzerland	2020	low	low	low	low	intermediate	low	missing	low
USA	2024	low	low	low	low	low	intermediate	missing	low
USA	2023	low	low	low	low	low	low	low	low
Vietnam	2022	low	low	low	low	low	low	missing	low
United Kingdom	1992	high	low	low	low	high	high	missing	high
Australia	2008	low	low	low	low	high	high	missing	high
China	2022	low	low	low	low	low	low	missing	low
Australia	2021	low	low	low	low	low	intermediate	missing	high
Australia	2021	low	low	low	low	low	low	missing	low
Finland	2022	low	low	low	low	intermediate	low	low	high
Canada	2023	low	low	low	low	low	low	low	low
Canada	2023	low	high	low	low	low	intermediate	low	high
China	2022	low	low	low	low	intermediate	intermediate	missing	low
China	2019	low	low	low	low	low	low	missing	low
China	2024	low	low	low	low	low	low	low	low
USA	2022	low	low	low	low	intermediate	intermediate	missing	low
China	2019	low	low	low	low	low	low	low	low
China	2020	low	low	low	low	low	low	missing	low
China	2022	low	low	low	low	low	low	low	low
USA	2022	low	low	low	low	low	intermediate	low	low
Isreal	2005	low	low	low	low	low	missing	missing	high
Taiwan	2011	low	low	low	low	low	missing	low	high
England	1992	low	high	low	low	intermediate	intermediate	high	high
China	2021	low	low	low	low	low	low	missing	low
Canada	2024	low	low	low	low	intermediate	intermediate	low	low
China	2018	low	low	low	low	low	high	low	low
Canada	2014	low	low	low	low	low	low	missing	low
China	2019	low	low	low	low	low	low	missing	low
USA	2021	low	low	low	low	low	low	low	low
USA	2021	low	low	low	low	low	low	low	low
China	2020	low	low	low	low	low	low	low	low
China	2017	low	low	low	low	low	low	missing	low
China	2016	low	low	low	low	low	low	missing	low
China	2024	low	low	low	low	low	low	low	low

Appendix 3.1 Descriptive characteristics of all members of the cohort at index date by health region and province overall.

		West (%)	Central (%)	Toronto (%)	East (%)	North West (%)	North East (%)	Total (%)
Age (years)	14-29	6761 (20.3)	5320 (23.6)	4993 (16.1)	4520 (19.8)	1138 (21.7)	459 (28.0)	23191 (19.9)
	30-49	11052 (33.1)	7776 (34.5)	10417 (33.6)	7564 (33.2)	1635 (31.1)	551 (33.7)	38995 (33.5)
	50+	15535 (46.6)	9414 (41.8)	15629 (50.4)	10689 (46.9)	2478 (47.2)	627 (38.3)	54372 (46.6)
Sex	F	14537 (43.6)	9966 (44.3)	13772 (44.4)	9613 (42.2)	2262 (43.1)	707 (43.2)	50857 (43.6)
	M	18811 (56.4)	12544 (55.7)	17267 (55.6)	13160 (57.8)	2989 (56.9)	930 (56.8)	65701 (56.4)
Income	Missing	259 (0.8)	136 (0.6)	434 (1.4)	199 (0.9)	64 (1.2)	17 (1.0)	1109 (1.0)
	<25k	12655 (37.9)	4707 (20.9)	14039 (45.2)	8183 (35.9)	2294 (43.7)	650 (39.7)	42528 (36.5)
	25k to 50k	7790 (23.4)	4420 (19.6)	6831 (22.0)	4859 (21.3)	1175 (22.4)	333 (20.3)	25408 (21.8)
	50k to 75k	5222 (15.7)	4622 (20.5)	4338 (14.0)	3561 (15.6)	686 (13.1)	316 (19.3)	18745 (16.1)
	75k to 100k	3976 (11.9)	4828 (21.4)	2623 (8.5)	3244 (14.2)	564 (10.7)	174 (10.6)	15409 (13.2)
	100k+	3446 (10.3)	3797 (16.9)	2774 (8.9)	2727 (12.0)	468 (8.9)	147 (9.0)	13359 (11.5)
Rurality	Urban	31585 (94.7)	21295 (94.6)	31039 (100.0)	20623 (90.6)	3975 (75.7)	1342 (82.0)	109859 (94.3)
	Rural	1763 (5.0)	1215 (5.1)	0 (0.0)	2150 (8.6)	1276 (19.5)	295 (15.3)	6699 (5.4)
Health Region	-	33348 (28.6)	22510 (19.3)	31039 (26.6)	22773 (19.5)	5251 (4.5)	1637 1.4)	116558 (100)
Charlson Comorbidity Index	0	7131 (21.4)	4498 (20.0)	5081 (16.4)	4235 (18.6)	1552 (29.6)	484 (29.6)	22981 (19.7)
	1	2273 (6.8)	1315 (5.8)	2124 (6.8)	1500 (6.6)	435 (8.3)	129 (7.9)	7776 (6.7)
	2	1321 (4.0)	713 (3.2)	1392 (4.5)	853 (3.7)	235 (4.5)	52 (3.2)	4566 (3.9)
	3+	1663 (5.0)	985 (4.4)	2044 (6.6)	1203 (5.3)	285 (5.4)	72 (4.4)	6252 (5.4)
	No hospitalization	20960 (62.9)	14999 (66.6)	20398 (65.7)	14982 (65.8)	2744 (52.3)	900 (55.0)	74983 (64.3)
Entry Year of Cohort	2014	15518 (46.5)	9838 (43.7)	15116 (48.7)	10579 (46.5)	2286 (43.5)	609 (37.2)	53946 (46.3)
	2015	5218 (15.6)	3726 (16.6)	4609 (14.8)	3551 (15.6)	843 (16.1)	241 (14.7)	18188 (15.6)
	2016	4522 (13.6)	3286 (14.6)	4007 (12.9)	3189 (14.0)	760 (14.5)	213 (13.0)	15977 (13.7)
	2017	4503 (13.5)	3148 (14.0)	3891 (12.5)	3040 (13.3)	742 (14.1)	257 (15.7)	15581 (13.4)
	2018	3587 (10.8)	2512 (11.2)	3416 (11.0)	2414 (10.6)	620 (11.8)	317 (19.4)	12866 (11.0)
	0 (lowest)	493 (1.5)	155 (0.7)	434 (1.4)	241 (1.1)	239 (4.6)	81 (4.9)	1643 (1.4)

Households and Dwellings Score	1	2848 (8.5)	6639 (29.5)	1827 (5.9)	2033 (8.9)	154 (2.9)	24 (1.5)	13525 (11.6)
	2	4019 (12.1)	3935 (17.5)	2626 (8.5)	2998 (13.2)	467 (8.9)	142 (8.7)	14187 (12.2)
	3	4878 (14.6)	3752 (16.7)	3122 (10.1)	3600 (15.8)	855 (16.3)	133 (8.1)	16340 (14.0)
	4	7515 (22.5)	3197 (14.2)	6145 (19.8)	4834 (21.2)	1293 (24.6)	476 (29.1)	23460 (20.1)
	5 (highest)	13595 (40.8)	4832 (21.5)	16885 (54.4)	9067 (39.8)	2243 (42.7)	781 (47.7)	47403 (40.7)
Material Resources Score	0 (lowest)	493 (1.5)	155 (0.7)	434 (1.4)	241 (1.1)	239 (4.6)	81 (4.9)	1643 (1.4)
	1	3743 (11.2)	2843 (12.6)	4148 (13.4)	3941 (17.3)	377 (7.2)	139 (8.5)	15191 (13.0)
	2	4406 (13.2)	5028 (22.3)	3369 (10.9)	3816 (16.8)	508 (9.7)	167 (10.2)	17294 (14.8)
	3	5039 (15.1)	5855 (26.0)	4254 (13.7)	3863 (17.0)	719 (13.7)	190 (11.6)	19920 (17.1)
	4	6823 (20.5)	4711 (20.9)	5840 (18.8)	4235 (18.6)	1163 (22.1)	328 (20.0)	23100 (19.8)
	5 (highest)	12844 (38.5)	3918 (17.4)	12994 (41.9)	6677 (29.3)	2245 (42.8)	732 (44.7)	39410 (33.8)
Age and Labour Force Score	0 (lowest)	493 (1.5)	155 (0.7)	434 (1.4)	241 (1.1)	239 (4.6)	81 (4.9)	1643 (1.4)
	1	6055 (18.2)	6587 (29.3)	7336 (23.6)	5193 (22.8)	506 (9.6)	94 (5.7)	25771 (22.1)
	2	6033 (18.1)	5003 (22.2)	7580 (24.4)	3723 (16.3)	625 (11.9)	259 (15.8)	23223 (19.9)
	3	6766 (20.3)	3823 (17.0)	6056 (19.5)	3226 (14.2)	800 (15.2)	308 (18.8)	20979 (18.0)
	4	6050 (18.1)	3279 (14.6)	4561 (14.7)	4134 (18.2)	1064 (20.3)	313 (19.1)	19401 (16.6)
	5 (highest)	7951 (23.8)	3663 (16.3)	5072 (16.3)	6256 (27.5)	2017 (38.4)	582 (35.6)	25541 (21.9)
Racialized and Newcomer Populations Score	0 (lowest)	493 (1.5)	155 (0.7)	434 (1.4)	241 (1.1)	239 (4.6)	81 (4.9)	1643 (1.4)
	1	5593 (16.8)	1556 (6.9)	175 (0.6)	4796 (21.1)	2341 (44.6)	684 (41.8)	15145 (13.0)
	2	7584 (22.7)	2482 (11.0)	1367 (4.4)	4841 (21.3)	1601 (30.5)	541 (33.0)	18416 (15.8)
	3	8522 (25.6)	3123 (13.9)	4618 (14.9)	5189 (22.8)	893 (17.0)	287 (17.5)	22632 (19.4)
	4	7236 (21.7)	5169 (23.0)	9064 (29.2)	4949 (21.7)	145 (2.8)	35 (2.1)	26598 (22.8)
	5 (highest)	3920 (11.8)	10025 (44.5)	15381 (49.6)	2757 (12.1)	32 (0.6)	9 (0.5)	32124 (27.6)

Appendix 3.2 Descriptive characteristics of all mental health and ED visits by health region and province overall.

		West	Central	Toronto	East	North East	North West	Total
Age (years)	14-29	4842	3210	3845	2621	1144	425	16087
	30-49	5735	3448	6673	3725	1123	501	21205
	50+	2887	1554	3827	1920	528	261	10977
Sex	F	5376	3184	4942	3529	1204	534	18769
	M	8088	5028	9403	5075	1591	653	29838
Income	Missing	202	82	504	176	53	1	1018
	<25k	6043	1874	6611	3789	1384	541	20242
	25k to 50k	3194	1541	2728	2137	656	277	10533
	50k to 75k	1873	1765	2112	932	283	220	7185
	75k to 100k	1114	1731	1190	880	220	67	5202
	100k+	1038	1219	1200	690	199	81	4427
Rurality	Urban	12755	7901	14345	7957	2154	960	46072
	Rural	709	311		647	641	227	2535
Health Region	-	13464	8212	14345	8604	2795	1187	48607
Charlson Comorbidity Index	0	5050	2554	4200	2934	1235	477	16450
	1	981	455	1304	588	274	165	3767
	2	344	173	550	205	70	60	1402
	3+	381	165	585	174	114	22	1441
	No hospitalization	6708	4865	7706	4703	1102	463	25547
Year of Cohort Entry	2014	5777	3520	7247	3648	1141	326	21659
	2015	2014	1191	2403	1234	401	173	7416
	2016	1924	1171	1684	1202	352	148	6481
	2017	1952	1233	1720	1376	466	222	6969
	2018	1797	1097	1291	1144	435	318	6082
Households and Dwellings Score	0 (lowest)	330	95	504	183	167	42	1321

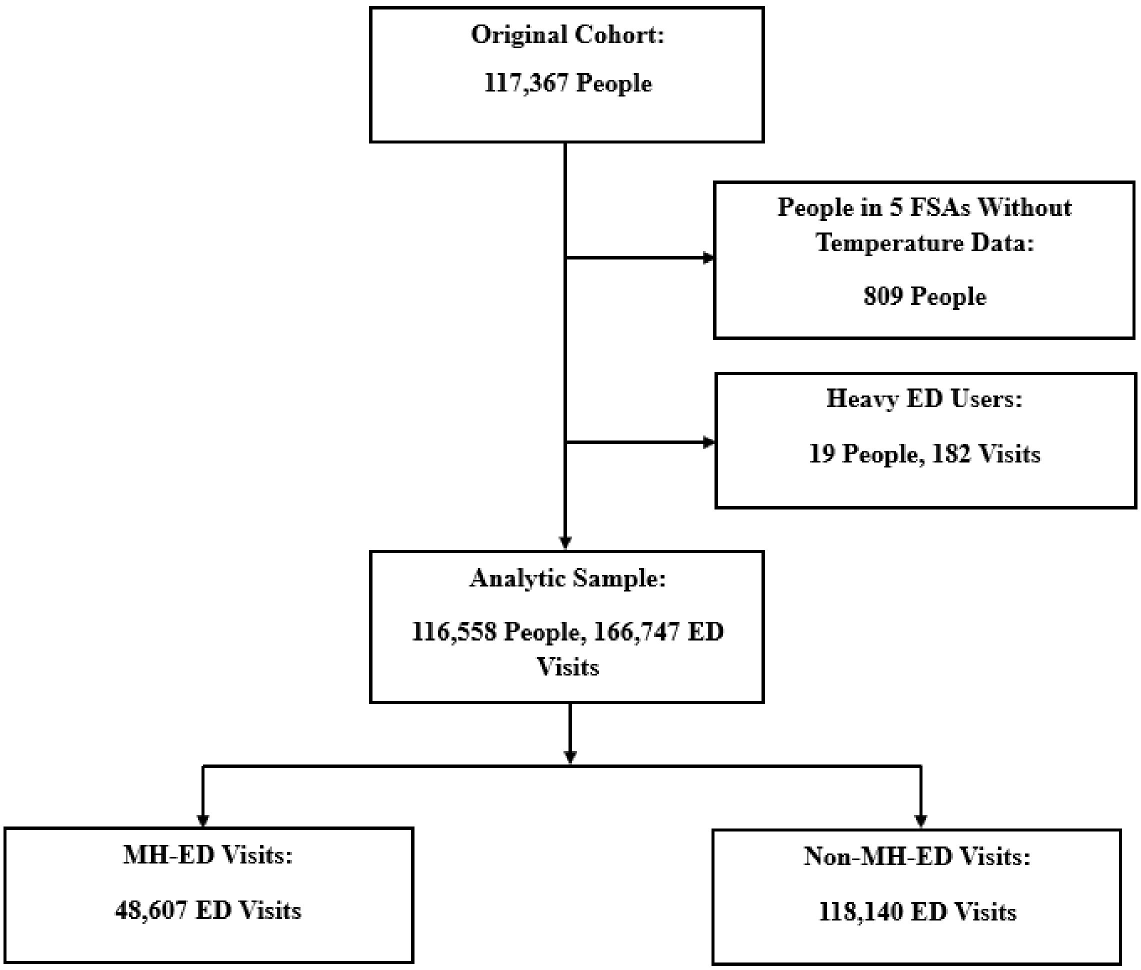
	1	780	2342	545	565	71	5	4308
	2	1194	1364	955	891	183	59	4646
	3	1560	1397	1178	1040	353	75	5603
	4	2905	1176	2736	1814	621	329	9581
	5 (highest)	6695	1838	8427	4111	1400	677	23148
Material Resources Score	0 (lowest)	330	95	504	183	167	42	1321
	1	1171	899	1998	1352	157	96	5673
	2	1347	1795	1351	1089	184	88	5854
	3	1663	2013	1986	1218	253	107	7240
	4	2852	1783	2591	1605	690	210	9731
	5 (highest)	6101	1627	5915	3157	1344	644	18788
Age and Labour Force Score	0 (lowest)	330	95	504	183	167	42	1321
	1	2319	2750	4003	2186	277	91	11626
	2	2609	1748	3253	1538	428	146	9722
	3	2772	1404	3303	1214	328	220	9241
	4	2795	1111	1678	1464	550	214	7812
	5 (highest)	2639	1104	1604	2019	1045	474	8885
Racialized Newcomer and Population Score	0 (lowest)	330	95	504	183	167	42	1321
	1	2083	425	113	1526	1183	610	5940
	2	2897	910	494	1754	847	274	7176
	3	3414	1296	2333	2176	497	205	9921
	4	3046	2019	4574	1832	76	40	11587
	5 (highest)	1694	3467	6327	1133	25	16	12662

Appendix 3.3 Descriptive characteristics of all non-mental health and ED visits by health region and province overall.

		West	Central	Toronto	East	North East	North West	Total
Age (years)	14-29	7958	4947	4639	4484	1817	781	24626
	30-49	11893	6286	10000	6787	2223	1022	38211
	50+	15938	8360	16535	10819	2834	817	55303
Sex	F	17571	9407	13531	10640	3420	1249	55818
	M	18218	10186	17643	11450	3454	1371	62322
Income	Missing	391	231	738	303	70	3	1736
	<25k	15877	5072	15019	9281	3174	1253	49676
	25k to 50k	8485	3967	5891	4827	1680	504	25354
	50k to 75k	5028	3526	4260	2934	833	467	17048
	75k to 100k	3289	4089	2597	2736	558	201	13470
	100k+	2719	2708	2669	2009	559	192	10856
Rurality	Urban	33063	18244	31174	19788	4754	2101	109124
	Rural	2726	1349		2302	2120	519	9016
Health Region	-	35789	19593	31174	22090	6874	2620	118140
Charlson Comorbidity Index	0	11415	5999	7244	6320	2639	966	34583
	1	3823	2155	4138	2619	736	335	13806
	2	2469	1059	2499	1391	435	189	8042
	3+	3777	2110	4637	2375	682	187	13768
	No hospitalization	14305	8270	12656	9385	2382	943	47941
Year of Cohort Entry	2014	15742	7965	14165	9461	2876	843	51052
	2015	5439	3221	5097	3359	1024	331	18471
	2016	5101	3098	4090	3277	935	286	16787
	2017	5257	2902	4064	3246	1070	503	17042
	2018	4250	2407	3758	2747	969	657	14788
Households and Dwellings Score	0 (lowest)	681	267	738	334	321	116	2457

	1	2062	4248	1195	1415	169	46	9135
	2	3468	3062	2024	2420	433	143	11550
	3	4298	3740	2638	3059	1012	178	14925
	4	8387	3090	5635	4892	1953	709	24666
	5 (highest)	16893	5186	18944	9970	2986	1428	55407
Material Resources Score	0 (lowest)	681	267	738	334	321	116	2457
	1	3067	2331	4441	3229	397	173	13638
	2	4098	4128	2986	3212	542	160	15126
	3	4882	4427	4350	3539	798	323	18319
	4	7202	4204	5132	4187	1672	473	22870
	5 (highest)	15859	4236	13527	7589	3144	1375	45730
Age and Labour Force Score	0 (lowest)	681	267	738	334	321	116	2457
	1	5731	5474	7647	4584	613	195	24244
	2	6595	3905	7041	3335	777	366	22019
	3	7166	3264	6401	3037	872	448	21188
	4	6778	3090	4250	3879	1503	536	20036
	5 (highest)	8838	3593	5097	6921	2788	959	28196
Racialized Newcomer and Popualtions	0 (lowest)	681	267	738	334	321	116	2457
	1	6513	1721	181	4976	3330	1233	17954
	2	7889	2985	1463	4768	1923	692	19720
	3	9013	3207	4848	5367	1094	445	23974
	4	7679	4273	9991	4400	186	110	26639
	5 (highest)	4014	7140	13953	2245	20	24	27396

Appendix 3.4 Study Flow Diagram



Curriculum Vitae

Name:		Diya Patel
Post-Secondary Education and Degrees		University of Western Ontario London, Ontario, Canada 2023- 2026 M.Sc.
		Carleton University Ottawa, Ontario, Canada 2019-2023
Honors and Awards:		Jim Robertson Award 2025
		Western Graduate Research Scholarship 2023-2025
Related Work Experience:		Graduate Research Assistant University of Western Ontario 2026
		Teaching Assistant University of Western Ontario 2024 -2025
		Co-op Student CIHI 2024
		Teaching Assistant Carleton University 2022 - 2023