Environmental Research 134 (2014) 339–344

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Summer outdoor temperature and occupational heat-related illnesses in Quebec (Canada)

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ARTICLE INFO

Article history:
Received 26 May 2014
Received in revised form
22 July 2014
Accepted 24 July 2014
Available online 7 September 2014

Keywords:
Ambient temperature
Workers
Heat-related illnesses
Compensation data
Climate change

ABSTRACT

Background: Predicted rise in global mean temperature and intensification of heat waves associated with climate change present an increasing challenge for occupational health and safety. Although important scientific knowledge has been gathered on the health effects of heat, very few studies have focused on quantifying the association between outdoor heat and mortality or morbidity among workers.
Objective: To quantify the association between occupational heat-related illnesses and exposure to summer outdoor temperatures.
Methods: We modeled 259 heat-related illnesses compensated by the Workers' Compensation Board of Quebec between May and September, from 1998 to 2010, with maximum daily summer outdoor temperatures in 16 health regions of Quebec (Canada) using generalized linear models with negative binomial distributions, and estimated the pooled effect sizes for all regions combined, by sex and age groups, and for different time lags with random-effect models for meta-analyses.
Results: The mean daily compensation count was 0.13 for all regions of Quebec combined. The relationship between daily counts of compensations and maximum daily temperatures was log-linear; the pooled incidence rate ratio (IRR) of daily heat-related compensations per 1 °C increase in daily maximum temperatures was 1.419 (95% CI 1.326 to 1.520). Associations were similar for men and women and by age groups. Increases in daily maximum temperatures at lags 1 and 2 and for two and three-day lag averages were also associated with increases in daily counts of compensations (IRRs of 1.206 to 1.471 for every 1 °C increase in temperature).
Conclusion: This study is the first to quantify the association between occupational heat-related illnesses and exposure to summer temperatures in Canada. The model (risk function) developed in this study could be useful to improve the assessment of future impacts of predicted summer outdoor temperatures on workers and vulnerable groups, particularly in colder temperate zones.

1. Introduction

Climate changes are undeniable and their potential impacts on human health are becoming increasingly important among scientific concerns and public health policies. Climate scenarios project an increase in global mean temperature and in the frequency and intensity of heat waves over most areas around the world in the near future (IPCC, 2013, 2014).

Several epidemiological studies have been conducted on the effects of heat on mortality and morbidity in the general population (Basu, 2009; Ye et al., 2012). These studies have usually shown a non-linear increase in mortality and morbidity, over a city-specific summer temperature threshold. With global warming, heat exposure may present an increasing challenge for public health.

Heat exposure is also associated with health issues among workers. During the 2003 and 2006 heat waves in France, 15 and 8 deaths caused by hyperthermia were reported among workers, respectively (INRS, 2009; Buisson, 2009), while in the United States, 423 deaths were attributed to heat stroke in the workplace between 1992 and 2006 (CDC, 2008). Industrial sectors with

Abbreviations: CCDO, Canadian Classification Dictionary of Occupations; CI, Confidence interval; IRR, Incidence rate ratio; NAICS, North American Industrial Classification System; WCB, Workers' Compensation Board.

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http://dx.doi.org/10.1016/j.envres.2014.07.018
0013-9351/

outdoor working activities, such as construction, agriculture, forestry, fishing, hunting and public services, present higher risks of death on hot days (Buisson, 2009; CDC, 2008; INRS, 2009). Descriptive morbidity studies, carried out on the working population of Washington State between 1995 and 2005 (Bonauto et al., 2007), and on working populations of the mining and the forestry sectors (Donoghue et al., 2000, 2004; Maeda et al., 2006), reported higher incidence of heat-related illnesses during the warmer months of the year and in specific occupations and/or sub-sectors.

Although important scientific knowledge has been gathered on the health effects of heat among workers (for a review, Jay and Kenny, 2010), very few studies have focused on quantifying the association between outdoor heat and heat illnesses. The risk function for the association between average summer temperatures and the number of occupational heat-related deaths was estimated in two studies; in the United States, the risk of on-duty coronary heart disease mortality among firefighters was not associated with increasing temperatures during months with average temperatures above 5 °C, between 1994 and 2004 (Mbanu et al., 2007), while in the whole working population of North Carolina between 1977 and 2001, the rate of heat-related death increased by 37% for each 1 °F increase (corresponding to approximately 77% per 1 °C increase) in average summer temperatures (Mirabelli and Richardson, 2005). In addition, only one pilot study, carried out by the Florida Department of Health (2012) between 2005 and 2009, reported a quantitative relationship between average summer temperatures and heat-related hospitalizations and emergency department visits, where cases were stratified in occupational and non-occupational groups. In this study, incidence rate ratios of 1.62 to 3.58 for every 5 °F increase (corresponding approximately to incidence rate ratios – IRRs - of 1.20 to 1.60 for every 1 °C increase) in daily maximum temperatures were calculated during the summer months in three different areas of the State.

Thus, there is evidence that outdoor heat may produce heat-related illnesses among workers, but these associations are still little explored. The aims of this study are to quantify the association between occupational heat-related compensations and exposure to summer outdoor temperature in Quebec (Canada).

2. Methods

The study analyzed the relationship between daily counts of compensations for heat-related illnesses and daily temperatures for all regions of Quebec (Canada) from May 1st to September 30th of each year between 1998 and 2010. These months cover the period when hot days may happen in Quebec, and the years of study were chosen according to availability of data. The study period consisted in 1989 days over the 13 years, and a total of 31,824 days-regions for analytical purposes (1989 days*16 health regions).

2.1. Compensation data

Compensations for heat-related illnesses were identified from a database of the Workers' Compensation Board (WCB) of Quebec. The WCB is the exclusive provider of compensations for employment injuries and illnesses in Quebec for persons who do work for an employer for remuneration. A few exceptions to this mandatory insurance provision exist in certain circumstances when work is done for the federal government, or for self-employed independent operators. The WCB covers 93% of the Quebec province workforce (AWCBC, 2013).

2.2. Study population

In the WCB database, all injuries are coded according to the nature of injury (i.e. physical characteristic of the injury) according to the Canadian Standards Association, Standard Z795. Compensations with any of the following nature codes were retained for the study period: 07200-Effects of heat or light, 07210-Heat stroke, 07220-Heat syncope, 07280-Multiple effects of heat or light, 07290-Effects of heat or light (not elsewhere classified) including heat-related fatigue and edema. Compensations for contact with hot objects or substances as events leading to the injury were excluded. To avoid misclassification, only compensations for acute heat exposure were retained for analyses. Case recurrence was verified and no claimant was compensated more than once for the same injury within 30 days.

Data obtained for each compensation included the claimant's date of birth and sex, the date of injury, the six-digit postal code of the employer establishment's location, the nature of injury, the North American Industrial Classification System (NAICS) code assigned to the employer's record, and the Canadian Classification Dictionary of Occupations (CCDO) code assigned to the claimant's occupation. When the postal code of the establishment's location was missing or erroneous (less than 7%), the postal code of the regional WCB office was used.

The establishment's postal code was used to classify each claim within one of the 16 health regions of Quebec (see Fig. 1 for health region names) and daily counts of heat-related injury compensations were calculated per health region, stratified by sex, age categories as found in the Labor Force Survey of Statistics Canada (15–24 years old, 25–44 years old, and 45 years old and more), and NAICS sector.

2.3. Meteorological data

Hourly meteorological data were obtained from the Environment Canada Data Access Integration Team (http://loki.qc.ec.gc.ca/DAI/DAI-e.html). One monitoring station, previously identified by Environment Canada as representative of the weather of each region (Martel et al., 2010), was chosen for each health region. The daily maximum hourly values in the 8-hour period between 9h00 and 17h00 were retained for dry bulb temperatures (°C), wet bulb temperatures (°C) and relative humidity (%). Wet bulb temperatures are obtained with a thermometer whose bulb is covered by a wet cloth and differ from the dry bulb temperatures by an amount that depends on the moisture content of the air (EC, 2013). The maximum daily temperature exposure was considered constant among the working population within each health region. For statistical analyses, days with less than 75% of meteorological data (2.5% of 31,824 days-regions) were excluded.

2.4. Statistical analyses

A risk function for the association between daily compensation counts and daily hourly maximum temperatures was developed using a generalized linear model with negative binomial regression for the health region with the highest compensation counts (i.e. Montreal, the largest urban area of the province). To control for temporal trends (i.e. seasonality, long term time trend), the model was adjusted for day of the week, month, year and for the two-week holiday of the construction sector (statutory in Quebec) and public holiday periods. Daily maximum relative humidity in the 8-hour period was also included in the model, since the increase in body temperature induced by heat exposure may be accelerated with high relative humidity (Parsons, 2003; Tanaka, 2007).

In an attempt to find a compromise between providing adequate adjustments and leaving sufficient information from which to estimate the temperature effect, the impact of including the year, relative humidity and temperature as linear or cubic spline function variables was assessed with the likelihood ratio test. In addition, the statistical interaction between temperature and relative humidity was verified. As an offset in the model, the monthly regional working population estimate obtained from the Labor Force Survey of Statistics Canada (table CANSIM 282–0001, http://www5.statcan.gc.ca/cansim/) was used. The model developed for the health region of Montreal is the following:

$$
\begin{aligned}
\text{Ln}\,[E(\text{Yt})] = {} & \ln\,(\textit{Monthly working population estimates}) \\
& + \beta_0 + \beta_{1-6}\textit{Day of the week} + \beta_{7-10}\textit{Month} + \beta_{11}\textit{Year} \\
& + \beta_{12}\textit{Construction sector holiday} + \beta_{13}\textit{Public holiday} \\
& + \beta_{14}\textit{Daily maximum relative humidity over } 8h \\
& + \beta_{15}\textit{Daily maximum temperature over } 8h + \varepsilon
\end{aligned}
$$

where E(Yt) is the expected daily counts of heat-related compensations.

This model (same variables with no spline function) was then applied to the other health regions of Quebec. Thus, IRRs per 1 °C increase, and 95% confidence intervals (CI) per health region were obtained. In very few cases the negative binomial model did not converge and when data were not over-dispersed, Poisson regression was used instead. Pooled effect sizes for Quebec (all health regions combined) were estimated using a random effect model with the method of DerSimonian and Laird for meta-analysis.

The same analyses produced estimates after stratification by sex and age group. The pooled estimates were based on the regions where heat-related compensations were found in every sex/age groups and for which models converged with negative binomial or Poisson regressions using the same adjustment variables. For these analyses, the monthly working population estimates of each subgroup for the whole province were used as the offset, because this information was not available at a regional level. The Cochran Q test was used to assess differences of effect of temperatures between sex and age subgroups (Kaufman and MacLehose, 2013).

As the studied outcomes include health effects that could be related to longer term exposure, such as heat-related fatigue and edema, time-lag phenomena were explored by looking at the association between heat-related compensations and the weather conditions of the current day (lag 0), and also with weather conditions of the two previous days (lag 1 and lag 2). The cumulative effect of two-day (mean