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by Matthew Quick and Michael Tjepkema

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## ABSTRACT

### Background

Household air conditioning is one of the most effective approaches for reducing the health impacts of heat exposure; however, few studies have measured the prevalence of household air conditioning in Canada.

### Data and methods

Data were obtained from the 2017 Canadian Community Health Survey and the 2017 Households and the Environment Survey. Statistics Canada linked the survey respondents and created survey weights. Four heat-vulnerable populations were defined: older adults, older adults living alone, older adults with at least one health condition associated with reduced thermoregulation and older adults living alone and with a health condition associated with reduced thermoregulation. Weighted ratios and logistic regression models were used to analyze person-level air conditioning rates for national, regional and heat-vulnerable populations.

### Results

Approximately 61% of the national population had household air conditioning. Regional rates ranged between 32% in British Columbia and 85% in Ontario. People living alone and people who did not own a home were significantly less likely to have air conditioning in Canada and in most regions. One heat vulnerable group, older adults living alone, had significantly lower air conditioning rates compared with the national and Ontario averages, at 56% and 81%, respectively.

### Interpretation

This study is the first to quantify air conditioning prevalence in Canada at the person-level. The results of this study may inform heat-health policies and climate change adaptation strategies that aim to identify populations with high risks of heat-related mortality or morbidity and low access to household air conditioning.

### Keywords

heat, air conditioning, vulnerable populations, aging, social isolation, climate change

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Extreme heat exposure has been shown to be associated with a variety of health outcomes. In Canada, between 0.2% and 0.7% of all deaths from 1986 to 2009 have been attributed to heat.<sup>1</sup> More recently, approximately 280 deaths occurred during the 2010 Quebec heat wave,<sup>2</sup> and 619 deaths occurred in British Columbia during the 2021 heat dome in Western North America.<sup>3</sup> In addition to mortality, short- and long-term heat exposure can lead to a variety of heat-related illnesses and outcomes, including heatstroke, exhaustion, dehydration and hospitalization resulting from respiratory and cardiovascular diseases.<sup>4,5,6</sup> With climate change projected to cause higher ambient temperatures and longer, more frequent and more intense extreme heat events,<sup>7</sup> the health impacts of heat exposure are expected to increase.<sup>8,9</sup>

Past research has consistently shown that household air conditioning is one of the most effective adaptation strategies to reduce heat-related mortality and morbidity.<sup>10,11,12,13,14</sup> However, to date, few studies have explored the prevalence of household air conditioning in Canada. Descriptive statistics suggest that about 60% of Canadian households owned an air conditioner in 2019, with provincial estimates ranging between 18% in Newfoundland and Labrador and 85% in Manitoba.<sup>15</sup> Richard et al.<sup>16</sup> observe that 73% of 238 adults with chronic heart and lung disease in Montréal had air conditioning, and Alberini et al.<sup>17</sup> find that 85% of 1,100 households in five Canadian cities had air conditioning, ranging from 97% in Windsor, Ontario to 53% in Fredericton, New Brunswick. Because existing studies focus on households and small populations from a few geographical contexts, there is a limited understanding of national-level air conditioning rates and if, and how, the prevalence of air conditioning varies by geography and individual characteristics (e.g., health conditions).

This study explores the prevalence of household air conditioning in Canada using two newly linked surveys: the 2017 Canadian Community Health Survey (CCHS) and the 2017 Households and the Environment Survey (HES). The first objective of this study was to quantify and describe the patterns of household air conditioning according to person-level sociodemographic characteristics and health conditions in Canada and in five geographical regions. The second objective of this study was to estimate household air conditioning rates among heat-vulnerable populations, or population groups with reduced thermoregulation and greater health risks resulting from heat exposure.

## Methods

### Data sources

Data were obtained from the 2017 CCHS and HES. The CCHS is a cross-sectional survey that collects person-level information related to health status, health determinants and health care use.<sup>18</sup> The CCHS target population is people aged 12 years and older living in the 10 provinces and the three territorial capitals. Excluded from the CCHS are people living on reserves and other Indigenous settlements, full-time members of the

Canadian forces, institutionalized populations (e.g., those living in correctional facilities, long-term care centres and hospitals), and children aged 12 to 17 living in foster care.

Eleven variables from the CCHS were included in this study. Seven variables captured the sociodemographic characteristics of the participants: older than 65 years (yes = 1; no = 0), male sex (yes = 1; no = 0), racialized group (yes = 1; no = 0), less than a high school education (yes = 1; no = 0), low-income status (yes = 1; no = 0), lives alone (yes = 1; no = 0) and lack of home ownership (yes = 1; no = 0). The term “racialized group” is used to label the visible minority concept. Under the *Employment Equity Act*, visible minorities are “persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour.”

Four variables captured health conditions associated with reduced thermoregulation and elevated health risks resulting from heat stress:<sup>19</sup> cardiovascular disease (yes = 1; no = 0), obesity (yes = 1; no = 0), diabetes (yes = 1; no = 0) and high blood pressure (yes = 1; no = 0). Cardiovascular disease included heart disease and stroke. People were defined as having high blood pressure if they reported having a diagnosis or taking related medications. Based on their residential address, participants were also grouped into five geographical regions defined by Statistics Canada:<sup>20</sup> Atlantic (New Brunswick, Newfoundland and Labrador, Nova Scotia and Prince Edward Island), Quebec, Ontario, Prairie (Alberta, Manitoba and Saskatchewan), and British Columbia.

Household air conditioning data were retrieved from the HES. The HES is a cross-sectional survey administered every two years by Statistics Canada to measure the environmental practices and behaviours of households.<sup>21</sup> The HES is a follow-up survey to the CCHS. The target population of the HES is all households in Canada, excluding those in the territories (i.e., Northwest Territories, Nunavut and Yukon), on reserves and other Indigenous settlements and those entirely composed of full-time Canadian Armed Forces members. Institutions are also excluded. For this study, people living in a household with a central or stand-alone (e.g., window) air conditioning system were defined as having air conditioning (yes = 1; no = 0).

### Heat-vulnerable population groups

Four heat-vulnerable population groups were considered in this study. The first was older adults (older than 65 years). Previous research has shown that age is the most important non-modifiable risk factor influencing heat vulnerability and that adults older than 65 years experience disproportionately high health risks.<sup>9,19</sup> Older adults may also experience age-related attenuation in thermal sensations and not feel the need to use an air conditioner.<sup>22</sup> The second heat-vulnerable population group was older adults living alone. Previous studies suggest that high social isolation increases the health impacts of heat.<sup>23,24</sup> The third population group was older adults with at least one of the four health conditions associated with reduced thermoregulation (see Section 2.1). The fourth heat-vulnerable population group was older adults living alone with a health

condition associated with reduced thermoregulation. This latter heat-vulnerable group was representative of most of the decedents during the 2021 heat dome event in British Columbia.<sup>3</sup> Note that additional heat-vulnerable population groups, such as infants, young children and people with schizophrenia, were not considered in this study.

**Data linkage and survey weights**

The people included in this study were the subset of CCHS participants who lived in dwellings included in the HES sample, responded to the HES, and accepted CCHS and HES data sharing agreements and record linkage. Approximately one-quarter of CCHS participants were linked to the HES. Survey weights were created by Statistics Canada to inflate the population and represent the CCHS target population. Based on the original survey weights created for the CCHS,<sup>18</sup> the weights for this linked cohort were inflated by province and age group to adjust for HES response rates. The survey weights were calibrated based on population totals in the full CCHS for each province, age group and sex. Health variables were also calibrated individually using the full CCHS for each province and age group. To capture uncertainty in the survey weights, 1,000 bootstrap replicates were created by sampling participants with replacement and recalculating the weights as described above. The linked cohort was composed of 14,418 people weighted to represent approximately 31 million people. Descriptive statistics for the weighted and unweighted data are shown in Appendix A.

**Data analysis**

Air conditioning rates were calculated using weighted ratios, where the numerator was the weighted count of people with air conditioning and the denominator was the weighted population count. Air conditioning rates were calculated at the national and

regional levels and for population groups defined by the seven sociodemographic characteristics and the four health conditions. Air conditioning rates were also calculated for the four heat-vulnerable population groups. Logistic regression models with 11 binary explanatory variables (the sociodemographic characteristics and health conditions) were applied to analyze the variability of access to household air conditioning at national and regional levels.

To quantify the degree to which air conditioning rates in heat-vulnerable populations were different from national and regional averages, logistic regression models with a single binary variable indicating membership in a heat-vulnerable population group were used. All weighted ratios and regression models were estimated using the replicate bootstrap survey weights. Data analyses were completed in R version 4.1.3<sup>25</sup> using the survey package version 4.0.<sup>26</sup>

**Results**

**National and regional rates of household air conditioning**

Table 1 shows the national and regional household air conditioning rates for the population groups defined by the seven sociodemographic characteristics and the four health conditions. Approximately 61% of the national population had household air conditioning and substantial interregional differences were observed: 85% of people in Ontario had air conditioning, 58% in Quebec, 49% in the Prairie region, 38% in the Atlantic region and 32% in British Columbia. These person-level results broadly align with previously published household-level data.<sup>15</sup> As highlighted in previous research,<sup>17</sup> regional variations in air conditioning align with historical climate patterns; air conditioning was more common in regions with

**Table 1**  
Air conditioning rates by selected person-level characteristics and regions, household population aged 12 years or older, Canada, excluding the territories, 2017

	National		Atlantic		Quebec		Ontario		Prairie		British Columbia	
	Percent	Standard error	Percent	Standard error	Percent	Standard error	Percent	Standard error	Percent	Standard error	Percent	Standard error
<b>Total</b>	61.1	0.6	37.5	1.5	57.8	1.3	85.3	0.9	48.9	1.1	31.9	1.6
<b>Sociodemographic characteristics</b>												
Older than 65 years	62.6	0.9	35.9	2.3	57.4	2.1	86	1.3	54.3	2.4	31.4	2.6
Male	63.1	0.7	36.5	2.2	58.6	1.8	86.8	1.1	49.9	1.7	33.6	2.3
Racialized group	61.8	1.5	20.8	5.9 †	58.7	4.5	87.5	1.8 †	37.7	2.9 †	17.8	2.6 †
Less than a high school education	51.3	2.3 †	23.6	3.8 †	39.3	3.8 †	76.3	4.1	53.7	4.7	34	6.5
Low-income status	54.5	2.2	28.1	5.6	48	3.9	77.3	3.2	37.5	4.7	24.8	4.6
Lives alone	52.5	1.4 †	27.8	2.9 †	49.8	2.3	74.3	2.5 †	46.1	2.8	27.2	2.9
Does not own home	49.8	1.5 †	33.3	3.7	48.6	2.7 †	71.4	2.5 †	35.5	2.7 †	24.2	3.6 †
<b>Health conditions</b>												
High blood pressure	64.5	1.1	38.7	2.7	59.8	2.8	86.7	1.5	54.7	2.6	31.9	3.2
Obesity	64.8	1.4 †	42.7	3.2	56.9	3.2	85.9	1.8	55.2	3	42.7	4 †
Cardiovascular disease	61	2	45.3	4.7 †	57.9	4.3	81.6	3	46.2	4.5	32.3	5.1
Diabetes	66.9	1.7 †	39.8	4.5	60.8	4.2	89.6	1.7 †	55	4.5	30.7	5.4

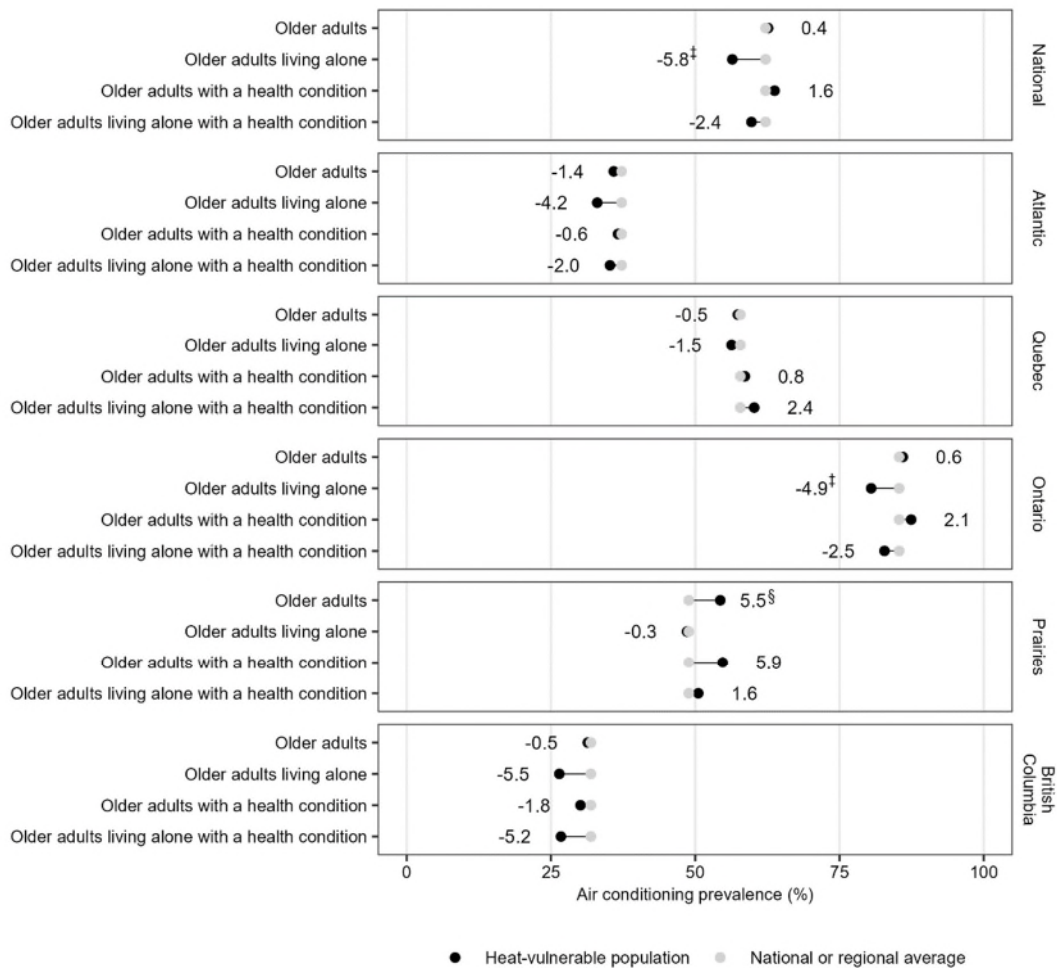
† β < 0 and p < 0.05 based on the logistic regression models.

‡ β > 0 and p < 0.05 based on the logistic regression models.

Notes: Standard errors were calculated using the bootstrap replicate weights.

Source: Statistics Canada, linked 2017 Canadian Community Health Survey and 2017 Households and the Environment Survey.

**Figure 1**  
**Air conditioning rates for four heat-vulnerable population groups in Canada, excluding the territories, 2017**



‡  $\beta < 0$  and  $p < 0.05$  based on the logistic regression models.

§  $\beta > 0$  and  $p < 0.05$  based on the logistic regression models.

**Notes:** The numbers represent the difference between the rates for the national or regional populations and the heat-vulnerable populations. The air conditioning rates can be found in Appendix B. The statistical significance of the differences were determined by the coefficients in the logistic regression models.

**Source:** Statistics Canada, linked 2017 Canadian Community Health Survey and 2017 Households and the Environment Survey.

humid climates (i.e., Ontario and Quebec), whereas air conditioning was less common in regions with more moderate climates (i.e., British Columbia).

Compared with the national average, people with obesity and diabetes had significantly ( $p < 0.05$ ) higher air conditioning rates, whereas those who had less than a high school education, lived alone and did not own a home had significantly ( $p < 0.05$ ) lower air conditioning rates. Adjusting for the underlying regional averages, people who did not own a home and lived alone had lower-than-average air conditioning rates in all regions. People who are part of racialized groups were significantly ( $p < 0.05$ ) less likely to have household air conditioning in the Atlantic, Prairie and British Columbia

regions, and people living alone were significantly ( $p < 0.05$ ) less likely to have household air conditioning in the Atlantic and Ontario regions. While higher air conditioning rates were observed for people with obesity in British Columbia, cardiovascular disease in the Atlantic region and diabetes in Ontario, patterns were inconsistent across the regions. Air conditioning rates for older adults, males and low-income households did not meaningfully depart from the national and regional averages.

### Air conditioning prevalence in heat-vulnerable populations

The prevalence of household air conditioning among the four heat-vulnerable population groups is shown in Figure 1. At the national level and in Ontario, older adults who lived alone had significantly ( $p < 0.05$ ) lower air conditioning rates than the respective national and regional averages (modeled estimates of 56% compared with 62% and 81% compared with 85%, respectively). In contrast, older adults had significantly ( $p < 0.05$ ) higher than average air conditioning rates in the Prairie region (modeled estimates of 54% compared with 49%). In the Atlantic, Quebec and British Columbia regions, air conditioning rates among the four heat-vulnerable population groups were not significantly different from the regional averages. Additional results are in Appendix B.

### Discussion

This study measured and described household air conditioning in Canada using two newly linked surveys. Focusing specifically on interpreting the sociodemographic characteristics, people who did not own their home were found to be less likely to have household air conditioning in Canada and in the Quebec, Ontario, Prairie and British Columbia regions (Table 1). This broadly aligns with previous research that observed lower air conditioning rates in multi-family rental housing.<sup>27,28</sup> Additionally, renters may have lower air conditioning rates because landlords do not provide air conditioning or building regulations may prohibit its use. Additionally, people living alone were found to have lower air conditioning rates in Canada and in the Atlantic and Ontario regions (Table 1). Similar patterns of people living alone having lower access to air conditioning have been observed elsewhere.<sup>28,29</sup>

This study also found that older adults who lived alone, in particular, were significantly less likely to have household air conditioning in Canada and Ontario. In general, older adults living alone have been found to have high health risks resulting from heat, as they are thought to be less likely to access informal networks of care (e.g., family members checking in on them), seek medical attention and leave non-air-conditioned homes to seek refuge elsewhere.<sup>12,23,24,29</sup>

One strength of this study is that the data are at the person-level and include information on health conditions. This allows for air conditioning rates to be estimated for a variety of population groups, including people with health conditions that reduce thermoregulation. This also helps inform heat-health and climate change adaptation strategies that aim to identify populations with high health risks resulting from heat and low access to air conditioning. For example, Canada's National Adaptation Strategy<sup>30</sup> proposes that the proportion of households with cooling systems be used as an indicator of health and well-being in climate change adaptation.

The limitations of this study are that the data linkage is for a single year, the surveys exclude institutionalized populations and populations living in Indigenous settlements who may also be vulnerable to heat stress, the data exclude people living in the three territories, and some health conditions may be under-reported or not included on the CCHS. Future work may consider measuring air conditioning rates for more specific population groups; exploring time trends in air conditioning prevalence;<sup>31</sup> and undertaking additional data linkage to allow for research exploring the associations between heat, air conditioning and health outcomes. Future research may also focus on further exploring the causes and impacts of the air conditioning rates identified in this study.

## Appendix A

## Sample size and descriptive statistics for the linked Canadian Community Health Survey and the Households and the Environment Survey cohort, household population aged 12 years or older, Canada, excluding the territories, 2017

	Unweighted	Weighted	
	Frequency	Frequency	Standard error
Total population (count)	14,418	30,986,000	...
Air conditioning prevalence (%)	56.2	62.6	0.6
<b>Region</b>			
Atlantic (%)	13.7	6.6	0
Quebec (%)	21.2	23.1	0
Ontario (%)	29.2	39.1	0
Prairie (%)	22.9	17.9	0
British Columbia (%)	14.1	13.3	0
<b>Sociodemographic characteristics</b>			
Older than 65 years (%)	29.2	17.8	0.1
Male (%)	45.8	49.4	0.2
Racialized group (%)	11.7	20.8	0.6
Less than a high school education (%)	7.7	4.8	0.2
Low-income status (%)	7.6	9	0.4
Lives alone (%)	24.3	13.4	0.4
Does not own home (%)	20.3	22.9	0.6
<b>Health conditions</b>			
High blood pressure (%)	22.9	17.9	0.3
Obesity (%)	20.9	18.3	0.5
Cardiovascular disease (%)	8.2	5.8	0.2
Diabetes (%)	9.1	7.2	0.2

... not applicable

**Note:** Counts are rounded to the nearest thousand.

**Source:** Statistics Canada, linked 2017 Canadian Community Health Survey and 2017 Households and the Environment Survey.

## Appendix B

## Air conditioning rates for four heat-vulnerable population groups by geographic region, Canada, excluding the territories, 2017

Heat-vulnerable population group	National		Atlantic		Quebec		Ontario		Prairie		British Columbia	
	Percent	Standard error	Percent	Standard error	Percent	Standard error	Percent	Standard error	Percent	Standard error	Percent	Standard error
Older adult	62.6	0.9	35.9	2.3	57.4	2.1	86	1.3	54.3	2.4 <sup>§</sup>	31.4	2.6
Older adult living alone	56.4	1.8 <sup>‡</sup>	33	3.8	56.3	3.3	80.5	2.6 <sup>‡</sup>	48.6	3.8	26.5	3.8
Older adult with a health condition	63.8	1.1	36.6	2.8	58.6	2.8	87.4	1.4	54.8	3.2	30.1	3.1
Older adult living alone with a health condition	59.7	2.1	35.2	4.9	60.2	4.3	82.8	2.7	50.5	4.6	26.7	4.9

<sup>‡</sup>  $\beta < 0$  and  $p < 0.05$  based on the logistic regression models.

<sup>§</sup>  $\beta > 0$  and  $p < 0.05$  based on the logistic regression models.

**Notes:** Older adults are older than 65 years. Standard errors were calculated using the bootstrap replicate weights.

**Source:** Statistics Canada, linked 2017 Canadian Community Health Survey and 2017 Households and the Environment Survey.



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