RESEARCH ARTICLE

Effect of occupational heat exposure on brick kiln workers in Eastern India

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ABSTRACT

Background: This study investigated the outcome of environmental heat and humidity on the health and productivity of brick kiln workers in eastern India, who are regularly confronted with high temperatures and humidity. *Materials and methods*: Both male and female workers were assessed for heat exposure impacts using the WBGT index and HOTHAPS questionnaire, and their productivity and working heart rates were also examined. *Results*: The results showed extremely high WBGT levels at midday, leading to early signs of heat stress such as sweating, headaches, rashes, fatigue, and heat exhaustion. Male brick molders experienced productivity losses of 3.75 to 6.56% per 1°C rise in WBGT across the 1st to 5th hours of exposure, while female molders saw losses of 5.55 to 6.48%. Higher temperatures also correlated with increased heart rates, indicating cardiovascular strain. *Conclusion*: The study underscored the differing impacts of heat on male and female workers, emphasizing the need for gender-specific interventions to mitigate occupational heat exposure.

Keywords: Heat exposure, Heat stress, WBGT index, Working heart rate, Productivity.

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INTRODUCTION

Most people globally reside and work in tropical regions, subjecting to hot and humid conditions. Climate change substantially influences human health and elevates occupational heat stress risks, particularly affecting the profound workforce in diverse industrial environments.[1] Occupational heat stress is a substantial outcome of climate change, directly impacting human health and potentially diminishing work performance and productivity.[2-3] In Western countries, research on heat-exposed workers has revealed that occupational heat stress is associated with several health impairments and reduced job productivity.[4-6] A recent study revealed that workers' physical work capacity decreases with increasing heat exposure.[7] Although few studies performed among the working population in some tropical countries like Malaysia, Bangladesh, Thailand, and Taiwan[8-13] investigate that elevated workplace temperatures adversely affect health and productivity across various informal industrial sectors.[14-19] However, knowledge remains scarce concerning occupational heat exposure and its health implications for workers in informal sectors within tropical and subtropical regions.

Heavy manual labor in hot conditions for prolonged periods with minimal access to cooling hampers the thermoregulatory capacity and intensifies morbidity and mortality rates.[14,20,21] Workers directly exposed to solar radiation are vulnerable to heat-related injuries.[12] The extent of forbearance to extreme climate elucidates the state of heat acclimatization to the hot and humid environment.[16, 22] The risk aggravates due to several factors such as an increase in the local mean air temperatures, lack of structural and physical protective measures, heightened physical work stipulations and diminished rest pauses, un-acclimatized, untrained workers, etc.[23]

Global warming has increased the adversity of heat on individuals working in hot climate areas.[24] There are few studies exist on how extreme weather events affect cardiac health among informal sector workers, despite expectations that increased heat exposure due to climate change may elevate cardiac events.[25,26] Despite prior research on workers' health, performance, and productivity consequences in various hot environmental settings,[27-32] occupational heat stress remains an understudied health issue in research. Consequently, there is a crucial need to improve the assessment methods linked to meteorological data for estimating the size of the problem and for developing appropriate interventions at the individual, workplace, and societal levels.[33] A subsequent study indicated that recurrent thermal stress heightens the risks of hospitalization and heat stroke.[34]

Eastern Indian brick kiln workers face elevated risk due to rapid urbanization and high demand for bricks. Exposed to harsh environmental conditions and physical labor, they also sustain intense heat from the kilns, exacerbated

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by rising temperatures as a result of global warming. The laborers in these industries do not undergo any training, so they are mostly unaware of safe working practices.[14] The subsisting study aims to assess the impact of occupational heat exposure on the health and productivity of brick kiln workers in Eastern India under extreme climate conditions.

MATERIALS AND METHODS

Study Areas

West Bengal, a state of Eastern India, is divided into 23 districts, with the study area located in Nadia district, which spans 22°53″ to 24°11″ N latitude and 88°09″ to 88°48″ E longitude. The weather of the district is humid and tropical. The brick kilns are located on the bank of the Jalangi River.

Study Population

The impact of heat on workers' health and productivity was studied among 25 brick kiln workers [Male (n1) = 15; Female (n2) = 10] in India. The study took place in the Nadia district brick kiln from March to May and involved both male and female workers who were engaged in different brick-making activities such as mud collection, brick molding, and sun-drying. Before carrying out the survey, the workers were informed about the study. All the subjects were right-handed. All the brick kiln workers spent almost 10-11 hours/day working, usually beginning the brick molding activity in the morning to noon and taking a rest at midday for tiffin or lunch break. After that, they performed multiple tasks such as preparing mud, arranging dried bricks, cleaning the working area for the next day's molding, etc. The study was carried out subsequent to obtaining their explicit consent and in strict compliance with the ethical guidelines enumerated by the Institutional Ethical Committee of the University of Kalyani. Clay collection activity and brick molding and sun-drying activities are shown in Figures 1(a), 1(b), and 1(c), respectively.

Socio-demographics and Questionnaires Study

Before performing this study, details of the study were explained to all the subjects. As the working population was illiterate, they were suitably interviewed in their local languages (Bengali, Hindi). A questionnaire was designed as HOTHAPS (High Occupational Temperature Health and Productivity Suppression)[35] to collect information on their work duration, nature of work, complaints about heat-related discomfort, clothing pattern, coping mechanism with heat, etc. Responses regarding the perception of heat stress-related symptoms were cross-checked at different times of the year.

Environmental Parameters

Heat stress

Air temperature (Ta, dry bulb temperature) was measured hourly during five work hours each day with a Digital Multi-Stem Thermometer with an external sensing probe (Model

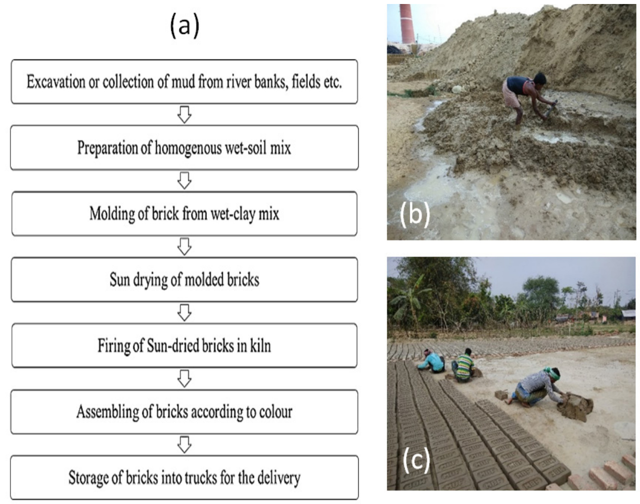

Figure 1: (a) Flow chart describing brick-making processes. (b) Process of clay collection. (c) Brick molding and sun-drying activities

No. ST-9269, India) shielded from the Sun and close to both the working populations. Wet Bulb Globe Temperature (WBGT) was measured at a fixed site in the field using a globe thermometer (for Tag), a natural wet-bulb thermometer (for Tnwb), and a dry bulb thermometer (shaded from the Sun producing Ta). The WBGT was then calculated using the standard formula.[21]

$$WBGT= 0.7\ Tnwb + 0.1\ Ta + 0.2\ Tg.$$

In relation to climate change, it is important to consider how the local climate has changed in recent decades. Detailed data are available from the ClimateCHIP database (Figure 2).

Physiological Parameters

Cardiovascular parameter

In the case of physiological data collection, the subjects were allowed to do their work at their natural speed in actual fieldwork, *i.e.*, brick making during working hours at three different temperature ranges (28–30°C, 31–33°C, and 34–36°C) from the subgroup of 25 subjects (male (n1) = 15, female (n2) = 10) in the age range of 30 to 42 years. No restriction was imposed on their speed of work. During the 5th hour of their work period, the Working Heart Rate (WHR) was measured using a wearable heart rate monitor around the chest (Polar FT60M BLK WD, Polar Electro Oy, Professorinitie 5, FI-90440 Kempele, Finland).

In a real work situation, after working for 30-45 min, the workforce rests for 5 - 10 min and then resumes their work.

Work productivity measurements

The brick-making activity started in the morning and went to noon, and then they rested at midday for a tiffin or lunch break. After that, they engaged in multiple tasks such as brick molding activity, mud preparation, arranging dried bricks, cleaning the working area for the next day's molding, etc.

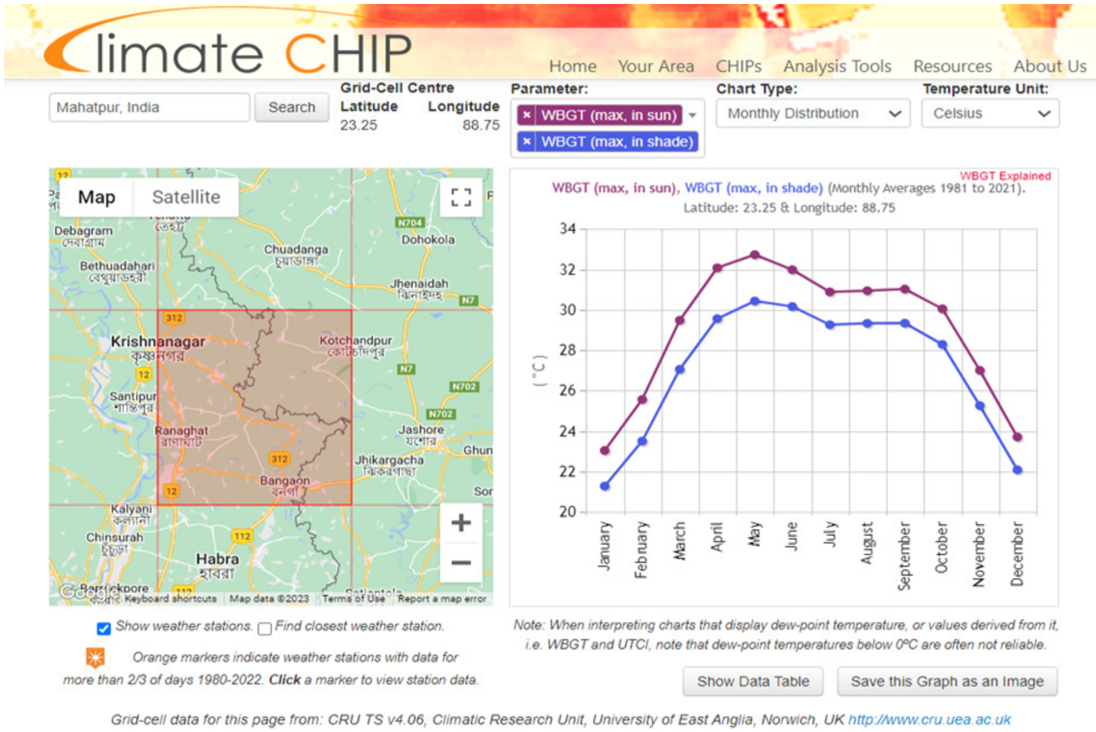

Figure 2: ClimateCHIP grid cell at Nadia with WBGTmax in the sun and the shade

Therefore, it was not quantifiable from productivity output. So, data collected after lunch sessions were not used in the analysis. So, our study was undertaken for five working hours (1^{st} hour to 5^{th} hour) per day. On the study day, a particular area was selected, and the work output was counted. The tally counters counted the productivity of 25 Brick kiln workers (male (n1) = 15, female (n2) = 10) per hour for 15 consecutive days by calculating the number of bricks molded by the brick kiln workers. The working hour excludes the rest breaks for tiffin (light meal or water intake) but includes small breaks (2–5 min) between work tasks as part of the normal work time management. During tally recording, the study's purpose was withheld from workers to prevent bias in productivity measurements. Results were categorized based on hourly WBGT readings, which fluctuated throughout each day.

Statistical Analysis

Descriptive statistics were used to analyze the socio-demographic characteristics, self-reported heat stress-related illness or symptoms, and environmental heat stress index. Demographic details and other data were represented as mean ± standard deviation and percentage when applicable. One-way ANOVA (analysis of variance) was used to determine the significant differences between WHR in three WBGT ranges. Simple linear correlation between 15-days 1^{st} hour and 5^{th} WBGT (°C) and 15-days 1^{st} hour and 5^{th}-hour correspondent mean productivity of male and female brick kiln workers. F-test was implemented to evaluate the statistical significance of the differences in productivity loss percentages between average-ranked male and female brick kiln workers. In all cases, differences were contemplated significant at $p < 0.05$.

RESULTS

In Nadia, West Bengal, almost 32% of the people are below the poverty level.[36] Many of the workers do not own their land and usually work as manual laborers in brickfields for their livelihood. Their daily earning is about Indian Rupees 200 to 250. In most cases, they are the only earning member of the family having at least 4 to 6 dependents. Table 1 depicts the demographic features of male and female brick molders. Heat stress-related responses from all the surveyed subjects by the 'HOTHAPS' questionnaire analyses are shown in Table 2.

Table 1: Socio-demographic information of brick kiln workers (Male = 15, Female = 10)

Parameters	*Male (60%)*	*Female (40%)*
Age (years)	39.00 ± 6.90	38.00 ± 9.00
Job experience (years)	13.00 ± 5.50	7.00 ± 2.30
Married	80.00%	90.00%
Smoker	80.00%	0.00%
Height (cm)	164.56 ± 5.39	151.83 ± 6.65
Weight (kg)	62.04 ± 6.85	51.43 ± 8.61
BMI (kg/m^2)	23.07 ± 3.61	22.40 ± 3.94
BSA (m^2)	1.67 ± 0.06	1.46 ± 0.12

Table 2: Heat stress-related symptoms of brick kiln workers (Male = 15, Female = 10)

Month	*Percentage (%) of Heat stress-related symptoms*							
	Prickly heat (%)	*Heat cramps (%)*	*heat exhaustion (%)*	*Heat stroke (%)*	*Heat syncope (%)*	*Sweating (%)*	*Headache (%)*	*Tiredness (%)*
Jan-Feb	4.0	0.0	0.0	0.0	0.0	16.0	24.0	52.0
Mar-Apr	60.0	8.0	70.0	0.0	4.0	72.0	40.0	72.0
May-Jun	80.0	12.0	76.0	4.0	4.0	100.0	76.0	100.0
Jul-Aug	8.0	8.0	64.0	0.0	0.0	64.0	80.0	100.0
Sep-Oct	0.0	8.0	28.0	0.0	0.0	52.0	28.0	72.0
Nov-Dec	0.0	0.0	0.0	0.0	0.0	24.0	28.0	44.0

Working heart rate (WHR) trends at three different temperature ranges of male and female brick kiln workers during the working period are shown in Figure 3.

The WHRs of both male and female brick molders were considerably lower (WHR for male workers 111.33 ± 2.09 and for female workers 115.60 ± 1.57, respectively) in low-WBGT ranges (28–30°C) than in higher (WHR for male workers 115.60 ± 2.64 and for female workers 122.40 ± 2.27 respectively) WBGT ranges (34–36°C) during their period of work. It was shown that increasing WHRs might be caused by increased WBGT ranges. The results were found significant for both male and female brick molders (p <0.05; computed F for male brick molders = 6.95, computed F for female brick molders = 15.55). Moreover, female molders showed higher WHRs than male molders at the same WBGT ranges.

The mean 1st-hour and 5th-hour productivity of male and female brick molders are compared in Figure 4 at the 1st-hour and 5th-hour WBGT ranges.

The productivities of male and female brick kiln workers on the hottest day of the study period are shown in Supplementary Figures S1(a) and S1(b), respectively. Similarly, the productivities of the same male and female brick kiln workers on the coolest day of the observation are shown in Supplementary Figures S2(a) and S2(b), respectively.

Relationship between the mean 1st-hour WBGT (°C) and mean 1st-hour productivity of male and female brick kiln workers were depicted in Figure 5, as well as the 5th-hour WBGT (°C) and mean 5th-hour productivity of male and female brick molders were shown in Figure 6. There were strong negative correlations (r = -0.984, -0.992; p <0.05) made between 1st-hour WBGT (°C) and 1st-hour male and female brick kiln workers' productivity, respectively. Similarly, there was a strong negative correlation (r = -0.989, -0.991; p <0.05) made between 5th-hour WBGT (°C) and 5th male and female brick kiln workers' productivity, respectively.

The first-ranked male subject lost 3.50, 5.05, 3.33, 3.40, and 6.05%, while the last-ranked male subject lost 3.74, 4.58, 3.79, 6.61, and 6.60% of productivity per increase in 1°C of each of 1st, 2nd, 3rd, 4th and 5th hour of WBGT, respectively. Similarly, the first-ranked female subject faced 5.71, 4.38, 4.88, 4.53, and 7.09%, while the last-ranked female subject lost 7.21, 4.66, 7.56, 6.00, and 5.04% of productivity losses per increase in 1°C of each of 1st, 2nd, 3rd, 4th and 5th hour of WBGT, respectively. On average, male brick molders faced 3.75, 3.61, 3.54, 4.99, and 6.56%; on the other hand, female subjects lost on average 5.55, 5.48, 5.17, 4.52, and 6.48% of productivity per 1°C increase in each of 1st, 2nd, 3rd, 4th and 5th hour of WBGT, respectively.

These ranked brick kiln workers' productivity losses were in supplementary Figures S3(a) and S3(b), respectively. F-test

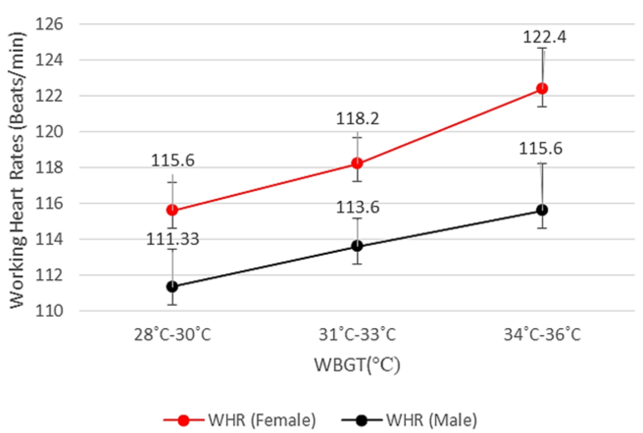

Figure 3: Working heart rate trend of male brick kiln workers (n1 = 15) and female brick kiln workers (n2 = 10) at different WBGT ranges

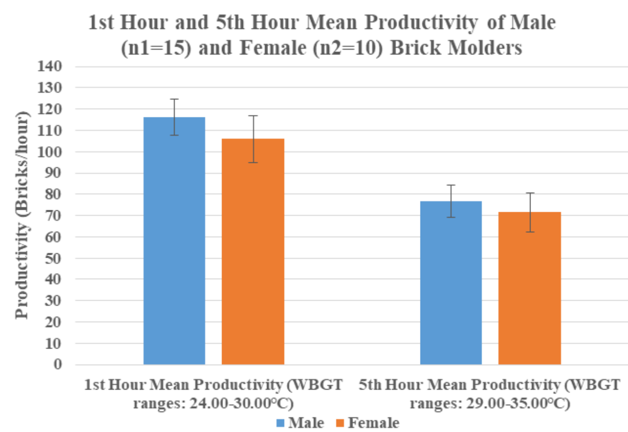

Figure 4: 1st-hour and 5th-hour WBGT (°C) range vs. 1st-hour and 5th-hour mean productivity of male (n1 = 15) and female (n2 = 10) brick molders

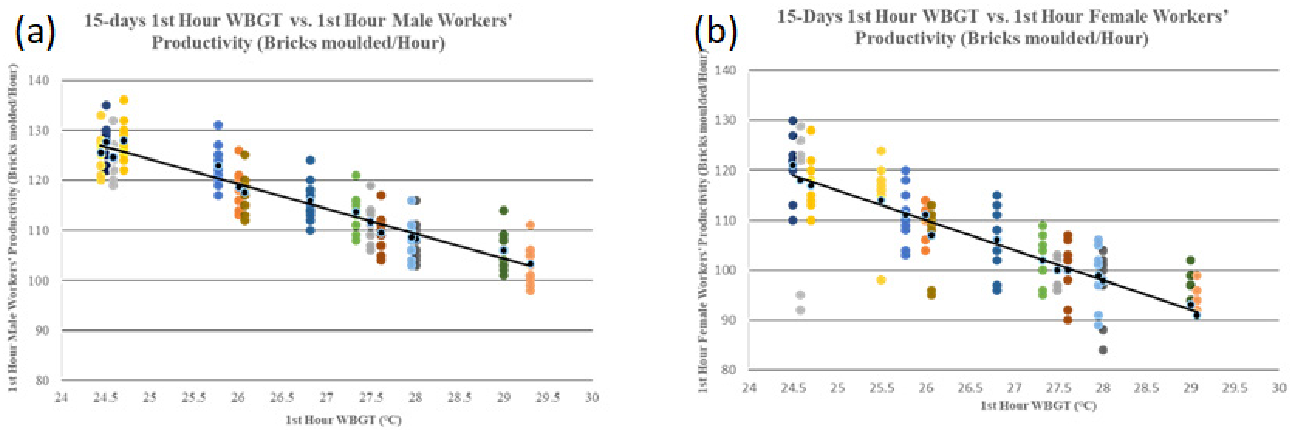

Figure 5: (a) Relationship between 15-days 1st-hour WBGT (°C) and male brick kiln workers' productivity. (b) Relationship between 15-days 1st-hour WBGT (°C) and female brick kiln workers' productivity

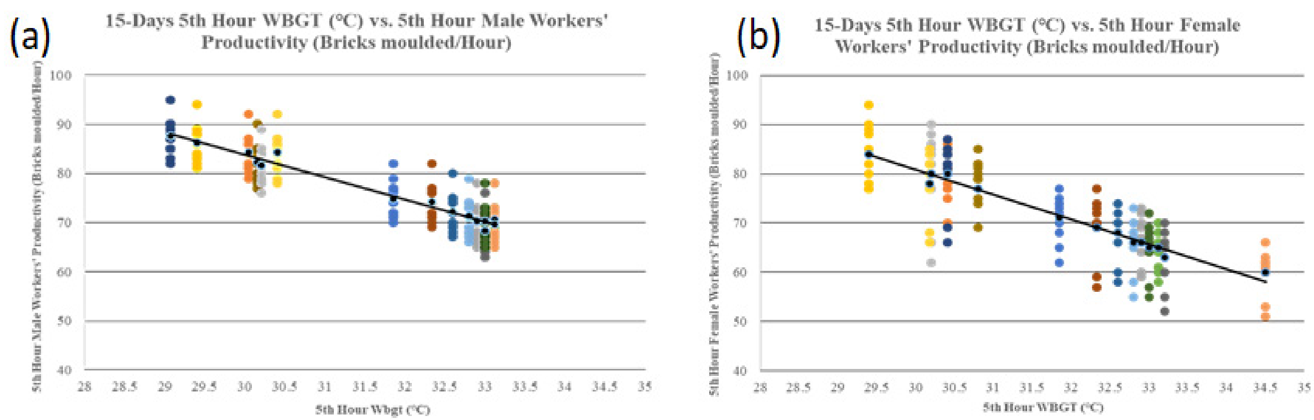

Figure 6: (a) Relationship between 15-days 5th-hour WBGT (°C) and male brick kiln workers' productivity. (b) Relationship between 15-days 5th-hour WBGT (°C) and female brick kiln workers' productivity

results showed that the percentage of hourly productivity losses of average-ranked male and female brick molders were not significant (p >0.05).

DISCUSSION

This study has examined the effects of extreme heat exposure on manual brick kiln workers, focusing on early heat stress symptoms, cardiac health, and work productivity. The study population primarily consisted of economically poor individuals, including migrants from the neighboring states of Odisha, Bihar, and Jharkhand. Due to the financial crisis, multiple family members often engaged in this work. These working populations were particularly vulnerable to workplace heat exposure, exacerbated by ambient temperatures and kiln-radiated heat. Although heat waves in winter-prone countries also infect workers' health and productivity, as well as physical work capacity,[37] the current study explored that brick kiln workers frequently experienced heat-related illnesses (HRI), with prevalent symptoms including excessive sweating, fatigue, headaches, and muscle cramps. Nearly 99% of workers reported discomfort, while exhaustion affected approximately 80%. More severe conditions, such as heat syncope and heat stroke, were predominantly observed during warmer months (March to June), though milder symptoms persisted throughout the year. These health issues likely arise from prolonged sun exposure during 5 to 10-hour workdays and inadequate hydration. Notably, about 60% of workers reported continuing to work in hot conditions due to destitution. A study in Thailand showed a significant association between the high temperature and the WBGT heat stress index recorded during May that exceeded the threshold limit of physiological capacity.[12]

Several studies in high-temperature work environments in different industrial settings have shown that increased temperature and humidity can directly affect the cardiovascular systems of the workers.[15,19,25] Working heart rates of both male and female respondents were found to be lower at lower WBGT ranges (28–30°C) than at higher WBGT ranges (31–33°C and 34–36°C) in this study, indicating their cardiovascular strain at high-temperature ranges.[38,39] This cardiovascular strain might be enhanced with the increase in age.[26]

Loss of working ability and/or productivity of workers can be positively dependent on intense thermal conditions, especially when physically demanding work is performed.[40] Generally, when a worker works in intense thermal conditions, his/her body might respond by slowing down its physical activity to increase its internal core body temperature.[41] In the context of brick kilns in India, almost all brick kiln workers reported that the reason for their lost productivity was due to excessive heat.[17] There was a significant negative correlation made between hourly WBGT (℃) and hourly productivity.[42] Heightened hourly WBGT values were associated with decreased concurrent productivity among brick kiln workers, regardless of gender. The most substantial productivity declines occurred during the fifth hour of work, with each 1°C increase in WBGT resulting in productivity losses of 6.56 and 6.48% for male and female workers, respectively. This result was more pronounced than during other working hours. From the first to fourth hours, male brick molders exhibited marginally lower productivity losses compared to their female counterparts per 1°C WBGT increase; however, these gender-based differences were not statistically significant (p >0.05). But in the case of an increase in 1℃ of 5th-hour WBGT, male respondents lost their productivity much more than the females. That result was not also significant (6.56% productivity loss was in male workers compared to 6.48% in female workers productivity losses per increase in 1℃ of 5th-hour WBGT, p >0.05). Moreover, most of the respondents (84%) reported productivity losses due to increased temperature during the day. These findings also supported the previous work done in South and Central Indian industries, where it had been estimated that above 27°C, there was approximately a 5% decline in productivity for every one-degree rise in WBGT.[42] Several studies performed in India disclosed that loss of productivity could mostly occur among outdoor/semi-outdoor occupations with high workloads (e.g., brick manufacturing, metal fabrication, construction, etc.). In contrast, loss of productivity might occur infrequently among indoor workers.[15,19] Hence, needless to say, in the current context of global warming, the rate at which temperatures continue to rise could have detrimental effects on the health and productivity of heat-exposed workers, posing a threat to tropical and subtropical countries like India.

Heat acclimatization can improve an individual's capacity for physical exertion in hot environments, reduce cardiovascular strain, and elicit a more pronounced sudomotor response to acute heat stress. However, the effectiveness of this adaptation depends on various factors, including exposure duration, type of physical activity, acclimatization status, and specific heat-work training.[2,43] Proper policy decisions may incorporate a combination of attenuation, adaptation, and social safeguarding approaches to address climate-related threats, enhance resilience, and improve the adaptive capacity of workers, thereby ensuring acceptable working conditions.[44,45]

However, in some cases, workers' behavior and wages can influence work quality, affecting economic outcomes. Therefore, this study has reported the impact of extreme outdoor temperatures on brick kiln workers' health, resilience, and productivity.

CONCLUSION

The extreme thermal work environment poses significant risks to brick kiln workers' health and productivity, exacerbated by projected climate change impacts. Heat reduces productivity and increases product costs due to human strain. Mitigation strategies include broad-brimmed hats, night work schedules, and adequate hydration. However, resource constraints often limit workers' access to these protective measures. Adequate nutrition is crucial for sustained productivity in high-temperature conditions. Many workers lack basic protective gear for various weather conditions. Adaptation measures are likely to vary based on each country's economic circumstances.

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PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.