

## RAPID REVIEW

# Interventions to Mitigate Heat-related Harms among Vulnerable Populations

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## Key Findings

- Interventions that aimed to prevent, mitigate or respond to heat-related harms (e.g., heat-related illness, stress and mortality) among key populations that were most evaluated in the literature included cooling strategies (i.e., cooling garments for outdoor workers, cooling centres for the public, or cooling apparatuses for personal use) followed by heat education and awareness interventions, and multi-component regional health alert systems. Evaluated interventions for specific populations included:
  - Older adults: Two studies examined risk communication and heat education interventions directed at older adults. It was found that these interventions improve protective behaviours and self-reported heat-stress.
  - Infants and young children: Two studies examined the effectiveness of cooling devices for infants (i.e., stroller configuration using moist muslin and a fan; and use of an ice-cooling device directed over top of an infant). It was found these interventions are effective in reducing air temperature surrounding infants.
  - Outdoor workers: Three experimental simulated environment studies found that cooling garments were effective in reducing heat-related stress among outdoor workers, while two field-based studies found mixed results. A further three studies found that heat education/awareness programs improve heat illness knowledge and decreases negative heat-related health outcomes. Mixed results were found on the effectiveness of changing work and rest schedules as well as hydration interventions aimed at outdoor workers.
  - Multiple vulnerable populations: one study found that access to cooling centres was significantly associated with reductions in heat-related illness mortality.
  - General public: five studies examining multi-component regional heat alert systems found that these systems reduce adverse health outcomes at population levels (e.g., mortality, morbidity, emergency department visits, and hospital admissions).
- Other interventions that were described in the literature, but not evaluated, include the use of air conditioning among older adults, inter-sectoral collaboration, specific provider considerations, awareness campaigns on the prevention of children being left in cars, industry- or organizational-level regulations and policies for outdoor workers, shifting work to cooler hours, the development of vulnerability indices, and other varied community-level considerations.

- Supportive evidence on the effectiveness of heat education and awareness programs, cooling strategies and regional heat alert systems merit consideration for implementation, or strengthening of current practices in Ontario.

## Background

Due to climate change, it is expected that heat events will become increasingly frequent, prolonged and severe.<sup>1</sup> There are varied terms and definitions for these events, but for the purpose of this report, heat event will be used to include: heat wave, heat dome, extreme heat event and heat warning. There are also multiple definitions and varied understandings of who is considered vulnerable to or at increased risk of heat-related health harms, at the individual- or community-level. For the purpose of this rapid review, these populations included, but were not necessarily limited to: seniors, people who live alone, people with pre-existing health conditions, people with pre-existing mental illness, people who use substances, people with limited mobility, people who are marginally housed, outdoor workers, people who are pregnant, infants and young children, and vulnerability as described in included studies.

Heat events have already caused increases in preventable deaths in Canada and comparable jurisdictions. A recent and severe heat event occurred in British Columbia (BC) in 2021 when over 600 people died due to a heat dome that lasted several days.<sup>2</sup> Nearly all deaths (98%) occurred indoors and the majority of deaths (56%) were among people who lived alone. Populations who were disproportionately represented in the heat dome deaths included older adults with chronic health conditions, people with chronic conditions that may impact cognition (e.g., schizophrenia) and people living in areas of higher material and social deprivation. Other examples of significant levels of excess mortality due to heat events include the 2018 heat event in Montreal that caused 66 deaths.<sup>3</sup> Similar to the BC event, low income and social deprivation were considered risk factors, and the majority of deaths were among older adults (66%) and people with chronic conditions (72% with any chronic condition, 25% with schizophrenia and 18% with alcohol or drug addiction).<sup>3</sup> A 2003 heat event in Europe that lasted over a week resulted in over 15,000 excess deaths in France and over 2,000 excess deaths in the United Kingdom (UK).<sup>4</sup> In 2022, over 2,800 heat-related deaths occurred in people age 65 years and older in the UK.<sup>5</sup>

In Ontario, the Heat Warning and Information Systems (HWIS) was launched in 2016.<sup>6-8</sup> The HWIS outlines the thresholds and processes for Heat Alerts and Extended Heat Alerts, and the roles, responsibilities and suggested preparedness and response activities for various public health, government and community partners: public health units (PHUs), municipalities, the Ministry of Health (MOH), Environment and Climate Change Canada (ECCC), Health Canada and Public Health Ontario (PHO).<sup>8</sup> Most responsibility sits with local health units and municipalities in terms of preparedness and response to Heat Alerts. The HWIS provides suggestions to allow for tailored regional approaches, but does not provide structured requirements or mandates for the local level.

The objectives of this rapid review are to identify published, peer-reviewed literature on public health, regional-, community-, or provider-level interventions, supports, or measures that can be used to prevent, mitigate or respond to health impacts of heat events, specifically for populations most vulnerable to heat harms. The scope of this work is focused on immediate- or short-term interventions or measures due to the timing of this report being released during summer. This work on short-term, downstream interventions does not negate the crucial need for additional work to investigate and address systems, policies and other societal structures that contribute to inequities which place certain populations at disproportionate risk of harm from heat events and climate change.

# Methods

## Search

PHO Library Services completed a Medline search on April 27, 2023. The following search strategy was used to obtain records: heat events (key terms included but were not limited to: heat wave, extreme heat, extreme hot weather, heat dome); AND heat impacts (key terms included but were not limited to: morbidity, mortality, environmental illness, heat stress disorders, heat stroke); AND populations or groups who are vulnerable to heat-related health harms (key terms included but were not limited to: vulnerable populations, elderly, social isolation, pre-existing condition, substance-related disorders, homeless); AND interventions to prepare for, prevent, mitigate, or respond to health harms (key terms included but were not limited to: prevention, disaster plan, relief work, health communication, public policy, occupational health services, cooling).

## Screening

Screening was conducted using Covidence software. Screening at the title/abstract level was first piloted with a random selection of 50 records. Two authors screened the 50 records independently to trial the eligibility criteria and compare agreement. Authors agreed on 80% of the pilot records and clarifications to the eligibility criteria were made after discussion among authors. Next, screening was conducted independently in duplicate for 20% of title/abstracts. There was agreement for 89% of records and the remainder of screening was conducted by single authors. All included articles from the title/abstract screening continued to the full-text review (n=137). Screening was conducted in duplicate for 100% of full-texts articles, with discussion among authors to resolve conflicts. Reasons for exclusion at the full-text review were recorded in Covidence. If the two screening authors did not reach consensus through discussion, a third author was consulted to resolve the disagreement. The eligibility criteria to screen records for inclusion in this rapid review can be found in Appendix A.

## Data Extraction

Data extraction was conducted by a single author. Details including publication date, study design, study period, jurisdiction, target population, intervention description, role or organization implementing the intervention, outcomes assessed, and key results (including outcome measure and confidence interval [CI]), were extracted, when reported, from each included record. Full data extraction tables are available upon request.

## Critical Appraisal

The quality, or risk of bias, of each included study was critically appraised according to the study design. For studies with review methods, the Health Evidence Quality Assessment Tool was used;<sup>9</sup> for RCTs, the Joanna Briggs Institute (JBI) Randomized Controlled Trial Checklist was used;<sup>10</sup> for quasi-experiments (including pre-post studies), the JBI Critical Appraisal Checklist for Quasi-Experimental Studies was used;<sup>11</sup> for cohort studies, the JBI Critical Appraisal Checklist for Cohort Studies was used;<sup>12</sup> for surveys or cross-sectional studies, the JBI Critical Appraisal Checklist for Analytical Cross Sectional Studies was used;<sup>12</sup> for case series, the JBI Critical Appraisal Checklist for Case Series was used;<sup>13</sup> for qualitative studies, the JBI Critical Appraisal Checklist for Qualitative Research was used;<sup>14</sup> and for mixed methods, the Mixed Methods Appraisal Tool was used.<sup>15</sup> Critical appraisal was conducted by a single author.

All quality appraisal tools included response options of ‘Yes’ or ‘No’, some also included alternate or intermediate response such as ‘can’t tell’, ‘unknown’, or ‘not applicable’. Consistent with the Health Evidence Tool,<sup>9</sup> we considered studies with 80% or more answers of ‘Yes’ to be strong quality, >40% to <80% answers of ‘Yes’ to be moderate quality and 40% or fewer answers of ‘Yes’ to be weak quality. This rating system is intended to provide a high level overview of the body of evidence, details of quality appraisal results for each included study are available upon request.

## Synthesis and Quality of Evidence

The results were assessed and discussed by all authors to identify consistencies, inconsistencies, gaps, and any other notable patterns across key results from relevant studies. Results were synthesized narratively due to the heterogeneity in methods, interventions and outcomes across included records.

## Results

The Library database search returned 1,235 results. After screening titles and abstracts for eligibility, 100 full-texts were screened and 46 records were included in this rapid review.

Five studies included review methods (three scoping reviews, one rapid review and one non-systematic literature review);<sup>16-20</sup> and 41 were primary studies of varied designs, including three randomized controlled trials,<sup>21-23</sup> 16 quasi-experiments,<sup>24-39</sup> one cohort,<sup>40</sup> 11 analytical cross-sectional,<sup>41-51</sup> one case series,<sup>52</sup> six qualitative,<sup>53-58</sup> and three mixed-methods.<sup>59-61</sup> Studies were conducted across multiple Organisation for Economic Co-operation and Development (OECD) jurisdictions including the United States (US) (n=21),<sup>21,22,24,27,32,35,36,41-43,45-47,49,50,52,53,55,56,59,60</sup> Australia (n=6),<sup>23,26,37,39,54,58</sup> Canada (n=5),<sup>25,34,48,57,61</sup> Slovenia (n=1),<sup>28</sup> Italy (n=2),<sup>29,30</sup> Spain (n=1),<sup>31</sup> Korea (n=1),<sup>33</sup> Japan (n=1),<sup>38</sup> Greece (n=1),<sup>40</sup> Netherlands (n=1),<sup>44</sup> Austria (n=1).<sup>51</sup>

Twenty-three studies quantitatively evaluated the effectiveness of an intervention for outcomes related to health of target populations (e.g., morbidity, mortality, behaviour, cooling, knowledge). Twenty-three studies described, developed or recommended interventions or measures to minimize heat harms among vulnerable populations, but the intervention was not quantitatively evaluated for effectiveness related to health outcomes, or provided only descriptive or qualitative evaluation results.

Across studies, key target populations for the described or evaluated interventions were identified. The results are organized based on the following populations: older adults; infants and children; outdoor workers; multiple vulnerable populations (i.e., studies where vulnerability variables [e.g., age and income] were considered); and the general population (with specific considerations for those vulnerable to heat, as described by individual studies).

## Older Adults

Nine studies included results relevant to interventions to mitigate heat health harms specifically among older adults.<sup>20,23,38,40,44,46,48,51,61</sup> The definition of older adults varied between studies, but most studies referred to individuals 65 years and older. Two studies received a rating of strong quality,<sup>51,61</sup> five received a rating of moderate quality,<sup>23,38,40,44,48</sup> and two received a rating of weak quality.<sup>20,46</sup>

The types of preparedness, mitigation or response interventions described in these studies included: health messaging or educational interventions directed at older adults (with or without water delivery, various formats),<sup>23,38,48</sup> cooling centres,<sup>46</sup> use of outdoor cool spaces,<sup>51</sup> communication or practices specifically from family doctors,<sup>20</sup> interventions or measures implemented in long-term care institutions,<sup>44</sup> use of cooling systems in the home (air conditioning [AC] or fan),<sup>40</sup> and one study explored multiple potential suggestions.<sup>61</sup>

## EFFECTIVENESS OF INTERVENTIONS – OLDER ADULTS

### COMMUNICATION OR EDUCATION

Only two studies conducted a direct assessment or evaluation of the effectiveness of the described interventions (i.e., one RCT, one quasi-experiment), both studied the effect of health communication tools directed at older adults and both received moderate quality ratings.<sup>23,38</sup>

Nitschke et al. (2017) conducted an RCT of a heat health message tool among older adults in South Australia.<sup>23</sup> The intervention group received an introductory letter (advised reader to take notice of public announcements, alerts or warnings about heat or other emergencies), and an intervention package which included: information sheet on how to deal with extreme heat conditions, “Top Tips Heat-Health Card”, a “Beat the Heat” fridge magnet, the South Australian Health Department’s “Extreme Heat Booklet”, and three South Australia Health advice fact-sheets. The control group received the introductory letter only. At follow up, air conditioner (AC) use during hot weather was higher in intervention (74.4%) versus control group (63.4%,  $p < 0.05$ ) despite similar prevalence of AC in homes (96% versus 97%). More people in the intervention group reported use of a wet cloth on their face, neck or body (most of the time to always) to cool down during heat waves (16% versus 8%,  $p < 0.05$ ); and more in the intervention group believed that they had enough information to “beat the heat” (94% versus 88%,  $p < 0.05$ ). After adjustment for confounders (mental health-related medication, health status and use of aids for walking), the intervention group was significantly associated with protection from self-reported heat stress (adjusted risk ratio [aRR]: 0.37, 95% CI: 0.22, 0.63) compared to the control group.

Takahashi (2015) conducted a quasi-experimental study in Japan among community dwelling older adults.<sup>38</sup> The study had three groups: 1) heat health warning (HHW): dissemination of HHWs via radio broadcast to each household, 2) HHW+W: dissemination of HHW, plus bottled water delivery to each household; 2 bottles with short messages about heat-related illness prevention behaviors were delivered weekly for 5 weeks, and 3) control: no intervention. Pamphlets created by the Ministry of the Environment about heat-related-illness prevention were delivered to the two intervention groups when the baseline questionnaires were collected. Key findings of this experiment included:

- Significant behaviour improvements in HHW+W compared to control: increased operating times of nighttime AC (adjusted odds ratio [aOR]: 1.49, 95% CI: 1.01, 2.19); improvement in the frequency of water intake (aOR: 1.77, 95% CI: 1.21, 2.58); improvement in cooling body (aOR: 1.87, 95% CI: 1.26, 2.80); improvement in reduced activities in the heat (aOR: 1.54, 95% CI: 1.01, 2.37)
- Significant behaviour improvements in HHW compared to control: increased hat or parasol use (aOR: 1.80, 95% CI: 1.17, 2.77).
- Knowledge scores did not improve significantly from pre- to post- assessments among any of the three study groups, though there were non-significant improvements in understanding of prevention and symptoms of heat-related illness (HRI). Knowledge about the effectiveness of electric fans to reduce ambient temperature and heat stroke events was low in all three groups.

## INTERVENTIONS DESCRIBED, NOT EVALUATED – OLDER ADULTS

The remaining seven studies used various study findings (e.g., survey responses, correlations, barriers and facilitators) to devise recommendations or suggestions related to the protection of older adults from heat-related harms, but did not evaluate the suggested interventions.

Four studies collected data from older adults regarding their behaviours, perceptions, barriers or suggestions,<sup>46,48,51,61</sup> one explored roles specifically for general practitioners to prevent heat-related harms in older adults patients,<sup>20</sup> one explored measures used in institutions for older adults,<sup>44</sup> and one examined the use of cooling systems (AC or fans) among older adults in their homes.<sup>40</sup> Common themes are summarized below.

### COMMUNICATION OR EDUCATION

Barriers reported by older adults in a Waterloo, Ontario survey included: heat warnings not always reaching older adults; lack of information on local resources; and many learned to rate temperatures using the Fahrenheit scale, and weather reports using Celsius were not as accessible to them.<sup>61</sup> A suggestion from this survey was that doctors, pharmacists, community centres and local news were trusted sources of information that could be used to disseminate heat-related information.<sup>61</sup> Based on survey findings among older adults, a study in Vienna, Austria suggested increased information and awareness-raising on the impacts of heat waves targeting older adults; inclusion of relatives, friends, neighbours to better assist older adults during heat waves; and increased communication of protective behaviours during a heat wave.<sup>51</sup>

### COOLING CENTRES

A 2018–2019 survey of older adults in Arizona found that 54% knew what a cooling center was, 36% knew of cooling center locations in their area, but only 8% had ever visited a cooling centre.<sup>46</sup> Reported barriers included awareness of location, transportation and inability to bring pets. Alternative options, such as libraries, restaurants, and friend or family homes, were reported as locations to seek cooling.<sup>46</sup> A survey conducted in Waterloo, Ontario also found older adults reported lack of information on local resources (e.g., cooling centres) as a barrier.<sup>61</sup> A study conducted in Vienna, Austria surveyed older adults and focused on potential outdoor cool green spaces, and also concluded there was a need for more information about cool spaces (indoor, or outdoor green spaces), overall provision of more in- and outdoor cooling spaces (i.e., green spaces with shade from trees, shaded benches), and more cooperation between urban planners and seniors' clubs.<sup>51</sup>

### USE OF AIR CONDITIONING

In a 2018–2019 survey in Arizona, US, 18% of older adults reported electricity cost always or sometimes constrained their use of AC. Additional reported barriers to AC use were devices not working, cost of repairs, and confusing technology.<sup>46</sup> Of note, Arizona Corporation Commission implemented a temporary ban on power shutoffs to maintain AC access during the summers of 2019 and 2020.<sup>46</sup> A Montreal study explored components of the Health Belief Model and AC use among middle-age to older adults which chronic illnesses (chronic obstructive pulmonary disease and/or congestive heart failure).<sup>48</sup> Three model components contributed significantly to AC use: perceived benefits, perceived barriers and cues to action (specifically, internal cue: sensitivity to heat). Based on this, study authors suggested public health communications should include strategies aimed at modifying beliefs about specific health benefits from AC use (e.g., allows one to continue daily activities and to avoid respiratory problems), and strategies to reduce or mitigate the perceived barriers to effective action (e.g., perceptions that air conditioner use could have drawbacks such as aggravating health problems or cooling the house too much). In an observational study conducted in Greece, elderly febrile patients who requested a

physician appointment in their home were prospectively followed over six weeks in July and August. Fevers were attributed to infection, non-infectious disease or unclear diagnosis. Multivariate analysis (assessing daily ambient temperature, use of cooling systems, patient age, and living conditions) indicated an association between use of cooling systems (AC or fan) and health outcomes among febrile older adults who had a physician home visit in summer months. Non-use of cooling systems was significantly associated with mortality (OR: 2.18, 95% CI: 1.06, 4.50).<sup>40</sup>

## **INTER-SECTORAL COLLABORATION**

Mallen et al. (2022) suggested enhanced collaboration among community sectors and education programs to improve protection of older adults from HRI.<sup>46</sup> Wilson et al. (2011) suggested general practitioners should link with community-based health professionals, to assist practitioners to manage those at risk during extreme heat.<sup>20</sup>

## **SPECIFIC CARE PROVIDER CONSIDERATIONS**

Wilson et al. (2011) suggested general practitioners should identify risk factors that may be exacerbated by extreme heat and develop mitigation strategies with patients; emphasize the importance of staying cool, wearing light clothing, reviewing medications and promoting appropriate lifestyle behaviours in older people.<sup>20</sup> Kunst et al. (2013) explored measures used in institutions for older adults.<sup>44</sup> Sixty-seven percent of participating institutions had a heat protocol, and this study found care managers at institutions with heat protocols considered institutional-level measures to mitigate heat harms “very important” slightly more often than those without heat protocols (32% and 23%, respectively). Across respondents, individual-level measures (e.g., offering additional fluids, reducing activity, adjust daily routine) were generally considered more important than institution-level measures (e.g., sun shades, mechanical or natural ventilation, available cooling rooms), for the protections of residents in institutions, suggesting a need for increased understanding of impact from organizational (upstream) versus individual (downstream) measures.

## **Infants and Children**

Three studies (two experimental and one survey) included results relevant to interventions to mitigate heat health harms specifically among infants and/or young children. The age ranges of infants and/or young children were not reported in the included studies. One was rated strong,<sup>26</sup> one moderate,<sup>31</sup> and one weak.<sup>49</sup>

The types of preparedness, mitigation or response interventions described in these studies included the use of cooling interventions directly for the infant,<sup>26,31</sup> and an educational intervention directed at parents.<sup>49</sup> The cooling interventions were evaluated, whereas the educational intervention was not.

## **EFFECTIVENESS OF INTERVENTIONS – INFANTS AND CHILDREN**

### **COOLING INTERVENTIONS**

Only two studies conducted a direct assessment or evaluation of the effectiveness of the described interventions (i.e., two experimental), both studied the effect of cooling interventions directly for the infant.<sup>26,31</sup>

Bin Maideen et al (2023) examined the cooling efficacy of eight different stroller configurations for use in hot and moderately humid summer weather (air temperature =  $33.3 \pm 4.1$  °C).<sup>26</sup> The lowest absolute in-stroller air temperature was observed in Muslin (100% cotton blanket draped over the stroller) + Moist (blanket saturated in water) + Fan (clip-on, battery operated fan attached to the front of stroller) ( $32.3 \pm 4.2$  °C). The next most effective configuration was the Muslin + Moist ( $33.6 \pm 5.1$  °C). Both of these configurations were significantly lower than the Closed Stroller Control configuration (stroller canopy pulled down) ( $37.5 \pm 4.7$  °C) ( $p < 0.009$ ). In contrast, the highest absolute in-stroller air temperature was observed in Flannelette Only (100% polyester blanket draped over the stroller) ( $40.0 \pm 4.8$  °C), followed by the Flannelette + Fan ( $39.5 \pm 4.2$  °C) and Muslin Only ( $39.2 \pm 4.5$  °C) configurations, all of which were higher than the Closed Stroller Control ( $p < 0.026$ ). No differences in absolute in-stroller air temperature were observed in the Fan Only ( $37.2 \pm 4.8$  °C) or the Muslin + Fan ( $37.9 \pm 3.3$  °C) configurations compared with the Closed Stroller Control configuration ( $p > 0.995$ )

Farre et al (2021) conducted an experiment aimed to design, evaluate, and test a novel cooling device.<sup>31</sup> In this low-cost and easy-to-assemble cooling device, airflow of room air passes through ice cubes in an insulated box and refrigerated air leaves through a pipe placed over top of the infant. The device provided sufficient refrigerating capacity for several hours from just 1–2 kg of ice obtained from a domestic freezer.

## **INTERVENTIONS DESCRIBED, NOT EVALUATED – INFANTS AND CHILDREN AWARENESS TO PREVENT CHILDREN LOCKED IN CARS**

The remaining study by Rossi (2013) described the ‘No Child Locked Inside’ awareness program that was planned to be implemented in Pompano Beach, Florida, US.<sup>49</sup> This awareness program includes education via local news media, newspapers, community events, public service announcements, city website, and local police enforcements. It also includes convincing store owners to place a “No Child Locked Inside” sticker at the entrance to all street front businesses in Pompano Beach. Lastly, it includes handing out “No Child Locked Inside” educational & awareness handouts to Pompano Beach residents. This last objective will be accomplished through the following activities: community events, distributing handouts, providing handouts at Car Seat Events by Fire Rescues, publishing handouts in newspapers/magazines every quarter, and posting handouts on the city website. This paper described, but did not evaluate, the action plan for this awareness program.

## **Outdoor Workers**

Twenty studies included results relevant to interventions to mitigate heat health harms specifically among outdoor workers. The most commonly described work industries were agriculture and construction. Seven studies received a quality rating of strong,<sup>22,27,28,30,34,39,54</sup> 11 received a rating of moderate,<sup>21,24,32,35,36,45,47,52,55,56,60</sup> and two received a rating of weak.<sup>16,18</sup>

The types of preparedness, mitigation or response interventions described in these studies included the use of cooling garments, education and awareness programs, work schedule adjustments, and hydration interventions.

## **EFFECTIVENESS OF INTERVENTIONS – OUTDOOR WORKERS**

Thirteen studies conducted a direct assessment or evaluation of the effectiveness of the described interventions (i.e., experimental, qualitative field-based studies). These studies evaluated the effect of wearing a cooling device while working in the heat, employees and/or employers participating in a heat education and awareness program, modifying the work schedule for employees, and drinking water at the workplace.



## COOLING GARMENTS

Five studies (three experimental, two field-based studies) evaluated the effects of wearing a cooling garment while working outdoors.<sup>21,27,28,30,60</sup> The three experimental studies found similar results suggesting that a wearable cooling garment (e.g., cooling vest or cooling jacket) was effective in reducing heat-related stress among workers (e.g., heart rate measures, internal core temperature, skin temperature) in a simulated environment.<sup>27,28,30</sup> Chicas et al. conducted two studies in the field with agricultural workers in Florida, examining the impact of a cooling bandana, a cooling vest, or both a cooling bandana and cooling vest on core body temperature, as well as perceptions of the participants using the garments.<sup>21,60</sup> Compared with the control group, the bandana group had lower odds of exceeding core body temperature (T<sub>c</sub>) of 38°C (OR: 0.7, 90% CI: 0.2, 3.2) and the vest group had higher odds of exceeding T<sub>c</sub> 38°C (OR: 1.8, 90% CI: 0.4, 7.9), however results were non-significant. The use of both cooling vest and bandana did not have a significantly different effect than the control group (OR: 1.3, 90% CI: 0.3, 5.6).<sup>21</sup> In the study focused on workers' perceptions of the garments, participants in the bandana group reported the bandana was practical to use at work and did not interfere with their work routine.<sup>60</sup> Participants using the cooling vest felt it was effective at cooling them, but the practicality of using the vest at work was met with mixed reviews.

## HEAT EDUCATION AND AWARENESS PROGRAMS

Four studies (one group randomized study, one case-control, one retrospective, and one cross-sectional,) examined the effects of heat education and awareness programs, three of which collected data from employees and one collected data from employers/crew leaders.

The three studies examining the effects of heat education/awareness programs on outdoor workers reported similar findings, that these programs improve heat illness knowledge and decreases negative heat-related health outcomes.<sup>22,28,35</sup> Chavez Santos et al (2022) examined heat education and awareness tools that included 1) worker education; and 2) a heat awareness mobile application that informs supervisors of hot conditions during the coming week and provides recommendations to keep workers safe.<sup>22</sup> After adjusting for maximum work-shift ambient Heat Index, the intervention group showed larger decreases in physiological strain index compared to the comparison group, particularly for higher work exertion levels, although results were not statistically significant. Grzywacz et al (2019) examined heat and pesticide safety curricula that included a facilitator guide that contains core learning objectives, scripts for delivering the material, and suggestions for facilitating participant involvement in learning.<sup>28</sup> Heat illness knowledge and behavioral intentions were reported to increase more for farmworkers assigned to the heat illness than for the pesticide safety curriculum. McCarthy et al (2019) conducted a retrospective analysis on the Voluntary Heat Stress Awareness Program (HSAP) implemented for municipal employees in Central Texas, US from 2009 to 2017.<sup>35</sup> The HSAP consisted of training and medical monitoring of enrolled employees. Over the 9-year time span, heat-related illness (HRI) significantly decreased. The odds of an HRI in 2015 to 2017 decreased by 91% and 66% compared with 2009 to 2011 and 2012 to 2014; respectively (OR: 0.092, 95% CI: 0.034, 0.250; and OR: 0.338, 95% CI: 0.122, 0.936).

One cross-sectional study by Luque et al (2020) collected data from crew leaders to measure the acceptability of the Occupational Safety and Health Administration (OSHA) heat safety tool app.<sup>30</sup> This app includes functions such as highlighting the importance of water, rest, and shade to avoid HRI. Crew leaders using the heat safety app rated the app very highly on relevance, functionality, value and privacy.

## WORK AND REST SCHEDULES

Three experiments evaluated the effectiveness of work-to-rest ratios and work hours among outdoor workers.<sup>34,36,39</sup>

Two studies found that rest breaks based on existing guidelines were not sufficient to bring core temperature down to baseline, while the other found that shorter, more frequent breaks were more effective at reducing thermal sensation and comfort. Uchiyama et al (2022) investigated the influence of shorter, more frequent rest breaks during simulated work (outdoor mining) in the heat on physical performance and psychophysiological responses.<sup>39</sup> Rest breaks in the current practice group occurred at 1:00 and 2:30 pm (30 min and 15 min, respectively), while in the experimental group were at 1:00 (15 min), 1:45, 2:25 and 3:05 pm (10 min each). Heart rate, thermal sensation, and thermal comfort were significantly higher at 120–180 min (all  $p < 0.05$ ) in current practice group compared to experimental group.

Mulholland et al (2023) measured the United States National Institute for Occupational Safety and Health (NIOSH)-recommended 45:15 min work:rest ratio during moderate-intensity work.<sup>36</sup> It was found that overall, rest intervals were inadequate for heart rate (HR) to return to baseline as evidenced by elevated HR at the end of both the first ( $p = 0.004$ ) and second ( $p < 0.001$ ) rest breaks ( $p < 0.001$ ). Neither rest break was sufficient to decrease gastrointestinal temperature from the end of the preceding work bout (both  $p = 1.00$ ). Skin temperature was elevated at 45 min compared to the end of the first ( $p = 0.02$ ) and second ( $p = 0.047$ ) rest breaks but not compared to baseline ( $p = 0.29$ ).

Lamarche et al (2017) evaluated body temperature responses in older workers during work performed in accordance to the American Conference of Governmental and Industrial Hygienists Threshold Limit Values Recommended (TLVR) guidelines.<sup>34</sup> The first work condition consisted of 120-min of continuous (CON) cycling at a wet-bulb globe temperature (WBGT) of 28.0°C (dry-bulb temperature, ~36.0°C; relative humidity, ~38%) (CON[28°C]). The remaining two work-simulated conditions consisted of intermittent work performed at work:rest allocations of: (1) 3:1 (i.e., 6 cycles of 15-min cycling + 5-min recovery) at a WBGT of 29.0°C (drybulb temperature, ~38.0°C; relative humidity, ~34%) (WR3:1[29°C]); or (2) 1:1 (i.e., 4 cycles of 15-min cycling + 15-min recovery) at a WBGT of 30.0°C (dry-bulb temperature, ~40.0°C; relative humidity, ~30%) (WR1:1[30°C]). The findings indicate that the TLVR guidelines do not prevent body core temperature from exceeding 38°C in older workers. Furthermore, a stable core temperature was not achieved within safe limits (i.e., 38°C) indicating that the TLVR guidelines may not adequately protect all individuals during work in hot conditions.

## HYDRATION INTERVENTIONS

Bartman et al (2022) conducted a simulated experiment evaluating the NIOSH recommendations (i.e., workers consume 237 mL of water every 15–20 min and allow for continuous work at heavy intensities in hot environments up to 34°C and 30% relative humidity).<sup>24</sup> It was reported that core temperature rose from baseline ( $36.8 \pm 0.3^\circ\text{C}$ ) to completion of 2 hour of work ( $38.1 \pm 0.6^\circ\text{C}$ ,  $p < 0.01$ ), with two of the eight participants reaching the 38.0°C threshold. Due to variable responses to heat strain, it was suggested that individualized plans for work-to-rest ratios and hydration strategies should be encouraged.

## INTERVENTIONS DESCRIBED, NOT EVALUATED – OUTDOOR WORKERS

The remaining seven studies described multiple interventions to mitigate the effects of heat events in outdoor workers, but did not evaluate effectiveness of those interventions.

A scoping review by Acharya et al (2018) summarized studies related to heat stress in workers in the construction industry and efforts in implementing preventive measures.<sup>16</sup> The types of interventions included:

- Workplace policies, regulations and recommendations, i.e., industry- and organizational-level structures to protect workers.
- Public educations and government guidelines: e.g., education campaigns, recommendations for employers, high temperature warnings, educational pamphlets.
- Limited work hours in the hottest portion of the day: noted the limitation of regulations to limit hours if not enforced/encouraged, or there is an actual or perceived benefit among workers to continue working through hottest hours.
- Required rest breaks and optimization of work-rest cycles: adhere to and encourage required breaks.
- Acclimatization to the heat: physiological adaptation to heat stress begins within three to four days of working in hot conditions but the hormonal regulation process of acclimatization starts three to four weeks later. This delayed response may mean that the workers are at an increased risk for experiencing HRI if heat stress prevention measures are not provided or adequately used.
- Workplace provisions, such as electric fans, ventilation, cool water dispensers, ice machines, breakfast and electrolyte replacements.

Another scoping review by El Khayat et al (2022) aimed to summarize the existing knowledge regarding the health impacts associated with climate change and heat stress, guide future research toward better understanding current and future climate change risks, and inform policies to protect the health and safety of agricultural workers.<sup>18</sup> The most common summarized interventions included maintaining proper hydration, taking breaks in shaded areas, going to air-conditioned places during or after work, changing work hours and activities, and taking extra breaks. Other preventive measures included acclimatization, HRI training, wearing sunglasses and sunscreen, and the use of rest stations or fans.

Three studies used interviews with workers to collect data regarding their knowledge, practice, perceptions, barriers or suggestions to heat-related interventions.<sup>54,56</sup> In a study by Lam et al. (2013), the majority of participants reported never having received formal HRI training, most participants were aware that extreme heat can cause illness and were able to accurately describe HRI symptoms, risk factors, and certain prevention strategies.<sup>49</sup> Location of drinking water at work (e.g., next to restrooms) and whether water is clean, but not necessarily chemically-treated, were important considerations in deciding whether workers drink the water provided by employers. In another study by Luque et al. (2019) involving farmworkers, there was consensus across the groups that the workers at highest risk for HRI were either inexperienced or new workers in the fields.<sup>56</sup> Farmworkers ascribed responsibility for one's well-being while working in the heat more as an individual factor than as an employer's responsibility. Farmworkers received training on the OSHA Heat Safety Tool app and provided positive feedback about the educational content and temperature information warnings. Hansen et al (2020) interviewed workers in Australia to better understand contributing risk factors and preventive actions based on personal experiences. Participants recommended greater awareness of heat risks and peer-support for co-workers.<sup>54</sup>

Arbury et al (2016) assessed 84 heat enforcement cases in the US from 2012 to 2013 in OSHA's database.<sup>52</sup> Under the OSHA, employers must implement the Heat Illness Prevention Program, which consists of a designated point person, monitoring work temperature, providing water, encouraging water intake, acclimatizing workers, using work/rest cycles, training workers on signs and symptoms of HRI, monitoring workers heat stress, and planning for heat emergencies. It was found that in the heat enforcement cases, most employers failed to implement common elements of the heat illness prevention program. Over 80% did not rely on national standard approaches to heat illness prevention.

A modelling study by Parsons et al. (2021)<sup>47</sup> examined shifting work hours to cooler times of the day. The primary outcome was related to labour and productivity losses, which is out of scope of this review. Secondary considerations related to implementation of the approach and workers' well-being and time shifting work hours were also described. These included: moving work to earlier hours may impact sleep duration, which is associated with injury risk; occupations and industries (e.g. construction) in certain settings may be limited in their abilities to shift work hours due to policies such as local noise ordinance; shifting hours has the potential to introduce additional hazards related to other aspects of ambient conditions, such as lighting; changes in work schedules need to be coordinated with childcare and other obligations to maintain overall community well-being. Workers and communities should be included in decision-making to ensure that important considerations are not overlooked.

## Multiple Vulnerable Populations

Six studies evaluated and/or described interventions to mitigate heat health harms that accounted for vulnerability (i.e., demographic variables such as age, sex, and income were considered). Four studies received a rating of strong quality,<sup>41-43,50</sup> and two received a rating of weak quality.<sup>17,59</sup>

## EFFECTIVENESS OF INTERVENTIONS – MULTIPLE VULNERABLE POPULATIONS

One study, with a strong quality rating, examined the effectiveness of an intervention (cooling centres) on health outcomes (mortality), specifically among people described in the study as socially vulnerable.

### COOLING CENTRES

Eisenman (2016) examined the association between pedestrian access to public cooling centres in Arizona, US and two outcomes: mortality from all internal causes, and mortality from heat-related illnesses using mortality data from the Arizona Department of Health Services.<sup>42</sup> Cooling centres included official cooling centers, public libraries, shopping malls, museums and restaurants. Social vulnerability variables during heat waves considered in this study were: percent female-led households (no male partner), percent living alone, percent living alone (>65 years old), percent foreign born, percent who work in construction, percent who work in agriculture, forestry, fishing and hunting, and mining, percent whose income in last 12 months is below poverty level, percent of households with no vehicles available, percent 65 years or older, percent Hispanic or Latino, percent health uninsured, percent female and percent renter households.

- Pedestrian access to public cooling centres did not modify the effect of temperature on all internal causes of mortality (incidence rate ratio [IRR]: 1.00; 95% CI: 0.99, 1.01; p=0.34).

- Pedestrian access to public cooling centres did modify the effect of temperature on HRI mortality:
  - There was a significant negative interaction between pedestrian access to public cooling centres and maximum temperature (IRR: 0.99; 95%CI 0.98, 1.00; p=0.03), meaning mortality from HRI increased faster as the maximum temperature increases in census tracts with less cooled space accessibility. In census tracts at the 25th percentile of pedestrian access to public cooling centres (i.e., lowest end of the distribution), the IRR was 1.38 (95% C: 1.12, 1.69; p=0.002), indicating that for every increase in maximum temperature by one degree Celsius, there was a 38% increase in deaths from heat-related illness.
  - Controlling for social vulnerability values, the interaction between pedestrian access to public cooling centres and temperature reduced the risk of death from HRI (IRR: 0.98, 95% CI: 0.96, 1.00; p=0.024), meaning, as maximum temperature increases, increasing access to public cooled spaces was associated with slower increases in the mortality rate from HRI.

## INTERVENTIONS DESCRIBED, NOT EVALUATED – MULTIPLE VULNERABLE POPULATIONS

Five studies included descriptions of interventions or suggestions to mitigate heat related health harms among people considered vulnerable to heat, but did not evaluate the suggested interventions' impact on health outcomes.

### COOLING CENTRES

Three studies specifically assessed cooling centre accessibility or distribution, all in US jurisdictions, and provided suggestions to enhance cooling centre access to better meet the needs of populations described as vulnerable to heat related harms.

An observational study examined cooling centres in 81 US cities, specifically, optimal access to cooling centres (i.e., within a 0.5 mile walk) for populations described as socially vulnerable. Vulnerability was based on a social vulnerability index [SVI] that considered: socioeconomic status, household composition and disability, racial and ethnic minority status and language, and housing type and transportation. Results were also sub-analysed by age.<sup>41</sup> SVI values were higher within cooling centre access areas than outside of cooling centre access areas (mean SVI value 0.65 and 0.48, respectively, p<0.001). Overall, adults aged ≥65 years were less represented than younger people within cooling centre access areas, but when accounting for poverty level, more adults ≥65 years living below the federal poverty level resided within cooling center access areas compared to outside access areas (16.9% versus 11.2%, p<0.001). The study suggested considering new cooling centers be placed in more densely populated areas or in areas that are convenient for older adults.

A study in Portland, Oregon, US assessed surface temperatures across city areas, access to refuge from the heat (including household AC, and public cooling centres), and considered socio-demographic indicators (income, race, education, age, and English speaking ability) to model urban heat island effects and consider adaptive capacities.<sup>50</sup> Accessibility to public cooling centres was a key outcome assessed in this study. Analysis showed that 3.4%–32.7% of the city's population could access a public cooling centre on foot (depending on walking speed), meaning even at top walking speed, less than a third of the population could access by foot. This suggested considerable barriers may be faced by people with mobility challenges (e.g., use a mobility aid, pre-existing health conditions). Analysis by sub-population (race, age) showed the Black populations had a significantly positive relationship with access to cooling centres, Asian and elderly populations had significantly negative relationships with access to public

cooling centres, and other tested socio-demographic characteristics did not significantly associate with cooling centre access. Elderly people have been disproportionately impacted by heat waves, and these results suggest they can also face barriers in accessing cooling centre locations.

Allen et al (2022) conducted an observational study in Virginia, US, assessing access to public cooling centres.<sup>59</sup> This study reported over 65% of residents in the state could reach a cooling centre within a 15-minute drive, however this favoured those with access to vehicles. Less than 7% of those experiencing the greatest level of poverty could reach cooling centres within a 15-minute drive. It also reported that heat-related hazard information is rarely included in city and county hazard plans.

## VULNERABILITY INDICES

A study by Hammer et al. (2020) described the development of a heat vulnerability index in Philadelphia, Pennsylvania, US, though the index was not evaluated.<sup>43</sup> The aim for this index was to identify priority areas that are most at risk of experiencing adverse health harms from heat, thereby allowing targeted preparedness and mitigation interventions (e.g., intervention pilot projects and policies, cooling centres, programs to increase community adaptive capacity, tree planting, green roofing). Socio-demographic factors included: age, educational attainment, language barrier, poverty, race/ethnicity, and social isolation. Health status factors included: asthma, chronic obstructive pulmonary disease (COPD), coronary heart disease (CHD), diabetes, hypertension and obesity. Using this index, authors found the areas of hottest surface temperatures tended to be in the more central locations in the city and could be almost 22°F hotter than the coolest areas. More affluent areas tended to be cooler due to greater green space and tree-lined streets. All census blocks considered by the index to be most vulnerable to heat were located in areas of low socioeconomic status.

Bundle et al. (2018) examined risk factors for overheating in UK domestic homes among adults over 75 years, babies and young children, and those with long-term physical or mental conditions, and/or multiple medications.<sup>17</sup> The authors considered results and described risk management suggestions. In relation to vulnerability indices, they suggested local authorities compile local profiles or maps of heat risk that consider risk factors related to occupants, building design and location.

## OTHER COMMUNITY-LEVEL CONSIDERATIONS

Bundle et al. (2018) described additional risk management suggestions, including:<sup>17</sup>

- Establish models of local service provision to support vulnerable people during warm weather. These could mirror services for cold homes recommended by the National Institute for Health and Care Excellence (NICE) or could form part of a combined seasonal health or healthy home service.
- Establish collaboration and partners among: local housing policy, planning, public health, social care, housing-related support services, environmental health and social agencies. Link work to local population needs assessments, and local housing and health strategies.

A study on urban heat island effects and adaptation capacities in Portland, Oregon, US described several suggestions to improve supports for those at greatest risk of heat exposure or harm.<sup>50</sup> These included: community engagement to better understand community members' experiences with heat events; work with local organizations to build capacity within the community; disseminate information to marginalized groups who may not trust government programs; issue information regarding cooling centres, heat warnings, and heat safety in multiple languages; and consider tailoring messaging to specific groups.

## General Public

Eight studies included results relevant to the general public and used population-level data, but also included sub-analyses related to intervention to mitigate heat harm among one or more groups considered vulnerable to heat. All of these studies explored regional heat alert plans. One received a rating of strong quality,<sup>19</sup> five received a rating of moderate quality,<sup>25,29,33,37,58</sup> and two received a rating of weak quality.<sup>53,57</sup>

### EFFECTIVENESS OF INTERVENTIONS – GENERAL PUBLIC REGIONAL OR COMMUNITY HEAT ACTION PLANS

Five studies examined population-level health outcomes of heat action plans, also known as heat alert and response systems or heat monitoring systems. These included one scoping review,<sup>19</sup> and four primary studies that conducted epidemiological evaluations using varied methods to assess impact on health outcomes (e.g., mortality).<sup>25,29,33,37</sup> All heat action plans involved multiple components and interventions, however studies evaluated the impact of the plan as a whole.

Hasan et al (2021) conducted a scoping review (quality assessment rating: strong) to explore literature on community-based heat awareness, mitigation, warning or education plans, measures or interventions.<sup>19</sup> Outcomes of interest included: mortality, morbidity and heat illness literacy. This review included 17 studies from various jurisdictions (Australia, Canada, China, Europe, France, India, Italy, Japan, Spain and US). Results were grouped into two main categories, each supported by studies that provided effectiveness evidence for outcomes including mortality, morbidity, knowledge, and protective behaviours. The synthesis highlighted:

- Heat action plans: typically included, but were not limited to establishing a heat monitoring system or warning system, information campaigns for the general population, the mobilization of health care professionals, volunteers, social workers and trained caregivers in the surveillance and management of individuals with known vulnerabilities, and infrastructure to manage heat events. Multi-sectoral engagement and multi-pronged approaches were highlighted as key components to heat action plans. The authors noted the importance of understanding the role and impact of the interaction of individual and institutional barriers and facilitators within municipal organizations. Targeted programs or measures for vulnerable populations included: distribution of water to older adults via volunteers, registering residents in hard to reach areas with local municipalities, establishing heat systems or protocols in long term care homes and schools.
- Awareness campaigns: generally occurred in community settings and contained guidelines on preventing heat stress, information on high-risk population groups (e.g., children and the elderly), and resources on prevention of heat illness, among other topics. Overall, these aimed to improve the community's knowledge, attitudes and perceptions towards the prevention of heat stress. The authors emphasized the importance of building local capacity and collaboration with local leaders (e.g., religious) to influence community members and encourage safety and precaution related to heat.

Benmarhnia et al. (2016) conducted a quasi-experiment in Montreal. This study used registry data for the summers of 2000–2007 to assess the impact of Montreal’s heat action plan, which involved a spectrum of interventions.<sup>25</sup> The heat action plan reduced mortality during hot days by 2.52 deaths per day (95% CI: –0.34, 5.38); reduced differences in mortality between the elderly (≥ 65 years) and non-elderly (0–64 years) during hot days by 2.44 deaths per day (95% CI: 0.27, 4.59); and reduced differences in mortality between individuals living in neighborhoods with low SES and those living in neighborhood with high SES during hot days by 2.48 deaths per day (95% CI: 0.69, 4.27).

de’Donato et al. (2018) conducted a pre-post study in Italy to assess the impact of implementing a heat plan on mortality.<sup>29</sup> The heat plan included public information campaigns, training of personnel, interventions for at-risk sub-groups, emergency protocols, and improving adaptive capacity (e.g., cooling centres). Estimated excess deaths spared over the entire study period (1999 to 2016) was 1,900.

Heo et al. (2019) conducted a quasi-experiment in Korea to assess a heat wave warning system.<sup>33</sup> The study period included the warm seasons of 2009 to 2014. There was no observed change in all-cause mortality during heat waves in the general population correlated with the heat alert plans. There was, however, reduction in risk among select sub-groups of the population: adults (19 to 64 years) without education (–0.144 deaths/1,000,000 people, 95% CI: –0.227, –0.061) and children aged 19 years and younger (–0.555 deaths/1,000,000 people, 95% CI: –0.993, –0.117). For cardiovascular and respiratory mortality, there were also significant decreases in for several subgroups including: people age 75 years and older who were unemployed or widowed, people aged 65 and older who were single or widowed, people aged 19 to 64 years with no education (i.e., without elementary school education), people age 65 years and older who had university or higher education and children under age 19 years old. A sensitivity analysis applied to children 0 to 19 years found the significant effect of heat warning impact on mortality applied mainly to children under 5 years.

Nitschke et al. (2016) conducted a pre-post study in Adelaide, South Australia.<sup>37</sup> This study compared two heat events, the first in 2009, which was followed by the implementation of a heat wave warning system, and the second heat event studied was in 2014. Outcomes included: ambulance calls, hospital admissions, emergency room presentations, and mortality. There were 9% fewer total ambulance calls and 59% fewer cardiac related ambulance calls in 2014 compared to 2009. There was a significant reduction of heat related emergency department presentations by 56%. There was not a significant difference in mortality between the 2009 heat event (35 cases) and 2014 (39 cases).

## **INTERVENTIONS DESCRIBED, NOT EVALUATED – GENERAL PUBLIC**

### **HEAT ALERT PLANS**

Three studies described descriptive or qualitative evaluations of heat alert plans, but did not examine effectiveness in relation to population health outcomes following implementation of the plans. These provide largely qualitative results related to facilitators, barriers and suggestions to improve regional heat alert plans.

Price et al. (2018) conducted a qualitative evaluation of a heat action plan in Montreal.<sup>57</sup> For two key evaluation components (implementation, practice and awareness), there were associated qualitative comments related to facilitators and challenges, or descriptive reflections and considerations:



- Heat action plan implementation. **Facilitating factors:** pertinent and clear communication during a heat wave; increased efficiency in process of identifying vulnerable homecare patients partly due to updates to a list prior to hot season; updates to volunteer lists earlier in year who could then be mobilized during heat wave; improved workload distribution and collaboration among personnel. **Challenges:** updating homecare client lists is time consuming; variable application of criteria to prioritize homecare patients across institutions; non-health professionals reported difficulty identifying early signs of heat-related illness, particularly among elderly and people with mental illness; ensuring availability of sufficient staff especially as heat waves can strike with little notice.
- Practice and awareness. **Healthcare professionals:** all preventive measures recommended in the heat response plan were mentioned during focus groups, and healthcare workers reported taking actions when recommended in the plan. All of the individual vulnerability factors mentioned in the heat plan were also mentioned in the various data sources. Awareness and adaptive measures among **vulnerable people:** Majority of participants in this focus group reported drinking more water and going to air-conditioned places as the main preventive measures. Among people who use alcohol or drugs who were sometimes homeless, extreme heat was not perceived as being an important threat to their health, compared to other daily issues they were facing. People with schizophrenia or drug/alcohol dependency reported finding heat-related info via TV, radio, pamphlets and posters from public health, newspapers, community centres, hospitals and other healthcare centres, family and friends.

Schuch et al. (2014) described desired features of heat wave management plans based on a literature review, and suggested merits and challenges to these features based on workshop and interview findings.<sup>58</sup> The study setting was South East Queensland Australia. The heat wave management plan was aimed at the general population, but included specific emphasis on prioritizing vulnerable groups (e.g., older adults, people with chronic conditions or disabilities, people in heat-exposed living conditions, people who are socially isolated, people in culturally or linguistically diverse communities, and people engaged in strenuous activities). Desired features and associated merits and challenges included:

1. Set strategies to deal with health risks from heat waves and urban heat island effect: allows prioritization of vulnerable groups, but there are limits in understanding the concept of vulnerability and there is great variability across groups considered at risk. Additional challenges are lack of services and institutional capacity.
2. Link to other sectors (e.g. urban planning and management), professionals (e.g. scientists, health and emergency managers), place-based community resources, and community-based agencies (e.g. Meals on Wheels, Red Cross): can allow co-benefits across sectors and promote collaboration and delegation of roles responsibilities. Challenges include competing priorities and ambivalence from the public and agencies, lack of services for disadvantaged areas, and lack of capacity and resources among community-based organizations.
3. Understand multiple factors influencing vulnerability: locally-based efforts can facilitate more meaningful understanding. Challenges included the great variability across factors that impact vulnerability and poor understanding of community-based factors.
4. Engage public in plan development and plan implementation: may improve risk perception, enable tailored approaches and measures and identify barriers. Challenges include varying perceptions across policy makers, and cultural and demographic groups.

5. Assess effectiveness of plans (measurement parameters: morbidity and mortality rates; reaching out to vulnerable groups): locally-based actions can contribute to increased effectiveness. Challenges came from difficulty in attributing morbidity or mortality to heat wave management plan among confounders and due to paucity of data.
6. Establish public health response and preparedness (guides for roles and responsibilities of agencies and stakeholders): may improve public and health service awareness and preparedness, and include strategies to support vulnerable groups. Challenges are competing priorities, ambivalence towards defining roles and responsibilities, reliance on volunteers and social networks with limited capacity and resources, and effectiveness of intervention being tempered by lack of improvement to underlying social and economic factors leading to vulnerability
7. Communication and public awareness strategies (e.g., written guidelines, media, or information hot line): can allow better dissemination of alerts and risk communication and target vulnerable groups. Challenges include limited information about vulnerable groups, people considered vulnerable may not consider themselves vulnerable, in reality messaging is often directed at broad population and not tailored

Austhof et al. (2021) qualitatively evaluated Arizona health departments' responses to heat events in the same time period as the COVID-19 pandemic.<sup>53</sup> This evaluation provided barriers and challenges, as well as suggestions for improvement. COVID-19 response efforts hindered departments' ability to work on heat-related projects, but partnerships and flexibility in response and adaptation helped mitigate some of the challenges. Cross-training programs, fostering flexibility and adaptability in the workforce, and building and sustaining external partnerships can support health departments anticipating the need to respond to simultaneous public health hazards in the future.

## Discussion

Studies included in this review described interventions intended to mitigate health effects from heat in different at-risk populations including older adults, infants and children, outdoor workers, multiple vulnerable populations, and general public. Across these subgroups, key interventions that were most thoroughly evaluated include cooling strategies (i.e., cooling garments for outdoor workers, cooling centres for the public, or cooling apparatuses for personal use) followed by heat education and awareness interventions. Conversely, the use of air conditioning among older adults, inter-sectoral collaboration, specific provider considerations, awareness campaigns on the prevention of children being left in cars, industry- or organization-level regulations and policies for outdoor workers, shifting work to cooler hours, and the development of vulnerability indices were described but not evaluated in any population.

Six of the eight studies that examined the effectiveness of cooling strategies (i.e., cooling devices, cooling garments for outdoor workers, and cooling centres for the public) found this intervention type to be effective in reducing the air temperature in the immediate vicinity of the device, reducing heat-related stress among outdoor workers, and reducing heat-related illness and mortality among multiple vulnerable populations. Two of the eight studies were field studies conducted among agricultural workers in Florida and found mixed results.

All five studies that examined the effectiveness of heat education and awareness programs found these interventions to be effective in improving protective behaviours and self-reported heat-stress among older adults and improving heat illness knowledge and decreasing negative heat-related health outcomes among outdoor workers. Five studies found that multi-component regional health alert systems are effective in reducing adverse health outcomes at population levels (e.g., mortality, morbidity, emergency department visits, and hospital admissions). Lastly, there were mixed results from three studies examining the effectiveness of work-to-rest schedules and one study examining the effectiveness of hydration interventions among outdoor workers.

Of the studies that examined effectiveness of the interventions, outcomes included health outcomes (mortality, morbidity), health knowledge, and protective behaviours. However, it is important to recognize other important outcomes that may be impacted by these interventions. For example, Parsons et al (2020) noted that changing working hours to the cooler part of the day would reduce labour losses.<sup>47</sup> However, employers will need to consider other factors such as child care, changes in workers' sleep schedules, potential increased risk of occupational injury due to fatigue or low lighting, and limitations due to policies such as local noise ordinance. Feasibility and cost of the interventions are factors that were out of scope of this rapid review, but would need to be considered for real-world applications.

The objective of this review was to identify interventions at the public health, regional, community, or provider-level that may be used to prevent, mitigate or respond to health impacts of heat events, specifically for populations most vulnerable to heat harms. Many jurisdictions (e.g., BC, Alberta and England) have identified groups that are most vulnerable to heat harms. These include people who are unhoused or underhoused, people in poverty, people with mental illness, people who use substances, people who are socially isolated or people with limited mobility.<sup>62-65</sup> This review found that outdoor workers and older adults were most represented in the literature. The previously mentioned groups were less represented in the literature. This gap between who jurisdictions consider vulnerable to heat events and which populations have been most heavily researched highlights the importance of better defining vulnerable populations to heat events and for further research to be conducted on additional groups that may be at elevated risk of heat-related harms.

## Strengths

This rapid review has many strengths. First, a library search using a reviewed four-term search concept was performed. Second, two authors screened all full text articles. Quality appraisal using reputable tools was completed. Lastly, feedback on the final content was received from subject matter experts and incorporated into the final product.

## Limitations

This rapid review is not without limitations, the majority of which stem from time constraints. Only one database was searched (Medline), therefore other relevant records may have been missed. Single authors screening occurred for 80% of the title and abstract level of screening, however we aimed to mitigate bias by first piloting 50 random search results with duplicate independent screening in order to refine and clarify eligibility criteria, and completed duplicate screening for 20% of titles before moving on to single author screening. Data extraction and quality appraisal were performed by single authors.

## Future Priorities

This review was intentionally scoped to focus on immediate or short-term measures due to the timing of release during the summer. However, there is considerable overlap across short-, intermediate- and long-term measures within a large spectrum of varied heat-related interventions, and opinions may vary on what is considered short-term. It is crucial to clarify that beyond immediate measures to mitigate major adverse health outcomes in an emergency context, there is a significant and likely greater need for long-term, upstream, broad system and infrastructure work to enhance preparedness and prevention of heat-related harms at the community-, regional- and provincial-levels. Future work should focus on more upstream measures, infrastructure or policies to prevent and mitigate heat-related harms in the context of ongoing climate change.

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## Appendix A: Inclusion and Exclusion Criteria

**Table 1. Inclusion and Exclusion Criteria**

Category	Inclusion Criteria	Exclusion Criteria
Population	<p>Groups vulnerable to heat health impacts. Key groups listed below, but not necessarily limited to:</p> <ul style="list-style-type: none"> <li>• seniors aged 65 years or older</li> <li>• people who live alone</li> <li>• people with pre-existing health conditions such as diabetes, heart disease or respiratory disease</li> <li>• People on certain medications that increase risk of heat harm</li> <li>• people with mental illness such as schizophrenia, depression, or anxiety</li> <li>• people with substance use disorders</li> <li>• people with limited mobility</li> <li>• people who are marginally housed</li> <li>• outdoor workers (e.g., agricultural workers)</li> <li>• people who are pregnant</li> <li>• infants and young children</li> <li>• People with low income/experiencing poverty</li> <li>• People living in difficult to cool spaces (e.g., high density living spaces, long-term care, top floor apartments)</li> </ul>	<p>Not focused, or not applicable to, heat-vulnerable or populations at risk of heat-related harms.</p> <p>People who work in hot environments, where heat is inherent to the role regardless of climate/weather conditions (e.g., firefighter, jobs with specialized equipment designed to manage heat exposure).</p> <p>People who exercise in hot weather who are otherwise not at greater risk of health harms from heat ('general population')</p>
Intervention	<p>Interventions, approaches, initiatives, supports, tools, activities, etc., that are directed at preparing for, preventing, mitigating or responding to heat harms among populations most vulnerable to these harms.</p> <p>Intervention is applicable/feasible to the Ontario real world context.</p> <p>Intervention timeline in relation to heat event: short term, immediate prevention or response activities, tools, or interventions that are implementable in the event of heat event this summer.</p> <p>Preparedness/mitigation/intervention facilitated/implemented by: public health agency, community-based organizations, municipal services, volunteer groups, service providers, employers, etc.</p>	<p>Interventions that are not focused on, or applicable to, identifying, reaching, supporting or protecting vulnerable groups from heat related harms. For example, directed only high level at general public without any considerations or mention of populations most vulnerable to heat harms.</p> <p>Interventions related to heat, when heat/working with fire is inherent to the job outside of climate/weather conditions (e.g., for firefighters, jobs with specialized equipment designed to manage heat exposure)</p>

Category	Inclusion Criteria	Exclusion Criteria
	Any ways to ensure vulnerable populations are identified and supported during extreme heat events. E.g., cooling centres, home and community care services identify and prioritize clients that fall in vulnerable group(s) for home visits and contact during an extreme heat emergency, messaging on self-care and caring for vulnerable persons during a heat event, use of culturally appropriate and multiple languages, engage and consult with vulnerable populations and associated community groups regarding preparing for and responding to heat events; checklists for community support groups or professionals conducting door-to-door or wellness checks.	Intervention timeline: long-term, i.e., not implementable in the event of a heat event this summer. Preparedness/mitigation/intervention facilitated/implemented by: individual vulnerable/at risk people (no involvement or support from public health, community, health provider, employer, etc.) No intervention described (e.g., described/measured harm from heat, but no interventions or mitigation measures).
Outcome	Mortality: heat-related or all-cause Morbidity: heat-related illness. Exacerbation of pre-existing health conditions due to heat. Health system resource use/capacity.	Non-health outcomes. Non-human outcomes (e.g., animals, pets, vegetation, agriculture/food supply).
Setting	Public health outreach, community-based groups. Hospital or clinic settings only if addressing support beyond direct treatment (e.g., may be relevant supports from social workers or patient navigator-type roles that extend beyond medical treatment).	Hospital or clinic setting focus only on direct treatment of heat-related illness (outside of public health role).
Event/issue	Heat event, extreme heat event, heat dome, heat wave, extreme temperature event (must be heat, not cold), simulated heat event (experimental).	Climate change in general, other non-heat climate change consequences: e.g., flooding, storms, fires.
Date limit	2011 to present	Published prior to 2011
Jurisdiction	OECD	Non-OECD
Study design	English language. Published review and primary indexed literature, any study design.	Abstract-only, full-text not available in English, animal studies, commentaries and perspectives, studies with no reported methods.

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