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Original Article

Heat Stress Vulnerability among Small-Scale Factory Workers and Adaptive Strategies in Ahmedabad: A Cross-Sectional Study

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ABSTRACT

Introduction: Global warming is likely to affect certain groups such as workers in heat-producing industries. With limited research exploring such an important area, this study aimed to explore the heat stress vulnerability and adaptive strategies of indoor small-scale factory workers.

Methods: This was a cross-sectional study and a mixed-method approach was used. The study setting was small-scale factory units. The quantitative component included environmental and biological monitoring from six units of steel rolling mills and foundry in the summer and winter seasons. The study was conducted during the period of November-2018 and May 2019. Heat stress was measured among workers using a portable Wet Bulb Globe Temperature (WBGT) meter. The physiological parameters of workers were also measured. The qualitative component included in-depth interviews of workers and supervisors from eleven units.

Results: The maximum temperatures recorded at steel rolling mills and foundry crossed Occupational Safety and Health Administration (OSHA) threshold (27.5℃) in summer as well as winter. The mean WBGT at the steel rolling mill recorded 31.5℃. The physiological measurements of workers also crossed the threshold level for heart rate and oral temperature in steel rolling and foundry units. The units had mechanisms to dissipate heat but lack a temperature monitoring mechanism inside the units. The workers wore lighter or fewer clothes as an adaptive measure but uncomfortable PPEs in foundry units were avoided.

Conclusion: Heat stress in small-scale industry units was found high and there is a high need to develop specific strategies for such vulnerably high heat-exposed groups.

Keywords: Foundry, Heat Stress, OSHA, Steel rolling mill, Wet Bulb Globe Temperature (WBGT)

Introduction

Global climate change has been one of the greatest challenges in the world in this century and much of this is anthropogenic. Human modifications of the environment have increased greenhouse gases and are a major process fueling global warming which is a key component of global climate change. The world is already witnessing record-breaking temperatures across several geographies and the heat waves have become frequent events in many regions. The Intergovernmental Panel on Climate Change 5th Assessment report also indicates an increase in frequency, length and intensity of heatwaves over most land areas in the future. [1,2]

The effects of global climate change on humans can be devastating. During the past two decades, the number of people exposed to heat waves has increased dramatically and consequently, heat-related health events and hazards have also increased.[3,4] The workplaces especially those of high heat-inducing nature (steel rolling mill, foundry) can compound risks posed by heat stress and the potential consequences of heat stress on workers are substantial.[5] Occupational heat stress risk is projected to become particularly high in middle and low-income tropical and subtropical regions.[6]

India is prone to climate and weather-sensitive health events and heat-related illnesses significant problems in India.[7] The study on analysis of summer temperature, frequency, severity, and duration of heatwaves and heat-related mortality between 1960 and 2009 showed that mean temperature across India has risen more than 0.5℃ over that period with the increase in heatwaves and increase of probability of heat-related mortality in India by 146%.[8,9] The western region of India is most susceptible to heatwaves and showed rising mortality due to extreme heatwaves in the months of summer over the years The changing trend in heat-related mortality was also observed across several years -1972, 1988, 1998 and 2003 in which there were more than 10 heat waves days on average across India, with a corresponding surge in heat-related mass mortality of between 650 and 1500 people.[10] However, the impacts of such heat stress on occupational safety and health remain understudied.[5,11]

Occupational heat stress is the net load to which a worker is exposed from the combined contributions of metabolic heat, environmental factors, and clothing which results in an increase in heat storage in the body.[12] Therefore, Occupational heat stress in industries especially those that have high heat-inducing nature of the environment is critical to understand as workers who are working in such an environment are vulnerable to heat stress and the economic burden is substantial.[13] In India, despite widespread recognition of this problem, a limited attempt has been made to estimate health impacts related to occupational heat stress. This has been reflected in the least control over reducing heat exposure at the workplace.[14] Heat stress due to climate change can compound heat exposures at the workplace, especially in vulnerable occupational settings.

In India, several small-scale industries produce heat and can be particularly vulnerable during the summer months. However, these industries operate in resource-constrained settings with minimal resources for occupational safety and health. Studies on the effects of heat stress on the workers working in these small-scale industries are limited and warrant more evidence.[15] This paper empirically measures the exposure to heat stress among the workers in a foundry, steel rolling mill units in the city of Ahmedabad, one of the metropolises badly affected by heat waves in the past decade[10]. Therefore, the objective of the study was to explore the heat stress vulnerability of indoor small-scale factory workers of foundry and steel rolling units and their adaptive strategies in Ahmedabad.

Methods

Ahmedabad, a city with more than 5 million residents is prone to extreme weather from heat waves (45℃) in summer and cold waves (8℃) in winter. Heatwaves are very common, and the night temperature also remains high during the heat waves. With more than 250,000 workers in about 65,000 small-scale industrial units, Ahmedabad is a busy manufacturing hub. Foundry, steel rolling and ceramic are the most common types of small-scale industries which usually employ 5 to 50 workers. The study adopted a mixed methods design.

The qualitative component of the study included in-depth interviews of workers and managers of small-scale industries which explored the vulnerabilities faced by workers and adaptive strategies employed by them. For this qualitative component, a purposive sampling technique was employed. A total of 30 workers and 7 supervisors from 11 units of steel rolling mill and foundry were purposively selected for in-depth interviews to provide insights into heat stress and adaptive strategies.

All the units sampled in our study were visited and physical observation of the nature of the working environment, working and living conditions of workers was conducted. In addition, areas covered by units for production, space for working, ventilation mechanism of units, and other factory-level facilities and measures for heat coping mechanisms were also observed. The workers' practices and behavior for heat coping and use of protective equipment (like gloves, shoes, and protective goggles) were also captured in observation.

The quantitative component included ambient temperature measurement of sample units and vital physiological parameters of the workers. For the assessment of ambient heat inside small-scale units, six units (three units each of the foundry and steel rolling mill) were selected. The reasons for selecting a smaller number of units for quantitative components than qualitative components include challenges in getting approval by the concerned authority for ambient temperature measurement inside units during that period as well as not feasible to cover more units during that limited period. The ambient heat of these units was measured using a portable heat stress WBGT meter. The measurements included the Globe Temperature (Tg), Air Temperature (Ta) and Relative Humidity (RH) and the combined index as the Wet Bulb Globe Temperature. The measurements were recorded in all six units between 2 PM and 6 PM and at regular intervals during those working hours. To understand the effect of heat waves on the same, the readings were done in two seasons; once in May (Summer) and once in December (Winter) months. The Foundry units had two dedicated areas and hence the measurements were done in both these areas separately.

The physiological measurement of 30 workers (16 workers in a steel rolling mill and 14 workers in a foundry) were taken. The smaller sample size for quantitative components is due to resource constraints, organizational level barriers such as approval to conduct the study at those small-scale units as well as a smaller number of workers available in the units of steel rolling mill and foundry during the summer months largely due to migration to hometown. The physiological parameters of workers are also measured between 2 PM and 6 PM while they are actively involved in work which included heart rate using a pulse oximeter, skin temperature using an infrared thermometer, and oral temperature using a digital thermometer.

The study approval was taken from the Institutional Review Board of Tata Institute of Social Sciences (TISS) by giving undertaking of all ethical guidelines. The study followed ethical principles as laid down in the Declaration of Helsinki. Being an observational study, the risks posed were minimal. All participants were informed about the purpose and process of the research and the role of the researcher. They were explained that their participation was voluntary and they had the right to leave the study at any time before the transcripts were analyzed. In addition, prior consent for the permission of audio recording for interviews was taken. The transcripts were anonymized to protect the identity of the units as well as the participants. Written informed consent was obtained before they participated in the study.

The qualitative data was transcribed and the transcripts were read and re-read. The data were analyzed using a thematic approach which helped draw codes and themes related to the perceptions of heat stress and the mechanisms employed to adapt to it and cope with it. The respondents were asked clearly defined open-ended questions and were open and free to not answer any of the questions.

The maximum and minimum temperature along with the Mean and Standard Deviation (SD) of WBGT were measured for May and December months and have been tabulated. Since both types of units included heavy work, the OSHA threshold of temperature above 27.5℃ on WBGT has been used for defining heat stress. For workers, minimum and maximum physiological parameter readings and Mean and Standard Deviation (SD) were calculated and presented for both types of units in both seasons (Summer and Winter). A heart rate of 110/minute and an oral temperature of 37.6℃ were considered as the threshold for these biological measurements in line with OSHA recommendations.

Results

The heat stress in the form of WBGT and its three components is presented in Table 1 to Table 4. It is important to note that the mean ambient temperatures inside the units during work hours of 2:00 PM-6:00 PM were higher than the maximum recorded temperatures for the city on the same day.

(Ahmedabad's Minimum and Maximum temperature was 16.3℃ - 31.0℃ respectively in winter (1-2 Dec 2018) and 26.0℃ - 41.8℃ in summer (1st May to 4th May 2019) on the day of ambient and physiological measurement).

Table 1: Measurement of Wet Bulb Globe Temperature (WBGT) in two types of industrial units, Ahmedabad

Wet Bulb Globe Temperature in Steel Rolling and Foundry Units					
Type of Industrial Unit	Season	Maximum WBGT Recorded (℃)	Minimum WBGT Recorded (℃)	Mean (WBGT) (℃)	Standard Deviation (WBGT)
Steel Rolling Mill (n=3)	Winter	28.3	24.3	26.5	1.04
	Summer	32.9	30.3	31.5	0.66
Foundry Mill (General area) (n=3)	Winter	24.8	20.4	21.8	1.36
	Summer	27.4	25.7	24.1	0.38
Foundry Mill (Furnace area) (n=3)	Winter	28.7	20.6	26.5	3.81
	Summer	28.5	26.2	27.4	0.92

The heat stress (WBGT) was more in the summer for both types of units. In the steel rolling mill, the heat stress in summer was in the hazardous range. The heat stress (WBGT) in the foundry was not high in the summer or winter months. However, within the foundry unit, the heat stress was significantly higher (3.9℃) near the heating furnace than in a general area in the winter season. There was also a Standard Deviation of 3.81 between the maximum and minimum WBGT recorded near the furnace area of the foundry. It is important to note that the furnace did not operate for the whole day. Instead, the units were starting the furnace only after 3.30-4:00 PM. This explains the readings are lower than the steel rolling units in both Summer and Winter seasons.

The difference in maximum WBGT recorded in the steel rolling mill between summer and winter was 4.6℃ while the difference in minimum WBGT recorded in the foundry between summer and winter was 2.6℃ in the general area and 0.2℃ near the furnace area (Table 1).

Table 2: Measurement of Ambient Air Temperature (T_a) in two types of industrial units, Ahmedabad

Ambient Air Temperature in Steel Rolling and Foundry Units					
Type of Industrial Unit	Season	Maximum Ambient (Air) Temp. Recorded (℃)	Minimum Ambient (Air) Temp. Recorded (℃)	Mean Ambient (Air) temperature (℃)	Standard Deviation (Ambient Temp.)
Steel Rolling Mill (n=3)	Winter	40.6	30.2	37	2.24
	Summer	49.4	42.6	46.5	1.88
Foundry Mill (General area) (n=3)	Winter	36.4	27.8	31.05	2.59
	Summer	41.4	36.9	39.7	1.21

Foundry Mill (Furnace area) (n=3)	Winter	44.1	28.7	35.6	7.38
	Summer	41.7	39.8	40.7	0.69

Table 3: Measurement of Globe Temperature (T_g) in two types of industrial units, Ahmedabad

Globe Temperature in Steel Rolling and Foundry Units					
Type of Industrial Unit	Season	Maximum Globe Temp. Recorded (℃)	Minimum Globe Temp. Recorded (℃)	Mean Globe Temperature (℃)	Standard Deviation Globe Temperature
Steel Rolling Mill (n=3)	Winter	45.2	33.1	40.6	2.6
	Summer	53.8	46.5	50.6	1.81
Foundry Mill (General area) (n=3)	Winter	36.8	27.5	31.7	2.75
	Summer	42.3	36.8	39.9	1.33
Foundry Mill (Furnace area) (n=3)	Winter	39.3	31.4	35.1	2.78
	Summer	46.9	40	43.5	2.49

Table 4: Measurement of Relative Humidity (RH)in two types of industrial units, Ahmedabad

Relative Humidity in Steel Rolling and Foundry Units					
Type of Industrial Unit	Season	Maximum Relative Humidity (%) Recorded (℃)	Minimum Relative Humidity (%) Recorded (℃)	Mean Relative Humidity (%)	Standard Deviation Relative Humidity (%)
Steel Rolling Mill (n=3)	Winter	37.9	11.6	23.1	5.71
	Summer	24.4	10.5	15	3.57
Foundry Mill (General area) (n=3)	Winter	32.5	18.5	25.4	4.49
	Summer	25.3	12.4	16.9	3.78
Foundry Mill (Furnace area) (n=3)	Winter	29.4	16.1	23.05	6
	Summer	18.1	13.6	15.2	1.91

The maximum and minimum ambient air temperature (Ta) along with mean ambient air temperature was higher in steel rolling mills than in foundry units in both winter and summer (Table 2).

The maximum and minimum globe temperature (Tg), as well as the mean globe temperature, was higher in the steel rolling mill than in foundry units in both winter and summer (Table 3).

The mean relative humidity (RH) was higher in foundry units than in steel rolling mills in both winter and summer (Table 4). However, within foundry units, relative humidity was higher in the winter season than in the summer. The standard deviation (SD) of relative humidity is on the higher side in the winter season for both types of units [Steel rolling mill - 5.71; foundry (furnace area) - 6.0].

Table 5: Physiological measurements of Workers in industrial units, Ahmedabad

Physiological Measurements of Workers in Steel Rolling and Foundry Units						
Type of Industrial Unit	Season	Heart Rate	Oxygen saturation SPO2	Oral temperature (℃)	Skin temperature (Forearm) (℃)	Skin temperature (Trunk) (℃)
		Min-Max Recorded	Min- Max Recorded	Min- Max Recorded	Min- Max Recorded	Min- Max Recorded
Steel rolling Mill (n=16)	Winter	70-129	95-99	35.2-39.3	32.5-34.8	33.4-35.5
	Summer	68-134	97-99	36.3-39.9	31.3-36.5	32.1-37.9
Foundry Mill (n=14)	Winter	97-120	96-99	35.8-36.8	31.7-35.7	31.4-35.0
	Summer	88-131	98-99	36.4-39.3	30.4-34.9	31.2-37.3

Table 6: Mean and Standard Deviation (SD) of Physiological measurements of Workers in industrial units, Ahmedabad

Physiological Measurements of Workers in Steel Rolling and Foundry Units											
Type of Industrial Unit	**Season**	**Heart Rate**		**Oxygen saturation SPO2**		**Oral temperature (℃)**		**Skin temperature (Forearm) (℃)**		**Skin temperature (Trunk) (℃)**	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Steel rolling Mill (n=16)	Winter	91	15.41	97.5	1.62	37.1	0.93	33.75	0.75	34.3	0.51
	Summer	103.6	21.63	98.3	0.67	37.5	1.15	34.4	1.45	35.05	1.95
Foundry Mill (n=14)	Winter	107.2	7.02	98.2	0.97	36.4	0.34	34.1	1.3	33.1	1.16
	Summer	109.2	12.5	98.3	0.48	37.2	0.68	32.5	1.41	34.4	1.87

Table 5 and Table 6 show the maximum and minimum recorded physiological parameters of workers along with mean and Standard Deviation (SD).

The maximum heart rates of workers crossed the OSHA threshold (>110 /minute) in both units in both seasons. The maximum oral temperatures also crossed the OSHA threshold (> 37.5℃) in workers of both steel rolling and foundry units. The oxygen saturations of workers were all above 95% in both seasons in sample units (Table 5).

The mean heart rate of foundry workers in the winter season was significantly higher than steel rolling mill workers during the working hours between 2:00 PM- 6:00 PM. The mean oral temperature in foundry units was higher than the OSHA threshold (> 37.5℃) in the winter season (Table 6).

Organizational level ambient heat controlling mechanism and facilities for workers:

The units were of medium size appx. 4000 to 5000 sq. ft. and had fans, exhaust fans, vents and ventilation in the unit. However, there were no systems to record/monitor the temperature inside them. The mechanisms at the organization level to dissipate heat included fans and ventilation. The heat furnaces in foundry units were started only after 4 PM. Water facilities were present in the units and units had a water cooler for drinking water purposes. There was an adequate water supply for workers to cleanse themselves during or at the end of duty. One of the units, a foundry also was providing glucose water to employees during the summer months. The factories provided personal protective equipment such as gloves and shoes. Foundries that had electric furnaces also had given protective eyewear to the workers who would work near the electric furnace. Factories were registered with the Employees State Insurance Corporation; a state-run health protection scheme for the employees and thereby the workers had some financial health protection.

Heat Coping and Adaptive Strategies of Workers: The workers had their coping strategies to cope with high heat and controlling body temperature. Workers used to consume more water and could take small breaks from work during work hours which were allowed by the factory managers. Almost all of the workers were men. Only in one foundry unit, four women were working which too was away from the heating furnace to carry sand toward the molding area. The nature of work for women in foundry units involves lifting sand and moving towards the molding area which is away from the heating furnace. Men were found using a piece of cotton cloth or napkin (Gamcha) to wrap around the head and face as protective measures to control head temperature and prevent burn against excessive heat. The usual clothes at work included a shirt and trousers. Men workers often used to remove their shirts and work in undershirts and fold the trouser up to the knees. There were their mechanisms to cope with excessive heat.

Protective Gear and Usage among Workers: Provisions of safety gear and protective equipment were poor from the organizational level although in some units despite the provision and availability of protective gear the utilization of safety gear among workers was generally poor. There were no specific protective gears to protect against the heat wave. Rather the protective gear of gloves and shoes became uncomfortable to wear during summer months and practically no one in the foundry units was found using the gloves or shoes. One of the workers quoted,

"We are being provided gloves, masks, shoes from factory owner but we are using gloves sometimes only as those protective aids are not useful or comfortable to work with."

The Foundry workers mentioned that the gloves made their hands sweaty which made it difficult to hold on to the equipment. Hardly anyone in the foundry used shoes because they felt that barefoot would be better than using shoes to prevent injury. A worker in the foundry unit explained for non-use of protective shoes,

"If we wear shoes in a foundry there are high chances of burn injury if the hot melted iron falls on shoes. If hot iron falls onto shoes, by the time we react and remove the shoes the melted iron will make a hole in the shoe and penetrate the skin and cause severe burn injury. On the other hand, chappals (Slippers) are relatively safe as we can quickly remove them in case of hot iron accidentally falling on the foot."

The workers in steel rolling mills however were found using gloves throughout to protect themselves from handling hot metals. Difficulty in breathing and suffocation was the chief barrier to using a protective mask.

Discussion

The hazardous working environment, poor ventilation, heat as well as a poor standard of protective equipment contribute to an adverse working environment and high perceived heat among small-scale industrial workers.[16] The study shows that the atmospheric temperature significantly affects the working environment and ambient temperature inside high heat-inducing working units. The steel rolling mills had very high heat stress in the summer months. Heat stress was also high in the furnace area of the Foundry units. The lower heat stress in the furnace area of foundry units compared to the steel rolling mills could be because the furnaces did not operate throughout the day but only after 4 pm which can affect the average temperature. The heat stress in ambient air starts reducing after 4 pm. The effects of heat stress were also evident in the biological monitoring of the workers as the maximum heart rate and an oral temperature of workers crossed the OSHA threshold level in both foundry and steel rolling units in the winter and summer seasons. Further, mean oral temperature also crossed the threshold (>37.5℃) in foundry units in the winter season. Heart rate along with body temperature has been recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) as a possible measure of heat stress. Heart rate monitors with alarm systems could be developed to notify workers of slowing down their activities or taking a break from work which contribute to preventing heat-related illness.[17]

The mitigation strategies included timing of using the furnace, ventilation, water coolers, etc. at the industrial unit level. However, there has been no measurement of temperature within the units. The personal protective equipment (PPEs) used to protect workers against injury and other hazards were found to complicate the heat stress and workers did not want to use PPEs because of the discomfort and inconvenience caused due to them, especially during the summer months.

Mitigation strategies employed by individual workers included drinking water, taking small breaks, use of cotton gear (*Gamcha*) to reduce the effects of excess heat. These strategies have been in use across several occupational settings in India.[18] However, the workers also did not use PPEs to reduce heat stress but this step could make them more prone to injuries. Literature shows that the use of PPE was much better in colder places such as Nepal than in the hot and humid city of Visakhapatnam.[18,19] Hence, the use of PPEs may be related to heat waves and heat waves can potentially change the behavior of workers.

The PPEs' use was lower in foundry units than in a steel rolling mill. Workers in steel rolling mills could not perform the work without the PPEs (gloves) as they had to handle hot material continuously and for a longer time and therefore used the PPEs more frequently. In contrast, the foundry workers could perform their work without gloves as they had to handle hot items intermittently. The use of PPEs was much lower among them and they resorted to cotton cloth for holding hot objects to avoid the inconvenience and discomfort associated with the use of PPEs. The quality of PPE determines its use; heavy PPEs were cited as a major reason for its non-use in Saudi Arabia.[20]

The National Policy on Safety, Health, and Environment at the Workplace of the Government of India provides a framework for developing and maintaining a safety culture and environment at the workplace.[21] The major legal provisions for the protection of health and safety includes the Factories Act, of 1948 which has provisioned for the structure and layout of the industry to maintain a proper temperature.[22] Despite that, many industries have an inadequate provision of cooling systems, natural shades, or shed with fans in the working place which is due to the poor regulatory framework. Although, this was not the case for this study's units; there are other units that operate in congested areas and can potentially get severely affected by heat waves. There is a need to record heat stress in these industries as a self-regulatory mechanism and a need to invest in engineering interventions to protect workers from occupational heat stress.

Ahmedabad Municipal Corporation (AMC) with a partner organization has rolled out a Heat Action Plan (HAP) for protection against high heat and heatwaves. The plan focuses largely on the general population and outdoor workers.[23] Recent evidence highlights the plight of those who live/work indoors in urban areas where the heat stress could be higher and most heat-health warning systems are based upon outdoor climate only.[24] Response to climate change also needs multi-faceted interventions including adaptation measures. Structure of industrial units, ventilation, scheduling of heat generating processes at a time of day when a heat wave is not at peak, breaks during work, monitoring heat stress through simple gadgets, availability of drinking water, and appropriate and comfortable PPEs will help address the issue.[25] The intervention could be a mix of educative, regulatory, and internal control mechanisms to reduce the effect of heat waves on workers.

This study has a few limitations. It is an exploratory study that documents heat stress in small-scale industrial units. However, it is limited to measurements in fewer settings. The sample size for workers was also small and generalizations are not possible. However, the study is among the first to explore the high heat stress in small-scale units which do not have their setup for occupational safety and overall regulatory governance is weaker. It is important that most of these units do not have any environmental monitoring and there are hardly any occupational safety and health measures apart from ESIS-linked insurance and the provision of PPEs.

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