



# Risk of hospitalization for fire-related burns during extreme cold weather



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## ABSTRACT

**Background:** Environmental factors are important predictors of fires, but no study has examined the association between outdoor temperature and fire-related burn injuries. We sought to investigate the relationship between extremely cold outdoor temperatures and the risk of hospitalization for fire-related burns.

**Material and methods:** We carried out a time-stratified case-crossover study of 2470 patients hospitalized for fire-related burn injuries during cold months between 1989 and 2014 in Quebec, Canada. The main exposure was the minimum outdoor temperature on the day of and the day before the burn. We computed odds ratios (OR) and 95% confidence intervals (CI) to evaluate the relationship between minimum temperature and fire-related burns, and assessed how associations varied across sex and age.

**Results:** Exposure to extreme cold temperature was associated with a significantly higher risk of hospitalization for fire-related burns. Compared with 0 °C, exposure to a minimum temperature of −30 °C was associated with an OR of 1.51 (95% CI 1.22–1.87) for hospitalization for fire-related burns. The associations were somewhat stronger for women, youth, and the elderly. Compared with 0 °C, a minimum temperature of −30 °C was associated with an OR for fire-related burn hospitalization of 1.65 for women (95% CI 1.13–2.40), 1.60 for age < 25 years (95% CI 1.02–2.52), and 1.73 for age ≥ 65 years (95% CI 1.08–2.77).

**Discussion:** Extremely cold outdoor temperature is a risk factor for fire-related burns. Measures to prevent fires should be implemented prior to the winter season, and enhanced during extreme cold.

## 1. Introduction

Fire-related burn injuries are a major global health concern (Othman and Kendrick, 2010; Turner et al., 2017). Fires in 2004 alone accounted for nearly 11 million burn injuries requiring hospital admission (Mathers et al., 2008), with an estimated 0.14 hospitalizations per 100,000 persons in high income countries (Sadeghi-Bazargani et al., 2017). Burns are an economic burden for healthcare and society, and the associated costs are increasing (Banfield et al., 2015; Parachute, 2015). Preventing burns is a major challenge, as common risk factors such as age, socioeconomic status, smoking and substance use are hard to target and explain only a portion of cases (Peck, 2011; Turner et al., 2017). Better prevention of fire-related burns may require closer attention to the surrounding environment. Few studies however have paid attention to environmental exposures as a potential target for prevention, in particular extremely cold temperatures.

A growing number of studies report a higher occurrence of burn

injuries during winter (Othman and Kendrick, 2010; Peden et al., 2008). In countries with cold climates, fires are more common during winter (Rohrer-Mirtschink et al., 2015), but the association of cold temperature with risk of burns has not yet been studied. Extremely cold weather is associated with high electricity consumption, hazardous use of heating sources such as kerosene heaters, fireplaces and wood stoves, and increased time spent indoors (Othman and Kendrick, 2010; Peck, 2011). Cold exacerbates energy consumption, and excessive energy demand has the potential to trigger fires and account for a large proportion of burn injuries. While average temperatures are expected to rise with climate change (Pachauri et al., 2014), extreme cold events are nonetheless expected to continue and possibly increase in northern regions (Liu et al., 2012; Tang et al., 2013). In light of the public health implications, we investigated the association between temperature during cold months and the risk of hospitalization for fire-related burn injury in a large Canadian province with subzero winter weather.

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## 2. Materials and methods

### 2.1. Study population

We retrieved data for 2470 hospitalizations for fire-related burn injury from 1989 to 2014 in the Maintenance and Use of Data for the Study of Hospital Clientele registry for the province of Quebec, Canada (Ministère de la Santé et des Services sociaux, 2016). This database compiles all discharge summaries for individuals hospitalized for burns in the province. Approximately one quarter of Canadians live in Quebec. We restricted the study to hospital admissions between November and April, the coldest months of the year in Quebec. We excluded hospitalizations between May and October when temperatures are much warmer, and unlikely to be associated with excessive energy demand due to cold.

### 2.2. Burns

We identified individuals with fire-related burn injuries using accident codes of the 9th and 10th Revisions of the International Classification of Diseases (ICD-9 E890-E899 and E988.1; ICD-10 X00-X09 and Y26). These codes include burns and smoke inhalation injuries that occurred in residential and nonresidential locations. We used the date of the injury to determine the timing of the burn. When the date of injury was missing (7.7%), we used the date the patient presented to the emergency department (4.7%) or was admitted (3.0%).

### 2.3. Exposure

We extracted hourly meteorological data from Environment Canada weather records collected from 18 monitoring stations in Quebec. Each station corresponded to the health region where the patient resided. The primary exposure was the coldest temperature reached on the day of the burn or the day before. The secondary exposure was cumulative cold, defined as the total number of days in which temperature was below  $-15^{\circ}\text{C}$ , or  $-25^{\circ}\text{C}$ , during the week preceding the burn.

### 2.4. Covariates

We adjusted for total daily snowfall (0, 1–4,  $\geq 5$  cm) and public holidays (yes, no), as fires may be more common at such times. Data suggest that snow may damage electrical infrastructures and cause power outages (Klinger et al., 2014), increasing the risk of fires due to use of candles and indoor heaters. Thus, snowfall may be a confounder. We investigated two potential effect modifiers, sex and age ( $< 25$ , 25–64,  $\geq 65$  years), in the event that the association of temperature with fire-related burn varied by subgroup. Studies suggest that certain populations, such as children and the elderly, are potentially more vulnerable to fire-related burns (Othman and Kendrick, 2010; Peck, 2011; Turner et al., 2017).

### 2.5. Study design

We used a time-stratified case-crossover study design to evaluate the association between cold temperature and hospitalization for fire-related burn injury. This design shares features with the case-control study, and is suited for the study of short-lived exposures and acute health events (Levy et al., 2001). The distinctive characteristic of the case-crossover design is that patients act as their own controls (Maclure and Mittleman, 2000). Patients are self-matched such that there is automatic adjustment for confounders that change little over time, whether or not data on confounders are available (Janes et al., 2005; Maclure and Mittleman, 2000). Thus, the case-crossover design automatically adjusts for covariates such as smoking and socioeconomic status. In the case-crossover design, the temperature exposure on the day of the burn is compared with temperature on control days.

We applied a time-stratified approach to select control days. Control days consisted of the same day of the week during the same month and year as the day of the burn (Levy et al., 2001). For example, if the burn occurred on a Tuesday in December 2001, control days were all other Tuesdays in December of the same year. Therefore, there were up to 4 control days for each case. This control selection strategy has been shown to counter bias associated with seasonal and temporal variation in temperature (Janes et al., 2005).

### 2.6. Data analysis

In the primary analysis, we estimated the impact of cold temperature on the likelihood of hospitalization for fire-related burns in the entire sample using conditional logistic regression. In secondary analyses, we stratified the data by sex and age group. We expressed the results as odds ratios (OR) and 95% confidence intervals (CI) for the relationship between temperature and fire-related burn hospitalization, adjusting for snowfall and public holidays. We used cubic splines with knots at the 5th, 50th, and 95th percentiles to analyze minimum temperature as a continuous variable, without assuming linearity (Durrleman and Simon, 1989). Splines have the advantage of modeling temperature across its entire range without forcing a predefined form (Durrleman and Simon, 1989).

Several sensitivity analyses were performed. The association with the mean temperature, rather than minimum temperature, was investigated in the event that mean temperature better captured trends in the data. The analysis for temperature the day of the burn was performed separately from temperature the day prior, to determine if associations differed. The analysis was restricted to much colder months, including December, January, and February, to determine if outlying months with somewhat warmer temperatures masked any associations. Finally, the association between temperature and hospitalization for fire-related burns was examined for rural versus urban place of residence, as remote areas may have less access to fire prevention services. Rural areas contain fewer than 10,000 inhabitants (Auger et al., 2009).

Statistical analyses were carried out using the restricted cubic spline macro in SAS version 9.3 (SAS institute Inc., Cary, NC) (Heinzel and Kaider, 1997). The institutional review board of the University of Montreal Hospital Centre waived the requirement for ethics as the data were de-identified. This study complied with the Tri-Council Policy Statement for ethical conduct of research involving humans in Canada.

## 3. Results

There were a total of 2470 patients hospitalized for fire-related burns between 1989 and 2014, including 1342 (54.3%) during temperatures between 0 and  $-14.9^{\circ}\text{C}$  and 893 (36.2%) during temperatures of  $-15^{\circ}\text{C}$  or less (Table 1). A third of patients (35%) were exposed to at least 3 days of temperature below  $-15^{\circ}\text{C}$  during the week before their burn. Among all hospitalized patients, approximately 10% were admitted to a burn unit. Females accounted for 34.3% of admissions, and persons aged  $< 25$  and  $\geq 65$  years represented 21.7% and 21.3% of patients, respectively.

In regression models, colder temperature was associated with a higher likelihood of hospitalization for fire-related burns (Fig. 1). Compared with  $0^{\circ}\text{C}$ , exposure to a temperature of  $-30^{\circ}\text{C}$  was associated with an OR of 1.51 for fire-related burn hospitalization (95% CI 1.22–1.87) after adjusting for total snowfall and public holidays. Statistically significant associations were present for both sexes, but the strength of the relationship was somewhat greater for women (Fig. 2). Compared with  $0^{\circ}\text{C}$ , exposure to a temperature of  $-30^{\circ}\text{C}$  was associated with an OR of 1.65 for women (95% CI 1.13–2.40) and an OR of 1.43 for men (95% CI 1.10–1.86).

Cold temperature was associated with fire-related burn hospitalization for all age groups, but associations were slightly stronger for

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