

Trial results for heat stress mitigation in Construction using ice slurry

25th May 2023



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Climate change increase heat stress risk on outdoor workers



Two construction workers in King George's Avenue wear helmets secured with cardboard to shield them from the afternoon sun. ST PHOTO: SHINTARO TAY

The no. of heat injuries in Singapore is low, but with rising temperatures, it is important for us to look for solutions now rather than later.

Table 7c: Number of confirmed occupational diseases cases by type, 2021 - 2022

Occupational Diseases by Types	2021	2022
Total	659	1,052
Noise-induced Deafness	168	624
<i>NID (E) - Early</i>	165	618
<i>NID (A) - Advanced</i>	3	6
Work-related Musculoskeletal Disorders	379	340
<i>Back injuries due to ergonomic risks</i>	323	310
<i>Tendinitis</i>	21	6
<i>Trigger Finger/Thumb</i>	6	1
<i>Nerve Disorder such as Carpal Tunnel Syndrome, Cubital Tunnel Syndrome</i>	8	2
<i>Lateral Epicondylitis (Tennis elbow)</i>	3	2
<i>Tenosynovitis</i>	0	1
<i>Others</i>	18	18
Occupational Skin Disease	79	63
<i>Eczema</i>	74	59
<i>Others</i>	5	4
Compressed Air Illness	9	7
<i>CAI Type 1</i>	7	5
<i>CAI Type 2</i>	2	1
Cancers	5	5
<i>Mesothelioma</i>	5	5
Occupational Lung Disease	2	3
<i>Occupational Asthma</i>	1	1
<i>Silicosis</i>	1	1
<i>Asbestosis</i>	0	1
Infectious Disease	2	2
Heat Disorder	5	1
Barotrauma	2	0

Source: Workplace Safety and Health Report 2022

THE STRAITS TIMES

SINGAPORE

S'pore stepping up efforts to tackle heat as temperatures could hit 40 deg C by 2045



Source: [The Straits Times](#)

While the number of reported injuries and illness is low, studies show that dehydration can cause decline in mental functions and reaction time. Thus increasing the risk of workplace accidents.

Dispensing ice slurry to workers to prevent heat stress

Using ice slurry to mitigate heat stress is :

- a recommended measure under [WSH Guidelines](#) to induce greater internal cooling for workers on hot days
- Proven in Sports science, and supported by NUS Project HeatSafe research and scientific papers

Effects of Ice slurry on worker – *in consultation with A/Prof Jason Lee (NUS Project HeatSafe)*

- **Improved heat tolerance**
 - ✓ More efficient than drinking cold water.
 - ✓ Ice particles within the body induces heat sink that cools the body core temp. by half a degree
- **Reduced risk of heat induced accidents**
 - ✓ Heat stress can lead to loss of focus and fatigue, poorer mental and physical performance.
- **Improved morale and work efficiency**
 - ✓ Workers with increased endurance are more productive.

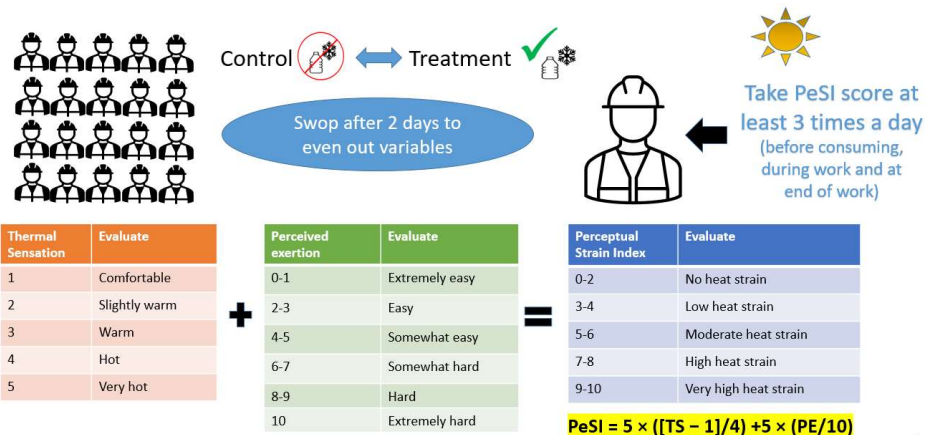


To test the solution in local Construction environment, we did a field test to gauge workers' reception to ice slurry and to measure the solution effectiveness

Overview

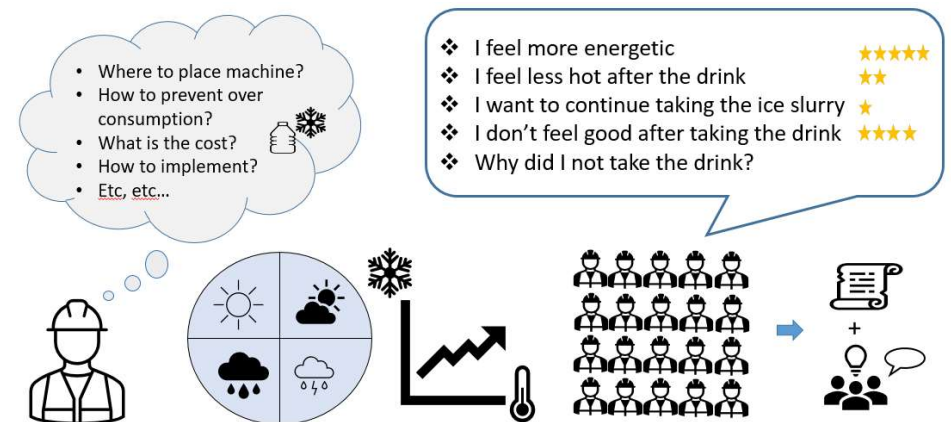
Phase 1 – to measure ice slurry effectiveness

Controlled implementation – only available to a selected group of workers
Collect data on PeSI score



Phase 2 – to gauge worker's reception

Full site implementation – available to all workers
Measure effectiveness of admin controls
Gauge worker reception to ice slurry



Supporting Partners:



The trial was carried out at Teambuild HDB construction site for about two weeks from 4 July till 15 July 2022

Teambuild Construction Group volunteered to host the trial at their HDB's residential block development at Yishun Avenue 8. More than **200 workers** participated in the trial.

Phase 1	4 days	40 workers participated
Phase 2	8 days	160+ workers participated

In total, **~900** litres of ice slurry was consumed during the trial (~700 litres was consumed across 8 days in Phase 2).



The ice slurry machine was set up at Teambuild Construction site canteen, for workers to take during breaks



Simplex/F&N installed ice slurry machine



100 plus ice slurry



Briefing by Teambuild at start of trial



Project Heatsafe showing how the WBGT works



WBGT meter at site entrance



Workers enjoying ice slurry during breaks



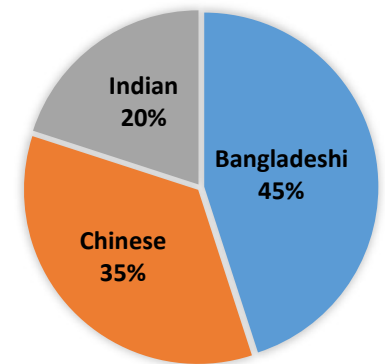
To measure the effectiveness of ice slurry, we used Perceptual Strain Index Score (PeSI) to compare differences between a control and treatment group of 40 workers

PeSI is computed from the **thermal sensation score (TS)** and **perceived exertion score (PE)**.

How hot the person is feeling

How much effort is the activity

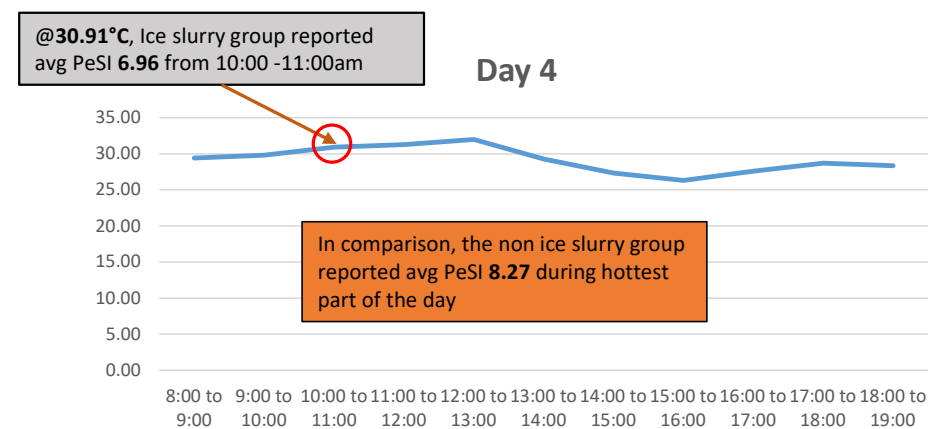
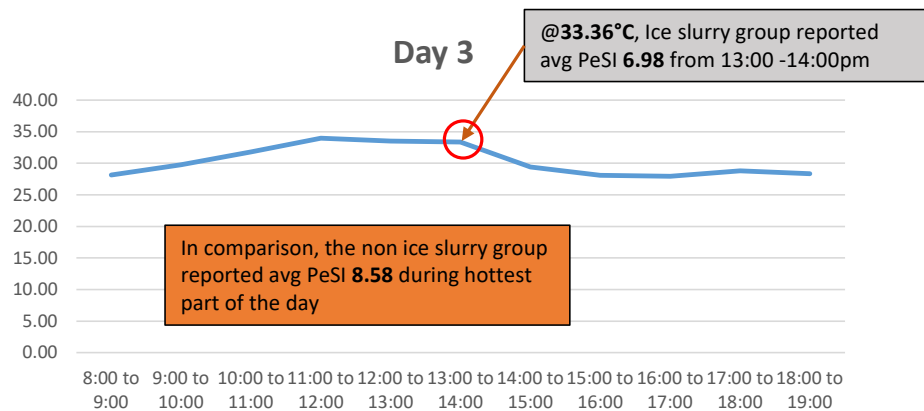
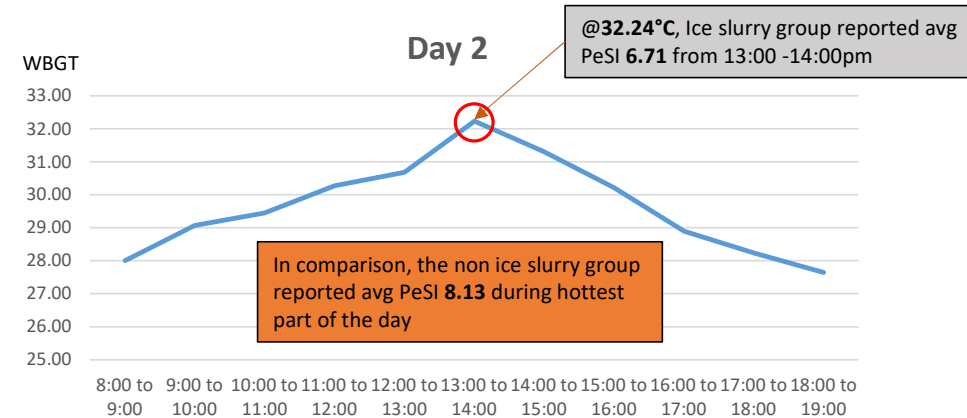
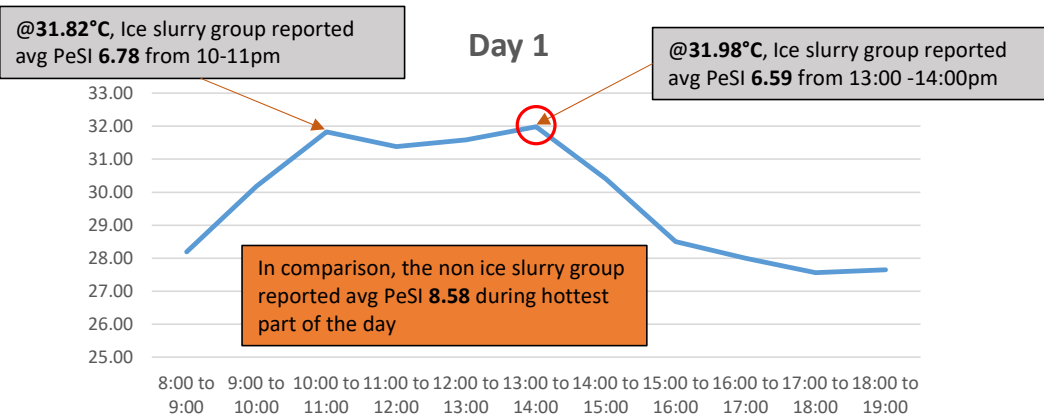
- ❖ Readings were taken 3-5 times a day for 40 workers, who consumed ice slurry ($\geq 400\text{ml}$ per serving) at 10 am, 1pm and 3pm
- ❖ On days workers did not drink ice slurry, the PeSI score was reported at end of work day, for work carried out at the hottest part of the day*.
- ❖ The workers performed an assortment of works, including rebar, formwork, concreting works
- ❖ Each worker was his own control and treatment - he drank ice slurry for 2 days and 2 days without.
- ❖ PeSI was taken at start of day, and compared against PeSI during work, to measure each worker's difference.



Nationality distribution for 40 workers (37 resident contractor workers, 3 supervisors)

* For practicality and ease of data collection reasons, we implemented end of day reporting in the field trial. The WBGT data was used to do matching and data analysis.

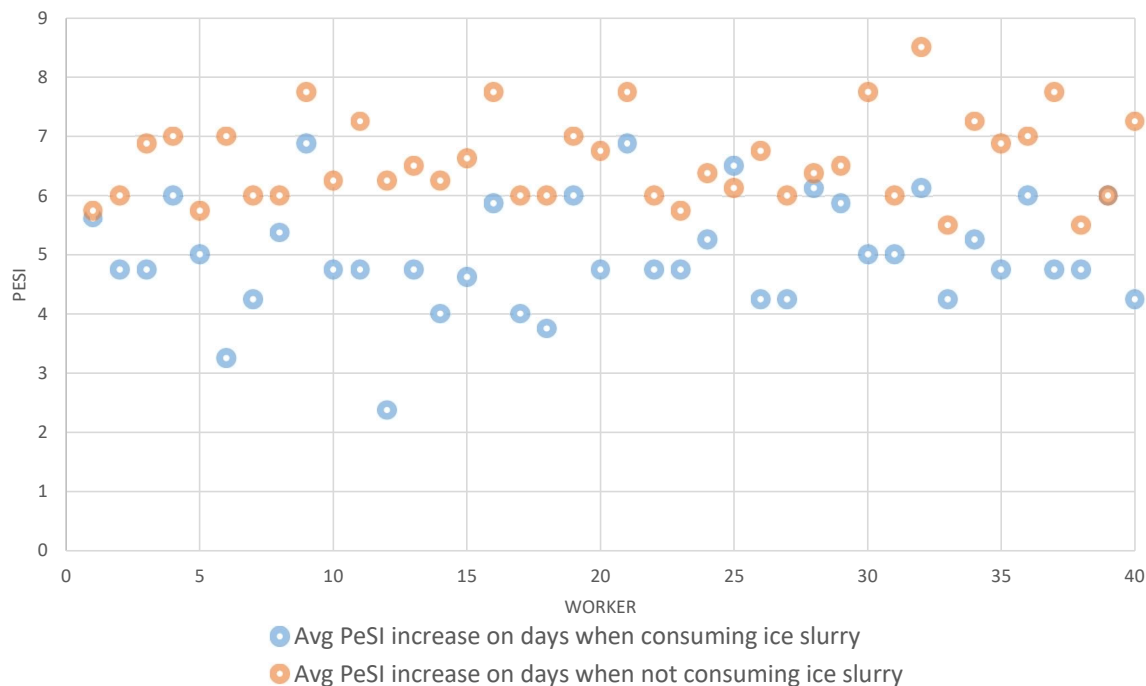
When comparing the average PeSI scores reported by workers at data points closest to the hottest part of the day, we found that workers taking ice slurry had lower average PeSI scores for all 4 days



○ Data points for comparison

On an individual worker basis, 38 out of 40 workers showed a smaller increase in PeSI (from start of day to hottest part of day) on days when they had ice slurry – reduced risk of heat injury. 1 worker showed no difference and 1 worker showed higher increase. (high PeSI score can reduce work productivity and increase the risk of heat injury)

Increase in PeSI from start of day to hottest part of day

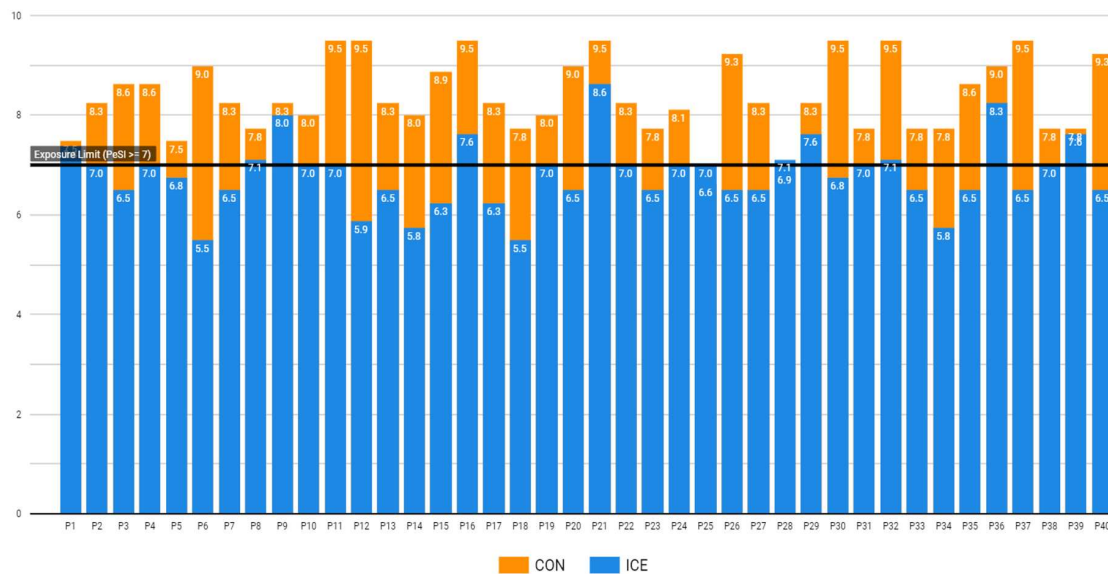


PeSI Table

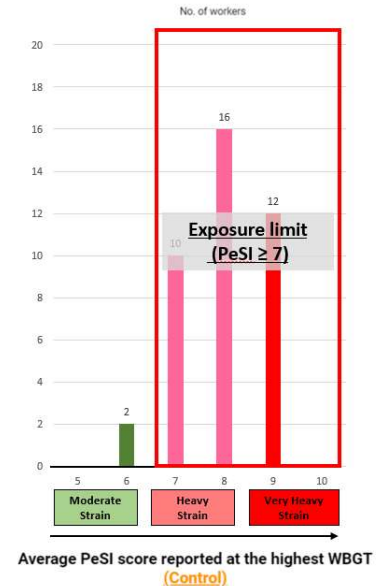
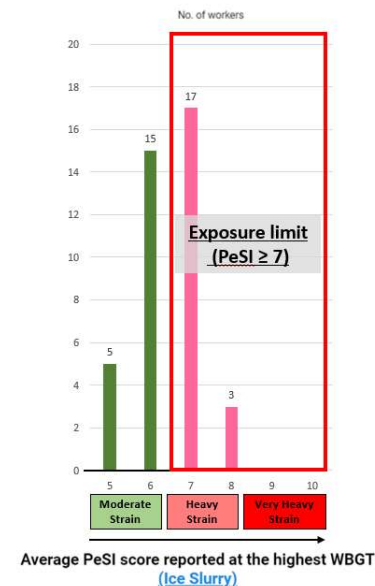
Perceptual Strain Index	Evaluate
0-2	No heat strain
3-4	Low heat strain
5-6	Moderate heat strain
7-8	High heat strain
9-10	Very high heat strain

The trial also found that majority of workers in ice slurry group had PeSI less than 7 during hottest part of the day, while control group was above 7. PeSI of 7 and above represents high to very high risk of heat injury.

Distribution of PeSI score at the hottest time of the day



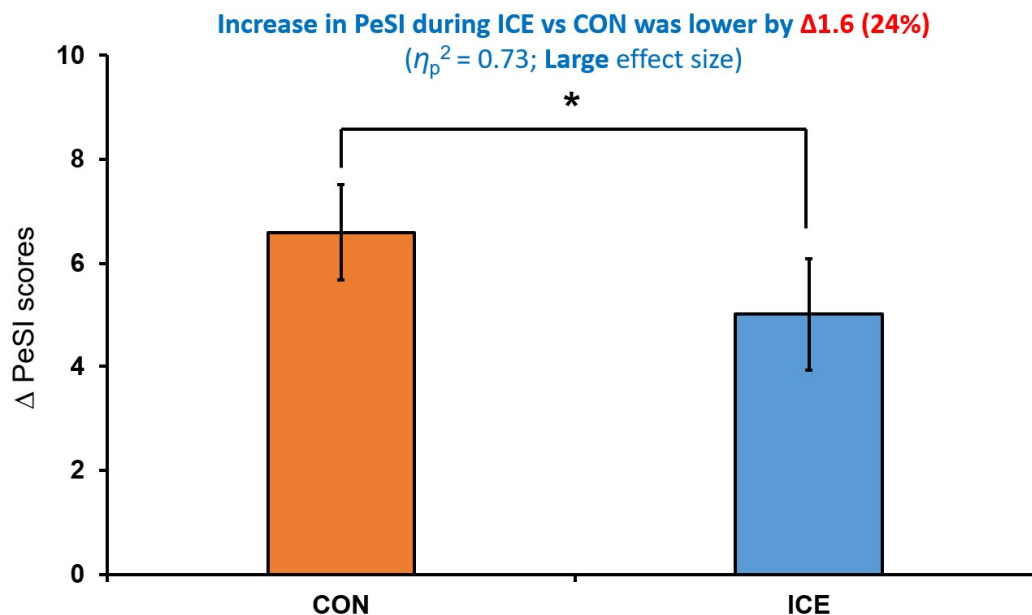
Categorization of workers at the hottest time of the day



Credit: [Project HeatSafe](#)

The average PeSI reduction for ice slurry group was 1.6, which was a significant reduction for worker's risk of heat injury

Average Increase in PeSI from start to hottest time of the day



Values are in mean \pm SD.

* Significant difference between ICE and CON, $P < 0.001$

Credit: [Project HeatSafe](#)

PeSI Table

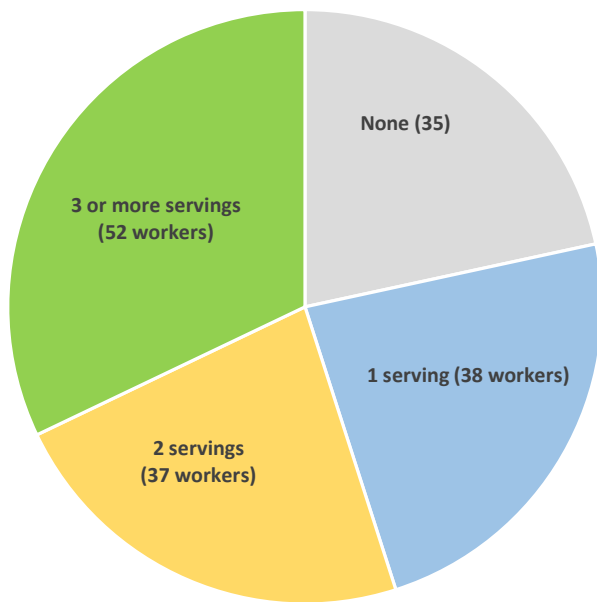
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Note:

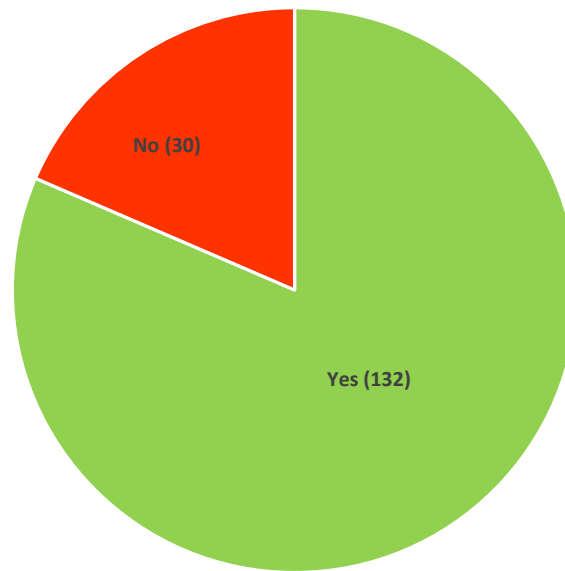
Effect sizes are reported as Partial eta squared (η_p^2) with demarcations of small (0.01), medium (0.06) and large (0.14) effects.

Majority of workers who consumed ice slurry said that ice slurry helped their work. Average consumption was 0.84L per worker per day (2.11 servings)

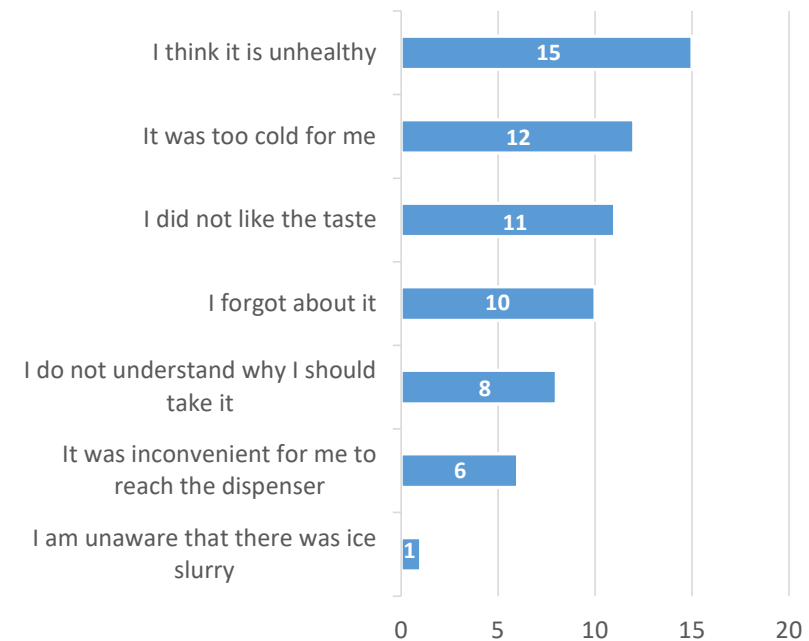
162 survey forms were submitted (160+ workers participated in Phase 2)



No. of servings taken per day on average (78% of workers consumed ice slurry)

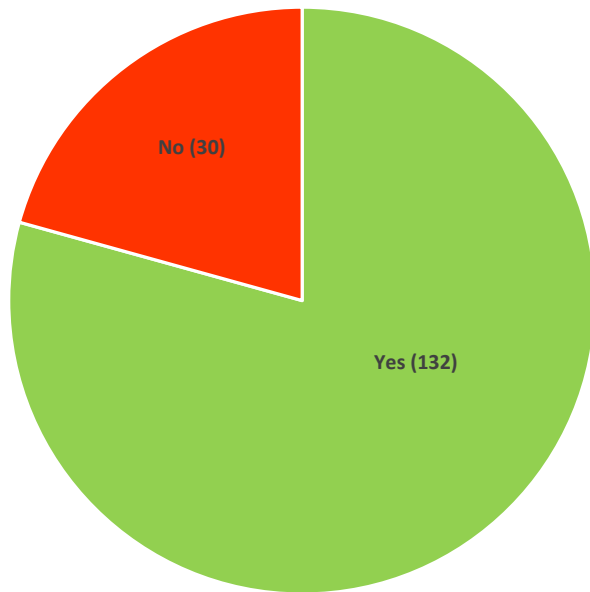


Did you feel that ice slurry helped your work? (81% of workers said 'Yes')

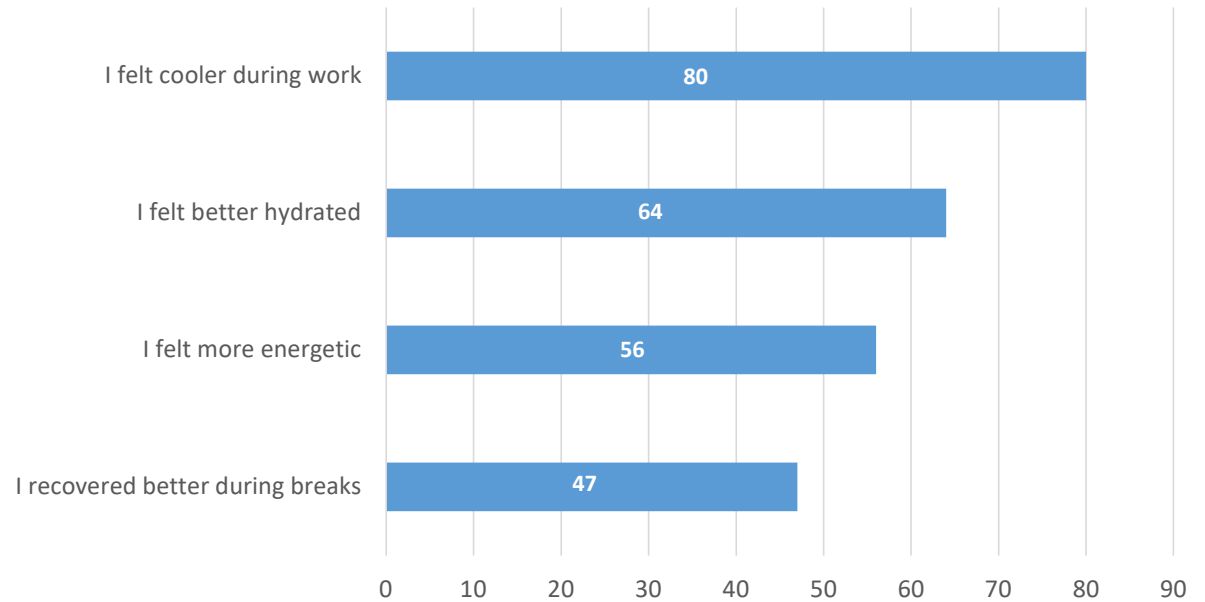


Reasons for not taking ice slurry (more than 1 reason could be selected)

Majority of workers who consumed ice slurry during the trial, also said they wish to continue consumption if it was available



Would you continue to take ice slurry if it was available after the trial?



Please tell us the benefits (more than 1 option could be selected).

Focused group discussion was conducted on 19 Aug 2022 to seek qualitative feedback from Teambuild's supervisors and workers

Participants Profile

- 5 Supervisors who participated in Phase 1 and 2
- 10 workers (mixed responses) from Phase 1 and 2
- 2 WSHI officers
- 1 Observer from Project HeatSafe



Key Findings

- Feedback was largely positive, with workers saying after taking ice slurry, work was easier and they felt less warm
- Concerns were raised by Supervisors, over cost and manpower constraints to implement ice slurry as a long term solution
- Most workers say they preferred isotonic 100 Plus ice slurry over other cold drinks brands after the trial, and some were willing to pay

The ice slurry solution was a worker centric heat mitigation solution and popular among workers



I felt very happy after drinking and work feels easier.



After trial, I prefer ice slurry over regular cold drinks



I need to factor cost and deploy additional labour to supervise machine



Breaktimes are hard to stagger. After 10 cups, the ice was more watery



If one cup 50 cents, I will still buy 2-3 per day, but prefer it free



I like that 100 plus did not cause spikes in energy and was hydrating



Queue times were long and I was too far away to get it during break



Observation: Some workers dislike cold drinks and prefer water or Chinese tea

What's next

What's next?

The manual dispensing machine used in the trial may not be suitable for rugged environments, and there is also cost to man and maintain the machine.

Hence, we continue to study the viability of using ice slurry, while F&N is exploring a different solution that will be more practical and scalable for on-site deployment.

Articles for further reading

Using ice slurry to mitigate heat stress

[Ice slurry ingestion during break times attenuates the increase of core temperature in a simulation of physical demand of match-play tennis in the heat](#)

[Industrial heat stress : Using ice slurry ingestion as a practical approach to reducing heat strain in workers](#)

[Ice slurry and cold drink reduces exercise induced physiological strain in the heat](#)

Using Perceptual strain index to measure risk of heat stress

[Validation of Perceptual Strain Index to Evaluate the Thermal Strain in Experimental Hot Conditions](#)

[Practical on-site measurement of heat strain with the use of a perceptual strain index](#)

Effects of heat stress on workers

[Heat Stress and Thermal Perception amongst Healthcare Workers during the COVID-19 Pandemic in India and Singapore](#)

[Effects of Heat Stress on Construction Labor Productivity in Hong Kong: A Case Study of Rebar Workers](#)

[Heat Safety in the Workplace: Modified Delphi Consensus to Establish Strategies and Resources to Protect the US Workers](#)

[Effects of Heat Stress on Construction Labor Productivity in Hong Kong: A Case Study of Rebar Workers](#)