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Drivers of self-reported heat stress in the Australian labour force

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ABSTRACT

Heat stress causes reductions in well-being and health. As average annual temperatures increase, heat stress is expected to affect more people. While most research on heat stress has explored how exposure to heat affects functioning of the human organism, stress from heat can be manifest long before clinical symptoms are evident, with profound effects on behavior. Here we add to the little research conducted on these subclinical effects of environmental heat using results from an Australian-wide cross-sectional study of nearly 2000 respondents on their self-reported level of heat stress. Slightly less than half (47%) of the respondents perceived themselves as at least sometimes, often or very often stressed by heat during the previous 12 months. Health status and smoking behavior had the expected impact on self-reported perceived heat stress. There were also regional differences with people living in South Australia, Victoria and New South Wales most likely to have reported to have felt heat stressed. People generally worried about climate change, who had been influenced by recent heat waves and who thought there was a relationship between climate change and health were also more likely to have been heat stressed. Surprisingly average maximum temperatures did not significantly explain heat stress but stress was greater among people who perceived the day of the survey as hotter than usual. Currently heat stress indices are largely based on monitoring the environment and physical limitations to people coping with heat. Our results suggest that psychological perceptions of heat need to be considered when predicting how people will be affected by heat under climate change and when developing heat relief and climate change adaptation plans, at work, at home or in public spaces. We further conclude that the perception of temperature and heat stress complements measures that assess heat exposure and heat strain.

1. Introduction

Globally, February 2016 was the hottest month, seasonally adjusted, since records began in 1880 (NOAA, 2016). Before that 2014 and also 2015 had the highest globally-averaged temperatures (NASA, 2016). Besides higher average temperatures, more frequent and longer lasting heat waves are predicted for the coming decades (Meehl and Tebaldi, 2004; Perkins et al., 2012; Coumou et al., 2013). Extreme heat is a leading cause of weather-related human mortality and morbidity in many countries (Kovats and Hajat, 2008; Luber and McGeehin, 2008; Costello et al., 2009; Bi et al., 2011). Heat stress can also exacerbate vulnerabilities to other hazards (Epstein and Moran, 2006) and amplify preexisting medical conditions (Huang et al., 2011; Vardoulakis et al., 2014). While acclimatization to heat may help, it may not protect humans from unprecedented or intolerable heat stress under severe warming scenarios (Sherwood and Huber, 2010).

So far, most work-heat related research, spanning disciplines such as physiology, epidemiology and ergonomics, has concentrated on people working under physical strain, such as construction workers, farmers and soldiers, and on people working in hot environments and/or wearing heavy clothing, such as fire fighters (Xiang et al., 2014a). This kind of research has also been restricted to exploring the link between heat exposure, measured using techniques such as wet bulb globe temperature (WBGT), the heat strain model (Malchaire, 2006) or thermal work limit (TWL) (Miller and Bates, 2007), and the physical symptoms of heat stress such as heat cramps, fainting, heat exhaustion and fatigue.

Heat stress research in the workplace has also helped understand and reduce vulnerability to heat by improving social, environmental, behavioral and health care and safety advice for when exceptionally hot conditions occur (Carson et al., 2006; Akompab et al., 2013; Lao et al., 2016). There is a growing body of literature, including from Australia, relating non-climatic parameters to workplace heat stress and impacts such as higher rates of accidents (Tawatsupa et al., 2013; Xiang et al., 2014b), distortions of time perception (Tamm et al., 2014), decision quality (McMorris et al., 2006; Gaoua et al., 2011) and productivity

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reductions (Kjellstrom et al., 2011; Sahu et al., 2013; Singh et al., 2013). Most of this research is confined to industries characterized by high ambient heat or levels of physical exertion. However, heat can cause stress without physical symptoms and can also occur among people not working in hot conditions or undertaking physical labour but who are exposed to hot weather in their daily environment (Zander et al., 2015). This suggests that there are factors other than the physical limits of core body temperature and actual heat exposure that can affect how a person copes with heat. Understanding these subclinical, largely psychological effects of heat have the potential to improve productivity and wellbeing in the same way that understanding the physical impacts of heat has decreased mortality and morbidity.

This study explores perceived heat stress of the general workforce in Australia, and specifically the factors affecting it. Understanding peoples' reported heat stress complements findings from research on actual heat exposure and symptoms of heat illness. Knowing what determines people's self-perceived heat stress is important for future adaptation. Any sign of heat stress, even as apparently trivial as feeling irritated, is important as it can already reduce people's well-being and productivity, and more severe heat stress can turn into serious heat illness. Once heat stress turns into serious adaptation capacity is compromised. It is therefore far better to address precursors of heat stress before physical stress is manifest. To the best of our knowledge, this is the first study anywhere that investigates factors affecting self-reported heat stress. The findings may improve understanding of the factors that need to be managed to support the public in dealing with increasing heat in Australia.

Our study differs from existing studies on occupational heat stress and vulnerability to heat stress/illness by asking explicitly about self-perceived heat stress over a one year time period, not during a specific heat wave, doing exercise or when working in hot environments.. Deliberately, we neither defined heat stress nor asked about different symptoms or heat illness. In so doing we acknowledged that individual responses to hot weather are likely to vary, with heat causing mild fatigue in one person inducing heat-related illness in another.

Many parts of Australia are generally hot throughout the year. Compared to the climate of recent decades, average temperatures are projected to rise by between 1.0 and 5.0 °C by 2070 and the number of heatwaves triple by 2050 (CSIRO and Bureau of Meteorology, 2014). Heat waves during summer in Australian cities are considered to have claimed more lives than any other natural disaster in the country (Coates et al., 2014). Each of the last three years (2014–2016) has set new records for heat across the country (Steffen and Fenwick, 2016) and in 2016 heat records have already been broken in the two most populated states: Victoria (9 °C above average for March; the hottest March on records ever; BoM, 2016) and New South Wales (7 °C above average for March).

2. Methods

2.1. Potential determinants of human heat stress and heat-related illness

If a person is exposed to a hot environment their level of heat stress depends on the interaction between the heat produced inside their body as a result of physical activity and the factors governing heat transfer between their body and the atmosphere (Parsons, 2009). Five factors (metabolic heat production of the body, clothing, air temperature, radiant temperature, humidity and air velocity) are usually included when calculating heat exposure in working environments (Parsons, 2009). Underlying physiological and psychological factors also influence vulnerability to heat waves (Basu, 2009; Gosling et al., 2009; Reid et al., 2009; Huang et al., 2011; Gronlund, 2014; Li et al., 2015; Table S1). These factors can be categorised into four types:

i) socio-economic and demographic (e.g. education, occupation (sector, workload), income, ethnicity),
ii) physical (illness, health and fitness, alcohol intake and smoking habits, age, gender),
iii) psychological (perceptions, experience),
iv) environmental (includes not only parameters such as temperature, humidity, rainfall and wind but also a person's location such as living/working near water, in the city or rural areas, their housing conditions such as insolation, availability of air-conditioning, and the local physical infrastructure to support heat relief).

Many of the factors are related. Older people, for instance, are more vulnerable to heat stress because they are less able to regulate and adapt their body temperature (Verbeke et al., 2001; Michelozzi et al., 2005) and they are also more susceptible to chronical illness and disabilities which may reduce their capacity to sweat and the efficiency of their cardiovascular system in distributing heat (Rowlinson et al., 2014). People of low socio-economic status and income are particularly susceptible to extreme heat events (Uejio et al., 2011; Zhang et al., 2013), for example, because they are less likely to purchase and operate air-conditioning (Gronlund, 2014).

Of the four groups, the least understood is that related to people's cognitive and psychological states (perceptions of climate change and experience of previous extreme weather events and temperature). Perceived personal experience with global warming, which is important for adaptation (Adger et al., 2007; Howe and Leiserowitz, 2013), increases certainty in the belief that global warming is happening (Spence et al., 2011; Akerlof et al., 2013; Howe and Leiserowitz, 2013) but whether this then affects the level of heat stress is unknown. It is known that the perception of temperature positively influences the concerns about climate change (Li et al., 2015) and that concerns about climate change positively influence the distress about it happening (Searle and Gow, 2010) but links between climate change concerns and heat stress as well as perceptions of temperature and heat stress are not yet well understood.

2.2. Sampling and data collection

The survey was delivered through a commissioned online survey (through MyOpinions PermissionCorp) during two waves, the first one in the first two weeks of May 2014, and the second one in the first two weeks of October 2014. Two reasons led to the choice of these two waves. First we tried to avoid very hot or cold periods across of Australia. Secondly, the replication of the same survey allowed us to compare the results and test the validity of our findings.

At the time of the survey MyOpinions had an active panel of 300,000 verified respondents which was actively managed panel in order to adhere to a strict "research only" policy governed by industry bodies such as ESOMAR, AMSRS and AMSRO. MyOpinions was also accredited to ISO 20252 and ISO 26362 to validate a commitment to professional standards and guidelines. Approximately half the panel had been recruited from a wide range of offline sources, the remainder having been recruited online. MyOpinions offered $2 to complete the survey which took 13–15 min to complete.

The sample frame consisted of panel members who were in the labourforce at the time of the survey with the age limited to between 18 and 65. The survey was conducted as follows: first, an invitation was emailed from the internet survey company to a random sample of eligible panel members (the predetermined sample frame) stratified by gender and age so that the final sample had similar proportions to the Australian labourforce population of 18 years and older. To avoid self-selection bias, panel members were not informed of the survey topic until they had agreed to complete the questionnaire. Nearly 24% of the 9,406 individuals who were contacted agreed to undertake the survey. Of these 86% (1,925) completed it.

The questionnaire had three parts:

Part 1. Demographic data (age, gender, postcode, income).