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Healthcare resource use and costs associated with extreme heat in Alberta, Canada

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Abstract

Objectives Heat events are a growing public health concern. There is an opportunity to better characterize how heat events affect healthcare system utilization. We evaluated the heat-related healthcare resource use and costs in Alberta, Canada in the summer of 2021 when record-breaking extreme heat events occurred in the province.

Methods We conducted a population-based cohort study using Alberta administrative health data from May to September 2021 to identify and describe patients who used heat-related healthcare resources over this period. Costs were quantified and reported in Canadian dollars (CA$) using 2023 values.

Results 4194 patients used heat-related healthcare resources, including 109 hospitalizations, 1020 ambulatory care visits (99.7% were ED visits), 310 ambulance transfers, and 5555 practitioner claims. Total heat-related healthcare costs were CA$3.2 million. Female sex, age, and a history of myocardial infarction, heart failure, dementia, or diabetes were found to be significantly associated with increased use of heat-related healthcare resources. History of cardiovascular disease (27.1%) or diabetes (12%) were more frequent in patients hospitalized or attended ED (30 and 14.2%, respectively) compared to those who only used outpatient or physician services (26.3 and 11.2%, respectively; all $p < 0.05$).

Conclusion Heat-related healthcare resource use and costs during the summer of 2021 in Alberta was substantial. Females, older persons, and people with a history of cardiovascular disease were the most affected. This is likely an underestimation of the overall heat impact. Additional research is needed to quantify the broader impact of extreme heat events on the healthcare system and on society.

1 Introduction

Extreme heat events are defined as consecutive days of uncommonly high atmospheric temperatures, in which there is an increase in population risk for heat-related illnesses such as dehydration, cramps, exhaustion, syncope, organ failure, stroke, and death [1–3]. Certain persons may have higher heat vulnerability due to heat sensitivity related to physiology or medications, as well as lack of acclimatization and adaptability to extreme heat. Heat-vulnerable populations include but are not limited to, older individuals, people with chronic conditions such as cardiovascular diseases, respiratory diseases, or mental health conditions, and persons experiencing low socioeconomic status or homelessness [3].

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Extreme heat events are a growing public health concern, and heat-related health effects can result in a substantial burden on the healthcare system. A comprehensive review of extreme heat impacts by Wondmagegn et al. found 10 studies in the United States (6 studies), Australia (2 studies), Germany (1 study), and Spain (1 study) [4]. The authors suggested that heat-related morbidity and mortality resulted in increased ambulance callouts, emergency department (ED) visits, and hospitalizations. The financial burden was substantial but varied, depending on the location, health outcomes, and population examined [4]. In Canada, reports on extreme heat impacts have focused on mortality, with limited evaluations of healthcare system resource use and costs [5–8]. The Canadian Institute for Climate Choices projected that the costs for death and reduced quality of life because of extreme heat could be as high as $3.9 billion per year in Canada [9].

The province of Alberta, Canada has a universal coverage and publicly funded healthcare system serving a population of more than four million people in a large and diverse geographic region. There were record daily high temperatures or near-record highs experienced at the end of June, with more extreme heat events occurring throughout July and August 2021 in the province [10–14]. Using daytime maximum temperature and nighttime minimum temperature criteria for heat warning in Alberta [15] for each of its 5083 geographic dissemination areas as a definition of heatwave, the Institute of Health Economics reported that there were as many as 34 unique heatwaves in the province during May to September 2021 [16].

Alberta has one of the most robust weather surveillance systems in Canada, but the impact of extreme heat on the healthcare system has yet to be evaluated. Accordingly, we conducted this study to provide contemporary data on the heat-related healthcare resource use and costs in the summer of 2021 in Alberta. Our study provides additional insights into the potential impact of extreme heat on the healthcare system and could further support developments and implementations of extreme heat mitigation strategies and improvements in healthcare service preparedness for future extreme heat events.

2 Methods

2.1 Data sources

We conducted a population-based study using Alberta administrative health data including the Discharge Abstract Database, the National Ambulatory Care Reporting System, the practitioner claims, and population registry databases [17]. The Discharge Abstract Database records all hospitalizations in the province and provides patient demographics, diagnoses, interventions, and discharge deposition. It also provides a resource intensity weight (RIW) representing the level of resource consumption during an inpatient stay contingent on the patient case-mix group [18, 19]. The National Ambulatory Care Reporting System contains all visits to ambulatory care facilities (including ED). Like the Discharge Abstract Database, the National Ambulatory Care Reporting System provides patient demographics, diagnoses, interventions during a visit, comprehensive ambulatory classification systems, and an outpatient RIW representing resource use during a visit. The practitioner claims database provides fee-for-service claims information for physicians and other providers of insured health services. Finally, the population registry provides demographic and vital statistics for all inhabitants of Alberta who are members of the Alberta Health Care Insurance Plan [17].

2.2 Study population

We included all hospitalizations, ambulatory care visits, and practitioner claims where a heat condition was coded as the primary or a secondary diagnosis of the health service encounter (Effect of heat and light condition: International Statistical Classification of Diseases and Related Health Problems 9 th Revision [ICD-9] code 992 and 10 th Revision [ICD-10] code T67, and exposure to excessive natural heat: ICD-10 code X30, excluding exposure to other and unspecified person-made environmental factors: ICD-10 code W99) between May and September 2021 (the study period). A period of May to September was selected to correspond to the timeframe when heatwaves were reported in the province in 2021 [16, 20]. Further, our initial examination of heat-related healthcare resource use in the province found that 100% of heat-related hospitalizations and 98.7% of heat-related ED visits in 2021 occurred during the May–September period.

2.3 Outcomes of interest

The primary variable of interest was heat-related healthcare resource utilization (HCRU) and costs, measured by the number of hospital admissions, number of ambulatory care visits (including the number of ED visits), number of ambulance activations with transport to the ED, and number of practitioner claims with a heat-related diagnosis. Other variables of interest included factors potentially associated with increased use of heat-related healthcare costs and distribution of the heat-related HCRU and costs by geographical area. A map of Alberta's five health zones and their population in 2021 is presented in Supplementary Fig. 1 and Supplementary Table 1 [21].

2.4 Costing methods

The healthcare costs included costs of heat-related hospitalization, ambulatory care visits (including ED visits), ambulance activations with transport to the ED, and practitioner claims. Hospitalization costs were calculated by multiplying the RIW with the cost of a standard hospital stay (CSHS) [19]. The CSHS provides an estimate of the costs of a standard hospital (RIW = 1.0) stay (e.g., nursing, diagnostics, and therapeutic costs). Similarly, the costs of an ambulatory care visit were derived by multiplying its outpatient RIW with the CSHS. Alberta-specific CSHS value in 2021 ($9220) was used [19]. The practitioner claims database provides costs for fee-for-service claims (paid amount). We used the system-assessed amount instead for a small proportion (about 10%) of the claims generated from salary-based physicians where the fee-for-service costs were unavailable. The costs of an ambulance activation with transport were $385 (2021 value that was set by the Government of Alberta). All costs were converted to 2023 Canadian dollar (CA$) values using the Consumer Price Index and Bank of Canada inflation calculator [22].

2.5 Statistical analysis

Patients were categorized into two mutually exclusive groups based on all heat-related health service encounters during the study period: 1) patients who were admitted or used ED, and 2) patients who did not (this patient group only used non-ED outpatient clinics or physician offices). Patient characteristics were reported as mean (standard deviation, SD), median (interquartile range, IQR), and count (proportion), as appropriate. Kruskal–Wallis and Student's t-tests were used for continuous variables, while χ^2 tests were used for categorical variables. Univariate general linear models (GLM) with a gamma distribution and log link were used to compare costs. Patient median household income in the residential neighborhood (forward sortation area level) was based on the 2020 Canada Census, while residency (urban or rural) was based on the 2nd digit of the postal code [23]. Previously validated ICD-10 codes were used to identify patient comorbidities [24], which were considered to be present if they were recorded in the DAD or NACRS during two years before the start of the study period.

A GLM model with a gamma distribution and log link was also used to examine risk factors associated with increased heat-related healthcare costs during the study period. Evidence in the literature suggested that the elderly and patients with comorbidities such as respiratory and cardiovascular diseases could be disproportionately affected by exposure to extreme heat [8, 25, 26]. Also, Liu et al. reported significant variations in access to healthcare services between rural and urban areas in Alberta [27]. Therefore, the primary variables of interest in the GLM model included patient sex, age, type of healthcare encounter, residence location (urban or rural), and health zone. We used a stepwise backward variable selection strategy and used the Likelihood Ratio (LR) test to examine the inclusion of additional risk factors in the final regression model. They included household income quartiles and 17 comorbidities (Table 1) [24]. Except for the primary variables, a variable remained in the final regression model if the LR test was significant at a 10% level. We did not use the traditional stopping rule of 5% significant level because it has been reported that a strict rule could lead to the exclusion of important variables [28–30]. Remained variables were checked for collinearity using correlation matrix.

All analyses were performed using SAS Studio (SAS Institute, Cary, NC) and Stata version 18 (Stata Corporation, College Station, TX); two-sided p values < 0.05 were considered statistically significant.

Table 1 Patient characteristics at baseline

Variable	All patients	Hospital and/or ED	Other	*p*
Patients, N (%)	4194	1056 (25.2)	3138 (74.8)	
Females, n (%)	2092 (49.9)	471 (44.6)	1621 (51.7)	<0.001
Age, in years, mean (SD)	58.1 (23.0)	43 (25.4)	63.2 (19.7)	<0.001
Age, in years, median (IQR)	64 (42–75)	39 (23–64)	67 (54–77)	<0.001
Age group, n (%)				
<18 years	265 (6.3)	151 (14.3)	114 (3.6)	<0.001
18–49 years	1,022 (24.4)	497 (47.1)	525 (16.7)	
50–64 years	850 (20.3)	155 (14.7)	695 (22.2)	
65–74 years	919 (21.9)	97 (9.2)	822 (26.2)	
≥75 years	1138 (27.1)	156 (14.8)	982 (31.3)	
Urban residence, n (%)	3589 (85.6)	789 (74.7)	2800 (89.2)	<0.001
Health zone				
Calgary	747 (17.8)	261 (24.7)	486 (15.5)	<0.001
Central	488 (11.6)	160 (15.2)	328 (10.5)	
Edmonton	2309 (55.1)	297 (28.1)	2012 (64.1)	
North	466 (11.1)	233 (22.1)	233 (7.4)	
South	184 (4.4)	105 (9.9)	79 (2.5)	
Household income ($, n, (%))				
≤60,000	490 (11.7)	205 (19.4)	285 (9.1)	<0.001
60,001–80,000	900 (21.5)	311 (29.5)	589 (18.8)	
80,001–100,000	825 (19.7)	208 (19.7)	617 (19.7)	
>100,000	1979 (47.2)	332 (31.4)	1647 (52.5)	
Comorbidities, n (%)				
Myocardial infarction	110 (2.6)	35 (3.3)	75 (2.4)	0.104
Heart failure	153 (3.7)	60 (5.7)	93 (3.0)	<0.001
Peripheral vascular disease	66 (1.6)	23 (2.2)	43 (1.4)	0.068
Cerebrovascular disease	174 (4.2)	42 (4.0)	132 (4.2)	0.747
Chronic pulmonary disease	319 (7.6)	136 (12.9)	183 (5.8)	<0.001
Dyslipidemia	137 (3.3)	31 (2.9)	106 (3.4)	0.484
Hypertension	689 (16.4)	184 (17.2)	505 (16.1)	0.313
Atrial fibrillation	198 (4.7)	50 (4.7)	148 (4.7)	0.981
Dementia	70 (1.7)	32 (3.0)	38 (1.2)	<0.001
Rheumatoid disease	85 (2.0)	11 (1.0)	74 (2.4)	0.009
Peptic ulcer	0 (0)	0 (0)	0 (0)	–
Liver disease	69 (1.7)	27 (2.6)	42 (1.3)	0.007
Diabetes	501 (12.0)	150 (14.2)	351 (11.2)	0.009
Hemiplegia or paraplegia	28 (0.7)	8 (0.8)	20 (0.6)	0.678
Renal disease	128 (3.1)	28 (2.7)	100 (3.2)	0.382
Cancer	236 (5.6)	47 (4.5)	189 (6.0)	0.055
Metastatic cancer	51 (1.2)	17 (1.6)	34 (1.1)	0.177
Charlson comorbidity score, mean (SD)	0.7 (1.5)	0.9 (1.8)	0.7 (1.4)	<0.001

SD standard deviation, *IQR* interquartile range

3 Results

3.1 Patient characteristics

There were 4194 unique patients who experienced at least one heat-related health service encounter from May through September 2021 in Alberta. Of them, 1056 (25.2%) patients had a hospital admission or ED visit associated

Table 2 Heat-related healthcare resource use by sex and age groups in Alberta, 2021

Variable, n (%)	Hospitalization	Ambulatory care visit		Ambulance activation	Practitioner claims
		All	ED visit		
All	109	1020	1017	310	5555
By sex					
Female	47 (43.1)	455 (44.6)	452 (44.4)	142 (45.8)	2650 (47.7)
Male	62 (56.9)	565 (55.4)	565 (55.6)	168 (54.2)	2905 (52.3)
By age group					
<18 years	4 (3.7)	152 (14.9)	152 (15.0)	12 (3.9)	276 (5.0)
18–49 years	13 (11.9)	499 (48.9)	497 (48.9)	110 (35.5)	1040 (18.7)
50–59 years	7 (6.4)	92 (9.0)	92 (9.1)	35 (11.3)	573 (10.3)
60–69 years	24 (22.0)	99 (9.7)	98 (9.6)	49 (15.8)	1176 (21.2)
≥70 years	61 (56.0)	178 (17.5)	178 (17.5)	104 (33.6)	2490 (44.8)

Table 3 Heat-related healthcare resource use and costs by health zone in Alberta, 2021

Variable	Number of events, n (%)						Total costs, $ mil
	All	Calgary	Central	Edmonton	North	South	
Hospital admissions	109	23 (21.1)	19 (17.4)	52 (47.7)	14 (12.8)	1 (0.9)	2.3
Ambulatory care visits	1020	251 (24.6)	153 (15)	272 (26.7)	234 (22.9)	110 (10.8)	0.5
ED visits	1017	251 (24.7)	153 (15)	272 (26.7)	234 (23)	107 (10.5)	0.5
Ambulance activations	310	72 (23.2)	26 (8.4)	137 (44.2)	61 (19.7)	14 (4.5)	0.1
Practitioner claims	5555	835 (15)	617 (11.1)	3373 (60.7)	570 (10.3)	160 (2.9)	0.3
Total costs, $ mil		0.6	0.2	2.0	0.3	0.1	3.2

ED Emergency Department. ED visits are a subset of ambulatory care visits

with extreme heat, while the remaining (74.8%) only visited outpatient clinics or physician's offices for extreme heat reasons (Table 1). None of 109 admitted patients had more than one admission and 16 (1.6% of 1000 patients with ED visit) patients had more than one ED visit.

Half of the study population (49.9%) were female. Cardiovascular conditions were presented in 27.1% of the study population with hypertension (16.4%), diabetes mellitus (12%), and chronic pulmonary disease (7.6%) being the most common comorbidities.

3.2 Healthcare services use and costs

During the period from May through September 2021, there were 109 heat-related hospitalizations, 1020 heat-related ambulatory care visits, 310 heat-related ambulance activations with transfer, and 5555 practitioner claims associated with a heat condition (Table 2). The majority of ambulatory care visits were to ED (99.7%). The majority of hospital admissions (96.3%) and ED visits (92.7%) were due to the exposure to excessive natural heat (ICD-10 code of X30) while all visits to non-ED outpatient clinics and physician's offices were due to the effect of heat and light condition (ICD-9 code of 992 and ICD-10 code of T67).

Total healthcare costs were estimated at CA$3.2 million, corresponding to CA$759 per patient during the study period (Table 3). Although there were only 109 heat-related hospitalizations with a mean (SD) hospital length of stay of 11 (24.1) days, the high costs of a hospitalization (mean = CA$20,668) resulted in a total hospitalization cost of CA$2.3 million, corresponding to 71.9% of the total heat-related healthcare costs during the study period. Consequently, the total heat-related cost per patient was much higher in patients with hospital inpatient/ED use (CA$2,789) than those who only used outpatient or physician services (CA$75; $p < 0.001$).

Patients who were admitted to the hospital or utilized the ED were less often female compared to those who only used outpatient or physician services (44.6 vs. 51.7%; $p < 0.001$) (Table 1). Overall, the proportions of services used by male patients were consistently higher than that of their female counterparts across hospitalizations, ED visits, ambulance activations, and practitioner claims. However, the total healthcare costs for females (CA$1.9 million) were about 50% higher than that of male counterparts (CA$1.3 million), because of higher costs per hospitalization in female patients (CA$31,904 vs. $12,151; $p < 0.001$). After risk adjustments, female patients incurred 18.3% higher costs ($p < 0.001$) than their male counterparts (Table 4).

Patients who were admitted to the hospital or utilized the ED were younger compared to those who only used outpatient or physician services (mean age 43 vs. 63.2 years; $p < 0.001$) (Table 1). There were more hospital admissions (56%) and practitioner claims (44.8%) by the most senior group (aged ≥ 70 years) than by other age groups. However, patients aged 18–49 years had half of the ED visits associated with extreme heat (48.9%) (Table 2). Patients aged ≥ 70 years incurred 34.5% of total heat-related healthcare costs (Fig. 1). For every 10-year older a patient was, they incurred 5% higher costs ($p < 0.001$) (Table 4).

Cardiovascular conditions were more frequent in those who were hospitalized or attended the ED (39.6%) compared to those who only used outpatient or physician services (26.3%; $p = 0.042$). Similarly, both diabetes (14.2 vs. 11.2%; $p = 0.009$) and chronic pulmonary disease (12.9 vs. 5.8%; $p < 0.001$) were also more prevalent in hospitalized/ED patients. As a result, the Charlson comorbidity score was higher in hospitalized/ED patients (mean = 0.9 vs. 0.7; $p < 0.001$). Patients with myocardial infarction (28.2% increase; $p = 0.009$), heart failure (35% increase; $p < 0.001$), dementia (48.2% increase; $p = 0.001$), and diabetes (38.7% increase; $p < 0.001$) had higher heat-related healthcare costs than those who did not have these conditions. In contrast, hypertension was associated with a reduction of 19.8% in healthcare costs (Table 4).

Patients in Edmonton Zone accounted for the majority of heat-related healthcare encounters and costs: 55.5% of the study population, 47.7% of hospital admissions, 25.7% of ED visits, 60.7% of practitioner claims, and 63.5% total healthcare costs compared to other zones (Table 3). After risk adjustment, there were no differences in heat-related healthcare costs between patients residing in urban and rural areas ($p = 0.692$). Compared to patients living in the lowest annual household income quartile (<CA$72,704), those who lived in the 2nd (CA$72,704-$97,023) and 4 th (≥CA$123,502) quartile areas incurred lower heat-related healthcare costs (both $p < 0.001$). Patients residing in the Edmonton Zone had higher heat-related healthcare costs than their counterparts in the other four health zones (all $p < 0.001$) (Table 4).

Table 4 Factors associated with patient's heat-related healthcare costs in Alberta, 2021 (N = 4194 patients)

Variable	Cost ratio (95% CI)	p
Type of healthcare service		
Hospital/ED (ref)	1.0	
Other	0.032 (0.030; 0.035)	<0.001
Female (vs. male)	1.183 (1.117; 1.253)	<0.001
Age (in year)	1.005 (1.004; 1.007)	<0.001
Rural residence (vs. urban)	1.020 (0.923; 1.128)	0.692
Health zone		
Edmonton (ref)	1.0	
Calgary	0.852 (0.787; 0.922)	<0.001
Central	0.776 (0.699; 0.861)	<0.001
North	0.729 (0.657; 0.809)	<0.001
South	0.544 (0.466; 0.635)	<0.001
Household income quartile		
1 st quartile (<$72,704) (ref)	1.0	
2nd quartile ($72,704–$97,023)	0.768 (0.707; 0.834)	<0.001
3rd quartile ($97,204–$123,501)	1.146 (1.050; 1.252)	0.002
4 th quartile (≥$123,502)	0.814 (0.744; 0.891)	<0.001
Comorbidity		
Myocardial infarction	1.282 (1.065; 1.544)	0.009
Heart failure	1.350 (1.149; 1.585)	<0.001
Hypertension	0.802 (1.186; 1.853)	<0.001
Dementia	1.482 (1.186; 1.853)	0.001
Liver disease	1.245 (0.995; 1.557)	0.056
Diabetes	1.387 (1.261; 1.525)	<0.001

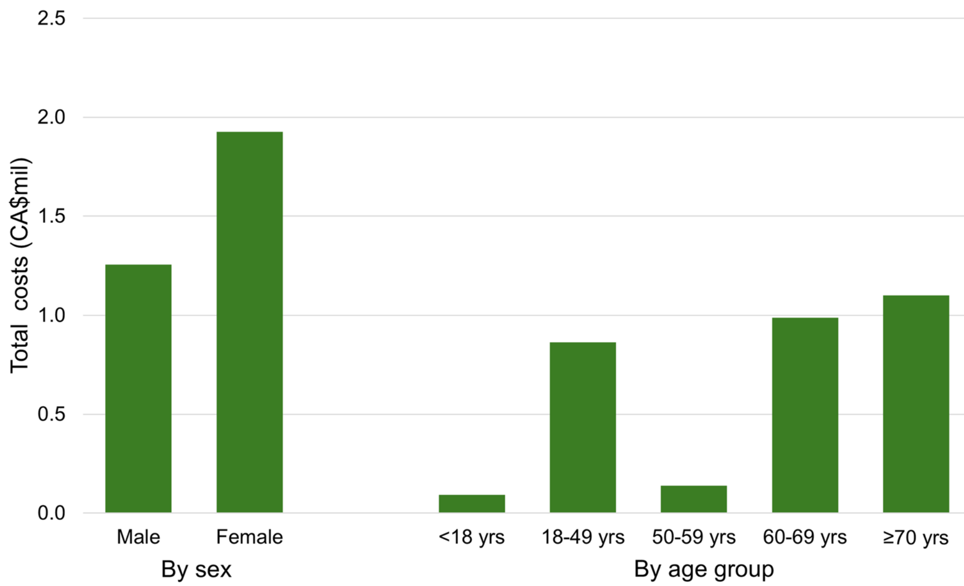

Fig. 1 Total heat-related healthcare costs by sex and age group in 2021 in Alberta

4 Discussion

Our population-based cohort study found that the total heat-related healthcare costs in Alberta during the summer of 2021 were $3.2 million. Hospitalizations accounted for the majority of these costs (71.9%). Most heat-related healthcare resources were used by people ≥70 years old (56% of hospital admissions, 33.6% of ambulance activations, and 44.8% of practitioner claims). However, most ED visits (48.9%) were by people aged 18 to 49 years. The Edmonton Zone accounted for approximately two-thirds of the total heat-related healthcare costs in the province. After risk adjustment, we found female sex, patient age, a history of myocardial infarction, heart failure, dementia, and diabetes, living in the Edmonton Zone, and living in lower-income neighborhoods were all significantly associated with an increase in heat-related healthcare costs.

Previous studies have reported increased healthcare resource use during heatwaves. A study in two community hospitals in Quebec by Kegel et al. found that heat events were significantly associated with approximately 10 additional daily ED visits and one day longer hospital length of stay [31]. A more recent study in Quebec by Boudreault et al. estimated that extreme heat was responsible for 170 hospitalizations, 6200 ED visits, and 1500 ambulance transfers each summer in the province [7]. In addition, a study in Ontario by Bai et al. also reported that about 11% of diabetes-related hospitalizations could be attributed to hot temperatures (99 th percentile) [32]. In Italy, Masiero et al. found increases in hospital use during hot days in patients with respiratory diseases, and elderly people accounted for a large proportion of this increase [33]. This finding is similar to ours where we found age was significantly associated with an increased use of heat-related healthcare resources and people aged ≥70 years incurred 34.5% of total heat-related healthcare costs. However, we found that chronic pulmonary disease was not significantly associated with increased use of heat-related healthcare costs in the present study. The difference in findings by Masiero et al. could be due to the differences in local population characteristics, availability and accessibility of healthcare systems, and adaptations [34].

We found that Edmonton Zone had the highest healthcare use burden due to extreme heat although it accounted for only 32.3% of the province population (Supplementary Table 1). The higher healthcare use burden due to extreme heat in Edmonton Zone could be the result of a higher exposure to heatwave where it accounted for 61.7% of combinations of heatwave/dissemination area (a geographical area unit) in the summer of 2021 in the province.[16] This finding suggests there might be a more urgent need for heat mitigation measures in the Zone, and policy makers in the Zone may want to consider both short and long term heat mitigation strategies such as heat warning system, providing public cooling infrastructure, outreach to vulnerable population, improving urban planning, reducing urban heat islands, and increasing green public spaces to not only prevent heat related healthcare use but also improve its people quality of life during the warm seasons. These measures have been used in other jurisdictions and may need to be tailored to local needs [35–37].

A review of the extreme heat effect in British Columbia, Canada in 2021 found a significant surge (almost double to approximately 12,000 calls) in ambulance arrivals during heat days [8]. Although we did not have data on ambulance activations that did not lead to a transfer to a healthcare facility (i.e., issues were resolved onsite), we found that there were more than 300 heat-related ambulance activations with transfer to ED during the same period in Alberta. It should be noted that our results included only ambulance transfers, so the impact of extreme heat could be significantly higher if non-transfer ambulance activations were considered. This finding highlights the importance of preparedness of ambulance services during heat days, so needed support services can be provided timely for patients when there is a surge. The British Columbia report has highlighted that many calls during heatwaves were put on the waiting or not responded to because of insufficient capacity [8].

We found that females had fewer heat-related hospitalizations than male patients did but incurred higher total heat-related healthcare costs because of higher costs per hospitalization. This finding is in line with reports by Lin et al. where the annual excess heat-related hospitalization costs were five times higher in females [38] and Schmeltz et al. where the adjusted costs per heat-related hospitalization were about US$750 higher in females [39]. Further, myocardial infarction, heart failure, dementia, and diabetes were found to be significantly associated with an increase in heat-related healthcare costs in the present study. Cui et al. (2005) reported that thermoregulatory response in patients with heart failure could be the reason that extreme heat is intolerable in this population [40]. Given the high healthcare cost burden in patients with cardiovascular diseases, especially myocardial infarction and heart failure reported previously [41–44], a targeted prevention strategy during heatwaves could be cost-effective to alleviate heat-related healthcare resource use in these populations.

We found that patients with hypertension had lower heat-related healthcare costs than those who did not have the condition. There could be multiple factors that may contribute to lower heat-related healthcare costs in patients with hypertension. Barnett et al. reported that increased temperature was associated with decreased systolic blood pressure, hence providing some benefits to patients with hypertension [45]. Further, the successful hypertension management programs in Canada could also play a positive role [46]. Fonseca et al. reported that people with hypertension may have better heat dissipation and body cooling though increased sweet evaporation which could be due to hypertensive medications (e.g., angiotensin-converting enzyme inhibitors or diuretics) [47]. However, this result should be interpreted with caution and further research is warranted because extreme heat could have elevated risks to patients with hypertension because it could lead to fluctuations in blood pressure or dehydration, in addition to the risk of other heat-related illnesses [48].

Although the present study provides novel data on the heat-related healthcare service use in Alberta during the summer of 2021 when there were extreme heat events, it has several limitations. First, our analysis lacks the evaluation of mortality data, due to the Coronavirus disease 2019 pandemic resulting in a backlog of death classification at the medical examiner's office and a large proportion of deaths in 2021 was temporarily coded as unknown/unspecified. Second, we only included the costs of heat-related hospitalization, ambulatory care visits, ambulance activations with a transfer, and practitioner claims and did not include several types of healthcare use (e.g., drug, home care, and ambulance activations that did not lead to a transfer) in the assessment because of the unavailability of data. Therefore, the overall heat-related healthcare resource use could be higher when these types of services were taken into consideration and even higher when considering the costs of extreme heat from a broader societal perspective (plus indirect costs such as travel time for healthcare service use and productivity losses). Further, we used ICD codes to determine the heat-related healthcare resource use, and that may underestimate the impact of extreme heat because of under-reporting (e.g., when extreme heat was a trigger for exacerbation of comorbidities but not recorded as a reason for healthcare use). Although ICD codes are commonly used to identify heat-related illnesses in the literature [49, 50], there are no validation studies for the use of ICD codes to identify heat-related conditions with Canadian administrative health datasets. DeGroot et al. (2017) cautioned low predictive properties of ICD-9 codes for exertional heat illnesses in the United States [51]. Nonetheless, our findings support that heat-related healthcare service use and costs in Alberta is significant and should be considered in healthcare planning.

5 Conclusion

Our population-based retrospective cohort study found sizable heat-related healthcare resource use and costs in Alberta in the summer of 2021. Females, people of advanced age, people with a history of cardiovascular diseases, and those living in lower-income neighborhoods are most affected. Additional research is warranted to quantify the broader impact of extreme heat events on the healthcare system and on society. Moreover, extreme heat mitigation strategies and preparedness should be built and continually improved to minimize the impacts of future extreme heat events which could be expected because of global warming.

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Author contributions D.T. conceptualized the study, conducted analyses, and drafted the manuscript. Both D.T. and L.W. contributed to the writing and critically reviewed the manuscript for intellectual content.

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Data availability This study used anonymized patient-level data. The data are not publicly available because of privacy and confidentiality requirements. However, the data could be requested from Alberta Health.

Code availability Not available.

Clinical trial number Not applicable.

Declarations

Ethics approval and consent to participate The study is a part of a health evidence review, commissioned and approved by Alberta Health.

Consent for publication Alberta Health approves publication.

Competing interests The authors declare no competing interests.

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