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An adaptation index to high summer heat associated with adverse health impacts in deprived neighborhoods

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Abstract Socially and materially disadvantaged urban areas present a group of factors strongly correlated with high heat and humidity adverse health effects, particularly in densely populated cities where the heat island effect extends over large areas. This paper presents an adaptation index to high summer heat whose validity was tested by correlating it with self-reported adverse health impacts to heat. The data comes from a 2011 cross-sectional study conducted in the most deprived areas in 9 cities of 100,000 or more inhabitants in Quebec (Canada). In total, 3,485 people were interviewed at home. An index of various behavioral adaptations was developed using a Multiple Correspondence Analysis. This individual-level adaptation index summarizes a range of 14 easy-to-use and energy-efficient solutions for cooling off or protecting oneself against the sun, both at home and in other places, whether indoors or out. In addition, it shows that adaptation to heat goes beyond air conditioning in the home. People who experience adverse effects of heat on their health tend to adopt more of the behaviors measured by the index than those perceiving little or none, regardless of their age group or presence of air conditioning at home. Monitoring and improving this index over time

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and in several populations and contexts would establish a significant milestone for adaptation in health promotion and prevention.

1 Introduction

Periods of high summer temperatures are already more frequent and severe, a phenomenon projected to intensify further in the near future (Hansen et al. 2012; Intergovernmental panel on climate change 2013). Urban areas, and especially large cities, will be particularly affected, as they already form urban heat islands (Oke 1987; Voogt 2002). This will affect their poorest neighborhoods even more, where several environmental and social conditions are strongly correlated to temperatures and to a high index of thermal discomfort (Klinenberg 2002; Ormandy and Ezratty 2012).

Québec, like the rest of Canada, is no exception, where poverty is concentrated in certain pockets of large urban centers (Canadian Council on Social Development 2007; Conference Board of Canada 2012), areas that correspond in general to the census' less advantaged dissemination areas (DAs) (Statistics Canada 2012) and where there are significant temperature differences in relation to the more affluent and greener areas (Bélanger et al. 2014).

From a public health perspective, it is important to ensure that these disadvantaged populations adapt adequately to high summer heat. Warning and monitoring systems have also been developed for this purpose in recent years and around the world (Centers for Disease Control and Prevention 2013; World Health Organization and World Meteorological Organization 2012), including Québec (Toutant et al. 2011). Though very useful for public health surveillance and prevention, data from these systems remain incomplete because they do not account for individual adaptation behaviors to heat.

To fill this gap, a recent survey documented preventative behaviors employed during high summer heat in very poor DAs of the most populous cities in Québec (Bélanger et al. 2014). These behaviors take into account the multifactorial nature of heat adaptation. Some behaviors involve personal cooling (e.g., taking showers more often than usual) or protecting oneself against the sun (e.g., wearing a hat), while others involve cooling the house (e.g., opening windows in the evening), keeping the house cool (e.g., closing the curtains when the sun shines) or decreasing use of heat sources (e.g., dryer).

For public health monitoring and promotion, it would be important, however, to summarize these many and diverse coping behaviors to heat. Clearly, we have multifactorial concepts that cannot be measured or captured by only one indicator. The creation of a composite index (CI) is thus warranted here. The number of CIs increases worldwide every year (Bandura 2008) and their popularity is due to the fact that they illustrate issues that are complex and sometimes difficult to grasp (e.g., environment, poverty) while reducing the size of a set of indicators without losing the underlying basic information. In addition, their aggregated and weighted values, defined for each unit of population studied, facilitate the interpretation of the results with regard to a battery of separate indicators (OECD/JRC European Commission 2008).

The goal of this study then was to create an index of adaptation to high summer heat, based on survey data conducted in the most disadvantaged DAs of the most populous cities in Québec, Canada, for the purpose of monitoring public health and prioritizing relevant health protection and promotion activities. The criterion-related validity of the heat-adaptation index was also tested through correlation with the measurement of self-reported health impacts.

2 Methods

The data used to create the heat adaptation index comes from a cross-sectional study using a stratified sample, conducted in the most disadvantaged DAs in 9 Québec cities of 100,000 or more inhabitants in 2011. These DAs contain both privately owned buildings and extensive low-rental housing. As opposed 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 (Société d'habitation du Québec 2013). This project was approved by the research ethics committee of the *Centre hospitalier universitaire de Québec*.

2.1 Study

A selection procedure similar to that proposed by Vallée et al. (2007) was used to produce representative samples for each of the 9 cities, in very materially and socially disadvantaged DAs, corresponding to quintile 5 of a widely used Canadian deprivation index (Pampalon and Raymond 2000). In total, 3,485 people were interviewed from December 21, 2010, to December 20, 2011. In the study, these respondents lived in areas located for the most part in intra-urban heat islands (66 %) or less than 50 m from a heat island (32 %) (Bélanger et al. 2015). Data was collected by means of a pre-tested questionnaire (basically closed-ended questions) prepared from a review of the literature on health and climate change and several similar questionnaires in regular use in Canada by statistical agencies. All measurement scales used in the study, including scales of the dependent variables, scored as acceptable (53 %), good (28 %) or excellent (19 %) (George and Mallery 2003; Gliem and Gliem 2003). The examination of the items characteristic curves (Thissen et al. 1988) also revealed that the scale items did measure very well the survey constructs, which was confirmed by the qualitative analysis of interviewees' comments. More details on this study methodology are available in Bélanger et al. (2014).

2.2 Adaptation index to high summer heat

The scope of this work is to use Multiple Correspondence Analysis (MCA) in order to aggregate 17 coping behaviors practiced in high summer heat (defined as summer days when it's very hot and humid and people have trouble sleeping well) into a single composite indicator.

2.2.1 Variables considered when creating the index

Initially, the study included 90 qualitative (or categorical) variables, but 73 were not considered in the creation of the heat adaptation index for various reasons (see online resource 1). Among these, air conditioning was not retained because it was correlated significantly with one other variable (air and opening windows: $r=-0.80$) and did not meet the criterion of ordinal consistency on the first axis (Asselin 2009). In other words, its preventive category was situated on the side of non-adaptation and its non-preventive category on the side of adaptation. This might be explained by the fact that using air conditioning reduces the need to use several other adaptation measures.

Thus, 17 behavioral variables were considered as potential components of the heat adaptation index. To summarize the results of the MCA and simplify their interpretation, these variables were recodified in binary form, with a preventive category ("yes" or "sometimes/often/always") and a non-preventive category ("no" or "never/rarely") for health impacts of heat. The response rate per variable was at least 97 %. These variables are: (1) drinking tap water as the main refreshment; (2)

consuming iced foods as refreshments; (3) taking showers or baths more often than usual; (4) sponging or spraying the face and neck with cold water; (5) avoiding using the stove and oven and (6) the dryer to reduce heat sources in the home as well as (7) switching off the computer when not in use; (8) closing curtains or blinds against the sun; (9) opening windows in the evening or at night to cool down the house; (10) using at least one protection against the sun on the balcony; (11) using the balcony and (12) the yard to cool off in the evening; (13) increasing visits to air conditioned places other than home; (14) swimming in a public pool, lake or river; (15) wearing a head covering against the sun; (16) applying sunscreen and packing a cool drink during outdoor activities despite the intense heat, between 11 am and 4 pm; and (17) adopting preventive behaviors based on weather information broadcast by the media or on the Internet. Finally, respondents who had no computer, dryer, curtains, balcony or yard were grouped under the non-preventive category, because the underlying motivation for the adoption (or non-adoption) of an adaptation was not significant for this study.

2.2.2 Building the index

Given that the data were categorical, the index was developed by using MCA (Asselin 2009; Greenacre 2007). Several authors have used MCA as a weighting method for the construction of a composite index (Canuel et al. 2014; Charreire et al. 2010; Cortinovis et al. 1993; Dossa et al. 2011; Howe et al. 2008). MCA is a data reduction procedure for categorical variables (nominal or ordinal) as much as Principal Components Analysis is for quantitative variables (Greenacre 2007).

The index of adaptation to high summer heat was developed using STATA software (StataCorp 2011). Data were weighted sequentially according to the weight of the DA, age and gender, in order to ensure calibration of the survey frequencies. By exploring the general structure of the data and studying the various combinations of variables, we were able to define the final model. Only the results of this model are presented in this article.

The interpretation of results is based on the MCA statistics under consideration and their graphical representations (Cahuzac and Bontemps 2008; Greenacre 2007). The major categories are those that have the highest quality of representation of factorial axes (or dimensions) (highest “sqcorr” values) and that contribute most to their formation (highest “contrib” values). Moreover, the number of axes is defined based on the table and scree plot of inertias using the “elbow criterion” (the number of axes before the break, followed by a steady decline). The graph of variable categories according to their coordinates (generated by the MCA model chosen) illustrates their contributions. The discriminating ability of a variable is supported by the distance of its categories on the two main axes.

2.2.3 Passive variables

In addition to the 17 active variables used in implementing the MCA, eight other variables, called passive or supplementary, were taken into consideration (Greenacre 2007). Passive variables do not contribute to building the index itself, but they serve more for interpretation and comparison purposes. They include features that may influence adaptation to heat (Basu and Samet 2002; Bouchama et al. 2007; Kovats and Hajat 2008; Luber and McGeehin 2008; Lundgren and Jonsson 2012), namely: gender, age, gender crossed with age, being a recent immigrant, type of household, living in low-income housing, having air conditioning in the house (here, 80 % window air conditioner, see Bélanger et al. 2014), as well as living in a city considered very hot based on average temperature observed over the last 30 years (Chebana et al. 2013). Access to air conditioning was preferred among variables bearing on its usage (e.g., usage during the day), as respondents whose homes were equipped with air conditioning in general operated their air conditioner day and night during high summer heat (access and use: r>0.9).

2.2.4 Criterion-related validity of the index

The essential function of the criterion validity is to define the relationship between test results (here, the score on the heat-adaptation index) and another criterion considered to be a major indicator of the construct to study (Hogan 2007). This indicator corresponds to the self-reported adverse health impacts. Measurement of the health impacts during high summer heat was developed as a proxy variable for the perceived overall state of health in a heat context. 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 (Fahimi et al. 2008; Jamrozik et al. 2014; Pierannunzi et al. 2013; Starr et al. 1999). The risk group consisted here of respondents saying that they felt (moderately or greatly) the harmful health effects of heat when it was very hot and very humid during the summer (vs. slightly or not at all). The criterion-related validity of the heat-adaptation index was tested by correlating the measurement of self-reported adverse health impacts using a nominal-type polytomous logistic analysis (Hosmer and Lemeshow 1989). Impacts were also considered as a passive variable and projected into the MCA space.

3 Results

3.1 MCA results

Seventeen behavioral variables were considered a priori in the MCA (online resource 1). They explain 64 % of the total inertia on dimension 1 (Dimension 2: 9 %, data not shown). However, three of them are only slightly divided between adaptation and non-adaptation during high summer temperatures, namely: using at least one adaptation for protection against the sun on the balcony; applying sunscreen and carrying a cool drink during outdoor activities between 11 am and 4 pm; and opening windows at night to cool the home (data not shown). These variables were therefore excluded from the index, which also improves the “use sparingly” criterion.

The remaining 14 variables (Table 1) explain 75 % of the total inertia on dimension 1 (dimension 2: 5 %) (online resource 2). Also, this is the only dimension that precedes the recess values, followed by a steady decrease in the scree plot on the inertias (online ressource 3). Dimension 1 then is the only dimension retained for further analysis of the MCA. None of these variables present categories with very low frequencies (online resource 4). None is strongly correlated with other components of the index (r≤0.35, data not shown).

The projection of non-standardized and standardized active variables coordinates are very similar. In addition, in both cases all preventive categories (which have negative coordinates) supporting adaptation during high summer heat are on the left of the graph and all non-preventive categories (positive coordinates) associated with non-adaptation are on the right. Also, only the results of the MCA standard (Fig. 1a) are shown below.

In general, the contribution of categories to dimension 1 is low (“contr” values in online resource 5). Nevertheless, we note that certain categories – projected farther along the axis – explain more adaptation (values≤−1) or non-adaptation (values≥1) during high summer heat,

Table 1 Listing of active and passive variables of the index

Active variables	
	Wearing a head covering when the sun is shining
	Taking showers or baths more often than usual to cool off
	Sponging or spraying the face and neck with cold water
	Eating iced foods to cool off
	Switching off the computer when not in use to reduce heat sources in the home
	Decreasing dryer use to reduce heat sources in the home
	Using the balcony to cool off in the evening
	Using the yard to cool off in the evening
	Swimming in a public pool, lake or river to cool off
	Frequenting places other than home for air conditioning to cool off
	Adopting preventive behaviors according to weather information transmitted through the media or on the Internet
	Closing curtains to keep the home cool when the sun is shining
	Decreasing oven use to reduce heat sources in the home
	Drinking tap water as a main drink for cooling off
Passive variables	
	Gender and age groups
	Immigrants
	Type of household
	Hottest cities according to average temperature over the last 30 years
	Subsidized housing
	Housing having an air conditioner and age group
	Health impacts of heat and age group

while others, located in the center of the axis (values between −1 and 1), are less influential in the sample studied.

Thus, the preventive category (item-1) most strongly related to adaptation (the largest circle on the left in Fig. 1b) is swimming in an outdoor public pool, lake or river (V9-1). It is followed by using the dryer less often to reduce home heat sources (V6-1) and frequenting places with air conditioning other than home (V10-1). Then come sponging or spraying the face or neck with cold water (V3-1), taking showers or baths more often than usual to cool off (V2-1), switching off the computer (if not used) to reduce heat sources in the home (V5-1), and using the yard to cool off in the evening (V8-1). Categories that do not separate low adaptation from non-adaptation much are: wearing a head covering when the sun is shining (V1-1), eating iced foods to cool off (V4-1) and adopting preventive behaviors based on weather information broadcast by the media or on the Internet (V11-1). The remaining preventive categories do so even less, namely, drawing the curtains closed against the sun to keep the home cool (V12-1), using the oven and stove less frequently to reduce heat sources (V13-1), using the balcony to cool off in the evening (V7-1) and choosing tap water as the main refreshment (V14-1).

In the same order of presentation (but to the right in Fig. 1b), the non-preventive categories most associated with non-adaptation are not taking baths or showers more frequently than

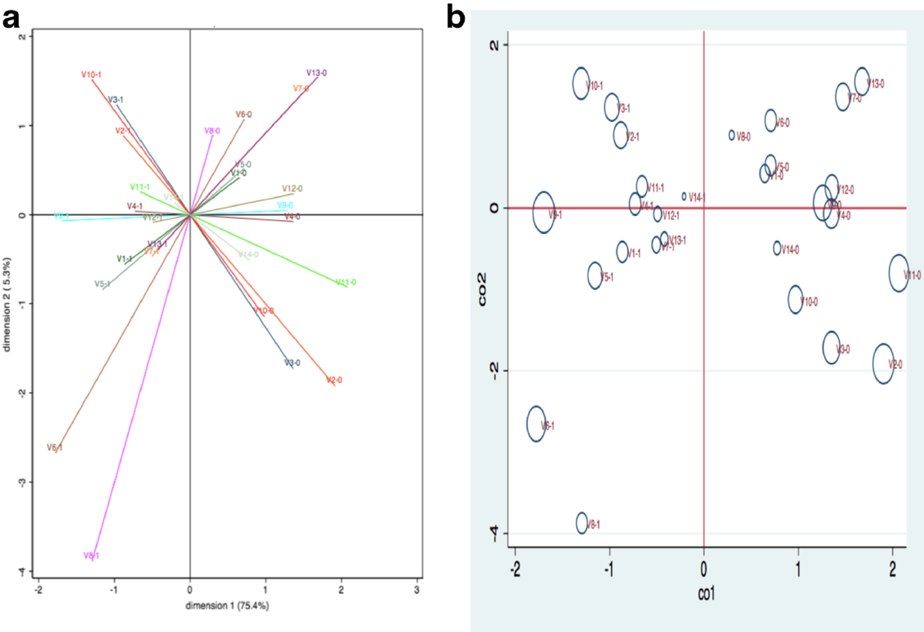

Fig. 1 Projection of standardized active variables with MCA (**a**) and symbols scaled according to relative contributions on the 1st axis (**b**). (Preventive categories on *left*; non-preventive on *right* of each figure): *V1*: Wearing a head covering when the sun is shining; *V2*: Taking showers or baths more often than usual to cool off; *V3*: Sponging or spraying the face and neck with cold water; *V4*: Eating iced foods to cool off; *V5*: Switching off the computer when not in use to reduce heat sources in the home; *V6*: Decreasing the use of the dryer to reduce heat sources in the home; *V7*: Using the balcony to cool off in the evening; *V8*: Using the yard to cool off in the evening; *V9*: Swimming in a public pool, lake or river to cool off; *V10*: Frequenting places other than home for air conditioning to cool off; *V11*: Adopting preventive behaviors according to weather information transmitted through the media or on the Internet; *V12*: Closing the curtains to keep the home cool when the sun is shining; *V13*: Decreasing the use of the oven to reduce heat sources in the home; *V14*: Drinking tap water as a main drink for cooling off

usual to cool off (V2 –0) and not adopting behavior based on weather information (V11-0). Then add not going swimming in a public pool, lake or river (V9-0), not sponging or spraying the face or neck with cold water (V3-0) and not eating iced foods as refreshments (V4-0). The other non-preventive categories have little influence on the adaptation index.

All active MCA variables have categories sufficiently isolated from one another to suggest that they have a good discriminant capability on dimension 1 (online resource 6); in other words, it is not just the effects of projection. In general, there are really no adaptation profiles of respondents (online resource 7).

3.2 Index values

The coordinates of the 14 active variables, generated by the MCA, made it possible to associate an index value to each respondent. For dimension 1, these values range from about −3 to +3 and are almost normally distributed. Thus, 16.6 % adopt the behaviors measured by the index (values≤−1 or pro-adaptation); 16.7 % adopt them little and even very little (≥1), and 66.7 % are situated between these two extremities (−1 to 1).

3.3 Comparisons of index values according to passive variables

Among the passive variables (Table 1), none presents categories or classes with very low frequencies (online resource 8). The projection of their coordinates (online resource 9) in the MCA universe shows mainly that the adoption of the adaptations measured by the index affects mostly the 18 to 44 age group (values≤−2 in Fig. 2). The 45 to 64 age group adopts them more or less (between −1 and 1), while those aged 65 and over adopt them very little or not at all (≥2). When gender is coupled with age group, we also note that women under age 64 have a higher adaptation score than men of the same age, especially in the 18 to 44 age group (around −3 for women, −1.5 for men), but no significant difference was observed in the 65 year and over group (almost 3 in both groups).

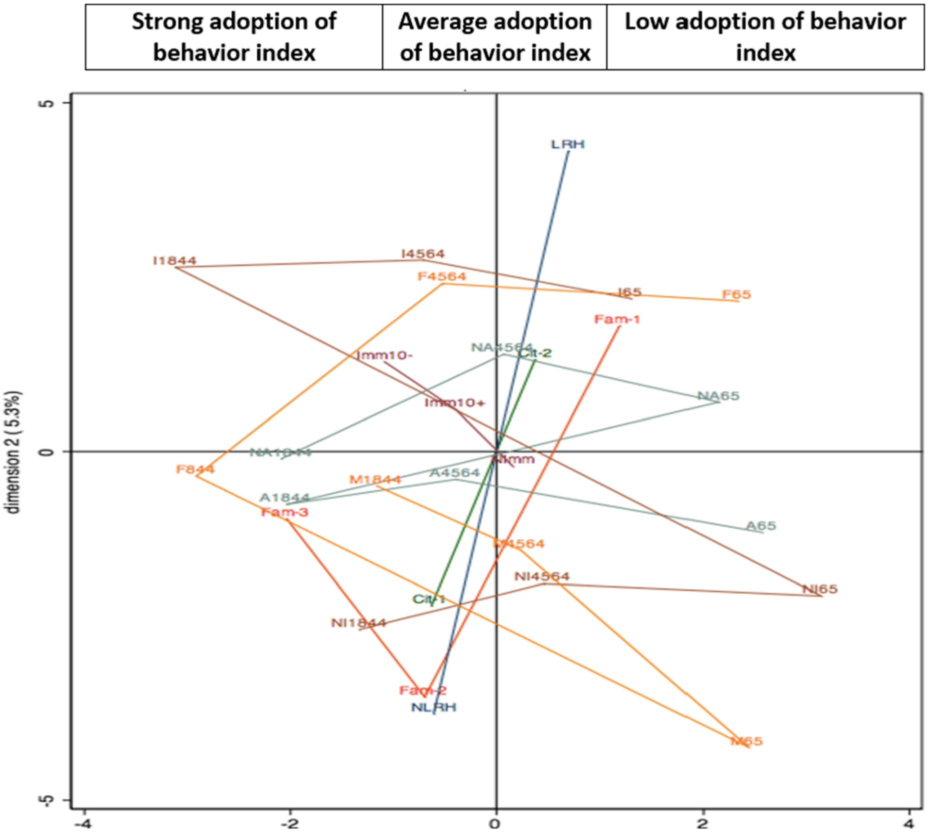

Fig. 2 Projection of passive variables in the standardized MCA index universe. (Preventive categories on *left*; non-preventive on *right*): *M1844:* Men 18–44 years; *M45-64*: Men 45–64 years; *M65*: Men ≥ 65 years. *F1844*: Women 18–44 years; *F45-64*: Women 45–64 years; *F65*: Women ≥ 65 years. *IMM10-* Immigrants who came to the country < 10 years before; *IMM10+*: Immigrants who came to the country ≥ 10 years before. *NImm*: Non-immigrants, born in Canada. *Fam-1*: Single-person households; *Fam-2*: Couples or non-family households of ≥ 2 persons; *Fam-3*: families. *Cit-2*: According to average temperature (last 30 years), cities among the hottest; *Cit-1*: not among the hottest. *LRH*: Home in low-income housing; *NLRH*: Home in the private market. *NA1844*: Non air-conditioned home, respondents aged 18–44 years; *NA45-64*: 45–64 years; *NA65*: ≥ 65 years. *A1844*: Air-conditioned home, respondents aged 18–44 years; *A45-64*: 45–64 years; *A65*: ≥ 65 years. *NI1844*: Without self-reported health impacts due to heat, respondents aged 18–44 years; *NI45-64*: 45–64 years; *NI65*: ≥ 65 years. *I1844*: Self-reported health impacts due to heat, respondents aged 18–44 years; *I45-64*: 45–64 years; *I65*: ≥ 65 years

Families are the type of household that score the most in terms of adaptation (values≤−2); this group's index value is approximately what is observed among the 18 to 44 year group. In contrast, people living alone represent the type of households that score the most in terms of non-adaptation (a little more than 1); they lie halfway between the 45 to 64 age group and older. Between these two extremes are households with at least two people and no children (between −1 and 0), which behave in more mixed way, as with the 45 to 64 age group.

The other passive variables have little influence on the heat adaptation index, including city of residence.

Finally, air conditioning in the home has little influence on the heat adaptation index. In fact, whether their homes have air conditioning or not, the 18 to 44 age group adopt adaptations measured by the index. In contrast, the 65 years and older group do little or none, while the 45 to 64 age group is midway between these two extremities. Among respondents as a whole, one in two was equipped with an air conditioner at home, usually a window model.

3.4 Application of the adaptation index to the prevalence of self-reported adverse health impacts during high summer heat

When projected in the MCA universe, the results show that people who experience adverse effects from heat on their health adopt more behaviors measured by the index than those who suffer little or none, independently of their age group (Fig. 2 and online resource 9). Then, we find the 18 to 44 age group with self-reported adverse health impacts from heat (index values around −3), followed by the 18 to 44 age group without impact (around −1.5) and the 45 to 64 age group with impact (near −1), followed by the 45 to 64 age group without impact (close to 1) with impacts (around 1.5), and finally the 65 and older group without impact (more than 3).

Considered overall, the prevalence of the health impacts of heat is estimated at 58 % in the pro-adaptation group, 46 % in the one that is more or less adaptive, and 33 % in the group that is very little or not at all adaptive (Table 2). These statistics remain in roughly the same order of magnitude when stratified according to age group or presence of air conditioning at home. Thus, compared to those who show low adoption of preventive measures of the index, the adaptation dimension is 2.5 to 3.7 times higher in the strong adoption group and 1.5 to 2.1 times higher among respondents who are average.

4 Discussion

The index developed in the study consists of 14 easy-to-use energy-efficient solutions for cooling off or protecting oneself against the sun, at home or in other places, whether indoors or outside. It explains 75 % of the total inertia due to a single dimension. While important for adaptation, following the evolution of those behaviors are generally not part of monitoring systems developed for heat waves (Centers for Disease Control and Prevention 2013; World Health Organization and World Meteorological Organization 2012). This index would thus better enable targeting of protection measures and health-promotion campaigns as they are suitable for sub-populations according to their own characteristics, as it can be measured easily at low cost through population surveys.

Air conditioning in the home was not retained as an active variable of the index, mainly because it did not meet the criterion of ordinal consistency on the first axis (Asselin 2009). In addition, unlike the other variables retained in the CMA, air conditioning produces

Table 2 Prevalence of self-reported adverse health impacts during high summer heat, according to index

Index	P % [A]	IC [B]	CV % [C]	RC [D]	IC [B]	Pr > Khi-2
All respondents						
Strong adoption of index	57.8	53.5–62.1	3.8	2.7	2.1–3.6	< 0.0001
Average adoption of index	46.3	44.1–48.4	2.4	1.7	1.4–2.1	< 0.0001
Low adoption of index	33.4	29.1–37.6	6.5	1.0		
Residents of air-conditioned housing						
Strong adoption of index	59.6	53.3–66.0	5.4	2.7	1.9–3.9	< 0.0001
Average adoption of index	52.9	49.8–55.9	3.0	2.1	1.6–2.7	< 0.0001
Low adoption of index	35.3	29.5–41.1	8.4	1.0		
Residents of non air-conditioned housing						
Strong adoption of index	56.1	50.0–62.2	5.5	2.8	1.9–4.1	< 0.0001
Average adoption of index	39.9	36.9–42.9	3.9	1.5	1.1–2.0	0.0229
Low adoption of index	31.3	24.9–37.7	10.5	1.0		
18–44 years						
Strong adoption of index	52.4	46.3–58.5	5.9	3.2	1.7–6.0	0.0004
Average adoption of index	37.9	34.1–41.6	5.1	1.7	0.9–3.2	0.0753
Low adoption of index	25.9	14.6–37.2	22.2	1.0		
45–64 years						
Strong adoption of index	64.0	56.9–71.2	5.7	2.5	1.6–3.9	< 0.0001
Average adoption of index	52.7	49.3–56.1	3.3	1.6	1.1–2.2	0.0095
Low adoption of index	41.6	34.1–49.1	9.2	1.0		
65 years						
Strong adoption of index	60.8	47.3–74.3	11.3	3.7	1.9–7.0	< 0.0001
Average adoption of index	46.0	41.9–50.2	4.6	2.0	1.5–2.8	< 0.0001
Low adoption of index	29.5	23.6–35.5	10.3	1.0		

[A] Prevalence of self-reported adverse health impacts during high summer heat in percentages

[B] Confidence interval of 95 %

[C] Coefficient of variation in percentages CV<15 %: estimate considered sufficiently accurate. CV of 15 % to 25 %: accuracy fair, estimate should be interpreted with caution. CV>25 %: accuracy too low for the estimate to be used other than as a guide

[D] Odds ratio

anthropogenic heat thus contributing to the urban heat-island effect (Bourque and Simonet 2007; de Munck et al. 2013). Finally, when considered as a passive variable, air conditioning is only weakly associated with the heat adaptation index. A similar conclusion has also been recently reported by an Australian study (Akompab et al. 2013), in which air conditioning in the home did not influence the total scores allocated to various adaptive behaviors to heat.

That said, these results appear to be contrary to what is generally reported in the scientific literature, where air conditioning in the home is recognized as a useful adaptation for people whose health is weakened during a heatwave (Kinney et al. 2008; Lundgren and Jonsson 2012; Reid et al. 2009). Most reviewed studies, however, are ecological in nature, almost always measuring air conditioning use at the zip or county level, while this study did measure its use at the dwelling level. Some studies, like Reid et al. (2009) also find that regardless of access to air conditioning or not, downtown areas of metropolitan areas (all our sample here) are always more vulnerable than areas further away from the center. In addition, in our study, it is possible that the weak association observed between air conditioning and the index is due to the fact that half of our sample lived in housing equipped with air conditioning. The categories of air conditioning is also found in the center of axis 1 of the MCA (therefore neither pro- nor anti-adaptation; data not shown). Furthermore, the beneficial effect on health would above all be particularly associated with central air conditioning (O'Connor et al. 2008; O'Neill et al. 2005). However, in very disadvantaged neighborhoods such as those included in our study, air conditioning comes mostly from window (or room) models, designed to be effective only for a single room and very costly to run (Shah 2014). Consequently, although air conditioning was not selected as an active variable in the CMA and appears weakly associated with adaptation to heat when considered as a passive variable, we suggest nonetheless adding air conditioning in the home as an indicator for systems that monitor the health impacts to heat, as air conditioning is known to reduce heat-related deaths and illness (Patz et al. 2014).

Age is the passive variable projected in the MCA universe that separates most distinctly adaptation from non-adaptation according to the index. It is highly likely that the 18 to 44 age group, especially those with young children, are more pro-adaptation during a heat wave, while people 65 years and older, the less pro-adaptation group, prefer to stay home, especially since the latter group does not have the obligation to leave home for work or family, as do younger adults. Moreover, in our study, 65.6 % of seniors do not even go out to do their shopping during high summer heat, while this percentage was 53 % among the 45 to 64 age group and 36.5 % among the 18 to 44 age group (data not shown). This pattern of behavior on hot days by seniors has been described elsewhere as "adapting by not acting" (White-Newsome et al. 2011).

On the other hand, only 5 of 14 adaptations measured in the index needed to go outside, 2 of whom on the balcony or in their backyard at night. In addition, 9 other adaptations (ex. drinking mostly water, sponging themselves with fresh water) could be applied by the majority of respondents, regardless of age. Consequently, not being compelled to go out cannot be the only hypothesis explaining the age differences observed. The Australian study (Akompab et al. 2013) is informative in this regard. Two psychosocial determinants of the Health Belief Model (HBM) have been associated with the total scores allocated to various adaptive behaviors to heat, namely a greater perception of the benefits to their health and knowing the signs that action should be taken. To our knowledge, this study is the only one of its kind in connection with the subject of our study. Other psychosocial research using the HBM or other psychosocial models (Godin 2012; Ory et al. 2002) are needed in this regard to further expand public health messages. However, it would also be appropriate to analyze the data using a mediator model (Hodson and Busseri 2012; Jones et al. 2005; Mathur 1998; Smith et al. 2008), as the effect of age could be mediated by perceptions.

Most self-reported heat-related illness in this study was in line with observed chronic illness usually associated with heat (Bélanger et al. 2014). Regardless of age group, people who feel the adverse effects of heat are somewhat more pro-adaptation than those who say they are only slightly or not affected. This result is reassuring, but it remains to be confirmed by other studies. Expanding the range of indicators associated with the prevalence of health impacts to other variable categories, such as indicators of prior state of health (Lundgren and Jonsson 2012; O'Neill et al. 2005), would be desirable.

5 Limitations of the study

As described in Bélanger et al. (2014), the samples in the study generally represented well the populations living in the visited DAs, and also the very disadvantaged DAs in Québec's nine large cities, due to the sampling plan that was adopted in the study (and that was taken into account in the weighting of the data), with some overrepresentation of elderly people due to their more important presence in subsidized public housing. On the other hand, the pairing of two types of recruitment (phone and door-to-door) reduced the risk of selecting only those who were at home and had a stationary telephone.

With respect to the index developed in the study, it is important to remember that it was developed in the most disadvantaged dissemination areas. For wider use, it would be wise to validate it in the general population. Moreover, as for all indices, we must be careful with its interpretation in order to avoid any simplistic policy uses or conclusions (OECD/JRC European Commission 2008). This index being based on individual behaviours only, we thus cannot make any statement about the role of larger scale institutional interventions in adaptation from this dataset.

6 Conclusion

This study has made it possible to develop an adaptation index to high summer heat focused on highly vulnerable people in urban deprived areas. This index, with the help of only one dimension, is a good summary of a range of 14 easy-to-use energy-efficient solutions for cooling off or protecting oneself against the sun, at home or in other places, whether indoors or outside. In addition, it shows that adaptation to heat goes beyond air conditioning in the home. Furthermore, the adoption of behaviors measured varies according to the prevalence of self-reported adverse health impacts in the context of heat. The follow-up of this index in monitoring systems (e.g., to compare regions or age groups over time) would therefore establish a significant milestone for adaptation to heatwaves, and be very useful for better targeting health protection and promotion heat adaptation programs. It can also prove useful in contexts where little data exists, as it can be built from surveys.

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