Working paper #1

Social Vulnerability and Heat: Systematic Literature Search and Narrative Synthesis

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(Social) vulnerability and resilience are complex issues. There are many definitions and applications of vulnerability and many (social) vulnerability indices exist. IPCC, for example, states in the 6th Assessment Report (2022/23), that vulnerability "encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt". There are many contextual conditions, factors und processes which generate and shape contextual vulnerability in social (and ecological) systems (O'Brien et al., 2007). Therefore, studies have to deal with socioecological and sociodemographic complexities (Harlan et al., 2013; Gronlund, 2014).

To gain more insight into these issues systematic literature searches in Scopus, Web of Science and Pubmed was performed. Taking into account which data were available from Statistics Austria, we used the following search terms: heat OR temperature AND vulnerab* AND (socioeconomic OR demographic OR dens* OR occupation OR immigrant). The search yielded 990 (Scopus), 1014 (Web of Science), and 1668 (Pubmed) records, respectively. After a first screening of titles and abstracts files were constructed. Duplicates and publications with no relevance for this project were deleted. Finally, results from 112 (scopus), 82 (Web of Science), and 86 publications (Pubmed) were analysed. In addition, 16 publications found in reference lists, etc. were examined. All these papers were read and are listed in the reference list at the end. Only a selection is presented in this synthesis in detail. The selection is mostly based on novel findings and on social and socio-economic or socio-demographic variables that are available on a district level in Austria for further reference for the next step of our study which will be an epidemiological research.

It is well known that persons with **low socioeconomic status**, the **elderly**, **migrants** and people with medical conditions are more heat-vulnerable. Therefore, communities with a higher proportion of these groups are more vulnerable. Vulnerability to heat and climate change is "determined by a community's ability to anticipate, cope with, resist, and recover from the impact of major weather events", as Shonkoff et al. (2011) formulates it. In the United States, 4 factors were the most important vulnerability variables and explained more than 75 % of the total variance: social/environmental vulnerability (education/poverty/race/green space combined), social isolation, percentage households without central air conditioning, and percentage elderly/diabetes (Reid et al., 2009). On the other hand, there can be large differences between cities and every city may have a different set of variables which are influencing vulnerability (Nanda et al., 2022).

Low socioeconomic status can be measured/defined in different ways. The variables are interconnected and entwined and are also associated with characteristics that increase vulnerability, like living in warmer neighbourhoods or working in occupations with greater heat exposure (Park et al., 2018). Interestingly, in some studies, men with higher **education** levels were more vulnerable to heat (Turin: Ellena et al., 2020a; Barcelona: Marí-Dell'Olmo et al., 2019). With regard to 66 communities in China, heat wave effects on mortality were stronger in populations with longer education (Ma et al., 2015). In a study in 31 major Chines cities, the illiterates were more vulnerable (Yang et al., 2019). Latin American cities with higher levels of poverty and income inequality experienced smaller heat effects on mortality (Bakhtsiyarava et al., 2023). In a multi-city study (340 cities in 22 countries) higher inequality (Gini index) was associated with higher heat impact (Sera et al., 2019). **No employmen**t or being neither employed nor looking for work increases vulnerability (Ellena et al., 2020b; Ho et al., 2017)

Besides older people **children** are also a risk group (reviews from Ellena et al., 2020b and Arsad et al. 2020, Sheffield et al., 2018). In some studies, **younger age groups** turned out to be (more) vulnerable (Zhang et al., 2023; Astone & Vaalavuo 2022; Sandholz et al., 2021; Varghese et al., 2019; Joe et al., 2016; Fuhrmann et al., 2016; Hondula et al., 2015; Leone et al., 2013). Heat can lead to fatalities in high school and college football (Boden et al, 2013). Younger workers can also be vulnerable subgroups (heat illness, injuries) (Varghese et al, 2019; McInnes et al., 2017; Adam-Poupart et al., 2016), probably because they are lacking experience and awareness. Karthick et al. (2022) state in a review on that older construction workers (over 55) are more affected by heat stress. Petiti et al. (2013) found older workers (>/= 65) in agricultural occupations to be at high risk of heat-associated death. Workers aged >/= 55 years in agriculture, forestry and fishing, in the electricity, gas and water industry and tradespersons had a higher injury/heat illness risk during heatwaves in Adelaide (Xiang et al., 2014).

In addition to the aforementioned **occupations**, Kim et al. (2020) name welding, metal, and mining industries as occupations at risk. In addition, Saidi & Gauvin (2023) list workers in foundries, agriculture, food manufacturing, firefighting services and police. Workers in extraction also have higher heat risks (Jung et al., 2021; Petiti et al., 2013). Vulnerable subgroups in 3 Australian cities included apprentice/trainee workers and labour hire workers (Varghese et al., 2013). In their review on construction workers Karthick et al. (2022) list, inter alia, women, obese and underweight, bar benders, bar fixers, scaffolders, steel fixers, form workers, electricians, plumbers, and concrete workers. Working indoors can also be associated with severe heat stress (Karthick et al., 2022; Varghese et al., 2019; McInnes et al., 2017; Adam-Poupart et al., 2016). Non-manual occupations may also be associated with heat health risks (Adam-Poupart et al., 2016). Varghese et al. (2019), McInnes et al. (2017), and Petiti et al. (2013) found male worker to be at higher risk. Female workers were vulnerable to injury after a warm night (McInnes et al., 2017).

Agricultural labour may be involved in the fact that not only urban populations, but also **rural populations** are vulnerable to heat (Arsad et al., 2022; Odame et al., 2018; Kovach et al., 2016). Socioeconomic factors, worse medical infrastructure, and the aging population may also play a role (Arsad et al., 2022; Wu et al., 2011). Remoteness led to more health service usage during heat waves in Western Australia) (Xiao et al., 2017). In Madrid, rurality was a protective factor (Lopez-Bueno et al., 2021). A rather complex role of urbanization und rurality in heat vulnerability was found in Korea: The association between population density and heat-mortality risk was U-shaped, with the rural populations at the highest risk (Lee et al., 2022). In urban areas, heat-mortality risk increased with population density. This association has been found in many studies (Ellena et al., 2020b). Only in few studies building densities have been used, which can be very different from population density.

A strong influence on Urban Heat Islands is vegetation density (Chacraborty et al., 2019) and the percentage of impervious surfaces (Lee & Brown 2022; Krstic et al., 2017). Mortality rates during heatwaves are higher in districts with a low proportion of

green spaces (Kim & Kim 2017; Bao et al., 2015). Urban green and blue reduced heat-related mortality in the elderly population of Lisbon (Burkart et al., 2016). Residents living in greener areas of New York City were less likely to die during and immediately after heat waves (Madrigano et al., 2015).

Socio-economically marginalised communities often live in warmer neighbourhoods with less (access to) green spaces and surface water (Burbidge et al., 2022; Napieralski et al., 2022, Chacraborty et al., 2019; Harlan et al., 2006)). In almost all major U.S. cities, there was a disproportionate heat exposure, with people living in poverty and people of color bearing a higher burden (Hsu et al., 2021). One can speak of heat-stress inequality (Alizadeh et al., 2022), heat injustice (Burbidge et al., 2022), climate (in)justice (Mitchell & Chakraborty 2018), and climate gap (Shonkoff et al, 2011). As Mitchell and Chacraborty (2018) formulate it: "Urban heat and social vulnerability present a varying landscape of thermal inequity in different metropolitan areas". Such inequalities and disparities will increase in the future (Alizadeh et al., 2022; Benmarhina et al., 2015b).

Poor **housing conditions** lead to stronger heat effects (Lopez-Bueno et al., 2022; Bezgrebelna et al., 2021; Bélanger et al, 2015; Klein-Rosenthal et al., 2014). A large percentage of old buildings was associated with higher effects on mortality in Barcelona (Xu et al., 2013). Lack of thermal insulation and living on the top floor was a risk factor in the 2003 heatwave in France (Vandentorren et al., 2006), more rooms reduced the risk. Air conditioning reduces vulnerability (Sera et al., 2020; Gronlund, 2014). Less access to AC was a vulnerability factor in a systematic review (Arsad et al., 2022).

Ethnic/racial **minorities** are other vulnerable groups (Ellena et al., 2022b; Gronlund, 2014; Klein Rosental et al.; 2014; Hondula et al., 2012). Apart from socioeconomic reasons occupation, social isolation and linguistic isolation/language barriers (Ellena et al, 2022b; Nayak et al., 2018; Hansen et al., 2014) may play a role. However, Karthick et al. (2022) found that Caucasian construction workers are more susceptible to heat. Persons living alone, being widowed, divorced, separated or never married are more vulnerable (Xia et al., 20023; Wong et al., 2016; Bao et al., 2015; Schifano et al., 2009; Staffoggia et al., 2006). These characteristics may be seen as proxies for social isolation (Ellena et al, 2020b; Kim et al, 2020). Social cohesion (Niu et al., 2021) and community stability (Sandholz et al., 2021) reduce vulnerability. Fear of crime can get people not to open windows in the night or travel to cooler places, as an ethnographic study of the 1995 Chicago heat wave showed (Klinenberg, 1999). Lack of mobility (Vandentorren et al., 2006) or lack of access to a vehicle (Renteria et al., 2022; Sabrin et al., 2022) are risk factors, too.

The **homeless** are also a heat-vulnerable group (Schwarz et al., 2022; Bezgrebelna et al., 2021; Ramin & Svoboda 2009), as are tourists (Hansen et al., 2013). Home ownership seems to be a protective factor (Ellena et al., 2020b; Mitchell & Chacraborty 2018).

With regard to **gender**, the majority of studies highlighted that females are at higher risk during heatwaves. However, Ngarambe et al. (2022), Kathana et al. (2022) and Salvador et al. (2023) reported the opposite. Mashhoodi (2021) found a “feminization of surface temperature” in 2400 Dutch residential zones and argues that this is more likely to occur in moderate climates with their high variations in land surface temperatures.

Finally, it has to be stressed that heat and climate change are important issues for socioeconomic equity, public health and human rights (Shonkoff et al., 2011).

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