Chapter 6. Care for vulnerable population groups: updated evidence on risk factors and vulnerability

Summary

In the last decade, the quantity of literature on factors affecting vulnerability to heat has greatly increased. It is well established that elderly people are most at risk to extreme heat; other vulnerable groups at greater risk include people with chronic conditions (such as cardiorespiratory diseases, endocrine system disorders, mental health disorders, metabolic disorders and kidney disorders), pregnant women, small children, workers, people living in urban settings in socially and economically deprived environments, migrants and travellers.

HHAPs should identify subgroups at risk, provide tailored advice, implement specific prevention measures and actively monitor those most at risk during heat-waves. To date, most national HHAPs mention vulnerable groups but do not contain actions addressed to them. More effort should be put into raising awareness and promoting active response measures and training of health and social care professionals. Monitoring and evaluation of these measures is also important to assess their effectiveness.

Key messages

- Evidence on who is most at risk during heat-waves has become more consistent.
- Vulnerable subgroups and their needs change over time and need ongoing monitoring and study.
- Public health prevention and response measures tailored to vulnerable groups need to be promoted – especially active response measures and proactive outreach for vulnerable individuals and their care givers by health and social services when warnings are issued during extreme events.
- Advice for vulnerable individuals should be improved, and health and social care training enhanced to improve awareness of risks and response.
- Actions targeted at vulnerable subgroups should be monitored and evaluated.

6.1 Introduction

The main objective of an HHAP in all its operational components is to reduce the health impacts of extreme heat. It is therefore of particular importance to focus on those population subgroups that are most vulnerable to heat as a result of pre-existing health, sociodemographic and environmental conditions. The WHO Regional Office for Europe's guidance on heat–health action planning acknowledged the importance of identifying and localizing vulnerable population subgroups (Matthies et al., 2008), defining this as a core element of HHAPs. Specific information and advice should be issued to these groups to improve awareness of the health risks and help protect them during heat-waves. Health and social services should focus efforts and resources on them, with specific response measures aimed at reducing health impacts.

Initially, the focus was mainly on elderly people, as the literature showing a greater risk of dying during heat-waves among this group was more robust, followed by subjects with chronic conditions (Kovats & Hajat, 2008; Basu, 2009). WHO's 2011 public health advice revised and updated individual (demographic, socioeconomic and health conditions) and environmental risk factors to identify better those most at risk and improve response measures addressed to them (WHO Regional Office for Europe, 2011). In the last decade the scientific literature addressing heat vulnerability factors and estimating the health risks among specific population subgroups has increased exponentially, confirming previous findings and shedding light on new subgroups at risk and potential response measures to protect them (Linares et al., 2020).

Both WHO publications stressed the need for an enhanced and more proactive approach in terms of both awareness-raising and response measures with reference to vulnerable groups. Active surveillance by health and social care services is still lacking and should be promoted at all levels. The 2008 WHO guidance provided examples of vulnerable group selection and identification through registry data and notifications by GPs and health services and gave general recommendations for GPs and retirement and care home medical staff (Matthies et al., 2008). The updated advice set out more exhaustive information on the health risks associated with heat for the different vulnerable groups (WHO Regional Office for Europe, 2011). Examples of specific health measures and practices or actions were not provided, however. To date, formal assessments of actions carried out, along with the coverage and an evaluation of these measures, are limited. This process would be useful not only to provide evidence of what is being done but also to identify best practices and ensure that resources are allocated in an efficient manner.

6.2 Heat vulnerability, vulnerable groups and risk factors

Specific vulnerability factors are able to confer a greater risk of dying due to exposure to extreme heat. These may be related to individual (age, gender, health status) or context characteristics, such as social and economic conditions and the environment (including climate, living environment of urban versus rural setting, level of air pollution, green areas, presence of AC and building structure). Vulnerability to heat varies geographically, based on these characteristics, but some common factors confer a greater vulnerability on individuals (Table 8).

Table 8. Summary of evidence on vulnerable subgroups

Subgroup	Relevant studies and factors
Elderly people	• Biological mechanisms: Kenny et al. (2010); Stapleton et al. (2014); Flouris et al. (2017) • Epidemiological studies/reviews: Kovats & Hajat (2008); Basu (2009); Bunker et al. (2016); Mayrhuber et al. (2018) • Parkinson's disease and dementia: Linares et al. (2016); Wei et al. (2019)

People with cardiovascular disease	• Biological mechanisms: Liu, Yavar & Sun (2015)
	• Epidemiological studies/reviews of:
	  • effects of heat on cardiovascular health: Bhaskaran, Hajat & Smeeth (2011); Gasparrini et al. (2012); Yu et al. (2012); Sun et al. (2016); Cheng et al. (2019)
	  • ischaemic stroke and heat metanalysis: Lian et al. (2015); Wang et al. (2016)
	  • acute myocardial infarction and heat: Bhaskaran et al. (2009); Bhaskaran, Hajat & Smeeth (2011); Goggins, Woo et al. (2012); Breitner et al. (2014); Kwon et al. (2015)

People with respiratory disease	• Biological mechanisms: Kenny et al. (2010); McCormack et al. (2016)
	• Epidemiological studies/reviews of:
	  • respiratory mortality: Benmarhnia et al. (2015); Cheng et al. (2019)
	  • respiratory morbidity: Turner et al. (2012); Anderson et al. (2013); Zhao et al. (2019)
	  • Chronic obstructive pulmonary disease (COPD) and asthma: McCormack et al. (2016); Zhao et al. (2019)

People with mental health disorders	• Biological mechanisms: Stöllberger, Lutz & Finsterer (2009); Thompson et al. (2018) • Epidemiological studies/reviews: Hansen et al. (2008); Page et al. (2012); Thompson et al. (2018) • Increases in ER visits: Wang et al. (2014); Thompson et al. (2018); Basu et al. (2018); Min et al. (2019) • Medication during heat: Martin-Latry et al. (2007); Stöllberger, Lutz & Finsterer (2009); Min et al. (2019)
People with diabetes	• Biological mechanisms: Yardley et al. (2013); McGinn et al. (2015); Carrillo et al. (2016); Kenny, Sigal & McGinn (2016); Notley et al. (2019) • Epidemiological studies/reviews: Yardley et al. (2013); Zanobetti et al. (2014)
Children	• Epidemiological studies/reviews: Sheffield & Landrigan (2011); Williams et al. (2012); Xu, Etzel et al. (2012); Xu, Sheffield et al. (2012); Xu et al. (2014); Iñiguez et al. (2016); Lam et al. (2016); Stanberry, Thomson & James (2018) • Asthma: Z Xu et al. (2013); Li et al. (2014); Xu et al. (2014) • Bacteria-related gastroenteritis: Xu, Sheffield et al. (2012); Xu et al. (2014); Carlton et al. (2016); Iñiguez et al. (2016)
Pregnant women	• Biological mechanisms: Strand, Barnett & Tong (2011); Carolan-Olah & Frankowska (2014); Zhang, Yu & Wang (2017) • Epidemiological studies/reviews: Dadvand et al. (2011); Kloog et al. (2012); Strand, Barnett & Tong (2012); Schifano, Cappai et al., (2013); Vicedo-Cabrera et al. (2014); Vicedo-Cabrera, Olsson & Forsberg (2015); Schifano et al. (2016); Cox et al. (2016); Basu et al. (2017); Ha et al. (2017); He et al. (2017); Khan et al. (2017); Zhang, Yu & Wang (2017); Guo et al. (2018); Asta et al. (2019); Son et al. (2019); Song et al. (2019); Sun et al. (2019); Gronlund et al. (2020); Ilango et al. (2020)
Workers	• Biological mechanisms: Jay & Brotherhood (2016); Meade et al. (2016); Ioannou et al. (2017); Quiller et al. (2017); Kenny (2019); Notley, Flouris & Kenny (2019) • Epidemiological studies/reviews: Ioannou et al. (2017); Quiller et al. (2017); Flouris et al. (2018); Marinaccio et al. (2019); Messeri et al. (2019); Schifano et al. (2019)

Further, the COVID-19 pandemic may augment the health risks from heat among these vulnerable groups (Box 7), as several of the risk factors for severe COVID-19 overlap with key heat risk factors (Wang et al., 2020; CDC, 2020; Singh et al., 2020; Bukhari & Jameel, 2020).

Box 7. Heat and COVID-19: vulnerable groups

People vulnerable to both COVID-19 and heat include:

- elderly people – especially those who are very old and those with multiple chronic conditions (Armitage et al., 2020; Bunker et al., 2016; Shahid et al., 2020; Wang et al., 2020) or living in nursing homes or residential care facilities without cooling or adequate ventilation (Klenk, Becker & Rapp, 2010; Nanda, Vura & Gravenstein, 2020);
- people with underlying medical conditions, including:
  - cardiovascular disease (heart failure, coronary artery disease or cardiomyopathies);
  - cerebrovascular disease;
  - hypertension;
  - chronic pulmonary disease such as COPD;
  - kidney disease;
  - diabetes;
  - obesity;
  - neurologic conditions such as Alzheimer's disease and dementia;
  - mental health issues (psychiatric disorders, depression) (Benmarhnia et al., 2015; Cheng et al., 2019; Lippi & Henry, 2020; Mantovani et al., 2020; Pranata et al., 2020; Shang et al., 2020; Singh et al., 2020; J Yang et al., 2020);
- people on medication, as some medication for the diseases listed above impairs thermoregulation and perception to risks related to heat exposure (Daanen et al., 2020);
- pregnant women (Zhang, Yu & Wang, 2017; Juan et al., 2020; Z Yang et al., 2020);
- essential (indoor/outdoor) workers exposed to heat (Flouris et al., 2018; Spector et al., 2019; Morabito et al., 2020);
- health workers and staff wearing personal protective equipment (PPE) that may increase thermal stress (Ehrlich, McKenney & Elkbuli, 2020; Morabito et al., 2020; Sud, 2020);
- people who are socially isolated (homeless people, migrants, old people living alone) and those with low income or inadequate housing, who have limited resources and access to care (Armitage et al., 2020; GHHIN, 2020; Martinez et al., 2020);
- people who have – or are recovering from – COVID-19, who may be more vulnerable to heat-related illness.

Heat-related health effects are largely preventable through good public health practice, while following relevant advice. Operational responses and implications for HHAPs related to COVID-19 are reported in Box 11 in Chapter 7. Moreover, it is particularly important that vulnerable subgroups continue to receive the necessary health and social care during the pandemic, and that awareness of risks and responses is enhanced (GHHIN, 2020; Martinez et al., 2020; Wood, 2020).

The WHO Regional Office for Europe has issued health advice for hot weather during the COVID-19 outbreak as described in Box 5 in Chapter 4, as well as guidance for health care of elderly people and management of long-term care facilities during the COVID-19 pandemic (WHO Regional Office for Europe, 2020a; 2020b; 2020c). Some countries have also updated HHAPs to account for the COVID-19 pandemic and to raise awareness of risks among vulnerable subgroups (HCSP, 2020; INSPQ, 2020; KLUG, 2020; PHE, 2020; RIVM, 2020).

6.2.1 Elderly people

Ageing affects thermoregulatory capacity and can reduce thermal perception, leading to compromised behavioural responses of elderly citizens to heat stress, and increasing the onset of heat-related illnesses and deaths (Kenny et al., 2010; Stapleton et al., 2014; 2015; Benmarhnia et al., 2015). A systematic review and meta-analysis including 61 studies on vulnerability to heat found the strongest evidence for old age, with an increasing trend in risk as age progresses from 65 years onwards (Benmarhnia et al., 2015). Controlled laboratory studies suggest that the detrimental impact of age on people's capacity to thermoregulate in a hot environment can be detected as early as 40 years, and that these differences become evident in most people by their mid-50s (Flouris et al., 2017).

Elderly people are at particular risk due to dysfunctional thermoregulatory mechanisms (limited sweating and skin blood flow), chronic dehydration, multiple chronic diseases (especially cardiopulmonary disease, diabetes and dementia), use of medications, disability and non-self-sufficiency and possible social isolation (Kovats & Hajat, 2008; Basu, 2009; Hajat, O'Connor & Kosatsky, 2010; Bunker et al., 2016; Mayrhuber et al., 2018). Neurodegenerative diseases like dementia and Parkinson's disease, which are associated with old age, have also been identified as risk factors, with evidence of an increase in hospitalization during heat-waves among patients with these conditions (Linares et al., 2016; Wei et al., 2019). Eurostat (2019) estimates that by 2050 an average 40% of the European population will be aged over 55 years (ranging between 47% in Italy and Portugal and 35% in Sweden). Ageing of the European population and rises in noncommunicable disease prevalence suggest that the number of subjects at risk in this group will continue to increase in the coming years.

6.2.2 Children

In summer and during heat-waves infants and children are particularly vulnerable to dehydration and heat stress, due to their greater body surface-to-volume ratio. Furthermore, children have less effective heat adaptation capacity than do adults (Committee on Sports Medicine Fitness, 2000).

Heat has also been associated with an increase in ER visits or hospital admissions for paediatric diseases, respiratory diseases, gastroenteritis, renal diseases and diseases of the central nervous system among children (Sheffield & Landrigan, 2011; Williams et al., 2012; Xu, Etzel et al., 2012; Xu, Sheffield et al., 2012; Xu et al., 2014; Iñiguez et al., 2016; Lam et al., 2016; Stanberry, Thomson & James, 2018). Asthma symptoms – especially wheezing and chest tightness – have been shown to worsen with increasing temperatures (Z Xu et al., 2013; Li et al., 2014; Xu et al., 2014). Bacteria-related gastrointestinal diseases among children are also more likely to increase with high temperatures (Xu, Sheffield et al., 2012; Xu et al., 2014; Iñiguez et al., 2016).

6.2.3 Pregnant women

Heat has been identified as a risk factor for adverse birth outcomes such as low birth weight and preterm birth (Strand, Barnett & Tong, 2011; Carolan-Olah & Frankowska, 2014; Zhang, Yu & Wang, 2017). During pregnancy, women may be more susceptible to heat stress due to body weight gain, which increases heat production and reduces capacity to lose heat by sweating. The fetus also adds its body composition and metabolic rate, which further alters the mother's heat stress. Difficulty in thermoregulation and dehydration among pregnant women may cause a decrease in uterine blood flow, which may trigger labour. Furthermore, heat stress may trigger a release of hormones such as cortisol or increase secretion of oxytocin and prostaglandin, which may in turn induce labour and increased uterine contractions (Strand, Barnett & Tong, 2011; Carolan-Olah &

Frankowska, 2014). To date, however, the causes or biological mechanisms associated with preterm births and low birth weight in response to heat are still unclear.

Several studies have shown a significant positive short-term association between exposure to heat and preterm delivery in Europe (Dadvand et al., 2011; Schifano, Cappai et al., 2013; Vicedo-Cabrera et al., 2014; Vicedo-Cabrera, Olsson & Forsberg, 2015; Cox et al., 2016; Schifano et al., 2016; Asta et al., 2019) and in Australia, China, the Republic of Korea and the United States (Kloog et al., 2012; Strand, Barnett & Tong, 2012; He et al., 2017; Guo et al., 2018; Son et al., 2019; Song et al., 2019; Sun et al., 2019; Ilango et al., 2020). A study conducted in the over 400 counties of the United States showed that the fraction of preterm births attributable to extreme heat was 154 (empirical 95% CI: 127, 173) preterm births per million (Sun et al., 2019). Studies conducted specifically on extreme events rather than temperatures increases also found a greater risk of preterm births during heat-wave episodes than non-heat-wave days (Schifano, Lallo et al., 2013; Ilango et al., 2020). Ilango et al. (2020) found that exposure to heat-waves of longer duration had greater effects in California compared to short-lived events; similar findings were observed in Italy when consecutive days of heat were considered (Schifano, Lallo et al., 2013). This aspect is important to bear in mind in HHAP preparedness, warning system advice and action modulation targeted to this specific vulnerable subgroup.

Effect estimates in the various studies diverge due to differences in study design, definition of critical windows of exposure and gestational age assessment, local climate and population adaptation, population characteristics, access to health care and pregnancy health care assistance (Ha et al., 2017; Zhang, Yu & Wang, 2017; Gronlund et al., 2020). Confounders and possible effect modifiers such as air pollution, humidity, maternal age, marital status, ethnicity, socioeconomic status, smoking or drinking status, previous pregnancies, antenatal visits and gestational complications and pre-existing health conditions (such as body mass index, hypertension and diabetes) should also be considered when studying determinants of birth outcomes (Strand, Barnett & Tong, 2011; Basu et al., 2017; Khan et al., 2017; Son et al., 2019; Sun et al., 2019). In a study conducted in the United States, extreme heat was strongly associated with preterm birth in regions with colder and drier climates, and among younger women (Sun et al., 2019). Pre-existing health conditions also influenced the risk of preterm delivery: Basu et al. (2017) found that women with pre-existing or gestational hypertension or diabetes were at greater risk. Similarly, Schifano et al. found that women with chronic disease (especially cardiac conditions) and young mothers (less than 20 years of age) were at higher risk of preterm delivery (Schifano, Cappai et al., 2013; Schifano et al., 2016).

Socioeconomic differences may further contribute to the differential risk of preterm birth when exposed to heat (Dadvand et al., 2011; Strand, Barnett & Tong, 2011; Basu et al., 2017; Zhang, Yu & Wang, 2017; Asta et al., 2019). Son et al. (2019) found a higher risk of preterm delivery among women residing in areas of low socioeconomic status and with low education levels. In urban areas, proximity to green space has been linked to beneficial health effects such as reduced stress, increased social contact and cohesion, increased physical activity and reduced temperature extremes – especially heat and lower air pollution levels (WHO Regional Office for Europe, 2016). Moreover, several studies have looked at the association between green space and preterm births, but results are contrasting: most studies have not found an association with preterm births (Asta et al., 2019; Kloog, 2019), while a beneficial effect on fetus growth has also been shown (Dadvand et al., 2012). These factors are important for heat prevention in order to identify those most at risk that need to be monitored actively with particular attention during heat-waves, as well as to provide accurate advice to improve awareness and preparedness.

6.2.4 Workers

In the occupational setting, workers can be exposed to heat for prolonged periods of the day – particularly those whose roles involve manual tasks (physical work) with elevated endogenous (metabolic) heat production. Workers thus experience negative effects of environmental heat stress at lower temperature levels than those eliciting public alerts. Furthermore, protective clothing and PPE required for work safety may hamper natural heat loss. For outdoor workplaces exposure to solar radiation may add to the environmental heat, while for indoor workplaces cooling of large production bays is often not possible, and industrial heat generated by machinery can increase indoor heating. At present, evidence-based recommendations for indoor workplaces or residential buildings are sparse (Kenny et al., 2019). If appropriate preventive action is not taken, however, workplace temperature can increase to dangerous levels. It is therefore advisable that indoor work areas include some form of climate control (AC, electric fans or the opportunity of cooling during breaks if solutions are not applicable at the workstation or are constrained by PPE).

Occupational heat strain (the physiological consequences of occupational (environmental) heat stress) undermines the health and productivity of workers in major industries including agriculture, construction, manufacturing, tourism and transportation (Ioannou et al., 2017; Quiller et al., 2017; Marinaccio et al., 2019; Messeri et al., 2019; Schifano et al., 2019). A recent systematic review and meta-analysis of 111 studies, including more than 447 million workers from over 40 different occupations, estimated that 35% of individuals who frequently work in heat stress conditions experience negative effects of occupational heat strain (Flouris et al., 2018). Workers who are particularly vulnerable to the impacts of heat are those who work under heat stress conditions for prolonged periods, those exposed to high heat in a hypo-hydrated state, those who are older and those with underlying pathophysiological conditions. Field and lab studies have investigated human responses to elevated thermal stress during work using various physiological measures, and it is quite clear that occupational heat stress and strain can negatively affect workers' health, impair their performance capacity and compromise work safety (Jay & Brotherhood, 2016; Meade et al., 2016; Ioannou et al., 2017; Quiller et al., 2017; Notley, Flouris & Kenny, 2019). Kenny et al. (2019) suggest that occupational heat strain has important impacts on health and should be promoted accordingly in the light of climate change and the resulting rise in heat stress in coming years.

6.2.5 People with pre-existing conditions

Subjects with **cardiovascular diseases** are at greater risk during extreme heat (Bhaskaran, Hajat & Smeeth, 2011; Gasparrini et al., 2012; Turner et al., 2012; Yu et al., 2012; Sun et al., 2016; Cheng et al., 2019) due to their limited cardiovascular adjustment, which is needed during exposure to heat stress. The mechanisms underlying initiation of cardiovascular disease in response to temperature challenges involve multiple physiopathology regulations (Liu, Yavar & Sun, 2015). Under controlled conditions, heat exposure has been shown to lead to increases in red blood cell counts, platelet counts and blood viscosity, as well as increases in heart rate (Bhaskaran et al., 2009). Temperature-induced damage is thought to be related to heat-mediated dehydration and heatstroke-induced systemic inflammatory response (Liu, Yavar & Sun, 2015).

Heat has also been identified as risk factor for ischaemic stroke, with differences by age and gender in a recent meta-analysis (Lian et al., 2015; Wang et al., 2016). Several studies have shown the effect of heat on acute myocardial infarction hospital admissions and mortality (Bhaskaran et al., 2009; Bhaskaran, Hajat & Smeeth, 2011; Goggins, Woo et al., 2012; Breitner et al., 2014). Kwon et al. (2015) recently focused on the risk factors of this relationship, and found that females, those aged 75 years and over and those with low socioeconomic status were at greater risk. The authors suggested that the lifestyles of subjects with a low socioeconomic status seemed to be more vulnerable to weather, which could affect increased acute myocardial infarction hospital admissions. Furthermore, elderly patients with diabetes were also found to be at greater risk when temperatures increased (Lam et al., 2018).

Several studies have identified individuals with underlying **respiratory diseases**, including COPD, as being at increased risk from the adverse health effects of heat (Kenny et al., 2010; Turner et al., 2012; Anderson et al., 2013; Benmarhnia et al., 2015; Cheng et al., 2019; Zhao et al., 2019). The underlying mechanisms through which high temperatures may increase this risk are not entirely clear. Studies have found that heat is associated with airways and systemic inflammation, and vascular changes may trigger a respiratory distress syndrome through episodes of activation of the complement system (Michelozzi et al., 2009; Zhao et al., 2019). A recent systematic review found a significant effect of heat-waves on total respiratory mortality and COPD mortality but not on morbidity, with contrasting effects in different regions of the world and by morbidity indicator (Cheng et al., 2019). A study on a cohort of COPD patients found that increases in indoor and outdoor temperatures were associated with increases in daily indicators of COPD morbidity, including respiratory symptoms and rescue inhaler medication use (McCormack et al., 2016). Among COPD patients symptoms can worsen in response to the hyperventilation required to disperse heat and the bronchoconstrictive effects of heat (McCormack et al., 2016). Among subjects with asthma it has been suggested that breathing hot humid air may result in bronchoconstriction and increased airways resistance that is mediated via cholinergic pathways (McCormack et al., 2016; Zhao et al., 2019). Furthermore, asthma medication may interfere with the thermoregulatory response, thereby increasing heat stress conditions.

Mental health and behavioural disorders such as depression, bipolar disorder, schizophrenia, mental disability and developmental disorders have been associated with a risk of worsening of health conditions during heat-waves or exposure to heat (Hansen et al., 2008; Page et al., 2012; Wang et al., 2014; Basu et al., 2018; Thompson et al., 2018; Min et al., 2019; Mullins & White, 2019). Exposure to high temperatures can cause particular discomfort and heat stress among people with mental disorders – they may become agitated, more aggressive and violent, with an increase in the risk of suicide and conflicts (Wang et al., 2014; Basu et al., 2018; Thompson et al., 2018; Kim et al., 2019; Min et al., 2019). A recent review reported that 15 of 17 studies found a positive and significant association between heat and suicide frequency (Thompson et al., 2018). Several studies have shown an increase in hospital admissions and mortality among subjects with diagnosed mental health illnesses (Hansen et al., 2008; Thompson et al., 2018; Min et al., 2019).

The biological mechanisms include heat altering the metabolites of certain neurotransmitters, such as 5-hydroxytryptamine and dopamine, which are associated with the onset of depression and bipolar disorders (Stöllberger, Lutz & Finsterer, 2009; Thompson et al., 2018). Another important aspect is the use of medication in this group and the role of heat in altering the effect of the drugs; for example, psychotic drugs have side-effects associated with heat (Martin-Latry et al., 2007; Stöllberger, Lutz & Finsterer, 2009; Min et al., 2019). Medication used in psychiatry increases vulnerability to heat-related morbidity by altering the body's thermoregulatory capacity. Furthermore, among this subgroup cognitive awareness of environmental conditions – in this case heat-waves – and the ability to undertake adaptive behaviours such as increased fluid intake or wearing appropriate clothing, especially in those with disabling mental illnesses such as Alzheimer's disease, dementia, senility, psychosis and developmental disorders, may increase the risk of adverse health effects during heat-waves (Hansen et al., 2008; Basu et al., 2018).

Mental health issues are not solely related to elderly people but also apply to younger individuals, increasing the pool of susceptible individuals (Basu et al., 2018; Mullins & White, 2019). In particular, the low perception of risk among this group calls for a more active role from caregivers and health and social services. Prevention measures need to address each subgroup accordingly, in both management and care. Although an association between mental health disorders and heat has been shown, more information on the causes of this are needed. Further research should focus on potential effect modifiers and confounders such as medication history, comorbidities and various social indicators (income, living conditions, AC usage), as well as more precise exposure mapping to better characterize this vulnerable group (Hansen et al., 2008; Wang et al., 2014; Basu et al., 2018).

Exposure to heat has been shown to increase the risk of hospitalization and death among individuals with **diabetes** during heat-waves (Stafoggia et al., 2006; Zanobetti et al., 2014). Patients with type 1 and type 2 diabetes mellitus and the pharmacological treatments they require may cause dehydration, lower skin blood flow and reduced sweating, which could consequently impair thermoregulation during heat-waves (McGinn et al., 2015; Carrillo et al., 2016; Kenny, Sigal & McGinn, 2016; Notley et al., 2019). A recent review addressed how comorbidities such as obesity, hypertension, dyslipidaemia, cardiovascular disease, diabetic neuropathy and skin disorders, as well as medication, may contribute to the level of vulnerability among diabetic patients (Yardley et al., 2013). Ageing can further undermine the ability of diabetes patients to thermoregulate (Carrillo et al., 2016). Performing physical work in the heat is another important challenge for patients with diabetes, as physical activity is recommended for diabetes management. In this regard, the evidence to date shows that exercise heat stress may pose a health concern in diabetes patients (Carrillo et al., 2016; Notley et al., 2019). A recent study in middle-aged well controlled type 2 diabetes patients showed, however, that heat acclimation can offset diabetes-related thermoregulatory impairments and health complications during heat exposure (Notley et al., 2019). Further research examining skin blood flow responses concurrently with changes in core temperature and the role of thermoregulatory responses during physical activity among people with diabetes is warranted to improve the knowledge base and introduce adequate response measures during heat-waves (Yardley et al., 2013; Kenny, Sigal & McGinn, 2016).

6.2.6 People affected by food- and waterborne diseases caused by a hot environment

Several studies have shown an association between heat and food- and waterborne diseases from the proliferation of different bacteria in hot environments: the most common health effects are **gastroenteritis and diarrhoea** (Tam et al., 2006; Zhang, Bi & Hiller, 2010; Carlton et al., 2016). A recent systematic review of the association between temperature and diarrhoea in studies in low-, middle- and high-income countries found a significant positive pooled estimate between temperature for both all-cause and bacterial diarrhoea (Carlton et al., 2016). Future climate change – especially associated with an increase in temperatures and changes in frequency and intensity of extreme events – may alter the distribution, survival and virulence of pathogens and changes in host exposure patterns, thus increasing the impact on health and the consequent additional burden to the health system. Advice and prevention on these aspects is limited and needs to be enhanced.

6.2.7 Travellers, tourists and migrants

People coming from cool or temperate climates who are not in good physical condition and not acclimatized to the heat may be at greater risk during heat-waves. They may be unaware of health risks and behavioural changes necessary to cope with heat (Hansen et al., 2013; Messeri et al., 2019; Pradhan et al., 2019). Migrant workers, refugees and internally displaced people may have pre-existing and post-displacement vulnerabilities such as malnutrition and untreated chronic medical conditions from limited access to health care and lack of shelter providing adequate protection, predisposing them to a greater risk to heat (Levy & Patz, 2015).

6.2.8 People affected by socioeconomic factors

Having low socioeconomic status and/or low income, living alone and being socially isolated were found to be associated with increased adverse health effects during extreme heat (Basu, 2009; Zanobetti et al., 2013; Benmarhnia et al., 2015). A systematic review and meta-analysis reported greater risk among people with low socioeconomic status and poor living conditions and built environment (Benmarhnia et al., 2015). Debate is ongoing around the role of socioeconomic factors in contributing to heat vulnerability, and whether it is solely individual or neighbourhood socioeconomic conditions that have an impact. Individual conditions (education, income and so on) influence health, while attitudes and behaviours diffused between people at the community or neighbourhood level may also influence health education.

The differential vulnerability of populations living in urban areas is also a matter of concern, considering the continual urbanization and urban growth in the WHO European Region. In metropolitan areas the effects of heat on health may be exacerbated by greater socioeconomic disparities, inadequate housing conditions and concurrent exposure to air pollution (O'Neill, Zanobetti & Schwartz, 2003; Reid et al., 2009; Kwon et al., 2015; Taylor et al., 2016; Urban et al., 2016; Willers et al., 2016). A recent study found a strong effect modification by social deprivation; this was greatest among population groups that were simultaneously exposed to high levels of air pollution or other environmental exposures, thus representing so-called environmental injustice (Benmarhnia et al., 2014).

Furthermore, in urban environments, temperatures are higher and the daily thermal pattern is different (less variable) from the surrounding rural areas due to the urban structure and materials that retain heat and alter the microclimate. This phenomenon is known as the urban heat island (UHI) effect. Few studies have accounted for the differential effect of heat within urban areas, mostly due to the limited availability of high spatial resolution temperature data and geocoded health data or data stratified by small spatial units. As expected, warmer inner city central areas of low socioeconomic status have shown greater heat-related effects (Smargiassi et al., 2009; Huang, Zhou & Cadenasso, 2011; Goggins, Chan et al., 2012; Wong, Paddon & Jimenez, 2013; Y Xu et al., 2013). Considering future climate change and the UHI effect in the United Kingdom, two studies estimated that, by 2080, a heat-wave could be responsible for an increase in mortality of around three times the rate observed in 2003, with 278 deaths compared to 90 (Heaviside, Vardoulakis & Cai, 2016; Heaviside, Macintyre & Vardoulakis, 2017). This aspect is important for the promotion of measures to reduce greenhouse gas emissions and to mitigate the UHI effect within cities. Further details on the built environment can be found in Chapter 8.

6.3 Identification, surveillance and mapping of vulnerable subgroups

As noted in the 2008 WHO guidance (Matthies et al., 2008), an important preparatory measure of an HHAP is identification and localization of vulnerable subgroups. Once formally identified, specific actions and response measures need to be put in place to protect those most at risk. Raising awareness and providing advice is insufficient for these subgroups: they need to be monitored actively and response measures addressed to them should be enhanced during heat-wave days.

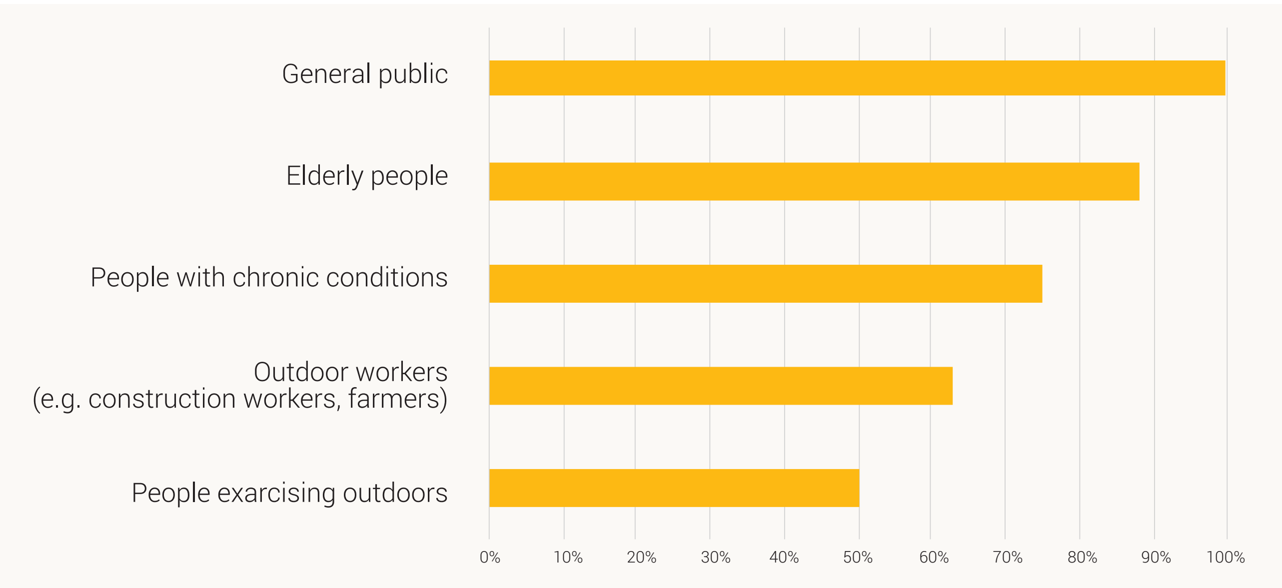
Active surveillance entails the identification of susceptible subgroups through health system registries, population registries and health and social service notifications. Most people suffering from chronic diseases receive specialist care, are partly monitored or traced by health services or are included in health registries.

Ad hoc surveillance systems to monitor the health status of vulnerable subgroups have been implemented throughout the summer to ensure a timely response during extreme events. Integrated syndromic surveillance systems were implemented by Public Health England in the United Kingdom (Elliot et al., 2014). GP active surveillance (home visits and questionnaire) and out-of-hours calls are used in France, Italy and the United Kingdom to monitor vulnerable groups and collect information on their health status during the summer (Michelozzi et al., 2010; Pascal et al., 2012; Elliot et al., 2014). The Italian HHAP, for example, formally requires the drawing up of lists of susceptible subgroups; these are sent to health authorities to implement active surveillance by GPs and social services (Michelozzi et al., 2010; Schifano, Lallo et al., 2013; Liotta, Inzerilli et al., 2018). A susceptibility score is defined at the local level based on individual risk factors associated with heat, using population and health registries (age, sex, health status, use of medication, access to health care services such as hospitalizations, ER visits, specialist care and so on) or through notifications from GPs and social services. Occupational health surveillance systems for sectors most at risk are also implemented to monitor prevalence of occupational heat strain and work injuries related to heat, to improve prevention and response (Casanueva et al., 2019; Morabito et al., 2019).

6.3.1 Current status of HHAP responses to vulnerable subgroups

Among the 16 countries that responded to WHO's 2019 survey of heat–health action planning and reported the existence of a national HHAP, 11 (69%) stated that their HHAP fully addresses vulnerable subgroups; the remaining five (11%) had only partial implementation of this component. The survey specifically enquired about how advice is issued to vulnerable subgroups and who is considered vulnerable in the HHAP. Specific vulnerable groups to whom advice is targeted include elderly people in 14 countries (88%), chronically ill people in 12 (75%), outdoor workers in 10 (63%) and people exercising outdoors in eight (50%) (Fig. 10).

Fig. 10. Vulnerable subgroups targeted in national HHAPs



Information is issued by all HHAPs to the general public, which is a way of raising awareness both in the general population and among vulnerable groups directly and indirectly through relatives, care givers and friends. Targeted advice is delivered to health care practitioners in 13 countries (81%), nursing homes in 12 (75%), health care administrators in 11 (69%), social workers in seven (44%) and schools in three (19%) (Fig. 11). Results from the survey show that although targeted information to the main vulnerable groups is defined, dissemination of risks and prevention measures is still very much limited to health care workers.

A multitude of means are used in HHAPs to communicate health advice during heat-waves to vulnerable subgroups, as described in Chapter 4. It is worth noting, however, that direct and proactive methods such as face-to-face interactions, direct messages or telephone calls are less used (less than 30%) than more indirect means such as websites and media (over 80%).

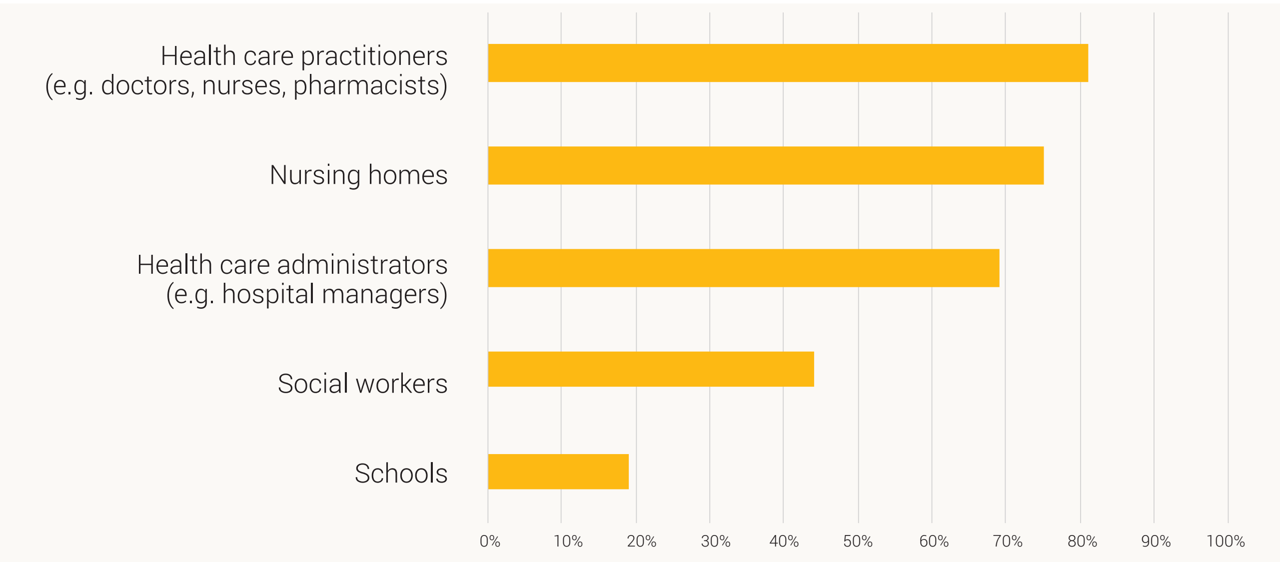
6.3.2 Vulnerability mapping in urban areas

Mapping is an increasing popular environmental health surveillance tool. It can identify important health and exposure disparities and help target interventions. Heat vulnerability mapping considers extreme heat risk factors and provides an aggregate measure of risk. Studies published in peer-reviewed journals have identified a series of risk factors that modify the heat–health association. These comprise factors that vary across space and are interlinked, including:

- environmental factors (UHI intensity, green space, air pollution, land use and land cover, building type, access to AC);
- sociodemographic factors (proportion of elderly population, low socioeconomic status, level of education, ethnic minority groups, public housing);
- and health factors (prevalence of chronic disease).

Several studies have developed vulnerability indicators that combine these risk factors and facilitate geographical representation through mapping to identify hotspots and areas most at risk. Satellite data for land coverage or UHI intensity have also been used with vulnerability characteristics from census data in North America and European cities (Reid et al., 2009; Kestens et al., 2011; Steeneveld et al., 2011; Tomlinson et al., 2011; Buscail, Upegui & Viel, 2012; Johnson et al., 2012; Heaton et al., 2014; Wolf, McGregor & Analitis, 2014; Taylor et al., 2015; Lim et al., 2016). Nayak et

Fig. 11. Stakeholders to whom specific advice on vulnerable subgroups is provided



al. (2018) defined a heat vulnerability index for New York State at the census tract level made up of four core risk factors: socioeconomic conditions; old age and social isolation; ethnicity, language and social barriers; and environmental exposure and urban design (land cover/land use, building age and so on). A similar model was developed to map at-risk areas in Rennes, France, to help target interventions for the most vulnerable populations (Buscail, Upegui & Viel, 2012). Bradford et al. (2015) defined a similar heat vulnerability indicator to identify the best spots to locate cooling centres according to high risk in Pittsburgh, United States. Taylor et al. (2015) looked at the spatial distribution of heat vulnerability across London, United Kingdom, considering UHI and housing characteristics to account for indoor heat and the importance of this factor when planning urban heat adaptation and mitigation measures (Box 8).

Vulnerability mapping, coupled with identification of vulnerable subjects, can help to guide prevention actions and target interventions at the local and community level, optimizing resources. Furthermore, heat–health warning systems could be spatially graded within urban areas to take heat vulnerability and other risk factors into account.

Box 8. Vulnerability mapping of excess heat-related mortality in London, United Kingdom

The derivation and combination of different variables for heat risk – age, UHI and dwellings – were integrated and presented over spatial distribution of heat vulnerability across the city of London. Population age and sex data were obtained at the ward level, and sex-specific age-standardized mortality rates in London were modified using seasonal data for England and Wales to reflect summertime mortality rates; the baseline mortality rate for each ward was calculated from these data. Internal temperatures were estimated using an extensively validated dynamic thermal modelling tool. During the study's period a range of 5.8 °C across dwelling types was estimated. The hottest buildings were bungalows built between 1900 and 1918; the coolest dwellings were ground-floor flats in high-rise buildings built after 1990.

The outdoor temperatures used in the models exceeded the temperature–mortality threshold, with a range of 7.4 °C between the hottest and coolest dwellings. The results indicated that top-floor flats and bungalows have a greater overheating health risk. Spatial variation of heat-related mortality was found to reflect background mortality rates due to population age, while dwelling characteristics were found to cause larger variation in temperature exposure (and therefore risk) than the UHI effect. The highest levels of excess mortality were found in areas with larger elderly populations, towards the outskirts of London. The results provide a platform for further work to investigate the effects of climate change, building retrofitting, population ageing and changes to the UHI effect on population mortality due to heat (Taylor et al., 2015).

6.4 Prevention measures and guidance

Recommendations accounting for new evidence on vulnerable subgroups should be integrated in HHAPs and included in education and outreach programmes. Health and social care staff should be trained on health risks associated with heat exposure among emerging vulnerable groups in order to respond in an efficient and timely manner.

An Australian survey showed that elderly people are generally resilient, but that interventions addressing multimorbidity, medication interactions and social isolation should be developed. Targeted education for elderly people on adaptation measures and the development of specific policy measures could ensure that the health impacts among this subgroup are reduced (Nitschke et al., 2013). Details of preparedness and response measures from health systems are outlined in Chapter 7. Furthermore, integration with European initiatives like the European Innovation Partnership on Active and Healthy Ageing seems a possible way forward to better address needs for heat prevention among the elderly population in the coming years (Liotta, Ussai et al., 2018).

Since most individuals with mentally illnesses are unaware of the risks from extreme temperature exposure, adequate patient counselling regarding exposure reduction, use of heat shelters in urban areas and preventive measures should be incorporated into outpatient care programmes and outreach groups (Hansen et al., 2008; Wang et al., 2014; Price et al., 2018). Patients with substance use disorders are often hard to reach using public health interventions, and not always in contact with professional health services. Alternative outreach measures need to be introduced to protect these subjects during heat-waves (Page et al., 2012).

With reference to pregnant women, midwives and gynaecologists need to be aware of the risks associated with heat during pregnancy and can advise pregnant women to adopt specific measures such as increasing fluid intake, residing in cool environments and reducing activity levels (Kovats & Hajat, 2008; Carolan-Olah & Frankowska, 2014).

6.5 Specific advice for at-risk subgroups

Awareness among vulnerable subgroups of the health risks related to heat is still low and needs to be addressed in HHAPs. The pool of vulnerable subjects changes over time due to ageing, deterioration of pre-existing health conditions or having another comorbidity and worsening of socioeconomic status. This should be addressed in information campaigns and response measures updating current informative material and adjusting prevention measures and actions to account for new evidence on vulnerable groups and local population susceptibility characteristics.

Vulnerable subgroups should be contacted at the beginning of summer, informed about health risks, given guidance on how to cope with heat and advised about the health and social care services available. In several European countries with an operational HHAP, brochures, leaflets and other information material are distributed in health care centres and GP practices. Information is also given to patients during check-up visits, sent via email or post or transmitted via telephone (Lowe, Ebi & Forsberg, 2011; Bittner et al., 2014; Casanueva et al., 2019). Active communication is limited, to date: only a few countries actively contact vulnerable individuals via email, phone calls or text message, as reported in WHO's 2019 survey of heat–health action planning, in Chapter 4 and publications (Lowe, Ebi & Forsberg, 2011). Further details on communication campaigns and informative material can be found in Chapter 4.

With HHAPs, occupational health prevention needs a specific intersectoral and multidisciplinary approach and targeted actions at several levels (individual, enterprise, local and national government) to include workforce categories, employers, unions and health and safety legislation.

Establishing active early warning systems to address occupational heat stress and strain is vital, alongside awareness-raising activities targeting the working population, regular communication about risks and continued monitoring and evaluation of activities (Morabito et al., 2019). Examples of integration of occupation health and worker heat prevention include adopting thresholds for work restrictions and guidance based on meteorological data; engineering solutions, such as cooling, AC and provision of sustainable energy sources; increased use of mechanization to reduce physical workloads; appropriate use of equipment and ventilation systems; and adoption of improved and heat-friendly PPE (Box 9).

Box 9. Occupational health in North Macedonia: heat-waves and workers' health

A national study carried out by the National Institute of Occupational Health in North Macedonia aimed to assess the attitudes, knowledge and practices of 350 outdoor workers regarding the harmful effects of heat-waves and protection from them. The interview results showed that more than 30% of the participants were not informed about procedures for dealing with the impact of heat-waves on human health. Lack of support by management (36%) and fear of losing their job (34%) were listed as the most significant impeding factors for use of health and safety procedures at work during heat-waves.

This was a trigger to the National Institute of Occupational Health to provide specific recommendations for employers, workers and specialists in occupational health, to ensure proper implementation of the measures proposed in the HHAP for prevention, alongside raising awareness among the working population, regular communication of risks and continual monitoring and evaluation of the activities conducted (EEA, 2014). Occupational health specialists and GPs play an important role in implementation of North Macedonia's HHAP of (Karadzinska-Bislimovska, 2015; Kendrovski & Spasenovska, 2011).

6.6 Conclusions

Information campaigns and informative material for vulnerable subgroups should be defined and updated regularly on the basis of new evidence and emerging risk factors. The diversity within vulnerable groups should be acknowledged in both advice tools and information campaigns and in the response measures implemented. Key aspects to promote are formal identification of vulnerable groups, active information and response measures and consistent evaluation of measures put in place targeted at these subgroups. Monitoring of vulnerable groups and health risks associated with heat should be undertaken to account for potential changes over time.

References[1]

Anderson GB, Dominici F, Wang Y, McCormack MC, Bell ML, Peng RD (2013). Heat-related emergency hospitalizations for respiratory diseases in the medicare population. Am J Respir Crit Care Med. 187(10):1098–103. doi:10.1164/rccm.201211-1969OC.

Armitage R, Nellums LB (2020). COVID-19 and the consequences of isolating the elderly. Lancet Public Health. 5(5):e256. doi:10.1016/S2468-2667(20)30061-X.

Asta F, Michelozzi P, Cesaroni G, De Sario M, Badaloni C, Davoli M et al. (2019). The modifying role of socioeconomic position and greenness on the short-term effect of heat and air pollution on preterm births in Rome, 2001–2013. Int J Environ Res Public Health. 16(14):2497. doi:10.3390/ijerph16142497.

Basu R (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environ Health. 8(1):40. doi:10.1186/1476-069X-8-40.

Basu R, Chen H, Li DK, Avalos LA (2017). The impact of maternal factors on the association between temperature and preterm delivery. Environ Res. 154:109–14. doi:10.1016/j.envres.2016.12.017.

Basu R, Gavin L, Pearson D, Ebisu K, Malig B (2018). Examining the association between apparent temperature and mental health-related emergency room visits in California. Am J Epidemiol. 187(4):726–35. doi:10.1093/aje/kwx295.

Benmarhnia T, Deguen S, Kaufman JS, Smargiassi A (2015). Vulnerability to heat-related mortality a systematic review, meta-analysis, and meta-regression analysis. Epidemiology. 26(6):781–93. doi:10.1097/EDE.0000000000000375.

Benmarhnia T, Oulhote Y, Petit C, Lapostolle A, Chauvin P, Zmirou-Navier D et al. (2014). Chronic air pollution and social deprivation as modifiers of the association between high temperature and daily mortality. Environ Health. 13(1):53. doi:10.1186/1476-069x-13-53.

Bhaskaran K, Hajat S, Haines A, Herrett E, Wilkinson P, Smeeth L (2009). Effects of ambient temperature on the incidence of myocardial infarction. Heart. 95(21):1760–9. doi:10.1136/hrt.2009.175000.

Bhaskaran K, Hajat S, Smeeth L (2011). What is the role of weather in cardiovascular disease? Aging Health. 7(1):1–3. doi:10.2217/ahe.10.83.

Bittner MI, Matthies EF, Dalbokova D, Menne B (2014). Are European countries prepared for the next big heat-wave? Eur J Public Health. 24(4):615–9. doi:10.1093/eurpub/ckt121.

Bradford K, Abrahams L, Hegglin M, Klima K (2015). A heat vulnerability index and adaptation solutions for Pittsburgh, Pennsylvania. Environ Sci Technol. 49(19):11303–11. doi:10.1021/acs.est.5b03127.

Breitner S, Wolf K, Peters A, Schneider A (2014). Short-term effects of air temperature on cause-specific cardiovascular mortality in Bavaria, Germany. Heart. 100(16):1272–80. doi:10.1136/heartjnl-2014-305578.

Bukhari Q, Jameel Y (2020). Will coronavirus pandemic diminish by summer? SSRN Electronic J. doi:10.2139/ssrn.3556998.

Bunker A, Wildenhain J, Vandenbergh A, Henschke N, Rocklöv J, Hajat S et al. (2016). Effects of air temperature on climate-sensitive mortality and morbidity outcomes in the elderly; a systematic review and meta-analysis of epidemiological evidence. EBioMedicine. 6: 258–68. doi:10.1016/j.ebiom.2016.02.034.

Buscail C, Upegui E, Viel JF (2012). Mapping heatwave health risk at the community level for public health action. Int J Health Geogr. 11:38. doi:10.1186/1476-072X-11-38.

Carlton EJ, Woster AP, DeWitt P, Goldstein RS, Levy K (2016). A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. Int J Epidemiol. 45(1):117–30. doi:10.1093/ije/dyv296.

Carolan-Olah M, Frankowska D (2014). High environmental temperature and preterm birth: a review of the evidence. Midwifery. 30(1):50–9. doi:10.1016/j.midw.2013.01.011.

Carrillo AE, Flouris AD, Herry CL, Poirier MP, Boulay P, Dervis S et al. (2016). Heart rate variability during high heat stress: a comparison between young and older adults with and without type 2 diabetes. Am J Physiol Regul Integr Comp Physiol. 311(4):R669–75. doi:10.1152/ajpregu.00176.2016.

1 All URLs accessed 30 September–2 October 2020.

Casanueva A, Burgstall A, Kotlarski S, Messeri A, Morabito M, Flouris AD et al. (2019). Overview of existing heat–health warning systems in Europe. Int J Environ Res Public Health. 16(15):2657. doi:10.3390/ijerph16152657.

CDC (2020). People at increased risk. In: Centers for Disease Control and Prevention [website]. Atlanta, GA: Centers for Disease Control and Prevention (https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/index.html).

Cheng J, Xu Z, Bambrick H, Prescott V, Wang N, Zhang Y et al. (2019). Cardiorespiratory effects of heatwaves: a systematic review and meta-analysis of global epidemiological evidence. Environ Res. 177:108610. doi:10.1016/j.envres.2019.108610.

Committee on Sports Medicine Fitness (2000). Climatic heat stress and the exercising child and adolescent: American Academy of Pediatrics policy statement. Pediatrics. 106(1 Pt 1):158–9.

Cox B, Vicedo-Cabrera AM, Gasparrini A, Roels HA, Martens E, Vangronsveld J et al. (2016). Ambient temperature as a trigger of preterm delivery in a temperate climate. J Epidemiol Community Health. 70(12):1191–9. doi:10.1136/jech-2015-206384.

Daanen H, Bose-O'Reilly S, Brearley M, Andreas Flouris D, Gerrett NM, Huynen M et al. (2020). COVID-19 and thermoregulation-related problems: practical recommendations. Temperature.1–11. doi:10.1080/23328940.2020.1790971.

Dadvand P, Basagaña X, Sartini C, Figueras F, Vrijheid M, de Nazelle A et al. (2011). Climate extremes and the length of gestation. Environ Health Perspect. 119(10):1449–53. doi:10.1289/ehp.1003241.

Dadvand P, de Nazelle A, Triguero-Mas M, Schembari A, Cirach M, Amoly E et al. (2012). Surrounding greenness and pregnancy outcomes in four Spanish birth cohorts. Environ Health Perspect. 120(10):1481–7. doi:10.1289/ehp.1205244.

EEA (2014). Implementation of the Heat–Health Action Plan of North Macedonia. Copenhagen: European Environmnet Agency (https://climate-adapt.eea.europa.eu/metadata/case-studies/implementation-of-the-heat-health-action-plan-of-the-former-yugoslav-republic-of-macedonia/fyrom_heat_plan.pdf).

Ehrlich H, McKenney M, Elkbuli A (2020). Protecting our healthcare workers during the COVID-19 pandemic. Am J Emerg Med. 38(7):1527–8. doi:10.1016/j.ajem.2020.04.024.

Elliot AJ, Bone A, Morbey R, Hughes HE, Harcourt S, Smith S et al. (2014). Using real-time syndromic surveillance to assess the health impact of the 2013 heatwave in England. Environ Res. 135:31–6. doi:10.1016/j.envres.2014.08.031.

Eurostat (2019). Ageing Europe: looking at the lives of older people in the EU. Luxembourg: Eurostat (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Ageing_Europe_-_looking_at_the_lives_of_older_people_in_the_EU).

Flouris AD, Dinas PC, Ioannou LG, Nybo L, Havenith G, Kenny GP et al. (2018). Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. Lancet Planet Health. 2(12):e521–e531. doi:10.1016/S2542-5196(18)30237-7.

Flouris AD, McGinn R, Poirier MP, Louie JC, Ioannou LG, Tsoutsoubi L et al. (2017). Screening criteria for increased susceptibility to heat stress during work or leisure in hot environments in healthy individuals aged 31–70 years. Temperature (Austin). 5(1):86–99. doi:10.1080/23328940.2017.1381800.

Gasparrini A, Armstrong BG, Kovats S, Wilkinson P (2012). The effect of high temperatures on cause-specific mortality in England and Wales. Occup Environ Med. 69(1):56–61. doi:10.1136/oem.2010.059782.

GHHIN (2020). Technical brief: protecting health from hot weather during the COVID-19 pandemic. Geneva: Global Heat Health Information Network (http://www.ghhin.org/heat-and-covid-19).

Goggins WB, Chan EY, Ng E, Ren C, Chen L (2012). Effect modification of the association between short-term meteorological factors and mortality by urban heat islands in Hong Kong. PLoS One. 7(6):e38551. doi:10.1371/journal.pone.0038551.

Goggins WB, Woo J, Ho S, Chan EY, Chau PH (2012). Weather, season, and daily stroke admissions in Hong Kong. Int J Biometeorol. 56(5):865–72. doi:10.1007/s00484-011-0491-9.

Gronlund CJ, Yang AJ, Conlon KC, Bergmans RS, Le HQ, Batterman SA et al. (2020). Time series analysis of total and direct associations between high temperatures and preterm births in Detroit, Michigan. BMJ Open. 10(2):1–8. doi:10.1136/bmjopen-2019-032476.

Guo T, Wang Y, Zhang H, Zhang Y, Zhao J, Wang Y et al. (2018). The association between ambient temperature and the risk of preterm birth in China.

Sci Total Environ. 613–14(12):439–46. doi:10.1016/j.scitotenv.2017.09.104.

Ha S, Liu D, Zhu Y, Kim SS, Sherman S, Mendola P (2017). Ambient temperature and early delivery of singleton pregnancies. Environ Health Perspect. 125(3):453–9. doi:10.1289/ehp97.

Hajat S, O'Connor M, Kosatsky T (2010). Health effects of hot weather: from awareness of risk factors to effective health protection. Lancet. 375(9717):856–63. doi:10.1016/S0140-6736(09)61711-6.

Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G (2008). The effect of heat waves on mental health in a temperate Australian City. Environ Health Perspect. 116(10):1369–75. doi:10.1289/ehp.11339.

Hansen A, Bi L, Saniotis A, Nitschke M (2013). Vulnerability to extreme heat and climate change: is ethnicity a factor? Glob Health Action. 6(1):21364. doi:10.3402/gha.v6i0.21364.

HCSP (2020). Coronavirus SARS-CoV-2 : gestion de l'épidémie en cas de survenue de vagues de chaleur [Coronavirus SARS-CoV-2: epidemic management in the event of heat-waves]. Paris: Haut Conseil de la santé publique (https://www.hcsp.fr/explore.cgi/avisrapportsdomaine?clefr=817).

He S, Kosatsky T, Smargiassi A, Bilodeau-Bertrand M, Auger N (2017). Heat and pregnancy-related emergencies: risk of placental abruption during hot weather. Environ Int. 111:295–300. doi:10.1016/j.envint.2017.11.004.

Heaton MJ, Sain SR, Greasby TA, Uejio CK, Hayden MH, Monaghan AJ et al. (2014). Characterizing urban vulnerability to heat stress using a spatially varying coefficient model. Spat Spatiotemporal Epidemiol. 8:23–33. doi:10.1016/j.sste.2014.01.002.

Heaviside C, Macintyre H, Vardoulakis S (2017). The urban heat island: implications for health in a changing environment. Curr Environ Health Rep. 4(3):296–305. doi:10.1007/s40572-017-0150-3.

Heaviside C, Vardoulakis S, Cai XM (2016). Attribution of mortality to the urban heat island during heatwaves in the West Midlands, UK. Environ Health. 15(Suppl 1):27. doi:10.1186/s12940-016-0102-7.

Huang G, Zhou W, Cadenasso ML (2011). Is everyone hot in the city? Spatial pattern of land surface temperatures, land cover and neighborhood socioeconomic characteristics in Baltimore, MD. J Environ Manage. 92(7):1753–9. doi:10.1016/j.jenvman.2011.02.006.

Ilango SD, Weaver M, Sheridan P, Schwarz L, Clemesha RES, Bruckner T et al. (2020). Extreme heat episodes and risk of preterm birth in California, 2005–2013. Environ Int. 137:105541. doi:10.1016/j.envint.2020.105541.

INSPQ (2020). COVID-19: adaptation of public health recommendations for extreme heat in accordance with physical distancing recommendations. Quebec: Institut national de santé publique du Québec (https://www.inspq.qc.ca/en/publications/3024-extreme-heat-physical-distancing-adaptation-of-PH-recommendations-covid19).

Iñiguez C, Schifano P, Asta F, Michelozzi P, Vicedo-Cabrera A, Ballester F (2016). Temperature in summer and children's hospitalizations in two Mediterranean cities. Environ Res. 150:236–44. doi:10.1016/j.envres.2016.06.007.

Ioannou LG, Tsoutsoubi L, Samoutis G, Bogataj LK, Kenny GP, Nybo L et al. (2017). Time-motion analysis as a novel approach for evaluating the impact of environmental heat exposure on labor loss in agriculture workers. Temperature (Austin). 4(3):330–40. doi:10.1080/23328940.2017.1338210.

Jay O, Brotherhood JR (2016). Occupational heat stress in Australian workplaces. Temperature (Austin). 3(3):394–411. doi:10.1080/23328940.2016.1216256.

Johnson DP, Stanforth A, Lulla V, Luber G (2012). Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data. Appl Geogr. 35(1–2):23–31. doi:10.1016/j.apgeog.2012.04.006.

Juan J, Gil MM, Rong Z, Zhang Y, Yang H, Poon LC (2020). Effect of coronavirus disease 2019 (COVID 19) on maternal, perinatal and neonatal outcome: systematic review. Ultrasound Obstet Gynecol. 56(1):15–27. doi:10.1002/uog.22088.

Karadzinska-Bislimovska J (2015). Climate change, extreme weather events and effects on workers' health in Macedonia. Eurodialogue. 20:143–50.

Kendrovski V, Spasenovska M (2011). Heat–health action plan to prevent the heat wave consequences on the health of the population in the former Yugoslav Republic of Macedonia. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/countries/north-macedonia/publications/heat-health-action-plan-to-prevent-the-heat-wave-consequences-on-the-health-of-the-population-in-the-former-yugoslav-republic-of-macedonia).

Kenny GP, Flouris AD, Yagouti A, Notley SR (2019). Towards establishing evidence-based guidelines on maximum indoor temperatures during hot weather in temperate continental climates. Temperature (Austin). 6(1):11–36. doi:10.1080/23328940.2018.1456257.

Kenny GP, Sigal RJ, McGinn R (2016). Body temperature regulation in diabetes. Temperature (Austin). 3(1):119–45. doi:10.1080/23328940.2015.1131506.

Kenny GP, Yardley J, Brown C, Sigal RJ, Jay O (2010). Heat stress in older individuals and patients with common chronic diseases. CMAJ. 182(10):1053–60. doi:10.1503/cmaj.081050.

Kestens Y, Brand A, Fournier M, Goudreau S, Kosatsky T, Maloley M et al. (2011). Modelling the variation of land surface temperature as determinant of risk of heat-related health events. Int J Health Geogr. 10(1):7. doi:10.1186/1476-072X-10-7.

Khan R, Anwar R, Akanda S, McDonald MD, Huq A, Jutla A et al. (2017). Assessment of risk of cholera in Haiti following Hurricane Matthew. Am J Trop Med Hyg. 97(3):896–903. doi:10.4269/ajtmh.17-0048.

Klenk J, Becker C, Rapp K (2010). Heat-related mortality in residents of nursing homes. Age Ageing. 39(2):245–52. doi:10.1093/ageing/afp248.

KLUG (2020). Informationen zu Hitze und COVID-19 [Information on heat and COVID-19] [website]. Berlin: Deutsche Allianz Klimawandel und Gesundheit (https://www.klimawandel-gesundheit.de/hitze-informationen/).

Kim Y, Kim H, Gasparrini A, Armstrong B, Honda Y, Chung Y et al. (2019). Suicide and ambient temperature: a multi-country multi-city study. Environ Health Perspect. 127(11):117007. doi:10.1289/EHP4898.

Kloog I (2019). Air pollution, ambient temperature, green space and preterm birth. Curr Opin Pediatr. 31(2):237–43. doi:10.1097/MOP.0000000000000736.

Kloog I, Melly SJ, Ridgway WL, Coull BA, Schwartz J (2012). Using new satellite based exposure methods to study the association between pregnancy $PM_{2.5}$ exposure, premature birth and birth weight in Massachusetts. Environ Health. 11(1):40. doi:10.1186/1476-069X-11-40.

Kovats RS, Hajat S (2008). Heat stress and public health: a critical review. Annu Rev Public Health. 29(1):41–55. doi:10.1146/annurev.publhealth.29.020907.090843.

Kwon BY, Lee E, Lee S, Heo S, Jo K, Kim J, Park MS (2015). Vulnerabilities to temperature effects on acute myocardial infarction hospital admissions in South Korea. Int J Environ Res Public Health. 12(11):14571–88. doi:10.3390/ijerph121114571.

Lam HCY, Li AM, Chan EY, Goggins WB (2016). The short-term association between asthma hospitalisations, ambient temperature, other meteorological factors and air pollutants in Hong Kong: a time-series study. Thorax. 71(12):1097–109. doi:10.1136/thoraxjnl-2015-208054.

Lam HCY, Chan JCN, Luk AOY, Chan EYY, Goggins WB (2018). Short-term association between ambient temperature and acute myocardial infarction hospitalizations for diabetes mellitus patients: a time series study. PLoS Med. 15(7):1–18. doi:10.1371/journal.pmed.1002612.

Levy BS, Patz JA (2015). climate change, human rights, and social justice. Ann Glob Health. 81(3):310. doi:10.1016/j.aogh.2015.08.008.

Li S, Baker PJ, Jalaludin BB, Guo Y, Marks GB, Denison LS et al. (2014). Are children's asthmatic symptoms related to ambient temperature? A panel study in Australia. Environ Res. 133:239–45. doi:10.1016/j.envres.2014.05.032.

Lian H, Ruan Y, Liang R, Liu X, Fan Z (2015). Short-term effect of ambient temperature and the risk of stroke: a systematic review and meta-analysis. Int J Environ Res Public Health. 12(8):9068–88. doi:10.3390/ijerph120809068.

Lim YH, Reid CE, Honda Y, Kim H (2016). Temperature deviation index and elderly mortality in Japan. Int J Biometeorol. 60(7):991–8. doi:10.1007/s00484-015-1091-x.

Linares C, Martinez-Martin P, Rodríguez-Blázquez C, Forjaz MJ, Carmona R, Díaz J (2016). Effect of heat waves on morbidity and mortality due to Parkinson's disease in Madrid: a time-series analysis. Environ Int. 89–90:1–6. doi:10.1016/j.envint.2016.01.017.

Linares C, Martinez GS, Kendrovski V, Díaz J (2020). A new integrative perspective on early warning systems for health in the context of climate change. Environ Res. 187:109623. doi:10.1016/j.envres.2020.109623.

Lippi G, Henry BM (2020). Chronic obstructive pulmonary disease is associated with severe coronavirus disease 2019 (COVID-19). Respir Med. 167:105941. doi:10.1016/j.rmed.2020.105941.

Liotta G, Inzerilli MC, Palombi L, Madaro O, Orlando S, Scarcella P et al. (2018). Social interventions to prevent heat-related mortality in the older adult in Rome, Italy: a quasi-experimental study. Int J Environ Res Public Health. 15(4):715. doi:10.3390/ijerph15040715.

Liotta G, Ussai S, Illario M, O'Caoimh R, Cano A, Holland C et al. (2018). Frailty as the future core business of public health: report of the activities of the A3 action group of the european innovation partnership on active and healthy ageing (EIP on AHA). Int J Environ Res Public Health. 15(12):2843. doi:10.3390/ijerph15122843.

Liu C, Yavar Z, Sun Q (2015). Cardiovascular response to thermoregulatory challenges. Am J Physiol Heart Circ Physiol. 309(11):H1793–812. doi:10.1152/ajpheart.00199.2015.

Lowe D, Ebi KL, Forsberg B (2011). Heatwave early warning systems and adaptation advice to reduce human health consequences of heatwaves. Int J Environ Res Public Health. 8(12):4623–48. doi:10.3390/ijerph8124623.

Mantovani A, Byrne CD, Zheng MH, Targher G (2020). Diabetes as a risk factor for greater COVID-19 severity and in-hospital death: A meta-analysis of observational studies. Nutr Metab Cardiovasc Dis. 30(8):1236–48. doi:10.1016/j.numecd.2020.05.014.

Marinaccio A, Scortichini M, Gariazzo C, Leva A, Bonafede M, de'Donato FK et al. (2019). Nationwide epidemiological study for estimating the effect of extreme outdoor temperature on occupational injuries in Italy. Environ Int. 133(Pt A):105176. doi:10.1016/j.envint.2019.105176.

Martin-Latry K, Goumy MP, Latry P, Gabinski C, Bégaud B, Faure I et al. (2007). Psychotropic drugs use and risk of heat-related hospitalisation. Eur Psychiatry. 22(6):335–8. doi:10.1016/j.eurpsy.2007.03.007.

Martinez GS, Linares C, de'Donato F, Díaz J (2020). Protect the vulnerable from extreme heat during the COVID-19 pandemic. Environ Res. 187:109684. doi:10.1016/j.envres.2020.109684.

Matthies F, Bickler G, Cardeñosa N, Hales S, editors (2008). Heat–health action plans. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/publications/abstracts/heathealth-action-plans).

Mayrhuber EAS, Dückers MLA, Wallner P, Arnberger A, Allex B, Wiesböck L et al. (2018). Vulnerability to heatwaves and implications for public health interventions – a scoping review. Environ Res. 166:42–54. doi:10.1016/j.envres.2018.05.021.

McCormack MC, Belli AJ, Waugh D, Matsui EC, Peng RD, Williams DL et al. (2016). Respiratory effects of indoor heat and the interaction with air pollution in chronic obstructive pulmonary disease. Ann Am Thorac Soc. 13(12):2125–31. doi:10.1513/AnnalsATS.201605-329OC.

McGinn R, Carter MR, Barrera-Ramirez J, Sigal RJ, Flouris AD, Kenny GP (2015). Does type 1 diabetes alter post-exercise thermoregulatory and cardiovascular function in young adults? Scand J Med Sci Sports. 25(5):e504–14. doi:10.1111/sms.12344.

Meade RD, Poirier MP, Flouris AD, Hardcastle SG, Kenny GP (2016). Do the threshold limit values for work in hot conditions adequately protect workers? Med Sci Sports Exerc. 48(6):1187–96. doi:10.1249/MSS.0000000000000886.

Messeri A, Morabito M, Bonafede M, Bugani M, Levi M, Baldasseroni A et al. (2019). Heat stress perception among native and migrant workers in Italian industries – case studies from the construction and agricultural sectors. Int J Environ Res Public Health. 16(7):1090. doi:10.3390/ijerph16071090.

Michelozzi P, Accetta G, De Sario M, D'Ippoliti D, Marino C, Baccini M et al. (2009). High temperature and hospitalizations for cardiovascular and respiratory causes in 12 European cities. Am J Respir Crit Care Med. 179(5):383–9. doi:10.1164/rccm.200802-217OC.

Michelozzi P, de'Donato FK, Bargagli AM, D'Ippoliti D, De Sario M, Marino C et al. (2010). Surveillance of summer mortality and preparedness to reduce the health impact of heat waves in Italy. Int J Environ Res Public Health. 7(5):2256–73. doi:10.3390/ijerph7052256.

Min M, Shi T, Ye P, Wang Y, Yao Z, Tian S et al. (2019). Effect of apparent temperature on daily emergency admissions for mental and behavioral disorders in Yancheng, China: a time-series study. Environ Health. 18(1):1–12. doi:10.1186/s12940-019-0543-x.

Morabito M, Messeri A, Crisci A, Pratali L, Bonafede M, Marinaccio A et al. (2020). Heat warning and public and workers' health at the time of COVID-19 pandemic. Sci Total Environ. 738:140347. doi:10.1016/j.scitotenv.2020.140347.

Morabito M, Messeri A, Noti P, Casanueva A, Crisci A, Kotlarski S et al. (2019). An occupational heat–health warning system for Europe: The HEAT-SHIELD platform. Int J Environ Res Public Health. 16(16):2890. doi:10.3390/ijerph16162890.

Mullins JT, White C (2019). Temperature and mental health: Evidence from the spectrum of mental health outcomes. J Health Econ. 68:102240. doi:10.1016/j.jhealeco.2019.102240.

Nanda A, Vura NVRK, Gravenstein S (2020). COVID-19 in older adults. Aging Clin Exp Res. 32(7):1199–202. doi:10.1007/s40520-020-01581-5.

Nayak SG, Shrestha S, Kinney PL, Ross Z, Sheridan SC, Pantea CI et al. (2018). Development of a heat vulnerability index for New York State. Public Health. 161:127–37. doi:10.1016/j.puhe.2017.09.006.

Nitschke M, Hansen A, Bi P, Pisaniello D, Newbury J, Kitson A et al. (2013). Risk factors, health effects and behaviour in older people during extreme heat: a survey in South Australia. Int J Environ Res Public Health. 10(12):6721–33. doi:10.3390/ijerph10126721.

Notley SR, Poirier MP, Sigal RJ, D'Souza A, Flouris AD, Fujii N et al. (2019). Exercise heat stress in patients with and without type 2 diabetes. JAMA. 322(14):1409–11. doi:10.1001/jama.2019.10943.

Notley SR, Flouris AD, Kenny GP (2019). Occupational heat stress management: does one size fit all? Am J Ind Med. 62(12):1017–23. doi:10.1002/ajim.22961.

O'Neill MS, Zanobetti A, Schwartz J (2003). Modifiers of the temperature and mortality association in seven US cities. Am J Epidemiol. 157(12):1074–82. doi:10.1093/aje/kwg096.

Page LA, Hajat S, Kovats RS, Howard LM (2012). Temperature-related deaths in people with psychosis, dementia and substance misuse. Br J Psychiatry. 200(6):485–90. doi:10.1192/bjp.bp.111.100404.

Pascal M, Laaidi K, Wagner V, Ung AB, Smaili S, Fouillet A et al. (2012). How to use near real-time health indicators to support decision-making during a heat wave: the example of the French heat wave warning system. PLoS Curr. 4:e4f83ebf72317d. doi:10.1371/4f83ebf72317d.

PHE (2020). Heat–health risks and COVID-19: actions to prevent harm [slide set]. London: Public Health England (https://www.gov.uk/government/publications/heatwave-plan-for-england/heat-health-risks-and-covid-19-actions-to-prevent-harm).

Pradhan B, Kjellström T, Atar D, Sharma P, Kayastha B, Bhandari G et al. (2019). Heat stress impacts on cardiac mortality in Nepali migrant workers in Qatar. Cardiology. 143(1):37–48. doi:10.1159/000500853.

Pranata R, Huang I, Lim MA, Wahjoepramono EJ, July J (2020). Impact of cerebrovascular and cardiovascular diseases on mortality and severity of COVID-19–systematic review, meta-analysis, and meta-regression. J Stroke Cerebrovasc Dis. 29(8):104949. doi:10.1016/j.jstrokecerebrovasdis.2020.104949.

Price K, Benmarhnia T, Gaudet J, Kaiser D, Sadoine ML, Perron S et al. (2018). The Montreal heat response plan: evaluation of its implementation towards healthcare professionals and vulnerable populations. Can J Public Health. 109(1):108–16. doi:10.17269/s41997-018-0020-2.

Quiller G, Krenz J, Ebi K, Hess JJ, Fenske RA, Sampson PD et al. (2017). Heat exposure and productivity in orchards: Implications for climate change research. Arch Environ Occup Health. 2(6):313–16. doi:10.1080/19338244.2017.1288077.

Reid CE, O'Neill MS, Gronlund CJ, Brines SJ, Brown DG, Diez-Roux AV et al. (2009). Mapping community determinants of heat vulnerability. Environ Health Perspect. 117(11):1730–6. doi:10.1289/ehp.0900683.

RIVM (2020). Vragen en antwoorden hitte en COVID-19 [Questions and answers on heat and Covid-19] [website]. Bilthoven: National Institute for Public Health and the Environment (https://www.rivm.nl/hitte/vragen-en-antwoorden-hitte-covid-19).

Schifano P, Asta F, Dadvand P, Davoli M, Basagaña X, Michelozzi P (2016). Heat and air pollution exposure as triggers of delivery: a survival analysis of population-based pregnancy cohorts in Rome and Barcelona. Environ Int. 88:153–9. doi:10.1016/j.envint.2015.12.013.

Schifano P, Asta F, Marinaccio A, Bonafede M, Davoli M, Michelozzi P (2019). Do exposure to outdoor temperatures, NO_2 and PM_{10} affect the work-related injuries risk? A case-crossover study in three Italian cities, 2001–2010. BMC Open. 9(8):e023119. doi:10.1136/bmjopen-2018-023119.

Schifano P, Cappai G, De Sario M, Bargagli AM, Michelozzi P (2013). Who should heat prevention plans target? A heat susceptibility indicator in the elderly developed based on administrative data from a cohort study. Healthy Aging Res. 2(2):1–10. doi:10.12715/har.2013.2.2.

Schifano P, Lallo A, Asta F, De Sario M, Davoli M, Michelozzi P (2013). Effect of ambient temperature and air pollutants on the risk of preterm birth, Rome 2001–2010. Environ Int. 61:77–87. doi:10.1016/j.envint.2013.09.005.

Shahid Z, Kalayanamitra R, McClafferty B, Kepko D, Ramgobin D, Patel R et al. (2020). COVID 19 and older adults: what we know. J Am Geriatr Soc. 68(5):926–9. doi:10.1111/jgs.16472.

Shang L, Shao M, Guo Q, Shi J, Zhao Y, Xiaokereti J et al. (2020). Diabetes mellitus is associated with severe infection and mortality in patients with COVID-19: a systematic review and meta-analysis. Arch Med Res. S0188-4409(20)30681-0. doi:10.1016/j.arcmed.2020.07.005.

Sheffield PE, Landrigan PJ (2011). Global climate change and children's health: threats and strategies for prevention. Environ Health Perspect. 119(3):291–8. doi:10.1289/ehp.1002233.

Singh AK, Gillies CL, Singh R, Singh A, Chudasama Y, Coles B et al. (2020). Prevalence of co morbidities and their association with mortality in patients with COVID 19: a systematic review and meta analysis. Diabetes Obes Metab. 10.111/dom.14124. doi:10.1111/dom.14124.

Smargiassi A, Goldberg MS, Plante C, Fournier M, Baudouin Y, Kosatsky T (2009). Variation of daily warm season mortality as a function of micro-urban heat islands. J Epidemiol Community Health. 63(8):659–64. doi:10.1136/jech.2008.078147.

Son JY, Lee JT, Lane KJ, Bell ML (2019). Impacts of high temperature on adverse birth outcomes in Seoul, Korea: disparities by individual- and community-level characteristics. Environ Res. 168(3):460–6. doi:10.1016/j.envres.2018.10.032.

Song J, Lu J, Wang E, Lu M, An Z, Liu Y et al. (2019). Short-term effects of ambient temperature on the risk of premature rupture of membranes in Xinxiang, China: a time-series analysis. Sci Total Environ. 689:1329–35. doi:10.1016/j.scitotenv.2019.06.457.

Spector JT, Masuda YJ, Wolff NH, Calkins M, Seixas N (2019). Heat exposure and occupational injuries: review of the literature and implications. Curr Environ Health Rep. 6(4):286–96. doi:10.1007/s40572-019-00250-8.

Stafoggia M, Forastiere F, Agostini D, Biggeri A, Bisanti L, Cadum E et al. (2006). Vulnerability to heat-related mortality: a multicity, population-based, case-crossover analysis. Epidemiology. 17(3):315–23. doi:10.1097/01.ede.0000208477.36665.34.

Stanberry LR, Thomson MC, James W (2018). Prioritizing the needs of children in a changing climate. PLoS Med. 15(7):11–14. doi:10.1371/journal.pmed.1002627.

Stapleton JM, Larose J, Simpson C, Flouris AD, Sigal RJ, Kenny GP (2014). Do older adults experience greater thermal strain during heat waves? Appl Physiol Nutr Metab. 39(3):292–298. doi:10.1139/apnm-2013-0317.

Stapleton JM, Poirier MP, Flouris AD, Boulay P, Sigal RJ, Malcolm J et al. (2015). Aging impairs heat loss, but when does it matter? J Appl Physiol (1985). 118(3):299–309. doi:10.1152/japplphysiol.00722.2014.

Steeneveld GJ, Koopmans S, Heusinkveld BG, van Hove LWA, Holtslag AAM (2011). Quantifying urban heat island effects and human comfort for cities of variable size and urban morphology in the Netherlands. J Geophys Res. 116(D20):D20129. doi:10.1029/2011JD015988.

Stöllberger C, Lutz W, Finsterer J (2009). Heat-related side-effects of neurological and non-neurological medication may increase heatwave fatalities. Eur J Neurol. 16(7):879–82. doi:10.1111/j.1468-1331.2009.02581.x.

Strand LB, Barnett AG, Tong S (2011). The influence of season and ambient temperature on birth outcomes: a review of the epidemiological literature. Environ Res. 111(3):451–62. doi:10.1016/j.envres.2011.01.023.

Strand LB, Barnett AG, Tong S (2012). Maternal exposure to ambient temperature and the risks of preterm birth and stillbirth in Brisbane, Australia. Am J Epidemiol. 175(2):99–107. doi:10.1093/aje/kwr404.

Sud SR (2020). COVID-19 and keeping clean: a narrative review to ascertain the efficacy of personal protective equipment to safeguard health care workers against SARS-CoV-2. Hosp Pediatr. 10(7):570–6. doi:10.1542/hpeds.2020-0135.

Sun S, Tian L, Qiu H, Chan KP, Tsang H, Tang R et al. (2016). The influence of pre-existing health conditions on short-term mortality risks of temperature: evidence from a prospective Chinese elderly cohort in Hong Kong. Environ Res. 148:7–14. doi:10.1016/j.envres.2016.03.012.

Sun S, Weinberger KR, Spangler KR, Eliot MN, Braun JM, Wellenius GA (2019). Ambient temperature and preterm birth: A retrospective study of 32 million US singleton births. Environ Int. 126(1):7–13. doi:10.1016/j.envint.2019.02.023.

Tam CC, Rodrigues LC, O'Brien SJ, Hajat S (2006). Temperature dependence of reported Campylobacter infection in England, 1989–1999. Epidemiol Infect. 134(1):119–25. doi:10.1017/S0950268805004899.

Taylor J, Davies M, Mavrogianni A, Shrubsole C, Hamilton I, Das P et al. (2016). Mapping indoor overheating and air pollution risk modification across Great Britain: a modelling study. Build Environ. 99:1–12. doi:10.1016/j.buildenv.2016.01.010.

Taylor J, Wilkinson P, Davies M, Armstrong B, Chalabib Z, Mavrogianni A et al. (2015). Mapping the effects of urban heat island, housing, and age on excess heat-related mortality in London. Urban Climate. 14(4):517–28. doi:10.1016/j.uclim.2015.08.001.

Thompson R, Hornigold R, Page L, Waite T (2018). Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. Public Health. 161:171–91. doi:10.1016/j.puhe.2018.06.008.

Tomlinson CJ, Chapman L, Thornes JE, Baker CJ (2011). Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. Int J Health Geogr. 10:42. doi:10.1186/1476-072X-10-42.

Turner LR, Barnett AG, Connell D, Tong S (2012). Ambient temperature and cardiorespiratory morbidity. Epidemiology. 23(4):594–606. doi:10.1097/EDE.0b013e3182572795.

Urban A, Burkart K, Kyselý J, Schuster C, Plavcová E, Hanzlíková H et al. (2016). Spatial patterns of heat-related cardiovascular mortality in the Czech Republic. Int J Environ Res Public Health. 13(3):284. doi:10.3390/ijerph13030284.

Vicedo-Cabrera AM, Iñiguez C, Barona C, Ballester F (2014). Exposure to elevated temperatures and risk of preterm birth in Valencia, Spain. Environ Res. 134:210–17. doi:10.1016/j.envres.2014.07.021.

Vicedo-Cabrera AM, Olsson D, Forsberg B (2015). Exposure to seasonal temperatures during the last month of gestation and the risk of preterm birth in Stockholm. Int J Environ Res Public Health. 12(4):3962–78. doi:10.3390/ijerph120403962.

Wang B, Li R, Lu Z, Huang Y (2020). Does comorbidity increase the risk of patients with COVID-19: evidence from meta-analysis. Aging (Albany NY). 12(7):6049–57. doi:10.18632/aging.103000.

Wang X, Cao Y, Hong D, Zheng D, Richtering S, Sandset EC et al. (2016). Ambient temperature and stroke occurrence: a systematic review and meta-analysis. Int J Environ Res Public Health.13(7). doi:10.3390/ijerph13070698.

Wang X, Lavigne E, Ouellette-kuntz H, Chen BE (2014). Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. J Affect Disord. 155(1):154–61. doi:10.1016/j.jad.2013.10.042.

Wei Y, Wang Y, Lin CK, Yin K, Yang J, Shi L et al. (2019). Associations between seasonal temperature and dementia-associated hospitalizations in New England. Environ Int. 126:228–33. doi:10.1016/j.envint.2018.12.054.

WHO Regional Office for Europe (2011). Public health advice on preventing health effects of heat: new and updated information for different audiences. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/2011/public-health-advice-on-preventing-health-effects-of-heat.-new-and-updated-information-for-different-audiences).

WHO Regional Office for Europe (2016). Urban green spaces and health: a review of the evidence. Copenhagen: WHO Regional Office for Europe (http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2016/urban-green-spaces-and-health-a-review-of-evidence-2016).

WHO Regional Office for Europe (2020a). Health advice for hot weather during the COVID-19 outbreak. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/technical-guidance/2020/health-advice-for-hot-weather-during-the-covid-19-outbreak-produced-by-the-who-european-region).

WHO Regional Office for Europe (2020b). Health care considerations for older people during COVID-19 pandemic. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/technical-guidance/health-care-considerations-for-older-people-during-covid-19-pandemic).

WHO Regional Office for Europe (2020c). Strengthening the health systems response to COVID-19. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/technical-guidance/health-systems/strengthening-the-health-systems-response-to-covid-19-technical-guidance-6,-21-may-2020-produced-by-the-who-european-region).

Willers SM, Jonker MF, Klok L, Keuken MP, Odink J, van den Elshout S et al. (2016). High resolution exposure modelling of heat and air pollution and the impact on mortality. Environ Int. 89–90:102–9. doi:10.1016/j.envint.2016.01.013.

Williams S, Nitschke M, Sullivan T, Tucker GR, Weinstein P, Pisaniello DL et al. (2012). Heat and health in Adelaide, South Australia: assessment of heat thresholds and temperature relationships. Sci Total Environ. 414:126–33. doi:10.1016/j.scitotenv.2011.11.038.

Wolf T, McGregor G, Analitis A (2014). Performance assessment of a heat wave vulnerability index for Greater London, United Kingdom. Wea Climate Soc. 6(1):32–46. doi:10.1175/WCAS-D-13-00014.1.

Wong KV, Paddon A, Jimenez A (2013). Review of world urban heat islands: many linked to increased mortality. J Energy Resour Technol. 135(2):022101. doi:10.1115/1.4023176.

Wood C (2020). COVID-19: protecting the medically vulnerable. Br J Nurs. 29(12):660. doi:10.12968/bjon.2020.29.12.660.

Xu Y, Dadvand P, Barrera-Gómez J, Sartini C, Marí-Dell'Olmo M, Borrell C et al. (2013). Differences on the effect of heat waves on mortality by sociodemographic and urban landscape characteristics. J Epidemiol Community Health. 67(6):519–25. doi:10.1136/jech-2012-201899.

Xu Z, Etzel RA, Su H, Huang C, Guo Y, Tong S (2012). Impact of ambient temperature on children's health: a systematic review. Environ Res. 117:120–31. doi:10.1016/j.envres.2012.07.002.

Xu Z, Sheffield PE, Hu W, Su H, Yu W, Qi X et al. (2012). Climate change and children's health—a call for research on what works to protect children. Int J Environ Res Public Health. 9(9):3298–316. doi:10.3390/ijerph9093298.

Xu Z, Huang C, Hu W, Turner LR, Su H, Tong S (2013). Extreme temperatures and emergency department admissions for childhood asthma in Brisbane, Australia. Occup Environ Med. 70(10):730–5. doi:10.1136/oemed-2013-101538.

Xu Z, Sheffield PE, Su H, Wang X, Bi Y, Tong S (2014). The impact of heat waves on children's health: a systematic review. Int J Biometeorol. 58(2):239–47. doi:10.1007/s00484-013-0655-x.

Yardley JE, Stapleton JM, Sigal RJ, Kenny GP (2013). Do heat events pose a greater health risk for individuals with type 2 diabetes? Diabetes Technol Ther. 15(6):520–9. doi:10.1089/dia.2012.0324.

Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q et al. (2020). Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. Int J Infect Dis. 94:91–5. doi:10.1016/j.ijid.2020.03.017.

Yang Z, Wang M, Zhu Z, Liu Y (2020). Coronavirus disease 2019 (COVID-19) and pregnancy: a systematic review. J Matern Fetal Neonatal Med. 1–4. doi:10.1080/14767058.2020.1759541.

Yu W, Mengersen K, Wang X, Ye X, Guo Y, Pan X, Tong S (2012). Daily average temperature and mortality among the elderly: a meta-analysis and systematic review of epidemiological evidence. Int J Biometeorol. 56(4):569–81. doi:10.1007/s00484-011-0497-3.

Zanobetti A, Dominici F, Wang Y, Schwartz JD (2014). A national case-crossover analysis of the short-term effect of $PM_{2.5}$ on hospitalizations and mortality in subjects with diabetes and neurological disorders. Environ Health. 13(1):1–11. doi:10.1186/1476-069X-13-38.

Zanobetti A, O'Neill MS, Gronlund CJ, Schwartz JD (2013). Susceptibility to mortality in weather extremes: effect modification by personal and small-area characteristics. Epidemiology. 24(6):809–19. doi:10.1097/01.ede.0000434432.06765.91.

Zhang Y, Bi P, Hiller JE (2010). Climate variations and Salmonella infection in Australian subtropical and tropical regions. Sci Total Environ. 408(3):524–30. doi:10.1016/j.scitotenv.2009.10.068.

Zhang Y, Yu C, Wang L (2017). Temperature exposure during pregnancy and birth outcomes: An updated systematic review of epidemiological evidence. Environ Pollut. 225:700–12. doi:10.1016/j.envpol.2017.02.066.

Zhao Y, Huang Z, Wang S, Hu J, Xiao J, Li X et al. (2019). Morbidity burden of respiratory diseases attributable to ambient temperature: a case study in a subtropical city in China. Environ Health. 18(1):1–8. doi:10.1186/s12940-019-0529-8.