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Clinical paper

The association of extreme environmental heat with incidence and outcomes of out-of-hospital cardiac arrest in British Columbia: A time series analysis

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Abstract

Background: The impact of extreme heat on out-of-hospital cardiac arrest (OHCA) incidence and outcomes is under-studied. We investigated OHCA incidence and outcomes over increasing temperatures.

Methods: We included non-traumatic EMS (Emergency Medical Services)-assessed OHCAs in British Columbia during the warm seasons of 2020–2021. We fit a time-series quasi-Poisson generalized linear model to estimate the association between temperature and incidence of both EMS-assessed, EMS-treated, and EMS-untreated OHCAs. Second, we employed a logistic regression model to estimate the association between "heatwave" periods (defined as a daily mean temperature > 99th percentile for ≥ 2 consecutive days, plus 3 lag days) with survival and favourable neurological outcomes (cerebral performance category ≤ 2) at hospital discharge.

Results: Of 5478 EMS-assessed OHCAs, 2833 were EMS-treated. OHCA incidence increased with increasing temperatures, especially exceeding a daily mean temperature of 25 °C Compared to the median daily mean temperature (16.9 °C), the risk of EMS-assessed (relative risk [RR] 3.7; 95% CI 3.0–4.6), EMS-treated (RR 2.9; 95%CI 2.2–3.9), and EMS-untreated (RR 4.3; 95%CI 3.2–5.7) OHCA incidence were higher during days with a temperature over the 99th percentile. Of EMS-treated OHCAs, during the heatwave (n = 179) and non-heatwave (n = 2654) periods, 4 (2.2%) and 270 (10%) survived and 4 (2.2%) and 241 (9.2%) had favourable neurological outcomes, respectively. Heatwave period OHCAs had decreased odds of survival (adjusted OR 0.28; 95%CI 0.10–0.79) and favourable neurological outcome (adjusted OR 0.31; 95%CI 0.11–0.89) at hospital discharge, compared to other periods.

Conclusion: Extreme heat was associated with a higher incidence of OHCA, and lower odds of survival and favourable neurological status at hospital discharge.

Keywords: Heat, Heatwave, Out-of-hospital cardiac arrest, Heart arrest

Introduction

The annual incidence of non-traumatic emergency medical services (EMS)-assessed out-of-hospital cardiac arrests (OHCA) is approximately 90 per 100,000 population in the North America.[1] On average, 8.5% of EMS-treated OHCAs survive with favourable neurological outcomes at hospital discharge.[2] However, it is unclear how extreme heat may affect the incidence and outcomes of OHCA.

Extreme heat is associated with increased mortality, but there is limited data supporting how heatwaves are related to OHCA incidence and patient outcomes.[3,4] Over the past century, the average temperature in British Columbia (BC), Canada has increased by an average 1.4 °C.[5,6] There was a period of extreme heat in western

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North America during the summer of 2021, including a Canadian record high temperature of 49.6 °C in BC.[7] Extreme heat events in North American are projected to recur with increased frequency and intensity,[8,9] which is also being witnessed throughout many other regions of the world, consistent with global patterns of climate change. Knowledge of how these events impact population health and emergency services is critical to mitigate future public health burdens.[10,11]

We sought to estimate if extreme heat was associated with OHCA incidence and outcomes. We examined EMS-assessed OHCA overall, as well as EMS-treated and EMS-untreated subgroups, given that heat may impact the conditions which influence the decision of EMS to treat an OHCA (for example, due to prolonged EMS response times during heatwaves), thus potentially impacting these cases to a different degree.

Methods

Study setting

This analysis used prospectively collected data from the BC Cardiac Arrest Registry[12] (approved by the University of British Columbia-affiliated Providence Health Care research ethics board [H15-03059]). BC has a population of approximately 5.2 million people (concentrated in urban and suburban settings),[13] and is divided into five separate health regions. See Supplemental Materials for additional descriptions of study methodology.

Selection of participants

We included consecutive non-traumatic OHCAs from the BC Cardiac Arrest Registry occurring during the warm seasons (June 1st to September 30th) of 2020 and 2021. Cases from the colder seasons were excluded to avoid confounding from cold weather.

Data collection

Trained staff of the BC Cardiac Arrest Registry prospectively identify consecutive non-traumatic EMS-assessed OHCAs, and abstract data into a REDCap database (Vanderbilt University, Nashville).[14] Cases are classified as "EMS-treated" if EMS personnel provide any medical interventions, or otherwise as "EMS-untreated".

We obtained temperature data from the *Historical Climate Data*, the Government of Canada, which contains hourly meteorological data for locations across BC.[15] Humidity and air quality data was from *Environment and Climate Change Canada,* the Government of Canada.[16] For our analysis involving a provincial dataset, we acquired hourly temperature values from each of the five health regions. We identified the most populous center in each health region (Fraser Health region: Surrey; Interior Health Region: Kelowna; Island Health region: Saanich; and, Northern Health Region: Prince George; Vancouver Coastal Health Region: Vancouver), and used hourly temperature data from these five sites to calculate a mean daily temperature value. Similarly, we used the mean daily humidity and air quality values. Humidity was evaluated on a scale of 0 to 100%. Air quality was evaluated using the Air Quality Health Index, a 10-integer scale incorporating hourly ambient concentrations of nitrogen dioxide, fine particulate matter, and ozone.[17] Using the mean daily temperature, humidity, and air quality values from these five regions, we calculated a mean daily values for the province, which was used for the primary analysis (with regional values used for sensitivity analyses).

Variable definitions

The threshold temperature of an extreme heat event can be an absolute threshold based on physiology or relative threshold based on location.[18] For our first analysis, examining daily OHCA incidence, we defined a "heat day" as a day for which the mean temperature was above the 99th percentile. In the second analysis, we examined the association of OHCA outcomes within a "heatwave" period, in comparison to other days. A "heatwave" was defined as at least two consecutive days in which the mean temperature was above the 99th percentile, plus three "lag days" (according to previous definitions[19,20]). Lag days are commonly included in heat-based analyses to account for persistent effects of heat-related morbidity and mortality after the extreme heat has abated.[21,22]

Data analysis

We used Microsoft Excel 2016 (Microsoft Corp, Redmond, WA, USA) and R (Foundation for Statistical Computing, Vienna, version 3.2.4) for data analysis. We described continuous variables as medians (with inter-quartile range [IQR]) and categorical variables as counts (with percentages). We reported OHCA incidence and characteristics and outcomes of the heatwave period(s), as well as non-heatwave days, in the warm seasons of both 2020 and 2021.

Quasi-Poisson Regression Model Examining the Cumulative Relative Risk for OHCA Incidence: In the first main analysis we examined the daily incidence of EMS-assessed, EMS-treated, and EMS-untreated OHCA, as a function of the range of daily mean temperatures, adjusted for humidity and air quality (given potential confounding[30])· We used a time-series quasi-Poisson generalized linear model, given that outcomes were overdispersed. To account for the delayed and non-linear effects of temperature on outcomes, we built a cross-basis matrix for the mean temperature using a distributed lag non-linear model (DLNM).[23] The DLNM was implemented in the dlnm library for the R program.[24] The cumulative effects of temperature within a few days after an exposure can be estimated by DLNM while it accounts for the collinearity of temperature using a smooth spline. According to the QAIC (Quasi-Akaike's Information Criterion),[25] we specified a cubic spline with three degrees of freedom and a degree of one for the mean temperature, and defined the delayed effect of temperature as three lag strata, assuming the effects as constant within each stratum.[19] To take into account that the effect of excessive heat may impact mortality for some days after exposure[21], we specified the lagged effect of temperature up to three days ("lag days").[22] For this model with quasi-Poisson family, the likelihood function is not explicitly defined, making it impossible to calculate AIC (Akaike's Information Criterion).[25] We used the QAIC by calculating the deviance of the quasi-Poisson model, as an alternative for AIC. We incorporated the cross-basis matrix for the mean temperature and other covariates in the regression model: a natural cubic spline for day of the year and humidity with two degrees of freedom based on QAIC, a linear term of air quality, and the day of the week as a factor variable.[26] To visualize the cumulative association between increasing mean daily temperature and outcomes, we plotted the RR of the daily mean temperature on outcomes (with 95% CI), demonstrating the risk at each temperature compared to that of the provincial median temperature.

To quantify the effect of the excessive heat on EMS-assessed, EMS-treated, and EMS-untreated OHCA incidence, we calculated cumulative relative risks (RRs) of these outcomes (with 95%

confidence intervals [CI]) over three lag days for increased temperatures, comparing risks of "heat days" (days with daily mean temperatures > 99th percentile) to the median value for the daily mean temperature during the entire study period.

Given that the mean provincial temperature, humidity, and air quality values may differ from conditions experienced in each region, we performed region-specific sensitivity analyses, repeating the primary analysis using data only from each of the five health regions.

Multivariable logistic Regression Model Examining OHCA Outcomes: In the second main analysis, EMS-treated OHCAs were dichotomized based on the date of OHCA occurrence: heatwave period(s) vs. non-heatwave period(s). We examined patient outcomes of survival and favourable neurological outcome at hospital discharge, defined as a cerebral performance category (CPC) score ≤ 2.[27] We performed a logistic regression analysis to estimate the association between the heatwave(s) period and patient outcomes, compared to non-heatwave period(s). We adjusted the model for Utstein variables (age, sex, initial EMS recorded rhythm [shockable vs. non-shockable], witnessed status [bystander vs. EMS vs. none], bystander CPR, location of the event (public [including street, public building, place of recreation, airport, casino, or other public location] vs. non-public [including house, apartment/condo, industrial site, non-acute healthcare facility, or other private location]), and 9–1-1 call-to-EMS arrival interval.

Results

Characteristics and outcomes of study subjects

During 2020 and 2021, there were a total of 16,038 EMS-assessed OHCAs in BC. After restricting the cohort to the warm season, we included 5478 EMS-assessed OHCAs (Fig. 1). Over the study timeframe, a single period (June 27–29, 2021, plus 3 lag days) satisfied our definition for "heatwave". Overall, 451 (8.2%) EMS-assessed OHCAs were in the heatwave period and 5027 (92%) were in the non-heatwave period. Table 1 shows the daily temperatures and OHCA incidence rates of the heatwave and non-heatwave periods.

Table 2 (and Supplemental Table 2) shows characteristics and outcomes of EMS-untreated cases; during the heatwave period cases tended to be older, were more often female, and were more commonly identified in the morning hours, in comparison to the non-heatwave period.

Table 3 (and Supplemental Table 3) shows the characteristics and outcomes of EMS-treated OHCAs. In the heatwave period, cases tended to be older, had bystander CPR less often, were less frequently found in public locations, and were most likely to be identified in the evening hours. While response times of the first EMS unit were similar, during the heatwave both Basic Life Support (BLS)- and Advanced Life Support (ALS)-trained unit response times tended to be longer, with fewer cases receiving care from an ALS paramedic unit. In the heatwave period, 30/179 (17%) achieved prehospital ROSC, 4/179 (2.2%) survived to hospital discharge, and 4/179 (2.2%) had favourable neurological outcomes at hospital discharge. In the non-heatwave period, 848/2646 (32%) achieved prehospital ROSC, 270/2630 (10%) survived to hospital discharge, and 241/2613 (9.2%) had favourable neurological outcomes at hospital discharge.

Quasi-poisson regression model examining the cumulative relative risk for OHCA incidence

Fig. 2 shows the cumulative association of daily EMS-assessed (1A), EMS-treated (1B), and EMS-untreated (1C) OHCA incidence. These curves were overall non-linear and J-shaped with higher risks of OHCA incidence with increasing temperatures, especially above a daily mean temperature of 25 . Results of region-specific models were consistent (Supplemental Figs. 1-5).

In comparison to the median value for the daily mean temperature of the entire study period (16.9), the relative risk during heat days of EMS-assessed, EMS-treated, and EMS-untreated OHCA were 3.7 (95% CI 3.0–4.6), 2.9 (95% CI 2.2–3.9), and 4.3 (95% CI 3.2–5.7) times higher, respectively. Region-specific models were consistent (Supplemental Table 3).

Multivariable logistic regression model examining OHCA outcomes

In the heatwave period, EMS-treated OHCAs had a 72% decrease in the odds of survival to hospital discharge (adjusted OR 0.28; 95% CI 0.10–0.79) and 69% decrease in the odds of a favourable

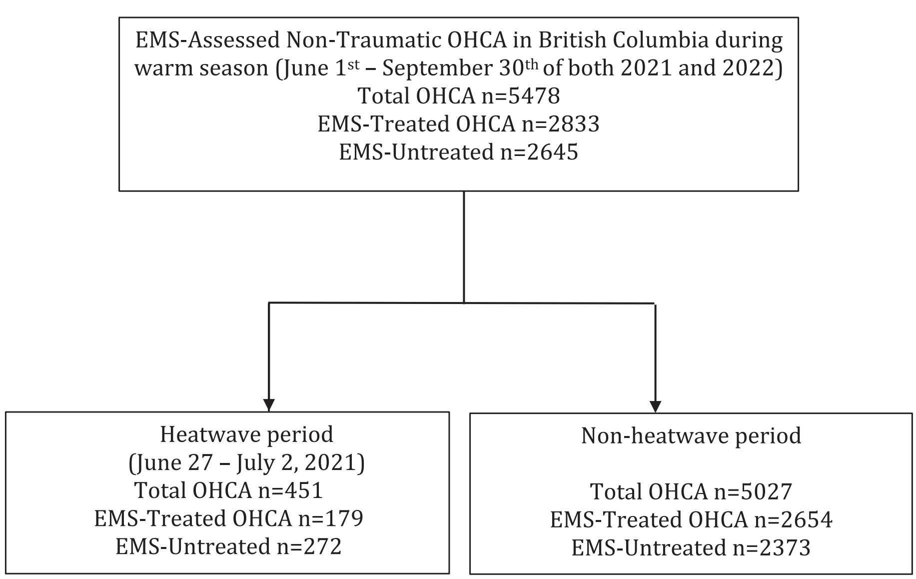

Fig. 1 – Flow chart of inclusion and exclusion criteria. Creation of Study Cohort – Inclusion and Exclusion Criteria.

Table 1 – Daily temperatures and OHCA Incidence of the Heatwave and Non-Heatwave Periods.

	Non-Heatwave Period n = 238 days Median (IQR)	Heatwave Period n = 6 days Median (IQR)
Temperature (daily),		
Mean[1] temperature	16.8 (15.0–19.4)	25.4 (23.2–27.3)
Highest temperature,	22.2 (19.5–25.4)	32.2 (28.4–36.2)
Lowest temperature,	11.7 (9.9–13.3)	18.1 (18.0–19.0)
Humidity (daily mean[1]), %	70.1 (64.7 – 76.2)	57.4 (53.2–59.5)
Air Quality Health Index (daily mean[1])	1.7 (1.5–1.9)	2.4 (1.8–3.0)
Daily OHCA Incidence, per 100,000		
EMS-assessed OHCA	0.40 (0.35–0.47)	1.06 (0.78–1.66)
EMS-treated OHCA	0.21 (0.17–0.25)	0.35 (0.27–0.88)
EMS-untreated OHCA	0.19 (0.15–0.23)	0.78 (0.47–0.86)

IQR, interquartile range; , degrees Celsius.

[1] For temperature, humidity, and air quality index, hourly data were used to calculate a mean value for the entire day.

Table 2 – Untreated patient characteristics divided by the non-heatwave and heatwave period.

Variable	Non-Heatwave summer days[1] 238 days OHCA n = 2373 (10.0/day) n (%) or median (IQR)	**Heatwave Period**[2] 6 days OHCA n = 272 (45.3/day) n (%) or median (IQR)
Patient Characteristics		
Age, years	65 (52–79)	74 (65–84)
Female sex	712 (30)	124 (46)
Time of Day of 9–1-1 Call		
Morning	918 (39)	183 (67)
Afternoon	854 (36)	86 (32)
Evening	425 (18)	16 (5.9)
Night	176 (7.4)	21 (7.7)
EMS Response Intervals, minutes		
9-1-1 call-to-first EMS unit	10.5 (7.0–18.5)	10.3 (7.0–16.3)
Past Medical History & Substance/Opioid Use[3]		
History of non-prescription drug use	188 (7.9)	3 (1.1)
Prescribed opioids	55 (2.3)	7 (2.6)
History of cancer	100 (4.2)	7 (2.6)
Recent non-prescription drug use	229 (9.7)	1 (0.4)
None of the above	1872 (79)	231 (85)
Reasons for non-treatment		
Written DNR	286 (12)	31 (12)
Terminal illness	61 (2.6)	1 (<1)
Verbal DNR	18 (<1)	0
Obvious death or non-recent CA	1994 (84)	236 (88)
Other/Unclear	13 (<1)	0

IQR, interquartile range; Morning: 06:00:00–11:59:59; Afternoon: 12:00:00–17:59:59; Evening: 18:00:00–23:59:59; Night: 00:00:00–05:59:59; EMS, emergency medical services (including Fire first responders); BCEHS, British Columbia Emergency Health Services (Paramedics); ALS, advanced life-support; Obvious death: showing signs of rigor mortis, lividity, or tissue decomposition; non-recent CA: prolonged time from OHCA to EMS assessment; DNR, do-not-resuscitate includes the provincial "No Cardiopulmonary Resuscitation" form, "Medical Orders for Scope of Treatment", an Advanced Directive, or a "Notification of Expected Death" form; verbal DNR: next-of-kin verbally request no resuscitation.

[1] Includes the dates of: June 1 – September 30, 2020 (122 days) and June 1–26, July 3-September 30, 2021 (116 days); 2020 EMS untreated n = 1270 (10.4/day); 2021 EMS untreated n = 1103 (9.5/day).

[2] Includes the dates of: June 27 – July 2, 2021 (6 days); n = 272 (45.3/day).

[3] Abstractors select "all that apply", thus, individual patients may be represented in multiple categories, with the exception of "none of the above".

Table 3 – EMS-treated patient characteristics divided by non-heatwave and heatwave periods.

Variable	Non-Heatwave Period[1] 238 days OHCA n = 2654 (11.2/day) n (%) or median (IQR)	**Heatwave Period**[2] 6 days OHCA n = 179 (29.8/day) n (%) or median (IQR)
Patient Characteristics		
Age, years	63 (48 – 77)	73 (57 – 83)
Female Sex	827 (31)	72 (40)
Initial Rhythm		
Shockable VF/pVT	389 (15)	23 (13)
Non-shockable	2169 (82)	144 (80)
Missing	96 (3.6)	12 (6.8)
Witnessed Status		
Bystander witnessed	975 (37)	56 (31)
EMS witnessed	241 (9.1)	25 (14)
Bystander CPR	1626 (67[3])	94 (61[3])
Location		
Public	498 (19)	12 (6.7)
Private	2082 (78)	160 (89)
Semi-Private	71 (2.7)	8 (4.5)
Time of Day of 9-1-1 Call		
Morning	765 (29)	48 (27)
Afternoon	779 (29)	40 (22)
Evening	684 (26)	64 (36)
Night	426 (16)	27 (15)
EMS Response Intervals, minutes		
9-1-1 call-to-first EMS	7.4 (5.7–10.6)	7.4 (6.1–11.3)
9-1-1 call-to-first Paramedic Unit	9.3 (6.7–13.5)	11.5 (7.3–20.1)
9-1-1 call-to-ALS Unit	13.5 (9.4–19.9)	16.8 (11.2–29.1)
ALS Present	1944 (73)	112 (63)
Past Medical History & Substance/Opioid Use[4]		
History of non-prescription drug use	361 (14)	9 (5.0)
Prescribed opioids	105 (4.0)	7 (3.9)
History of cancer	166 (6.3)	13 (7.3)
Recent non-prescription drug use	568 (21)	8 (4.5)
None of the above	1797 (68)	147 (82)
Outcomes		
ROSC	848 (32)	30 (17)
Survival to hospital discharge	270 (10)	4 (2.2)
Favorable neurological outcome at hospital discharge [5]	241 (9.2)	4 (2.2)

IQR, interquartile range; VF, ventricular fibrillation; pVT, pulseless tachycardia; EMS, emergency medical system (including fire-rescue units, and Paramedic units of either Basic Life Support or Advanced Life Support [ALS] training); Public location: street, public building, place of recreation, airport, casino, other public location; Private location: house, apartment/condo, other private location; Semi-private location: healthcare facility, nursing home, industrial site; Morning: 06:00:00–11:59:59; Afternoon: 12:00:00–17:59:59; Evening: 18:00:00–23:59:59; Night: 00:00:00–05:59:59; ROSC, return of spontaneous circulation; neuro, neurological.

[1] Includes the dates of: June 1-September 30, 2020 (122 days) and June 1–26, July 3-September 30, 2021 (116 days); 2020 EMS-treated OHCA n = 1350; 2021 EMS-treated OHCA n = 1304.

[2] Includes the dates of: June 27-July 2, 2021; EMS-treated OHCA n = 179.

[3] Denominator for the proportion with bystander CPR is the number of cases that were not witnessed by EMS.

[4] Abstractors select "'all that apply", thus individual patients may be represented in multiple categories, with the exception of "none of the above".

[5] Note: missing neurological outcomes are only in those who survived to hospital discharge.

neurological outcome at hospital discharge (adjusted OR 0.31; 95% CI 0.11–0.89), compared to the non-heatwave period.

Discussion

Over a 2-year period in British Columbia, we investigated the impact of heatwave temperatures on the incidence and outcomes of non-traumatic OHCA. Our data indicates that OHCA incidence remains relatively constant in most temperatures, however as temperatures increase to the extreme there is a multi-fold increase in OHCA incidence, including both EMS-treated and EMS-untreated cases. EMS-treated OHCAs occurring during periods of extreme heat had a decreased odds of survival and survival with favourable neurological outcome at hospital discharge, in comparison to normal temperature periods. These data demonstrate the relationships between extreme heat and OHCA incidence and outcomes, and may assist EMS agencies and other policy stakeholders with resource planning,

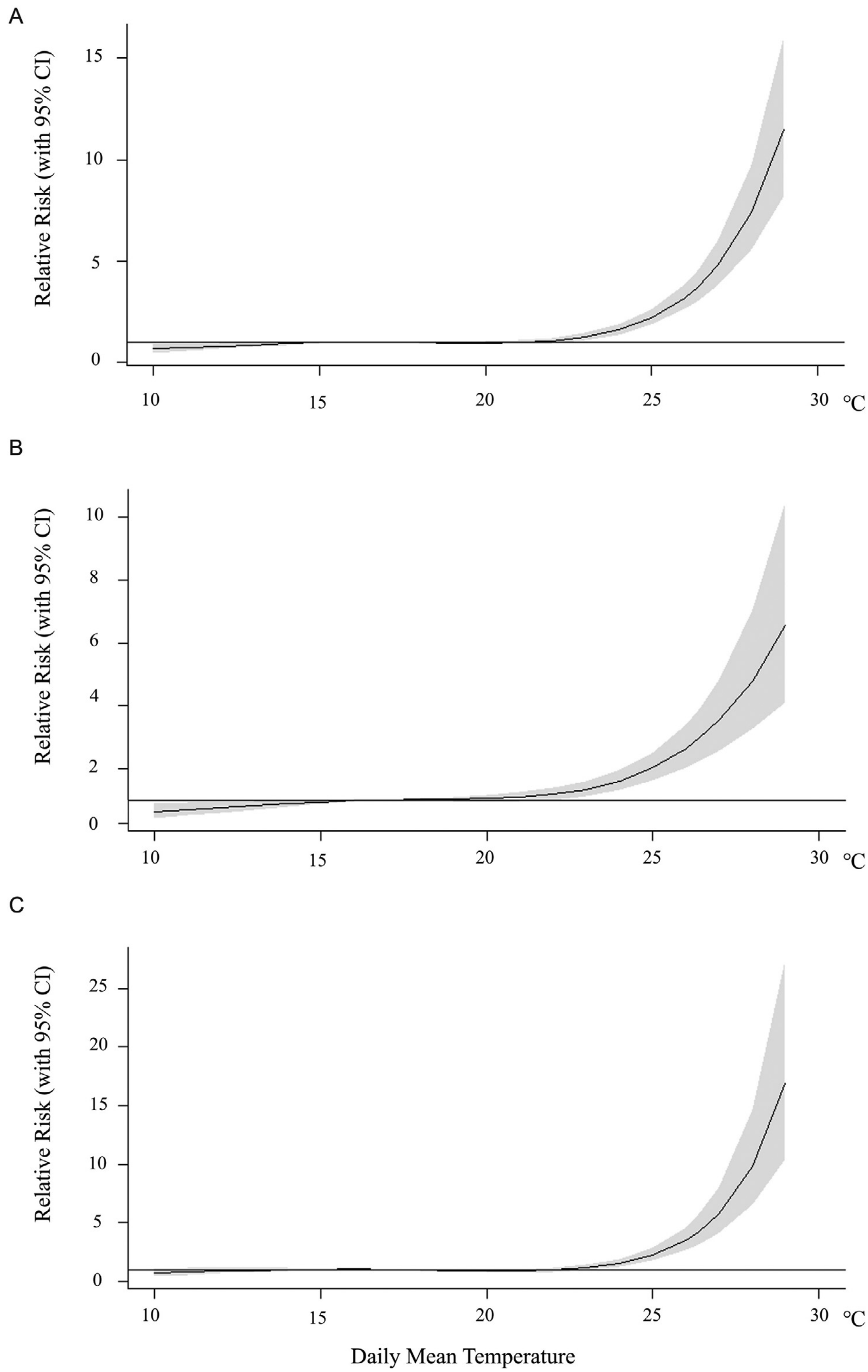

Fig. 2 – The Association between Daily Mean Temperature and EMS-Assessed (A), EMS-treated (B), and EMS-untreated (C) OHCA Incidence. Shading demonstrates the 95% confidence interval (CI). A Relative Risk > 1 indicates a higher incidence of OHCA.

especially since extreme heat events can be predicted in advance, and may occur in increased frequency in the future given the effects of climate change.

Over a range of temperatures, we observed an increase in the cumulative relative risk for the incidence of OHCA during periods of extreme heat, compared to periods with average temperatures.

This increase was most pronounced above a daily mean temperature of 25 . Among untreated heatwave-period OHCAs, cases were older than during non-heatwave days, and two thirds were discovered in the morning, with reasons for non-treatment being a prolonged period until discovery in nearly all cases. Similarly, for EMS-treated cases, the median age was higher for heat-wave cases, with fewer cases in public locations, suggesting excess cases may have been of advanced age and perhaps stranded in hot residences due to decreased mobility, for which the arrest etiology may be less likely to be primary cardiac. However, interestingly, the proportion of cases with initial shockable rhythms was similar, arguing against this hypothesis. Further, although we did not have extensive data on comorbidities, we found that the proportion of untreated cases with malignancy, DNR orders, and terminal illness was similar between periods.

Our data demonstrates a bleak picture with regards to OHCA survival during the heat wave. OHCA incidence increased substantially with a disproportionately greater decrease in survival. Even if 100% mortality in the excess OHCAs during a heatwave period is assumed—if one was to assume that these cases were frail elderly individuals—survival was still less than expected. While the factors are beyond the scope of this analysis, we postulate that they arise from a combination of direct health effects of increased temperature, differences in characteristics in the OHCA cases during the heatwave, and decreased ability of the health system to respond, given the substantial increase in patients. To support the latter factor, we found that, while Fire Department responders had a similar response time, BLS and especially ALS units had a longer response time, which may have impacted outcomes.

We found a lower proportion of cases (in EMS-assessed and EMS-treated categories) during the heatwave who had a history of non-prescription drug use or evidence of recent non-prescription drug use at the scene. Individuals using non-prescription drugs may be considered a vulnerable group of society, and thus one may have hypothesized that the heatwave may have resulted in worse outcomes for this group, however this does not appear to have been the case. A previous study reported that cocaine-related mortality increased with a maximum daily temperature > 31.1 °C, however that opioid overdose deaths were not associated with environmental temperature.[28]

North American heat events have been little described with respect to OHCA; while there are population, regional and analytic differences, our findings are consistent with other regional data. Doan et. al. reported that OHCA risk in Australia increased with higher heat thresholds. When heatwaves were defined as the daily average temperature above the 99th percentile (28.2 °C), the risk of OHCA increased 1.48 times, compared to 1.25 times when the threshold was at the 95th percentile (26.7 °C).[29] In Japan, Onozuka et. al. found an association between temperature > 99% percentile and a 1.21 relative risk of OHCA incidence, compared to the daily mean summer temperature (25 °C).[30] Similarly, during a 2003 heatwave in Paris (with a 2-week mean temperature of 38.1 °C) OHCA incidence increased 2.5-fold.[31] Kang et. al. analyzed 50,318 OHCAs from seven Korean cities, and reported that a daily maximal temperature > 33 °C was associated with a 16% increase of OHCA risk.[4] Unsurprisingly, people greater than 65 years were more susceptible and adverse events were observed up to 4 consecutive days after the heatwave. Finally, Chen reported on six cities from varying climactic regions in China to demonstrate that both extremely hot and cold temperatures led to increased risk of out-of-hospital cardiac death (relative risk 1.49 comparing 1st and 25th percentile, and relative risk 1.53 comparing 99th and 75th percentiles), with additional risk increased in males, elderly, and less-educated individuals.[32] Similar associations have been found between increased heat and overall cardiovascular-related mortality and morbidity.[33] Conversely, Seah et. al found that decreased temperature was associated with an increased NSTEMI risk.[34] We extend the existing literature by describing the impact of heatwave temperatures on OHCA incidence, as well as neurologically favourable survival, in North America.

Interestingly, while increased OHCA incidence is consistently associated with increased temperatures, the absolute temperatures defining these thresholds vary between different regions. Given that individuals are generally prepared for their typical climate (regardless of the actual temperature), the key factor is likely the degree to which a temperature varies from that average—at which point individuals have difficulty coping and emergency health systems may become overburdened. The threshold at which a community becomes adversely affected by extreme heat is likely dependent on heat mitigation strategies (e.g., air conditioning availability) and ability of emergency systems to respond to heightened volumes.

We report several limitations. We examined the association of environmental temperature with incidence and outcomes, however the actual temperature experienced by the individual experiencing a cardiac arrest may have differed from the temperature used in the analysis. For example, many cases may have been indoors, which may have been cooler or hotter than the exterior temperature. We did not consider socioeconomic factors such as income or wealth, building construction, or living arrangements (such as living by oneself). Our data for the 9-1-1 call time reflects the time the caller was connected with the BCEHS dispatch center. We did not have data on the time that the call was first initiated or the time the caller was first in contact with the primary answering centre. We cannot account for factors such as high non-OHCA call volumes or EHS crew fatigue, either of which could have changed EHS actions during the heat event. Our analysis looking at individual regions and the extremes of temperatures were limited by small sample size. Our analysis included a single "heatwave"; other heatwave events may differ in effects. Finally, we cannot extrapolate our results to regions with alternate prehospital or medical systems, or in settings with differing community characteristics.

Conclusion

Extreme heat was associated with an increased incidence of OHCA overall, and lower odds of survival and favourable neurological outcomes, compared to non-heatwave periods, among EMS-treated OHCAs.

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CRediT authorship contribution statement

Laiba Khan: Writing – original draft, Methodology, Investigation, Data curation. **Takahisa Kawano:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Jacob Hutton:** Investigation, Methodology, Writing – review & editing. **Michael Asamoah-Boaheng:** Writing – review & editing, Methodology, Investigation. **Frank X. Scheuermeyer:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Michael Christian:** Writing – review & editing, Methodology, Investigation. **Leon Baranowski:** Writing – review & editing, Methodology, Investigation. **David Barbic:** Writing – review & editing, Methodology, Investigation. **Jim Christenson:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Brian Grunau:** Conceptualization, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100560.

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