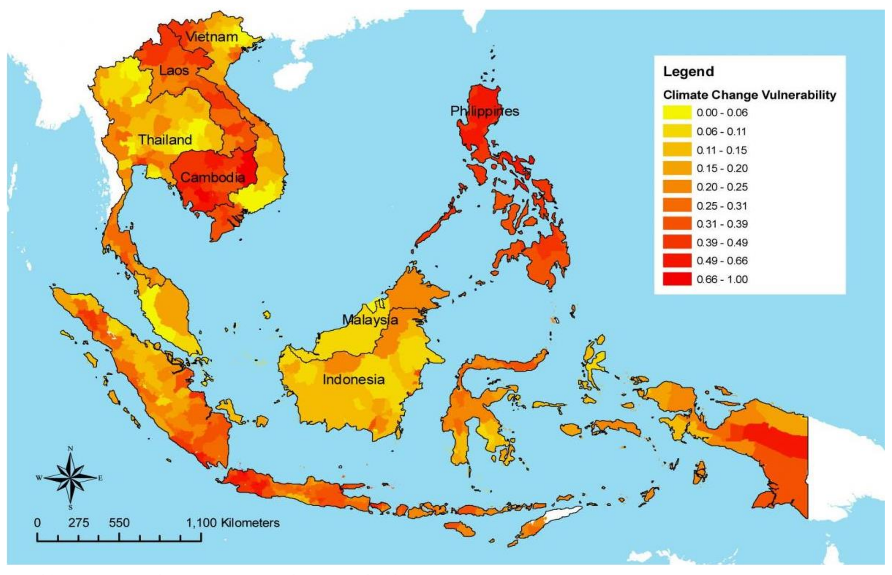
Effects of Heat Stress on Cambodian Construction Productivity

Latin Heang[1], Kinnaleth Vongchanh[1,2*], Sarin Chan[2], Pheak Kor[2], Yang Yang[3]
1 Research and Innovation Center, Institute of Technology of Cambodia, Russian Fed. Blvd, Post Box 86, Phnom Penh, Cambodia
2 Department of Industrial and Mechanical Engineering, Institute of Technology of Cambodia, Russian Fed. Blvd, Post Box 86, Phnom Penh, Cambodia
3 Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Hom, Kowloon, Hong Kong
*Corresponding author: kinnalethv@yahoo.co.uk

មន្ទីរពិសោធន៍កម្ដៅ THERMAL LABORATORY
The CCCA3 Knowledge Sharing Event
Sokha Beach Resort, Sihanoukville. 28-29th December, 2023.

Background and objectives



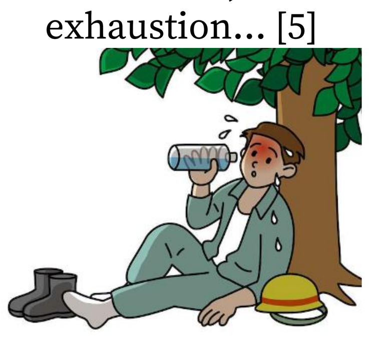
Climate Change Vulnerability (Source: IDR, Last update 31 Jan 2009)

Cambodia, located in the tropics, has an average temperature of 28℃ [1]. Climate change could lead to a 10% decrease in Cambodia's GDP by 2050, affecting many sectors including manufacturing, agriculture, and especially construction [2].

The construction sector is at risk due to heat stress on workers [3]. Studies have found that workers can lose half of their work ability at temperatures of 33-34°C [4]. This study aim to investigate how heat stress affects worker productivity in Cambodia's construction sector, a case study in Phnom Penh in different weather conditions.

Heat stress may result in several issues

Several illnesses: heat stroke, heat exhaustion... [5]



Decrease productivity [6]

Increase chance of injuries [7]

Approaches and technology used

1. Questionnaire Survey: Collect data on personal factors such as age, weight, height, alcohol drinking habits, smoking habits, and medical history. And psychometric factors including rate perceived exertion and thermal sensation were questioned and record in every 15 mins.

2. Physiological Monitoring: Monitor heart rate to assess the work intensity of the workers using heart rate sensor (Polar H10). The heart rate was monitored every minute, and this data was utilized to compute the maximum heart rate percentage (%Hrmax) at 15-minute intervals.

3. Environmental Monitoring: Using heat stress monitor (QuesTemp 36), environmental parameters such as dry and wet bulb temperatures, relative humidity, and globe temperature were measured onsite every 15 minutes to calculate the Wet Bulb Globe Temperature (WBGT).

4. Productivity Observation: Observe and record the direct working time, indirect working time, and non-productive time, every minute. This data is then used to compute construction labor productivity at 15-minute intervals.

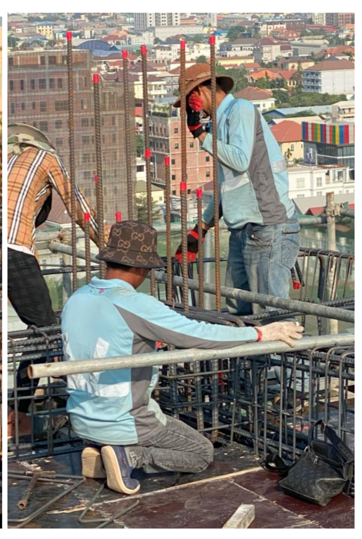
5. Data Analysis: Analyze the collected data to study the relationship between heat stress and labor productivity as well as its impact on other variables. Our analytical approach incorporates descriptive statistics, correlation analysis, and ANOVA testing.

On site data collection

Questionnaire
(Questionnaire + Measurement)

Physiological Monitoring
Heart rate sensor (Polar H10)

Environmental Monitoring
Heat Stress Monitor (QuesTemp 36)



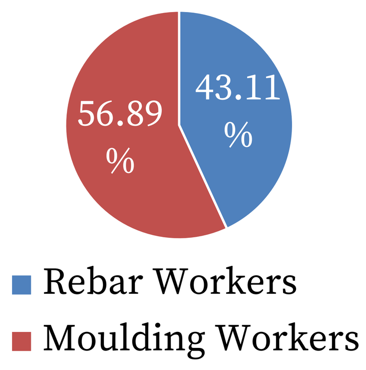
Productivity Observation
(Observed and record activities)

Results

- **Demographic Information**

Parameters	Mean (± SD)	Unit
Age	**34** (± 11)	years
BMI*	**22.27** (± 2.78)	kg/m^2
Gender (Male)	**100**	%
Molding workers	**40**	Workers
Rebar workers	**34**	Workers

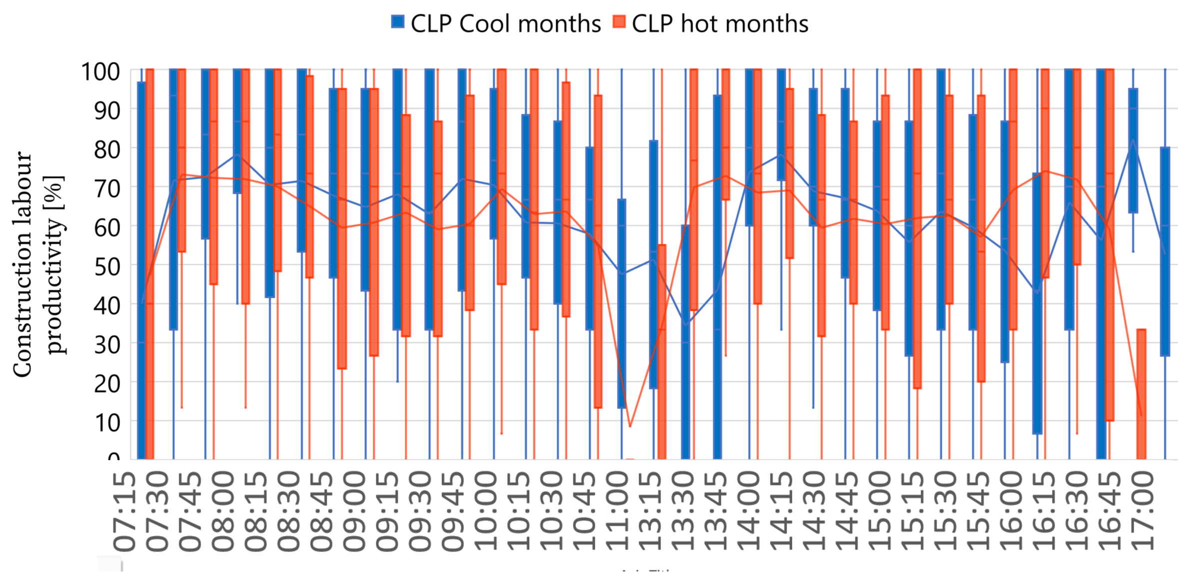
The total collected data sets was 2067, 74 workers



Rebar worker

Molding worker

- **Construction labor productivity during cool and hot months**



Construction labor productivity

CLP	Cool	Hot	Unit
Mean	61.02	63.4	%
Obs.	1107	960	Set
P_{value}	0.28		

=> T-test result showed that there is no significant difference between mean of productivity in hot and cool months.

- **Effect of heat stress on labor productivity, work intensity, perceptual strain and work duration**

- **Correlation analysis:**

	CLP	WBGT	age	WD	$\%HR_{max}$	BMI	ADH	SH	PeSI
CLP		-0.089***	0.077***	0.122***	0.087***	0.001	0.007	0.015	0.098***
WBGT	-0.089***		0.202***	-0.231***	0.239***	-0.026	-0.005	-0.136***	0.374***
age	0.077***	0.202***		-0.022	0.414***	0.227***	-0.046*	-0.195***	0.028
WD	0.122***	-0.231***	-0.022		-0.147***	-0.009	-0.016	0.073**	-0.185***
$\%HR_{max}$	0.087***	0.239***	0.414***	-0.147***		0.138***	-0.042	-0.166***	0.067**
BMI	0.001	-0.026	0.227***	-0.009	0.138***		0.232***	-0.157***	-0.156***
ADH	0.007	-0.005	-0.046*	-0.016	-0.042	0.232***		0.022	-0.120***
SH	0.015	-0.136***	-0.195***	0.073**	-0.166***	-0.157***	0.022		0.070**
PeSI	0.098***	0.374***	0.028	-0.185***	0.067**	-0.156***	-0.120***	0.070**	

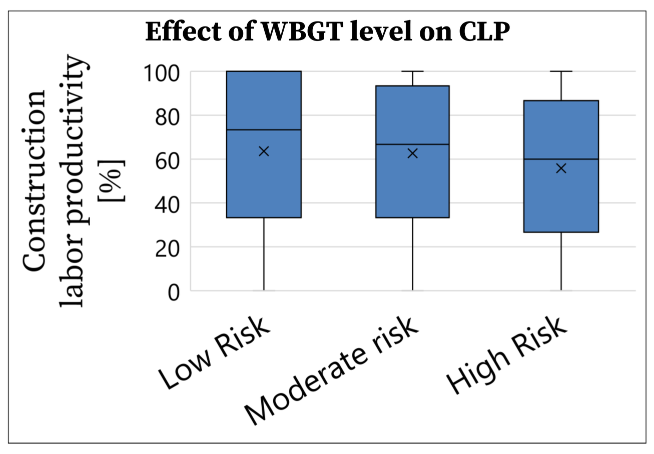
Computed correlation used pearson-method with listwise-deletion.

- **ANOVA test (n=2067)**

ANOVA test on effect of WBGT on CLP, work intensity, PeSI, WD

WBGT (℃)	CLP (%) Pr < 0.002274 **	$\%HR_{max}$ Pr <2.2e-16 ***	PeSI Pr < 2.2e-16 ***	WD Pr < 1.2e-14 **
High Risk (WBGT>32.1)	55.82 ± 34.96	55.67 ± 8.66	3 ± 1.27	109± 92.29
Moderate Risk (29.4 < WBGT < 32.1)	62.64 ± 33.38	51.14 ± 7.67	2.24 ± 1.16	138± 92.04
Low Risk (WBGT < 29.3)	63.60 ± 34.13	49.98 ± 8.00	1.45 ± 0.80	156± 92.08

Effect of WBGT level on CLP



Findings

Heat stress (WBGT) has significant **negatively impacts construction labor productivity** and **work duration** due to physiological strain, while simultaneously **increasing work intensity** and **perceptual strain**, indicating that workers are exerting more effort and experiencing increased discomfort in high heat conditions.

Scale up plan

The findings highlight the importance of **managing heat stress** in the **workplace** to **protect worker health** and **maintain productivity**. It suggests that **employers** in the construction industry (and other industries where workers are exposed to high temperatures) **should implement measures** to **reduce heat stress**, such as providing **rest breaks**, **hydration**, and **cooling areas**, and **scheduling heavy work** for cooler area of the day.

References

[1] Climate CHIP. (2023). Climate CHIP. Retrieved December 12, 2023, from https://climatechip.org/your-area-climate-data
[2] CCCA2. (2018). Annual Progress Report 2018.
[3] CCCA3. (2021). Understanding the Effects of Heat Stress on Labor Productivity in Cambodia's Garment Industry, Construction and Education Sectors. National Council for Sustainable Development. https://ncsd.moe.gov.kh/resources/document/understanding-effects-heat-stress-labour-productivity
[4] Kjellstrom, T., Maître, N., Saget, C., Otto, M., & Karimova, T. (2019). Working on a warmer planet: The impact of heat stress on labour productivity and decent work. Geneva: International Labor Organization.
[5] USAID. (2019). Climate Risk Profile Cambodia. https://www.climatelinks.org/sites/default/files/asset/document/2019_USAID_Cambodia CRP.pdf
[6] Yi, W., & Chan, A. P. C. (2017). Effects of heat stress on construction labor productivity in Hong Kong: a case study of rebar workers. International Journal of Environmental Research and Public Health, 14(9), 1055.
[7] Spector, J. T., Masuda, Y. J., Wolff, N. H., Calkins, M., & Seixas, N. (2019). Heat exposure and occupational injuries: review of the literature and implications. Current Environmental Health Reports, 6, 286–296.

CAMBODIA CLIMATE CHANGE ALLIANCE
Implemented by:
Funded by:
ស៊ុយអែត Sverige
Heat Stress Cambodia
NUS National University of Singapore
The Hong Kong Polytechnic University 香港理工大學
CAMBODIA CLIMATE CHANGE ALLIANCE
Implemented by:
Funded by:
ស៊ុយអែត Sverige