Risk and protective factors for heat-related events among older adults of Southern Quebec (Canada): The NuAge study

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ABSTRACT

OBJECTIVES: Extreme heat is known to increase heat-related health outcomes (HRHO). Incidence and predictors of HRHO were examined among older adults living in Quebec (Canada).

METHOD: This prospective five-year study used data from the first follow-up of community-dwelling older adults from the NuAge cohort (2005–2006), located in three health regions of Southern Quebec. Medical, social and environmental factors, identified in Health Canada guidelines (2011), were used to develop the Older Adult Health Vulnerability Index (OAHVI). HRHO, obtained from a medico-administrative database, were defined as events occurring on a hot day (maximal temperature $\geq 30^{\circ}\text{C}$) between 2006 and 2010. Two outcomes were examined: heat-related 1) emergency department presentations (EDPs) and 2) health events (i.e., EDP, hospitalizations or deaths). Multivariate logistic regressions were performed to assess the associations between risk and protective factors, including OAHVI, and both outcomes.

RESULTS: EDP and hospitalizations were, respectively, 2.6 (95% CI: 2.0–3.5) and 1.7 (95% CI: 1.1–2.6) times more frequent on hot days compared to normal summer days. Low household income and disability increased risk of heat-related EDP (AOR = 3.20; 95% CI: 1.16–8.81 and AOR = 2.66; 95% CI: 1.15–6.14 respectively) and health events (AOR = 2.84; 95% CI: 1.06–7.64 and AOR = 2.51; 95% CI: 1.13–5.61 respectively). High social participation was a protective factor of heat-related EDP (AOR = 0.05; 95% CI: 0.01–0.20) and health events (AOR = 0.04; 95% CI: 0.01–0.18). Older adults presenting ≥ 6 OAHVI factors out of 9 were 7–8 times more at risk of heat-related EDP (OR = 7.40; 95% CI: 1.51–36.19) and health events (OR = 7.77; 95% CI: 1.63–37.20) compared to participants having 0–1 factor.

CONCLUSION: Social participation, reduced autonomy and low income were predictors of HRHO. The OAHVI, also a strong predictor, should help clinicians identify high-risk elderly patients.

KEY WORDS: Extreme heat; risk factors; protective factors; heat stress disorders; morbidity; aged

La traduction du résumé se trouve à la fin de l'article.

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Experts believe that climate change will impact human health by increasing the incidence of diseases and deaths during intense heat periods.¹ These periods can cause a range of heat-related illnesses (HRI) and exacerbate pre-existing chronic conditions.²

Only a few studies have estimated the incidence of heat-related health outcomes (HRHO), all among the general population.^{3–8} Monthly incidence rates of emergency department presentation (EDP) for HRI reached 0.2 per 100,000 person-days in the summer months of 2007 and 2008 in North Carolina.⁸ Those rates likely underestimate the true occurrence of HRI as a result of underdiagnosis⁸ and do not include indirect effect of heat, namely deterioration of pre-existing conditions. Analysis of all-causes HRHO may give a more comprehensive approach to estimate the total burden of heat.⁹ All-causes death, hospitalization and EDP rates varied from 2–3, 14–30 and 115–390 per 100,000 person-days respectively according to health regions in Quebec affected by heat waves in 2010 and 2012 through 2014.^{3–5,7} Death rates varied according to age groups, with older adults being most at risk compared to other age groups.^{3,7}

Heat vulnerability of older adults could be related to multimorbidity (i.e., co-existence of ≥ 2 chronic conditions),

polypharmacy, loss of autonomy, social isolation, altered physiological response to extreme thermal conditions or a compromised ability to sense heat and to manifest appropriate behaviour such as fluid intake.¹⁰ A recent study showed that heat vulnerability was very common in Quebec, with 87% of older

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Quebecers presenting simultaneously with at least two medical, social or environmental conditions previously identified as HRHO predictors.¹¹

To effectively prevent HRHO, it is important to identify key predictors. A meta-analysis of six case-control studies carried out in American and European general populations showed that confinement to bed, inability to care for oneself, not leaving home daily, psychotropic medications, as well as cardiovascular, mental and pulmonary illnesses increased risk of heat-related death, whereas frequent social contact, air conditioning (AC) at home and visiting air-conditioned places decreased the risk.¹² Two case-control studies conducted during the 2003 European heat wave among older adults found that: in Italy,¹³ receiving home public assistance, high co-morbidity and dependency in ≥ 1 activity of daily living (ADL) were associated with heat-related deaths; in France, significant risk factors included cardiovascular disease, hypertension, psychiatric and neurologic diseases, confinement to bed or armchair, loss of autonomy and living alone.¹⁴

Predictors of heat-related morbidity have been less studied and could differ from those related to mortality. A better knowledge of them is critical for successful development and implementation of prevention strategies. Indeed, heat-related morbidity is presumably far more frequent than heat-related death and can have a significant impact on older adults' overall health and well-being. In a general population in the United States (summers 2001–2010), low-income neighbourhood, lack of health insurance, neurological disorders and psychoses increased the risk of heat-related hospitalization.¹⁵ In the general population of India (summer 2011), having chronic, diarrheal or infectious pre-existing conditions and not seeking heat-related health information before a heat wave increased the risk of self-reported HRI.¹⁶ Finally, heat-related morbidity during the 2003 heat wave in France was associated with several risk factors, including stopping usual activities during a heat wave, and having diabetes, respiratory, neurological or cardiovascular diseases, whereas house ventilation was a protective factor among older adults.¹⁷

To date, most studies on heat vulnerability have been cross-sectional or case-control and conducted during a specific heat wave. There is a need to examine predictors of HRHO using a cohort design which has stronger potential to increase internal validity and clarify the relationships. Moreover, a simultaneous assessment of medical, social and environmental predictors is essential to adequately examine their independent contribution to heat vulnerability. Furthermore, predictors of HRHO in older adults have not been thoroughly studied, restricting the capacity for stakeholders to develop and implement tailored preventive strategies among this vulnerable population.

The aims of this prospective cohort study were to 1) describe the incidence of HRHO, including EDP, hospitalizations and deaths over a five-year period and 2) assess their medical, social and environmental predictors among older adults living in Southern Quebec.

METHODS

Setting

This study was conducted in three health regions located in Southern Quebec, namely Montreal, Laval and the Eastern

Townships. They encompass respectively the first, the third and the sixth most populous cities in the province of Quebec. In 2013, older adults represented between 16% and 19% of the population, depending on the region.¹⁸

Participants and study design

The Quebec longitudinal study on nutrition as a determinant of successful aging (NuAge study) is a four-year study of community-dwelling older adults living in one of the three health regions mentioned above.¹⁹ A random sample stratified for age (68–72, 73–77, 78–82 years) and sex was obtained from the Régie de l'assurance maladie du Québec (RAMQ) medico-administrative database and used to identify potential participants. Participation rate was 58.6%. The final NuAge cohort was composed of 853 men and 940 women generally in good health at recruitment, without cognitive impairment, free of disabilities in ADL, and able to walk one block or climb a one-floor flight of stairs without rest. They did not report heart failure, chronic obstructive pulmonary disease requiring oxygen therapy or oral steroids, inflammatory digestive diseases, or cancer treated by radiation therapy, chemotherapy or surgery in the past five years.

This study combined data from the NuAge study and the RAMQ, as well as geospatial data from the Institut national de santé publique du Québec (INSPQ). Individual-level factors were measured at the first NuAge follow-up (2005–2006, $n = 1,679$; 6% lost to follow-up). Data were self-reported during in-person interviews with trained nurses or dietitians at the Institut Universitaire de Gériatrie de Montréal (IUGM) and Sherbrooke (IUGS) using validated questionnaires.¹⁹ Merged individual-level and geospatial data were linked with the RAMQ medico-administrative data on EDP, hospitalizations and deaths over five summer seasons (2006–2010), using health insurance number (HIN) as a unique identifier. Because of missing data with respect to HIN, 446 participants were excluded (27%), resulting in a final study sample of 1,233 participants.

Variables

Independent Variables

An older adult heat vulnerability conceptual model has been developed and was described in detail elsewhere (Figure 1).¹¹ Briefly, all factors were identified in Health Canada guidelines² and grouped into nine categories: 1) physical health disorders, 2) mental health and cognitive disorders, 3) loss of autonomy, 4) central nervous system medication use, 5) cardiovascular medication use, 6) social isolation, 7) low socio-economic status (SES), 8) environmental risk factors, and 9) highly protective or protective factors.

Physical Health Disorders

Self-reported physical health disorders were measured using the OARS (Older Americans Resources and Services) Multidimensional Functional Assessment Questionnaire (physical health dimension)²⁰ and classified according to the International Classification of Diseases, ninth revision. Obesity was defined as a body mass index ≥ 30 kg/m².

Mental Health and Cognitive Disorders

The 30-item Geriatric Depression Scale (GDS)²¹ and the Modified Mini-Mental State examination (3MS)²² were used to assess the

Figure 1. Older adult's heat vulnerability model adapted from Health Canada guidelines (2011)¹¹

presence of depressive symptoms (GDS ≥ 11) and cognitive impairment (3MS < 80) respectively.

Loss of Autonomy

Disability, defined as needing help in ≥ 1 ADL, was assessed using the Functional Autonomy Measurement System (SMAF).²³ Being bedridden during the daytime was measured during the six-month follow-up phone calls.

Central Nervous System and Cardiovascular Medication Use

Medication use was classified according to the American Hospital Formulary Service.

Social Isolation

Not knowing anyone sufficiently to visit them, and not leaving home were measured with the OARS Multidimensional Functional Assessment Questionnaire (social dimension).²⁰

Low SES

Low household income was defined as a household income of less than \$20,000. Material deprivation was calculated at the dissemination area level using the Pampalon deprivation index.²⁴ Participants in the fifth quintile were considered as living in materially deprived neighbourhoods.

Environmental Factors

Using participants' personal address transformed into unique latitude and longitude, a geomatic specialist determined whether this location was in an urban heat island (UHI), a coolness island or neither according to analysis of land surface temperature from

Landsat satellite images. Analysis of these images allowed identification of areas covered by the warmest temperatures spectrum (heat islands) and those covered by the spectrum of the coldest temperatures (coolness islands) in inhabited areas.²⁵

Protective Factors

Social participation was measured using a 10-item questionnaire scored on a 5-point scale from 1 (almost every day) to 5 (never).²⁶ A score ≤ 30 reflected several activities at least once a week to almost daily, indicating high social participation. Visiting places with air conditioning (AC) was defined as visiting at least one air-conditioned place almost every day.

Older Adults Heat Vulnerability Index (OAHVI)

The OAHVI was developed to assess the cumulative risk of HRHO. A score ranging from 0 to 9 was calculated from the sum of categories of factors previously shown (1 point/category). Higher values reflect increased heat vulnerability.

Dependent Variables: HRHO

Hot temperature days (HTD) were defined as days with a maximal temperature $\geq 30^{\circ}\text{C}$, as mortality increases at this threshold in Canadian communities.²⁷ HRHO were defined as all-cause EDP, hospitalization (excluding day surgery) or death occurring during a HTD between May 15 and September 15 of years 2006 through 2010. Day surgeries were excluded because, in Quebec, they are generally planned in advance and are thus very unlikely to be related to or caused by heat. Given the small number of heat-related hospitalizations ($n = 26$) and deaths ($n = 2$) during the five summers investigated, separate analyses for these

outcomes could not be performed. Two outcomes were examined in this study: heat-related 1) EDP and 2) health events (EDP, hospitalization or death).

Data analyses

All-cause EDP, hospitalization and death rates during hot and normal summer days were computed separately by dividing the occurrence of ≥ 1 health event per person during the five summers investigated by the number of person-days at risk during this period. Two sets of bivariate and multivariate logistic regression analyses were performed to identify predictors of both outcomes. Final multivariate models retain all independent and significant predictors ($p < 0.05$). Data were weighted for sex, age and region and analyses were performed with SAS 9.2 statistical software.

Ethics

The NuAge study was approved by the IUGM and IUGS ethics committees. All participants signed an informed consent form including an authorization to include their data in the NuAge database for investigative work by NuAge investigators and collaborators. This secondary study was approved by the IUGS, the Commission d'Accès à l'Information du Québec and the RAMQ. This study conformed to the principles embodied in the Declaration of Helsinki.

RESULTS

The 1,233 study participants were similar to older adults excluded from this study because of missing HIN ($n = 446$) with respect to sex, age, education and income. However, as compared to study participants, those excluded were less likely ($p < 0.05$) to suffer from cardiovascular disease, take anti-Alzheimer's agents, not know anyone sufficiently to visit them, not leave home, or live in a UHI, and were more likely to live in a coolness island.

Out of 620 summer days observed between 2006 and 2010, 45 (7.3%) and 34 (5.5%) were HTD in Montreal/Laval and the Eastern Townships respectively. During this period, 77 (15.1%) EDP, 26 (10.3%) hospitalizations and 2 (8.3%) deaths occurred during HTD. EDP and hospitalizations among older adults were 2.6 (95% CI: 2.0–3.5) and 1.7 (95% CI: 1.1–2.6) times more frequent on HTD than on normal summer days respectively (Table 1). No statistical differences were observed between hot and normal summer days with respect to mortality rates.

Results of bivariate logistic regression analyses are shown in Table 2. Some medical factors, namely cardiovascular disease, diuretic medication use and limitations in ADL, increased the risk

of heat-related EDP or health events ($p < 0.05$). Surprisingly, renal disease and antiepileptic medication use were found to be negatively associated with both outcomes. However, because of their very low prevalence in our sample (2%–3%) and the lack of biological plausibility to support their counterintuitive association, these factors were not included in multivariate analyses. Low household income was the only social factor related to both outcomes. Living in a UHI was associated with more heat-related health events but not with EDP. Finally, high social participation was a strong protective factor for both outcomes. Final independent and significant predictors of HRHO were the same for both outcomes (Table 3). Disability and low household income were independent risk factors while high social participation was a strong independent protective factor of heat-related EDP and health events.

Associations between the OAHVI, treated as a categorical (0–1, 2–3, 4–5, 6–9) or a continuous (ranging from 0 to 9) variable, and both outcomes are presented in Table 4. Older adults presenting at least six factors out of nine (representing 10% of the sample) were 7–8 times more likely to have a heat-related EDP and health events as compared to participants having none or only one factor. Furthermore, for each additional risk factor or absence of protective factor, the likelihood of HRHO over five years increased by approximately 40%.

DISCUSSION

Incidence of heat-related EDP (158 per 100,000 person-days) among this generally healthy cohort of older adults living in Southern Quebec was similar to all-ages rates previously reported in Quebec (115 to 390 per 100,000 person-days).^{3–5,7} However, these provincial rates varied greatly from one year to another and were measured only in health regions that experienced heat waves, which may imply higher burden than single HTD. Defined as maximal/minimal temperature of $\geq 31^{\circ}\text{C}/\geq 18^{\circ}\text{C}$ (threshold for Eastern Townships) and $\geq 33^{\circ}\text{C}/\geq 20^{\circ}\text{C}$ (threshold for Montréal/Laval) for at least three days,⁷ only one heat wave occurred in Montreal/Laval and two in the Eastern Townships during the five summers investigated. Daily temperature might better capture effects of heat, being more sensitive than heat waves. Also, given the general good health and autonomy of the NuAge participants at baseline, the true incidence among the whole older adult population could be higher than what was observed in our study when accounting for those with poorer health and greater loss of autonomy and frailty.

A wide range of medical, social and environmental factors were simultaneously examined in this study. In multivariate analyses,

Table 1. Rates of emergency department presentations, hospitalizations and deaths (all-cause) during hot temperature days ($T_{\text{max}} \geq 30^{\circ}\text{C}$) and normal summer days ($T_{\text{max}} < 30^{\circ}\text{C}$)

Health outcomes	ID per 100,000 person-days (95% CI)		ID ratio (95% CI)
	HTD	NSD	HTD/NSD
Emergency department presentations	158 (128 to 188)	60 (55–65)	2.6 (2.0–3.5)
Hospitalizations	53 (36 to 70)	32 (29–35)	1.7 (1.1–2.6)
Deaths	4 (–1 to 9)	3 (2–4)	1.3 (0.3–6.0)

Note: ID = incidence density; CI = confidence interval; HTD = hot temperature days; NSD = normal summer days.

Table 2. Frequency of heat-related EDP and health events from May 15 to September 15 (2006–2010) according to risk and protective factors and bivariate associations

	HREDP		HRHE	
	Yes* <i>n</i> (%) [†]	OR (95% CI) [‡]	Yes <i>n</i> (%) [†]	OR (95% CI) [‡]
RISK FACTORS				
Health conditions				
Physical health disorders				
Cardiovascular disease (<i>n</i> = 468)	35 (7.6)	1.77 (0.82–3.84)	39 (9.7)	2.14 (1.02–4.48) [‡]
Pulmonary disease (<i>n</i> = 54)	5 (11.6)	2.39 (0.53–10.72)	6 (14.4)	2.61 (0.70–9.72)
Neurological disease (<i>n</i> = 17)	1 (4.1)	0.74 (0.08–6.73)	1 (4.1)	0.62 (0.07–5.67)
Renal disease (<i>n</i> = 58)	2 (0.9)	0.16 (0.04–0.71) [‡]	3 (1.4)	0.20 (0.06–0.71) [‡]
Hypertension (<i>n</i> = 614)	36 (5.3)	0.92 (0.43–1.99)	41 (5.8)	0.80 (0.39–1.65)
Diabetes (<i>n</i> = 134)	9 (7.2)	1.38 (0.42–4.55)	13 (8.9)	1.48 (0.52–4.23)
Obesity (<i>n</i> = 292)	23 (8.4)	1.83 (0.81–4.17)	27 (10.1)	1.92 (0.88–4.20)
≥1 physical health disorder (<i>n</i> = 136)	55 (6.2)	1.60 (0.60–4.28)	63 (7.5)	1.91 (0.73–4.97)
Mental health or cognitive disorders				
Depressive symptoms (<i>n</i> = 110)	4 (7.9)	1.55 (0.43–5.54)	5 (8.1)	1.32 (0.38–4.57)
Cognitive impairment (<i>n</i> = 31)	2 (7.0)	1.25 (0.20–7.94)	3 (7.9)	1.22 (0.23–6.53)
≥1 mental health or cognitive disorder (<i>n</i> = 136)	6 (7.7)	1.47 (0.46–4.75)	8 (8.0)	1.27 (0.41–3.95)
Loss of autonomy				
Needing help in activities of daily living (<i>n</i> = 276)	26 (9.8)	2.56 (1.16, 5.63) [‡]	30 (10.5)	2.19 (1.03–4.67) [‡]
Obligation to stay in bed during daytime (<i>n</i> = 110)	8 (5.5)	0.95 (0.32–2.75)	9 (5.8)	0.85 (0.31–2.37)
≥1 factor associated with loss of autonomy (<i>n</i> = 343)	29 (8.8)	2.08 (0.98–4.40)	33 (9.4)	1.79 (0.87–3.68)
≥1 health condition (physical or mental health/cognitive disorders, or loss of autonomy) (<i>n</i> = 976)	59 (6.1)	1.43 (0.57–3.63)	68 (7.3)	1.70 (0.68–4.21)
Medication use				
Central nervous system medication use				
Anti-Parkinson's agent (<i>n</i> = 17)	1 (3.9)	0.67 (0.08–5.94)	1 (3.9)	0.57 (0.07–5.03)
≥1 CNS medication use (<i>n</i> = 103)	2 (0.5)	0.08 (0.02–0.38) [§]	4 (4.2)	0.60 (0.11–3.40)
Cardiovascular medication use				
Diuretic (<i>n</i> = 238)	16 (10.2)	2.39 (1.04–5.46) [‡]	19 (11.0)	2.12 (0.96–4.68)
Antiarrhythmic or cardiotonic (<i>n</i> = 464)	33 (5.9)	1.07 (0.51–2.23)	39 (7.5)	1.24 (0.61–2.54)
Nitrate vasodilator (<i>n</i> = 78)	5 (5.0)	0.88 (0.21–3.58)	6 (5.4)	0.80 (0.21–3.01)
ACE-II inhibitor (<i>n</i> = 242)	17 (5.8)	1.04 (0.47–2.33)	19 (6.0)	0.89 (0.41–1.93)
Calcium channel blocker (<i>n</i> = 247)	21 (7.9)	1.57 (0.69–3.60)	23 (8.8)	1.47 (0.67–3.22)
≥1 cardiovascular medication use (<i>n</i> = 640)	44 (6.9)	1.62 (0.72–3.64)	50 (8.0)	1.62 (0.75–3.49)
≥1 CNS or cardiovascular medication use (<i>n</i> = 682)	45 (6.6)	1.46 (0.65–3.28)	52 (8.3)	1.83 (0.83–4.04)
Social factors				
Social isolation				
Living alone (<i>n</i> = 389)	15 (4.8)	0.80 (0.33–1.93)	19 (5.3)	0.73 (0.32–1.67)
Not leaving home (<i>n</i> = 60)	5 (5.0)	0.89 (0.25–3.12)	5 (5.0)	0.75 (0.21–2.60)
≥1 factor associated with social isolation (<i>n</i> = 446)	20 (4.9)	0.82 (0.36–1.87)	24 (5.4)	0.73 (0.33–1.60)
Low socio-economic status (SES)				
Household income <\$20,000 (<i>n</i> = 188)	13 (14.3)	3.11 (1.26–7.67) [§]	16 (14.7)	2.81 (1.16–6.80) [‡]
≤ primary school level (<i>n</i> = 247)	18 (8.5)	1.57 (0.61–4.00)	21 (12.2)	2.13 (0.86–5.28)
Material deprivation (most deprived quintile) (<i>n</i> = 109)	11 (9.8)	2.08 (0.72–6.05)	11 (9.8)	1.69 (0.59–4.88)
≥1 factor associated with low SES (<i>n</i> = 439)	36 (11.9)	3.43 (1.68–6.98) [§]	41 (13.6)	3.37 (1.71–6.67) [§]
≥1 social factor (<i>n</i> = 701)	43 (7.0)	1.58 (0.79–3.15)	50 (8.1)	1.57 (0.80–3.09)
Environmental factor				
Living in an urban heat island (<i>n</i> = 386)	24 (8.3)	1.79 (0.86–3.74)	29 (10.5)	2.20 (1.11–4.36) [‡]
PROTECTIVE FACTORS				
Highly protective factor				
High social participation (<i>n</i> = 127)	3 (1.2)	0.18 (0.04–0.90) [‡]	3 (1.2)	0.15 (0.03–0.75) [‡]
Visiting places with air conditioning (<i>n</i> = 106)	8 (2.4)	0.39 (0.12–1.26)	8 (2.4)	0.32 (0.10–1.05)
≥1 highly protective factor (<i>n</i> = 256)	10 (1.2)	0.16 (0.06–0.46) [§]	10 (1.2)	0.14 (0.05–0.39) [§]
Protective factor				
Talking on phone daily (<i>n</i> = 730)	45 (6.2)	1.58 (0.68–3.68)	51 (7.0)	1.35 (0.60–3.04)
≥1 highly protective or protective factor (<i>n</i> = 801)	50 (5.8)	0.97 (0.47–2.01)	56 (6.6)	0.89 (0.44–1.82)
Total sample (<i>n</i> = 1233)	77 (5.9)	–	87 (6.8)	–

Note: HREDP = heat-related emergency department presentation; HRHE = heat-related health events; OR = odds ratio; CI = confidence interval; CNS = central nervous system.
 * Factors for which there was no occurrence of both outcomes have been removed as well as those having a coefficient of variation >15.

† Weighted data for sex, age and regions.

‡ $p < 0.05$.

§ $p < 0.01$.

Table 3. Multivariate associations of risk and protective factors with heat-related EDP and health events*

Risk and protective factors [†]	HREDP		HRHE	
	AOR (95% CI)	<i>p</i> value	AOR (95% CI)	<i>p</i> value
Needing help in activities of daily living	2.66 (1.15–6.14)	0.022	2.51 (1.13–5.61)	0.025
Household income <\$20,000	3.20 (1.16–8.81)	0.025	2.84 (1.06–7.64)	0.038
High social participation	0.05 (0.01–0.20)	<0.0001	0.04 (0.01–0.18)	<0.0001

Note: HREDP = heat-related emergency department presentation; HRHE = heat-related health events; AOR = adjusted odds ratio; CI = confidence interval.

* Weighted data for sex, age and regions. **Factors are adjusted for factors presented in the table.**

Table 4. Association of cumulative risk index (OAHVI) with heat-related EDP and heat-related health events*

OAHVI [†]	n (%)	HREDP		HRHE	
		OR (95% CI)	p value	OR (95% CI)	p value
Categorical score					
0–1	171 (12.8)	1.0		1.0	
2–3	646 (39.3)	2.10 (0.53–8.33)	0.324	2.15 (0.55–8.51)	0.227
4–5	665 (37.8)	4.19 (1.08–16.19)	0.184	5.51 (1.44–21.09)	0.043
6–9	197 (10.1)	7.40 (1.51–36.19)	0.022	7.77 (1.63–37.20)	0.024
Continuous score[‡]					
	3.6 ± 1.6 [‡]	1.38 (1.10–1.72)	0.006	1.42 (1.16–1.74)	0.001

Note: HREDP = heat-related emergency department presentation; HRHE = heat-related health events; OR = odds ratio; CI = confidence interval.

* Weighted data for sex, age and region.

† Cumulative number of risk factors, or absence of protective factors (range from 0 to 9).

‡ Mean ± SD.

high social participation was strongly associated with decreased risk of heat-related EDP and health events. This is consistent with previous studies where increased social contact has been associated with a decreased risk of heat-related mortality¹² whereas stopping usual activities during a heat wave has been associated with an increased risk of heat-related morbidity.¹⁷ ADL limitation was an independent risk factor of both outcomes. Loss of autonomy in ADL has been previously associated with heat-related mortality.¹³ Although disability and social participation may be correlated, we observed that they made distinct contributions to HRHO. Needing help in ADL signals an inability to care for oneself, which could lead to difficulties in achieving appropriate actions in order to prevent HRHO. In contrast, high social participation may protect against extreme heat as it may increase awareness among friends/family that a person feels ill, and may provide opportunities to seek advice.² Promoting social participation among older adults could be an effective strategy to prevent HRHO. Age-friendly cities, an approach that supports the creation of active living communities and fosters community engagement,²⁸ could help reach out to isolated older people, who are highly vulnerable to heat owing to a poor health status or potentially unhealthy behaviours contributing to dehydration and impaired judgement.

Low household income was associated with increased risk of both outcomes, which is consistent with results from a study conducted during the 1999 Chicago heat wave.¹³ Low income is associated with financial barriers that restrict a person's ability to take actions to reduce his or her heat vulnerability (e.g., purchase of air conditioning).²

A major challenge when studying predictors of HRHO is determining the distinctive role of treatment versus underlying pathology being treated. In our study, a subanalysis showed that diuretic medication was associated with heat-related EDP, independently of cardiovascular disease, hypertension and edema (OR = 2.91, 95% CI: 1.23–6.92; data not shown). This suggests that simultaneous assessment of medication use and related diseases is needed to adequately assess potential causal factors. Further studies are needed to address this issue in Quebec.

Living in a UHI was positively associated with heat-related health events but this association did not remain significant when controlling for other factors in multivariate analysis. However, during the 2011 heat wave in the Eastern Townships, 51% of the

deceased resided in a UHI, a statistically higher proportion than during the reference periods (31%).²⁹ Furthermore, in Montréal between the months of June and August in the period 1990–2003, the risk of death on warm summer days was greater in areas with high surface temperature (i.e., micro-UHI) as compared to areas with low surface temperature.³⁰ This supports the hypothesis that people living in UHI are at higher risk of HRHO.

A positive gradient was observed between our OAHVI and both HRHO. This “easy-to-measure” index could be used clinically to determine the heat vulnerability of an individual. These results suggest that accumulation of medical, social and environmental risk factors, as well as absence of protective factors increase heat vulnerability. Assessment of all dimensions of heat vulnerability, using a biopsychosocial approach, is essential to identify most-at-risk older adults and prevent heat-related issues.

Strengths

Based on a large sample of older Quebecers, this five-year study contributes to the current knowledge on predictors of HRHO. In contrast to earlier research, this study objectively measured HRHO. Moreover, selection of risk and protective factors was based on an older adult's heat vulnerability model adapted from recent Health Canada guidelines, which encompasses every dimension of heat vulnerability. Finally, we proposed an “easy-to-measure” cumulative index based on this holistic conceptual model, which was found to be an important predictor of individuals' global risk of HRHO.

Limitations

Factors were not specifically measured during HTD. Over the five-year period of investigation, variations could have occurred with respect to health status and social contacts which could have been over- or underestimated. Another limitation is related to lack of information on AC at home; however, this was indirectly estimated by low SES as individuals with low income are less likely to have AC at home and to use it. In addition, visiting air-conditioned public places, a reasonable alternative to AC at home, was analyzed. Other factors identified in Health Canada guidelines were not available in our database, such as living on the top floor of a building or having a history of heat stroke/illness. Generalizability of our findings to other populations might be difficult since the study sample was composed of generally healthy community-dwelling older adults.

Finally, analyses of specific predictors of hospitalizations and deaths could not be performed.

REFERENCES

- Intergovernmental Panel on Climate Change. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014. Available at: https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf (Accessed June 20, 2015).
- Health Canada. *Extreme Heat Events Guidelines: User Guide for Health Care Workers and Health Administrators*, 2011. Available at: <http://www.hc-sc.gc.ca/ewh-semt/pubs/climat/users-guide-utilisateur/index-eng.php> (Accessed March 5, 2012).
- Bustanza R, Lebel G, Gosselin P, et al. Health impacts of the July 2010 heat wave in Québec, Canada. *BMC Public Health* 2013;13:56. doi: 10.1186/1471-2458-13-56.
- Bustanza R, Lebel G, Dubé M. Surveillance des impacts sanitaires des vagues de chaleur extrême au Québec – Bilan de la saison estivale 2013. Québec, QC: Institut national de santé publique du Québec, 2014. Available at: https://www.inspq.qc.ca/Data/Sites/1/SharedFiles/bise/ArticlePrinc_1_Juillet2014.pdf (Accessed July 20, 2015).
- Bustanza R, Lebel G, Dubé M. Surveillance des impacts sanitaires des vagues de chaleur extrême au Québec – Bilan de la saison estivale 2014. Québec, QC: INSPQ, 2015. Available at: <https://www.inspq.qc.ca/bise/surveillance-des-impacts-sanitaires-des-vagues-de-chaleur-extreme-au-quebec-bilan-de-la-saison-estivale-2014> (Accessed July 20, 2015).
- Bustanza R, Lebel G. Surveillance des impacts sanitaires des vagues de chaleur extrême au Québec – Bilan de la saison estivale 2011. Québec, QC: INSPQ, 2012. Available at: https://www.inspq.qc.ca/pdf/publications/1508_SurImpactsSaniVaguesChaleurExtremeQc_Bilan2011.pdf (Accessed July 20, 2015).
- Lebel G, Bustanza R. Surveillance des impacts sanitaires des vagues de chaleur extrême au Québec – Bilan de la saison estivale 2012. Québec, QC: INSPQ, 2013. Available at: https://www.inspq.qc.ca/pdf/publications/1688_SurImpactsSaniVagueChalExtrQc.pdf (Accessed July 20, 2015).
- Lippmann SJ, Fuhrmann CM, Waller AE, Richardson DB. Ambient temperature and emergency department visits for heat-related illness in North Carolina, 2007–2008. *Environ Res* 2013;124:35–42. PMID: 23643292. doi: 10.1016/j.envres.2013.03.009.
- Petkova EP, Morita H, Kinney PL. Health impacts of heat in a changing climate: How can emerging science inform urban adaptation planning? *Curr Epidemiol Rep* 2014;1:67–74. PMID: 25422797. doi: 10.1007/s40471-014-0009-1.
- Kenny GP, Yardley J, Brown C, Sigal RJ, Jay O. Heat stress in older individuals and patients with common chronic diseases. *CMAJ* 2010;182:1053–60. PMID: 19703915. doi: 10.1503/cmaj.081050.
- Laverdière É, Gendreau M, Gaudreau P, Morais JA, Shatenstein B, Payette H. Prevalence of risk and protective factors associated with heat-related outcomes in Southern Quebec: A secondary analysis of the NuAge study. *Can J Public Health* 2015;106:e315–21. doi: 10.17269/CJPH.106.5029.
- Bouchama A, Dehbi M, Mohamed G, Matthies F, Shoukri M, Menne B. Prognostic factors in heat wave related deaths: A meta-analysis. *Arch Intern Med* 2007;167:2170–76. PMID: 17698676. doi: 10.1001/archinte.167.20.ira70009.
- Foroni M, Salvioli G, Rielli R, Goldoni CA, Orlandi G, Zauli Sajani S et al. A retrospective study on heat-related mortality in an elderly population during the 2003 heat wave in Modena, Italy: The Argento Project. *J Gerontol A Biol Sci Med Sci* 2007;62:647–51. PMID: 17595422. doi: 10.1093/gerona/62.6.647.
- Bretin P, Vandertoren S, Zeghnoun A, Ledrans M. Étude des facteurs de décès des personnes âgées résidant à domicile durant la vague de chaleur d'août 2003. Institut de Veille Sanitaire. 2004. Available at: http://www.invs.sante.fr/publications/2004/chaleur2003_170904/rapport_canicule.pdf (Accessed January 31, 2013).
- Schmeltz MT, Sembajwe G, Marcotullio PJ, Grassman JA, Himmelstein DU, Woolhandler S. Identifying individual risk factors and documenting the pattern of heat-related illness through analyses of hospitalization and patterns of household cooling. *PLoS One* 2015;10:e0118958. PMID: 25742021. doi: 10.1371/journal.pone.0118958.
- Tran KV, Azhar GS, Nair R, Knowlton K, Jaiswal A, Sheffield P et al. A cross-sectional, randomized cluster sample survey in household vulnerability to extreme heat among slum dwellers in Ahmedabad, India. *Int J Environ Res Public Health* 2013;10:2515–43. PMID: 23778061. doi: 10.3390/ijerph10062515.
- Larrieu S, Carcaillon L, Lefranc A, Helmer C, Dartigues JF, Tavernier B et al. Factors associated with morbidity during the 2003 heat wave in two population-based cohorts of elderly subjects: PAQUID and Three City. *Eur J Epidemiol* 2008;23:295–302. PMID: 18270795. doi: 10.1007/s10654-008-9229-3.
- Institut de la statistique du Québec. Panorama des régions du Québec, 2014. Available at: <http://www.stat.gouv.qc.ca/statistiques/profils/panoramaregions.html> (Accessed August 8, 2014).
- Gaudreau P, Morais JA, Shatenstein B, Gray-Donald K, Khalil A, Dionne I, et al. Nutrition as a determinant of successful aging: Description of the Quebec longitudinal study NuAge and results from cross-sectional pilot studies. *Rejuvenation Res* 2007;10:377–86. PMID: 17708689. doi: 10.1089/rej.2007.0596.
- Fillenbaum GG, Smyer MA. The development, validity and reliability of the OARS multidimensional functional assessment questionnaire. *J Gerontol* 1981;36:428–434. PMID: 7252074. doi: 10.1093/geronj/36.4.428.
- McDowell I, Newell C. *Measuring Health: A Guide to Rating Scales and Questionnaires*. New York, NY, Oxford: Oxford University Press, 1996; 314–23.
- Teng EL, Chui HC. The Modified Mini-Mental State (3MS) examination. *J Clin Psychiatry* 1987;48:314–18. PMID: 3611032.
- Hébert R, Guibault J, Desrosiers J, Dubuc N. The Functional Autonomy Measurement System (SMAF): A clinical-based instrument for measuring disabilities and handicaps in older people. *Geriatr Today: J Can Geriatr Soc* 2001;4:141–47.
- Institut national de santé publique du Québec. *Guide méthodologique: «L'indice de défavorisation matérielle et sociale: en bref»*, 2010. Available at: http://www2.inspq.qc.ca/santescope/documents/Guide_Metho_Indice_defavo_Sept_2010.pdf (Accessed June 17, 2014).
- Boulfroy E, Khaldoune J, Grenon F, Fournier R, Talbot B. Conservation des îlots de fraîcheur urbains – Description de la méthode suivie pour identifier et localiser les îlots de fraîcheur et de chaleur. Centre d'enseignement et de recherches en foresterie de Sainte-Foy inc. et Université de Sherbrooke, 2012.
- Lefrançois R, Leclerc G, Dubé M et al. Valued activities of everyday life among the very old: A one-year trend. *Act Adapt Aging* 2001;25:19–35. doi: 10.1300/J016v25n03_02.
- Casati B, Yagouti A, Chaumont D. Regional climate projections of extreme heat events in nine pilot Canadian communities for public health planning. *J Appl Meteorol Climatol* 2013;52:2669–98. doi: 10.1175/JAMC-D-12-0341.1.
- Public Health Agency of Canada. *Age-Friendly Communities*, 2016. Available at: <http://www.phac-aspc.gc.ca/seniors-aines/afc-caa-eng.php> (Accessed June 17, 2014).
- Lebel G, Bustanza R, Dubé M. *Évaluation du Fichier hebdomadaire des décès pour l'estimation des impacts des vagues de chaleur*. Québec, QC: INSPQ, 2015. Available at: https://www.inspq.qc.ca/pdf/publications/1962_Evaluation_Fichier_Deces_Impact_Chaleur.pdf (Accessed December 6, 2015).
- Smargiassi A, Goldberg MS, Plante C, Fournier M, Baudouin Y, Kosatsky T. Variation of daily warm season mortality as a function of micro-urban heat islands. *J Epidemiol Community Health* 2009;63:659–64. doi: 10.1136/jech.2008.078147. PMID: 19366997.

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RÉSUMÉ

OBJECTIFS : La chaleur extrême est connue pour augmenter la survenue d'événements morbides ou fatals liés à la chaleur. L'incidence et les facteurs prédisant la survenue d'événements morbides ou fatals liés à la chaleur ont été examinés chez les personnes âgées vivant au Québec (Canada).

MÉTHODES : Cette étude prospective sur cinq ans a utilisé les données du premier temps de suivi de l'étude longitudinale NuAge, une cohorte de personnes âgées vivant dans la communauté dans trois régions sociosanitaires du Sud du Québec. Des facteurs médicaux, sociaux et environnementaux, identifiés dans les lignes directrices de Santé Canada (2011) ont été utilisés pour développer un indice de vulnérabilité à la chaleur des personnes âgées (IVCPA). Les événements morbides ou fatals liés à la chaleur, obtenus à partir d'une base de données médico-administrative, ont été définis comme des événements survenant un jour de température élevée (température maximale $\geq 30^{\circ}\text{C}$) entre les années 2006 et 2010. Deux événements morbides ou fatals liés à la chaleur ont été examinés : 1) visite à l'urgence liée à la chaleur (VULC) et 2) tout événement liés à la chaleur (ÉLC [c.-à-d., visites à l'urgence, hospitalisations ou décès]). Des analyses de régressions logistiques multivariées ont été réalisées pour examiner les associations entre les facteurs de risque et de protection, incluant l'IVCPA, et les deux événements.

RÉSULTATS : Les visites à l'urgence et les hospitalisations étaient, respectivement, 2,6 (IC à 95 % : 2,0–3,5) et 1,7 (IC à 95 % : 1,1–2,6) fois plus fréquentes les jours de température élevée comparativement aux jours de température normales. Le faible revenu du ménage et la perte d'autonomie étaient associés à un risque accru de VULC (RCA = 3,20; IC à 95 % : 1,16–8,81 et RCA = 2,66; IC à 95 % : 1,15–6,14 respectivement) et

d'ÉLC (RCA = 2,84; IC à 95 % : 1,06–7,64 et RCA = 2,51; IC à 95 % : 1,13–5,61 respectivement). Une participation sociale élevée était un facteur de protection de VULC (RCA = 0,05; IC à 95 % : 0,01–0,20) et d'ÉLC (RCA = 0,04; IC à 95 % : 0,01–0,18). Les personnes âgées présentant ≥ 6 facteurs sur une possibilité de 9 de l'IVCPA étaient 7 à 8 fois plus susceptibles d'avoir une VULC (RC = 7,40; IC à 95 % : 1,51–36,19) ou un ÉLC (RC = 7,77; IC à 95 % : 1,63–37,20) par rapport aux participants ayant 0–1 facteurs.

CONCLUSION : La participation sociale, la perte d'autonomie et le faible revenu étaient d'importants prédicteurs de la survenue de VULC et d'ÉLC. L'indice cumulatif, également un prédicteur important, pourrait aider les cliniciens à identifier les patients âgés à haut risque.

MOTS CLÉS : chaleur extrême; facteurs de risque; facteurs de protection; troubles de santé liés à la chaleur; morbidité; vieillissement