

Article

Perceived Adverse Health Effects of Heat and Their Determinants in Deprived Neighbourhoods: A Cross-Sectional Survey of Nine Cities in Canada

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Abstract: This study identifies several characteristics of individuals who report their physical and/or mental health as being adversely affected by summertime heat and humidity, within the most disadvantaged neighbourhoods of the nine largest cities of Québec (Canada). The study is cross-sectional by stratified representative sample; 3485 people were interviewed in their residence. The prevalence of reported impacts was 46%, mostly physical health. Female gender and long-term medical leave are two impact risk indicators in people <65 years of age. Low income and air conditioning at home are risk indicators at all ages. Results for having ≥ 2 diagnoses of chronic diseases, particularly for people self-describing as in poor health (odds ratio, $OR_{<65} = 5.6$; $OR_{\geq 65} = 4.2$), and perceiving daily stress, are independent of age. The prevalence of reported heat-related health impacts is thus very high in those inner cities, with notable differences according to age, stress levels and long-term medical leave, previously unmentioned in the literature. Finally, the total number of pre-existing medical conditions seems to be a preponderant

risk factor. This study complements the epidemiologic studies based on mortality or severe morbidity and shows that the heat-related burden of disease appears very important in those communities, affecting several subgroups differentially.

Keywords: heat waves; health impacts; deprived neighbourhoods; sex; long-term medical leave

1. Introduction

Climate change is well established internationally, as demonstrated by the most recent report of the IPCC [1] and a recent publication by NASA researchers that proposes that these changes have caused the extremely high temperatures and heat waves of the last 30 years [2]. These high temperatures have health consequences on populations worldwide, as reviewed recently [3,4]. However, these studies show a wide heterogeneity across studies. This may be explained by the range of population studies in various geographical locations, different sociodemographic characteristics and local adaptation factors. Many studies also focus on a single or a few health outcomes.

While most studies have evaluated general practitioners visits, emergency room visits or hospitalization as outcome indicators, very few seem to have used self-reported health effects so far even if such surveys are generally easy to implement and cost-effective. Moreover, the validity of self-reported *versus* medical-based diagnoses and behaviours has been well established over time, several countries and data collection methods, especially as a tool for predicting future risks and as an epidemiologic survey tool for prevention and public health actions [5–8], including for older people [9]. Perceived health is thus a reliable and valid subjective measurement of the overall state of health, which can reflect certain health aspects difficult to identify clinically (e.g., first stage of a disease) and is often more effective than clinical measures for predicting help-seeking behaviours and health service use [10–17]. This self-reporting approach for evaluating environmental exposures is also documented if not as well assessed [18,19].

These high temperatures have health consequences under all latitudes and on northern populations too, and Canadians are no exception [4]. In the province of Québec, for example, the increase in average temperatures will likely lead to an increase in the summer death rate (non-traumatic causes) in the order of 2% in 2020 and 10% in 2080, under IPCC CO₂ emission scenario A2 [20]. A significant excess of 30.1% in weekly deaths (all causes combined) was also documented there during the July 2010 heat wave, compared to the equivalent weeks in previous years [21]. Various risk indicators associated with the adverse health impacts of heat in industrialized countries have been reported in the scientific literature, particularly since the European heat wave of 2003 [22–24]. Among these indicators, advancing age is well documented, while low socioeconomic level appears to be strongly predictive of disease and poor quality of life [25].

In Canada, poverty is mainly an urban problem. In fact, Canada's large urban regions and its metropolitan census regions have a disproportionate number of poor people [26]; Montréal, Québec's metropolis, figures among Canadian cities with one of the highest levels of poverty [27]. In addition, pockets of poverty are often concentrated in certain areas which generally correspond to the most

socially and materially disadvantaged census dissemination areas (DAs) [28]. These areas present a group of factors strongly correlated with high heat and humidity discomfort, particularly in densely populated cities where the heat island effect extends over large areas and may reach a greater intensity as compared with rural or semi-urban regions [29–31]. In Québec, these DAs contain both privately owned buildings and extensive low rental housing. Contrary to the former, low-rental subsidized housing is intended to support those less affluent. In 2006, more than half of their clientele were the elderly [32] who are considered vulnerable to heat effects given the increasing probability of multimorbidity with age [33]. The elderly, however, are not a homogeneous group and living in a very disadvantaged DA may not necessitate surveillance simply because DAs are identified as being the most likely to have heat islands.

The present study aims to identify sociodemographic, sociocultural, socioeconomic and other subgroups with health problems which report their health being adversely affected by very hot and humid summer episodes (called ‘health impacts’ or ‘impacts’ below). It also considers residence (or not) in low-rental housing.

2. Experimental Section

This study is cross-sectional using a stratified sample, conducted in 2010–2011 in the most disadvantaged DAs in Québec cities of 100,000 inhabitants or more. It has been approved by the ethics committee of the *Centre hospitalier universitaire de Québec*.

2.1. Population Studied and Sample

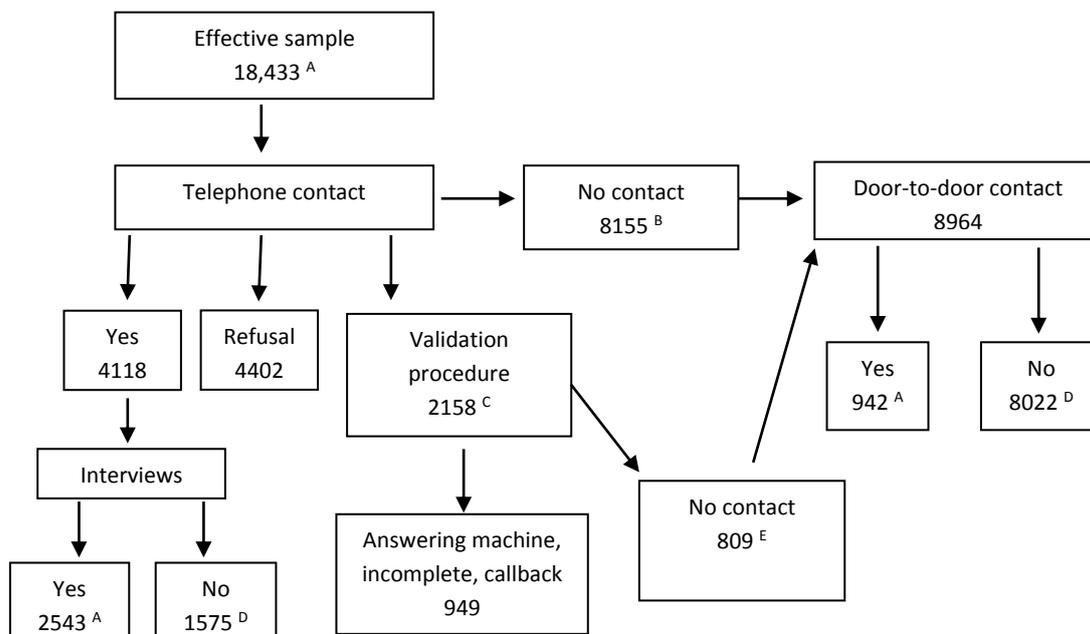
The choice of the most populated cities was justified by the much larger and significant urban heat islands present in densely populated regions in comparison to rural or semi-urban regions, as assessed for the province [34]. In 2011, Québec had nine cities with 100,000 inhabitants or more. Those cities represented about 47% of the total population in the 2011 census [35].

To produce representative samples for each of these cities, the two-step selection procedure proposed by Vallée *et al.* [36] was used. The first step not only established the number of very materially and socially disadvantaged DAs, according to a widely used Canadian deprivation index [37] including at least one public low-rental housing building, but also the number of households (among low-rental housing and among other) to be surveyed. The households’ and DAs’ total numbers in the nine cities being quite different, we used two sampling weights to compensate for possible over- or under-representation of DAs and households. Households were randomly selected within given DAs, while DAs were selected on a non-random basis. More precisely, within each city, DAs have been sampled in such a way that the sampling and the population distributions of age and sex variables are as close as possible (see [36] for more details). The second step randomly identified the households to be visited within the selected DAs. One person per household was interviewed. All the respondents were 18 years of age or older, could converse in French or in English, and were responsible for the household from the standpoint of care or family support. For households with more than one responsible person, the person with the most recent birthday was chosen.

In total, 3485 people were interviewed from December 21, 2010, to December 20, 2011. Of these individuals, 1729 lived in low-rental housing, and 1756 did not. The response rate was 19% (Figure 1).

The response rate by question as another measurement of the survey response rate was at least 95% for more than nine questions out of 10. If there was no response, it was generally due to the fact that the question did not apply to the respondent's situation (for more details, see B éanger *et al.* 2013 [38]).

Figure 1. Distribution of the sample of households.



^A Response rate = 18.9%, or 2543 + 942/5230. ^B People for whom there was immediately a door-to-door process to be conducted: 3879 no telephone service, three non-residential numbers, 1917 no telephone number, 2356 addresses where the telephone number was associated with a different address. ^C Answering machine = 173. Incomplete = 19. Callback = 696. No contact = 870 (≥ 15 calls = 760, no answer = 94, busy signal = 16). ^D Of this number, it is impossible to differentiate households that refused to participate from those that could not be reached (information sheet, in person), from those that were excluded by the survey firm (e.g., quotas reached); ^E No contact = 755 of 760: 15 calls or more.

2.2. Participant Recruitment

A short invitation letter regarding study participation was sent to all randomly selected households on behalf of the *Institut national de sant é publique du Qu ébec*. After a 7–10 day time period, households were contacted by telephone by a survey firm to set up an appointment. When telephone contact could not be established (Figure 1), interviewers went on-site to leave an invitation in the mailbox or to personally invite the sampled households.

2.3. Dependent Variable

The measurement of health impacts (*i.e.*, two questions regarding physical and mental health, respectively) during very hot and humid summer conditions was based on the perceived overall state of health in such a context as a proxy variable. More specifically, the preamble and questions were based on similar ones used in the Canadian Community Health Survey since 2001 [39]. More specifically, the respondents were asked if “their physical health was negatively affected when it’s very hot and humid in the summer”; a subsequent similar question dealt with mental health being

negatively affected. The risk group consisted of participants who reported their physical and/or mental health as moderately or greatly adversely affected by very hot and humid weather conditions (vs. slightly or not at all).

2.4. Independent Variables

In the study, the choice of risk indicators considered as independent variables was based on the scientific literature on human health and oppressive heat. According to the model of Kovats and Hajat [40], these indicators belong to three groups. The first group consists of risk indicators which can impact heat exposure (e.g., the temperature inside the dwelling). The second group involves the states or conditions which increase heat sensitivity (e.g., state of health), while the third involves access to treatment (e.g., reduced mobility). In this study, the risk indicators essentially relate to the second and third groups, except air conditioning (first group). They include demographic, cultural, economic, and lifestyle variables, diagnoses of self-reported chronic diseases, health-related perceptions, as well as variables pertaining to disabilities, reduced mobility, social support, social contacts, and health care and services, including home care and home services.

2.5. Data Collection

After two days of training, 21 interviewers conducted face-to-face interviews. These interviews, computer-aided and lasting 54 minutes on average (including the informed consent form), were conducted in each participant's home. Participants received \$10 as payment for their time.

Data was collected by means of a questionnaire (basically closed-ended questions) prepared from a review of the literature on health and climate change and various population survey questionnaires (e.g., Canadian Community Health Survey, 2007 [41]). Six partner institutions of the project and five experts working in the health and climate change field in Canada commented on a preliminary version of the questionnaire. Furthermore, two pretests were conducted before data collection. The purpose of the first pretest, carried out on 30 people from the target population was to verify the understanding and clarity of the questions, as well as to allow analysis of the psychometric qualities of the measurement scales, by using item response theory [42]. The second pretest, carried out by the survey firm on 30 other individuals from the target population, verified the duration of the questionnaire, its fluidity during the interview, and identified certain logic problems in its organization (e.g., filter questions). These 60 people were excluded from the sample.

2.6. Statistical Analyses

As alluded to earlier, we used a sampling design that enables weighting of data sequentially according to the weights of DAs and households. The analyses, carried out using the survey procedures in SAS 9.3 (e.g., proc surveylogistic), take these weights into account just like the sampling plan stratified according to the municipalities.

The missing data were not considered in the analyses; however, clarifications have been provided at the bottom of the tables for the few variables with more than 5%.

The 95% confidence intervals (CI) and coefficients of variation (CV) were calculated in order to express either the precision of a given estimation, or its relative precision. In this article, all the estimates had CVs below 15% (not reported in the tables in order to make them more concise), and are therefore considered as being sufficiently precise [43].

Standard hypotheses tests (t-test, F and chi-square tests) together with classical univariate and bivariate analyses have been performed to explore and assess associations between variables. A multivariate and weighted logistic regression model has been used to identify the main variables associated with the prevalence of perceived adverse health impacts during very hot and humid summer conditions. More precisely, generalized estimating equations (GEE) methods [44] have been used in order to take into account spatial autocorrelation among participants within specific DA/communities. The model was evaluated for the influence of the season in which the interview took place. The correlation ($r \geq 0.6$) between these variables (taken two at a time) was also verified by means of tetrachoric (binary variables) or polychoric (variables with at least three strata) correlation coefficients. To take these situations of interaction into account, the analysis was stratified according to age groups in order to facilitate future interventions, and dummy variables were used for other variables. Finally, the C index is presented to give an idea of a model's discriminant capacity; the expected value is between 0.5 (the model does not discriminate) and 1.0 (it discriminates perfectly). The statistical rejection threshold retained is $\alpha \leq 0.01$, given the high number of participants and comparisons made.

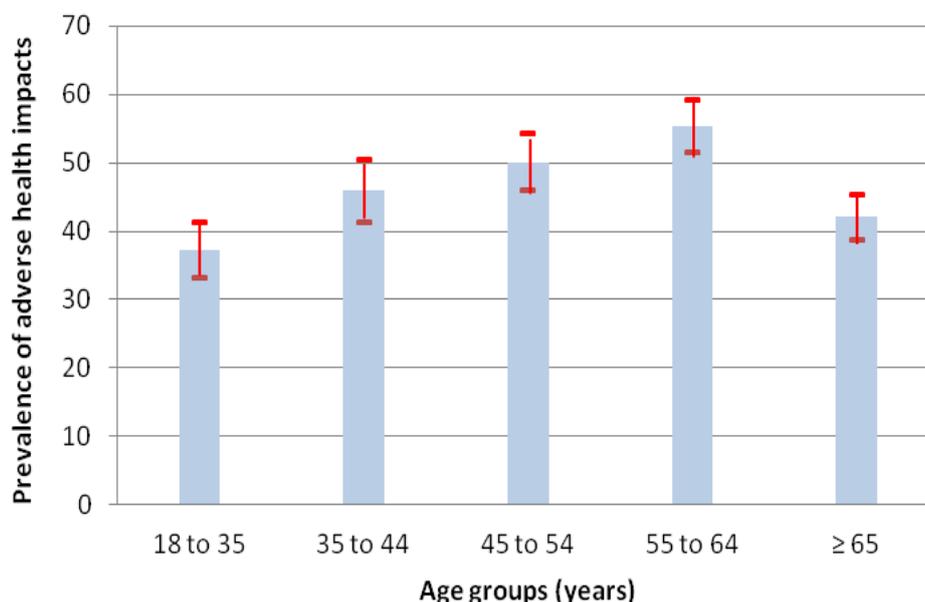
3. Results and Discussion

Among the 3485 respondents living in the very disadvantaged dissemination areas of the nine most populated cities within Québec, the prevalence of physical and mental health impacts during very hot and humid summer conditions was respectively 44.0% (CI: 42.2–45.7) and 17.8% (16.4–19.1). Combined together, the prevalence of health impacts was 46.0% (CI: 44.2–47.8). This latter prevalence was used in the analyses.

3.1. Bivariate Analyses

3.1.1. Sociodemographic and Sociocultural Characteristics

The prevalence of health impacts increased with advancing age, but only up to 65 years of age. It went from 37.2% in those 18–35 years of age to 55.3% in those 55–64 years of age, and then decreased to 42.1% in those 65 years of age and older (Figure 2; Table 1). The prevalence of impacts was higher in women (51.9%) than in men (39.1%), and also in one-person households (48.0%) compared to households with two or more people (43.7%). Women and people living alone who reported impacts were generally older. No difference was observed for the prevalence of impacts by city of residence ($p = 0.6825$).

Figure 2. Prevalence of perceived adverse health effects during very hot and humid summer conditions, (with 95% confidence intervals), by age group.**Table 1.** Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on sociodemographic and sociocultural characteristics.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Age^E				<0.0001
• 18 to 35 years	17.6 (16.2–19.0)	37.2 (33.1–41.3)	0.8 (0.7–1.0)	
• 35 to 44 years	13.4 (12.2–14.6)	45.9 (41.3–50.5)	1.2 (0.9–1.5)	
• 45 to 54 years	18.5 (17.1–19.9)	50.1 (45.9–54.3)	1.4 (1.1–1.7)	
• 55 to 64 years	21.3 (19.8–22.7)	55.3 (51.5–59.1)	1.7 (1.4–2.1)	
• ≥65 years	29.3 (27.7–30.9)	42.1 (38.8–45.4)	1.0	
Sex^F				<0.0001
• Female	54.2 (52.5–56.1)	51.9 (49.7–54.1)	1.7 (1.5–2.0)	
• Male	45.8 (44.0–47.6)	39.1 (36.3–41.9)	1.0	
Lives alone^G				0.0200
• Yes	45.6 (43.9–47.4)	48.0 (45.6–50.4)	1.2 (1.0–1.4)	
• No	54.4 (52.6–56.1)	43.7 (41.1–46.3)	1.0	
Types of households				0.0008
<i>Non-family households</i>				
• 1 person (lives alone)	54.4 (52.6–56.2)	48.0 (45.6–50.4)	1.4 (1.1–1.7)	
• ≥2 people	6.6 (5.7–7.6)	38.1 (31.0–45.1)	0.9 (0.6–1.3)	
<i>Family households</i>				
• Couple with children	14.3 (13.0–15.5)	42.9 (37.4–48.3)	1.1 (0.8–1.5)	
• Single-parent family	14.1 (12.9–15.2)	50.9 (46.4–55.4)	1.6 (1.2–2.0)	
• Couple without children	10.6 (9.5–11.7)	39.9 (35.1–44.6)	1.0	
Place of birth				0.0035
• Elsewhere than in Canada	20.4 (19.1–21.8)	40.9 (37.0–44.7)	0.8 (0.6–0.9)	
• Canada	79.6 (78.2–81.0)	47.4 (45.4–49.4)	1.0	

Table 1. Cont.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Length of residence^H				0.0059
• Arrived in <10 years	6.7 (5.9–7.6)	37.6 (31.2–43.9)	0.7 (0.5–0.9)	
• Arrived ≥10 years	13.6 (12.4–14.8)	42.4 (37.6–47.2)	0.8 (0.7–1.0)	
• Born in Canada	79.6 (78.2–81.0)	47.4 (45.4–49.4)	1.0	
Languages of conversation				0.0017
• 1 of the 2 official languages	39.0 (37.3–40.7)	48.5 (45.6–51.4)	1.4 (1.2–1.7)	
• 2 official languages	36.9 (35.2–38.7)	47.1 (44.1–50.1)	1.3 (1.1–1.6)	
• ≥1 official language and ≥1 non-official language	24.0 (22.6–25.5)	40.5 (37.1–44.0)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal;

^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio; ^E Average age: 53.3 years (CI: 52.7–53.9); ^F Mean age for women: 54.8 years; males: 51.5 years; $p < 0.0001$; ^G Mean age when lives alone: 59.8 years; ≥2 people: 45.6 years; $p < 0.0001$; ^H Mean age when immigrated <10 years: 38.4 years; ≥10 years: 52.9 years; born in Canada: 54.6 years; $p < 0.0001$.

3.1.2. Socioeconomic Characteristics

Two respondents out of five reported an income of less than \$15,000 (Canadian dollars) in the previous year (Table 2). In this group, prevalence of health impacts was higher (48.4%) than in slightly more affluent households (\$15,000–\$30,000 = 40.7%; ≥\$30,000 = 40.6%). As well, long-term medical leave (which involved 22% of the respondents of <65 years) seemed to be the situation most highly associated with impacts, with an odds ratio (OR) of 4.9 (CI: 3.9–6.3), when compared to those who worked. People on long-term medical leave (where three out of four had an income of less than \$15,000) were older on average than respondents experiencing other situations, with the exception of pre-retired or retired people. These two groups of respondents (those with incomes <\$15,000 and those on long-term medical leave) resided most often in low-rental housing rather than in other housing. Finally, one respondent out of two owned an air conditioning system, generally a window device that would be used day and night during very hot and humid summer conditions. Health impacts prevalence was a little higher in this group (OR = 1.4, CI: 1.1–1.8) when compared to households without air conditioning.

3.1.3. Lifestyle

The results showed that 37.4% of the respondents were obese and 26.7% were overweight, based on body mass index (calculated from reported height and weight) (Table 3). In these two groups of people, the prevalence of reported health impacts was slightly higher (49.4% and 46.8%, respectively) than for thin people or those with a normal build (41.2%). A higher prevalence of impacts was also associated with sedentariness and with other lifestyle factors.

Table 2. Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on socioeconomic characteristics.

Variables	% ^A (IC) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Level of education				<0.0001
• At most, secondary studies	54.9 (53.2–56.7)	49.4 (47.0–51.8)	1.5 (1.2–1.8)	
• Post-secondary studies, but not university	21.7 (20.3–23.2)	45.3 (41.5–49.1)	1.3 (1.0–1.6)	
• University studies (partial or complete)	23.3 (21.8–24.8)	39.8 (36.2–43.4)	1.0	
Household income (after taxes, all sources, 12 months)				0.0006
• <\$15,000	42.8 (41.0–44.6)	48.4 (46.2–50.5)	1.4 (0.9–2.4)	
• \$15,000 to <\$30,000	30.1 (28.4–31.7)	40.7 (37.3–44.1)	1.0 (0.7–1.5)	
• ≥\$30,000	27.1 (25.5–28.8)	40.6 (31.2–50.0)	1.0	
Respondent's main situation^E				<0.0001
• Long-term medical leave ^F	16.1 (14.8–17.4)	72.2 (68.2–76.2)	4.9 (3.9–6.3)	
• Unemployed situation, but subject to change	13.6 (12.4–14.9)	42.7 (37.9–47.6)	1.4 (1.1–1.8)	
• Preretirement or retirement	33.7 (32.1–35.4)	43.0 (39.9–46.0)	1.4 (1.2–1.7)	
• Other situations (e.g., maternity leave, natural caregiver)	8.9 (7.9–9.8)	50.9 (45.2–56.5)	2.0 (1.5–2.6)	
• Paid employment or self-employed	27.7 (26.1–29.3)	34.5 (31.3–37.6)	1.0	
Economic situation of the household in relation to the other households in the neighbourhood				<0.0001
• Much worse or slightly worse	17.9 (16.5–19.3)	59.4 (55.2–63.7)	2.3 (1.9–2.9)	
• Similar	51.8 (49.9–53.6)	46.5 (43.9–49.1)	1.4 (1.2–1.7)	
• Better or much better	30.4 (28.7–32.1)	38.6 (35.3–41.9)	1.0	
Low-rental housing resident^G				<0.0001
• Yes	46.6 (44.8–48.4)	54.1 (51.5–56.7)	1.8 (1.6–2.2)	
• No	53.4 (51.6–55.2)	39.0 (36.7–41.4)	1.0	
Air conditioning at home				0.0246
• Yes ^H	49.5 (47.7–51.2)	50.9 (48.4–53.4)	1.4 (1.1–1.8)	
• No	50.5 (48.8–52.3)	41.3 (38.9–43.8)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal; ^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio; ^E Mean age. For long-term medical leave: 52.9 years; workers: 41.7 years; situation likely to change: 39.4 years; others situations: 45.5 years; pre-retired or retired people: 70.7 years; $p < 0.0001$; ^F 75% of these people received an income of <\$15,000 in the last year; ^G Compared to the context of not living in low-rental housing, in low-rental-housing there is a higher percentage of elderly people 65 years of age or more (OR_{GR2} = 3.7, IC: 3.1–4.4, $p < 0.0001$), of people with an income of < \$15,000 (OR = 5.9, CI: 5.0–7.1, $p < 0.0001$) and of people on long-term medical leave (OR = 3.6, CI: 3.1–4.4, $p < 0.0001$); ^H 80% of these people own a window air conditioner.

Table 3. Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on lifestyle.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Body mass index^E				<0.0001
• Obesity	37.4 (35.6–39.1)	49.4 (46.5–50.3)	1.4 (1.2–1.7)	
• Overweight	26.7 (25.1–28.3)	46.8 (43.3–50.3)	1.3 (1.0–1.5)	
• Thin or normal build	36.0 (34.3–37.7)	41.2 (38.2–44.1)	1.0	
Frequency of physical activities (3 months)^F				0.0003
• No, never	32.1 (30.4–33.7)	51.1 (48.0–54.2)	1.4 (1.2–1.7)	
• Yes, <1 time/day	35.1 (33.4–36.8)	45.0 (42.0–48.0)	1.1 (0.9–1.4)	
• Yes, ≥1 time/day	32.9 (31.2–34.6)	42.2 (39.1–45.4)	1.0	
Duration per practice (3 months)				<0.0001
• 0 minutes	32.1 (30.4–33.7)	51.1 (48.0–54.2)	1.7 (1.4–2.1)	
• 1–30 min	17.6 (16.3–19.0)	52.7 (48.6–56.9)	1.8 (1.5–2.3)	
• 31 - 60 min	24.5 (22.9–26.0)	43.0 (39.5–46.6)	1.3 (1.0–1.5)	
• >60 min	25.9 (24.3–27.5)	38.1 (34.6–41.6)	1.0	
Frequency of alcohol consumption, last 12 months				<0.0001
• No, never	34.7 (33.0–36.4)	51.6 (48.6–54.6)	1.7 (1.4–2.0)	
• Yes, <1 time/month	15.8 (14.5–17.0)	50.1 (45.8–54.5)	1.6 (1.3–2.0)	
• Yes, ≥1 time/month, but not every week	17.2 (15.8–18.5)	45.1 (40.8–49.3)	1.3 (1.0–1.6)	
• Yes, ≥1 time/week	32.4 (30.7–34.1)	38.7 (35.5–41.8)	1.0	
Smokers in the dwelling daily or almost daily				0.0083
• Yes	37.4 (35.7–39.2)	49.1 (46.2–52.1)	1.2 (1.1–1.4)	
• No	62.6 (60.8–64.3)	44.2 (41.9–46.4)	1.0	
Main mode of transport to get around locally, last 12 months				0.0004
• Public transport	57.7 (56.0–59.4)	48.9 (39.6–45.1)	1.3 (1.1–1.5)	
• Automobile	42.3 (40.6–44.0)	42.3 (49.0–54.5)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal; ^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio; ^E Body mass index, mass/height²: thin or normal build ≤ 25; overweight = 25 to <30; obesity = 30 or more; ^F Mean age: if ≥ 1 time/month: 50 years; <1 time/month: 55 years; never alcohol: 56.4 years; *p* < 0.0001.

3.1.4. Diagnoses of Chronic Diseases

More than two respondents out of five (43.7%) reported no diagnosis (Dx) of chronic diseases (all causes); 24.6% mentioned only one, 13.3% two, and 18.4% at least three (Figure 3; Table 4). The prevalence of reported heat induced health impacts increased with the number of reported chronic diseases as follows: 33.9% (0 Dx), to 44.3% (1 Dx), 60.1% (2 Dx) and 67.0% (≥3 Dx). For example, of the 13.3% of respondents having declared been diagnosed with two chronic diseases, 60.1% reported that high heat and humidity adversely affected their health. Advancing age and reported impacts followed the same trend. The prevalence of impacts was also associated with multimorbidity when considered by system, specifically cardiovascular multimorbidity (≥2 Dx, OR = 2.3, CI: 1.8–2.9) and respiratory multimorbidity (≥2 Dx, OR = 5.0, CI: 3.6–7.0). Respondents with any of the

self-reported main medical conditions were also more susceptible to impacts. These conditions were: hypertension, hypercholesterolemia, asthma, chronic bronchitis, diabetes and arthritis.

Figure 3. Prevalence of perceived adverse health effects during very hot and humid summer conditions, (with 95% confidence intervals), by number of reported medical diagnoses.

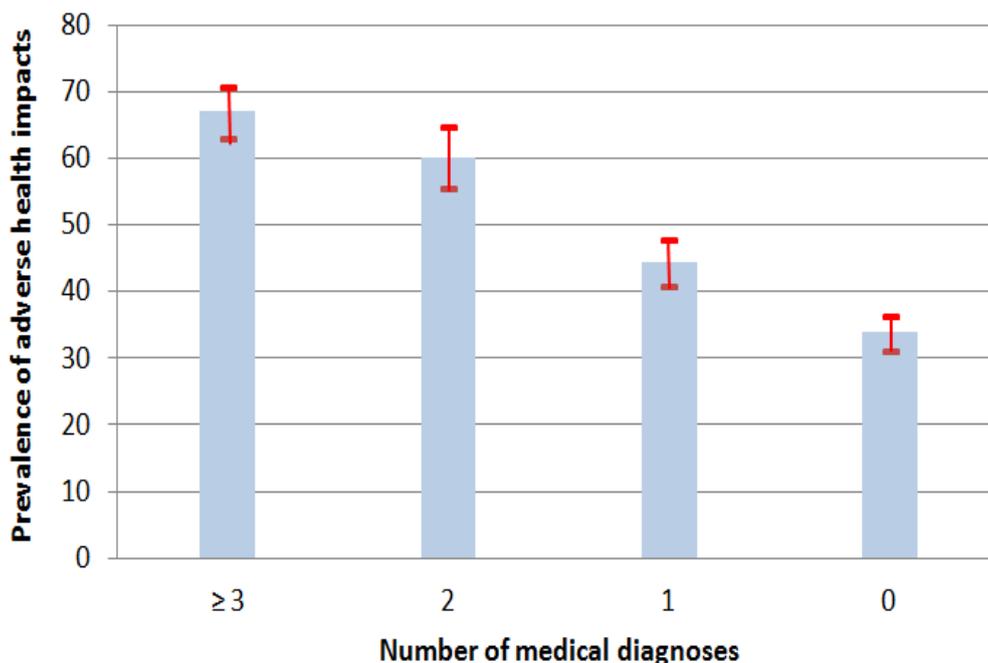


Table 4. Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on diagnoses of chronic diseases.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Diagnoses all causes^E				<0.0001
• Yes, ≥3 diagnoses	18.4 (17.1–19.7)	67.0 (63.1–70.8)	4.0 (3.2–4.9)	
• Yes, 2 diagnoses	13.3 (12.2–14.5)	60.1 (55.5–64.7)	2.9 (2.4–3.7)	
• Yes, 1 diagnosis	24.6 (23.0–26.1)	44.3 (40.8–47.9)	1.6 (1.3–1.9)	
• No, no diagnosis	43.7 (42.0–45.5)	33.9 (31.3–36.5)	1.0	
Diagnoses of the cardiovascular system				<0.0001
• Yes, ≥2 diagnoses	11.6 (10.4–12.7)	61.4 (56.3–66.5)	2.3 (1.8–2.9)	
• Yes, 1 diagnosis	19.2 (17.8–20.6)	53.4 (49.4–57.5)	1.6 (1.4–2.0)	
• No, no diagnosis	69.3 (67.7–70.9)	41.4 (39.3–43.5)	1.0	
<i>Hypertension</i>				<0.0001
• Yes	18.9 (17.4–20.4)	56.2 (51.9–60.6)	1.8 (1.5–2.2)	
• No	81.1 (79.6–82.6)	41.4 (39.3–43.5)	1.0	
<i>Hypercholesterolemia</i>				<0.0001
• Yes	14.1 (12.7–15.4)	56.7 (51.5–61.9)	1.9 (1.5–2.3)	
• No	85.9 (84.6–87.3)	41.4 (39.3–43.5)	1.0	

Table 4. Cont.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Diagnoses of the respiratory system				<0.0001
• Yes, ≥2 diagnoses	6.2 (5.4–7.1)	77.5 (71.8–83.2)	5.0 (3.6–7.0)	
• Yes, 1 diagnosis	16.0 (14.8–17.3)	59.6 (55.4–63.9)	2.2 (1.8–2.6)	
• No, no diagnosis	77.7 (76.3–79.2)	40.7 (38.7–42.7)	1.0	
<i>Asthma</i>				<0.0001
• Yes	14.4 (13.2–15.7)	68.6 (64.2–73.0)	3.2 (2.6–4.0)	
• No	85.6 (84.3–86.8)	40.7 (38.7–42.7)	1.0	
<i>Chronic bronchitis</i>				<0.0001
• Yes	9.1 (8.0–10.1)	70.4 (65.0–75.9)	3.5 (2.6–4.6)	
• No	90.9 (89.9–92.0)	40.7 (38.7–42.7)	1.0	
Diagnoses of the central nervous system^F				<0.0001
• Yes, ≥1 diagnosis	5.4 (4.6–6.2)	78.8 (72.5–85.1)	4.9 (3.4–7.2)	
• No, no diagnosis	94.6 (93.8–95.4)	43.0 (41.1–44.9)	1.0	
<i>Mental disorders</i>				<0.0001
• Yes	3.6 (2.9–4.2)	79.8 (71.9–87.7)	5.3 (3.2–8.6)	
• No	96.5 (95.8–97.1)	43.0 (41.1–44.9)	1.0	
<i>Other nervous disorders</i>				<0.0001
• Yes	1.7 (1.3–2.2)	82.2 (72.1–92.2)	6.1 (3.1–12.2)	
• No	98.3 (97.8–98.7)	43.0 (41.1–44.9)	1.0	
Diagnoses of systems other than those above				<0.0001
• Yes, ≥2 diagnoses	7.8 (6.8–8.7)	68.5 (62.7–74.3)	3.3 (2.5–4.4)	
• Yes, 1 diagnosis	25.8 (24.2–27.3)	54.1 (50.7–57.7)	1.8 (1.5–2.1)	
• No, no diagnosis	66.5 (64.8–68.2)	39.6 (37.4–41.7)	1.0	
<i>Diabetes</i>				<0.0001
• Yes	15.1 (13.6–16.6)	57.3 (52.0–62.5)	2.1 (1.6–2.6)	
• No	84.9 (83.4–86.4)	39.6 (37.4–41.7)	1.0	
<i>Arthritis</i>				<0.0001
• Yes	9.0 (7.8–10.1)	61.0 (54.5–67.6)	2.4 (1.8–3.2)	
• No	91.1 (89.9–92.2)	39.6 (37.4–41.7)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal;

^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio; ^E Mean age: when no diagnosis: 45.6 years; 1 diagnosis: 56.0 years; 2 diagnoses: 59.6 years; ≥3 diagnoses: 63.4 years, $p < 0.0001$; ^F This analysis does not include the 7.6% of respondents that did not answer the questions relating to the central nervous system. When they are taken into account by means of a dummy variable, the analysis shows that the respondents that did not answer were 2.0 (1.5; 2.7) times more likely to report health impacts during very hot and humid summer conditions (vs. no diagnosis involving this system). They were also slightly younger (51.6 years) than the other respondents (≥1 diagnosis = 56.6 years, without diagnosis = 53.2 years, $p < 0.0001$).

3.1.5. Disabilities, Reduced Mobility and Perceptions Related to State of Health

Around 30% of the respondents reported (a) at least one functional disability, or (b) at least one physical or mental disability (the definitions of these disabilities are presented in Table 5). In both cases, the affected people (a. 60.1%, b. 63.6%) were more susceptible to adverse health impacts during

very hot and humid summer conditions than those mentioning having no disability (a. 40.4%, b. 38.2%). A similar observation was made for people requiring help to get around in the neighbourhood. Furthermore, the prevalence of impacts varied most of the time with the perception of state of health and the perception of stress. In fact, the better the perceptions, the lower the prevalence of reported impacts.

Table 5. Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on disabilities, the need for help getting around in the neighbourhood and health-related perceptions.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
≥1 functional disability^E				<0.0001
• Yes	28.9 (27.3–30.5)	60.1 (56.9–63.3)	2.2 (1.9–2.6)	
• No	71.1 (69.5–72.7)	40.4 (38.3–42.5)	1.0	
≥1 physical or mental disability^F				<0.0001
• Yes	30.7 (29.1–32.3)	63.6 (60.6–66.6)	2.8 (2.4–3.3)	
• No	69.3 (67.7–70.9)	38.2 (36.1–40.3)	1.0	
Needing help getting around in the neighbourhood				<0.0001
• Yes	16.4 (15.2–17.7)	59.5 (55.4–63.7)	1.9 (1.6–2.3)	
• No	85.6 (82.3–84.8)	43.3 (41.4–45.3)	1.0	
Perception of general state of health^G				<0.0001
• Fair or poor	27.0 (25.4–28.6)	67.9 (64.6–71.1)	4.7 (3.9–5.6)	
• Good	30.9 (29.3–32.6)	47.3 (44.0–50.5)	2.0 (1.7–2.4)	
• Very good or excellent	42.1 (40.3–43.9)	31.2 (28.7–33.7)	1.0	
Mostly stressful days^H				<0.0001
• Yes, rather or extremely stressful	24.8 (23.3–26.3)	57.8 (54.4–61.2)	2.3 (1.8–2.9)	
• Yes, but not very or only slightly	57.6 (55.9–59.4)	43.6 (41.2–45.9)	1.3 (1.1–1.6)	
• No, not at all	17.5 (16.2–18.9)	37.6 (33.3–41.8)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal; ^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio; ^E Constantly or periodically, difficulty hearing (even with a hearing aid), seeing (even wearing glasses), communicating (even in their own language), walking, climbing stairs, bending, reaching or gripping an object, learning, or performing other similar activities; ^F Physical condition or mental state or health problem that reduces the amount or type of physical activity that a person can do at home, at work or at school, or in other activities, for example, in getting around or in leisure activities; ^G Mean age: when described state of health as being fair or poor: 59.9 years; better: 50.8 years, $p < 0.0001$; ^H Mean age: most of days as rather or extremely stressful: 48.2 years; not very stressful: 55 years, $p < 0.0001$.

3.1.6. Social Support and Social Contacts

In general, there were no associations between variables related to social support or social contacts and the prevalence of adverse health impacts (Table 6), except for the variable “Not having been able to rely on someone within 80 km of their dwelling when a situation required help within the last year”. This situation affected people slightly older than the other respondents.

Table 6. Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on support and social contacts.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Help received if bedridden				0.0596
• Never	13.5 (12.4–14.8)	51.9 (47.0–56.7)	1.6 (1.1–2.3)	
• Sometimes	12.3 (11.2–13.5)	52.2 (47.1–57.2)	1.1 (0.8–1.6)	
• Often or always	74.1 (72.6–75.7)	44.0 (41.9–46.1)	1.0	
Help received to go to the doctor				0.0538
• Never	13.0 (11.8–14.2)	53.6 (48.6–58.5)	1.6 (1.1–2.3)	
• Sometimes	10.5 (9.4–11.6)	51.2 (45.7–56.8)	0.9 (0.6–1.4)	
• Often or always	76.5 (75.0–78.0)	44.0 (42.0–46.1)	1.0	
Help received to prepare meals when disabled				0.0243
• Never	16.7 (15.4–18.1)	54.7 (50.2–59.1)	1.5 (1.1–2.2)	
• Sometimes	12.5 (11.3–13.6)	49.7 (44.7–54.6)	0.8 (0.6–1.2)	
• Often or always	70.8 (69.2–72.4)	43.2 (41.1–45.4)	1.0	
Help received to perform household tasks when disabled				0.0520
• Never	17.3 (15.9–18.7)	50.7 (45.4–56.0)	1.5 (1.1–2.2)	
• Sometimes	12.2 (11.0–13.3)	48.5 (45.8–51.2)	0.9 (0.6–1.3)	
• Often or always	70.6 (68.9–72.2)	43.2 (40.4–46.0)	1.0	
Number of helpers who supported the respondent, last 12 months, and living < 80 km from the dwelling^E				0.0079
• No helpers	12.2 (11.0–13.4)	47.0 (43.1–50.8)	1.4 (1.1–1.7)	
• 1 or 2 helpers	46.1 (44.3–47.9)	46.1 (43.1–47.9)	1.2 (1.1–1.5)	
• ≥3 helpers	41.7 (40.0–43.5)	45.9 (43.1–48.7)	1.0	
Face-to-face contacts with the family				0.3267
• No contact	11.7 (10.6–12.8)	49.4 (44.3–54.6)	1.2 (0.9–1.5)	
• A few times per month, but not every week	49.5 (47.7–51.3)	45.7 (43.1–48.2)	1.0 (0.9–1.2)	
• A few times per week	38.8 (37.1–40.6)	45.0 (42.1–47.8)	1.0	
Face-to-face contacts with friends				0.0399
• No contact	7.0 (6.1–6.9)	52.9 (46.0–59.7)	1.2 (0.9–1.5)	
• A few times per month, but not every week	35.4 (33.7–37.1)	47.5 (44.6–50.5)	1.0 (0.9–1.2)	
• A few times per week	57.6 (55.9–59.4)	44.5 (42.1–46.8)	1.0	
Face-to-face contacts with neighbours				0.4974
• No contact	14.6 (13.3–15.8)	46.1 (41.5–50.7)	1.0 (0.8–1.2)	
• A few times per month, but not every week	50.6 (48.9–52.4)	44.7 (41.7–47.7)	0.9 (0.8–1.1)	
• A few times per week	34.8 (33.1–36.5)	47.1 (44.6–49.6)	1.0	
Member of a non-profit organization or association				0.9453
• Yes	24.5 (23.0–26.1)	46.2 (42.6–49.7)	1.0 (0.9–1.2)	
• No	75.5 (74.0–77.0)	46.0 (44.0–48.1)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal; ^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio; ^E Average number of helpers: 2.6 helpers (CI: 2.5–2.7), OR = 0.9 (CI: 0.9–0.9). Mean age: if 1 or 2 helpers: 54.2 years; ≥3 helpers: 52.4 years; $p < 0.0001$.

3.1.7. Health, Home Care and Services

Among all respondents, 16.3% had spent at least one night in a hospital, a nursing home, or a convalescent home in the last year (Table 7). As well, 67% had consulted at least one health professional during the same period. Moreover, 9.4% had access to care or home services either completely or partially subsidized by government programs. For these three groups of respondents, the prevalence of adverse health impacts during very hot and humid summer conditions was higher than the comparison groups.

Table 7. Prevalence of reported adverse health impacts, very hot and humid summer conditions, based on health or home care and services.

Variables	% ^A (CI) ^B	P ^C (CI) ^B	OR ^D (CI) ^B	Pr > Chi-2
Treating physician's office as primary place of consultation, in general				0.0443
• Yes	65.4 (63.7–67.1)	47.5 (45.4–49.7)	1.2 (1.0–1.4)	
• No	34.6 (32.9–36.3)	43.7 (40.6–46.7)	1.0	
Stay ≥1 night in a hospital, a nursing home, a convalescent home, last 12 months				<0.0001
• Yes	16.3 (15.0–17.6)	59.4 (55.1–63.7)	1.9 (1.6–2.3)	
• No	83.7 (82.4–85.0)	43.4 (41.5–45.3)	1.0	
≥1 health professional consulted, last 12 months (without stays)				<0.0001
• Yes	67.0 (65.4–68.6)	48.8 (46.7–51.0)	1.4 (1.2–1.6)	
• No	33.0 (31.4–34.6)	40.4 (37.3–43.4)	1.0	
Home care or services paid completely or in part by the government				<0.0001
• Yes	9.4 (8.4–10.3)	57.1 (51.7–62.7)	1.6 (1.3–2.1)	
• No	90.7 (89.7–91.6)	44.9 (43.0–46.7)	1.0	

^A %: weighted frequencies in percentages. The percentages have been rounded to the nearest decimal;

^B CI: 95% confidence intervals; ^C P: prevalence of reported adverse health impacts (moderate or high) during very hot and humid summer conditions; ^D OR: odds ratio.

3.2. Multivariate Analyses

In the multivariate analysis, eight indicators explained the prevalence of adverse health impacts during very hot and humid summer conditions, namely being female, being under 65 years of age, having an annual income of less than \$15,000, a long-term medical leave situation, air conditioning at home, the number of diagnoses of chronic diseases, the perception of a fair or poor state of health, and the perception that most days were rather or extremely stressful (Table 8). A rather strong correlation was observed between age and long-term medical leave (tetrachoric correlation = -0.63), as well as between the number of diagnoses and a state of health perceived as fair or poor (polychoric correlation = 0.63). To take this into account, the analysis was stratified according to age groups (<65 years and ≥65 years), and a dummy variable pairing the diagnoses and the perceived state of health was used.

This latter model shows that being female and out of work under long-term medical leave are two self-reported health-impact risk indicators among those under 65 years of age (Table 8). Low income

is associated with more adverse impacts among this group and the elderly, like air conditioning at home. Finally, the effect of the number of diagnoses of chronic diseases (<65 years OR = 1.9, CI: 1.4–2.6; ≥65 years OR = 1.9, CI: 1.3–2.8), particularly among individuals considering their state of health as being fair or poor (<65 years OR = 5.6, CI: 3.9–8.0; ≥65 years OR = 4.2, CI: 2.9–6.2), and perceiving the presence of stress almost daily (<65 years OR = 1.5, CI: 1.3–1.9; ≥65 years OR = 1.9, CI 1.2–2.9) were the indicators most strongly associated with the increased prevalence of self-reported impacts in both age groups. This model is not influenced by the season in which the interview took place.

Table 8. Variables explaining the prevalence of reported adverse health impacts, very hot and humid summer conditions.

Independent variables	OR ^A (CI) ^{B,C}		
	All ^D	< 65 years	≥ 65 years
≥65 years (vs. <65 years)	0.6 (0.5–0.8) *	---	---
Women (vs. men)	1.6 (1.3–1.9) *	1.7 (1.4–2.1) *	1.4 (1.0–1.9)
Income <\$15,000 (vs. ≥\$15,000)	1.4 (1.1–1.6) †	1.3 (1.1–1.6) †	1.5 (1.1–2.1) ‡
Long-term medical leave (vs. no)	2.0 (1.5–2.6) †	2.0 (1.5–2.7) *	---
Air conditioning at home (any type)	1.5 (1.3–1.8) *	1.6 (1.3–1.9) *	1.4 (1.0–1.9) †
Diagnoses of chronic diseases (vs. none)			
• 1 diagnosis	1.4 (1.2–1.8) ‡	---	---
• 2 diagnoses	2.2 (1.7–2.9) ‡	---	---
• ≥3 diagnoses	2.8 (2.2–3.6) *	---	---
Fair or poor state of health (vs. good, very good or excellent)	2.1 (1.7–2.6) *	---	---
≥2 diagnoses (Dx) of chronic diseases and perceived state of health (vs. <2 Dx and state perceived as good, very good or excellent)			
• ≥2 Dx	---	1.9 (1.4–2.6) *	1.9 (1.3–2.8) †
• State of health perceived as fair or poor	---	2.2 (1.5–3.1) *	1.6 (1.0–2.7)
• ≥2 Dx and state of health perceived as fair or poor	---	5.6 (3.9;8.0) *	4.2 (2.9;6.2) *
Most days rather or extremely stressful (vs. slightly, not very, or not at all)	1.6 (1.3–2.0) *	1.5 (1.3–1.9) *	1.9 (1.2–2.9) ‡

^A OR: odds ratio; ^B CI: 95% confidence intervals; ^C *p* value associated with Chi-2 of Wald; *: $p \leq 0.0001$; †: $p \leq 0.001$; ‡: $p \leq 0.01$; †: $p \leq 0.05$; no notation: $p > 0.05$; ^D $-2 \log$: 72685.040; C index: 0.72. This model is not influenced by the season in which the interview took place ($p > 0.05$).

3.3. Discussion

In this study, the prevalence of self-reported adverse health impacts during very hot and humid summer conditions was 46% among participants, mainly on physical health with some simultaneous mental health impacts. While high, this prevalence could correspond to the reality of very disadvantaged dissemination areas in Québec's most populated cities, where several conditions strongly correlate with high temperatures and thermal discomfort indices [34,45], as described in the introduction. The prevalence of impacts is, however, a subjective measurement, the reliability and

validity of which is well established, as mentioned in the introduction, but heat exposure self-reporting should be further studied.

The risk indicators associated with the prevalence of self-reported health impacts identified subgroups more likely to feel the harmful effects of heat. Two of these subgroups were clearly associated with prevalence, independently of age. They consisted of people who described most of their days as being rather or extremely stressful and of people reporting at least two diagnoses of chronic diseases, particularly those who considered their state of health as being fair or poor. Women and people on long-term medical leave characterized only those under 65 years of age. Finally, households with very low income (<\$15,000) and air conditioning at home are associated with both groups.

High daily stress helped to explain the prevalence of self-reported health impacts in a context of heat, for all ages. In this study, 25% of the respondents said they felt such stress, which is similar to the 26.3% documented in the general population of Québec (≥ 15 years of age) in 2007–2008 [43]. Stress does not always lead to disease [46]. When it is prolonged however it can become chronic and play a negative role in health, either by causing functional disorders (e.g., sleep disturbances, mood disorders), or by initiating and maintaining diseases (e.g., inflammatory diseases, depression), or by promoting the adoption of unsuitable behaviours (e.g., excessive alcohol consumption). In addition, chronic stress could be one of the vulnerability factors of people with age-related pathologies [47–49]. The addition of thermal stress could therefore be sufficient for those individuals feeling high daily stress to perceive more health impacts in a context of heat.

The relationship between multimorbidity (≥ 2 diagnoses) and the prevalence of self-reported adverse health impacts clearly illustrates that the state of health determines physiological or biological susceptibility to heat, independently of age, corroborating what was found elsewhere [29,37,40,50]. The bivariate analysis showed that multiple and various chronic disorders can place a heavy toll on the body in a context of heat and humidity (Table 4). However, only multimorbidity (≥ 2 diagnoses) was associated with the prevalence of impacts in the multivariate analysis. In population surveys, this indicator is related to individual characteristics such as advancing age and polymedication, but also to organizational characteristics including an increase in medical consultations and the use of emergency departments [51,52]. Thus, multimorbidity could be an indicator of choice for identifying people who must receive particular attention from public authorities in surveillance, as well as in active support and follow-up during episodes of very hot and humid summer conditions. To this end, the priority would be identifying chronic disorders which compromise thermoregulation [50]. Individuals with such diseases would be particularly vulnerable to heat impacts, particularly if they are unable to seek refuge in a cool area. Validating the number of chronic disorders to use as the action threshold would be equally important to pursue.

The perception of being in poor health was strongly associated with the prevalence of health self-reported impacts in the bivariate analyses. However, in the multivariate analysis, its main contribution was its interaction with multimorbidity in the two age groups. The combination of these variables may take into account distinct characteristics of a person's state of health in a context of heat. As mentioned earlier, these perceptions can reflect certain health aspects difficult to identify clinically and are useful for predicting help-seeking behaviours and health service use [10–17]. Multimorbidity refers to diagnoses of chronic diseases and therefore to a clinical measurement, although self-reported

here. In the study, 27% of the respondents described their state of health as fair or poor, which was much higher than the 9.8% documented in the general population of Québec (≥ 12 years of age) in 2007–2008 [43]. This difference could be due to the fact that our sample (≥ 18 years of age) was, on average, relatively old (53 years of age) and from the most disadvantaged neighbourhoods of the most populated cities, but a more detailed explanation eludes us at this time.

The prevalence of self-reported health impacts was higher for women than for men, but only for those under 65 years of age. The women may have had a tendency to consider a wider range of factors when they evaluated their impacts given their tendency to do so for perceived health status [10]. On the other hand, this sex-related difference may be biological [53]. For example, female sex hormones substantially affect certain bodily responses to heat [54], as is the case for pain [55]. From 45–64 years of age in particular, women go through menopause, a period characterized by a sudden and dramatic decrease in hormone levels, contrary to men, whose drop in hormone levels is more gradual throughout andropause [56]. Improving the understanding of the mechanisms underlying the differences in sex-based health impacts in a context of heat could therefore be beneficial in ensuring that clinical settings and public health can offer more personalized adaptation strategies.

In this study, air conditioning was associated with the prevalence of self-reported health impacts during hot and humid summer conditions. The transversal design of our study did not allow verifying the beneficial effects of air conditioning to reduce or stabilize health impacts, or, on the other hand, to reduce normal physiological adaptation and potentially increase heat-related impacts [57]. A recent survey in five Canadian cities [58] similarly reported that heat-related illnesses was higher among those with cardiovascular and respiratory illnesses, higher among younger respondents and bore no relationship with the availability of air conditioning at home. On the basis of scientific literature though, it remains very likely that air conditioning during heat waves in cities brings positive effects on heat-related morbidity and mortality when diagnosed in a medical setting [57]. However, no epidemiologic study so far seems to have included indoor dwelling temperature as an exposure variable, thus precluding any firm conclusion on this topic, nor allowing population- and evidence-based recommended thresholds for setting home air conditioning optimal temperatures [59]. This could be of great interest as air conditioning use increases steadily in several countries [60,61], and is not innocuous at the community level, given its contribution to greenhouse gases and air pollutants, system-wide blackouts or other similar and costly maladaptations [62,63].

The final two indicators of the prevalence of self-reported health impacts were long-term medical leave and very low income. While the first indicator involved a particular situation for those under 65 years of age, and the second characterized also those 65 years of age and older, both spoke to poverty. In fact, 75% of those under 65 years on long-term medical leave reported an annual income below \$15,000. According to several authors, people very economically disadvantaged are one of the main groups at high heat-related risk for adverse health impacts [22,40].

In fact, poverty brings its share of consequences which have an impact on health (e.g., the lack of resources necessary for adaptation to heat) [64]. Consequently, one would expect that the low-rental housing context, which is aimed at supporting households in a difficult economic situation, would explain the prevalence of impacts not only in bivariate analysis, but also in multivariate analysis. This was not the case, suggesting that it is not living in low-rental housing *per se* that contributes to health impacts during very hot and humid summer conditions, but rather that certain characteristics of its

residents, such as the proportion of people under 65 years of age on long-term medical leave, which explains the prevalence of impacts.

In the present study, advancing age was associated with an increase in the prevalence of self-reported health impacts, but only up to 64 years of age, the threshold where the prevalence decreased (Table 1). Therefore, those 65 years and older were less likely to report impacts than younger participants. *A priori*, this observation seems contrary to what has been reported in the scientific literature, where advanced age is a risk factor for morbidity and mortality in a context of heat [22,25]. This difference may be due to the subjective nature of our impact measurement. Thus, older people could have a less accurate perception of the consequences of heat on their health, particularly because of physiological changes (e.g., reduced thermoregulation) or perceptual changes (e.g., reduced perception of heat and thirst) associated with their aging [33,65,66]. On the other hand, many older people could in fact be less at risk than younger age groups, particularly if they have the possibility of adapting well to heat, such as by not having to leave their dwelling for work or the family, contrary to younger working people. Older people do not comprise a homogeneous population simply because they belong to the same age group. A similar observation could be applied to people living alone, a characteristic generally considered as being a risk factor during very hot and humid summer conditions [67], while in this study, its relationship with the prevalence of impacts was low in the bivariate analysis and not statistically significant in the multivariate analysis. Refining these indicators would therefore be most useful from the standpoint of public health surveillance and emergency preparedness.

3.4. Limitations of the Study

The study's response rate was low, but the response rate by question (considered as being another measurement of the survey's response rate) was very good. No response rate from Canadian surveys can be used for comparison purposes, particularly because none of these surveys specifically targeted the very disadvantaged DAs studied. Based on a previous qualitative study conducted in two of the sampled cities [68] and due to the characteristics of the communities studied (large urban centres, multiethnic environments, *etc.*), it seems, however, that this rate could in fact represent what can realistically be obtained in the very disadvantaged DAs of Québec's large cities.

For ethical considerations, no information was collected from people deciding not to participate in the study. In order to make up for this limitation, certain statistics were compared to census data available by DA at the *Institut national de santé publique du Québec*. On this basis, it is possible to propose that the data from the study are comparable (from the standpoint of response rates) to those of the 2006 Census regarding the percentage of:

- non-family households (census = 56.1%; study = 61%);
- non-family households of only one person (87.6% and 90%);
- non-family households of at least two people (11.8% and 10%);
- single-parent families among the family households (34.4% and 36.2%);
- couples with or without children among the family households (65.4% and 63.8%);
- couples with children among the family households (46.8% and 42.4%);
- couples without children among the family households (53.5% and 57.6%);

- people born elsewhere than in Canada (20.9% and 20%);
- immigrants speaking neither French nor English (2.0% and 0, because speaking one of the two official languages was a selection criterion in the study);
- dwellings requiring major repairs (11.1% and 14.2%);
- single-family homes (individual, semi-detached, row housing) (5.7% and 6.1%).

The study, however, seemed to underestimate the average income per household (census = \$29,779; study, estimate using the midpoint of the \$5000 strata = \$23,679), and overestimate the average age (census, ≥ 18 years = 47 years; study = 53 years). These differences could be due to the fact that half of the sample comes from low-rental housing, considering the design of our study. Low-rental housing is mainly intended for low-income households and those experiencing a difficult economic situation. Also, half of the low-rental housing clientele consisted of elderly people. Furthermore, the average income (\$31,724) and age (49.1 years) of the group not living in low-rent housing in the study were comparable to the census data.

Based on this information and despite the low response rate, it is therefore possible to state that the samples in the study generally represented well the populations living in the visited DAs, and also all the very disadvantaged DAs in Québec's nine largest cities, due to the sampling plan that was adopted in the study (and that was taken into account in the weighting of the data). The percentages of elderly people and people with low income (which reduced the average income) seem, however, to be overestimated due to the study's design.

Moreover, given the use of two distinct methods of recruitment and the change in procedure during data collection, the people recruited by telephone and those recruited door-to-door were compared. The results of these comparisons (presented in a methodological report, see Bédanger *et al.* [30]) indicate that door-to-door collection made it possible to increase the representation of the very disadvantaged DAs and to include people who would not have otherwise participated (e.g., incorrect contact information). Thus, the pairing of the two types of recruitment reduced the risk of selecting only those who were at home and who had only one stationary telephone. The sampling plan adopted in the study therefore minimized potential selection biases.

4. Conclusions

In conclusion, the present study documented the prevalence of reported health impacts during very hot and humid summer conditions in the most disadvantaged dissemination areas of Québec's most populated cities. Seven risk indicators were associated with this prevalence. Perceived stress and multimorbidity, particularly if paired with perceived state of health, demonstrated the significance of factors having an impact on heat sensitivity, both in those under 65 years of age and in those 65 years of age and older. Female sex, long-term medical leave, and very low income suggest biological, perceptual or contextual differences that can have an impact either on heat exposure or on adaptation in both of the age groups. Based on the C index (around 0.7, which indicates that the model's discriminant capacity is average), it appears that the scope of the indicators associated with the prevalence of health impacts should be broadened to other categories of variables, such as the characteristics of the dwelling and lifestyle. Finally, according to our data, it seems that the use of these seven simple indicators would identify, from existing or future population surveys, subgroups at

high risk of experiencing the adverse consequences of oppressive heat and could constitute the basis of a heat vulnerability index to be built from existing survey data in most developed countries.

This study complements the epidemiologic studies based on mortality or severe morbidity (emergency rooms visits or hospitalisations) and shows that the heat-related burden of disease appears very important, affecting several subgroups differentially. These indicators can help to better target public preventative and emergency interventions in the future at a low cost, as they are often available from existing community surveys and health surveillance reports. Relevant further research should focus on: (1) validity of self-reported heat exposure; (2) better identification of chronic diseases compromising thermoregulation; (3) better understanding of the mechanisms underlying the differences in sex-based health impacts in a context of heat; (4) better assessment of indoor temperature as an exposure variable for heat impacts.

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Author Contributions

All authors contributed to the study design. Diane Belanger and Pierre Gosselin supervised data collection. Diane Belanger and Belkacem Abdous were responsible for data analysis. All authors contributed to data interpretation and writing of the paper. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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