GeoHealth

COMMENTARY

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Key Points:

- There is an inconsistency in the amount, type, and depth of mortality data across extreme heat events (EHEs) in Canada
- There are challenges in ascertaining heat as the direct or indirect cause of death
- Consideration of compounding impacts of social vulnerability indicators is inconsistent across reports of EHE-related deaths

Supporting Information:

Supporting Information may be found in the online version of this article.

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Reflections on a Century of Extreme Heat Event-Related Mortality Reporting in Canada

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Abstract Climate change is causing more frequent and severe extreme heat events (EHEs) in Canada, resulting in significant loss of life. However, patterns across mortality reporting for historical EHEs have not been analyzed. To address this gap, we studied deaths in Canadian EHEs from 1936 to 2021, identifying trends and challenges. Our analysis revealed inconsistencies in mortality data, discrepancies between vulnerable populations identified, difficulties in determining the cause of death, and inconsistent reporting on social vulnerability indicators. We provide some observations that could help inform solutions to address the gaps and challenges, by moving toward more consistent and comprehensive reporting to ensure no population is overlooked. Accurately accounting for affected populations could help better target evidence-based interventions, and reduce vulnerability to extreme heat.

Plain Language Summary Climate change in Canada is leading to more severe heatwaves, causing many unnecessary deaths. However, there is no understanding of patterns of death across these extreme heat events (EHEs). To fill this gap, we studied data from EHEs in Canada between 1936 and 2021 to help identify trends and challenges. Our analysis revealed inconsistent and limited information about deaths, discrepancies between vulnerable populations identified in literature and reported data, difficulty in determining direct heat-related causes of death, and inconsistent consideration of social vulnerability indicators. We provide some observations that could help inform ways to address these challenges, by moving toward more consistent and comprehensive reporting of heat-related mortality data across Canada. This more accurate information could help target evidence-based interventions, reduce vulnerability, and improve Canadians' ability to adapt to extreme heat.

1. Introduction

More frequent and intense heatwaves are negatively impacting the health of a growing number of Canadians. For example, the unprecedented 2021 western North America heat dome, the deadliest weather disaster in Canadian history, showed the significant impact that extreme heat can have on health. In British Columbia (BC) alone, there were 619 deaths (BC Coroners Service, 2022a) caused by the heat dome. People more at risk of death during extreme heat events (EHE) include: those with pre-existing disease, mental illness, substance use disorder, and disabilities; older adults, especially seniors; and those who are economically and socially marginalized (Government of Canada, 2011). Historically, there have been individual reports and articles describing the populations impacted in past EHEs in Canada. For example, there have been discrete analyses of major EHEs, such as Lee et al.'s (2023) analysis of the prevalence of chronic diseases in decedents of the 2021 BC EHE, and D. Kaiser et al.'s (2019) review of people who died in the 2018 EHE in Montreal. However, there is no known retrospective analysis of populations who died during past EHEs across Canada that span different timeframes (cross-temporal) and locations (cross-geographical). A better understanding of these past EHEs could help to identify similarities or differences in socio-demographic characteristics of decedents (Baudry & Burnette, 1938; BC Coroners Service, 2022a; BC Coroners Service (BCCS), 2021; Bustinza et al., 2013; CBC News, 2018; Environment and Climate Change Canada, 2016; Environment and Climate Change Canada (ECCC), 2017; Government of Canada, 2011; Henderson et al., 2021; Henderson, Lamothe, et al., 2022; Henderson, McLean, et al., 2022; Johnson, 2021; D. Kaiser et al., 2019; Kosatsky, 2010; Kosatsky et al., 2012; Lee et al., 2023; Price et al., 2013; Stewart et al., 2017; White et al., 2022). Through this reflective commentary, we aim to fill this gap by: (a) examining the socio-demographic characteristics of people who died *across* past EHEs in Canada; and (b) identifying trends and gaps in the mortality data to inform policy recommendations. An analysis of risk factors *across time and place* is necessary to learn the various ways in which heat-related deaths have been counted and characterized, and to understand the implications for reporting these deaths. Our inquiry, through an analysis of strengths and weaknesses of historical reports of heat-health deaths in Canada, is intended to help health officials and epidemiologists improve methods and tools for counting and reporting heat-related deaths for future EHEs. In doing so, we aim to assist health authorities with better targeting heat-health interventions to populations at greater risk to heat-health impacts.

2. How Did We Determine Which EHEs to Examine?

For the purpose of this commentary, we define "excess mortality" during an EHE as the difference between observed mortality and expected mortality for the same period. We define "heat-*attributable* deaths" as the number of deaths assessed to be due to exposure to extreme heat according to the clinical or public health criteria of the jurisdiction in which the heat deaths were reported. Furthermore, we define "heat-*related* deaths" as where there is evidence to support that extreme heat contributed substantively to the cause of the death, recognizing that exposure to extreme heat can exacerbate existing health conditions and contribute to mortality even if it is not deemed by a coroner or medical examiner as the *sole* or *primary* cause of death. The difference between "heat-attributable" and "heat-related" as used in this commentary is the presence ("heat-attributable") or absence ("heat-related") of a medical personnel's confirmation that the heat had directly contributed to the death.

First, we identified past EHEs in Canada between 1900 and 2021 for which the number of deaths (total excess mortality or heat-related deaths specifically) has been reported in a peer-reviewed epidemiologic study or in news media. A peer-reviewed search strategy was conducted on 27 April 2022 in Medline (Ovid), Embase (Ovid), and Scopus. Gray literature searches were subsequently conducted through Google, Government of Canada resources, Aurora (Library and Archives Canada), and Canada Commons (formerly "Canadian Electronic Library"). There is no numeric figure for articles searched through in the gray literature as such searches yield tens of thousands of results. Instead, the lead author executed the search strings and screened through the most relevant results. Additionally, a news-media article search was conducted through ProQuest and Google News ($n = 340$). The main search concepts comprised terms related to heatwaves, extreme heat, hot weather events, and mortality. EHEs were included if they occurred in Canada between 1900 and 2021 and the number of deaths (total excess mortality or heat-related deaths specifically) was reported. We excluded past EHEs for which there was no empirical death data reported for the event (i.e., derived from actual mortality data, rather than estimates based on modeling projections). Further, events that did not meet the Environment and Climate Change Canada (ECCC) definition (and regional requirements) of an EHE (two consecutive days of weather that meets or exceeds the criteria set for the region based on daytime highs and nighttime lows and maximum humidity thresholds) were excluded (Environment and Climate Change Canada, 2010). Duplicates were then screened manually. The resulting list of past EHEs with reported casualties (Table 1) was cross-referenced in consultation with ECCC, which confirmed the list against their records of EHEs. This review process resulted in six EHEs identified within various reports, articles, and newspaper articles ($n = 17$) (Figure 1).

Second, on 2 May 2022, we searched peer-reviewed articles ($n = 230$) and gray literature in the same databases as above (excluding ProQuest and Google News) to identify which populations were identified as vulnerable to extreme heat. The search concepts comprised terms related to age (seniors, elderly, older citizens, children, infants), housing (people experiencing homelessness, homeless), socio-economic status (low-income, poverty), chronic disease (co-morbidities, chronic medical conditions, underlying health conditions, physically impaired) and other terms related to marginalization (socially isolated, socially vulnerable, vulnerable, disadvantaged, transient, visible minority, Black, Brown, Indigenous, newcomers, immigrants, rural). The risk factors identified in these articles were synthetized and used to support the identification of vulnerabilities in each of the six analyzed EHEs.

3. What Does the Data Show About the Characteristics of Populations Who Died in Past EHEs in Canada?

Through our finalized sample of data, we identified six past EHEs in Canada with a sum total of 1,348–2,626 heat-related deaths between 1936 and 2021 (Table 1).

Despite the high mortality counts overall for the EHEs assessed, the quantity and quality of information available on deaths during the EHEs were varied, with much greater details available for more recent and higher-mortality events (Table 2). EHEs before 2000 seldom included published socio-demographic details about the individuals

Table 1
Overview of Past Extreme Heat Events (EHEs) in Canada 1900–2022

Year	Location	Intensity (temp ranges)	Number of deaths	Method used to generate mortality statistic
1936 July 5–17	Ontario and Manitoba	Temperatures above 30°C, reaching 42.2°C	814 (Baudry & Burnette, 1938)	Not stated
			1180 (Environment and Climate Change Canada (ECCC), 2017)	Not stated
2009 July 27–August 3	British Columbia	Temperatures as high as 34.4°C	122-156 excess deaths (Henderson et al., 2016; Kosatsky, 2010; Kosatsky et al., 2012; Stewart et al., 2017)	Excess mortality
			72 directly attributed to heatwave by BCCDC (Henderson et al., 2016)	
2010 July 4–9	Québec and Ontario	Max. temperatures reaching past 30°C, min. temperatures above 20°C, high humidity	106 (Price et al., 2013) −280 (Bustinza et al., 2013) excess deaths (counted only in Québec)	Excess mortality
2015 June 30–July 6	British Columbia	Temperatures as high as 42.9°C in Abbotsford	134 (in Greater Vancouver Regional District) (Mangione, 2021)	Not stated
2018 June 30–July 5	Québec and Ontario	Max. daily temperatures varied between 31.9°C and 35.5°C, min. daily temperatures between 20°C and 24.2°C	50 excess deaths (Henderson, Lamothe, et al., 2022)	Excess mortality
			66 heat-attributable deaths (D. Kaiser et al., 2019)	Analysis of death certificates
			70 deaths "as a result of heat-related complications" (CBC News, 2018)	Not stated
2021 June 27–July 2	British Columbia, Yukon, Alberta, Saskatchewan, Manitoba, Northwest Territories ("2021 western North America heat dome")	49.6°C in Lytton, BC—new all-time Canadian temperature record	BC: 740 excess deaths (BCCDC) (Henderson et al., 2021)	Excess mortality
			619 identified as heat-attributable (BC Coroners Service, 2022a)	Review of circumstances around deaths by multi-disciplinary panel
			AB: 66 deaths (to be confirmed) (Calgary Emergency Management Committee, 2022; Johnson, 2021)	Excess mortality

Note. While there were numerous EHEs in Canada between 1936 and 2009, our inclusion/exclusion criteria—which focused on there being reported heat-related deaths—led to the list of EHEs above. For instance, there were several EHEs that met the ECCC's historic standards for "extreme heat" but had no associated mortality data in peer-reviewed analyses or news-media articles. Also, there were records of heat-related deaths but no concrete historic EHE associated with them, as illustrated in Hofmann et al. (1998), who provide deaths due to excessive heat and excessive cold over an extended period from 1965 to 1992 in Canada.

who died. Starting in the 2000s, the number of deaths during EHEs was documented in both the media and academic articles, though reporting on factors such as social vulnerability indicators was missing from most media and academic articles about EHEs. For EHEs with death counts identified in the literature, *age* was mentioned in all reports, followed by *sex* in most. There was no mention of racial, ethnic, or Indigenous identity in any media or academic reports of deaths across all past EHEs studied, except for the coroner's report on the 2021 western North America heat dome (BC Coroners Service, 2022a). Canadian health systems data generally do not include information on race and ethnicity, which contributes to ongoing gaps in knowledge and is reflected in the omission of race/ethnicity data in reports about mortalities across past EHEs in Canada.

Several common demographic and vulnerability factors emerged across two or more of the six historical EHEs we studied. These characteristics included: people 65 years and older (Henderson, Lamothe, et al., 2022; Semenza et al., 1996); living alone (Gasparrini et al., 2012; Henderson, McLean, et al., 2022); of low-income (BC Coroners Service, 2022a; Henderson, McLean, et al., 2022); who live in urban heat islands with little to no surrounding greenspace (BC Coroners Service, 2022a; Hauen, 2018; Henderson, McLean, et al., 2022; Kinney et al., 2008); with pre-existing chronic health conditions (e.g., cardiovascular disease, hypertension, diabetes) (BC Coroners

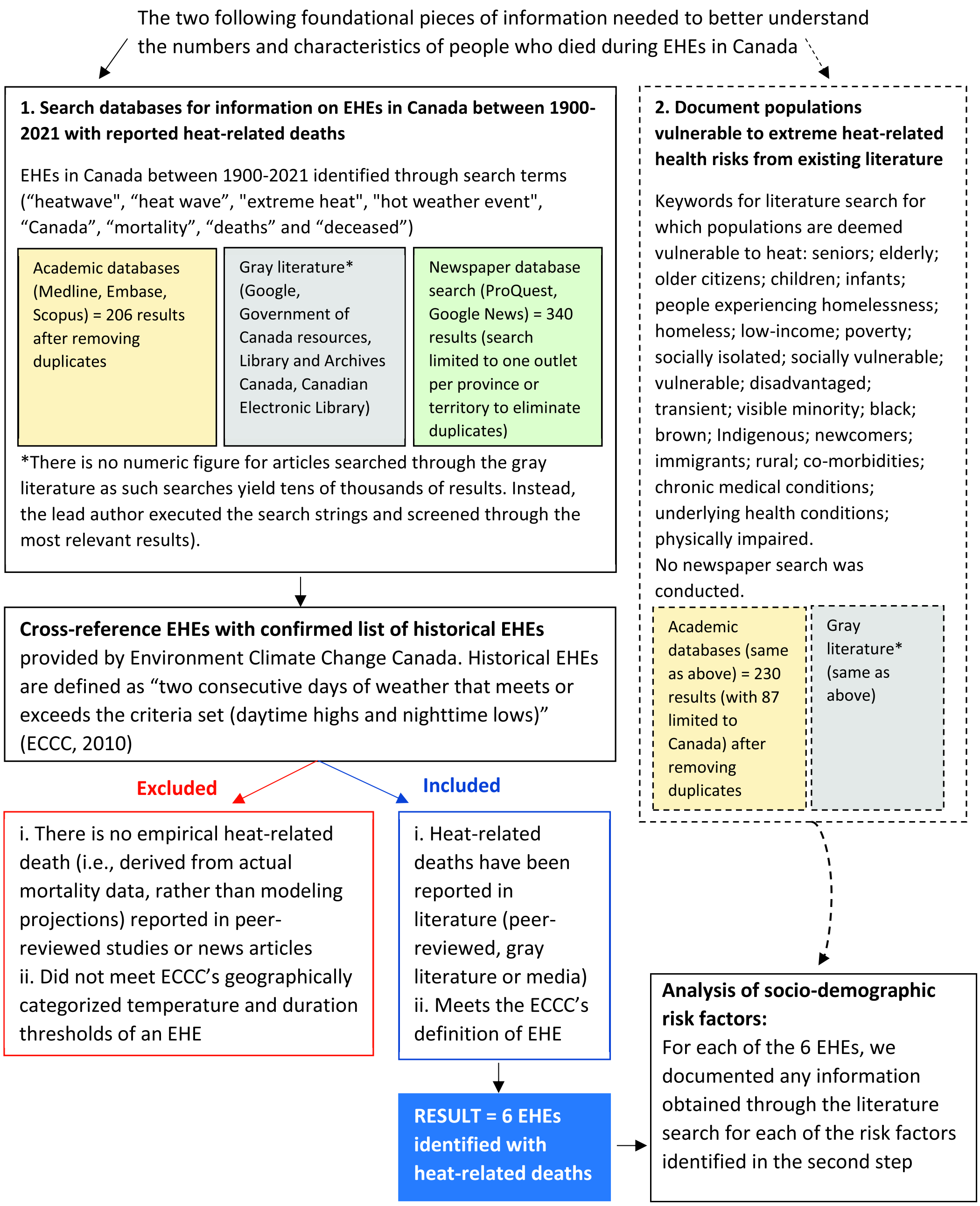

Figure 1. Flowchart of methods for selecting inclusion of historical heat waves in Canada.

Service, 2022a; Kalkstein & Smoyer, 1993); and, with mental illnesses—namely substance use disorders, anxiety and mood disorders (Table 3) (Chersich et al., 2020; Kalkstein & Smoyer, 1993; Kuehn & McCormick, 2017). This aligns broadly with the populations identified as most-at-risk in the literature, with the new insight that people with schizophrenia have died at alarmingly disproportionate rates across several EHEs in Canada (e.g., 2018 Montreal and 2021 BC) (BC Coroners Service, 2022a; D. Kaiser et al., 2019; Lee et al., 2023; Price et al., 2013). Only a few reports provided sex or gender differences in rates of heat-related death, which limited our ability to identify a pattern (Gan & Henderson, 2019; Henderson, McLean, et al., 2022; Kosatsky et al., 2012). In addition, only two analyses (of the same EHE) have indicated that the majority of heat-related deaths occurred indoors (BC Coroners Service, 2022a; Henderson, McLean, et al., 2022).

Table 2
Overview of Vulnerability Factors or Death Characteristics Identified or Considered in Mortality per Extreme Heat Events as Found in Peer-Reviewed Articles, Gray Literature, and Media Coverage of These Events

	1936 ON and MB	1941 AB and BC	2009 BC	2010 QC and ON	2015 BC	2018 QC and ON	2021 heat dome
Age	(x)		X	x	X	x	x
Sex	(x)		x		X		x
Social isolation				x	X	x	x
Material deprivation (e.g., housing status)	(x)		x		X	x	x
Greenspace access/urban heat island (UHI) effect			x	x	X	x	x
Administrative Health Area			x	x		x	x
Indigenous identity							x
Race or ethnicity							
Physical disabilities							(x)
Location of death (e.g., at home, hospital, care home)			x	x	x	x	x
Access to A/C						x	x
Mental illness				x		x	x
Substance use				x		x	x
Pre-existing chronic health conditions				x		x	x

Note. x = information available about deaths in corresponding category. (x) = a passing mention by media coverage or non-health groups (e.g., Human Rights Watch), rather than an official count by the corresponding health authority or coroners service. Shaded in gray = no information available (as opposed to lack of death).

4. What Are the Shortcomings in Existing Mortality Data About Past EHEs in Canada?

4.1. Variability in Definitions Lead to Challenges in Ascertaining a Death as Attributable to, or Related to, Extreme Heat

The literature we reviewed did not have a uniform pan-Canadian approach to defining a heat-related death, which leads to challenges in ascertaining heat as the causal or contributing factor of death. For example, the BC Coroners Service defines a "heat-related death" as one where: (a) the localized environment or body temperature is in keeping with hyperthermia; or (b) there is no direct temperature at the time of death but there is evidence (circumstantial, environment, medical history) to support that heat played a significant causal effect on the death (BC Coroners Service (BCCS), 2021). Whereas for the 2010 EHE in Québec, the medical team at Santé Montréal (Montreal Public Health) developed a medical chart extraction form based on information in the literature provided in case-control studies, which was then used to classify mortality cases into categories based on contribution of heat to the death: *confirmed, probable, unlikely, or indeterminate* heat-related cases (Henderson, Lamothe, et al., 2022).

Henderson, Lamothe, et al. (2022) speak to this discrepancy by outlining the three common approaches taken by different agencies in Canada in attributing deaths to EHEs: (a) vital statistics coding; (b) probabilistic methods; and (c) enhanced surveillance (Table 4). These different approaches of identifying EHE-related deaths are evidenced in various EHEs. For the 2018 EHE in Montréal, of the 353 deaths recorded in the vital statistics data over the 8-day period, 36 were identified by vital statistics coding; 49 by probabilistic methods; and 58 by enhanced surveillance (Henderson, Lamothe, et al., 2022) Of these deaths, 70 were identified by a single approach while 32 were identified by more than one approach (Henderson, Lamothe, et al., 2022).

For the 2021 western North America heat dome, the British Columbia Centre for Disease Control (BCCDC) used probabilistic methods based on 10 years of historic data to estimate the expected number of deaths, and subtracted the expected number from the observed number to estimate total *excess* deaths, yielding 740 excess deaths from all causes over the 8-day period of the EHE (Henderson et al., 2021). The BC Coroners Service, on the other hand, investigated all deaths that were reported to the Service (approximately 50% of all deaths during the heat dome), and ascertained which were directly attributable to the heat during the event and in the weeks that followed (i.e., would not have occurred in the absence of the heat dome) (Table 4). The BC Coroners Service reported 619 heat-

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Table 3
A Closer Look at Mortality Data per Extreme Heat Events in Relation to Vulnerability Factors

	2009 British Columbia	2010 Québec and Ontario	2015 British Columbia	2018 Québec and Ontario	2021 western North America heat dome
Age	Highest in 65–74 years category (1.47x higher than 8 previous weeks) (Kosatsky et al., 2012)	33% increase in crude rate for 0–64 and 75+ year old groups (Bustinza et al., 2013)	Risk of mortality higher for age group 65–74 years, though not statistically significant (Gan & Henderson, 2019)	Majority (n = not available) were over 60 (CBC News, 2018)	Of 434 community deaths, 81.6% were in those 65 and older (Henderson et al., 2021) Of 619 heat deaths, 67% were 70 years of age or older; 90% were over age 60 (BC Coroners Service, 2022a)
Sex	Men were 1.12x at higher risk than women (Kosatsky et al., 2012)		Risk of mortality higher for males, especially in the greater Vancouver region, though not statistically significant (Gan & Henderson, 2019)		54.6% females; 45.4% males, with female sex reported as an important risk factor for community deaths (Henderson et al., 2021) Females and males were equally affected, although males who died tended to be younger (BC Coroners Service, 2022a)
Social isolation		Among community deaths, many with mental illness who died lived alone (Price et al., 2013)	No significant association reported (Gan & Henderson, 2019)	69% of 55 community deaths lived alone (D. Kaiser et al., 2019)	28.1% of community deaths in the materially and socially deprived group (14.9% among typical weather deaths) (Henderson et al., 2021) 56% of 619 heat deaths lived alone (BC Coroners Service, 2022a)
Material deprivation	Higher risk in areas where more than 20% of residents are below the low-income cut-off (Kosatsky et al., 2012)		No significant association reported (Gan & Henderson, 2019)	Average annual income before taxes for those who died from heat: $47,583 CAD ($59,126 CAD for those who died of other causes) (D. Kaiser et al., 2019)	Increased community death risk for materially deprived, but socially privileged (21.2% of heat-dome deaths compared to 19.7% of "typical weather" deaths) (Henderson et al., 2021) Materially *and* socially deprived (28.1% of heat dome deaths compared to 14.9% of "typical weather" deaths) (Henderson et al., 2021)
Greenspace access/ UHI effect	Higher risk in areas with higher population density and lower greenspace (Kosatsky et al., 2012; Vancouver Coastal Health, 2011)	Proportion of people who lived in UHI at the time of death is higher compared to comparison periods (Bustinza et al., 2013)	Higher level of neighborhood greenness associated with lower risk of heat-related mortality (Gan & Henderson, 2019)	Heat-attributable deaths were twice as likely to be in UHI areas with the highest temperature (D. Kaiser et al., 2019)	The community deaths had lower surrounding greenness and higher building density, and were closer to major roads and further from large bodies of water (Henderson et al., 2021)
Administrative Health Area (AHA)	Those in more densely populated and less advantaged AHAs were more likely to die (Kosatsky et al., 2012)	Areas with highest total death rates compared to the same period in 2005–2009, which may indicate a higher number of heat-related deaths: Montréal (2.81), Montérégie (2.31) and Outaouais (2.42) (Bustinza et al., 2013)		Three boroughs with highest proportion of heat deaths: Rosemont-La Petite-Patrie, Villeray-Saint-Michel-Parc-Extension, and Mercier-Hochelaga-Maisonneuve (D. Kaiser et al., 2019)	More than half of decedents lived in the Fraser Health Authority area 51% of 619 heat deaths in Fraser Health; 23% in Vancouver Coastal Health region (BC Coroners Service, 2022a)

Table 3
Continued

	2009 British Columbia	2010 Québec and Ontario	2015 British Columbia	2018 Québec and Ontario	2021 western North America heat dome
Indigenous identity					9 (1.5% of 619 deceased) heat deaths were identified as being Indigenous (BC Coroners Service, 2022a)
Race or ethnicity					
Physical disabilities					No known deaths categorized explicitly or solely under "disability" in available reports, though some illnesses, such as schizophrenia, can be considered a disability (BC Coroners Service, 2022a) Human Rights Watch interviewed people with disabilities, who elaborated on the heavy burden of the heat dome (Human Rights Watch, 2021)
Location of death (e.g., at home, hospital, long term care (LTC))	Outside institutions 1.43x higher than in hospitals or other care facilities (Kosatsky et al., 2012)	Of 106 deaths, 88% occurred in the community, and 12% in LTC and hospitals (Price et al., 2013)	Living in institutional residences associated with decreased risk of heat-related mortality (Gan & Henderson, 2019)	Of 55 deaths, 71% occurred in private apartments; 16% in LTC; 7.2% in rooming house (D. Kaiser et al., 2019)	98% of 619 deaths took place indoors in a residence (BC Coroners Service, 2022a)
Access to A/C				All community deaths had no A/C (D. Kaiser et al., 2019)	Scenario of homes without A/C showed steadily increasing indoor temperatures between 30°C and 40°C during the heat dome, with little overnight cooling 7% ($n = 46$) of 619 decedents had A/C present in their residence. Of those, 7 were on at the time of death but may have been in a different room or improperly used (e.g., blowing hot air) (BC Coroners Service, 2022a)
Mental illness		Of 106 deaths, 32 had mental illness (Price et al., 2013): **14 schizophrenia**		Of 66 heat deaths, 9.1% had cognitive disorders; **25.8% schizophrenia** (D. Kaiser et al., 2019)	Schizophrenia was most strongly associated with higher risk of death during the EHE. Odds of EHE mortality was significantly increased also for those with depression (BC Coroners Service, 2022a; Lee et al., 2023)[a]
Substance use		Of 106 deaths, 13 had excessive alcohol consumption (Bustinza et al., 2013)		Of 66 heat deaths, 18.2% excessive alcohol consumption; 3% substance addiction (D. Kaiser et al., 2019)	Substance use disorder was associated with increased odds among deaths with pending cause (awaiting coroner's certificate of death) (Lee et al., 2023)[a]
Pre-existing chronic health conditions		77 of 106 deaths had comorbidities, of which cardiovascular and mental		Majority (n = not available) had chronic	Odds of death were significantly increased for those with schizophrenia,

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Table 3
Continued

	2009 British Columbia	2010 Québec and Ontario	2015 British Columbia	2018 Québec and Ontario	2021 western North America heat dome
		illness were most common (Price et al., 2013) (statistics for each condition in isolation were unavailable). Of 106 deaths, 15 had asthma; 10 Dementia; 31 Diabetes; 17 Ischemic cardiomyopathy; 49 Hypertension; 12 Cancer (Bustinza et al., 2013)		illnesses (CBC News, 2018) Of 66 confirmed and probable heat deaths, 31.8% had hypertension; 25.8% diabetes; 8.2% obesity; 18.2% dyslipidemia; 16.7% pulmonary dysfunction; 16.7% cardiomyopathy; 12.1% smoking; 7.6% cancer (D. Kaiser et al., 2019)	chronic kidney disease, depression and diabetes, as well as for those with 4 or more chronic diseases (Lee et al., 2023)[a]

[a]This reference falls outside of the search dates described in the methods, but is included as it validates the information first provided in a presentation by Henderson, Lamothe, et al. (2022) and Henderson, McLean, et al. (2022) that falls within the criteria for search dates.

attributable deaths (BC Coroners Service, 2022a). This process of ascertaining the cause of death includes "attending the location of the death when possible, completing a physical assessment of the decedent, conducting interviews with family, friends and persons or service providers involved in the decedent's life, arranging necessary post-mortem testing, obtaining medical records, and documenting the investigation's findings in a coroner's report" (BC Coroners Service, 2022a).

As these examples from British Columbia and Québec demonstrate, current ways of categorizing a death as heat-related do not distinguish whether the death is attributable *primarily to,* or *associated with,* heat exposure. This incongruity is a result of many factors, which leads to the possibility of some important indicators of EHE-related deaths not being captured. Reasons behind the incongruity could include: different approaches to classifying extreme heat-related deaths taken by varying provincial public health agencies, each with its own strengths and limitations; difference in the extent to which contributing factors or circumstances around death are included in vital statistics data across provinces and territories, then carried over into the national data set; and physicians' not taking account of potential contributing causes in death certificates (Henderson, Lamothe, et al., 2022). Ascertaining extreme heat as a causal or contributing factor of death is a crucial, yet difficult, first step in discerning who dies and why during Canadian EHEs (Gasparrini et al., 2012; Henderson, Lamothe, et al., 2022; Semenza et al., 1996). Research suggests that the actual number of deaths related to extreme heat in the United States may be substantially larger than previously reported, which may indicate some deaths where heat played a *contributing* role have been overlooked (Fischer et al., 2004; Rainham & Smoyer-Tomic, 2003). Hence, appropriately attributing EHE-related deaths is important to accurately account for the health impacts of EHEs and their mortality burden, which can inform the development of effective preventative measures (Environment and Climate Change Canada, 2016).

4.2. Inconsistency in the Quantity and Quality of Mortality Data Available Across and Within EHEs

Beyond differences in mortality counts resulting from different approaches taken by various agencies, other inconsistencies persist, such as the extent or level of detail on sociodemographic characteristics of mortality data reported across past EHEs in Canada. More detailed mortality data (e.g., sex, co-morbidities, socioeconomic characteristic of neighborhood, substance use) are available only for EHEs after the year 2000. Inconsistencies in mortality data are especially evident for EHEs that had health impacts across provincial boundaries. For example, even though the July 2010 heatwave extended across southern Québec and Ontario, unlike its Québec counterpart, the Government of Ontario released no official reports with mortality numbers for Ontario's population (Hauen, 2018). This may be due to the different approaches to counting heat-related deaths that exist between

Table 4
Different Approaches to Attributing Individual Deaths to Hot Weather (28)

Method (and EHE in which it was used)	Vital Statistics Coding	Probabilistic Methods (in 2021 western North America heat dome)	Enhanced Surveillance (in 2018 Montreal EHE)
Purpose	To declare a cause of death according to international standards (e.g., ICD-10)	Separate excess deaths from expected deaths	An enhanced surveillance protocol for identifying deaths attributable to extreme temperatures
Procedure	Clinicians and coroners send certificates of death to vital statistics agencies across Canada	The number of expected deaths (N) during an EHE is calculated	Using all available records, relevant details (e.g., location of death, ambient temperature, air conditioning, and known comorbidities of the decedent) are entered into an enhanced surveillance form
	Vital statistics agencies translate these documents into data for provincial and national reporting on mortality	N from vital statistics records are randomly and repeatedly resampled from the records of all deaths observed during the EHE	
	Underlying causes of death recorded on the certificates are interpreted and coded according to standard protocols (US National Vital Statistics System, 2020)	Subsequently, the sampled EHE deaths are matched to randomly-sampled comparators from records of deaths that occurred during typical summer weather	Following, a decision tree is used to classify each death as being (a) confirmed, (b) probable, (c) unlikely, or (d) indeterminate with respect to EHE attribution
Key elements	The ICD-10 code X30 is used when high temperatures are *solely* responsible for a death (i.e. the death would not have occurred in the absence of high temperatures)	Several known risk factors of hot weather mortality (age, setting of death, population density, neighborhood deprivation, and surrounding residential greenness) are considered in conditional logistic regression to evaluate differences between the EHE deaths and the comparison group (Kosatsky et al., 2012)	"Confirmed" = deaths with a recorded body temperature >40°C "Probable" = when the temperature at the time and place of death was elevated and the cause was a condition associated with heat-related mortality (e.g., myocardial infarction or neurological disorders) "Unlikely" = deaths due to accidents, trauma, suicide, homicide, advanced cancer, surgical complications, or when there was evidence of air conditioning at the place of death "Indeterminate" = deaths with no information about ambient temperature or air conditioning and due to a cause not included in the confirmed or unlikely categories
Limitations	Individuals with comorbidities are more susceptible to heat-related death, which makes it challenging to conclude that heat was the *causal* factor	The results are only available to those who apply the method, and they are not reflected in provincial or national vital statistics data	The results are only available to those who apply the method, and they are not reflected in provincial or national vital statistics data
Other notes	Vital Statistics Council for Canada and various provincial vital statistics agencies	Developed by the BCCDC after the 2009 EHE in greater Vancouver	Developed by the Montreal Regional Public Health Department (Direction régionale de santé publique—DRSP) following the 2010 EHE in Montréal

Note. This table was developed based on Henderson, Lamothe et al.'s (2022) analysis of the different approaches to EHE mortality attribution, which highlighted the need for more systematic and cooperative approaches.

jurisdictions as well as various agencies (e.g., coroners services, vital statistics, epidemiologists, and public health surveillance). The Office of the Chief Coroner in Ontario, for example, defines "heat-related deaths" as *those* "*accidental deaths where heat is believed to be the direct cause of death (e.g., heat stroke, hyperthermia)*" (Hauen, 2018). These deaths are indicated as "X30" as per the International Classification of Disease, Tenth Revision (ICD-10) codes. The code T67 can also be used to account for heat exposure as a contributing cause of death. However, this code is considered to be in the secondary field, which is not included in national vital statistics mortality reporting.[17] This likely leads to fewer number of deaths reported when compared with Québec's mortality number for the same 2010 heatwave, which was the difference in all-cause deaths and average number of deaths in the comparison periods in the previous 5 years (Hauen, 2018).

We also found varying death counts for the same event according to *when* the analysis of deaths took place (e.g., during, immediately following, or long after the EHE). Media articles and reports published during or immediately following EHEs may be based on limited information compared with more detailed retrospective analyses. Also, there are some EHEs that met ECCC's historical thresholds for extreme heat (e.g., 1941 EHE in Alberta and British Columbia and 1988 EHE in Ontario), and yet, no reports of heat-related deaths were found in peer-reviewed articles or the news-media. Kalkstein and Smoyer (1993) provide modeled estimates of mortality for the 1988 EHE in Ontario, but we chose not to include this EHE in our study as it did not meet the inclusion criteria of using actual mortality data.

4.3. Not All Groups Identified as Vulnerable to Heat in the Literature Are Considered in Mortality Counts of EHEs

Existing articles documenting mortality impacts of EHEs in Canada do not report on all the populations identified in the literature as vulnerable to EHEs. For example, even though pregnant people are identified as at risk of stillbirth in the literature (Chersich et al., 2020), most reports on EHE-related deaths in Canada did not report on deaths below 65 years of age, automatically excluding fetuses from available death counts, even if the values may have been zero (Kuehn & McCormick, 2017). Likewise, people with physical disabilities are identified as more vulnerable to heat-related health risks in the literature (Boon et al., 2011; Human Rights Watch, 2021), but were not identified in mortality counts across all past Canadian EHEs; perhaps one reason for this omission is the lack of a universal definition of "disability" used by different data collection agencies in Canada. For populations identified in the literature as vulnerable to EHEs, it is unclear if their omission from EHE-related mortality reports reflect a lack of heat-related deaths in these specific populations, the inability for data to capture this information, or an oversight in the reporting. In other words, the issue may lie more in the "raw" primary mortality data collected that is inadequate in documenting information that may lead to considering heat as a plausible cause or contributor of death, rather than in the analyses conducted. Another possible explanation is that some populations are more susceptible to heat-related morbidity than mortality, and the literature reviewed for this analysis focused on mortality only. Additionally, as noted above, some populations and population characteristics may not be reported on within mortality counts due to different methods used by various agencies in defining and counting heat-related deaths.

4.4. Inconsistent or Limited Consideration of Compounding Impacts of Social Vulnerability Factors

While many articles and reports about past EHEs in Canada state the importance of social vulnerability indicators, they are inconsistently included in peer-reviewed articles or news reports about past EHEs, or are limited in scope. Not accounting for the *compounding* impacts of multiple social vulnerability factors may result in overlooking some populations, such as: those already living in high pollution areas and those made more susceptible to the compounding risk of heat and air pollution (Fischer et al., 2004; Rainham & Smoyer-Tomic, 2003); low-income families living in poor quality housing that provides no refuge from heat (Hernández, 2013, 2016); people with chronic physical or mental illnesses who are also of low socio-economic status who may not have access to healthcare (R. Kaiser et al., 2001), or people who have difficulty accessing cooling centers due to stigma (Gorman et al., 2020). Reporting on a comprehensive list of social vulnerability characteristics and factors that may have contributed to heat-deaths (even if the values are zero or not available) is necessary in order to establish targeted heat-health protection plans and actions that protect marginalized populations.

An in-depth look at how different social vulnerability factors amplify one's risk of death from extreme heat can be demonstrated through the example of people with schizophrenic disorder who died in the 2018 EHE in Montreal (Carrier, 2019). Even though people with schizophrenia represent only 0.6% of Montreal's population, they accounted for 25.8% ($n = 17$) of heat-related deaths. A more in-depth analysis found that many lived alone and had at least one other chronic illness, and none had air conditioning in their place of residence (Carrier, 2019; Price et al., 2013). While no conclusive causal relationship can be drawn based on one example case, a closer look at different intersecting vulnerability factors could establish that more than schizophrenia alone heightens one's risk of heat-related death.

5. Discussion: Implications for Practice

Below we share some observations that could help inform solutions to address the gaps and challenges identified above, by moving toward evidence-based, consistent, and more comprehensive reporting across jurisdictions and agencies—ultimately to ensure that no population is overlooked.

5.1. Explore Consistent Ways of Collecting and Reporting Heat-Related Mortality Data to Better Understand Populations Most at Risk to Heat

Currently, there are different published mortality figures associated with the same EHEs, resulting from various ways of counting heat-related deaths (e.g., excess deaths vs. coroner-verified heat-attributable deaths), as well as different jurisdictional approaches to counting heat-related deaths (e.g., Ontario vs. Quebec's mortality figures for the 2018 EHE; Alberta vs. BC's mortality figures for the 2021 heat dome). These inconsistencies point to differences in defining and counting heat-related deaths. More consistent mechanisms for collecting and counting heat-related deaths—including how heat-related mortality is defined and how data are collected and reported publicly—could improve the consistency and reliability of data, an address the currently fragmented approach to reporting across Canada (Table S1). Where possible, information could be shared publicly to facilitate comparison and inform action. One approach could be to clarify heat-related data terminology. For example, there is confusion about the meaning of the term "heat-related deaths," which we found is often used in news and some epidemiological reports to refer to all excess deaths that occur during an EHE, while in vital statistics coding it is reserved for deaths coded as X30 (accidental death caused by exposure to excessive natural heat) (US National Vital Statistics System, 2020). It may be important to collect data for instances where heat contributed to, but may not be the direct or primary cause of, a death. Where possible, efforts to make heat-related mortality data public would help facilitate comparisons and inform action.

5.2. Foster Inter-Agency Cooperation for Attributing Deaths to Extreme Heat

Not all groups identified as vulnerable to heat-related mortality in the literature were found in the mortality information we assessed. This may be due to limitations in defining heat-related deaths (as discussed above), or limitations to information (or lack thereof) captured by clinicians and coroners attending to the deaths. Given their crucial role in ensuring that heat-related mortality is accounted for in vital statistics data, coroners, clinicians, and other relevant agencies and organizations could collaborate to enrich the data sources that are ultimately used to identify heat-related deaths and their risk factors (Table S1). There could be procedural agreements across agencies—such that a hot weather warning could trigger regional public health reminders for medical personnel and coroners to consider extreme heat in deaths as a causal or contributing factor—which would allow coroners to further investigate and make an appropriate attribution (College of Physicians and Surgeons of British Columbia, 2021). For example, during the 2021 heat dome the BC Coroners Service sent a message to all physicians across the province with a request to report deaths to the BC Coroners Service where heat was considered in any way as contributing to death and to not issue any medical certificates of death for these situations (College of Physicians and Surgeons of British Columbia, 2021). Furthermore, inter-agency cooperation could support the development of an agreed-upon approach to attributing mortality, combining strengths from each current method (e.g., vital statistics coding, probabilistic methods, and enhanced surveillance). For example, Henderson, Lamothe, et al. (2022) note that combining different approaches during "rapid assessments" of heat-related deaths could ensure that the vital statistics records appropriately reflect whether heat *contributed to* or *caused* an individual's death.

5.3. Explore More Routine Collection of Qualitative Health Data

Qualitative health data can enhance understanding of the impacts of the intersecting, cascading, and compounding factors that affect vulnerable populations' susceptibility to heat-related death (Keller, 2013). No such qualitative data was found among our data set. Collecting qualitative health data more routinely for all heat-related deaths could lead to a more nuanced understanding of the circumstances around these deaths, allowing health authorities to develop better targeted intervention strategies. Qualitative data about the interplay of various social vulnerability factors could be obtained, for example, through interviews with family, loved ones, or caregivers of decedents (Keller, 2013). Important insights may emerge from interviews that would otherwise not be captured through pre-formed surveys.

5.4. Augment Mortality Data With Other Relevant Data Sets Beyond Health

Few of the historical reports we reviewed of heat-health deaths in Canada included complementary data on characteristics beyond "health," such as built environment characteristics at the site of death. Data sets that extend beyond health characteristics could supplement mortality data to provide more holistic, contextualized

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information about EHE-related deaths. Routinely collecting these data could provide timely information about external factors that may have heightened one's exposure to extreme heat, and therefore, risk of heat-related mortality. For instance, Henderson, McLean, et al. (2022) reported that lack of access to greenspace within a 100-m radius of one's residence was a significant vulnerability factor for heat-related deaths. Overlapping mortality data with physical geographical data such vegetation indices or heat distribution maps could offer important insights about built environment factors that may render already-at-risk populations more susceptible to heat (Henderson, Lamothe, et al., 2022; Henderson, McLean, et al., 2022). Other examples of data linkages that could be made include: proximity to a public cooling center; maintenance status of residence; local energy or utility costs; and regional electricity blackout data—all of which may shed light on factors outside of the deceased's control that may have contributed to their death.

6. Limitations and Future Directions

This study was limited to EHEs for which a number of attributable deaths had been reported in an epidemiologic study, gray literature, or news-media. Thus, there may have been other EHEs for which there were deaths, but that were excluded from our data set because they were not reported publicly in academic literature, gray literature, or news-media. In this vein, there is a need for more epidemiological studies of historical EHEs, particularly for provinces without heat-related death reporting protocols. Organizations with access to rich raw historical mortality data sets—in particular, provincial and territorial governments—could conduct historical analyses of likely past EHE to determine the number of heat-related deaths that occurred. To facilitate comparison, such studies could use existing frameworks to analyze heat-related deaths. More physiological and qualitative studies could also help with better understanding trends that have emerged through epidemiological studies, such as the disproportionately high rates of heat-related mortality among people with schizophrenia (Cornwall, 2023; D. Kaiser et al., 2019; Lee et al., 2023; Price et al., 2013). Additionally, while this commentary has focused on heat-related mortality, more attention is also warranted to enhancing reporting for heat-related morbidity.

7. Conclusion

This analysis provides an overview of mortality *across* major EHEs in Canada over the last century, leading to identification of trends in data over temporal and geographical boundaries that warrant attention. Beyond noting factors that have *consistently* been present among EHE-related decedents, our examination of past EHEs in Canada identified the following shortcomings and challenges in how heat-related deaths have been counted and reported: (a) inconsistency in the amount, type, and depth of mortality data across EHEs in Canada, making comparative analysis difficult; (b) discrepancy between populations identified in the literature as vulnerable and those reported on within mortality counts; (c) challenges in ascertaining heat as a direct or indirect cause of death; and (d) inconsistent consideration of compounding impacts of social vulnerability indicators.

Addressing these challenges could support better understanding populations more at risk to heat. It is through such cross-temporal and -geographical analyses that alarming patterns such as the disproportionately high heat-related mortality rates of people with schizophrenia across EHEs can be identified. In turn, accurately accounting for which populations died across past EHEs in Canada is important for helping health authorities at all levels to better target evidence-based interventions, and thereby effectively reduce vulnerability and increase adaptive capacity of Canadians to extreme heat.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

Data from various academic journals, government agencies and news media outlets were used in the creation of this manuscript. Academic articles include: Baudry and Burnette (1938), Boon et al. (2011), Bustinza et al. (2013), Chersich et al. (2020), Fischer et al. (2004), Gasparrini et al. (2012), Henderson et al. (2021), Henderson, Lamothe, et al. (2022), Henderson, McLean, et al. (2022), D. Kaiser et al. (2019), Kalkstein and Smoyer (1993), Keller (2013), Kosatsky (2010), Kosatsky et al. (2012), Kuehn and McCormick (2017), Lee et al. (2023), Price et al. (2013), Rainham and Smoyer-Tomic (2003), Semenza et al. (1996), Stewart et al. (2017), and White et al. (2022). Gray literature reports include: BC Coroners Service (2021, 2022a), Calgary Emergency Management Committee (2022), Carrier (2019), College of Physicians and Surgeons of BC (2021), Environment and Climate Change Canada (2017), Government of Canada (2011), Hofmann et al. (1998), and Human Rights Watch (2021). News media articles include: CBC News (2018), Hauen (2018), Johnson (2021), and Mangione (2021). Some data used for the creation of this manuscript were not publicly available as they were only accessible to employees of Health Canada. These data are stored in the following in-text data citation references: BC Coroners Service (2022b), Gan and Henderson (2019), and Henderson et al. (2021).

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