KEY FINDINGS

International
Labour
Organization

ASSESSMENT OF OCCUPATIONAL HEAT STRAIN AND MITIGATION STRATEGIES

in Qatar

ILO Project Office
for the State of Qatar

Assessment of occupational heat strain and mitigation strategies in Qatar

Summary of key findings from a report prepared by the FAME Laboratory for the International Labour Organization, the Qatar Ministry of Administrative Development, Labour and Social Affairs, and the Supreme Committee for Delivery and Legacy.

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Report Number:
FL/2019/13

ASSESSMENT OF OCCUPATIONAL HEAT STRAIN AND MITIGATION STRATEGIES IN QATAR

Summary of Key Findings

Average temperature and humidity are high and rising, leaving workers at increased risk of heat-related illnesses.

Climate change is occurring at an accelerated pace, with an average warming of 1.5°C anticipated over the next two to three decades across the globe. In the Gulf region, and the Qatar peninsula in particular, workers perform manual labour in hot and humid conditions often exceeding 45°C and 90 per cent relative humidity, and under intense solar radiation. This mix of factors can cause significant heat strain – a term used to describe the physiological effect on the body caused by environmental / occupational heat stress.

To protect workers' health, the Government of Qatar introduced a prohibition in 2007 on outdoor work during the hottest time of the day, from 11:30 to 15:00, from June 15 to August 31 (Ministerial Decision No. 16 of 2007). In this 11-week period, labour inspectors ordered the closure of 310 worksites for violating this regulation. However, weather data from the Qatar Meteorological Department (Figure e1) suggest that individuals working outdoors are potentially performing their job under significant occupational heat stress conditions for at least four months of the year.

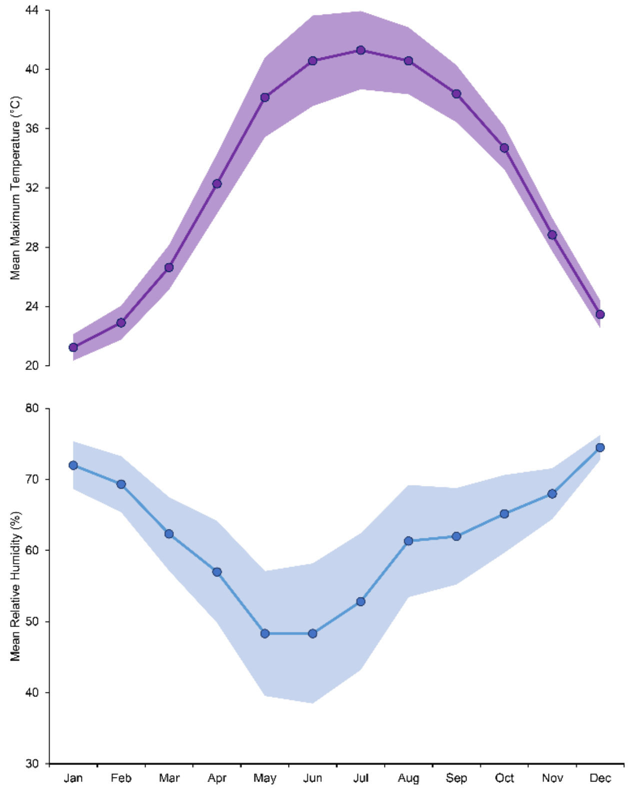


Figure e1. Monthly environmental conditions (mean±standard deviation) recorded from 1962 to 2013 by the Qatar Meteorological Department.

In the summer of 2019, the most in-depth study of its kind was conducted in Qatar to inform evidence-based strategies to mitigate heat stress.

The study was conceptualized by the Ministry of Administrative Development, Labour and Social Affairs (ADLSA), the International Labour Organization (ILO) and the Supreme Committee for Delivery and Legacy (SC), and independently carried out by the FAME Laboratory (University of Thessaly, Greece).

The research project was undertaken to accurately determine the magnitude of occupational heat stress (OH-stress) and strain (OH-strain) experienced by workers who perform manual labour in Qatar, and to customize and optimize mitigation strategies to safeguard workers' health and wellbeing – without losing sight of the consequences for the local economy. These evidence-based strategies include possible amendments to current legislation, as well as measures that can be introduced at the enterprise level.

Construction and agriculture are the two sectors in which heat stress conditions are most evident. Field research was therefore carried out throughout the summer of 2019 on a large construction site (a World Cup stadium employing over 4,000 workers) with a comprehensive heat stress management plan already in place, as well as a small farm with 40 workers with minimal mitigation measures. Data were gathered on environmental, labour, physiological, and perceptual (psychological / subjective) indicators during various work shifts, including one piloted during the normally prohibited period from 11:30 to 15:00 (on the basis of a special exemption granted by ADLSA, conditional upon the introduction of specific precautions). Each worker who participated in the study tested four different strategies: business as usual, hydration, clothing, and work-rest ratio. Covering 125 workers over 5,500 work hours, this represents the most in-depth research of its kind ever carried out, and the first in the Gulf region.

This summary of key findings presents analysis of the heat stress conditions on these work sites and in different shifts, the heat strain experienced by workers, as well as the impact of the various mitigation strategies tested.

Despite higher heat and humidity in Qatar, this study reveals that occupational heat strain levels are similar to or less severe than those uncovered by studies conducted in several countries outside the Gulf region – especially when mitigation measures are adopted. This has implications for overall international perceptions of the issue of working conditions in Qatar and the region, as the findings are relevant for many other countries (both within and beyond the region).

Key Finding No.1:

Heat stress conditions vary considerably according to different jobs, workshifts and work sites. A wet-bulb globe temperature (WBGT) index that draws on Meteorological Department data is a reliable basis on which employers can adjust heat mitigation strategies.

The wet-bulb globe temperature (WBGT) and Humidex are two indices commonly used to evaluate the level of heat stress experienced by the body. Humidex does not reliably reflect the differences between indoor and outdoor environments, or between day and night. In contrast, WBGT takes into account solar radiation as well as wind speed, and can more accurately determine the increased OH-stress experienced when working outdoors in the sun.

There is considerable variability in conditions from shift to shift. In addition, there can also be a substantial difference year on year. Compared to historical records, the environmental conditions tested during this research were relatively cool (by about 6°C) and dry (by about 12 per cent relative humidity). This was taken into account when considering recommendations for the future, since OH-stress in Qatar during the summer is typically higher than during summer 2019.

When comparing the data generated by the Qatar Meteorological Department with that of the weather stations set up around the work sites for the purposes of this study, it was found that the network of national weather stations (which is extensive, relative to the geography and size of the country) provides data that fairly accurately reflect the ambient conditions in occupational settings and WBGT.

Key Finding No.2:

While night shifts can reduce workers' exposure to high levels of heat stress, the conditions are still challenging. Moreover there are risks to workers getting insufficient sleep. The time period between 16:00 and 02:00 offers the optimum combination of low occupational heat stress and limited risk of sleep deprivation.

According to WBGT, individuals working outdoors in the sun perform a large part of their job under unsafe (i.e., "high" or "extreme") occupational heat stress levels, but this drops to 12 per cent for those working indoors or in the shade (Table e1).

During the night, the workers perform their job almost the entire time (96 per cent) at safe occupational heat stress levels (i.e., "no", "low", or "moderate"), but this drops to 69 per cent during the day (Table e1).

Table e1. Proportion (per cent) of the shift that workers spent at different levels of occupational heat stress according to WBGT in indoor / shaded areas, in the sun, as well as during the day and night. Field research data from construction and agricultural work sites.

WBGT heat stress risk →	None (<27.8°C)	Low (27.8 - 29.4°C)	Moderate (29.5 - 31.0°C)	High (31.1 - 32.1°C)	Extreme (>32.1°C)
Indoor / shaded areas	13%	57%	18%	11%	1%
In the sun	19%	9%	17%	22%	33%
Day (04:54 - 18:25)	17%	23%	29%	13%	18%
Night (18:26 - 04:53)	80%	16%	4%	0%	0%

0-9 10-29 30-59 60-79 80-100

Note: day / night cycles were determined based on average sunrise / sunset times in July 2019.

Night shifts can reduce workers' exposure to heat stress. However, the potential adverse effects of night shifts on workers' safety, productivity, and health have been widely reported in the literature. Sleep deprivation accumulating over consecutive days can lead to acute or chronic fatigue and increase the risk of accidents. Focus group discussions with small groups of workers, management, and health-and-safety representatives revealed that many of those working during night hours are getting insufficient sleep. A work shift between 16:00 and 02:00 offers the optimum combination of low OH-stress and limited risk of sleep deprivation.

Key Finding No.3:

Contrary to common misconceptions, no difference was found among nationalities and ethnic groups in terms of susceptibility to heat strain. While most workers are healthy young individuals, one third of them reported symptoms or conditions that increase their likelihood of experiencing heat illness when working under occupational heat stress. Proactive health checks, monitoring, and functional assessments at fixed intervals are important to prevent, diagnose, and manage heat-related symptoms and chronic disease among workers, and to assist them to remain fit for duty.

The workers that took part in the study reflected the demographics of the manual labour workforce in the country, in terms of sex, age, and nationality. All of the workers were men, most were lean and in their early 30s – a population that the literature suggests is the most resilient to physical work in hot environments.

In the course of the research, one of the farm workers participating in the study collapsed during work. An ambulance took him to hospital, where he discovered that he was diabetic. At the farm, half of the workers tested had symptoms or conditions that increase the likelihood of heat illness when working under occupational heat stress. This dropped to 21 per cent among the construction workers, probably because at the construction site all workers receive medical screening and monitoring. Therefore, those on the construction site with a chronic disease such as diabetes are aware of the relevant risks, and receive treatment and advice on taking precautions, such as adjusting their workload accordingly.

When broken down by country of origin, similar core body temperatures during work were observed.

Key Finding No.4:

> The core body temperature of the tested workers was within normal levels for the vast majority of their work shift. However, one in three workers performed up to five per cent of their job while hyperthermic (core temperature 38.0-38.4°C), and this can account for up to 30 minutes during a work shift. An extensive heat mitigation plan, such as the one already in place at the construction site, can reduce the period of hyperthermia, while further improvement can be achieved by supplementing such heat mitigation plans with the hydration strategy tested in this study.

While performing their job, the workers tested had a normal average core body temperature (37.3°C). However, there are marked variations during a work shift, from a normal level of 36.7°C up to extreme hyperthermia at 39.2°C.

Hyperthermia (even for a few minutes) was a relatively frequent phenomenon in the tested manual labourers, of whom one in three exceeded the safety threshold of 38°C proposed by the World Health Organization at some time during their work shift.

Although it is important to know that a worker's core body temperature has exceeded the safety threshold of 38°C, the most vital fact is how long the worker is hyperthermic during his / her work shift. The workers studied performed nearly two thirds of their work at normal core temperature levels (36.5-37.4°C), one third at borderline-hyperthermic levels (37.5-37.9°C), and five per cent of their work at hyperthermic levels (38.0-38.4°C; Table e2).

The construction workers spent 0 to 3 per cent of their work shift at hyperthermic levels (depending on the work shift), and this increased to eight per cent among the farm workers, since minimal mitigation measures were in place.

Workers testing the hydration strategy had water brought to them (as opposed to having to walk to the water station) and were advised to drink 750 ml (3 cups) of water every hour from the start until the end of their work shift. This water consumption was supplemented with a total of one tablespoon of salt (for the entire work shift) to avoid hyponatremia. Workers also had water sprinkled on their face, neck and arms (if the worker was wearing a t-shirt) to help increase evaporative cooling and help limit the rate of dehydration. This strategy was the most effective in reducing the time that workers spent at hyperthermia or borderline hyperthermia (Table e2).

Table e2. Proportion (per cent) of the shift that workers spent at different levels of hyperthermia across the strategies tested in the current field research. Data indicate percentages from all workers combined.

Strategy	Hyperthermia levels based on core temperature Normothermia (36.5 - 37.4°C)	Borderline hyperthermia (37.4 - 37.9°C)	Hyperthermia (38.0 - 38.4°C)	Elevated hyperthermia (≥38.5°C)
Business as usual (BAU)	60%	35%	5%	0%
Hydration strategy (HYD)	71%	27%	2%	0%
Clothing strategy (CLO)	60%	37%	3%	0%
Work-rest ratio strategy (W-R)	63%	35%	2%	0%
Average	**63%**	**34%**	**3%**	**0%**

0-9	10-29	30-59	60-79	80-100

Key Finding No.5:

> Workers at both work sites tested performed their job at a low pace during all work shifts due to high heat stress. By self-pacing and performing their job at a low intensity, workers were mostly able to avoid the high levels of heat strain that would be expected, when considering the harsh environmental conditions. Workers must be empowered to take breaks and remove themselves from situations in case of imminent danger to their safety or health. Enhancing workers' ability to self-pace must be a key element of any effective heat stress mitigation plan.

The amount of time spent doing work is significantly impacted by the level of OH-strain experienced by workers (and vice versa). Heart rate measurements suggest that the workers perform their job at a low intensity, a finding that holds true across the different work shifts and heat mitigation strategies tested. The low intensity and the ability to self-pace were verified by real-time task analysis, as the research team monitored work effort throughout each worker's shift on a second-by-second basis.

During the two regular shifts at the construction site, workers spent about 60 per cent of their time on unplanned breaks (Table e3). These are spontaneous breaks taken whenever workers themselves see fit, and do not include the planned breaks administered by management, such as for meals. The time spent on unplanned breaks dropped to 23 per cent for the farm workers, who reported being less empowered to self-pace and take breaks.

The majority of work at both work sites tested was categorized as "low intensity" (Table e3).

Table e3. Proportion (per cent) of the shift that workers spent at different levels of work effort.

		Work effort levels			
		Work break ($0\ W / m^2$)	Low-intensity work ($0.1 - 1.4\ W / m^2$)	Moderate-intensity work ($1.5 - 15.4\ W / m^2$)	High-intensity work ($>15.4\ W / m^2$)
Current work shifts	Work shift 1: 00:00 - 11:00 (construction)	62%	32%	5%	1%
Current work shifts	Work shift 2: 15:30 - 02:30 (construction)	63%	31%	5%	1%
Current work shifts	Work shift 3: 04:30 - 11:00 (agriculture)	23%	67%	10%	0%
Pilot shift	Work shift 4: 06:00 - 17:00 (construction)	42%	40%	18%	0%

0-9 | 10-29 | 30-59 | 60-79 | 80-100

The work-rest balance that workers naturally adopted while performing their job aligned to a large extent with international standards, such as the Threshold Limit Values proposed by the American Conference of Governmental Industrial Hygienists (Table e4). These work-rest cycles are based on WBGT and are adjusted according to work intensity and whether the workers are acclimatized to the environmental conditions. This finding underlines the value of allowing workers to self-pace and determine when they need to take breaks.

Table e4. Recommended work-rest cycles for acclimatized workers (°C WGBT).

Work-to-Rest Cycle	Low intensity	Moderate intensity	Heavy work	Very heavy work
75% to 100% work	31.0	28.0	-	-
50% to 75% work	31.0	29.0	27.5	-
25% to 50% work	32.0	30.0	29.0	28.0
0% to 25% work	32.5	31.5	30.5	30.0

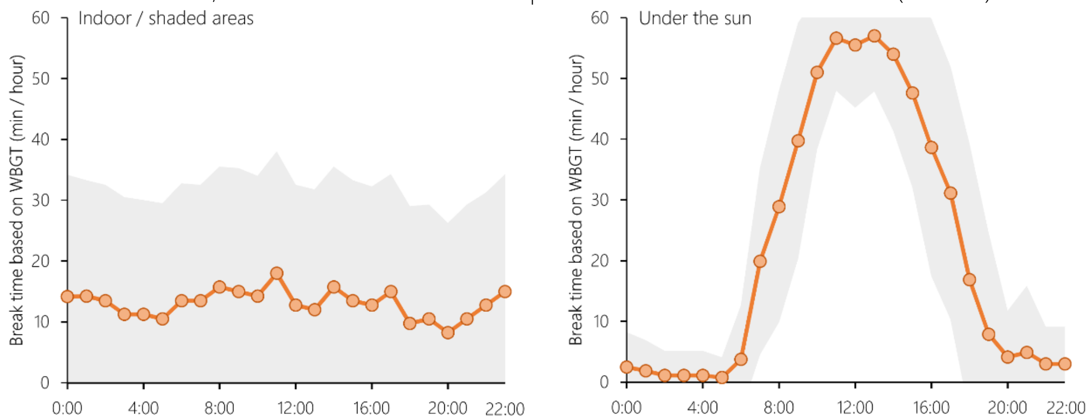
Key Finding No.6:

Individuals working indoors or in the shade can safely work continuously with average breaks of 15 minutes per hour. However, those working in the sun between 10:00 and 15:00 are at high risk of occupational heat stress, based on WBGT.

When work-rest ratios based on WBGT are applied to summer 2019 data for Qatar, the recommended work time is very low for outdoor work performed in the sun from 10:00 to 15:00 (Figure e2). This partially corresponds to the prohibited working hours established in the Ministerial Decision of 2007. However, it is important to note that in summer 2019, the Labour Inspection Department extended the prohibition to include all work on construction sites, indoor or outdoor, as a precautionary measure, even though the recorded WBGT suggested an average break of about 15 minutes per hour would suffice for indoor work, rather than total stoppage (Figure e2).

When the recommended WBGT-based break times during an entire 24-hour day are summed up, they account for approximately 32 per cent of shift duration. These breaks varied widely according to actual conditions. Night work entailed much less break time than day work, and work indoors or in the shade entailed 10-15 per cent less than in exposed areas.

Figure e2. The recommended break time based on WBGT during the day (in indoor / shaded areas and in the sun) in the field research for the period July 1 to 20, 2019. Circles represent averages. Grey areas represent the standard deviation around the average. As the vertical axis increases from 0 to 60, the recommended break time per hour is increased from no break (at 0 min) to no work (at 60 min).



Key Finding No.7:

Clothing and hydration were the most effective strategies for mitigation of OH-strain in workers fully empowered to self-pace. The work-rest ratio strategy offered the most effective mitigation for those who were less empowered to self-pace and negotiate breaks with their supervisors.

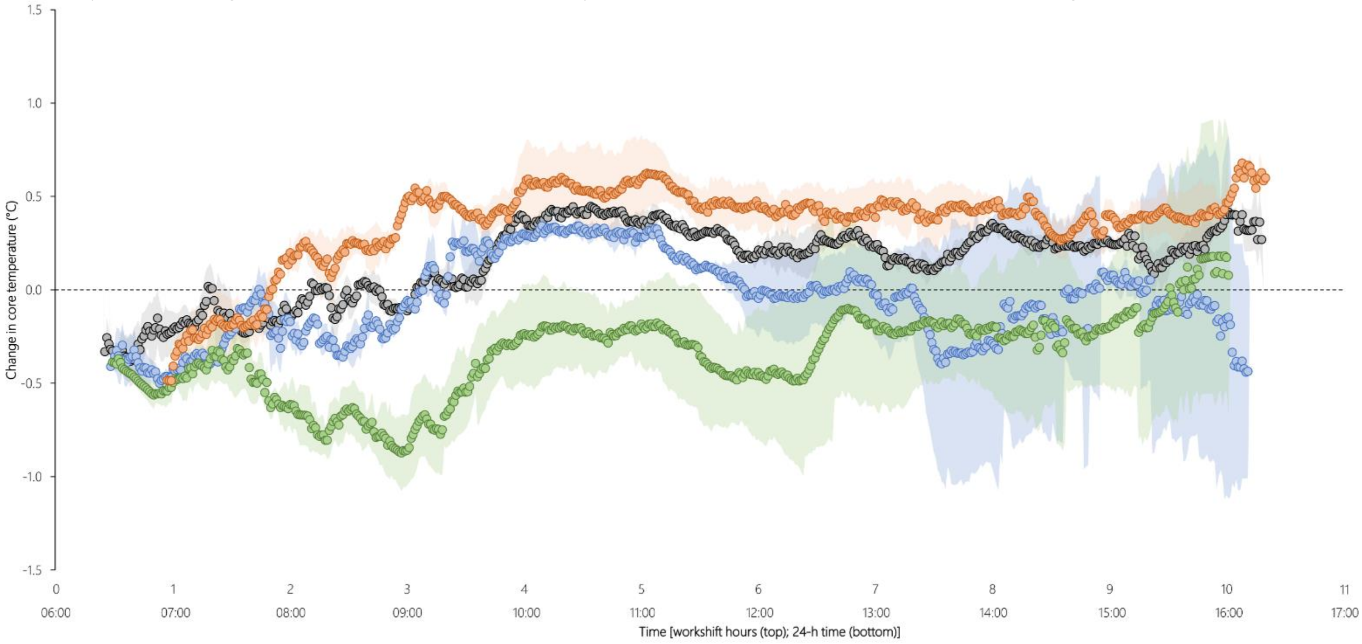
Extensive analysis was undertaken to confirm that the present findings are not influenced by confounding factors including day-to-day changes in climate conditions, tasks, and work demands. When all relevant factors were considered, clothing and hydration were the most effective strategies to mitigate OH-strain in the workers studied (Figure e3).

Construction and agricultural workers in Qatar typically wear durable coveralls of a dark colour. As part of the clothing strategy, the workers tested their usual clothes against two sets of white coveralls (cotton and a cotton / polyester blend); a suit (jersey and trousers) made of light, breathable material developed by the SC; and a cooling vest with fans powered by solar panels.

Workers were given a demonstration on how to maximize the use of the three clothing ensembles prior to the start of the test. The SC suit also had a removable collar, as well as cuffs and pockets that can be dipped in cool water to increase heat dissipation. However, the effect of all clothing ensembles was often cancelled out by workers wearing a t-shirt or vest under the top. Some workers reported having wetted the collar and cuffs of the SC suit at the start of the shift or intermittently during the shift, but few did so systematically throughout their shift.

Of the three clothing strategies tested, the lowest levels of OH-strain were observed when workers wore either white coveralls or the suit developed by the SC, particularly when working the piloted midday shift (06:00 – 17:00). The suit developed by the SC was also the most effective strategy for reducing the workers' self-perceived OH-strain.

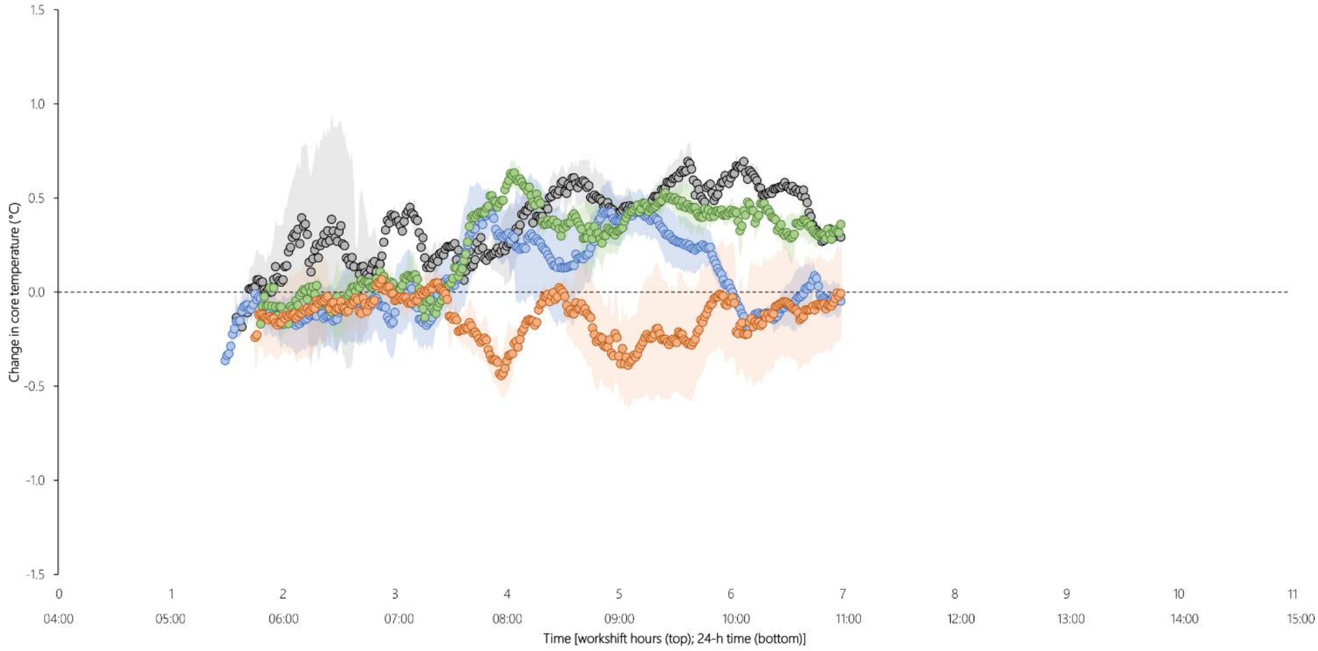
Figure e3. Difference between observed core temperature and expected core temperature as predicted by ISO 7933:2018 guidelines during piloted work shift 4 (06:00 to 17:00) in construction across the BAU (black), HYD (blue), CLO (green), and W-R (orange) strategies. Circles represent averages of one minute. Shaded areas represent the standard deviation around the average.



The work-rest ratio strategy involved instructing workers to take a ten-minute break every hour (where possible), but it did not yield very demonstrable results among the workers in the construction site. This is probably because these workers were able to self-pace. Focus group discussions with the construction workers, welfare officers and safety officers all confirmed workers' ability to freely inform their supervisors when they needed to take a break.

The strategy was more effective in reducing the OH-strain experienced by the farm workers (Figure e4) perhaps because these workers were not as empowered to self-pace and negotiate breaks with their supervisors. In one focus group, farm workers described the peace of mind that came from knowing that they could rest for ten minutes without any pressure to get back to work.

Figure e4. Difference between observed core temperature and expected core temperature as predicted by ISO 7933:2018 guidelines during work shift 3 (04:00 to 11:00) in agriculture across the BAU (black), HYD (blue), CLO (green), and W-R (orange) strategies. Circles represent averages of one minute. Shaded areas represent the standard deviation around the average.



Key Finding No.8:

One third of workers were dehydrated at the start of the work shift and this increased during the course of the shift to 41 per cent. Dehydration was very frequent at the farm, where minimal mitigation measures were in place, but less frequent at the construction site, where extensive heat mitigation measures were implemented. Providing workers with 750 ml of water on an hourly basis (acting as a reminder to drink, and also relieving them of the need to walk to the water cooler) was the most effective strategy to reduce the incidence of dehydration, with the added benefits of reducing hyperthermia and improving labour effort.

Dehydration was a frequent phenomenon among the workers, with 30 per cent of them arriving to work in a dehydrated state, and 41 per cent of them finishing their work shift in a dehydrated state. This was much higher among the farm workers than the construction workers. Averaging all strategies, 60 per cent of the farm workers arrived at work in a dehydrated state, and of these 74 per cent also finished the shift in a dehydrated state.

The urine colour scale used in the field research (as already used by the Government and many enterprises) was proven to be a practical and cost-effective method to diagnose dehydration in manual labour workers in Qatar.

The impact of hydration status on thermoregulation during work and exercise is well established in the literature. The hydration strategy (bringing water to workers and sprinkling water on their faces, necks and arms) proved the most effective in reducing the occurrence of dehydration (Table e6).

Table e6. Occurrence of dehydration based on urine specific gravity under the BAU and HYD strategies across the tested work shifts.

Strategy	Work shifts currently in place						Piloted work shift		TOTAL	
	Work shift 1: 00:00 to 11:00 (construction)		Work shift 2: 15:30 to 02:30 (construction)		Work shift 3: 04:30 to 11:00 (agriculture)		Work shift 4: 06:00 to 17:00 (construction)			
	Start	End	Start	End	Start	End	Start	End	**Start**	**End**
BAU	15%	19%	10%	7%	56%	79%	6%	6%	**30%**	**41%**
HYD	7%	4%	16%	10%	55%	53%	6%	0%	**23%**	**19%**

0-9	10-29	30-59	60-79	80-100

Key Finding No.9:

Two-thirds of the workers at the construction site, where extensive heat mitigation measures were implemented, considered their conditions to be safe. Most of the workers in the farm, where minimal mitigation measures were in place, did not feel that the conditions were safe. Moreover, the SC suit was the most effective in reducing the workers' self-perceived OH-strain in two of the work shifts tested, while the hydration strategy was the most effective in reducing the workers' self-perceived OH-strain in the other two shifts.

In order to complement the physiological data collected, a standardized survey was administered to assess workers' self-perceived OH-strain across the different work shifts and strategies tested. The perceived OH-strain in construction workers was significantly lower than that reported by farm workers. About two thirds of construction workers felt that they work at safe OH-strain levels under the 'business as usual' strategy, compared to only four per cent of farm workers. Two thirds of the farm workers felt that they work at dangerous OH-strain levels under the same strategy, that is, when minimal mitigation measures are in place (Figure e5).

The clothing strategy was the most effective in reducing workers' self-perceived OH-strain in two of the shifts studied (1 and 3) with the SC suit more effective than the white coveralls (Figure e6). Focus group discussion reaffirmed the survey result showing a preference for the clothes designed by the SC. The hydration strategy was the most effective in reducing the workers' self-perceived OH-strain during work shifts 2 and 4.

Figure e5. Workers' responses in the Heat Strain Score Index survey assessing their self-perceived OH-strain during the BAU (top left), HYD (top right), CLO (bottom left), and W-R (bottom right) strategies across the tested work shifts currently in place [work shift 1: 00:00 - 11:00 (construction); work shift 2: 15:30 - 02:30 (construction); work shift 3: 04:30 - 11:00 (agriculture)] and the piloted work shift [work shift 4: 06:00 - 17:00 (construction)].

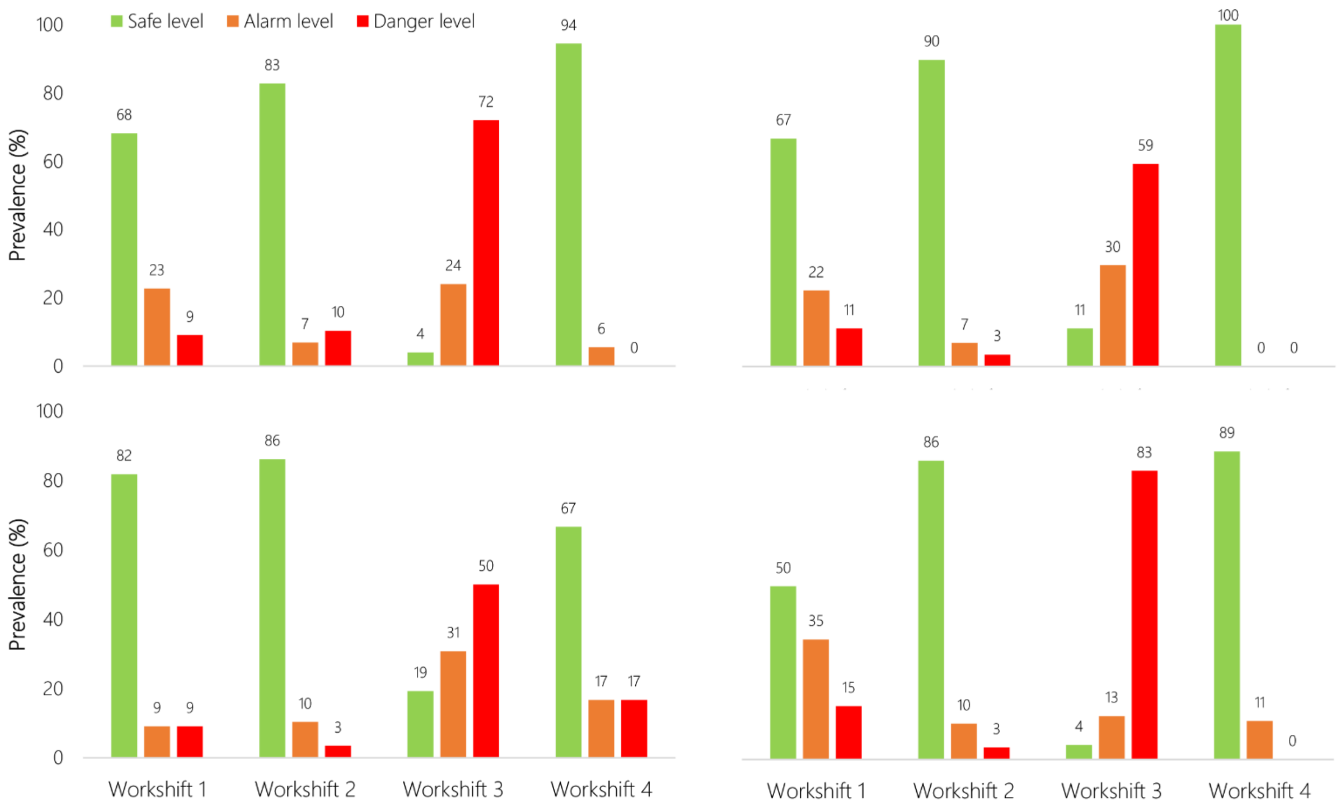
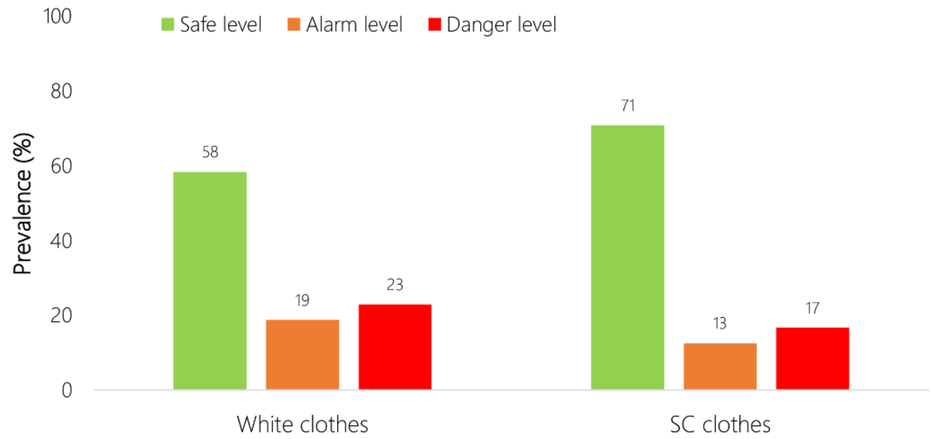


Figure e6. Workers' responses in the Heat Strain Score Index survey assessing self-perceived OH-strain in the CLO strategy, broken down into those who received white coveralls (left) and those who received clothes designed by the SC (right).



The Ministerial Decision No. 16 of 2007 that prohibits work from 11:30 to 15:00 is partially effective. Mere adherence to it is insufficient, and additional measures are needed.

The farm workers studied received limited specific heat-related support, being supported in effect only via the Ministerial Decision. The field research was therefore able to evaluate this strategy when used as the primary heat mitigation method.

The research concluded that workers on the farm were at moderate to high risk of heat strain. This conclusion was derived from recorded duration of hyperthermia and level of dehydration, backed up by the view of more than two thirds of agricultural workers who, when responding to a standardized survey on workers' self-perceived OH-strain, indicated that they felt that they work at dangerous OH-strain levels.

The research provides conclusive evidence that enterprises can significantly reduce the risk of heat strain by effectively applying a comprehensive range of mitigation strategies.

The construction site studied had introduced a raft of heat stress mitigation strategies over and above the legal requirement to stop work from 11:30 to 15:00. This included shaded areas every 100-200m, water stations with cool water and rehydration salts every 300-400m, mandatory water bottles carried by each worker throughout their work shift, ventilated areas and air-conditioned rest areas. Workers had received training on the effects of OH-stress and dehydration backed up by reminders on large signposts. This was reinforced throughout every shift by a large cohort of safety and welfare officers. The SC also supported annual medical checks for workers and reassigned workers who were identified as unfit for work in their current occupations.

The field research was thus able to evaluate this array of heat mitigation protocols. The research concluded that these workers were at low risk of OH-strain. No case of heat strain has been reported at the clinic since 2017, a significant achievement given that more than 4,000 workers are on site.

This does not mean that more cannot be done, as clearly demonstrated by the data on dehydration and heat strain symptoms, as well as focus group feedback on night-shift workers not getting quality sleep and having to use crowded cooling rooms.

For the first time, a qualitative evidence-based approach was developed to evaluate the different heat mitigation strategies following comprehensive testing.

Each of the tested strategies was evaluated using the following five domains: (1) Strength of evidence; (2) Impact on health; (3) Impact on work; (4) Feasibility / Implementation; (5) Environmental sustainability. The development of effective recommendations will hinge on a holistic synthesis of all five domains, rather than a restrictive comparison between one strategy and another. Such an approach reflects recent developments on the assessment of risk and bias, as well as on evaluating the effectiveness of health-related interventions.

For instance, a strategy may be highly effective in reducing OH-strain but place an enormous burden on productivity, rendering it unlikely to be deemed feasible by employers. Similarly, a strategy deemed effective and practical in Qatar may not be supported by evidence in other parts of the world, raising the possibility that it may be less effective or applicable in occupational settings that differ in some way from those tested here.

The evaluation of the different strategies revealed that the hydration strategy was considered to be “highly acceptable”, while the comprehensive heat mitigation plan used for the construction workers was considered “moderately to highly acceptable”.

The clothing strategy tested was considered to be “moderately acceptable”. More specifically, the present evaluation does not support the use of the tested cooling vest as a heat mitigation strategy, but does support the adoption of the white coveralls and the clothes designed by the SC when other – more effective – heat mitigation strategies have been already implemented (namely, assessment of OH-stress via WBGT, the tested hydration strategy, as well as the comprehensive heat mitigation plan used for the construction workers).

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