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Employee Wellness in a Changing Climate: Environmental Heat Stress Driving Need for Targeted Health Promotion and Risk Reduction

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Abstract

Objectives: Evaluate the effects of increased ambient temperatures among outdoor workers on physiological heat stress through continuous monitoring of heart rate variability. **Methods:** A digital smartphone health promotion application was deployed to engage and educate construction workers about stress and other risk reduction; to determine body mass index; and to measure the impact of elevated temperatures on physiological stress measured by tracking continuous non-exertional heart rate variability using a wearable device over 24 hours. **Results:** Post-program self-rating of health status improved among 56% of participants. A linear relationship was observed between external ambient temperature and physiological stress. Healthy weight people demonstrated less dynamic HRV change and stress with rising temperature compared to those obese/overweight. Physiological stress levels peaked during the hottest hours of the day, with high BMI workers having the greatest increases in stress. **Conclusions:** Physiological heat stress is impacting outdoor workers in the construction industry, with greater severity observed as BMI increases. Framing climate change as an occupational health issue will help employers understand and mitigate the negative impact of a changing climate on outdoor workers. Use of personal mobile digital technology enables employers to effectively monitor and target physiological heat stress and mental stress among at-risk employees.

Keywords: Climate Change, Employee Health, Employee Wellness, Heat Stress, Mental Stress

1. Introduction

1.1 Global Climate Change and Increased Risk and Incidence of Heat Stress

The effects of climate change are manifesting globally across multiple dimensions of organizational and individual life and wellness, as continued greenhouse gas emissions into the Earth's atmosphere produce extreme weather events, record high temperatures, rising sea levels, and other negative impact[1]. Mitigating and acclimating to climate change where possible in coming years will require global, national and local efforts, as well as employer organizational and individual worker adaptation across many different areas of human activity including in the home, in community and public settings, and in the workplace. This analysis focuses on the effects of increased ambient temperatures in the work environment, and the resultant physiological heat and mental stress affecting employees in the workplace. Evidence is presented that demonstrates how rising temperatures attributable to climate change have created a discrete physical and mental health risk for workers across the globe. This can be expected to continue and potentially increase as climate change worsens in coming years and decades, and therefore employers should take steps to adapt now in order to protect the health and safety of their workers.

As of 2017, human-induced climate change elevated mean global temperatures approximately 1 degree centigrade above pre-industrial era levels, an increase of about 0.2

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degrees centigrade per decade[2]. The effects of climate change are widespread today, with extreme weather events an increasingly frequent and recognizable indicator of changing global temperatures. For example, in 2021, North America experienced multiple record-breaking heat waves during the northern hemisphere summer which contributed to many fatalities, while New Zealand simultaneously experienced an extreme cold snap during the southern hemisphere winter season[3,4]. These extreme temperature and weather events will become more commonplace in coming years as greenhouse gases continue to increase in the atmosphere[1,2].

As climate change progresses, one factor that human populations will have to adapt to is the effect of intensified heat. Heat stress is one of the most direct deleterious effects whereby climate change negatively impacts human health in general, and specifically within the workplace[5,6]. The Intergovernmental Panel on Climate Change (IPCC) reviewed and collated extensive data predicting that there will be warmer and more frequent hot days and nights over most land areas during the remaining decades of the 21st century[5]. Heat stress caused by elevated global temperatures will especially impact workers in industries where it is difficult to control local workplace temperature within indoor environments. However, outdoor workers will be the most vulnerable to heat stress and its broader impact on health and well-being. Among the primary sectors expected to be affected directly by increasing climate change induced heat stress will be workers within agriculture, construction, delivery services, fisheries, forestry, manufacturing and transportation industries, and those employed in outdoor and semi-outdoor workspaces lacking adequate air conditioning[7].

Factors which contribute to and exacerbate heat stress in the workplace include an urban "heat island effect" where urban construction and density intensify the buildup of heat, the intensity of physical work/labor, individual physiological differences and vulnerabilities (e.g., from existing chronic diseases or excess body weight), and work in low-income settings where mitigation or prevention of severe heat exposure is often not possible[7]. Climate change creates many potential problems and hazards in the workplace, especially in the aforementioned sectors. Among them are increased ambient temperatures, air pollution, ultraviolet radiation exposure, disruptive weather, and enhanced transmission and spread of vector-borne diseases[7]. In addition, research shows that the impact of severe heat stress and heat exposure at work can extend beyond work hours and affect workers outside the workplace and in their homes[7]. Chronic heat stress can cause serious health problems for workers, including heat stroke, heat exhaustion, rhabdomyolysis, heat cramps, heat rash, and liver and kidney problems resulting from dehydration[8,9].

The impacts of a changing climate on employee health and wellness in at-risk industries are likely to already be manifesting and will worsen in coming decades. Thus it is critical for workplaces across industries – especially those where outdoor or manual labor is substantial – to anticipate and plan to manage the effects of heat stress on workers. Climate change is rapidly becoming an occupational health risk for many workplaces, with potentially severe effects on worker health among those exposed to intense heat. It is estimated that nearly 70 million work-life years will be lost by 2030 as a result of reduced labor productivity and increased worker absenteeism due to heat stress[9,10]. Climate change and heat stress as occupational health issues are not part of a distant reality – they are already occurring today and require planning and preparation to protect and support the well-being of workers across industries. This study systematically captured construction worker heat stress data to provide insight on outdoor heat exposure, so that the issue can be targeted and prevented before causing major disruptions in the workplace.

2. Methods

2.1 Intervention Objectives and Technology Deployed

An on-demand, digital interactive mobile application was deployed via smartphone to engage, educate, socially connect and motivate employees in a stress reduction and wellness promotion program. The application platform used to deliver the intervention suite and to capture impact data was the Wellteq V.1 smartphone application. The program objective was to drive specific digital stress reduction, wellness engagement and education content and functionality to employee participants, and then measure the impact of the program. The vehicle used by participants to receive communications and share their data was their personal smartphone.

The construction firm engaged an employee wellness initiative involving a six-month personalized, digital health promotion program which included use of the aforementioned mobile application. The program, a health promotion "Tune Up Challenge", focused on two main areas for preventive intervention: engagement to create positive health changes through personalized, digital support and on-site health education services; and improved understanding of the impact of stress on health and in the working environment (including exposure to excessive heat). The program included two four-week stress reduction challenges implemented for a leading Australian construction firm. This was supported by onsite health and wellness practitioners (nurses or licensed vocational

Figure 1. Mobility of engagement, content delivery, functionality, and impact measurement.

nurses), who conducted physical health checks and engaged additional in-person educational sessions.

The technology implementation deployed a digital mobile platform with continuous stress monitoring via Garmin Vivo smart wearables, in-application wellness surveys, and onsite health assessments. The on-demand mobile application and platform engaged, educated and motivated participating employees, and measured the impact of the program on self-reported mental stress reduction and the comprehension and adoption of health promotion/illness risk reduction behaviours. Figure 1 illustrates the kind of mobile functionality through which participating employees were engaged and conveyed education and motivation to drive personal stress and other risk reduction, and to promote wellness.

2.2 Study Setting

The wellness promotion/stress reduction program was implemented in an enterprise setting within the employee population of a leading construction firm in Australia. The construction work settings involved substantial job functions in outdoors settings. All participants owned mobile smartphones onto which the stress reduction and wellness promotion application was downloaded, and through which employee engagement and messaging occurred.

2.3 Study Participants and Selection

Employee participants self-selected or volunteered for the program, which included modest engagement and performance incentives. Of 97 employee participants, 89% were male. Job roles included labourers (32%), engineers (31%), office staff (20%), operators (13%) and administration (4%). A majority of participants had an overweight (43%) or obese (30%) body mass index (BMI), with only 26% in the healthy range and 1% were underweight. Eighty percent of participants completed the first program challenge, and 67% completed the second challenge of the program.

2.4 Intervention Content and Outcomes Metrics Captured

The stress reduction intervention methods deployed over the course of the 6-month program included easy to assimilate, timely online and onsite employee stress education, risk reduction and physical activity promotion. These were enhanced with targeted mental well-being e-learning and content modules on the importance of, and methods for, reducing avoidable stress. All interventions were embedded within a communication and engagement framework that conveyed emotionally reinforcing and supportive motivational messaging at critical junctures. Straightforward messages conveyed personalized practical educational content, instructive tips, and resources around the importance and "how to" of reducing stress and promoting wellness.

The digital health promotion program involved individual and group challenges. Perceptions of health status, wellness and stress were recorded using a health risk assessment (HRA) tool. Physiological stress levels were measured by tracking continuous non-exertional heart rate variability (HRV), a stress indicator, through the Garmin watch wearable. HRV was not recorded when participants were exercising or physically active, so as not to confound stress with physical exertion. Personal program performance metrics were conveyed to employee participants, and awards and incentives deployed to increase adoption of stress reduction and general wellness promoting behaviors, program compliance and completion. The design of the digital engagement and education programs were based on peer reviewed scientific evidence of behavioural response or engagement, and sustained impact.

The digital program included the application of brief HRA and status assessments, with a focus on attainable employee health behaviour change, including perceived reduction in workplace and home stress, along with several general wellness indicators. This data capture was leveraged in an individually targeted manner to motivate engagement of needed stress reduction behaviors and cognitive techniques. Education was communicated through the mobile application as well as onsite engagement, focusing on the unhealthy impact of stress and how to manage it through increased mindfulness, active stress reduction, and cognitive and physical relaxation techniques. Mobile application content and functionality were deployed in a manner that dovetailed into and was synergistic with onsite engagement. Combining Garmin's powerful wearable device capabilities with sophisticated employee data analytics and insights engines enabled 24-hour mapping of the daily lifecycle of individual physiological stress among participating employees.

Participants provided information enabling calculation of their BMI. Changes in the measured non-exertional heart rate variability or HRV over the course of 24 hours served as a sensitive indicator of experienced stress level and were tracked with changing external temperature for outside workers exposed to ambient temperatures, and then stratified by participant BMI.

3. Results

The program demonstrated substantial improvements in key measures of participants' health risk as measured by HRAs completed through the Wellteq mobile digital application and on-site health assessments. In addition, increased stress as measured by continuous HRV monitoring demonstrated a direct relationship with rising external temperature among outside workers.

3.1 Perceived Health Status Improvement

Post-program self-rating of health status improved among 56% of participants, 32% stated that their health status was unchanged, and 12% stated it had deteriorated. After six months of participation in the Tune Up challenge, the following improvements were observed: a 44% improvement in participants' rating of their health status; a 15% improvement in reported resiliency; a 29% increase in energy levels; a 20% increase in daily water consumption; a 25% decrease in daily cigarette consumption (with one out of six quitting), and a 30% reduction in consumption of sugary drinks. Reported stress levels decreased by 37% at home, and by 10% at work.

3.2 Body Weight and Heat Induced Physiological Stress

There was a linear relationship between external ambient temperature and physiological stress (Figure 2). Healthy weight individuals demonstrated relatively less dynamic change in stress level than other groups, as indicated by heart rate variability, throughout the day and with changing outdoor temperatures. Underweight participants had the largest changes in experienced stress, while overweight and obese individuals experienced increased substantial stress particularly when temperatures were markedly elevated.

The exacerbation in experienced stress may reflect reduced thermoregulatory system effectiveness among those who were overweight, obese or underweight, with elevated

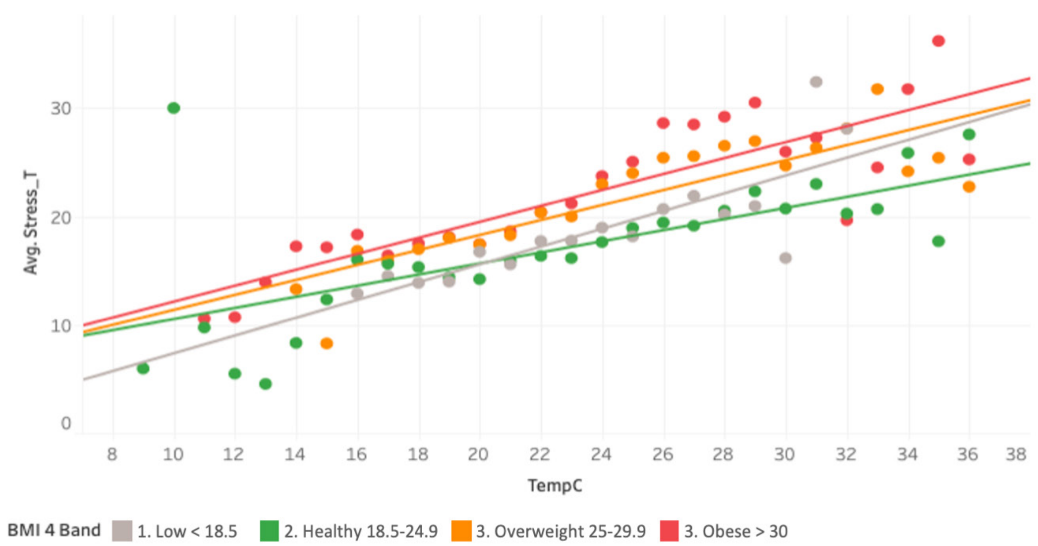

Figure 2. Heat stress-induced heart rate variability by temperature and body mass index.

ambient temperatures increasing stress on cardiac and other physiological functioning. Figure 2 demonstrates the stress-induced HRV observed over 24 hours stratified by the participants' BMI across 4 strata of low, healthy, overweight and obese BMI. As temperature increased, those who were overweight or obese experienced the most stress, with stress level peaking across the hottest hours of the day.

Figure 3 shows the relationship between BMI, stress and time of day. While individuals in most BMI segments demonstrated increased stress during the hottest hours of the day, those with greater BMI and obese or overweight had the greatest sustained increases.

3.3 Occupational Role and Stress

Based on the HRV data collected, a higher rate of physiological stress was observed among operators and laborers – both of whom are outdoor/external workers exposed to ambient heat during the hottest hours of the day (Figure 4). This is likely due to individuals in these occupational roles having greater exposure to environmental factors such as heat and direct sun, which can produce physiological heat stress and associated mental stress[7]. Engineers and administrative workers had the lowest stress responses over the 24-hour observation period, presumably due to their lack of exposure to severe heat relative to the outdoor workers. The solid blue curve in Figure 4 tracks the mean heat stress-induced HRV across all occupational roles.

4. Discussion

Our findings indicate that the magnitude of physiological stress produced rises with increasing temperature, and climbs most dramatically as BMI increases, with individuals who are overweight or obese experiencing the greatest stress levels. As the impact of climate change grows in coming years, outdoor workers will likely be exposed to higher peak daily

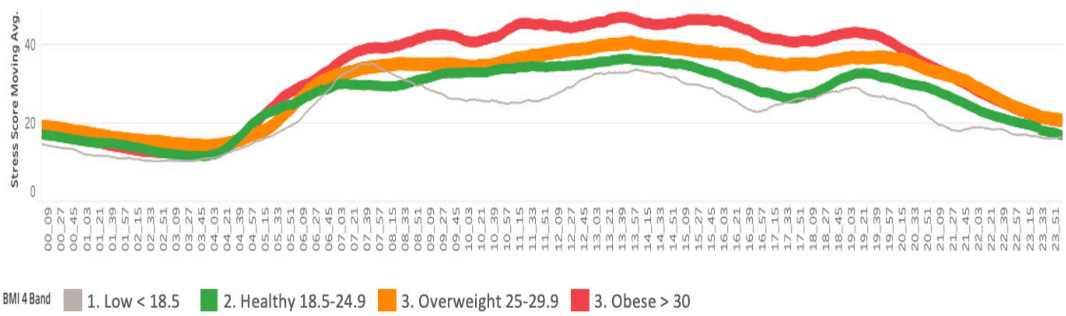

Figure 3. Heat stress-induced heart rate variability by time of day and body mass index.

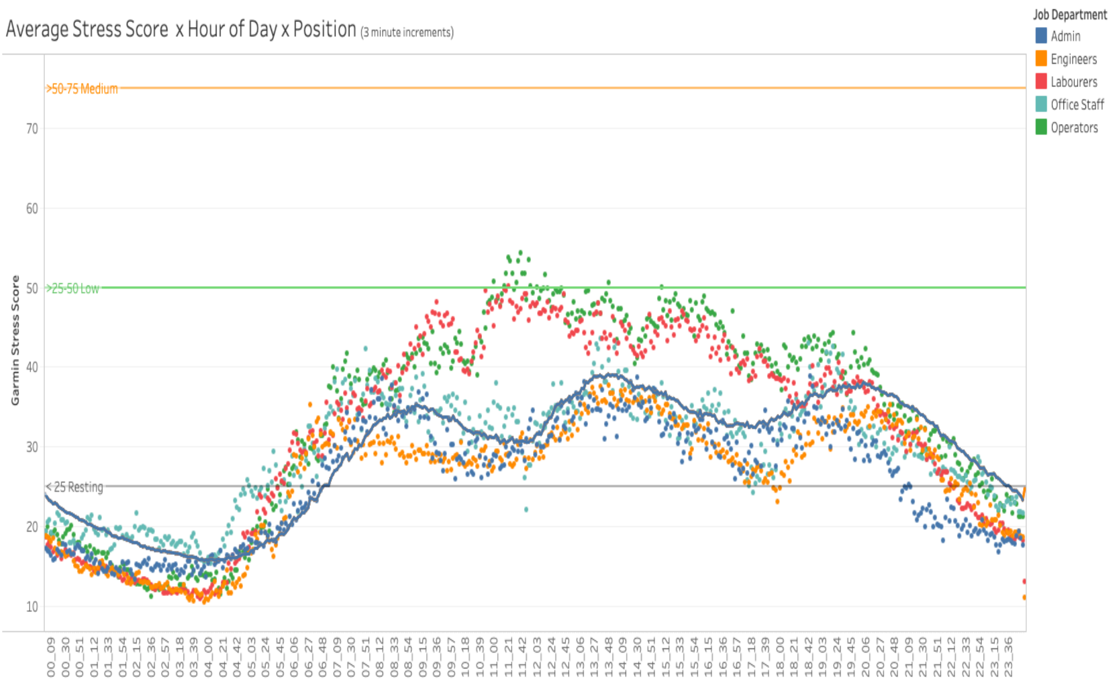

Figure 4. Heat stress-induced heart rate variability by time of day and occupational role.

temperatures, causing increased physiological heat stress and resultant mental stress with compromise of wellness/well-being. In order to interrupt this mounting challenge to employee wellness, future programs and research should assess the potential value and impact – and any associations – between more frequent work breaks, consumption of caffeinated drinks which can exacerbate experienced stress, and the nutritional profile of food consumed by outdoor workers in order to identify which of these, if any, may be contributing factors.

The program deployed to measure physiological heat stress and resulting mental stress in workers provides valuable analyses to inform employers of this risk among outdoor workers, and enables them to implement outdoor work policies and processes that may reduce the impact of heat and mental stress on their employees who work outside and are routinely exposed at length to elevated ambient temperatures. Increasing global temperatures will make efforts to mitigate the risk and impact of heat stress on outdoor workers an employer health and safety imperative. Programs and personalized wearable technologies and applications such as those deployed in this study can aid in measuring the magnitude of heat stress experienced among outdoor workers, and evaluate the impact and value of specific measures taken to mitigate heat stress and the magnitude of mental stress change that results.

The literature on climate change, heat stress, and occupational health focuses largely on the causal links between them and the potential effects that increased heat stress and a hotter climate will have on outdoor workers and their employers[5,7,9,10]. The data presented in this analysis shows concrete ways employers can detect, monitor, and target heat stress within at-risk categories of their employee population. As climate change worsens and heat stress becomes a more common and severe problem, collecting such data will be invaluable to employers and workers alike. Productivity and absenteeism, as well as avoidable health care utilization, are negatively impacted by heat and mental stress, and thus compelling efforts to reduce stress and increase resiliency among exposed employees across different work settings may yield a positive return on investment by improving employee physical and mental health and well-being[7,9,10].

5. Conclusions

The negative impact of climate change on workers is an increasing problem that will confront many industries across global markets and regions in coming decades. As these analyses demonstrate, its effects are already being experienced in Australia. Rising temperatures will have a severe impact on human health[5]. In particular, workers who are exposed regularly to heat outdoors – such as those in agriculture, the construction and forestry industries, fisheries, transportation and delivery services, and employees working in outdoor workspaces, in semi-outdoor workshops and settings – are at elevated risk[7]. Workers with high BMI will be at particularly high risk, as shown by our data. Heat stress increases risk of worker health problems such as heat stroke, heat exhaustion, rhabdomyolysis, heat cramps, heat rash, and liver and kidney problems caused by moderate to severe dehydration[8,9].

The continued framing of climate change as an occupational health issue will be essential in helping employers understand that mitigating the negative effects of a changing climate on their exposed workers is imperative. Increasing incidence of heat stress among exposed employees presents a major threat to their health, safety, and well-being which can in turn impact the performance of companies through decreased productivity and increased absenteeism due to injury or illness, along with associated employee avoidable health care utilization[9,10].

Deployment and use of personal mobile digital technology and interventions like those described and evaluated in this study illustrate how companies can effectively and cost-effectively detect, measure, monitor and target physiological heat stress and resultant mental stress occurring among their employees. These technologies offer substantial value to employers, enabling efforts to manage the consequences of rising temperatures in at-risk worker segments.

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