Heat stress and its impacts on human health and occupational work

Jason KW LEE Ph.D., FACSM

Heat Resilience & Performance Centre
Human Potential Translational Research Programme
WHO-WMO GHHIN SE Asia Heat Health Hub

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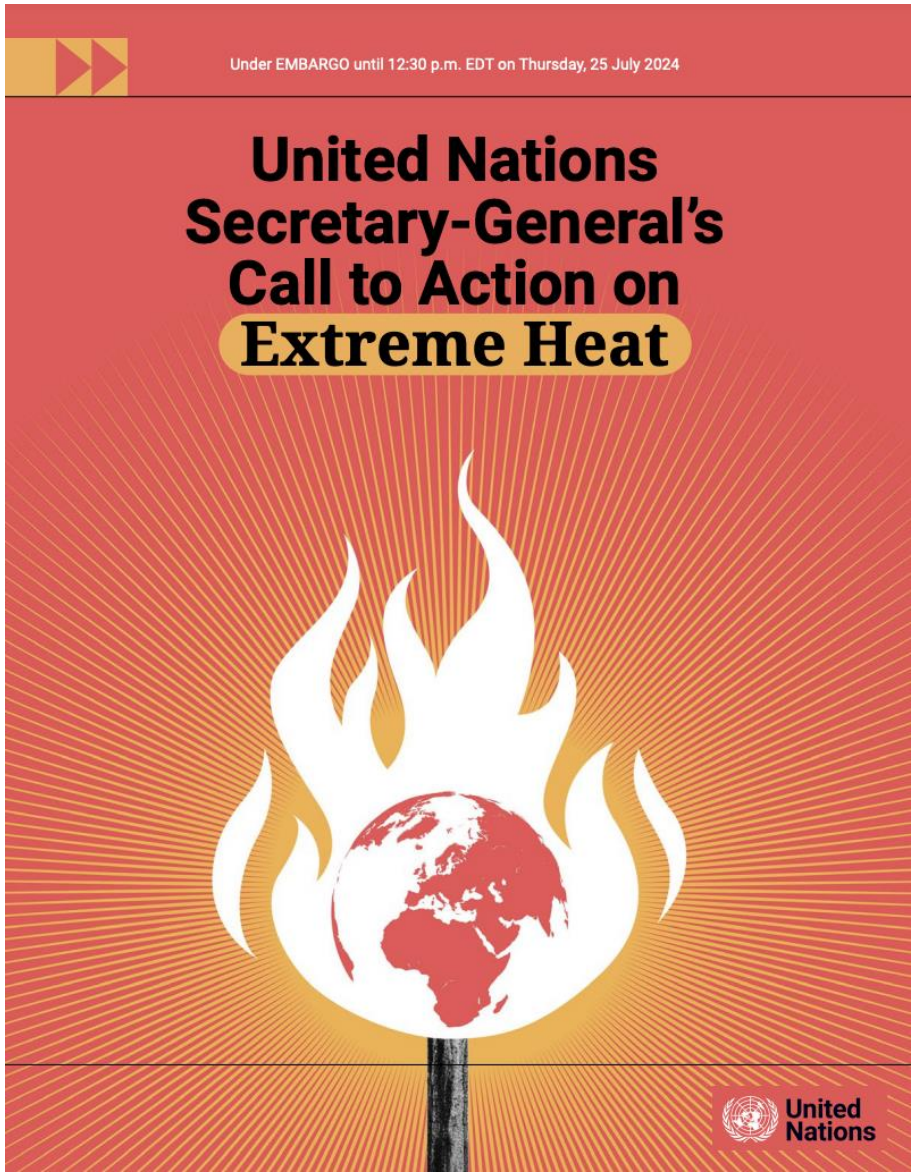
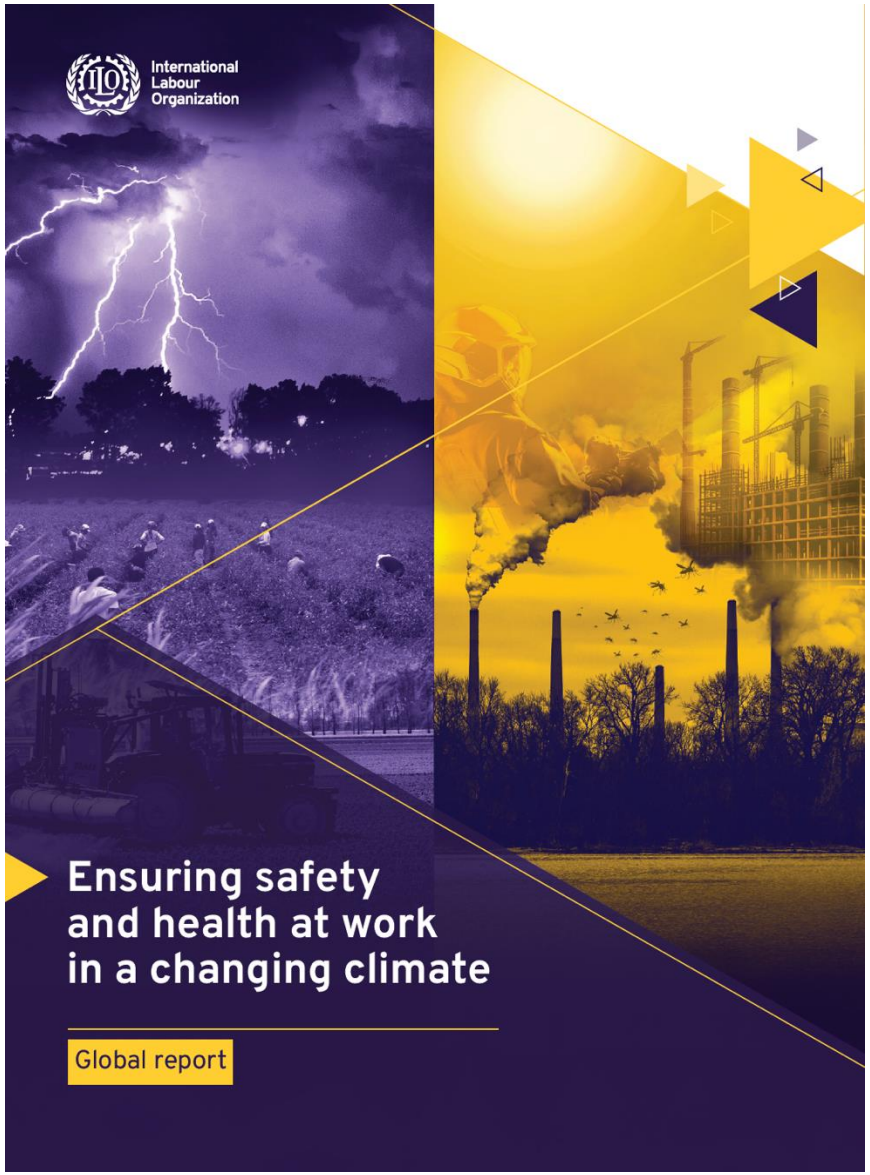
“The era of global boiling has arrived.”

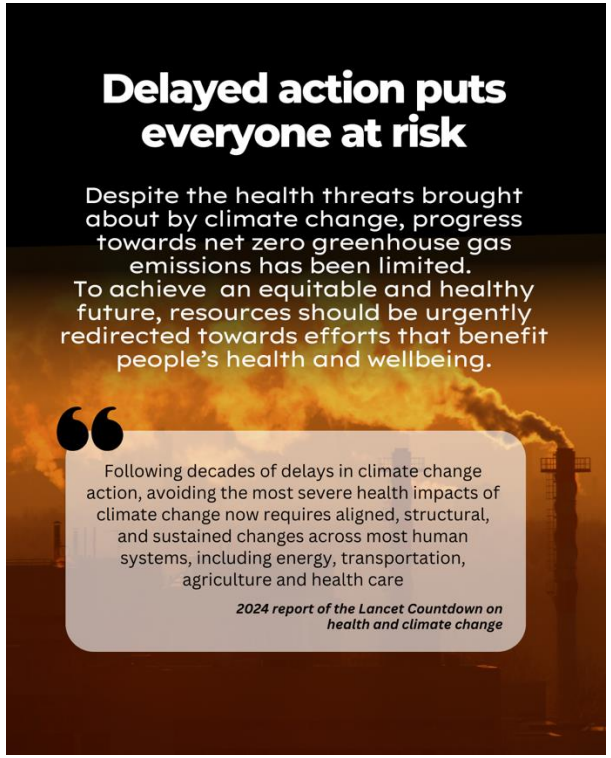
United Nations Secretary-General
António Guterres
July 2023


Under EMBARGO until 12:30 p.m. EDT on Thursday, 25 July 2024
United Nations Secretary-General's Call to Action on Extreme Heat
United Nations


International Labour Organization
Ensuring safety and health at work in a changing climate
Global report

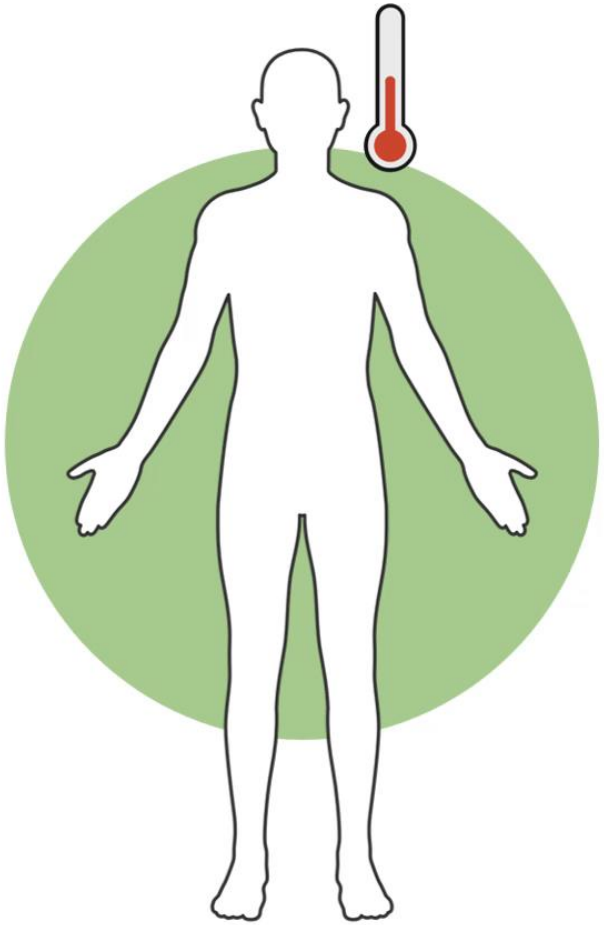
The 2024 report of the *Lancet* Countdown on health and climate change: facing record-breaking threats from delayed action

Marina Romanello, Maria Walawender, Shih-Che Hsu, Annalyse Moskeland, Yasna Palmeiro-Silva, Daniel Scamman, Zakari Ali, Nadia Ameli, Denitsa Angelova, Sonja Ayeb-Karlsson, Sara Basart, Jessica Beagley, Paul J Beggs, Luciana Blanco-Villafuerte, Wenjia Cai, Max Callaghan, Diarmid Campbell-Lendrum, Jonathan D Chambers, Victoria Chicmana-Zapata, Lingzhi Chu, Troy J Cross, Kim R van Daalen, Carole Dalin, Niheer Dasandi, Shouro Dasgupta, Michael Davies, Robert Dubrow, Matthew J Eckelman, James D Ford, Chris Freyberg, Olga Gasparyan, Georgiana Gordon-Strachan, Michael Grubb, Samuel H Gunther, Ian Hamilton, Yun Hang, Risto Hänninen, Stella Hartinger, Kehan He, Julian Heidecke, Jeremy J Hess, Louis Jamart, Slava Jankin, Harshavardhan Jatkar, Ollie Jay, Ilan Kelman, Harry Kennard, Gregor Kiesewetter, Patrick Kinney, Dominic Kniveton, Rostislav Kouznetsov, Pete Lampard, Jason K W Lee, Bruno Lemke, Bo Li, Yang Liu, Zhao Liu, Alba Llabrés-Brustenga, Melissa Lott, Rachel Lowe, Jaime Martinez-Urtaza, Mark Maslin, Lucy McAllister, Celia McMichael, Zhifu Mi, James Milner, Kelton Minor, Jan Minx, Nahid Mohajeri, Natalie C Momen, Maziar Moradi-Lakeh, Karyn Morrisey, Simon Munzert, Kris A Murray, Nick Obradovich, Megan B O'Hare, Camile Oliveira, Tadj Oreszczyn, Matthias Otto, Fereidoon Owfi, Olivia L Pearman, Frank Pega, Andrew J Perishing, Ana-Catarina Pinho-Gomes, Jamie Ponmattam, Mahnaz Rabbaniha, Jamie Rickman, Elizabeth Robinson, Joacim Rocklöv, David Rojas-Rueda, Renee N Salas, Jan C Semenza, Jodi D Sherman, Joy Shumake-Guillemot, Pratik Singh, Henrik Sjödin, Jessica Slater, Mikhail Sofiev, Cecilia Sorensen, Marco Springmann, Zélie Stalhandske, Jennifer D Stowell, Meisam Tabatabaei, Jonathon Taylor, Daniel Tong, Cathryn Tonne, Marina Treskova, Joaquin A Trinanes, Andreas Uppstu, Fabian Wagner, Laura Warnecke, Hannah Whitcombe, Peng Xian, Carol Zavaleta-Cortijo, Chi Zhang, Ran Zhang, Shihui Zhang, Ying Zhang, Qiao Zhu, Peng Gong, Hugh Montgomery*, Anthony Costello**



HOW DOES THE BODY RESPOND TO HEAT?

THERMOREGULATION



OUR UNIQUE CHALLENGE

HIGH TEMPERATURES

HIGH HUMIDITY

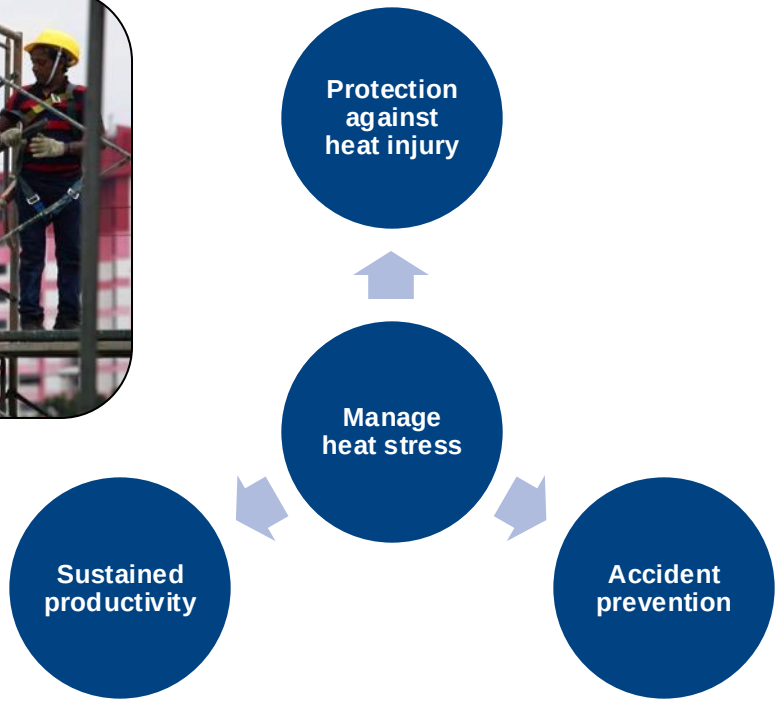
SUSTAINED EXPOSURE

"Relax. Pot temperatures have been going up and down for centuries."

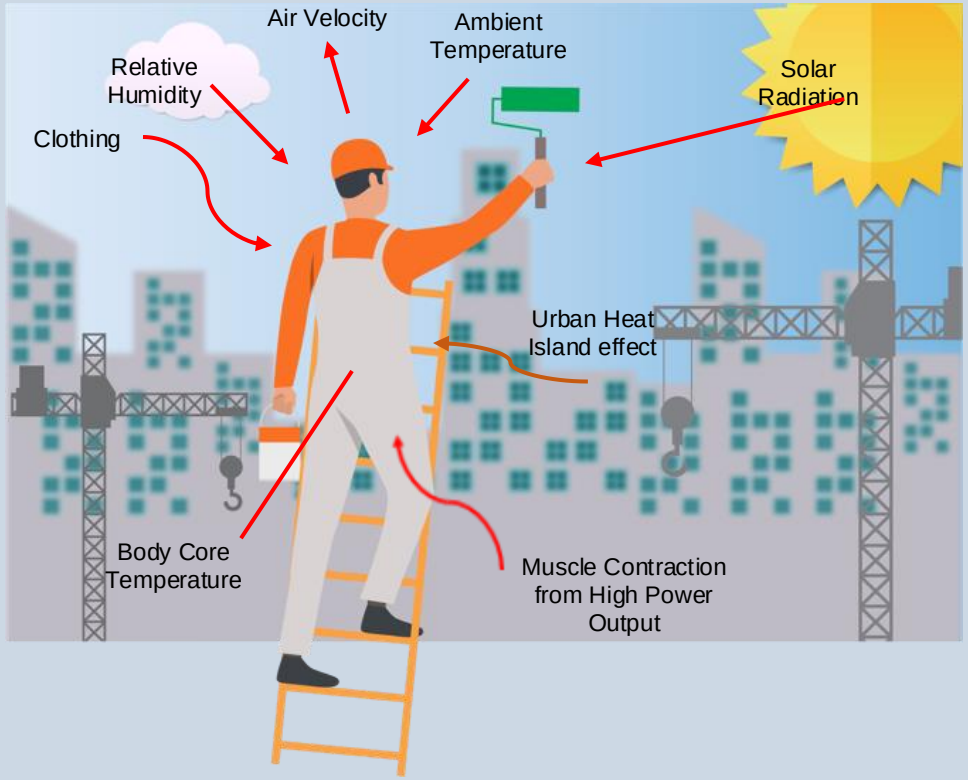
OUR UNIQUE CHALLENGE

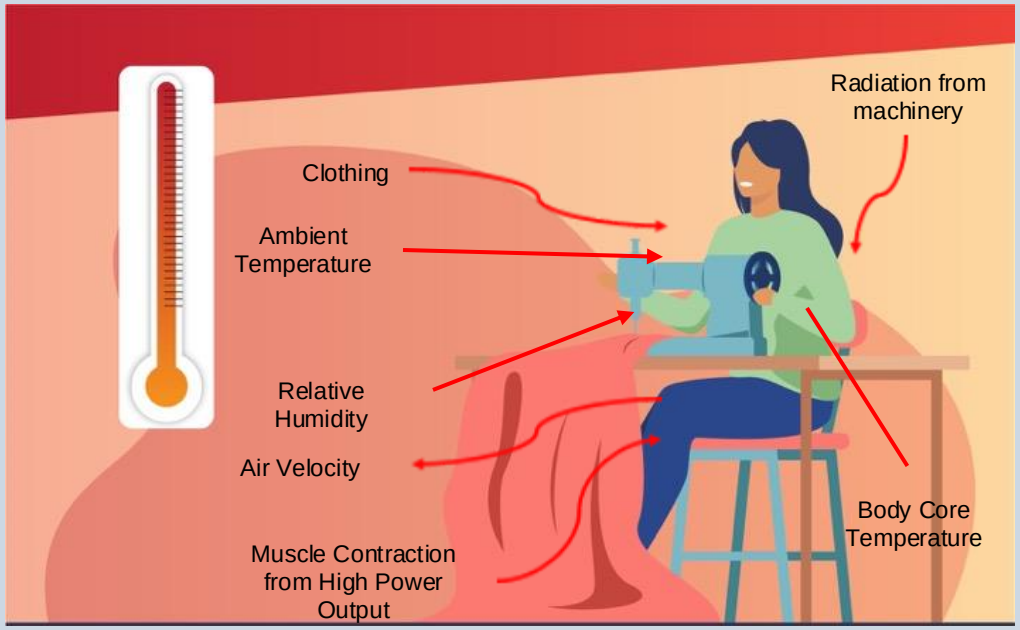
The Problem


10
20
30

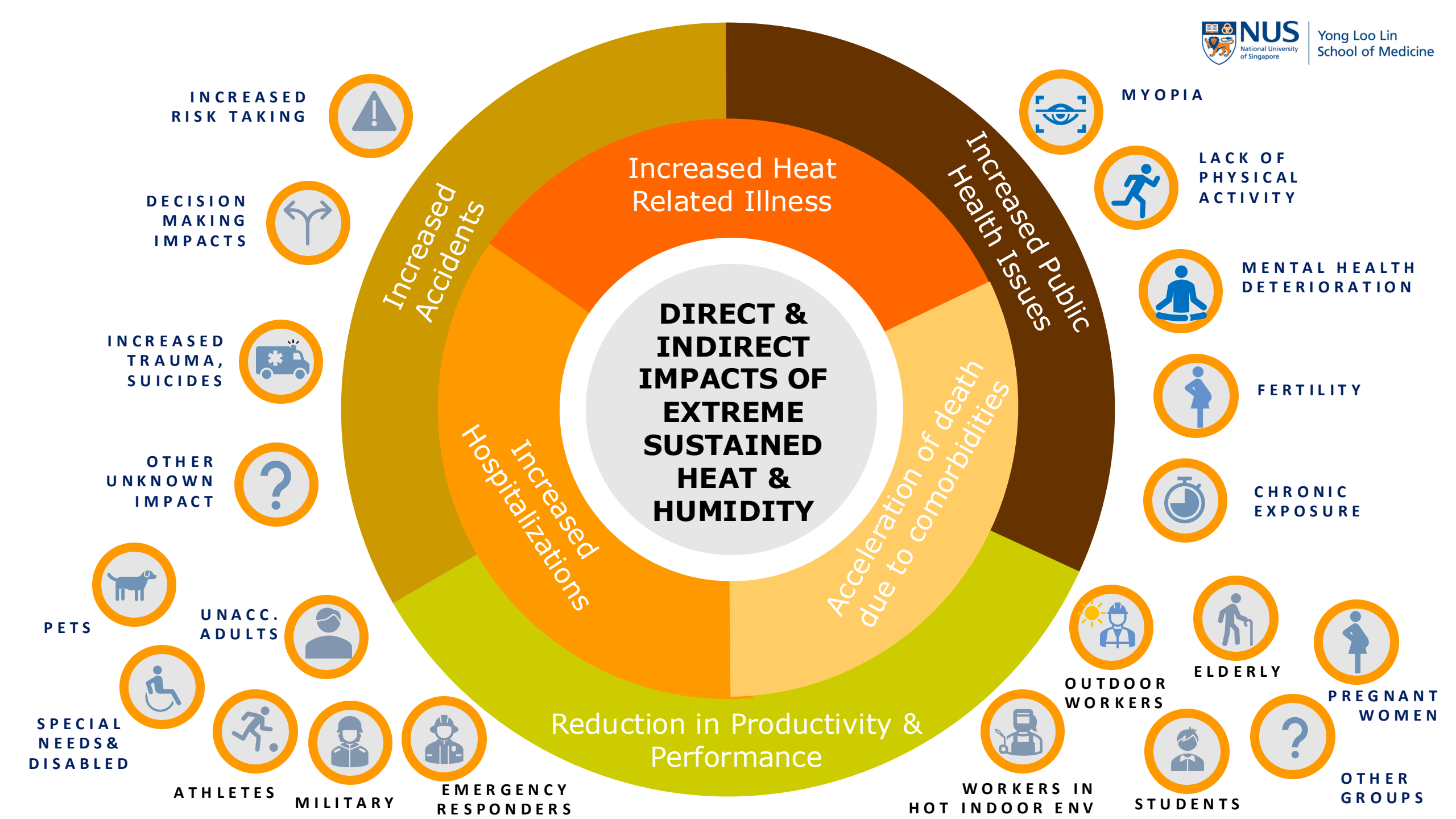

Protection against heat injury
Manage heat stress
Sustained productivity
Accident prevention

HEAT STRESS VS. HEAT STRAIN?





Climate + Clothing + Exercise (Heat Stress) → **Heat Strain** ⚠


NUS National University of Singapore
Yong Loo Lin School of Medicine
INCREASED RISK TAKING
DECISION MAKING IMPACTS
INCREASED TRAUMA, SUICIDES
OTHER UNKNOWN IMPACT
PETS
UNACC. ADULTS
SPECIAL NEEDS& DISABLED
ATHLETES
MILITARY
EMERGENCY RESPONDERS
MYOPIA
LACK OF PHYSICAL ACTIVITY
MENTAL HEALTH DETERIORATION
FERTILITY
CHRONIC EXPOSURE
OUTDOOR WORKERS
ELDERLY
PREGNANT WOMEN
WORKERS IN HOT INDOOR ENV
STUDENTS
OTHER GROUPS
Increased Accidents
Increased Heat Related Illness
Increased Public Health Issues
Increased Hospitalizations
Acceleration of death due to comorbidities
Reduction in Productivity & Performance
DIRECT & INDIRECT IMPACTS OF EXTREME SUSTAINED HEAT & HUMIDITY

The Washington Post
Democracy Dies in Darkness

Hotter days bring out hotter tempers, research finds

Studies add to the literature showing how people act out aggressively when it's hot

6 min 32

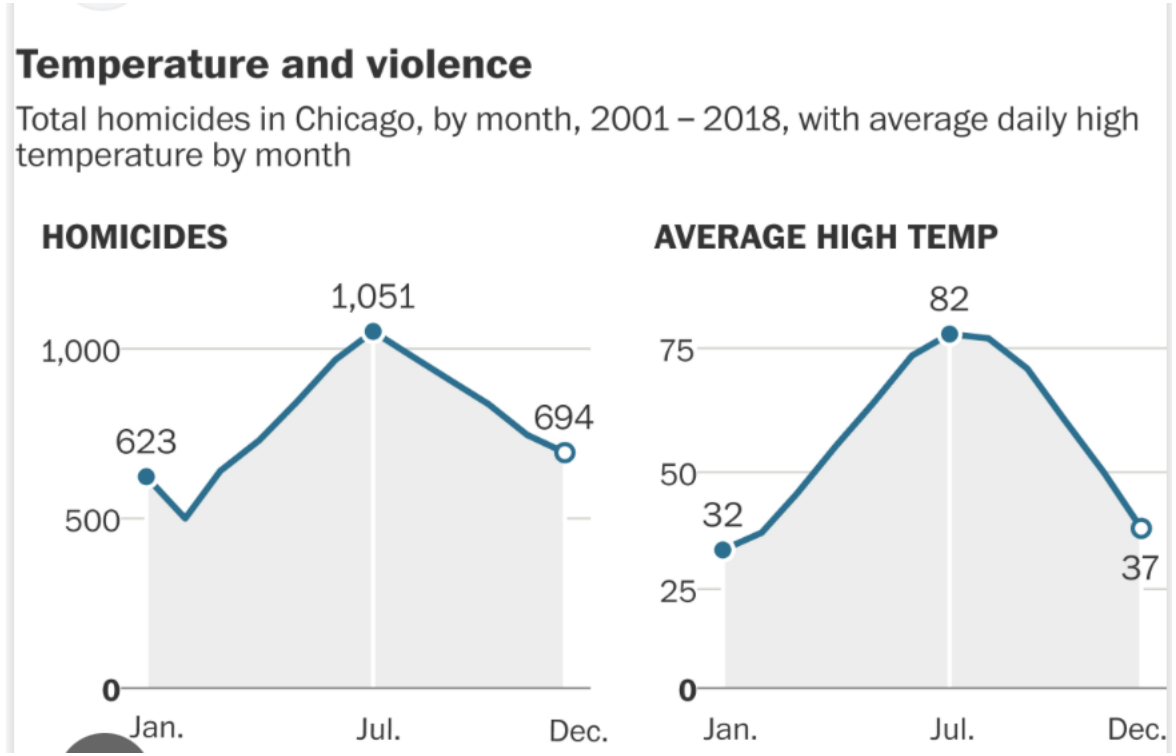
(Washington Post illustration; iStock)

Heat and Risky Behaviors: How High Temperatures Increase Violence in Prison

By Wisconsin School of Business

September 23, 2021

Two new studies warn that a hotter world will be a more violent one



Heat increases risk taking

Appl Ergon. 2017 Jul;62:150-157. doi: 10.1016/j.apergo.2017.02.018. Epub 2017 Apr 6.

Effects of heat stress on risk perceptions and risk taking.

Chang CH[1], Bernard TE[2], Logan J[2].

Author information

Abstract

Exposure to extreme heat at work is a serious occupational hazard, as exposure can result in heat-related illnesses, and it has been linked to increased risk of accidents and injuries. The current study aimed to examine whether heat exposure is related to changes in individuals' psychological process of risk evaluation, and whether acclimatization can mitigate the effect of heat exposure. A study with quasi-experiment research design was used to compare participants' risk perceptions and risk-taking behaviors at baseline, initial exposure to heat, and exposure after acclimatization across male participants who were exposed to heat (N = 6), and males (N = 5) and females (N = 6) who were in the control group who were exposed to ambient temperature. Results show that participants perceived the same risky behaviors to be less risky (p = 0.003) and demonstrated increased risk-taking behaviors (p = 0.001) after initial heat exposure. While their risk perceptions returned to baseline level after acclimatization, their risk-taking behaviors remained heightened (p = 0.031). Participants who were not exposed to heat showed no significant fluctuation in their risk perceptions and risk-taking. Our findings support that risk-related processes may explain the effects of heat exposure on increased accidents and injuries beyond its direct impact on heat-related illnesses.

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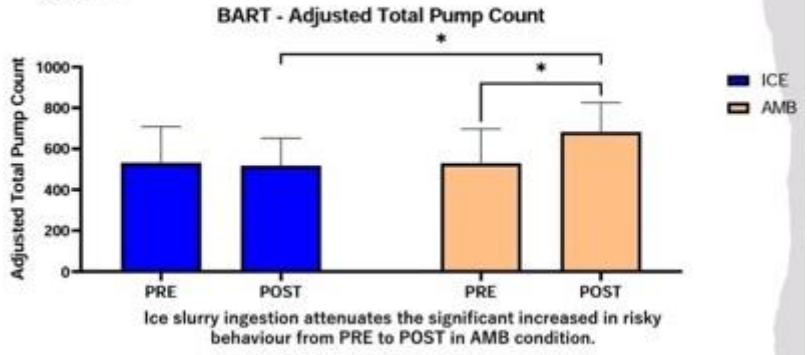
36 lives lost: Workplace fatalities in S'pore in 2022

Participants perceived the same risky behaviours to be less risky after heat exposure

Beyond its direct impact on heat-related illnesses, heat exposure can increase accidents and injuries

Heat and Risk-Taking Behaviour

Cognitive Task BART (1) – Adjusted Total Pump Count



Ice slurry ingestion attenuates the significant increased in risky behaviour from PRE to POST in AMB condition.

Cognitive Task BART (2) –Total Earnings

Greater risk-taking propensity in AMB was rewarded with higher total earnings, but risk is not always rewarded.

PROJECT HEATSAFE

NUS National University of Singapore | Human Potential Translational Research Programme
Yong Loo Lin School of Medicine

A multidisciplinary approach to augment occupational health and work productivity in a warming world

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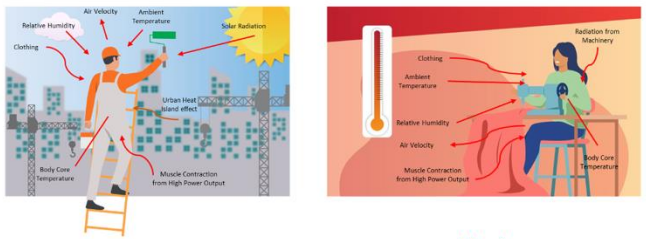
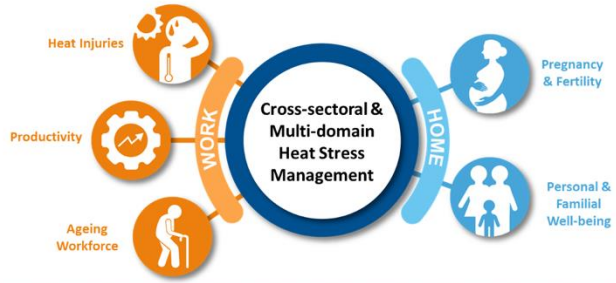
Heat Strain in Occupational Populations



Heat Stress + Clothing + Exercise ⟶ Heat Strain ⚠

Project HeatSafe's Multidisciplinary Approach



Methodology

1. Profile in-situ environmental conditions at worksites

2. Administer surveys

3. Physiology and Ethnography field case studies

Expected Outcomes

- ✓ Economic analysis of work productivity loss due to the heat
- ✓ Impact of heat strain on workers' physiology and performance
- ✓ Social and knock-on impacts of heat on workers and their families
- ✓ Potential interventions to adopt in occupational settings

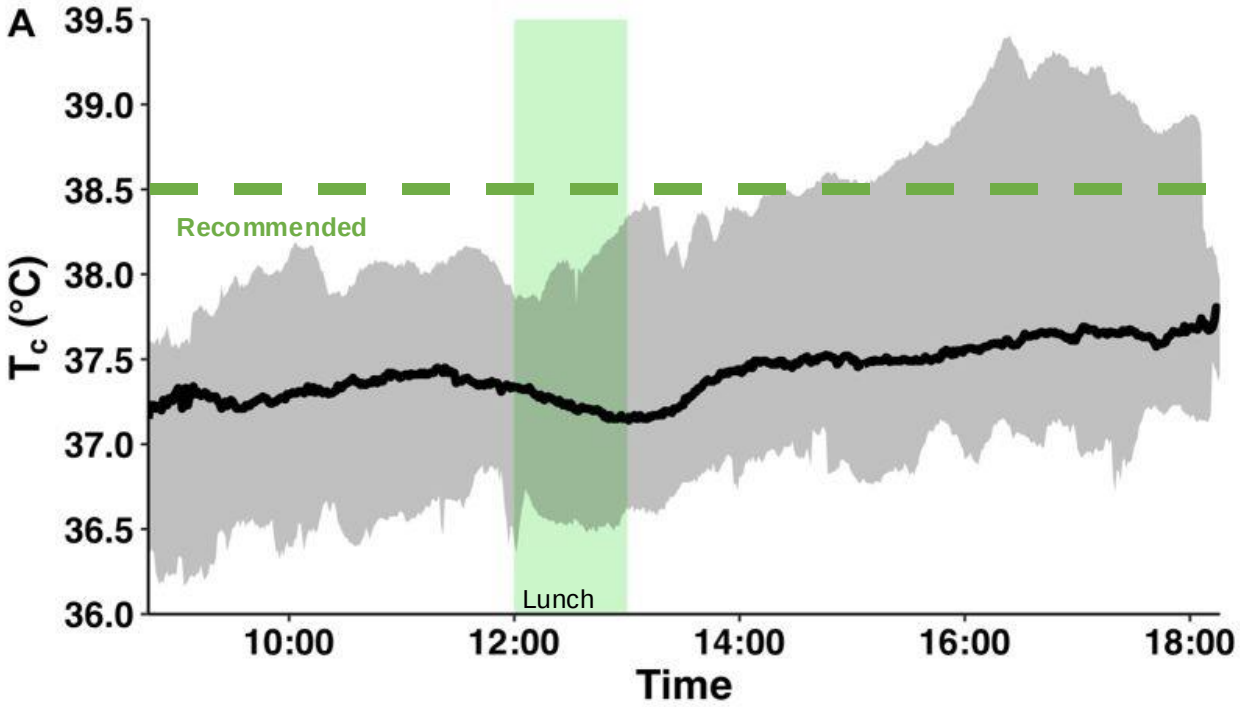
Evaluating Interventions

CREATE | NUS Human Potential Translational Research Programme Yong Loo Lin School of Medicine | (SEC) SINGAPORE-ETH CENTRE | MINISTRY OF MANPOWER | WSH Institute | Tsinghua University | Health and Environment International Trust (HEIT) | 서울대학교 SEOUL NATIONAL UNIVERSITY

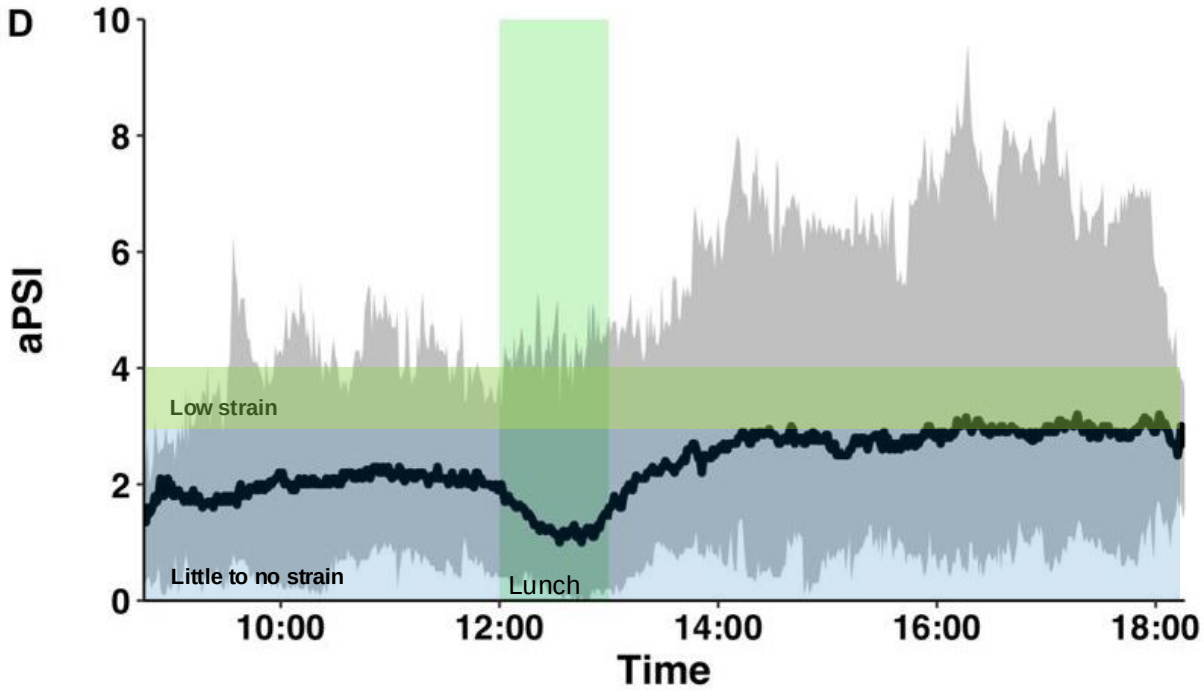
Physiological & Ethnographic Case Studies

Are construction workers working within safe limits?

Body core temperature < 38.5°C

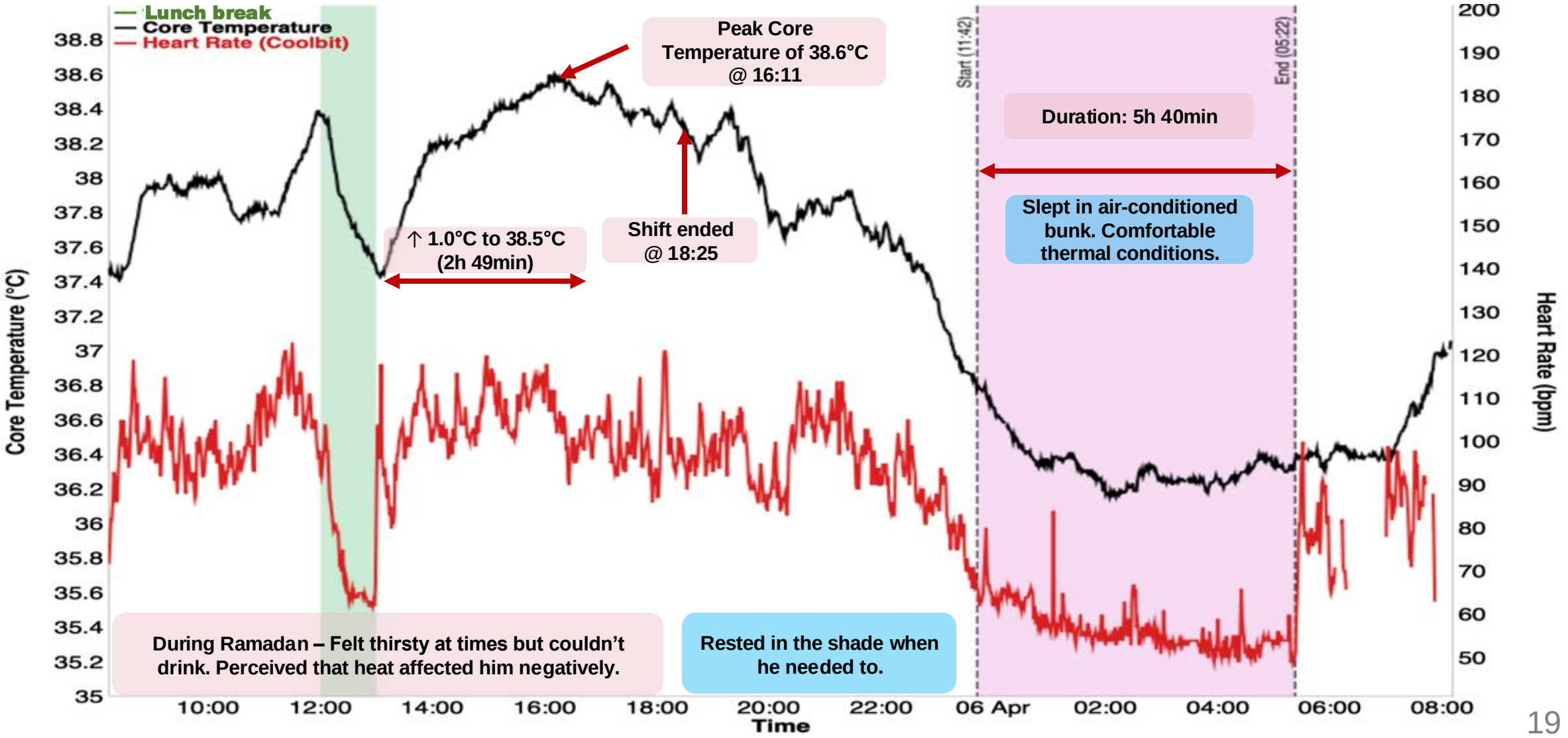


Low physiological strain



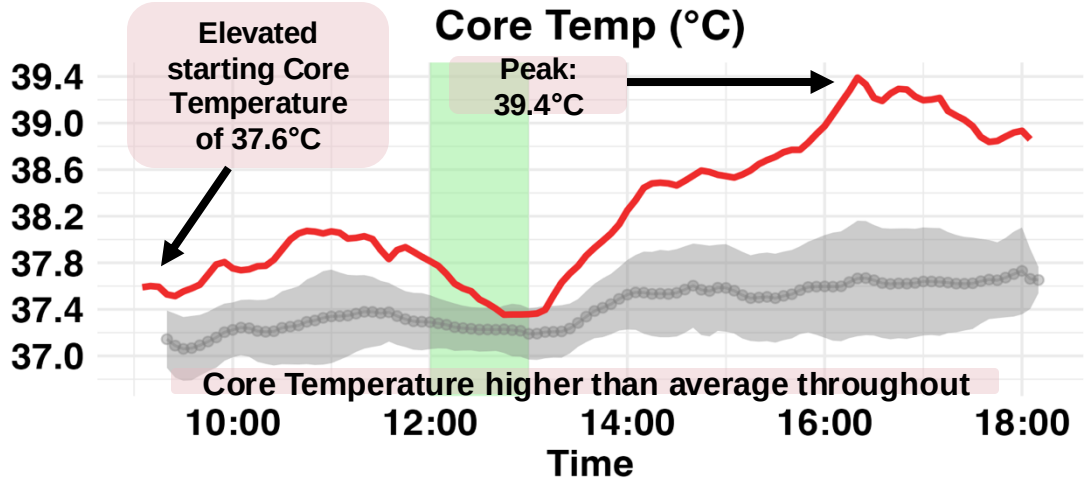
Identifying Outliers

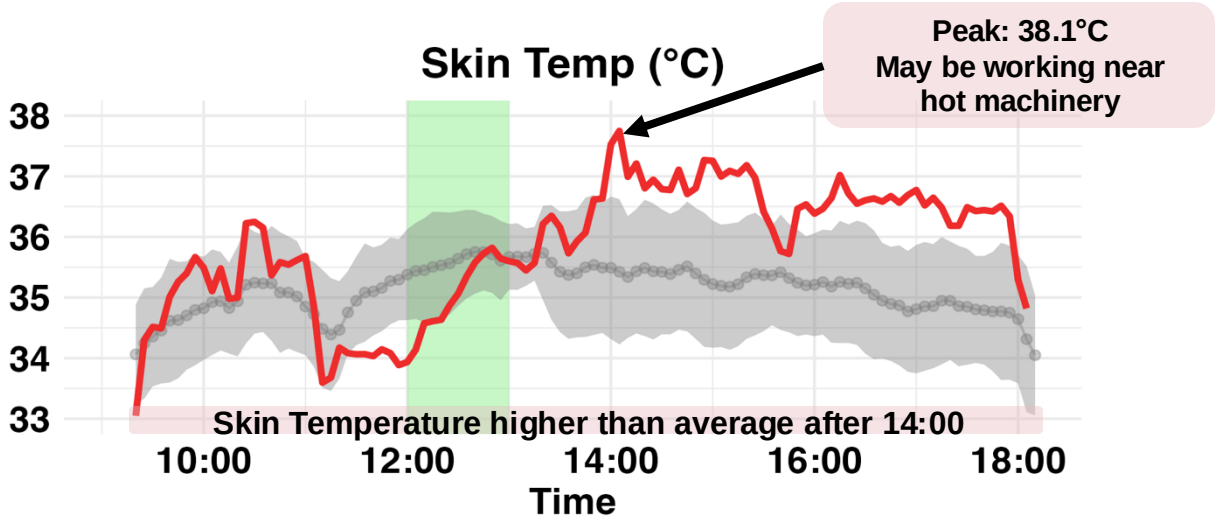
30 year old Lifting Supervisor with 7 years experience
BMI: 23.6 kg/m^2 **(Overweight)**
Pre-Shift Hydration Status: Hydrated
Profiled in Warm period (during Ramadan)

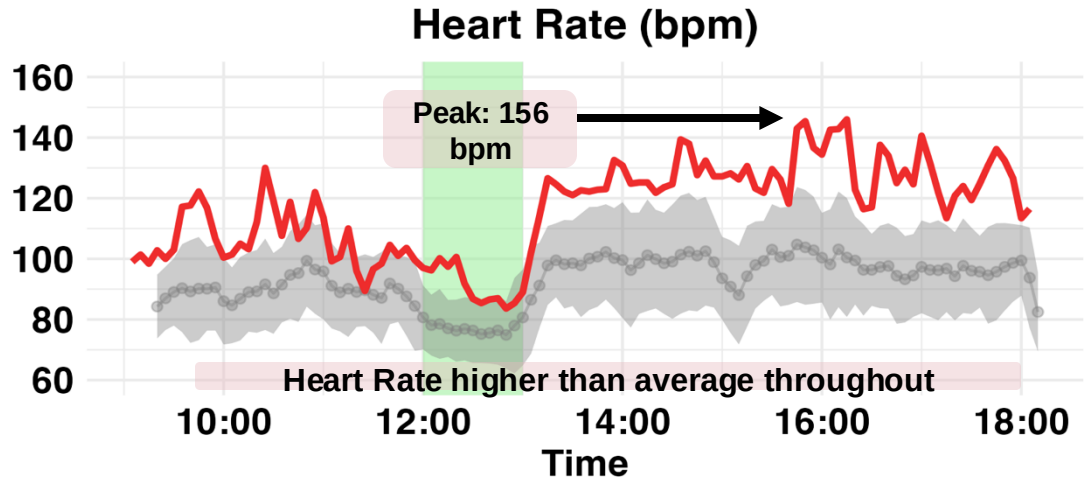


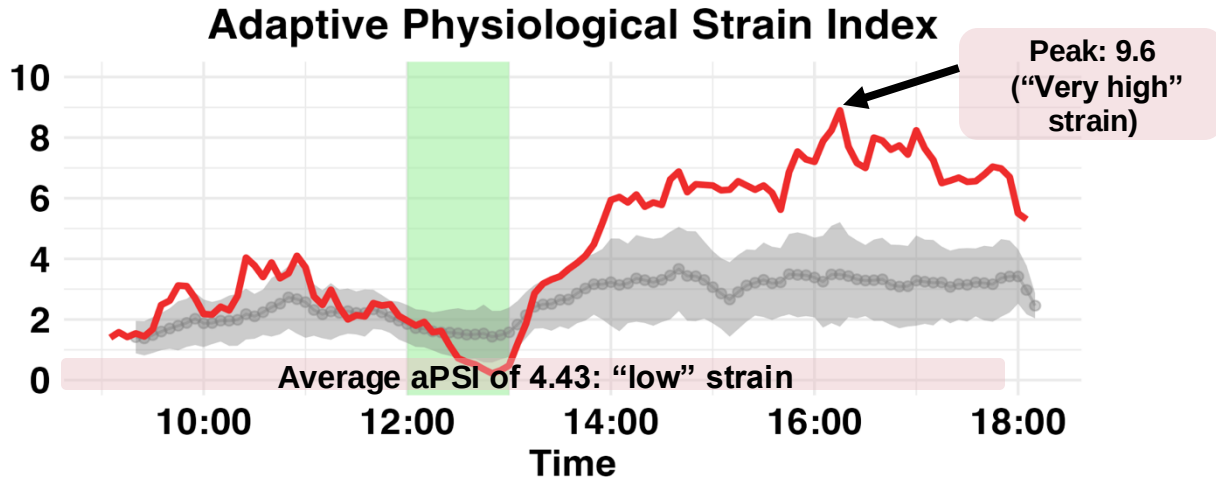
Identifying Outliers

35 year old General Worker
BMI: 28.5 kg/m^2 **(Overweight)**
Pre-Shift Hydration Status: Hydrated
Profiled in Warm period





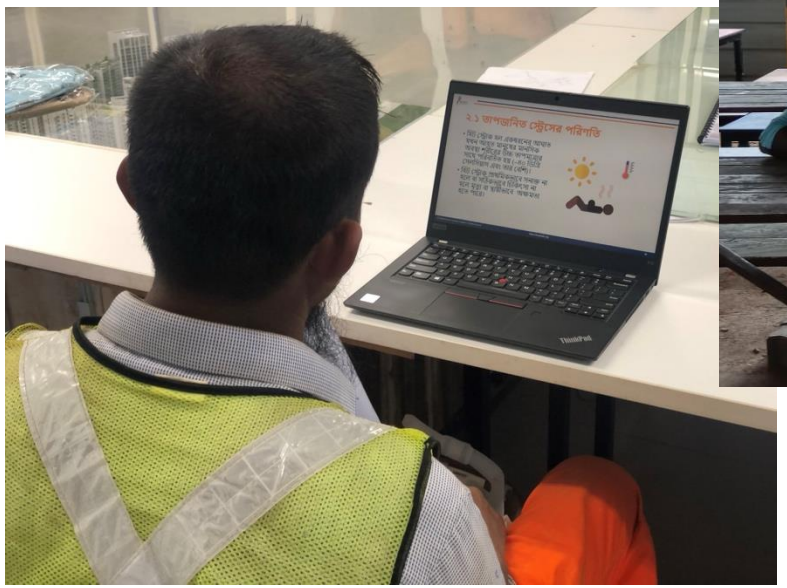


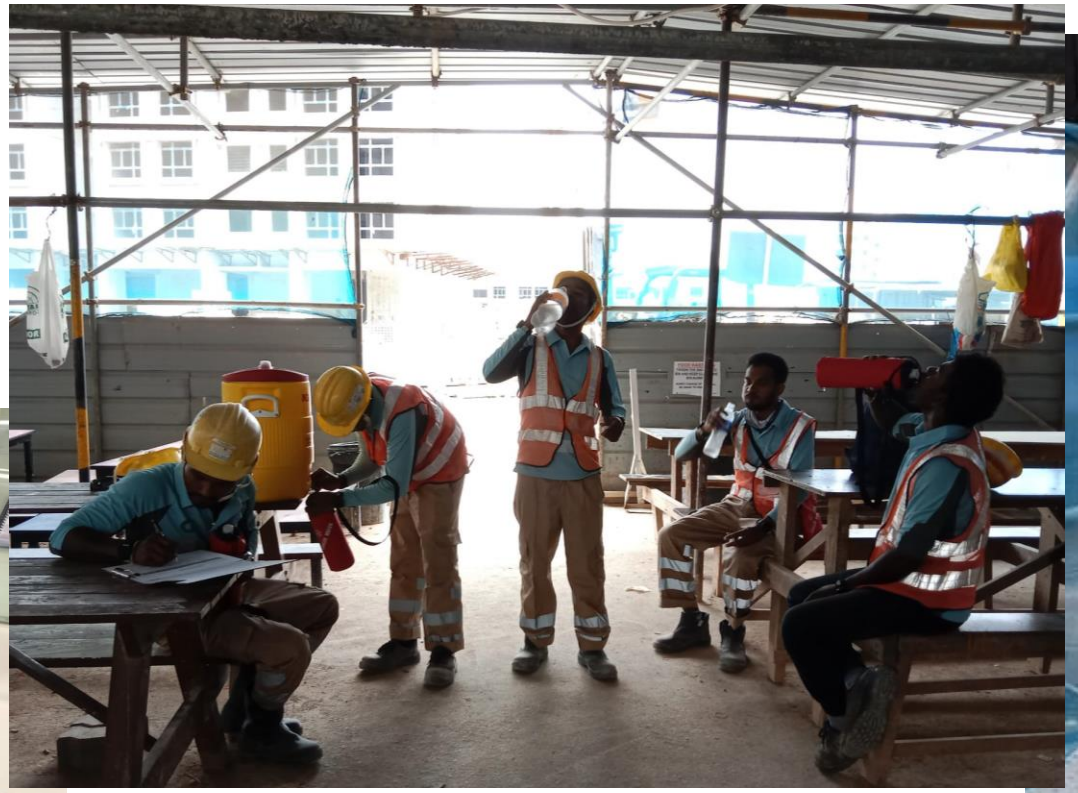


Interventions Field Study

Intervention	Details	Benefits
	Heat Stress Education Video - Native language - Heat-health knowledge	↑ Heat adaptation behaviours ↓ Physiological strain ↓ Dehydration
	Scheduled Breaks under Shade - Break 1: 1000 to 1015 - Break 2: 1430 to 1445 - Break 3: 1630 to 1645	↑ Work output & productivity ↓ Heat illness symptoms ↓ Kidney damage/injuries
	Personal Equipment - Work attire - Insulated bottle sleeve	↓ Perceptual strain ↓ Physiological strain

Interventions Field Study





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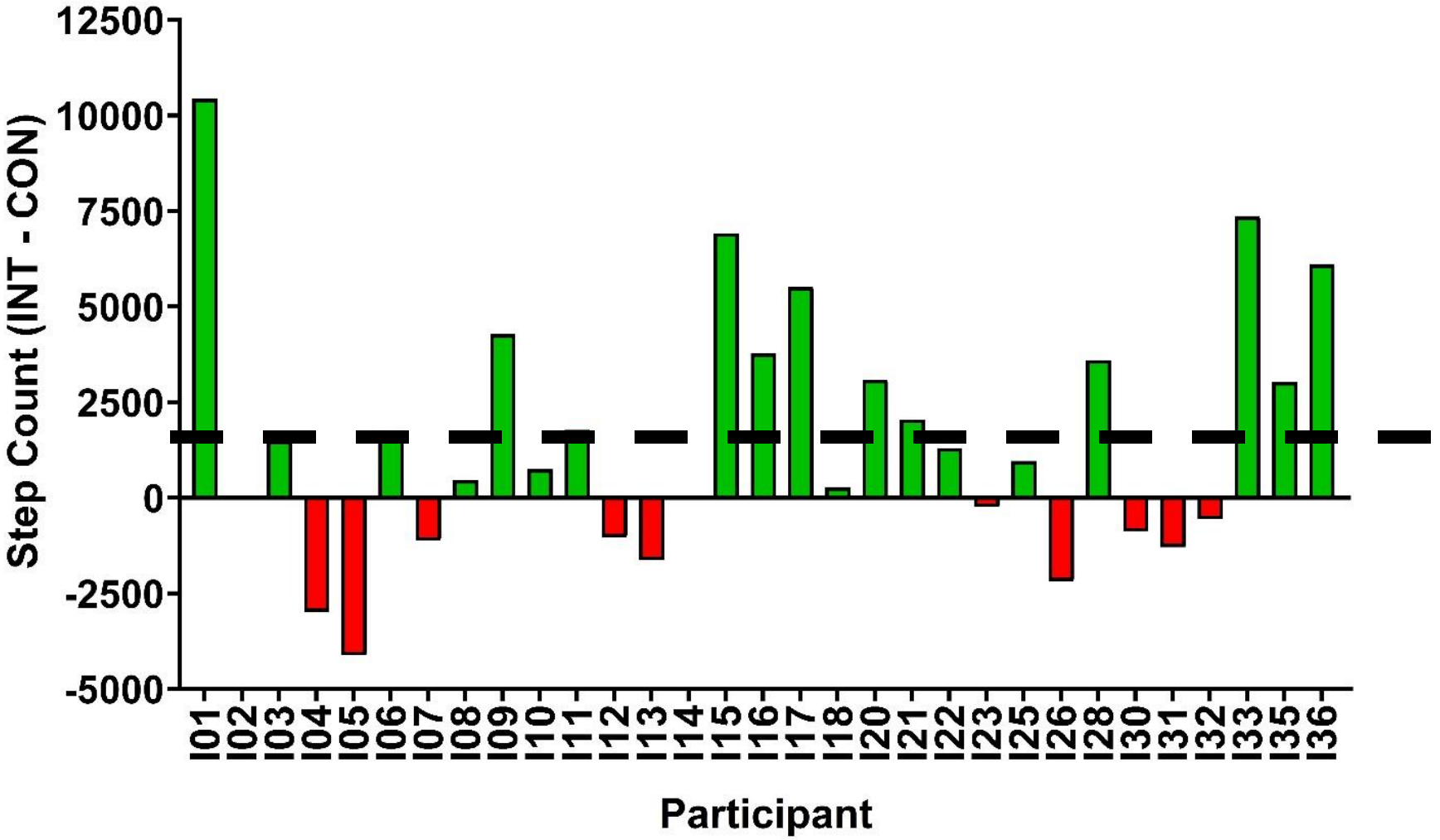


What were the positive outcomes from the interventions?

10% ↑ in steps

1,500 more on average

Possible increase in work output

PROJECT HEATSAFE: RESEARCH TO POLICY

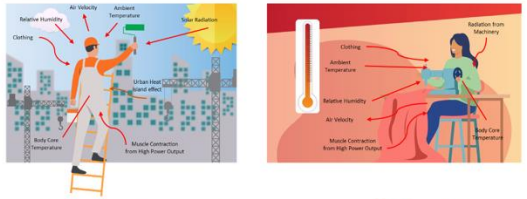
PROJECT HEATSAFE

NUS Human Potential Translational Research Programme Yong Loo Lin School of Medicine

A multidisciplinary approach to augment occupational health and work productivity in a warming world

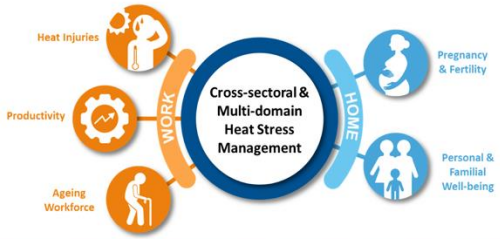
Follow us on Twitter: @ProjectHeatSafe

Heat Strain in Occupational Populations



Heat Stress + Clothing + Exercise → Heat Strain ⚠

Project HeatSafe's Multidisciplinary Approach



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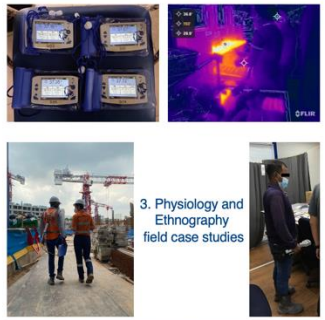

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MINISTRY OF MANPOWER

About us

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Enhanced Measures to Reduce Heat Stress for Outdoor Workers

Singapore

cna

Mandatory hourly breaks for some outdoor workers when weather gets too hot: MOM

THE STRAITS TIMES

About 1 in 3 workplaces inspected from March to June breached heat safety rules: MOM

Migran

High heat stress levels increase the risks of heatstro

MINISTRY OF MANPOWER | About Us | Work passes | Employment practices | Workplace safety and health | More | myMOM Portal

2024

Revised framework to guide employers and protect outdoor workers against heat stress

6 September 2024 | Workplace safety and health

REVISED FRAMEWORK TO GUIDE EMPLOYERS AND PROTECT OUTDOOR WORKERS AGAINST HEAT STRESS

With global warming, rising temperatures in Singapore will place workers, especially outdoor workers, at an increased risk of heat stress. Unlike the general population, outdoor workers have less discretion over their work activities, and may be more vulnerable to heat stress. The Ministry of Manpower (MOM), in consultation with the industry and tripartite partners, has reviewed our heat stress management measures to ensure outdoor workers are adequately protected at varying temperatures, while allowing flexibility for employers to adjust and implement measures based on their localised conditions.

REPRESENTATIVE REQUIREMENTS

Ministry of Culture, Community and Youth

<u>General Public</u>

- Impact of heat on health and performance
- Changing dynamics of sports participation

<u>Athletes and Officials</u>

- Sport-specific recommendations for heat adaptation

Ministry of Education SINGAPORE

<u>School-going Children & Adolescents</u>

- Impact of heat on health and participation in physical activity
- Risk factors for heat injuries
- Heat acclimatisation for sedentary individuals

MINISTRY OF HEALTH SINGAPORE

<u>Patients</u>

- Impact of heat on patient recovery, thermal comfort and health outcomes

<u>Healthcare Workers</u>

- Impact of heat on productivity and decision-making
- Heat adaptation measures while in PPE

MINISTRY OF MANPOWER

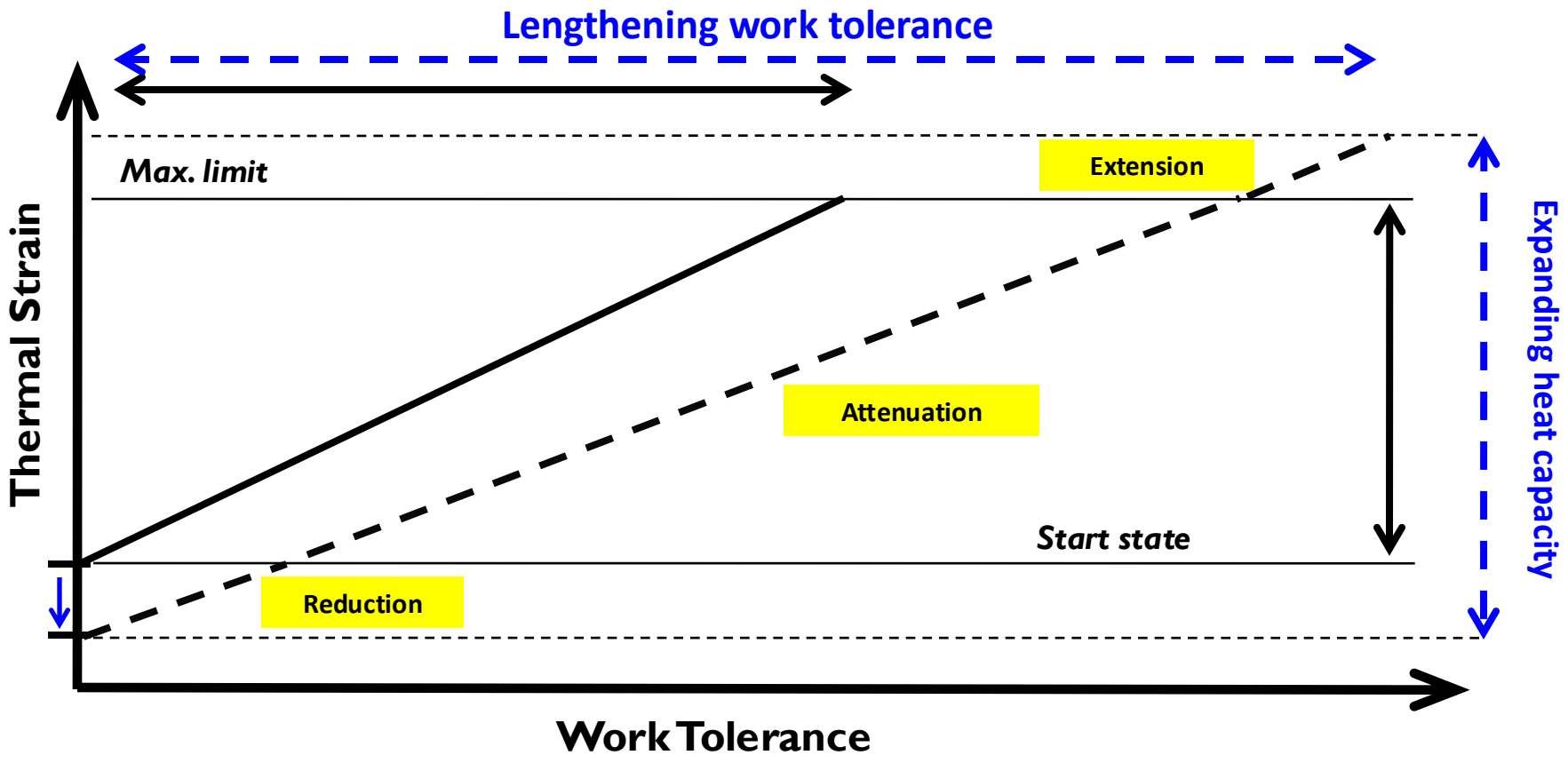
<u>Construction Workers</u>

- Medical surveillance for heat injuries
- Pre-activity risk factors and real-time monitoring

<u>Platform/Gig Workers</u>

- Impact of heat on productivity, safety and health outcomes

PHYSIOLOGICAL SOLUTIONS



Alhadad et al. (2019); Front. Physiol.

PHYSIOLOGICAL SOLUTIONS

AEROBIC FITNESS CONDITIONING

- Reduction
- Attenuation
- Extension

HEAT ACCLIMATIZATION

- Reduction
- Attenuation

PRE-ACTIVITY COOLING

- Reduction

WORK REST CYCLES

- Reduction
- Attenuation

HYDRATION

- Attenuation

Alhadad et al. (2019); Front. Physiol.

Old “Drug”, New Tricks?

Heat Resilience & Performance Centre

Heat Resilience & Performance Centre (HRPC)

The HRPC will be a first-of-its-kind research centre, to better enable the SAF to manage future challenges arising from climate change & extreme heat. It will consolidate technical expertise from the Yong Loo Lin School of Medicine in NUS, DSO National Laboratories & operational insights from the SAF. Its four key research thrusts are:

1 **Active & comprehensive surveillance** to deepen understanding of exertional heat illnesses by discovering new factors that could influence the onset of heat injury, to reinforce research focus & mitigation strategies.

2 **Real-time prediction & detection** of at-risk soldiers to comprehensively prevent heat injury through the development of capabilities to visualise the "heat health" status of troops, allowing for active risk management & training optimisation.

3 **Strengthening soldiers' heat resilience** through investigations into novel & more efficient heat mitigating strategies by pushing the boundaries in physiological knowledge of heat health & harnessing research in material sciences, design & engineering.

4 **Infrastructure enhancement** to reduce heat stress of soldiers through R&D into novel solutions & designs for military infrastructure through the adoption of physiological, social & technological concepts.

SOUTHEAST ASIA HEAT HEALTH HUB

A Regional Hub of GLOBAL HEAT HEALTH INFORMATION NETWORK

A PLATFORM FOR OUR REGION TO COLLECTIVELY PREPARE FOR & PROTECT POPULATIONS FROM THE HEALTH IMPACTS OF EXTREME HEAT

PEOPLE

Connect people and institutions form multi-disciplinary partnerships to reduce heat risks

SCIENCE & INFO

Accelerate the generation of evidence, actionable knowledge, and standardised guidance and risk metrics

ACTION

Catalyse regional, national and local policy and action to minimize societal consequences of heat impacts

Champion collaborative approaches and platforms to gather and engage with key stakeholders

Develop SEA focused reports on community policy, research lessons, impacts and challenges

Create programs and resources to share activities, experience, and research approaches

Advocate for evidence-based information, policies & guidelines to address heat related health risks

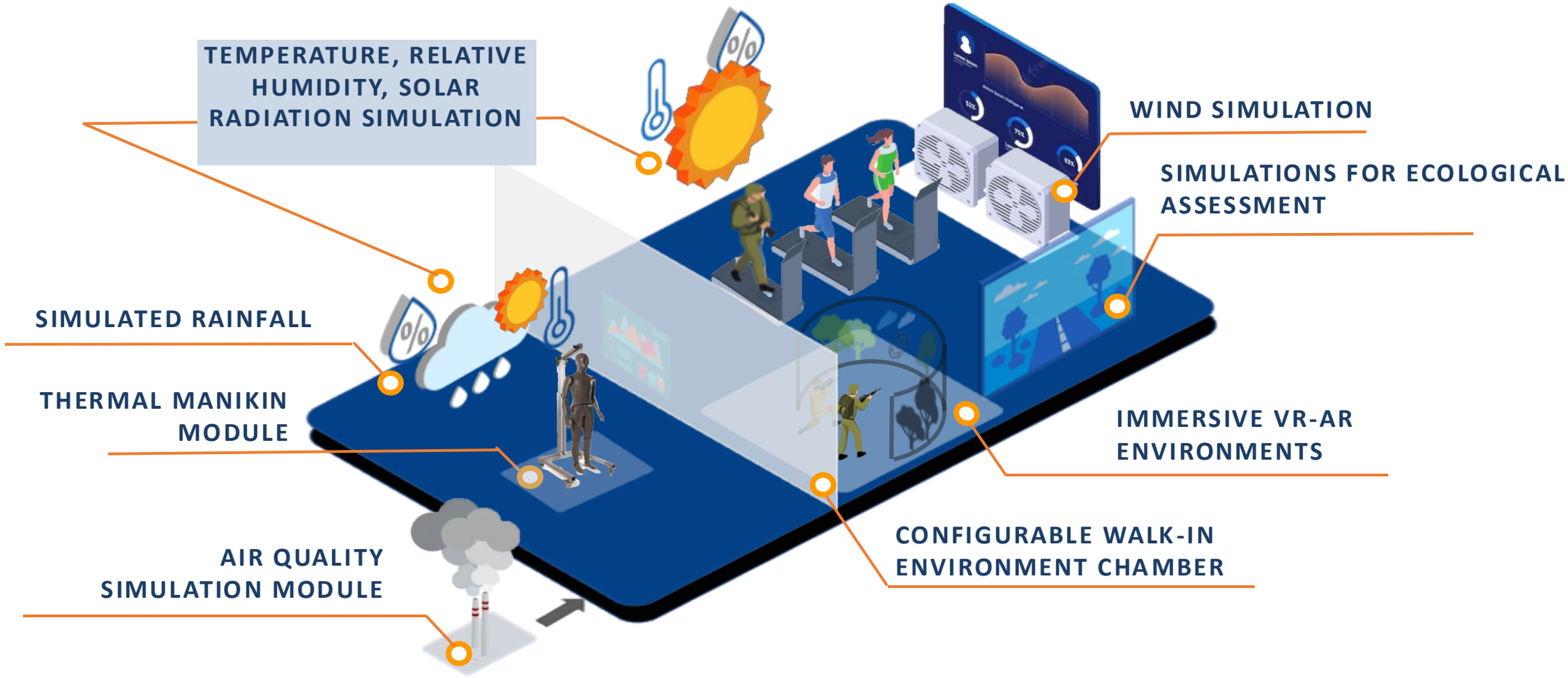
Urban Heat

Occupational Heat

Cultural & Traditional Practices

Plans to initiate a WHO Collaborating Centre for Heat Health

INTEGRATED CLIMATIC SIMULATION LABORATORY



World Health Organization

WORLD METEOROLOGICAL ORGANIZATION

Extreme heat is a global health emergency.

Billions of people are at risk of preventable death and illness from extreme heat. The Global Heat Health Information Network is helping to increase awareness and capacity to better manage and adapt to the health risks of dangerously hot weather in a changing climate.

LEARN MORE

SCROLL

The Global Heat Health Information Network is an independent, voluntary, and member-driven forum of scientists, practitioners, and policy makers focused on improving capacity to protect populations from the avoidable health risks of extreme heat in our changing climate.

INAUGURAL REGIONAL HEAT HEALTH FORUM

HEAT RESILIENCE & PERFORMANCE CENTRE

A globally-connected, first-class research centre enabling humans to thrive in a warming world

www.medicine.nus.sg/hrpc