PRESS RELEASE

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Heat stress causes lower fertility, productivity and reduced cognitive capacity: Project HeatSafe

18 March 2024, Singapore – How much of an impact and influence does heat stress have on one's health, work productivity and even the economy? Led by Lead Principal Investigator Associate Professor Jason Lee, Deputy Director of the Human Potential Translational Research Programme (HPTRP), and Director of the Heat Resilience and Performance Centre at the Yong Loo Lin School of Medicine, National University of Singapore (NUS Medicine), Project HeatSafe is the first large-scale study in Singapore and the region aimed at investigating the impact of rising heat levels on the health, productivity and well-being of occupational workers in tropical climates such as Singapore, on an individual level, as well as the impact of heat stress on a macroeconomic and national level.

Funded by Singapore's National Research Foundation, the key partners of Project HeatSafe include the Singapore-ETH Centre, Singapore's Ministry of Manpower, and Workplace Safety and Health Institute as well as overseas institutions such as the Health and Environment International Trust, Tsinghua University, Vietnam Military Medical University, Institute of Technology of Cambodia and Seoul National University.

[1]According to the Third National Climate Change Study by Singapore's Centre for Climate Research Singapore, there will be increasingly more warm nights, on top of hotter days. Occurrences of high heat stress will significantly be more frequent than occurrences of moderate heat stress.

The findings from Project HeatSafe give a multi-faceted perspective of how heat stress, will lead to detrimental impacts and consequences on the individual, from compromised decision-making, cognitive capacities and productivity, to affecting one's health and well-being such as fertility and pregnancy outcomes, as well as on a macroeconomic scale, specifically labour and economic productivity.

Assoc Prof Jason Lee said, "Project HeatSafe seeks to understand the complex threats that extreme heat exposure poses to human health, well-being and work productivity in tropical countries, such as Singapore, and find sustainable and scalable solutions to mitigate and reduce the growing impacts of heat stress. Given our strategic location, and expertise in heat stress management, Singapore is well-placed to lead the way in developing and deploying solutions to counter the complexities of increasing heat stress and help individuals, communities and society as a whole, thrive in this warming world."

Environmental Monitoring at Workplaces

The wet-bulb globe temperature (WBGT) is a measure of heat stress in direct sunlight, which considers humidity, air temperature, wind speed and solar radiation. The monitoring of WBGT

[1]Singapore experienced daily maximum temperatures exceeding 35 degree Celsius 21.4 days per year on average in the last 40 years. By end century, we will see between 41 and 351 days per year on average of such high daily maximum temperatures. From an average of 76 nights per year in the last 40 years, Singapore could experience warm nights exceeding 26.3 degrees Celsius most nights in the year by end century.

is important in managing workers' heat exposure. In a study of 24 indoor and outdoor workplaces, the team, led by Research Assistants Clarence Leow and Trinh Tran from HPTRP, placed WBGT monitors at workplaces around the island to measure the hourly WBGT and compared the readings against the hourly WBGT captured at the nearest weather stations. They focused on the hourly timepoints during working hours, from 7am to 7pm.

Hourly WBGT readings were classified into the various heat stress risk levels, as defined by the Ministry of Manpower. Notably, the consistency of measurement between WBGT heat stress risk levels at the weather station and at the workplace declined with increasing heat stress. At a low risk level below WBGT 31 degree Celsius, the agreement was robust at 93%. However, this decreased to 32% at a moderate risk level (between 31 and 32 degree Celsius) and to 14% at high risk levels (above 32 degree Celsius). This observation is significant, as workers could be exposed to higher heat stress levels at the workplaces than what is reported by the NEA weather stations. If unmonitored, the workers could be unduly exposed to heat for long periods and succumb to heat strain.

Due to differences in geographical locations, the WBGT at workplaces and weather stations may largely differ, which could lead to misreporting and create more health risks for outdoor workers after prolonged sun exposure. Within the same worksite, heat stress levels can also differ at both indoor and outdoor workplaces. This finding serves as a reminder for workplaces to monitor their own WBGT levels to better monitor and protect their workers' health and well-being.

Impact of heat stress on health, well-being and productivity

The study led by Dr Natalia Borzino, Postdoctoral Researcher from the Singapore-ETH Centre aimed to find out how workers and their employers perceived heat stress during the hottest months of the year, between April to August, and the impact on workers' productivity.

Through surveys with 355 workers and 214 employers in Singapore, the team found that the higher the physical and mental exertion faced in the job role, the higher the productivity and economic losses. The economic loss significantly increased along with workers exposed to adverse environmental conditions at the workplace, such as working under the sun or semi-outdoor spaces or being exposed to additional sources of heat (e.g. machineries).

It is estimated that for every hot day, the reduced workers' productivity during working hours (i.e., presenteeism) translates into a median income loss of S$21 per worker, which is about 24% of the daily median salary of the surveyed workers.

Around 70% of employers surveyed did not feel that these productivity losses of the workers from heat represented a problem for their companies. However, they recognise the value and importance of educating workers about the impact of occupational heat strain on their health, well-being, and work performance. Other recommendations from employers include implementing specific heat adaptation measures at the workplaces, such as regular work-rest cycles and water breaks, investing in cooling uniforms, and installing alert systems in the event of high temperatures.

Impact of heat stress on cognitive capacity and decision-making

A combination of high body core temperature, high skin temperature and increased heart rate, causes a reduction in postural balance during attention-demanding tasks, which can lead to reduced productivity and cognitive capacity, resulting in impaired decision-making and a higher risk of injury.

Using a Virtual Reality task, 18 healthy men were tasked to complete welding and plank-walking, tasks typically executed at construction sites under three different WBGT – 25 degree Celsius, 28 degree Celsius and 32 degree Celsius. The range of WBGTs was meant to simulate Singapore's current cool and warm environmental conditions, as well as the projected hot environmental conditions in the future.

Interventions, such as consuming ice slurry, work-rest cycles and having regular water breaks need to be implemented effectively and in a timely manner. This study was led by Research Fellows Beverly Tan and Sharifah Badriyah Alhadad from NUS Medicine.

Impact of heat stress on indoor and outdoor construction workers

Both indoor and outdoor construction workers are affected by heat stress and global warming.

In studying the effects of occupational heat stress on indoor and outdoor construction workers, 79 indoor and 76 outdoor construction workers were profiled during a 9-hour work shift and interviewed on their work experiences and perceptions of heat stress.

It was found that both indoor and outdoor construction workers experienced low physiological strain overall, despite varying WBGT levels, likely due to the ability to self-pace. However, some workers displayed prolonged high thermal strain, specifically a body core temperature above 38 degree Celsius.

Based on the interview responses, 65% of respondents felt that their productivity was reduced and they tend to work at a slower pace when they worked on hot days. The most common heat-related symptom was fatigue which was felt by 60% of respondents, while 37% experienced headaches after prolonged heat exposure during work.

Research Assistants Kwek Jun Hao and Gerald Tan from NUS Medicine, who led the study, recommended that additional measures such as heat stress education and training, enforced work-rest cycles, and water breaks be implemented, especially for those workers who displayed high psychological strain or possess risk factors for heat injury. Regular heat stress training and education for the managers and workers are also key to support and advance their current limited knowledge in the use of heat adaptation measures to better manage workplace heat stress and heat strain.

Impact of chronic extreme heat on fertility and pregnancy outcomes in Singapore

The study of extreme heat on local fertility outcomes for women and men have not been well-studied in tropical countries, such as Singapore, compared to countries with four seasons. Led by Principal Investigators, Asst Prof Huang Zhongwei, Assoc Prof Chan Shiao-Yng and Research Fellow Samuel Gunther from NUS Medicine, the team collected sperm samples from 818 men to analyse for risk of low sperm quality. There was a higher risk of low sperm concentration and low sperm count in men who were exposed to extreme heat 15 to 69 days before their semen was collected.

The team also analysed birth records of over 30,000 mothers over the three pregnancy trimesters for risk of pre-term birth and small-for-gestational age birth.

There is also a lower risk of preterm birth for women exposed to extreme heat at their third trimester of pregnancy. For women at their second trimester of pregnancy, there is lower risk of small-for-gestational-age birth in Chinese women, but a higher risk in Malay women. Based on survey responses from over 300 women, the team saw indications of protective measures taken by pregnant women, but the level of adoption of these measures was less for women who already had children at home. The proportion of pregnant survey respondents who used

more air-conditioning on hot days increased by 30% from first trimester to third trimester. Behaviourally, the proportion of respondents who spent less time outdoors on hot days, increased by 12% from the first trimester to the third, and the proportion who exercise less on hot days also increased by 11%. However, women who already had children at home were less likely to adopt these two protective behaviours.

“In a population that is consistently exposed to high heat, the occurrence of extreme heat is still associated with higher risk of lower sperm quality and adverse birth outcomes,” Samuel Gunther added.

Macroeconomic impact of heat on labour productivity losses of industries

Through an interdisciplinary approach by combining various data sources incorporated into a supply-driven Input-Output (IO) model, the study evaluated the macroeconomic impact of heat on labour productivity among the 42 industries of the Singapore economy. These were further classified into four big sectors – services, manufacturing, agriculture, and construction.

In 2018, the total average annual percentage reduction in productive working time due to heat in all four sectors was on average 11.3%, which caused a total economy-wide output loss of S$1.18 billion. This percentage is forecasted to increase to 14% in 2035, causing an economy-wide output loss of S$2.22 billion.

In 2018, all sectors of the economy experienced a greater indirect economic loss due to heat because of sector interdependencies at a macroeconomic level. Sector interdependencies are important for capturing the cascading effects of a decrease on labour productivity from a single sector on the remaining sectors and the economy.

This study was led by Dr Natalia Borzino, Postdoctoral Researcher from Singapore-ETH Centre, Prof Renate Schubert from Singapore-ETH Centre, Prof Noah Lim from NUS Faculty of Business, and Prof Cai Wenjia from Tsinghua University.

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Our multidisciplinary and real-world approach to education, research and entrepreneurship enables us to work closely with industry, governments and academia to address crucial and

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Through a dynamic and future-oriented five-year curriculum that is inter-disciplinary and inter-professional in nature, our students undergo a holistic learning experience that exposes them to multiple facets of healthcare and prepares them to become visionary leaders and compassionate doctors and nurses of tomorrow. Since the School's founding in 1905, more than 12,000 graduates have passed through our doors.

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