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Heat stress risk and resilience in the urban environment

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ABSTRACT

Heatwaves have been subject to significant attention in Australia and globally due to their negative impacts on the ecosystem, infrastructure, human health and social life. Measures to increase resilience to heatwaves, however, are mostly isolated in different disciplines. This paper proposes a framework integrating urban and infrastructure planning, building design, public health and social research to comprehensively assess heat stress resilience. The proposed framework can assist decision makers in the evaluation of different policy changes addressing heat stress resilience and contribute to more comprehensive and effective heatwave management.

An online survey was undertaken with a representative sample (N = 393) from Adelaide, South Australia, to explore heat stress resistance of the built environment, adaptation and heat-related, self-reported health problems. The study established the magnitudes of the secondary negative impacts of heatwaves on public health and daily routines. The findings identify a low level of resistance to heat stress by the built environment. It was concluded that community education along with focused building and planning regulations has the potential to significantly increase heat stress resilience.

1. Literature review of heat stress resilience

Heatwaves can have a negative impact on the ecosystem, infrastructure, human health and social life (Zuo et al., 2014). The two most commonly researched negative impacts relate to health outcomes (Bi et al., 2011; Li, Gu, Bi, Yang, & Liu, 2015) and excess electricity demand (Santamouris, 2014; Santamouris, Cartalis, Synnefa, & Kolokotsa, 2015). In Australia, heatwaves are responsible for more deaths than all other natural hazards combined (Coates, Haynes, O'Brien, McAneney, & De Oliveira, 2014). Peak electricity demand increases the risk of power outages, depriving individuals from air-conditioning (Maller & Strengers, 2011). The disproportionally high electricity demand is reflected in increasing electricity prices (Saman et al., 2013) that are the main contributors to energy poverty (Chester & Morris, 2011). A third negative impact of heatwaves that has been under-researched is excess water use (Hatvani-Kovacs, Belusko, Pockett, & Boland, 2016). Excess water use can be more detrimental in cities suffering from water scarcity (Tapper, 2012), especially in the context of climate change.

Heat-related vulnerability has only been investigated by public health researchers (Maller & Strengers, 2011), hence other important impacts such as peak electricity and water demands have been neglected, even though these issues are critical. Morbidity, excess energy and water use are intertwined. Excess electricity consumption due to cooling is acknowledged as a preventative measure against morbidity (Patz, Frumkin, Holloway, Vimont, & Haines, 2014). Further preventative measures are increased green spaces (Mirzaei, Olsthoorn, Torjan, & Haghighat, 2015) and irrigation (Georgescu, Morefield, Bierwagen, & Weaver, 2014) that can decrease air temperature of the microclimate. Therefore, the three infrastructures of public health, energy and water supplies should be interpreted simultaneously. Such an integrative assessment of vulnerability and negative impacts would provide a more comprehensive assessment of heat stress resilience and heatwave management.

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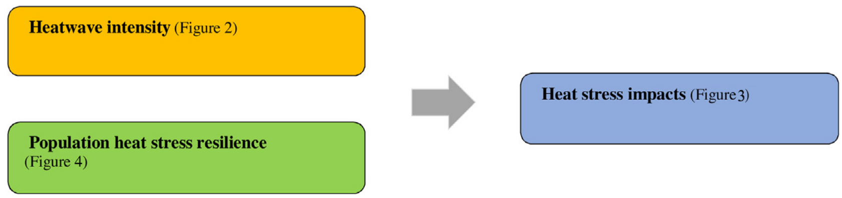

Fig. 1. The assessment of heat stress risk.

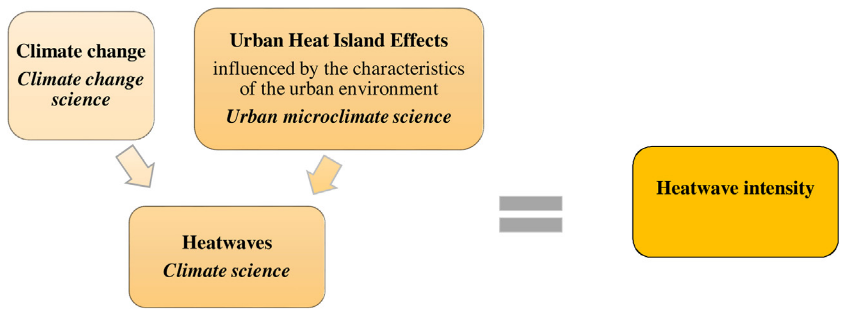

Fig. 2. Contributors to heatwave intensity (the research disciplines of the elements are displayed in italics).

A further concern regarding vulnerability is that only a limited number of studies have evaluated self-reported health problems, instead of mortality or morbidity data recorded by Coroners' offices, hospitals and/or ambulance services (Bi et al., 2011; Coates et al., 2014; Li et al., 2015; Nitschke et al., 2011). They have concentrated on particularly vulnerable social groups such as lower socioeconomic and aged communities (Bélanger, Gosselin, Valois, & Abdous, 2015; Nitschke et al., 2013). Hence, still more information is needed about the broader health impacts of heatwaves on the general population.

One approach to analyse vulnerability is heatwave vulnerability mapping. This method considers further demographic and urban characteristics to inform public health services about the expected number of heat-related health incidences across metropolitan regions (Bao, Li, & Yu, 2015; Chow, Chuang, & Gober, 2012; Huang, Zhou, & Cadenasso, 2011; Keramitsoglou et al., 2013; Loughnan, Tapper, Phan, & McInnes, 2014; Tomlinson, Chapman, Thornes, & Baker, 2011). Vulnerability mapping relies on census and GIS based urban datasets (Zaidi & Pelling, 2015) that are aggregated at a neighbourhood scale and, consequently, cannot differentiate household characteristics. Consequently, vulnerability mapping neglects the capacity for individual adaptation (Zaidi & Pelling, 2015). Studies considering individual adaptation capacity to heatwaves have, meanwhile, focused only on special social groups (Bélanger, Abdous, Gosselin, & Valois, 2015; Loughnan, Carroll, & Tapper, 2014a; Nitschke et al., 2013). Extending the conclusion of Zaidi and Pelling (2015) about the overlooked importance of adaptation at an individual scale, the various heat stress resistant characteristics of the built environment is also a critical element. Only a limited body of research has investigated the impact of the heat stress resistance of buildings on heat-related health problems (Bélanger, Gosselin et al., 2015; Loughnan, Carroll, & Tapper, 2014b; Taylor et al., 2015). Heat stress resistance will be a significant concern into the future, since cooling compared to heating consumption will rise with the combined increasing number of energy efficient buildings and climate change (Karimpour, Belusko, Xing, Boland, & Bruno, 2015; Saman et al., 2013).

Consequently, the current knowledge is incomplete regarding heat stress resistance of the existing building stock, the adaptation capacity of the general population, and the efficacies of heat stress resistant features and adaptation techniques to decrease heat-related negative health problems. Therefore, urban design and public health policies lack sufficient consideration to implement heat stress resistant building design (Zuo et al., 2014) and adaptive measures (Fernandez Milan & Creutzig, 2015; Maller & Strengers, 2011). The current study is designed to address these data and policy gaps. Hence the aims of this paper are to: (1) propose a new framework for urban heat stress risk and resilience and (2) explore the elements of heat stress resilience. Heat stress resilience is explored from a representative survey sample of the Adelaide metropolitan region, South Australia (SA).

2. The framework of heat stress risk and heat stress resilience

The framework of climate-related impacts devised by the IPCC (Intergovernmental Panel on Climate Change, 2014) was applied to study heat stress risk. According to the IPCC framework, the impact of risk is influenced by three elements, including hazard, the vulnerability and the exposure. Adaptation and mitigation are captured only as a secondary socioeconomic process. Tran et al. (2013) devised a similar framework, complete with adaptation, however the connection between adaptation, vulnerability and exposure was only noted but not explored. Furthermore, they neglected the fact that the majority of adaptation techniques, such as air-conditioning or nocturnal ventilation, do influence the level of exposure.

In the proposed framework, hazard refers to heat stress. The impact of heat stress depends on two independent variables, namely the heatwave intensity and the mechanism of the population heat stress resilience (Fig. 1).

The first aspect of heat stress risk assessment is the intensity of a heatwave (Fig. 2) that can be exacerbated by climate change (Intergovernmental Panel on Climate Change, 2013; Nairn & Fawcett, 2013; Perkins & Alexander, 2013) and urban heat island effects (UHIEs) (Santamouris, 2015). Some urban scale mitigation techniques can mitigate the intensity of heatwaves and increase the heat stress resistance of the built environment (Gartland, 2008). For example, the application of materials with high solar reflectance in the built environment, such as reflective roof tops, can simultaneously save energy, increase thermal comfort, mitigate UHIEs and decrease carbon emissions (Cotana et al., 2014). Mitigation is, nevertheless, beyond the scope of this study.