

# **Occupational Heat Exposure and Its Impact on Outdoor Workers: Implications for Traffic Police**

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## **Abstract**

Outdoor workers, especially Traffic police in Bangladesh are often exposed to harsh environments, particularly in prolonged heat in duty as most of the time they work outside. This review analyzes various peer reviewed papers published between 2016 to 2025 focusing on heat stress, fatigue and other occupational challenges faced by outdoor workers. A narrative review approach is used to analyze physiological, psychological and other cognitive functions

using metrics like Wet Bulb Globe Temperature (WBGT) thresholds, risk ratios for health outcomes. Key findings indicate that 50%-79% officers report dehydration, cramps, and excessive sweating due to excessive heat which lead to fatigue in 40–70% of cases. During heat wave, productivity losses rise up to 40%. Heat stress increases the risk of renal dysfunction and cardiovascular strain. Cognitive effects included reduce in work capacity, increase in errors. Various intervention methods such as scheduled rest breaks can reduce fatigue and core temperature. The review underscores the need of coping mechanisms for traffic police such as hydration, scheduled breaks, protective gears, better policies in workplaces. Future studies should focus on long-term effects on their cognitive functions such as decision making and also longitudinal studies, gender specific interventions to enhance resilience in high-risk conditions.

## **Keywords**

Heat stress, Physiological impacts, Outdoor workers, Occupational challenges.

## **1. Introduction**

Outdoor workers are increasingly exposed to hot weather as they have to work outside for a long time and due to rising global temperatures and urban heat island effects they are placed at elevated risk for heat-related illnesses, physiological strain and fatigue. (Ebi et al., 2021; Ioannou et al., 2022). Heat stress is the net heat load on human body that is composed of combined combination of metabolism, environmental factors (*i.e.*, air temperature, humidity, radiant heat, and air movement), and clothing (Cramer et al., 2022; *Ergonomics of the Thermal Environment - Assessment of Heat Stress Using the WBGT (Wet Bulb Globe Temperature) Index*, 2017). When excess heat is gained by the body but the body can't dissipate it through sweating and vasodilation, the core body temperature rises causing various physiological disorientation that can progress from mild discomfort to life-threatening events (Ebi et al., 2021; Habibi et al., 2024; Morrissey et al., 2021). The most widely accepted heat stress index the Wet-Bulb Globe Temperature (WBGT) reportedly exceed 30-38°C during summer which is far above the accepted range of 26-30°C by The American Conference of Governmental Industrial Hygienists (ACGIH) in tropical and subtropical regions (Ioannou et al., 2022; Venugopal et al., 2020). A 0.62 °C per decade rise in temperature and a 2.57 °C increase in heat index for every 1.5 °C of global warming is projected in Southeast Asia due to accelerating climate changes (Amnuaylojaroen et al., 2022). Cities like Dhaka, Ahmedabad, Kualalampur experiencing amplified heat exposure by an additional 4-8°C (Harlan et al., 2006).

Various studies demonstrates that heat stress significantly affects physiological parameters such as core temperature, skin temperature, heart rate, and dehydration and metabolic rate (Ioannou et al., 2022). For outdoor workers, those who are exposed to prolonged high temperature these physiological parameters can be life threatening. Not only physiological and health complications, heat stress also impairs cognitive functioning and productivity of a worker (Morrissey et al., 2021). Occupational heat exposure reduces ability to work and lead to various occupational injuries (Lucas et al., 2014). These detrimental effect at overall lead to economic and productivity loss of a worker, decreasing their efficiency (Szewczyk et al., 2021). In summary, the worldwide 2.41 billion outdoor workers along with traffic polices are in high risk of developing heat stress related physiological and mental problems due to their unavoidable high heat (Habibi et al., 2024).

Despite extensive studies on various occupational group, traffic police- a highly valuable workforce remained completely understudied. Their unique combination of cognitive demands, prolonged standing, and exposure to urban heat islands makes them particularly vulnerable to both physiological and cognitive strain (Liu et al., 2023; Hsu & Rodríguez, 2024). This gap in knowledge hinders the development of interventions and workplace guidelines that could reduce health risks, fatigue, and productivity losses in this population.

By synthesizing evidence from physiological, occupational and cognitive studies, this review provides a comprehensive overview of physiological problems, cognitive impairments, productivity loss and economic burden of various occupational group due to heat stress and implications should be taken towards the occupational group, especially traffic police to minimize these detrimental effects.

## **2. Methodology**

This study followed a narrative review approach to synthesize insights from recent studies on heat stress, occupation heat stress and fatigue, with relevance to traffic police. Literature was searched in Google Scholar, PubMed and

Scopus studies published between 2016 to 2025 (generally), using terms such as “heat stress”, “outdoor workers”, “physiological impact”, “fatigue”, “cognitive performance”, “productivity loss”, “economic loss” and “traffic police”. Studies were included if they assessed outdoor occupational heat exposure and reported physiological, cognitive, productivity-related, or economic outcomes. Research focused on indoor settings or lacking measurable heat exposure indicators was excluded.

Various key information from each study such as population, environmental conditions, outcome indicator, and key findings-was extracted, analyzed and tabularized. Analyzed data was then organized into thematic sections (physiological strain, cognitive and fatigue outcomes, productivity effects, and economic impacts) to develop a better understanding of occupational heat stress and its implications for traffic police.

### 3. Result and Discussion

#### 3.1 Descriptive Analysis

Figure 1 represents the regional analysis of the studies selected for the review paper. The selected studies for this review paper have a wide geographical distribution across the world. Some of the papers were studied those are mainly focused on review studies across the world. 5 researches were based on India, which provides a strong research insight among diverse occupational groups. Bangladesh (n = 2), China (n = 4) and Iran (n = 3) also included a substantial number of studies reflecting the heat stress concern over the world. Moderate research has been conducted on USA (n = 3) highlighting the increasing heat stress effect growing over the country. Single studies were reported from UK, Sudan, Ghana, Mexico, Thailand, Malaysia. Overall, the distribution indicates a dominance of heat stress research on tropical and sub-tropical regions, Middle East region and sub-Saharan region, where outdoor workers are more likely to exposed high temperature and perform labor intensive works.

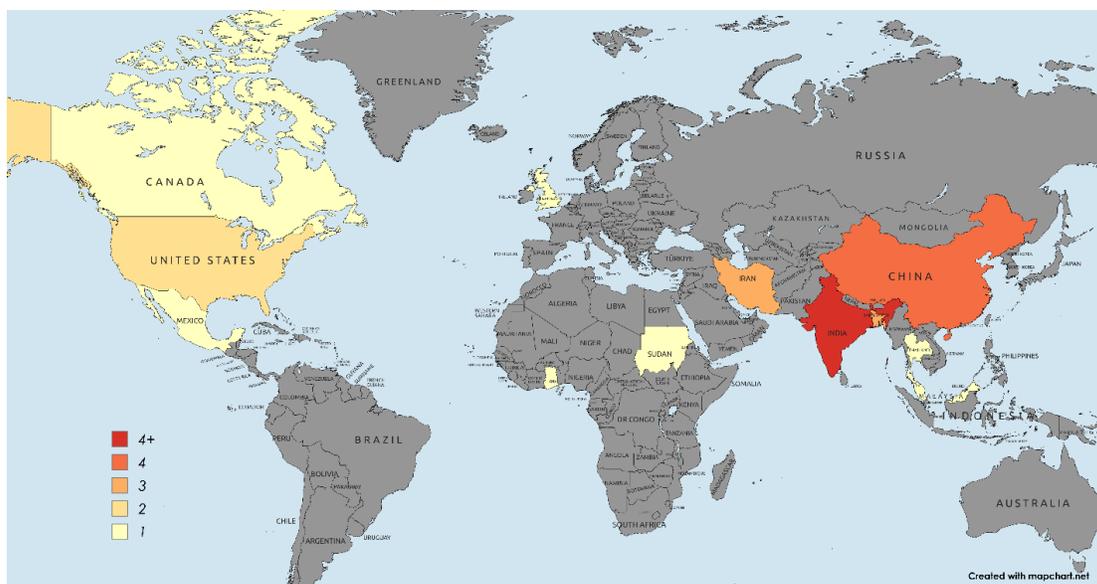


Figure 1. Regional distribution of studies

This review paper includes studies conducted on workers from a various range of occupation. Most of studies were done in Traffic polices as they have to work long time in outdoor and has a greater expose to high heat (Golbabaei et al., 2016; Ibrahim et al., 2015; Irniza et al., 2017; Raval et al., 2018). Agricultural workers and Industrial workers were prioritized in subsequent number of studies as they are exposed to prolonged heat and labor intensive work (Ioannou et al., 2021, 2022; Venugopal et al., 2023; Wagoner et al., 2020). Few of the studies were conducted on Construction, power plant and Mining workers suggesting limited works on these occupational groups (Nunfam et al., 2020; Venugopal et al., 2020).

Table 1. Summary of the studies

| Region      | Country             | Effects  | Factors  |
|-------------|---------------------|--|--|
| Global      | Multiple            | Increased mortality, morbidity, kidney dysfunction, dehydration, fatigue   | Climate change, urban heat islands, lack of acclimatization          |
| Asia        | India               | Heat syncope, heat rashes, kidney stones, reduced productivity             | WBGT >30°C, low hydration, heavy workloads, outdoor labor            |
|             | Bangladesh          | Skin temperature rise, productivity loss (\$281/person/year)               | High humidity, low education, small enterprises                      |
|             | Thailand            | Reduced work performance (4–10%), increased heat index (+2.57°C)           | RCP8.5 climate scenario, decade-long warming trends                  |
|             | China               | Higher road injury risk for pedestrians/cyclists vs. motorists             | Exposure to open heat, behavioral gaps in adaptation                 |
| Middle East | Iran                | Heat strain (WBGT >1), cardiovascular strain                               | Limited cooling infrastructure, air pollution interaction            |
| Africa      | Sudan, Ghana        | WBGT >25°C, heat stress symptoms (88.9% awareness but low training)        | Mining/farming sectors, fan misuse in high heat                      |
| Americas    | USA, Mexico, Canada | 100% fatal heat cases exceed OELs; agricultural workers exceed WBGT limits | Unacclimatized labor, Heat Index inaccuracies, metabolic rates >300W |
| Europe      | UK                  | Productivity loss (1.6–5.4%), southern regions most affected               | Climate zones, occupational susceptibility (e.g., construction)      |

Table 1 summarizes the studies synthesized in this review paper. These papers contain global regional in heat related occupational impact. It highlights how various region of the world with changing climate experiences rising morbidity, productivity loss, and injury risk due to heat stress. It also outlines key environmental and occupational factors influencing the heat stress.

### 3.2 Physiological and Health Impact

Figure 2 presenting the exposure to heat in terms of Wet-Bulb Globe Temperature (WBGT) in various occupational group. Traffic police in India and Sudan experiences WBGT ranging 26.4°C-36.1°C at average where the threshold limit is 26-30°C by The American Conference of Governmental Industrial Hygienists (ACGIH) (Golbabaee et al., 2016; Ibrahim et al., 2015; Irniza et al., 2017; Raval et al., 2018). The agricultural, construction, salt pan, power plant workers also experience high WBGT temperature than the safe limit (Ioannou et al., 2021, 2022; Venugopal et al., 2023; Wagoner et al., 2020).

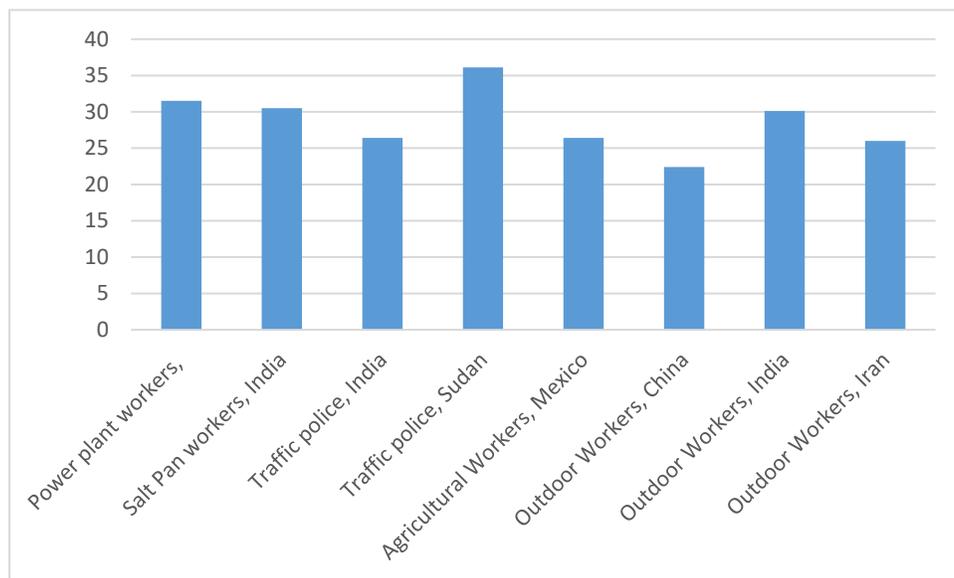


Figure 2. Occupational and regional distribution of WBGT

Table 2. Physiological and Health impact

| Parameter / Condition            | Key Finding (Magnitude/Prevalence) | Statistical Significance/Context                                       |
|----------------------------------|------------------------------------|--|
| Core Body Temp (CBT)             | ↑ 0.25°C (from 36.25→36.50°C)      | P<0.014 (Statistically significant increase)                           |
| CBT Exposure Time                | ≥80% of workday at 37–38°C         | High chronic exposure  |
| Skin Temp (Ear)                  | ↑ 0.60°C (from 36.46→37.06°C)      | P=0.0001 (Highly significant increase)                                 |
| Protective Clothing Heat         | 36.9°C inside                      | ↑4.7°C above ambient   |
| Heart Rate (HR)                  | ↑ 2.4 bpm (from 69.9→72.3 bpm)     | P<0.001 (Highly significant increase)                                  |
| Systolic BP                      | ↑ 4.6 mmHg (from 118.1→122.7 mmHg) | Significant increase (Implied)   |
| Diastolic BP                     | ↑ 4.7 mmHg (from 79.1→83.8 mmHg)   | Significant increase (Implied)   |
| Dehydration (USG ≥1.020)         | 28.2% prevalence                   | Clinically relevant threshold  |
| Severe Dehydration (USG >1.030)  | 40% prevalence                     | Indicates substantial fluid deficit                                    |
| Sweat Rate                       | 50% of workers                     | High sweat rate (>1.2 L/h)   |
| Compromised eGFR (< 90)          | 51.3% prevalence                   | Indicates potential mild to moderate Chronic Kidney Disease (CKD) risk |
| Severely Compromised eGFR (< 60) | 6.8% prevalence                    | Indicates moderate to severe CKD                                       |
| Kidney Stones                    | 9% prevalence                      | High prevalence, suggesting chronic dehydration impact                 |
| Heat Symptoms                    | 94% reported heavy sweating        | Near-universal reporting of key heat symptom                           |
| Thermal Discomfort               | Significant discomfort             | Specifically noted when using respirators                              |
| Work Injury Risk (WBGT)          | 4.8% injuries linked to heat       | 4.1% compensation payouts linked to heat                               |

Table 2 indicates the key physiological impacts experienced in heat stress across the studies. It is shown that Core body temperature increased 36.25°C to 36.50°C ( $p < 0.014$ ) due to heat stress in power plant workers where they were exposed to heat in 80% of the day at 37-38°C (Mousavi et al., 2025). There is a significant relation of ear temperature with WBGT. With increasing WBGT ear temperature increased to 36.46°C to 37.06°C ( $P=0.0001$ ) (Pourvakhshoori et al., 2020).

Heat stress also affects cardiovascular responses as it studied in power plant workers. Heart rate increases due to prolonged heat exposure from 69.9 beats per minutes to 72.3 beats per minutes. Systolic and diastolic blood pressure also increases in heat exposure (Mousavi et al., 2025).

Exposure to high temperature also deteriorated to hydration status. 28.2% of 352 saltpan workers were reported with dehydration with an Urine Specific Gravity (USG) greater equal to 1.020 (Venugopal et al., 2023). In North Mexico, 40% of total grape harvester studied were found having a USG > 1.030 suggesting the development of severe dehydration among them (Wagoner et al., 2020). Sweat rate also increases with high WBGT temperature, (Srinivasan et al., 2024) reported 50% his total population had a increase in sweat rate (>1.2L/h) in high temperature. Renal strain also emerged as a concern as in a study, 51.3% of total salt pan workers ( $n = 352$ ) showed reduced estimated glomerular filtration rate (eGFR < 90 mL/min/1.73 m<sup>2</sup>) and 6.8% showed < 60 mL/min/1.73 m<sup>2</sup> (Venugopal et al., 2023). There also report of kidney stones, 9% steel workers had kidney stone prevalence (Venugopal et al., 2020). The physiological strain translated into noticeable health impacts. Heavy sweating (94%), intense thirst (94%), dry mouth (81%), and loss of work capacity (69%) were reported by traffic police in Ahmedabad, India (Raval et al., 2018). In covid-19, using respirators causes thermal discomfort to users (Foster et al., 2020). Fatigue (57.9%), dizziness (31%), and muscle cramps (16.4%) were reported by the traffic polices in Kualalampur, Malaysia (Irniza et

al., 2017). Work injury risk in construction workers in China also increased with WBGT, 4.8% risk increased as follows (Ma et al., 2019). Workers wearing clothing such as mascot clothing also accounted for thermal discomfort as their internal temperature increased 4.7°C higher than ambient outside temperature.

These findings suggest that outdoor workers in various regions faces various physiological, health and high-risk impact such as increase in body temperature, cardiovascular problems, dehydration and renal problems due to heat strain. These effects can impair the physiological function of the body and can cause various health related issues.

### 3.2 Cognitive and Productivity Impact

Heat stress has a impact on cognitive functioning and productivity of outdoor workers along with physiological and health impacts. Various studies reported on work capacity reduction, work hour reduction low job satisfaction, low reaction time and higher fatigue level (Table 3).

Table 3. Cognitive and Productivity Impact

| Parameter / Measure                   | Key Finding                                | Significance / Context  |
|---------------------------------------|--|---|
| Work Capacity Reduction               | Predicted ↓ up to 40%                      | Significant economic and output threat.   |
| Work Performance Decrement (Thailand) | ↑4% to >10%                                | Demonstrates measured performance loss due to heat.                                       |
| Lost Work Hours (Canada)              | 21.8 hours/worker/year lost                | Quantifies the direct time/economic loss.   |
| Increased Heat Warnings               | +12.5 hourly WBGT warnings/year            | Linear trend indicating growing thermal risk exposure.                                    |
| Commission Error (CPT)                | ↑ 3× (from 0.17→0.51)                      | P<0.001. Significant increase in false alarms/mistakes.                                   |
| Omission Error (CPT)                  | ↑86% (from 0.14→0.26)                      | P<0.001. Significant increase in missed targets/lapses.                                   |
| Correct Responses (CPT)               | ↓8.3% (from 149.69→137.23)                 | P<0.001. Significant reduction in successful task completion.                             |
| Reaction Time (RT)                    | Correlated with SBP & HR                   | r=0.368–0.492. Links cognitive speed directly to physiological strain.                    |
| Fatigue Level (Mascots)               | Mean score 13.07 at 40 min                 | High fatigue noted under specific high-heat/stress conditions (like wearing mascots/PPE). |
| Thermal Comfort Loss                  | Vote ↑ from 0.83→3.22                      | Represents a shift from slightly warm to very uncomfortable.                              |
| Workload Level                        | 62.8% reported heavy workload              | High perceived effort, compounding the heat effect.                                       |
| Job Satisfaction Correlation          | Inverse correlation (r=-0.639)             | P<0.001. Strong evidence that heat/strain reduces satisfaction.                           |
| Job Performance Score                 | Mean 66.6 (SD = 12.1)                      | Baseline measure of overall performance.  |
| Injury Risk (Taiwan)                  | Heat associated with ↑ cumulative RR       | Risk Ratio increases with higher heat percentiles (clear dose-response).                  |
| Emergency Dept. Calls                 | 41% of cities showed higher RR during heat | Indicates higher general health emergencies during heatwaves.                             |
| Fire Dept. Calls                      | 79% of cities showed higher RR during heat | Suggests a link between heat and increased non-medical emergency workload.                |

Table 3 represents the productivity, cognitive functioning and overall work capacity of outdoor workers in heat exposure. (Koteswara Rao et al., 2020) predicted up to 40% drop in work capacity. There is also 4-10% work performance decrement in work performance reported in Thailand (Amnuaylojaroen et al., 2022). In Canada, excessive heat accounted for an estimated 21.8 lost work hour per worker annually with a trend of more than 12.5 hourly WBGT warnings per year (Vanos et al., 2019). These productivity and cognitive functioning hindrance reflected in broader workforce with 62.8% mining workers in Ghana has reported heavy workload in heat intensive environments (Nunfam et al., 2020). Job satisfaction decreases significantly with increasing thermal state (r = -0.639,

$p < .001$ ) accompanied by a lower job performance score (66.6) (Dehghan et al., 2016). (Mousavi et al., 2025) showed that cognitive functioning also affected by heat stress as Commission error, omission error increases significantly while correct responses are decreases. Reaction time is strongly correlated with systolic blood pressure and heart rate ( $r = 0.368-0.492$ ), suggesting a physiological basis for cognitive impairment (Golbabaie et al., 2016). Heat exposure also accumulates rapid fatigue and loss of thermal comfort during prolonged task in mascot clothing (Liu et al., 2023). Heat events increases emergency responses as 41% and 79% cities reported higher relative risks (Williams et al., 2020). Also, In Taiwan heat associated high relative risk among the community (Hsu & Rodríguez, 2024).

Collectively, these findings indicate that heat stress imposes various physiological, cognitive and operational inefficiencies. It reduces work capacity, work performance, job satisfaction and up to 40% drop in performance. These impairments contribute broader inefficiencies and hinder the productivity of a worker.

### 3.3 Economic Impact

Along with the physiological, cognitive and productivity impairment by heat stress, it is equally necessary to address these human performance losses translate directly into economic consequences.

Table 4. Economic Impact

| Parameter / Measure                   | Key Finding (Annual Cost/Share)         | Context / Impact Type   |
|---------------------------------------|---|---|
| Direct Loss (Agriculture)             | \$59–90 per worker                      | Sector with high outdoor exposure and physical labor.   |
| Direct Loss (Construction)            | \$41–72 per worker                      | Sector with high outdoor exposure and physical labor.   |
| Attributable Insurance Payout (China) | 4.1% of total payout                    | Share of worker compensation claims directly linked to heat.  |
| Total Economic Loss (Canada)          | C\$221,200 / year                       | Total quantified annual loss for a specific study area/region.                                      |
| Social Costs (Europe)                 | \$2–3 per capita (average total losses) | Represents the broad societal cost distributed across the population.                               |
| Individual Annual Loss (Bangladesh)   | \$281 per person                        | High individual economic burden in a heat-vulnerable, lower-income economy.                         |
| Absenteeism Cost                      | \$144 per person annually               | Financial cost associated with workers missing work due to heat-related illness or safety concerns. |

Table 4 exhibits substantial economic losses across various work sectors due to heat exposure. In agriculture and construction sector, direct loss accumulated 59-90 USD and 41-72 USD per worker respectively. In Europe, the average social cost due to heat stress accounted 2-3 USD per capita (Orlov et al., 2019). (Vanos et al., 2019) estimated the total economic loss in Canada in a year (221,200 CAD) due to heat stress. In China 461 individual injury claims due to heat stress and about 4.1% of total insurance payout was accumulated for this (Ma et al., 2019). The individual annual loss per son due to heat stress was 281 USD and due to absenteeism the economic loss counted 144 USD per person (Bardhan et al., 2024).

Overall, the evidence demonstrates notable economic burden at worker, organizational and national level due to heat stress. Sectors like agriculture and construction along with other various section are affected, with rising heat driving increased compensation, personal and social loss.

### 3.3 Implications for traffic police

Integrating the above findings, traffic police emerged as one of the most impacted critically groups. They consistently work on extreme environment, often the WBGT exceed ACGIH threshold limit. They develop various heat induced fatigue which affects their working capability and lowers the productivity which can possibly affect the whole traffic system of a region. It is appeared that structured intervention policies can reduce physiological, health and economic impact arise due to heat stress (Glaser et al., 2022). Therefore, after synthesizing various studies, proposed implications are:

- Mandatory hydration supply to prevent high sweat loss, dehydration and better renal health.
- Rotational duty schedule to reduce the exposure of high heat.

- Heat protective clothing and cooling gear to minimize thermal discomfort.
- Integrating enough breaks to duty schedule.
- Training on heat related illness recognition for early detection and prevention of heat related severe health outcome.

#### **4. Conclusion**

This review highlights the impact of heat stress on physiological, cognitive, productivity and economic consequences of outdoor workers across the diverse sector and region. Evidence from recent studies shows increases in core temperature, cardiovascular strain, dehydration, and heat-related illnesses as WBGT levels rise. The cognitive consequences—such as slower reaction time, high error rates and lower job satisfaction collectively undermine and operational reliability. The productivity loss—reduced work hours, reaction time and lower work performance translated into considerable economic burden at individual, organizational and national level.

The reviewed studies span traffic police, agriculture, mining, construction, manufacturing, service sectors, and general outdoor occupations and the findings provide valuable implications for traffic police to reduce heat induced counteract impacts. The physiological strain, cognitive impairment, and productivity decline observed in other outdoor occupational personnel indicate a similar vulnerability for this group, underscoring the need for more targeted research.

Overall, the studies demonstrates that heat stress is a growing occupational risk driven by climate change and urban heat intensification. Various adaptation strategies—including hydration strategies, rest periods, protective clothing, workload division, and worker education—is needed for reducing heat-related risks. Future research should focus on integrating physiological monitoring, exposure modeling, decision making effects and sector-specific assessments to provide more effective heat-management insights for all outdoor workers.

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## Biographies

**Professor Dr. Mohammad Iqbal** is currently serving as a Professor at Shahjalal University of Science and Technology (SUST), Sylhet-3114, Bangladesh under the Department of Industrial and Production. He is the founder lecturer of Department of Industrial and Production, SUST. He served as the Head of the dept. for 13 years. Dr. Iqbal was the Dean of School of Applied Science and Technology for two years. Professor Iqbal was a visiting research scholar at the Merry O' Connor Process Safety Research Center, College station, Texas A & M University, Texas, USA. Professor Iqbal is a member of U.S exchange alumni. He was the Head of Petroleum and Mineral Engineering Department, SUST for one year. Dr. Iqbal is actively involved in research and teaching of Mechanical, Industrial, Production Engineering and environment related topics. Dr. Iqbal has been awarded for the best research paper presentation in several international conferences. He has 34 years of industrial, research and teaching experiences. He was a member, Peer Review Committee on Engineering & Applied Science, Ministry of Science, Information and Communication, Republic of Bangladesh Government for the financial year June 2006-July 2007. His affiliations as a researcher have contributed more than 35 publications in peer-reviewed national and international journals. He has more than 90 national and international publications in conference proceedings. He is one of the advisors to the Sylhet Chamber of Commerce and Industries, Sylhet, Bangladesh. Dr. Iqbal served as the member of SUST Research Centre,

Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh (October, 2011- February, 2020). Dr. Iqbal served as the Chair, IEOM Society, Bangladesh Chapter in 2018- 2020. Dr. Iqbal was the Conference Chair of IEOM Society of Bangladesh in the year 2019. Dr. Iqbal was the honorary secretary of IEB (Institution of Engineers Bangladesh) Sylhet Centre, Sylhet, Bangladesh (April, 2018- September, 2020). Dr. Iqbal was the Co-chair, of IEOM Society, Bangladesh (2020-2021). Dr. Iqbal is a Lifetime Member, IEOM Society and Life member, Institution of Engineers, Bangladesh (IEB), Bangladesh. Dr. Iqbal is a member of ASHRAE, Bangladesh Chapter, Bangladesh since 2022. He received award as a Distinguished Professor and Leadership in Recognition and Appreciation of Outstanding Teaching and Research in Ergonomics and Serving in the Academic Leadership and Professional Leadership Positions at IEOM Bangladesh Chapter, December 27, 2022.

**Nayan Debnath Pranta** is an undergraduate at the Department of Industrial and Production Engineering (IPE) at Shahjalal University of Science and Technology (SUST) in Sylhet-3114, Bangladesh. He has interest with Human Factors and Ergonomics, Sustainable Manufacturing, Production System Optimization, and Machine Learning and Artificial Intelligence may apply in Industrial Operations. He is focused upon developing analytic and technical skills in relation to modern manufacturing and industrial systems.

**Nilufa Yeasmin** is an undergraduate at the Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh. Her research interest includes Human Factors and Ergonomics. Her research interest includes Production System Optimization. Her research interest includes Supply Chain Management. Her research interest includes Lean Manufacturing and Quality Management. She currently researches with Professor Dr. Mohammad Iqbal, Department of Industrial and Production Engineering, SUST, to develop human-centered and data-informed sustainable and efficient manufacturing systems intently.

**Arnab Laskar** studies as an undergraduate student within the Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh, specializing in Human Factors & Ergonomics, Organizational Behavior, Supply Chain Management, Quality Control Management, Machine Learning, and Industry 4.0. Currently researching projects under Professor Dr. Mohammad Iqbal in the Department of Industrial and Production Engineering, SUST, he aspires to work in the field of Smart Manufacturing Systems and Ergonomic, Human-Centered Design.

**Professor Dr. Salma Akhter's** career has evolved over a duration of 23 years in academia, professional and research arena. Started career as a lecturer in the department Chemical Engineering and Polymer Science, in 2001 and rose to the rank of Professor in 2014, Shahjalal University of Science and Technology, Sylhet, Bangladesh. She is a Grade – I Professor since 2023. Apart from her teaching responsibilities, she is actively involved in various research projects. She obtained her B.Sc. Engg in Chemical M.Sc. Engineering from BUET (1996), Bangladesh and obtained PhD from Chemical Engineering Department (BUET) in 2012 respectively. During her PhD study, he was engaged in a research work on 'Textile Sludge Disposal Using Incineration Technique' funded by BUET. Prof. Salma completed her M. Engg. From Dublin City University, Dublin, Republic of Ireland (1997-2000). Dr. served as a visiting research scholar at Marry Kay O'Conner Process Safety Center Texas A& M University, College Station, Texas, USA in the year 2018 and worked in a research team there. Prof. Salma pioneered in many development activities of SUST. Aside from serving as a faculty member, she also served in many administrative positions on SUST which includes Assistant Provost of Female students' halls, Head of the Department of Chemical Engineering and Polymer Science, SUST. Dr. Salma has been involved in professional works since 1996. He has completed more than 14 professional projects so far. She was the Team member of different Safety committees in Bangladesh. She worked as a member for SUST in a joint research project on 'plastic management in Sylhet City' with Sylhet City Corporation, Sylhet and Research England QR Global Challenges Research Fund, UK. Her field of expertise includes Energy – Safety practice, Energy Management; Climate change and global warming, Environment; Process safety, occupational health safety and fire safety, safety and Health, Gas field safety and security Solid-Waste Management. Dr. Salma has been involved in significant number of research projects mostly through her MS and Undergraduate students which have been funded by Ministry of Science & Technology, SUST Research Centre (SUST) and World Bank. She has supervised more than 37 Undergraduate students and MS students so far. She has published 27 Journal papers in reputed journals and more than 45 International conference papers in reputed conference proceedings.