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Correlates of hot day air-conditioning use among middle-aged and older adults with chronic heart and lung diseases: the role of health beliefs and cues to action

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Abstract

Extreme ambient heat is a serious public health threat, especially for the elderly and persons with pre-existing health conditions. Although much of the excess mortality and morbidity associated with extreme heat is preventable, the adoption of effective preventive strategies is limited. The study reported here tested the predictive power of selected components of the Health Belief Model for air-conditioning (AC) use among 238 non-institutionalized middle-aged and older adults with chronic heart failure and/or chronic obstructive pulmonary disease living in Montréal, Canada. Respondents were recruited through clinics (response rate 71%) and interviews were conducted in their homes or by telephone. Results showed that 73% of participants reported having a home air conditioner. The average number of hours spent per 24-hour period in air-conditioned spaces during heat waves was 14.5 hours (SD = 9.4). Exploratory structural equation modeling showed that specific beliefs about the benefits of and drawbacks to AC as well as internal cues to action were predictive of its level of use, whereas the perceived severity of the effects of heat on health was not. The findings are discussed in light of the need to adequately support effective response to extreme heat in this vulnerable population.

Introduction

Unusually hot weather is now recognized as a serious public health threat [1–3]. Recent heat waves have resulted in significant excess immediate mortality and morbidity [3–7]. Prolonged exposure to extreme heat, especially consecutive nights with high minimum temperatures, as during the 2003 heat wave in France and the 1995 Chicago episode, can provoke thousands of deaths [2, 5, 8]. Outside of these clearly demarcated 'heat waves', isolated days with temperatures only several degrees above average have been associated with higher-than-expected numbers of deaths from causes only indirectly related to overheating [9, 10]. Temperature change need not be extreme for heat-related risks to accrue: in the UK, older persons are at heightened mortality risk with any temperature rise above 17°C, and risk increases linearly or more as temperatures rise further [11]. Exposure to heat can exacerbate existing cardiovascular and respiratory conditions, resulting in increased hospital admissions and mortality [12, 13]. Indeed, the health effects of extreme heat persist long after temperatures have cooled: follow-up of heatstroke patients shows important declines in functional status, associated with prolonged hospitalization and earlier death [7]. It is expected that the public health problems attributable to extreme heat will be especially

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significant when combined with the increased vulnerabilities of an aging population and phenomena such as global climate change, urban heat islands and air pollution [1–5].

Older adults are at especially high levels of risk for heat-related illnesses, as are those living alone, without access to air-conditioning (AC), in urban areas, and with pre-existing health conditions [1, 3, 11, 14]. Mortality in the 2003 European heat wave was markedly higher among older adults living outside of institutions than in either the institutionalized elderly or in younger adults [15, 16] and was especially high among those with limited autonomy [14–17]. Nor do these risks apply only to the oldest old: heat-related mortality risk rises with increasing age after about 50 years [2].

Heat-related health risk is distributed inequitably across population groups. A recent review concluded that poverty is an important determinant of heat-associated mortality risk in American but not in European cities [2]. However, in the French heat wave of 2003, income was an independent predictor of mortality [17]. Coupled with the established link between ill health and poverty among older persons [18], older adults living in poverty may be the most vulnerable of all, for example, having to choose between purchasing food or buying and running an air conditioner [19].

Much of the excess mortality and morbidity associated with heat illness is believed to be preventable through the implementation of heat emergency plans and warning systems that lead to adoption of behavioral adaptations such as AC use and increased fluid intake [1, 4, 19]. In the Chicago heat wave of 1995, mortality was significantly lower among people who had working air conditioners in their homes or in their apartment lobbies or who visited air-conditioned places [8]. Although one study in the United States showed that over the period 1987–2000 cardiovascular mortality risks associated with cold temperatures have been constant among older persons [20], heat-related deaths in this population have declined. This was attributed to increased use of AC, in combination with other factors such as improved health care. In the French heat wave of 2003, older persons who visited air-conditioned or cooled places or who used cooling techniques and devices including air conditioners were less likely to die from heat-related causes than those who did not [14]. Exposure to AC, even for a limited time, thus can act as an important protective measure against heat-related mortality. Further, if AC or other recourse to personal cooling is employed, the need for activity reduction and supplementary hydration, other commonly recommended hot day protection behaviors, is much reduced [21].

Despite the effectiveness of such preventive measures, public recognition of the health risks associated with hot weather is low, as is adoption of effective preventive strategies. A study in four North American cities found that despite widespread awareness of heat advisories, only about half of urban residents adopted preventive actions [22]. Similarly, Kalkstein and Sheridan [23] showed that only 50% of residents who had heard heat advisories did something different on the days they heard them. Although evidence on the responses of the older adults to environmental health issues is more limited than that for the general population, some evidence suggests that older people are less likely to change behaviors in light of climate change [24]. Faced with environmental health threats, older people are equally unlikely or more unlikely than the general population to undertake protective actions, due to in part to perceptions of invulnerability [25]. And, one study has shown that likelihood of behavior change in response to heat advisories is related to age: whereas 67% of those aged 42–53 years reported making such changes, only 40% of those over 65 years reported doing so [23].

Given the potential to decrease their health risk from elevated heat events through more effective preventive action, it is of interest to identify the perceptions and beliefs that predict the adoption of such preventive behaviors among people at risk for heat-related illness.

The Health Belief Model

The Health Belief Model (HBM), originally proposed over 35 years ago [26–28], is one of the most widely used conceptual frameworks for the study of health behavior. Over hundreds of studies, support has been found for the predictive role of all of its main components in the adoption and maintenance of health promoting and prevention behaviors. The HBM's components are (i) perceived susceptibility: an individual's perception of his or her risk of developing the health problem or being affected by the health threat; (ii) perceived severity or seriousness of the health threat. The combination of susceptibility and severity has been termed as perceived threat; (iii) perceived benefits of the preventive action, i.e. the perceived efficacy of the behavior in reducing the health threat's severity or the individual's susceptibility to it, as well as non-health-related benefits; (iv) perceived costs, barriers or disadvantages to the prevention action and (v) cues to action: the presence of information, reminders or bodily events that incite or encourage preventive action. A sixth component, self-efficacy, has been included more recently [28]. The model posits that each of these factors makes an independent contribution to adoption or maintenance of specific health behaviors.

Health beliefs and health threat response among older adults

Several studies have established the predictive validity of the HBM in older populations, for a variety of health issues. For example, older adults' influenza vaccination behaviors were predicted by perceived barriers, perceived benefits and perceived severity [29]. HBM components predicted sun-exposure protective behaviors in seniors [30], as well as health maintenance activities aiming to prevent health deterioration [31]. In a qualitative study of older women, low levels of perceived vulnerability were associated with a lack of attention to future health [32]. It is important to note that preventive health behavior in older adults seems more influenced by subjective than actual health status [33].

With respect to adaptation to climate change, no study has tested the Heath Belief Model in its entirety nor examined its utility in understanding preventive behaviors of vulnerable populations. However, studies have shown that a variety of beliefs—some corresponding or being very close to those of the HBM—predict adaptive behaviors. Studies of population response to natural hazard warnings have consistently shown that response is partly determined by perceived urgency of the threat [34]. In summarizing major covariates of hazard warning responses, Mileti and Sorenson [35] note that physical and social cues, perceived risk, perceived efficacy and proximity to the hazard all increase adequacy of response. Although there are few data on older people's beliefs in relation to heat protective behavior, those that exist suggest that HBM components may be useful predictors. A recent study of older people's (mean age of 80 years) perceptions of heat-related health risk in United Kingdom found that respondents did not necessarily perceive themselves as either 'old' or at risk, although they would have been identified as vulnerable by existing public health criteria. A minority was aware that their existing medical condition or medication increased their risk [36]. However, most reported adopting preventive behaviors, based on 'common sense' (p. 124), during previous heat waves. A survey of Phoenix, Arizona, residents found that while 93% of those over 65 years were aware of the heat warning system, older respondents were less likely than the youngest respondents to believe that heat was very dangerous to them—i.e. had low levels of perceived risk [23].

The study reported here tested the predictive power of selected components of the HBM for AC use among non-institutionalized older adults with two serious chronic health conditions: chronic heart failure (CHF) and/or chronic obstructive pulmonary disease (COPD). These individuals are highly vulnerable to heat threats: much of the excess mortality associated with extreme heat occurs through respiratory and/or cardiovascular failure [9]. Given the frequency of these two chronic conditions among older persons, and their association with social and economic disadvantage [18], individuals treated for CHF and COPD could be considered as representing members of the population vulnerable to serious consequences of heat exposure through both age and illness. The study addressed two main questions: (i) what proportion of high-risk middle-aged and older adults with chronic heart and/or lung disease living at home display the preventive health behavior of air conditioner use? and (ii) what predictive role do health beliefs and perceptions play in that behavior? Although relying on self-reported behaviors, the study assessed usual behavior during high heat periods rather than behavioral intentions, which have been shown to be poor predictors of response to environmental health threats [34].

Methods

Sample and data collection procedures

We conducted a cross-sectional interview survey of middle-aged and older adults with CHF and/or COPD in Montréal, Canada. Patients were recruited from two CHF and three COPD clinics attached to two university teaching hospitals. Their participation was solicited either in the clinic waiting rooms (all patients were approached) or by telephone if patients were receiving treatment at home (patients meeting eligibility criteria were selected from clinic lists). Eligibility criteria were residence in the Montréal metropolitan area (population 3M), speaking either English or French and having a home telephone. Interviews were conducted either at home or at the clinic, according to respondents' preferences. Of the 343 patients solicited, 242 (71%) completed the interview. Four interviews with incomplete data were removed from the sample before analysis for a final $n = 238$. The interviews took place between 30 May 2005 and 6 October 2005. Daily mean temperatures during this period were 2.4°C above the long-term daily average [37].

Measures

The study questionnaire was developed in English following a literature review and consultation with professionals from two of the participating clinics. It was translated into French by members of the study team and back translated by a professional translator. The few differences were reconciled by the study team. The questionnaire was piloted in both languages. It consisted of 169 closed-ended items measuring among others, the HBM constructs. Perceived severity of health effects of heat waves was measured by nine items, for example: 'During a heat wave, if I do not protect myself from the heat, respiratory difficulties caused by the heat can lead me to be hospitalized' ($\alpha = 0.93$). Perceived susceptibility to heat effects was measured by three items, for example: 'Because of my state of health, if I do not protect myself from the heat, I am more likely to suffer from respiratory difficulties during a heat wave' ($\alpha = 0.88$). Perceived benefits of protective (AC) behavior was measured by five items, for example: 'During a heat wave, using an air conditioner at home allows me/would allow me to continue my daily activities as usual' ($\alpha = 0.86$). Perceived barriers to the health action were measured by eight items, for example: 'Does/could the following reason prevent you or limit you from using your air conditioner? It is not good for my health' ($\alpha = 0.84$). Perceived severity, susceptibility, benefits and barriers were measured on 4-point agree–disagree scales. Cues to action were measured by three items: 'Has your doctor or nurse ever told you that your health problem can make you more sensitive to the heat' (yes or no); 'Have you ever heard an extreme heat warning?', scored as 'no', 'yes, this summer' and 'yes, last summer or earlier'; and 'How sensitive are you to heat?', scored as very/somewhat/not really/not at all sensitive. Self-reported presence of an air conditioner (yes or no) and number of daytime and nighttime hours of air conditioner use (combined into a 24-hour measure then divided by 24) were used to assess the targeted behavior. Table I lists all items assessing health beliefs and cues to action. The SF-36 physical and mental health subscales [38] were also administered, as were items recording participants' sociodemographic and lodging characteristics. Not reported in this article but also assessed were knowledge of heat impacts, self-efficacy for adopting heat-protective behavior and attitudes toward heat advisories [39].

Analyses

An exploratory structural equation modeling (ESEM) approach was used. Recently developed

Table I. *Number and proportions of respondents falling into different response categories for each item of the scales assessing selected HBM components*

Items	Strongly disagree, *n* (%)	Disagree, *n* (%)	Agree, *n* (%)	Strongly agree, *n* (%)
Perceived benefits of AC				
'During a heat wave, using an air conditioner at home allows me /would allow me to':				
Q12: Continue my daily activities as usual (*N* = 238)	9 (3.8)	28 (11.8)	110 (46.2)	91 (38.2)
Q13: Avoid suffering from respiratory problems (*N* = 237)	7 (3.0)	37 (15.6)	101 (42.6)	92 (38.8)
Q14: Keep my health stable (*N* = 234)	7 (3.0)	35 (15.0)	115 (49.1)	77 (32.9)
Q15: Sleep better (*N* = 235)	12 (5.1)	35 (14.9)	76 (32.3)	112 (47.7)
Q16: Reduce the humidity level (*N* = 231)	4 (1.7)	24 (10.4)	111 (48.1)	92 (39.8)
Perceived barriers to AC				
'Does/could the following reason prevent you or limit you from using your air conditioner at home during a heat wave':				
Q17: It is too expensive to buy or run (*N* = 237)	85 (35.9)	113 (47.7)	20 (8.4)	19 (8.0)
Q18: It is difficult to adjust the temperature (*N* = 237)	79 (33.3)	146 (61.6)	10 (4.2)	2 (0.8)
Q19: It is not good for my health (*N* = 236)	81 (34.3)	132 (55.9)	15 (6.4)	8 (3.4)
Q20: It can make certain health problems worse (*N* = 237)	72 (30.8)	127 (54.3)	27 (11.5)	8 (3.4)
Q21: It prevents fresh air from getting in (*N* = 238)	69 (29.0)	126 (52.9)	31 (13.0)	12 (5.0)
Q22: It makes my home too cold (*N* = 237)	71 (30.0)	126 (53.2)	33 (13.9)	7 (3.0)
Q23: It is not comfortable (*N* = 238)	78 (32.8)	122 (51.3)	31 (13.0)	7 (2.9)
Q24: It makes too much noise (*N* = 235)	72 (30.6)	122 (51.9)	27 (11.5)	14 (6.0)
Perceived severity of heat effects on health				
'During a heat wave, if I do not protect myself from the heat':				
Q67: Respiratory difficulties caused by the heat can lead me to be hospitalized (*N* = 238)	0 (0.0)	44 (18.5)	88 (37.0)	106 (44.5)
Q68: Being weakened by the heat can lead me to be hospitalized (*N* = 238)	0 (0.0)	49 (20.6)	92 (38.7)	97 (40.8)
Q69: Dehydration caused by the heat can lead me to be hospitalized (*N* = 236)	2 (0.8)	49 (20.8)	93 (39.4)	92 (39.0)
Q70: Respiratory difficulties caused by the heat can provoke long-term damage to my health (*N* = 226)	1 (0.4)	35 (15.5)	115 (50.9)	75 (33.2)
Q71: Being weakened by the heat can provoke long-term damage to my health (*N* = 228)	0 (0.0)	36 (15.8)	123 (53.9)	69 (30.3)
Q72: Dehydration caused by the heat can provoke long-term damage to my health (*N* = 228)	0 (0.0)	41 (18.0)	117 (51.3)	70 (30.7)
Q73: Respiratory difficulties caused by the heat can lead to my death (*N* = 231)	6 (2.6)	74 (32.0)	95 (41.1)	56 (24.2)
Q74: Being weakened by the heat can lead to my death (*N* = 231)	7 (3.0)	75 (32.5)	101 (43.7)	48 (20.8)
Q75: Dehydration caused by the heat can lead to my death (*N* = 231)	7 (3.0)	62 (26.8)	104 (45.0)	58 (25.1)

Table I. *Continued*

Items	Strongly disagree, *n* (%)	Disagree, *n* (%)	Agree, *n* (%)	Strongly agree, *n* (%)
Perceived susceptibility to heat effects				
'Because of my state of health, if I do not protect myself from the heat':				
Q64: I am more likely to suffer from respiratory difficulties during a heat wave (*N* = 238)	1 (0.4)	13 (5.5)	74 (31.1)	150 (63.0)
Q65: I am more likely to become weak during a heat wave (*N* = 238)	0 (0.0)	17 (7.1)	85 (35.7)	136 (57.1)
Q66: I am more likely to become dehydrated during a heat wave (*N* = 237)	1 (0.4)	22 (9.3)	87 (36.7)	127 (53.6)
Cues to action	Not at all sensitive, *n* (%)	Not really sensitive, *n* (%)	Somewhat sensitive, *n* (%)	Very sensitive, *n* (%)
How sensitive are you to heat? (*N* = 237)	4 (1.7)	42 (17.7)	73 (30.8)	118 (49.8)
	Yes, *n* (%)	No, *n* (%)		
Have you heard an extreme heat warning [this summer or last summer]? (*N* = 237)	200 (84.4)	37 (15.6)		
Has your doctor or nurse ever told you that your health problem can make you more sensitive to the heat? (*N* = 237)	137 (57.8)	100 (42.2)		

[40, 41], ESEM allows for the simultaneous estimations of exploratory factor analysis (EFA) and confirmatory factor analysis models. It was deemed appropriate for use with the present data set given the need to evaluate the unknown factor structure of newly created scales and to estimate direct paths between factors in a context where small sample size precludes cross-validation. Analyses were conducted using MPlus Version 6 [42]. Default options were used as for the estimation [weighted least squares mean and variance adjusted (WLSMV)] and rotation methods (GEOMIN). The WLSMV estimator is recommended for categorical outcomes (B. O. Muthén, S. C. du Toit, D. Spisic, unpublished results). Its good performance for smaller sample sizes and computational speed has also been underscored [43]. Cues to Action was modeled as a composite variable [44]. Two measurement models using multiple indicators of latent constructs could indeed be defined. In line with classical test theory, the direction of causality could flow from construct to measure (principal factor or reflective model). Alternatively, it could also flow from measure to construct, as is the case in a composite latent variable or formative model. Given this and other criteria (indicators being not interchangeable, etc.) [45], it appeared reasonable to model the Cues to Action construct as an index produced by the observed variable (sensitivity to heat, advice from their doctor and having heard of an extreme heat warning) rather than an underlying constructs causing them.

Finally, exploratory analysis revealed a high degree of colinearity ($r = 0.65$) between severity and perceived susceptibility. Following a procedure used in another HBM validation study [46], perceived susceptibility was not included in the model.

Ethics

The Research Ethics Board of McGill University and those of the participating hospitals approved the study protocol. Participants signed informed consent forms after being apprised of the means used to protect their confidentiality and being assured that their responses would in no way affect their health care.

Results

Respondents' characteristics

Table II shows respondents' sociodemographic and health characteristics. Their average age was 67.8 years; 61% were male. About 16% were widowed, while the remainder were married or living with a partner (51%) or single, separated or divorced (33%). The personal income data show that about one-quarter of respondents (27%) could be considered as living in poverty, with incomes below \$15 000 Canadian per year. Respondents reported a number of health problems over and above those for which they were recruited (COPD or CHF): at least 26% of respondents reported suffering from arthritis or rheumatism, insomnia, diabetes, asthma or a vision problem.

Table II *Participants' sociodemographic and health characteristics (N = 238 unless indicated)*

Characteristics	*n* (%)
Age (years) (*n* = 236)	
40–59	51 (21.6)
60–69	79 (33.5)
70–79	83 (35.2)
⩾80	23 (9.7)
Sex	
Male	145 (60.9)
Female	93 (39.1)
Marital status (*n* = 237)	
Married	122 (51.5)
Single/separated/divorced	78 (32.9)
Widowed	37 (15.6)
Living situation (*n* = 237)	
Alone	92 (38.8)
With others (spouse or other people)	145 (61.2)
Mother tongue	
French	189 (79.4)
English	36 (15.2)
Other	13 (5.5)
Annual household income (*n* = 213)	
⩽\$14 999	58 (27.2)
\$1500–\$29 999	68 (31.9)
⩾\$30 000	87 (40.8)
Years of education (*n* = 237)	
⩽6	27 (11.4)
7–12	121 (51.1)
⩾12	89 (37.6)
Health problems	
COPD or other pulmonary condition	160 (67.2)
Cardiac insufficiency	117 (49.2)
Arthritis/rheumatism	106 (44.5)
Insomnia	76 (31.9)
Diabetes	63 (26.5)
Asthma	63 (26.5)
Vision problem	62 (26.1)

AC use

Almost three-quarters (174 or 73%) of study participants reported having a home air conditioner (at least one unit in at least one room). When asked about their air conditioner use during heat waves, 31.5% reported that they occasionally or never spend time in an air-conditioned location, while 68.1% indicated doing so always or often. The average number of hours spent per 24-hour period in air-conditioned spaces during heat waves was 14.5 hours (SD = 9.4). There were few sociodemographic differences between those participants with and without home AC. *t*-tests showed no significant differences between those with (n = 173) and without (n = 64) home air conditioners were not significantly different ($p < 0.05$) in terms of gender, income, living arrangement, and physical or mental health status as measured by the SF-36 subscales. However, those with home air conditioners were marginally older than those without (68.5 versus 65.8 years, $t(234) = -1.92$, $P = 0.06$).

Structural equation model fitting

The factor loadings gave a clear interpretation of the factors in term of perceptions of severity, barriers and benefits (see Table III). Nevertheless, several items had significant cross-loadings, confirming the suitability of an ESEM approach. Only the item reflecting sensitivity to heat was a significant predictor of variability in the Cues to Action composite with items related to advice from their doctor and having heard an extreme heat warning being non-significant.

The chi-square test of exact fit emerged as statistically significant (χ^2 [277, N = 235] = 879.03, $P <$ 0.001). Sample size independent indexes provide a more nuanced picture with the Comparative Fit

Table III. *Factor loadings for EFA with GEOMIN rotation of perception of barriers and benefits to AC use and perception of severity of health effects of heat wave items*

Items	Barriers		Benefits		Severity	
	Standard estimate	95% CI	Standard estimate	95% CI	Standard estimate	95% CI
Benefits						
Q12: Daily activities	0.27	0.21, 0.51	**0.64**	0.52, 0.76	−0.04	−0.22, 0.14
Q13: Avoid respiratory problems	0.05	−0.29, 0.38	**0.77**	0.66, 0.87	0.12	−0.12, 0.37
Q14: Health stable	0.14	−0.17, 0.46	**0.80**	0.69, 0.91	0.06	−0.16, 0.28
Q15: Sleep better	0.17	−0.08, 0.43	**0.59**	0.49, 0.70	0.10	−0.09, 0.29
Q16: Reduce humidity	0.26	0.03, 0.50	**0.60**	0.49, 0.71	0.00	−0.07, 0.08
Barriers						
Q17: Expensive	**0.57**	0.47, 0.68	−0.08	−0.22, 0.07	−0.05	−0.21, 0.11
Q18: Temperature	**0.73**	0.65, 0.81	0.01	−0.09, 0.11	−0.01	−0.12, 0.11
Q19: Not good for health	**0.85**	0.78, 0.92	0.07	−0.05, 0.20	0.08	−0.05, 0.22
Q20: Health problems	**0.78**	0.71, 0.85	0.02	−0.09, 0.13	0.09	−0.07, 0.24
Q21: Fresh air	**0.57**	0.48, 0.66	0.03	−0.10, 0.15	0.02	−0.10, 0.14
Q22: Home too cold	**0.77**	0.69, 0.85	0.18	0.06, 0.30	0.02	−0.05, 0.09
Q23: Not comfortable	**0.79**	0.69, 0.89	0.26	0.14, 0.38	−0.02	−0.09, 0.04
Q24: Too much noise	**0.50**	0.39, 0.60	0.21	0.08, 0.34	0.04	−0.09, 0.16
Severity						
Q67: Respiratory difficulties/hospitalization	−0.02	−0.10, 0.05	−0.14	−0.27, −0.00	**0.98**	0.92, 1.04
Q68: Weakened/hospitalization	0.00	−0.05, 0.06	−0.18	−0.30, −0.05	**1.02**	0.96, 1.08
Q69: Dehydration/hospitalization	−0.01	−0.07, 0.05	−0.25	−0.37, −0.12	**0.90**	0.81, 0.98
Q70: Respiratory difficulties/long-term damages	−0.04	−0.11, 0.04	**−0.67**	−0.81, −0.54	**0.99**	0.83, 1.16
Q71: Weakened/long-term damages	0.03	−0.04, 0.09	**−0.69**	−0.84, −0.54	**1.04**	0.86, 1.22
Q72: Dehydration/ long-term damages	0.05	−0.04, 0.14	**−0.56**	−0.70, −0.42	**0.97**	0.82, 1.12
Q73: Respiratory difficulties/death	**−0.47**	−0.66, −0.28	0.09	0.01, 0.16	**1.01**	0.88, 1.13
Q74: Weakened/death	**−0.51**	−0.71, −0.32	0.01	−0.02, 0.04	**1.05**	0.93, 1.16
Q75: Dehydration/death	**−0.38**	−0.55, −0.21	−0.01	−0.05, 0.03	**0.96**	0.87, 1.05

Factor loadings >0.40 are in boldface; correlations between factors: barriers–severity, 0.43; barriers–benefits, 0.30; severity–benefits, 0.46.

Index (0.955), the Tucker–Lewis Index (0.943) and the root mean squared error of approximation (0.096) reflecting acceptable to marginal fit. Although more research is needed regarding the appropriateness of such indexes for ESEM models given their greater number of estimated parameters [41], it is reasonable to conclude that the selected HBM components provide an adequate explanation of AC use (see Fig. 1). Overall, 31.6% of the variance in AC use behavior was accounted for by components of the HBM.

That is, the model showed that three components, perceived benefits, perceived barriers and cues to action, contributed significantly to AC use, in the expected directions: those who saw benefits such as allowing them to continue daily activities and to avoid respiratory problems were more likely to have a higher level of AC use. Perceptions that air conditioner use could have drawbacks such as aggravating health problems or cooling the house too much were predictive of less AC use. Cues to action were associated with higher level of AC use. Perceived severity of health problems associated with extreme heat, measured as the beliefs that heat waves could lead to hospitalization because of the respondent's health status, also did not significantly predict AC use behavior.

In an ancillary analysis, we tested a model including a direct relationship between annual household income and AC use. The estimated coefficient emerged as non-significant (results available upon request to the first author).

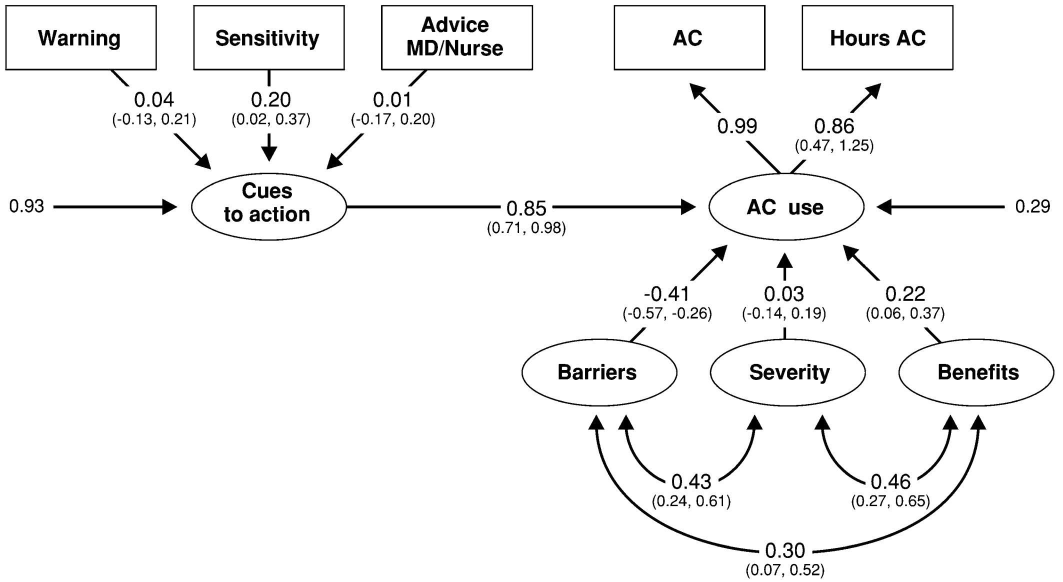

Fig. 1. Depiction of the causal model between perceived benefits, perceived barriers, perceived severity, cues to action and AC use, with standardized causal coefficients. Unstandardized residual variances for Cues to Action and AC use were constrained to 0.3. The coefficient linking AC use to AC was constrained to 1.0.

Discussion

The purpose of this study was to test the predictive power of selected components of the HBM for heat-related protective behavior among non-institutionalized middle-aged and older adults with serious chronic health conditions. Semenza *et al.* [24] estimated that more than half of the deaths related to the Chicago heat wave of 1995 'could have been prevented if each home had a working air conditioner' (p. 487). Our data partially validate the HBM by suggesting that above and beyond access to AC, beliefs in this particularly vulnerable population about AC may determine its actual level of use. About one-third of our sample of persons with CHF or COPD did not use AC regularly or did not use at all during periods of extreme heat, and those who used it, did so for, on average, just over half of each 24-hour period. ESEM showed that specific beliefs about the benefits of and drawbacks to AC, as well as cues to action were predictive of its level of use. Those who believed that using AC would help them, for example, to continue their daily activities, prevent respiratory problems and maintain their health were most likely to use it more. Similarly, those who believed that AC would bring drawbacks did not use AC as much.

While results showed a positive predictive role for cues to action, a closer look at estimates showed that only one causal indicator, sensitivity to heat, significantly contributes to the composite variable, with parameters for indicators related to advisories and advice from doctor or nurse emerging as non-significant. While this result certainly confirms the importance in the adoption of protective behavior of internal cues such as symptoms over external signals such as advisories or advice from a health professional [47], it might also reflect the difficulty of empirically identifying cues instigating action [28].

Effective communication plans and public education tools have been highlighted as key components of the public health response to extreme heat events [3]. However, current strategies such as heat advisories do not appear to be reaching their targets effectively and contribute little to the adoption of protective behaviors [15, 24]. Although the importance of defining and locating high-risk populations, such as older adults and the chronically ill, and providing them with effective information about extreme heat has been emphasized [3, 48], the best ways to reach these vulnerable subgroups remain unclear [36]. Our data support these findings, showing that extreme heat advisories and advice from a doctor or nurse do not significantly contribute to the cues to action composite variable. Some authors have argued that communications should be improved by increasing public awareness that heat advisories are based on human health responses and by emphasizing the vulnerability aspect through their messaging [22]. This has been recommended in particular for the older adults [49]. However, as discussed by Champion and Skinner [28], it is possible that the predictive value of susceptibility may depend on the perceived level of severity so that 'a heightened state of severity is required before perceived susceptibility becomes a powerful predictor' (p. 61). This suggests that perceptions of vulnerability may be heightened most effectively when heat waves are seen as having more serious consequences on health. This hypothesis is consistent with work that has shown the potential in exploring alternative patterns of relationships for the HBM components [28], and this would certainly deserve further research. Interestingly, warning older people about health risks associated with aging and heat may have paradoxical effects: many older people do not see themselves as old or at risk [36] and those who associate aging with limitations in their lives are less likely to engage in preventive or adaptive behaviors [32, 50].

Several issues limit the interpretation of the current findings. First, although the recruitment mode allowed for the recruitment of a heterogeneous sample of non-institutionalized cardiac and COPD patients, representativeness is not guaranteed: still, the age and sex (a male majority) distribution of study participants does reflect the mix of CHF and COPD clinic patients in Montréal (according to the directors of the participating clinics), and the choice of university clinics facilitated recruitment of participants from across the socioeconomic spectrum. Second, the study is limited by its cross-sectional design. Longitudinal studies following the health belief patterns of older adults over time and before and after persuasive interventions would be invaluable in identifying the determinants of heat protective behaviors. Third, the sample size precluded the testing of alternative patterns of relationships, such as multiplicative approaches to major dimensions in the model. Further research should consider replication with larger samples and extensions with alternative causal models.

Despite its limitations, the present study is important in that it is one of the first, if not the first, to examine the usefulness of selected components of the HBM in understanding preventive behaviors related to climate change phenomena such as extreme heat. For non-institutionalized persons with existing serious health conditions, our data suggest that public health communications should include strategies aimed at modifying beliefs about specific health benefits from AC use, as well as strategies to reduce or mitigate the perceived barriers to effective action, especially among populations whose existing health problems also help to limit their mobility, restrict the social networks and isolate them [14, 49]. Such public health communications should form part of an integrated multidimensional emergency strategy [2, 34] that supports adequate citizen response [51].

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Conflict of interest statement

None declared.

References

1. McGeehin MA, Mirabelli M. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. *Environ Health Perspect* 2001; **109**(Suppl. 2):185–9.
2. Kovats RS, Hajat S. Heat stress and public health: a critical review. *Annu Rev Public Health* 2008; **29**: 41–55.
3. Luber G, McGeehin M. Climate change and extreme heat events. *Am J Prev Med* 2008; **35**: 429–35.
4. Brücker G. Vulnerable populations: lessons learnt from the summer 2003 heat waves in Europe. *Euro Surveill* 2005; **10**: 147.
5. Cassadou S, Chardon B, D'helf M *et al*. *Vague de chaleur de l'été 2003: relations entre températures, pollution atmosphériques et mortalité dans neuf villes françaises (Rapport d'étude),* 2004. Retrieved from Institut de Veille sanitaire website. Available at: http://www.invs.sante.fr/publications/2004/psas9_070904/rapport.pdf. Accessed: 26 October 2010.
6. Conti S, Meli P, Minelli G *et al*. Epidemiological study of mortality during the summer 2003 heat wave in Italy. *Environ Res* 2005; **98**: 390–9.
7. Argaud L, Ferry T, Le QH *et al*. Short- and long-term outcomes of heatstroke following the 2003 heat wave in Lyon, France. *Arch Intern Med* 2007; **167**: 2177–83.
8. Semenza JC, Rubin CH, Falter KH. Heat-related deaths during the July 1995 heat wave in Chicago. *N Engl J Med* 1996; **335**: 84–90.
9. Baccini M, Biggeri A, Accetta G *et al*. Heat effects on mortality in 15 European cities. *Epidemiology* 2008; **19**: 711–9.
10. Hajat S, O'Connor S, Kosatsky T. Health impact of hot weather: from awareness of risk factors to effective health protection. *Lancet* 2010; **375**: 856–63.
11. Hajat S, Kovats RS, Lachowycz K. Heat-related and cold-related deaths in England and Wales: who is at risk? *Occup Environ Med* 2007; **64**: 93–100.
12. Basu R, Samet JM. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev* 2002; **24**: 190–202.
13. Michelozzi P, Accetta G, De Sario M *et al*. High temperature and hospitalizations for cardiovascular and respiratory causes in 12 European cities. *Am J Respir Crit Care Med* 2009; **179**: 383–9.
14. Vandentorren S, Bretin P, Zeghnoun A *et al*. August 2003 heat wave in France: risk factors for death of elderly people living at home. *Eur J Public Health* 2006; **16**: 583–91.
15. Delarozière JC, Sanmarco JL. Excess mortality in people over 65 years old during summer heat waves in Marseille. Comparison before and after a preventive campaign. *Presse Med* 2004; **33**: 13–6.
16. Medina-Ramon M, Zanobetti A, Cavanagh D *et al*. Extreme temperatures and mortality: assessing effect modification by personal characteristics and specific cause of death in a multi-city case-only analysis. *Environ Health Perspect* 2006; **114**: 1331–6.
17. Belmin J, Auffray JC, Berbezier C *et al*. Level of dependency: a simple marker associated with mortality during the 2003 heatwave among French dependent elderly people living in the community or in institutions. *Age Ageing* 2007; **36**: 298–303.
18. Grundy E, Sloggett A. Health inequalities in the older population: the role of personal capital, social resources and socio-economic circumstances. *Soc Sci Med* 2003; **56**: 935–47.
19. Nord M, Kantor LS. Seasonal variation in food insecurity is associated with heating and cooling costs among low-income elderly Americans. *J Nutr* 2006; **136**: 2939–44.
20. Barnett AG. Temperature and cardiovascular deaths in the US elderly: changes over time. *Epidemiology* 2007; **18**: 369–72.
21. Bueno MJ, Wall AJ. Effect of hypohydration on core temperature during exercise in temperate and hot environments. *Pflugers Arch* 2000; **440**: 476–80.
22. Sheridan SC. A survey of public perception and response to heat warnings across four North American cities: an evaluation of municipal effectiveness. *Int J Biometeorol* 2007; **52**: 3–15.
23. Kalkstein AJ, Sheridan SC. The social impacts of the heat-health watch/warning system in Phoenix, Arizona: assessing the perceived risk and response of the public. *Int J Biometeorol* 2007; **52**: 43–55.
24. Semenza JC, Hall DJ, Wilson BD *et al*. Public perception of climate change: voluntary mitigation and barriers to behavior change. *Am J Prev Med* 2008; **35**: 479–87.
25. Perry RW, Lindell MK. Aged citizens in the warning phase of disasters: re-examining the evidence. *Int J Aging Hum Dev* 1997; **44**: 257–67.
26. Becker MH. The Health Belief Model and personal health behavior. *Health Educ Monogr* 1974; **2**: 324–473.
27. Janz NK, Becker MH. The Health Belief Model: a decade later. *Health Educ Q* 1984; **11**: 1–47.
28. Champion VL, Skinner CS. The Health Belief Model. In: Glanz K, Rimer B, Viswanath K (eds). *Health Behaviour and Health Education: Theory, Research and Practice*, 4th edn. San Francisco, CA: Jossey-Bass, 2008, 45.
29. Nexoe J, Kragstrup J, Sogaard J. Decision on influenza vaccination among the elderly: a questionnaire study based on the Health Belief Model and the Multidimensional Locus of Control Theory. *Scand J Prim Health Care* 1999; **17**: 105–10.
30. Carmel S, Shani E, Rosenberg L. Skin cancer protective behaviors among the elderly: explaining their response to a health education program using the Health Belief Model. *Educ Gerontol* 1996; **22**: 651–68.

31. Jensen J, Counte MA, Glandon GL. Elderly health beliefs, attitudes, and maintenance. *Prev Med* 1992; **21**: 483–97.
32. Pinquart M, Sörensen S. Factors that promote and prevent preparation for future care needs: perceptions of older Canadian, German, and U.S. women. *Health Care Women Int* 2002; **23**: 729–41.
33. Perrig-Chiello P, Stähelin H. Health control beliefs in old age—relationship with subjective and objective health and health behaviour. *Psychol Health Med* 1999; **4**: 83–94.
34. Sorenson JH. Hazard warning systems: review of 20 years of progress. *Nat Hazards Rev* 2000; **1**: 119–25.
35. Mileti D, Sorenson J. *Communication of Emergency Public Warning. A Social Science Perspective and State-of-the-Art Assessment,* 1999. Retrieved from Emergency Management Center website. Available at: http://emc.ornl.gov/EMCWeb/EMC/PDF/CommunicationFinal.pdf. Accessed: 26 October 2010.
36. Abramson V, Wolf J, Lorenzoni I *et al*. Perceptions of heat-wave risks to health: interview-based study of older people in London and Norwich, UK. *J Public Health* 2008; **31**: 119–26.
37. CRIACC—Centre de Ressources en impacts et adaptation au climat et à ses changements. *Summer 2005 Climate Summary*, 2007. Retrieved from CRIACC—Centre de ressources en impacts et adaptation au climat et à ses changements website. Available at: http://www.criacc.qc.ca/climat/suivi/ete05/bilan_e.html. Accessed: 26 October 2010.
38. Ware JE, Jr, Snow K, Kosinski MA *et al*. *SF-36 Health Survey Manual and Interpretation Guide*. Boston, MA: The Health Institute, New England Medical Center, 1993.
39. Kosatsky T, Dufresne J, Richard L *et al*. Heat awareness and response among Montreal residents with chronic cardiac and pulmonary disease. *Can J Public Health* 2009; **100**: 237–40.
40. Asparouhov T, Muthén B. Exploratory structural equation modeling. *Struct Equ Modeling* 2009; **16**: 397–438.
41. Marsh HW, Muthén B, Asparouhov T *et al*. Exploratory structural equation modeling, integrating CFA and EFA: application to students' evaluations of university teaching. *Struct Equ Modeling* 2009; **16**: 439–76.
42. Muthén LK, Muthén BO. *Mplus User's Guide*, 6th edn. Los Angeles, CA: Muthén & Muthén, 1998–2010.
43. Flora DB, Curran PJ. An empirical evaluation of alternative methods of estimation for confirmatory factor analysis with ordinal data. *Psychol Methods* 2004; **9**: 446–91.
44. MacCallum RC, Browne MW. The use of causal indicators in covariance structure models: some practical issues. *Psychol Bull* 1993; **114**: 533–41.
45. Jarvis CB, Mackenzie SB, Podsakoff PM. A critical review of construct indicators and measurement model misspecification in marketing and consumer research. *J Consum Res* 2003; **30**: 199–218.
46. Aiken LS, West SG, Woodward CK *et al*. Health beliefs and compliance with mammography screening recommendations in asymptomatic women. *Health Psychol* 1994; **13**: 122–9.
47. Hochbaum GM. *Public Participation in Medical Screening Programs: A Socio-psychological Study*. Washington, DC: US Department of Health, Education, and Welfare, 1958.
48. Kovats RS, Kristie LE. Heatwaves and public health in Europe. *Eur J Public Health* 2006; **16**: 592–9.
49. Thomas N, Soliman H. Preventable tragedies: heat disaster and the elderly. *J Gerontol Soc Work* 2002; **38**: 53–66.
50. Levy BR, Myers LM. Preventive health behaviors influenced by self-perceptions of aging. *Prev Med* 2004; **39**: 625–9.
51. Thirion X, Debensason D, Delarozière JC *et al*. August 2003: reflections on a French summer disaster: why were its medical consequences so serious? Are we sure to do better next time? *J Contingencies Crisis Manage* 2005; **13**: 153–8.