Austin Environmental Sciences

Open Access

Austin Publishing Group

Research Article

Comparison of Heat Risk Profiles among Women Working in Indoor and Outdoor Sectors in the Context of Climate Change

Shanmugam R, Latha PK and Venugopal V*
Department of Environmental Health Engineering, Sri Ramachandra Institute of Higher Education and Research, Chennai, India

***Corresponding author:** Vidhya Venugopal, Department of Environmental Health Engineering, Sri Ramachandra Institute of Higher Education and Research, No: 1, Ramachandra Nagar, Porur, Chennai-600116, Tamil Nadu, India

Received: October 21, 2022; **Accepted:** November 14, 2022; **Published:** November 21, 2022

Abstract

Introduction: Rising temperatures and heat events potentially cause adverse health consequences for working population, especially increased risk of Heat Related Illnesses (HRIs) for women. There is minimal evidence comparing the risk of heat stress impacting women working indoors vs outdoors.

Methodology: Between 2017 and 2019, we conducted a cross-sectional study among 903 women in four outdoor and three indoor sectors. We measured Wet Bulb Globe Temperature (WBGT) and physiological Heat Strain Indicators (HSI) such as Core Body Temperature, Sweat Rate, and Urine Specific Gravity, as well as self-reported symptoms of HRIs using a validated HOTHAPS questionnaire. Multivariate Logistic Regression models were used to compare the heat risks in the indoor and outdoor sectors using SPSS version 16.0.

Results: WBGT exposures were high in both the outdoor (Avg. WBGT=28.8°C±2.4°C) and indoor (Avg. WBGT=28.7°C±3.5°C) sectors. WBGT surpassed the Threshold Limit Value in 67% of Outdoor Women Workers (OWW) compared to 59% of Indoor Women Workers (IWW). OWW reported more symptoms of HRIs (94% vs. 81%), and even after controlling for potential confounders, there was a significant positive correlation between heat exposures and HRIs for the OWW (AOR: 3.7; 95% CI: 2.4-6.1). OWW had a 1.5-fold greater risk of measured HSI that was above safe limits (95% CI: 1.1-2.1) and a 2.1-fold higher risk of urogenital problems (95% CI: 2.1-3.8) than the IWW.

Conclusion: Our findings show that OWW are at a higher risk of HRIs due to direct sun exposure, excessive labor, and a lack of welfare facilities. Strong labour policies and enhanced workplace welfare facilities are urgently needed to protect these women.

Keywords: Climate Change; Occupational Heat Stress; Physiological Heat Strain; Dehydration; Indoor Sector; Outdoor Sector

Abbreviations

HRIs: Heat-Related Illnesses; EBGT: Wet Bulb Globe Temperature; ACGIH: American Conference of Governmental Industrial Hygienist; HIS: Heat Strain Indicators; CBT: Core Body Temperature; USG: Urine Specific Gravity; SwR: Sweat Rate; HOTHAPS: High Occupational Temperature Health and Productivity Suppression; COR: Crude Odds Ratio; AOR: Adjusted Odds Ratio; IWW: Indoor Women Workers; OWW: Outdoor Women Workers; TLC: Threshold Limit Value; PPE: Personal Protective Equipment

Introduction

The influence of climate change on people's living and working environments poses health concerns to millions of individuals [1]. The rise in global temperatures exacerbates the existing heat burden in indoor and outdoor work environments [2]. A large percentage of women work in occupations with significant heat exposure [3], and they are frequently subjected to intense workloads at home due to cooking and other household responsibilities. Extreme heat poses a greater threat to women and imposes a greater load on them, particularly when they are outdoors [4]. High temperatures, humidity, and radiant heat may increase the risk of heat exposure for women working outdoors in industries such as agriculture, bricks, and saltpans, placing them at risk for a range of occupational hazards [5]. While outdoor workers with heavy workloads are more susceptible to heat, indoor and semi-indoor women are equally at risk, particularly if there is insufficient ventilation and/or no cooling system [5] leading to reduced alertness and work capacity [1,6]. Even hot indoor work situations are challenging for women who perform physically demanding duties for extended periods [7], especially if they are wearing protective equipment, which exacerbates heat stress.

Heat is a potential threat for women in various outdoor and indoor environments, resulting in a variety of Heat-Related Illnesses (HRIs) when the human body absorbs and emits more heat than it can disperse [8]. When the air temperature surpasses 37°C, the only mechanism for cooling the body is the evaporation of perspiration, but high air humidity and clothing significantly inhibit sweat evaporation [5]. Size, physical capacity, and other physiological variables make women more susceptible to health concerns [9]. The heat dissipation

Citation: Shanmugam R, Latha PK and Venugopal V. Comparison of Heat Risk Profiles among Women Working in Indoor and Outdoor Sectors in the Context of Climate Change. Austin Environ Sci. 2022; 7(4): 1085.

mechanism is less effective in hot conditions due to a reduction in the thermal gradient, which happens when skin temperature approaches or exceeds environmental temperature, causing an increase in core body temperature. This effect is exacerbated by excessive humidity, which inhibits sweat evaporation and evaporative cooling. This reaction leads to needless water loss, which may result in dehydration.

Women are more vulnerable to HRIs, depending on their exposures (outdoor or indoor) and other socioeconomic variables [10]. As a result of poor working conditions and lack of access to cooling and other preventative and protective measures, they are also disproportionately disadvantaged. Dehydration and inadequate fluid replacement can wreak havoc on a person's health, leaving them more susceptible to the detrimental effects of high-heat loads [11]. Workplace conditions play a significant role in increasing heat exposure, sensitivity to heat, prolonged work, and acclimatization capacity, and in certain instances may raise the dangers during temperature extremes, hence increasing the risk of climate-related health outcomes [12]. No research has compared the heat-health risks of indoor and outdoor women to identify who is more susceptible. Understanding the disparities in vulnerability can serve in defining the effects of climate change and in prioritizing and developing initiatives to protect vulnerable women from heat stress. Our objective was to examine the heat exposures and HRI hazards of outdoor and indoor female employees.

Materials and Methods

Study Design, Settings, and Sample Size

We conducted a cross-sectional study to examine the differences in women's health between indoor and outdoor hot working environments in the context of climate change in various outdoor (agriculture, construction, brick making, and salt pans) and indoor (commercial kitchen, garments, and steel) work sectors in Tamil Nadu, Southern India. We recruited 120 research participants using the random cluster sampling method, with a total sample size of 903 to account for attrition and lost-to-follow-up. We contacted 13 workplaces, including at least three in each type of sector. To reduce selection bias, we randomly selected workplaces from among the willing workplaces in each industry. We identified workplaces with high ambient heat exposures (from heat-generating operations or direct sun exposures) and manual labour by women. The Sri Ramachandra Institution of Higher Education and Research's Institutional Ethics Committee (IEC-NI/21/FEB/77/37) has granted approval. Then, we asked permission from the various workplaces to conduct the evaluations. Before beginning the study, we educated the female employees about the risks and benefits of participation and obtained written agreement from every woman recruited.

We began the study by administering screening questionnaires and excluding women with diabetes, hypertension, thyroid diseases, respiratory diseases, heart diseases, and/or any co-morbidity, as well as those taking Non-Steroidal Anti-Inflammatory Drugs or herbal drugs. Included were women between the ages of 18 and 70 who have worked in the same area for at least six months (Figure 1).

Heat Stress Profile, and Workload

The Wet Bulb Globe Temperature (WBGT), a direct measurement that represents the human body's reaction to heat stress [13], was used to profile the environmental heat exposure. The international standard for WBGT [1] employs multiple formulae for indoor and outdoor measurements based on three temperature variables: Ta, air temperature; Tg, globe temperature; and Tnw, natural wet bulb temperature, which accounts for evaporation [14]. We monitored hourly ambient WBGT during normal shift hours with the 3M QUESTemp° heat stress metre (Ta, Tnw, and Tg: 0.5°C; RH: 5%) and used an hourly average as the representative WBGT exposure during a work-shift. Using American Conference of Governmental Industrial Hygienist (ACGIH) guidelines, a qualified Industrial Hygienist categorised the employment type. We classified the women in each group (indoor and outdoor) as exposed or unexposed based on the WBGT permissible ACGIH Threshold Limit Value (TLV) of 27.5°C for heavy workers and 28°C for moderate workers in order to evaluate the risk of heat stress and the corresponding WBGT at which continuous work could be safely performed [15].

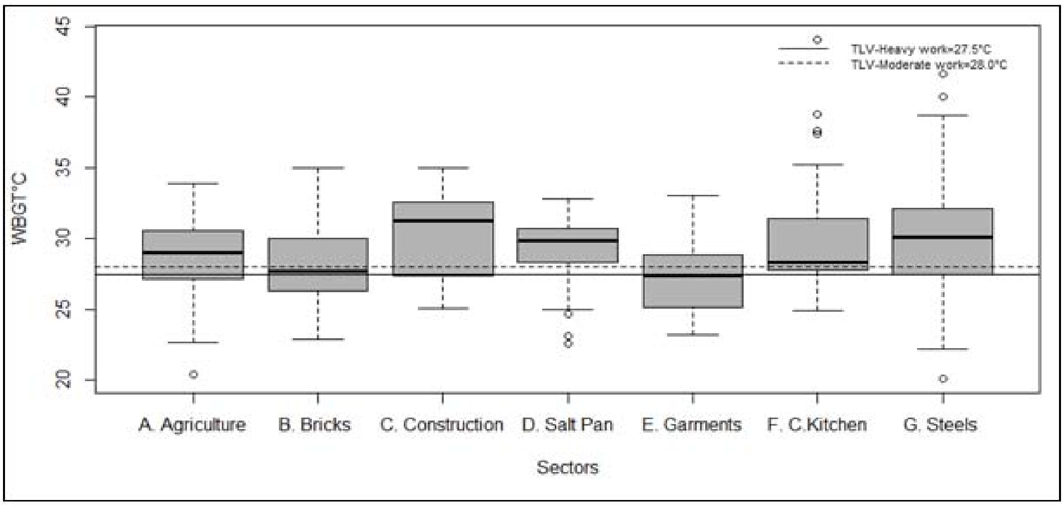

Figure 1: Attributed Wet Bulb Globe Temperature (WBGT) profiles across various outdoor and indoor sectors (2017-2019) in Southern India.
**Note: A –D are Outdoor sectors; E-G are Indoor sectors*

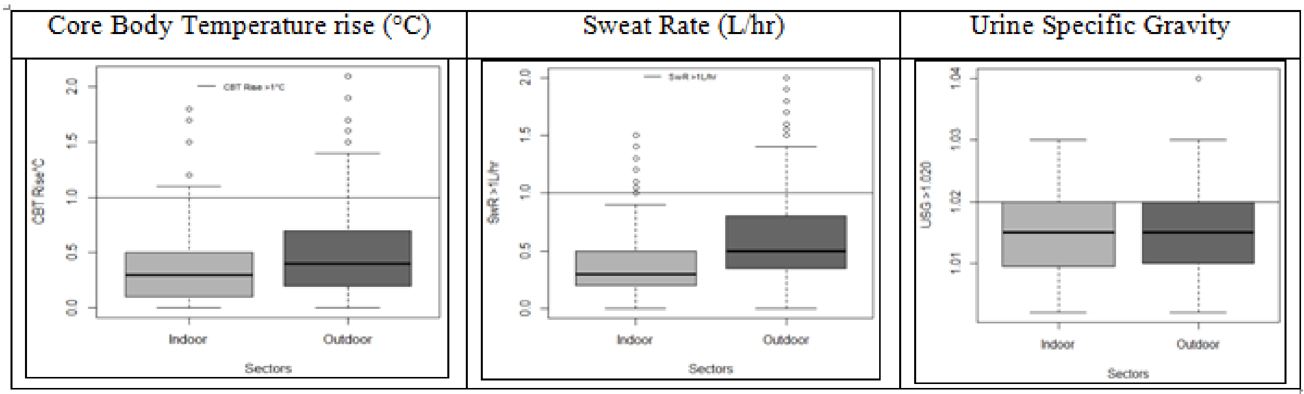

Figure 2: Comparing the distribution of workers with measured heat strain indicators in indoor and outdoor sectors in Southern India (n=903).

Heat Exposures - Women's Perception of Health

We administered a validated High Occupational Temperature Health and Productivity Suppression (HOTHAPS) questionnaire with detailed questions about occupational heat exposure (work duration, timing, and years of exposure), medical history, personal history, and experience with HRI symptoms, and collected perception data on heat exposures, health impacts [5]. The HRI symptoms were well described to the women. If the woman reported any of the following symptoms, including excessive sweating/thirst, dizziness, muscle cramps, headache, nausea/vomiting, fainting, or prickly heat, she was labelled as experiencing HRIs.

Heat Stress –Health Implications

We used standard methodologies and measurement protocols to quantify the Heat Strain Indicators (HSI), such as Core Body Temperature (CBT), Urine Specific Gravity (USG), and Sweat Rate (SwR) [16-17]. And we measured the pre and post shift body weight to calculate the SwR using Canadian sports Association formula [18], and measured Core Body Temperature (CBT) with a Digital Infrared Thermometer (Rossmax), USG with a refractometer during pre and post shifts. CBT rise of >1°C [8,14], SwR of >1l/hr [8,14], and USGs of >1.020 [19] were used to define HSI in our study.

Data Analysis

Using the chi-square test with a p-value threshold of 0.05, we compared the baseline characteristics of indoor women to those of outdoor women and to examine the significance of the relationship between the variable. We also determined the proportion of heat-exposed and unexposed indoor and outdoor participants who self-reported HRI symptoms and HSI. We employed bivariate analysis [Crude Odds Ratio (COR)] and multivariate analysis within a group to assess the exposure risk level for Indoor Women Workers (IWW) and Outdoor Women Workers (OWW). Using multivariate logistic regression, we adjusted for potential confounding variables using a step-by-step approach. Adjusted Odds Ratio (AOR) is displayed alongside the corresponding p-values and 95% confidence ranges. For statistical analysis, we used version 16.0 of SPSS.

Results

Descriptive Analyses

For screening purposes, we visited 13 workplaces and interviewed 950 women. However, we recruited 903 women after excluding 5% of women based on our study's inclusion/exclusion criteria. Outdoor 67.4% (N=609) and indoor 32.6% (N=294) women were included. (Table 1) displays the descriptive characteristics of the study population in both groups. The outside workers were considerably older than their indoor counterparts (mean difference 3.6 years, median difference 3 years). The percentage of literate individuals was much greater in indoor sectors (61%) than in outdoor sectors (47.0%). Manual work with heavy workload was significantly higher among outdoor is 83.1% and moderate workload was high among indoor is 95% ($p<0.0001$).

Figure 1 shows that both outdoor and indoor female workers were exposed to heat [WBGT (°C)]. In outdoor (Avg. WBGT of 28.8°C ± SD of 2.4°C) and indoor (Avg. WBGT of 28.7°C ± SD of 3.5°C) workplaces, heat exposures exceeded the TLV for 67.2% (N=409) of OWW and 68% (N=200) of IWW. The outdoor sectors with the highest WBGT exposure were the construction and brick sectors (35°C), while the indoor sector with the highest WBGT exposure was the commercial kitchen (44.1°C). Despite the fact that WBGT levels were high in both sectors, OWW reported significant heat exposure problems ($p<0.01$) (Table 2). Due to radiant heat from the industrial processes, the indoor WBGT was high in commercial kitchens and steel manufacturing; however, these women were exposed to WBGT temperatures above 28°C for the majority of the year.

Table 2 shows the distribution of quantitative HSIs such as CBT, SwR, and USG, as well as self-reported HRI symptoms, across outdoor and indoor women. Outdoor women are exposed to heat which is equal to indoors. But the outdoor sectors had a significantly greater self-reported HRI distribution than indoor sectors (94 % vs. 81 %, p=0.0001). Other self-reported HRI symptoms are considerably greater among OWW ($p<0.0001$). Similar tendencies were seen for measured HSI, with outdoor women having a significantly larger percentage of HSI than IWW ($p<0.0001$).

Risks of HRI/HSI

Comparable tendencies are observed in measured HSI, with the OWW having a significantly higher proportion of HSI than the IWW (Figure 2). Figure 2 demonstrates that, with the exception of USG, the other assessed HSI, including CBT and SwR, increased among OWW

Table 1: Descriptive comparison of characteristics of women from the outdoor sector vs. indoor sector (N=903).

Variables		Outdoor (n=609)		Indoor (n=294)		χ^2; p-value
		N	%	N	%	
Age	<40 yrs	319	52.4	153	52.0	0.009; 0.924
	≥40 yrs	290	47.6	141	48.0	
Literacy Status	Literate	286	47.0	180	61.2	16.1; 0.0001
	Illiterate	323	53.0	114	38.8	
Duration of Employment	≥5 Years	245	40.2	138	46.9	3.6; 0.056
	<5 Years	364	59.8	156	53.1	
Work category	Heavy	506	83.1	14	4.8	498.2; 0.0001
	Moderate	103	16.9	280	95.2	
Self-Reported HRI*	Yes	573	94.1	238	81.0	37.3; 0.0001
	No	36	5.9	56	19.0	

*Note: *Self-reported Heat-Related health Illness (HRI) include excessive thirst, excessive sweating, muscle cramps, heat exhaustion, prickly heat, heat rashes.*

Table 2: Descriptive comparison of variables of women's heat strain based on heat exposure (WBGT°C) between sectors (n=903).

S. no	Study variables		Outdoor (N=609)	%	Indoor (N=294)	%	Chi-square χ^2; p-value
1	WBGT°C	Number of workers exposed to > TLV	409	67.2	200	68.0	6.4; 0.01
2	Self-reported HRI symptoms	Any Heat stress symptoms	573	94.1	238	81.0	37.3; 0.0001
3		Dehydration	381	62.6	*104*	35.4	52.5; 0.0001
4		Uro-genital issues	469	77.0	168	57.1	26.1; 0.0001
5		Urine color/Volume	383	62.9	154	52.4	9.1; 0.003
6	Measured Heat Strain Indicators	Rise in Core Body Temperature >1°C	84	13.8	13	4.4	19.1; 0.0001
7		Sweat Rate above>l/hr	112	18.4	16	5.4	28.7; 0.0001
8		Urine Specific Gravity	138	22.7	51	17.3	0.3; 0.590
9		Anyone Heat strain Indicator	269	44.2	71	24.1	37.3; 0.0001

Note: The numbers mentioned in this table indicates the number of Cases frequented

during the post shift. We detected substantial differences between pre-shift and post-shift USG levels in these women.

The bivariate analysis demonstrates that OWW are at a greater risk (Table 3) because to the prevalence of HRIs and other self-reported symptoms. In addition, the multivariate analysis did not change when correcting for confounding variables such as age, education, and years of heat exposure. The OWW developed at least one urogenital issue, as demonstrated by the multivariate analysis, which indicates a 2.1-fold increased risk of urogenital disorders (Table 3).

The comparison analyses (bivariate and multivariate) between the heat-exposed and unexposed groups are presented in Table 4. (Above and below TLV values for each category). After adjusting for all covariates, our findings indicate that women who were exposed to heat outdoors had a 1.7-fold greater likelihood of reporting HRI symptoms than women who were exposed to indoor heat. Compared to the unexposed group, heat-exposed outdoor women had a significantly increased risk of dehydration (AOR: 1.3; 95% CI: 1.1-1.8) and urinogenital problems. Due to insufficient welfare facilities, one-third of women experienced urogenital issues such as changes in the volume and colour of urine, difficulties passing pee, a burning feeling, and kidney stones. Even after correcting for all confounding variables, the heat-exposed group had a 1.5-fold higher incidence of HSI. The risk of an increase in SwR (AOR: 2.7; 95% CI: 1.7-4.3) was significantly higher for the heat-exposed group (Table 4), indicating that they were mildly dehydrated.

Discussion

The findings of this cross-sectional study show that regardless of age, outdoor versus indoor women had differing probabilities of developing HRI. Outdoor sectors are more susceptible to physiological heat stress and HRIs than women in indoor sectors. IWW was similarly exposed to heat and workload, but their risk profile differed from that of indoor women in terms of welfare facilities and ways for preventing heat stress. Due to the greater incidence of HRIs in outdoor sectors [17], the OWW had a lower level of literacy (47%), as well as less awareness and comprehension of heat protection. Nevertheless, the heat levels in both groups exceeded the TLV values for safe work limits [15]. The OWW had nearly double the heavy labour intensity of indoor women, which is a significant risk factor for HRIs [16,20]. There is more mechanization/automation in indoor industries, which reduces work intensity and, as a result, heat stress risks are lower [15], and larger welfare amenities, such as cooling systems and sanitary access [3], are more prevalent to protect them.

Outdoor women were exposed to direct sunlight [15] and the percentage of HRI symptoms was higher among them than IWW (table 3 & 4). Dehydration, in turn, raises the risk of HRI and HSI in workers, especially those who are exposed to high ambient

Table 3: Results of logistic regression models comparing self-reported heat stress and measured heat strain indicators between outdoor (n=609) and indoor (n=294) workers in Southern India.

Study Variables	N (%) Present	N (%) Absent	Bivariate OR≠ (95 % CI); p-value*	Multivariate OR≠ (95 % CI); p-value*
SELF-REPORTED HEAT STRESS SYMPTOMS				
Heat stress symptoms (anyone)				
Indoor	238 (26.4)	56 (6.2)	1	1
Outdoor	573 (63.5)	36 (4.0)	**3.7 (2.4-5.8) 0.0001**	**3.7 (2.4-5.9) 0.0001**
Dehydration				
Indoor	104 (11.5)	190 (21.0)	1	1
Outdoor	381 (42.2)	228 (25.2)	**3.1 (2.2-4.1) 0.0001**	**3.1(2.2-4.1) 0.0001**
Change in urine volume/color				
Indoor	154 (17.1)	140 (15.5)	1	1
Outdoor	383 (42.4)	226(25.0)	**1.5 (1.1-2.0) 0.003**	**1.4(1.1-1.9) 0.009**
Urinogenital issues				
Indoor	178 (19.7)	116 (12.8)	1	1
Outdoor	469 (51.9)	140(15.5)	**2.1 (1.6-2.9) 0.0001**	**2.1(1.5-2.8) 0.0001**
MEASURED INDICATORS OF HEAT STRAIN				
Rise in CBT (<1 °C, >1 °C)				
Indoor	13 (1.4)	279(30.9)	1	1
Outdoor	84 (9.3)	506 (56.0)	**3.5 (1.9-6.5) 0.0001**	**3.6(1.9-6.7) 0.0001**
SwR(> 1 l/hr, < 1 l/hr)				
Indoor	16 (1.8)	276 (30.6)	1	1
Outdoor	112 (12.4)	478 (52.6)	**4.1 (2.3-6.9) 0.0001**	**3.7(2.1-6.5) 0.0001**
USG (< 1.020, > 1.020)				
Indoor	51 (8.3)	122 (20.1)	1	1
Outdoor	138 (22.6)	297 (48.8)	1.1 (0.7-1.6) 0.59	1.1(0.7-1.7) 0.437
Measured Heat strain Indicators (anyone)				
Indoor	71 (7.9)	221 (24.5)	1	1
Outdoor	269 (29.8)	321 (35.5)	**2.6 (1.9-3.5) 0.0001**	**2.7(2.1-3.8) 0.0001**

*Note: Multivariate analysis corrects for age, education, years of exposure; *p-Value<0.05 is significant; ≠More than 1 denotes the presence of risk*

temperatures and engage in strenuous physical activity [3,12]. The number of women with increased USG change was significantly higher among the outdoor sectors (15.2 % vs. 5.6 %), and they were at a higher risk of having mild to moderate dehydration. According to previous literatures, USG rises with lower body mass owing to sweat loss caused by heat and strenuous physical exercise [21-24].

The greater incidence of assessed HSI in heat-exposed outdoor sectors (Table 4) has been recorded earlier [3], and continuous occupational heat exposure has been connected to long-term health effects such as cardiovascular disease and chronic renal disease [25]. When sweat evaporation is insufficient and other physiological adjustments are unable to prevent the core body temperature from rising [20,26-28], heat and heavy workloads cause dehydration, heat-related illnesses, and decreased productivity. This is true for outdoor industries in underdeveloped nations with little technology and a heavy reliance on human labour [17,20,29-30]. IWW experience heat strain when exposed to high temperatures and a heavy effort, especially when wearing semi-permeable or impermeable Personal Protective Equipment (PPE) [31-32]. The results of our experiment confirmed the findings of prior research that connected occupational heat stress to dehydration and high USG [3,31,33-34].

The heat-exposed OWW had a 1.3-fold increased risk of dehydration, which attains statistical significance in multivariate models after controlling for possible confounders (Table 4). The prevalence of dehydration and HRIs among outdoor suggests a lack of hydration and heat stress management techniques at work [28,33], which is supported by the women's' self-reported HRI symptoms [35]. The hot and humid environment that occurs in southern India for 6-8 months of the year [35] contributes to the heat load, reducing worker health and productivity today [36] and in the future [10], particularly with the expected temperature increase due to climate change.

OWW may be more susceptible to the negative impacts of heat stress since they're less likely to obtain adequate heat mitigation,

Table 4: Results of logistic regression models comparing self-reported heat stress and measured Heat strain among exposed and unexposed workers in organized and unorganized workers in Southern India.

Study Variables	N (%) Present	N (%) Absent	Bivariate OR≠ (95 % CI); p-value*	Multivariate OR≠ (95 % CI); p-value*
Self-reported heat stress symptoms				
Heat stress symptoms (anyone)				
Unexposed group	278 (30.8)	44 (4.9)	1	1
Exposed group	533 (59.0)	48 (5.3)	**1.7 (1.1-2.7) 0.01**	**1.7(1.1-2.7) 0.009**
Dehydration				
Unexposed group	156 (17.3)	166 (18.4)	1	1
Exposed group	329 (36.4)	252 (27.9)	**1.1 (1.1-1.8) 0.018**	**1.3(1.1-1.8) 0.019**
Change in urine volume/color				
Unexposed group	186 (20.6)	136 (15.1)	1	1
Exposed group	351 (38.9)	230 (25.5)	1.1 (0.8-1.4) 0.437	1.1(0.8-1.4) 0.436
Urinogenital issues				
Unexposed group	212 (23.5)	110 (12.2)	1	1
Exposed group	435 (48.2)	146 (16.2)	**1.5 (1.1-2.1) 0.004**	**1.5(1.1-2.1) 0.005**
Measured heat strain symptoms				
Rise in CBT (<1 °C, >1 °C)				
Unexposed group	30 (3.3)	290 (32.1)	1	1
Exposed group	67 (7.4)	495 (54.8)	1.2 (0.8-2.1) 0.245	1.2(0.8-2.1) 0.262
SwR(> 1 l/hr, < 1 l/hr)				
Unexposed group	24 (2.7)	296 (32.8)	1	1
Exposed group	104 (11.5)	458 (50.7)	**2.8 (1.7-4.4) 0.0001**	**2.7(1.7-4.3) 0.0001**
USG (< 1.020, > 1.020)				
Unexposed group	72 (8.0)	122 (13.5)	1	1
Exposed group	117 (13.0)	297 (32.9)	0.6 (0.4-0.9) 0.028	0.6(0.4-0.9) 0.043
Measured Heat strain Indicators (anyone)				
Unexposed group	103 (11.4)	217 (24.0)	1	1
Exposed group	237 (26.2)	325 (36.0)	**1.5(1.1-2.0) 0.003**	**1.5(1.1-2.1) 0.003**

*Note: Multivariate analysis corrects for age, education, years of exposure; *p-Value<0.05 is significant; ≠More than 1 denotes the presence of risk*

protection. Even though both groups were exposed to significant levels of heat in the present investigation, outdoor work in a hot work environments offers a high risk of heat stress owing to vigorous labor and sun radiation [33,37]. The undercounted number of HRIs and deaths [38-39] among exposed workers in both sectors may obscure the enormous potential danger of heat-related injury and accident. As a result, measures for heat protection and mitigation must take into account in both the indoor and outdoor sectors [3,12,40].

Heat stress has a significant effect on workplace health and productivity in a fast developing economy such as India [41]. Elevated CBT and SwR have negative consequences on the work, including physical fatigue, lethargy, reduced judgment and attentiveness, which may contribute to poor performance outcomes [33]. While control mechanisms such as cooling interventions, employment rotation, and better welfare facilities are in place in indoor industries with correspondingly protective legislation, women in outdoor sectors lack these safeguards [17,42], putting them at a greater risk. To protect them, outdoor industries need better labour rules and training on the dangers of occupational heat stress, particularly in spotting early signs of heat stress before it worsens [43]. This does not diminish the need for preventative measures and adaptation strategies for women who work indoors in high-heat environments.

In addition, OWW are more vulnerable than IWW, particularly those with prolonged heat exposure and unprotective working conditions. Due to a lack of proper infrastructure, workers' risky behaviour (especially when working for piece-rate pay) [44], lack of workplace regulations such as work duration, improper work/rest schedule practises, and inadequate welfare facilities, the health risks associated with heat exposure are greater for these workers. Management, organisations, and the government owe these women additional safety by providing training, protective workplace laws, and cooling treatments as part of long-term Occupational Safety and Health practises. Without aggressive intervention, outdoor women in unorganised sectors would be pushed farther into health and economic hardship [20,44-46] as climate change proceeds.

Conclusion

Our findings demonstrate a significant association between heat exposure, workload, HRIs, and HSIs, as well as subsequent and detrimental health effects among heat-exposed women. In conclusion, OWW, especially those with lengthy durations of chronic heat exposure, are more susceptible to heat-related illnesses than IWW, particularly while working in protected environments. Lack of workplace controls, such as automation, and low levels of literacy make outdoor women more susceptible to the adverse effects of heat stress. Climate predictions necessitate prompt intervention and thorough adaptation measures, while also supporting and ensuring regional and national mitigation actions.

Acknowledgment

The authors highly acknowledge and thank the Department of Environmental Health Engineering, Sri Ramachandra Institute of Higher Education and Research, Chennai for providing us this platform for carrying out the work. The authors are also grateful to the management of the various workplaces and study participants for their kind cooperation and support to conduct the study.

Funding

Funding from the Department of Science and Technology is highly acknowledged.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

Ethical approval: IEC-NI/21/FEB/77/37.

Author Contributions

Rekha S and Dr. Vidhya Venugopal conceived of scope and contributed to writing and editing, PK Latha, supported in data collection, consolidation, analysis, writing, and editing.

References

1. Lundgren K, Kuklane K, Gao C, Holmer I. Effects of heat stress on working populations when facing climate change. Industrial health. 2013; 51: 3-15.
2. Watts N, Amann M, Arnell N, Ayeb-Karlsson S, Beagley J, Belesova K, et al. The 2020 report of the Lancet Countdown on health and climate change: responding to converging crises. The Lancet. 2021; 397: 129-70.
3. Venugopal V, Rekha S, Manikandan K, Latha PK, Vennila V, Ganesan N, et al. Heat stress and inadequate sanitary facilities at workplaces–an occupational health concern for women? Global health action. 2016; 9: 31945.
4. Sorensen C, Saunik S, Sehgal M, Tewary A, Govindan M, Lemery J, et al. Climate change and women's health: Impacts and opportunities in India. GeoHealth. 2018; 2: 283-97.
5. Kjellstrom T. Climate change, direct heat exposure, health and well-being in low and middle-income countries. Global health action. 2009; 2: 1958.
6. Dunne JP, Stouffer RJ, John JG. Reductions in labour capacity from heat stress under climate warming. Nature Climate Change. 2013; 3: 563-66.
7. Holmer I. Protective clothing in hot environments. Industrial health. 2006; 44: 404-13.
8. Parsons K. Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance: CRC press, 2014.
9. Diverde H. The sanitary situation and its health effects on women exposed to occupational heat in Chennai, India, 2013.
10. IPCC. Technical Summary: Global warming of 1.5° C. An IPCC Special Report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. In: Allen M, Antwi-Agyei P, Aragon-Durand F, Babiker M, Bertoldi P, Bind M, et al., editors: Intergovernmental Panel on Climate Change, 2019.
11. Maughan R. Impact of mild dehydration on wellness and on exercise performance. European journal of clinical nutrition. 2003; 57: S19-S23.
12. Venugopal V, Chinnadurai JS, Lucas RA, Kjellstrom T. Occupational heat stress profiles in selected workplaces in India. International journal of environmental research and public health. 2016; 13: 89.
13. Yaglou C, Minaed D. Control of heat casualties at military training centers. Arch. Indust. Health. 1957; 16: 302-16.
14. Parsons K. Human heat stress: CRC Press, 2019.
15. ACGIH. TLVs and BEIs: Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices: ACGIH. 2018.
16. Venugopal V, Latha P, Shanmugam R, Krishnamoorthy M, Johnson P. Occupational heat stress induced health impacts: A cross-sectional study from South Indian working population. Advances in Climate Change Research. 2020; 11: 31-39.
17. Venugopal V, Latha P, Shanmugam R, Krishnamoorthy M, Omprashanth R, Lennqvist R, et al. Epidemiological evidence from south Indian working population—the heat exposures and health linkage. Journal of Exposure Science & Environmental Epidemiology. 2021; 31: 177-86.
18. Palmer MS, Spriet LL. Sweat rate, salt loss, and fluid intake during an intense on-ice practice in elite Canadian male junior hockey players. Applied Physiology, Nutrition, and Metabolism. 2008; 33: 263-71.
19. Stedman TL, Dirckx JH. Stedman's concise medical dictionary for the health professions: Illustrated: Lippincott Williams & Wilkins, 2001.
20. Hansson E, Glaser J, Weiss I, Ekström U, Apelqvist J, Hogstedt C, et al. Workload and cross-harvest kidney injury in a Nicaraguan sugarcane worker cohort. Occupational and environmental medicine. 2019; 76: 818-26.
21. Wesseling C, Aragón A, González M, Weiss I, Glaser J, Rivard CJ, et al. Heat stress, hydration and uric acid: a cross-sectional study in workers of three occupations in a hotspot of Mesoamerican nephropathy in Nicaragua. BMJ open. 2016; 6: e011034.
22. Wendt D, Van Loon LJ, Lichtenbelt WDM. Thermoregulation during exercise in the heat. Sports medicine. 2007; 37: 669-82.
23. Popowski LA, Oppliger RA, Lambert P, Johnson RF, Gisolf C. Blood and urinary measures of hydration status during progressive acute dehydration. Medicine and science in sports and exercise. 2001; 33: 747-53.
24. Oppliger RA, Magnes SA, Popowski LA, Gisolfi CV. Accuracy of urine specific gravity and osmolality as indicators of hydration status. International Journal of Sport Nutrition and Exercise Metabolism. 2005; 15: 236-51.
25. Tawatsupa B, Lim LL, Kjellstrom T, Seubsman S-a, Sleigh A, Team TCS. Association between occupational heat stress and kidney disease among 37 816 workers in the Thai Cohort Study (TCS). Journal of epidemiology. 2012; 22: 251-60.
26. Akerman AP, Tipton M, Minson CT, Cotter JD. Heat stress and dehydration in adapting for performance: Good, bad, both, or neither? Temperature. 2016; 3: 412-36.
27. Kjellstrom T, Lemke B, Otto M, Hyatt O, Dear K. Occupational heat stress contribution to WHO project on "global assessment of the health impacts of climate change," which started in 2009. Mapua: Health and Environment International Trust. 2014.
28. Lucas RA, Epstein Y, Kjellstrom T. Excessive occupational heat exposure:

a significant ergonomic challenge and health risk for current and future workers. Extreme physiology & medicine. 2014; 3: 1-8.

29. Wesseling C, Crowe J, Hogstedt C, Jakobsson K, Lucas R, Wegman DH. Resolving the enigma of the mesoamerican nephropathy: a research workshop summary. American Journal of Kidney Diseases. 2014; 63: 396-404.

30. Coco A, Jacklitsch B, Williams J, Kim J-H, Musolin K, Turner N. Criteria for a recommended standard: occupational exposure to heat and hot environments. control Ccfd, editor 2016.

31. Krishnamurthy M, Ramalingam P, Perumal K, Kamalakannan LP, Chinnadurai J, Shanmugam R, et al. Occupational heat stress impacts on health and productivity in a steel industry in Southern India. Safety and health at work. 2017; 8: 99-104.

32. Wesdock JC, Donoghue AM. Life-threatening heat-related illness with severe hyponatremia in an aluminum smelter worker. American journal of industrial medicine. 2019; 62: 1068-75.

33. Flouris AD, Dinas PC, Ioannou LG, Nybo L, Havenith G, Kenny GP, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. The Lancet Planetary Health. 2018; 2: e521-e31.

34. Crowe J, Nilsson M, Kjellstrom T, Wesseling C. Heat-related symptoms in sugarcane harvesters. American journal of industrial medicine. 2015; 58: 541-48.

35. Venugopal V, Latha P, Shanmugam R, Krishnamoorthy M, Srinivasan K, Perumal K, et al. Risk of kidney stone among workers exposed to high occupational heat stress-A case study from southern Indian steel industry. Science of The Total Environment. 2020; 722: 137619.

36. Sheridan SC, Allen MJ. Temporal trends in human vulnerability to excessive heat. Environmental research letters. 2018; 13: 043001.

37. Nag P, Nag A, Sekhar P, Pandit S. Vulnerability to heat stress: Scenario in western India. National Institute of Occupational Health, Ahmedabad 2009.

38. Xiang J, Bi P, Pisaniello D, Hansen A. Health impacts of workplace heat exposure: an epidemiological review. Industrial health. 2014; 52: 91-101.

39. Sheridan SC, Kalkstein AJ, Kalkstein LS. Trends in heat-related mortality in the United States, 1975–2004. Natural Hazards. 2009; 50: 145-60.

40. Gao C, Kuklane K, Östergren P-O, Kjellstrom T. Occupational heat stress assessment and protective strategies in the context of climate change. International journal of biometeorology. 2018; 62: 359-71.

41. Sanders ML. Being nonprofit-like in a market economy: Understanding the mission-market tension in nonprofit organizing. Nonprofit and Voluntary Sector Quarterly. 2015; 44: 205-22.

42. Venugopal V, Chinnadurai J, Lucas R, Vishwanathan V, Rajiva A, Kjellstrom T. The Social Implications of Occupational Heat Stress on Migrant Workers Engaged in Public Construction: A Case Study from Southern India. International Journal of the Constructed Environment. 2016; 7: 25-36.

43. Groot E, Abelsohn A, Moore K. Practical strategies for prevention and treatment of heat-induced illness. Canadian Family Physician. 2014; 60: 729-30.

44. Spector JT, Krenz J, Blank KN. Risk factors for heat-related illness in Washington crop workers. Journal of agromedicine. 2015; 20: 349-59.

45. Hansson E, Glaser J, Jakobsson K, Weiss I, Wesseling C, Lucas RA, et al. Pathophysiological mechanisms by which heat stress potentially induces kidney inflammation and chronic kidney disease in sugarcane workers. Nutrients. 2020; 12: 1639.

46. Bodin T, García-Trabanino R, Weiss I, Jarquín E, Glaser J, Jakobsson K, et al. Intervention to reduce heat stress and improve efficiency among sugarcane workers in El Salvador: phase 1. Occupational and environmental medicine. 2016; 73: 409-16.