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Personal Protective Equipment (PPE) And Thermal Comfort - Productivity Impacts among Healthcare Workers in Southern IndiaduringCOVID-19 pandemic

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Abstract

Background: In non-air-conditioned work environments due to COVID restrictions, personal protective equipment (PPE) causes significant heat stress for health care workers (HCWs), especially when the ambient temperatures are high. Heat stress is an established risk for thermal discomfort, Heat-Related Illnesses (HRIs), and Productivity Losses (PL). However, data on the influence of Personal Protective Equipment (PPE) on health and productivity among frontline healthcare workers is limited. To close this gap, the current study will investigate healthcare workers' perceptions of the effects of PPE on their thermal comfort and PL

Study Design: A Cross-sectional study.

Methods: During April-May 2020, a cross-sectional survey with 115 HCWs from health care centres across Southern India was undertaken. Using a portable data logger, we analyzed the Wet Bulb Globe Temperature (WBGT) index. We used a validated High Occupational Temperature Health and Productivity Suppression (HOTHAPS) questionnaire to record HCWs' perceived thermal comfort and a questionnaire from The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE 2004) to record the PL's perceived thermal comfort.

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Results: The average WBGT was found to be 30.0°C±1.9°C. A total of 79% (n=91) HCWs were exposed to heat above the permissible limit and the most exposed (29%, n=33) were nurses. While 96% of HCWs reported thermal discomfort, with the highest percentages among nurses, medical doctors (36%) reported increased PL as a result of PPE-induced thermal discomfort. With heat exposure, there was a significant association between perceived thermal discomfort and PL (COR: 10.87; CI: 1.082-109.32; p-value=0.013). HCWs who used N95 mask and gown as PPE had a 4.0- and 5.6-times increased risk of heat discomfort and PL, respectively

Conclusion: To avoid health and productivity risks among HCWs wearing PPEs, sustainable, cost-effective, and practicable self-cooling solutions are required, particularly as climate change progresses.

Keywords: Thermal comfort, Climate change, Productivity loss, Health care workers

Highlights

- Personal protective equipment (PPE) causes significant heat stress for health care workers (HCWs).
- PPE-induced thermal discomfort was prevalent among nurses.
- There is a significant association between perceived thermal discomfort and productivity loss (PL).
- Protective labour policies and cooling intervention are needed in the changing climate.

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Background

Personal protection equipment (PPE) is an important part of safely treating SARS-CoV-2 patients among healthcare workers (HCWs). The World Health Organization declared a pandemic owing to the outbreak of the coronavirus disease on March 11, 2020. (COVID-19). From the moment the COVID-19 pandemic was declared until the end of August 2020, the number of cases in India climbed from 60 to 3,542,733. Gloves, medical masks, goggles or face shield, and gowns are among the PPE used by HCWs to guard against COVID-19, as are respirators (i.e., N95 or FFP2 standard or similar) and aprons for specialised procedures.[1] PPEs can protect the HCWs from getting sick, but the impermeable and encapsulating nature of some PPEs makes it hard for people to get rid of heat. This, combined with the extra weight and limited mobility of some PPE, can make heat stress even worse and, as a result, increase thermal strain in HCWs.[2]

Thermal comfort is described as "the state of mind that conveys happiness with the thermal environment" by the international standard organisation (ISO) 7730 (1994). Thermal comfort is defined by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 55 as "that state of mind that conveys happiness with the thermal environment." It is concerned with the inhabitants' ability to adjust to thermal equilibrium, physiological, psychological, and behavioural changes in a certain habitat for a specific climate.[3] According to studies, rising temperatures are projected to cause thermal discomfort in about 60% of India's working population, including healthcare personnel in their workplaces,[4] and the need for workplace cooling measures is growing. Thermal stress can be exacerbated by hot and humid weather, proximity to other sources of heat, and cooling constraints or absence thereof. The effect of thermal stress can be a problem for HCWs during the pandemic, with temperatures in India reaching 42.2 °C in June 2020.[5]

This increase in temperature is likely to increase thermal stress at work and reduce worker productivity.[6] In this study, productivity loss (PL) is defined as a decrease in work performance or productivity. Heat exposure has been shown to reduce physical capability and productive working time in several studies.[6] According to ISO 7243, human work capability begins to decline at a Wet Bulb Globe Temperature (WBGT) of 25°C, and it becomes extremely difficult to perform any physical labour once the WBGT value exceeds 40 °CK.[7] Heat exposures beyond human endurance cause workers to reduce physical activity, a natural defence mechanism to avoid heat gain,[8] which

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has direct consequences for workers' ability and performance,[7] and thus has direct consequences for workplace productivity and economic loss.[9]

While there has been research on HCWs' knowledge, attitudes, and practises (KAP), [10] none has measured HCWs' KAP addressing PPE use and heat stress management during this pandemic. As a result, the primary goal of this study was to determine how HCWs in India felt about PPE use and thermal stress while performing treatment and care activities (TCAs) during the global COVID-19 pandemic. The secondary goal was to investigate how workers felt about PL as a result of increased thermal stress from PPE use and increased ambient temperature from poor ventilation. With the epidemic still raging over the world, we hope that the findings of this study will help to better understand the thermal strain encountered by HCWs wearing PPE and to identify appropriate strategies to reduce thermal stress among HCWs.

Methods

Study design

This study adopted a cross-sectional observational design. The data collection was conducted in May and June 2020 among healthcare workers (HCWs) of health care centres spread across Ariyalur, Chennai, Mumbai, Nellore, Pondicherry, Vishakhapatnam, Salem, Sir City, Srikakullam, Thiruchillapalli, Thiruvarur and Vellore, cities of Southern India. The Institutional Ethics Committee (IEC) granted us ethical approval (Reference No.: IEC-NI/17/APR/59/54).The workers were recruited for the study based on the inclusion criteria of age (18–60 years) and at least one year of exposure at the same workplace.We excluded workers with pre-existing medical conditions like diabetes, hypertension, cardiac illnesses, thyroid diseases, or any co-morbid conditions. Based on their willingness to take part in the study, we recruited a total of 115 workers for the study. We explained the risks and benefits of participating in the study and obtained an online-based signed informed consent.

Qualitative data

The data on workers' subjective thermal comfort was collected using a questionnaire derived from,[3] which has three components. The first phase gathered demographic and job information from

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HCWs. The second segment included questions about the use of personal protective equipment (PPE) at work and other heat-related issues. The understanding of HCWs about thermal stress was studied in the third portion. In the third portion, a 5-point Likert Scale was employed, with 1 indicating strong disagreement and 5 indicating strong agreement; other details, such as nature of work, were based on ACGIH.[11] We used a validated High Occupational Temperature Health and Productivity Suppression (HOTHAPS) questionnaire to record the workers' perceptions of PL.[12] In English, questionnaires were standardised. Wherever possible, hard-copy questionnaires were given out during breaks. Electronic copies were offered at less-accessible facilities, and informed agreement was sought before delivering the questionnaire.

Quantitative data

The environmental parameters such as the ambient temperature, Relative Humidity (RH) and, dew point were recorded using data loggers (EL-USB-2-LCD+, Lascar Electronics, U.K.). Loggers were placed in selected work areas, about 1.5 m from the ground and walls, and 1.5 m from direct heat sources. Wet-bulb globe temperature (WBGT) an globally accepted heat index,[13] was estimated using the online heat stress index calculator available in the Climate CHIP tool.[14] Based on the WBGT values, we categorized the HCWs heat exposures into unexposed (<27.5°C) and exposed (≥27.5°C). Then we used the WBGT permissible heat exposure TLV to evaluate the risk of heat stress and the corresponding WBGT under which continuous work during an hour could be safely undertaken.[15]

Data analysis

Means with standard deviations (SD) and medians with interquartile ranges (IQR) were used to describe normally and non-normally distributed variables, respectively.We did all data analysis using SPSS version 15.0. We used the bivariate analysis to identify associations between heat and productivity for workers using the chi-square test. We use the Crude Odds Ratio (COR) to measure the association with the cut-off of 0.05 to interpret the significance of the p-values.

Results

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Demographic characteristics of participants

A total of 115 HCWs were surveyed in the present study, of which 57% were males and 43% were females. Table 1 shows the descriptive characteristics of the study population. The study population's mean age was 32.9 9.5 years, and the maximum number of workers was between 20 and 30 years old. The majority of respondents either held a medical (45 physicians; 39% in total) or nursing role (33 nurses; 29% in total). Respondents were distributed across a range of work locations, with a majority in the Fever Facility (Table 1). The study population was engaged in jobs with 38 (33%) heavy work, and the rest had moderate workloads (n =77, 67%). Their anthropometric data shows that the majority of them were reported to be over weight (51%), but none reported a fasting habit.

Table 1. Demographic Characteristics and work information of the study Participants from various health care canters (n=115**)**

S. No	Variables	Factors	n	Percentage (%)	Mean (SD –IQR)
1.	Age (Years)	20-30	55	48	32.9 (9.5-12)
		31-40	39	34	
		41-50	11	10	
		>50	10	9	
2.	Gender	Male	66	57	NA
		Female	49	43	
3.	BMI (kg/m^2)	<19	6	5	24.6 (3.5-4.1)
		19-24	42	37	
		24.01 - 30	59	51	
		>31 Obesity	8	7	
4.	Role of Job	Medical	45	39	NA
		Nursing	33	29	
		Operations	4	3	
		Sanitary		4	
		Worker	5		

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		Others	28	24	
5.	Location of job	Tentage	2	2	NA
		Fever Facility	24	21	
		Clean Area	25	22	
		others	64	56	
6.	Work Category	Heavy	38	33	NA
		Moderate	77	67	

Note: Data expressed in n (%) for categorical variables, mean (standard deviation [SD]) and median (inter-quartile range [IQR]) for continuous variables, NA is Not Applicable

Workplace thermal discomfort profiles

In the present study we define the thermal discomfort with reference to the heat profile in the work place which has been quantified by the heat index WBGT. The averages WBGT in the HC centres were measured to be 30.0°C±1.9°C(Figure 1). Exposure to heat above the safe limit (ACGIH, 2018) among the 115 workers was 79% (n=91), with a maximum of 24% (n=28) in the Chennai and Nellore HC centres. Based on the WBGT (attributed) profiles, the HCWs engaged with heavy workload had a 4.4 times higher risk of thermal discomfort than workers doing moderate work and it had a high statistical significant (chi-sq=5.78,P>0.016) (Table 3).

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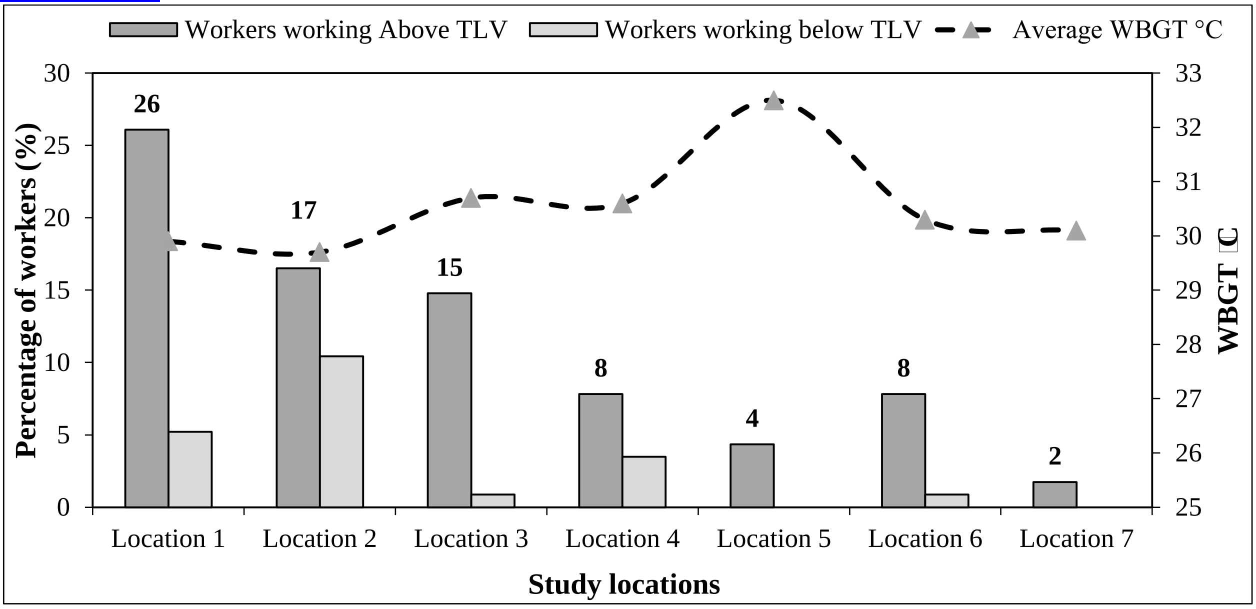

Figure 1. Wet Bulb Globe Temperature (WBGT) profiles and percentage of workers working above safe limit across various healthcare centresin 2020 in Southern India
(Note: Location 1:Nellore,Sricity,Manama, Location 2:Chennai,Sriperumbudur, Location 3: Thiruvarur, Ariyalur,Thiruchirappalli,Salem, Location 4: Srikakulam,Vizhag, Location 5: Pondicherry, Location 6: Vellore, Location 7: Mumbai)

PPE Usage Practices and workers perception on thermal comfort and productivity loss

Among the HCWs, irrespective of the job maximum, the majority of workers were wearing gloves (90%), followed by surgical (89%) and N95 masks (85%). And when we observed, based on the job profile, the maximum number of PPEs were worn by the nurses, followed by the physicians. And it was also observed that 31 (27%) of the HCWs wore all 6 PPEs during work and only 67 (58%) of the workers removed them during their break time. Based on this PPE usage, their perception of thermal discomfort was perceived by 111 (96%) of the workers, and among them, 94 (85%) wore more than 3 PPEs. However, no significant association was observed with the exposure. The risk was 14.7 times higher among the exposed workers (OR = 14.7, CI = 0.7929 to 280.24, p 0.07) (Table 3). The maximum number of HCWs' perceptions of thermal discomfort was experienced by workers who used the PPEs for more than 6 hours a day, 32 (28%) (Table 2). Irrespective of the

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number and the type of PPEs worn, a significant association was observed between the thermal response and the heat exposure, and the risk of thermal stress was 10.87 high among the exposed workers (OR-10.8, CI = 1.082–109.32, P 0.01). In addition to the heat exposure, the work load of the workers also significantly contributes to the thermal stress (OR = 4.4, CI = 1.225–15.75, p 0.016) (Table 3).

When relating the PPE usage and the PL, a reduction in work output was perceived by 37 (32%), and the maximum number of PL was perceived by the doctors and physicians who wore both the N95 mask and gown, 16 (14%) (Table 2). A high statistical significance was observed with the exposure (OR = 0.40, CI = 0.166-0.982, p 0.04) (Table 3). Also, the risk of PL was 2.045 high among the heat exposed workers who wore gloves, googles, and face shields (OR = 2.045, CI-0.30-0.05, P 0.53). Surprisingly, 36 (97%) of the workers who perceived thermal stress also perceived PL, which was a great observation of the present study. PL was also significantly associated with the work load of the workers, though a remarkable risk was not observed (p 0.002) (Table 3).

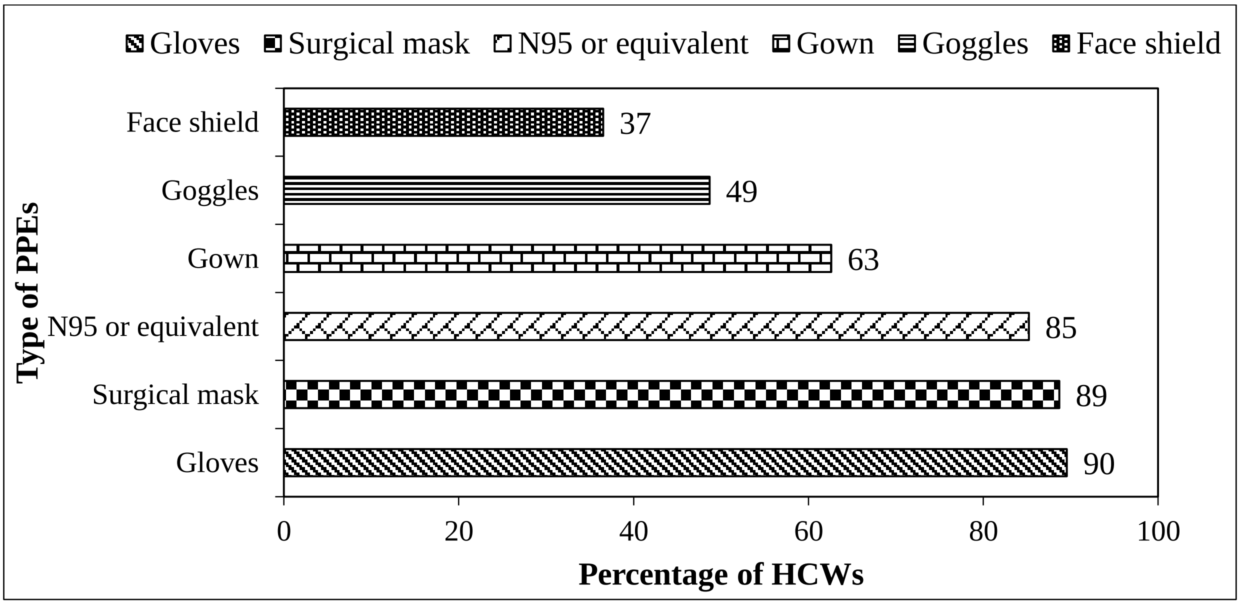

Figure 2. Type of PPE worn by HCW respondents during their shifts

Table 2. Perceived Impact of PPE usage and related thermal stress and productivity loss

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No	Study variables	Thermal stress n (%)	Comparison between working above heat safe limit and below safe limit (OR, CI, p-value)	Productivity loss n (%)	Comparison between working above heat safe limit and below safe limit (OR, CI, p-value)
1.	Gloves, googles, face shield	37 (33)	NA	10 (7)	2.045,0.30-0.05, 0.532
2.	N95 mask and gown	67 (58)	NA	16 (14)	1.8,0.20-16.8,0.56
3.	More than 3 PPEs	31 (27)	NA	7 (6)	1.91, 0.21-17.2,0.55
4.	More than 6 Hours/shift in PPE	32 (28)	0.96,0.92-1.01,0.44	7 (6)	0.50, 0.17-1.470.203
5.	Don't remove PPE on breaks	21 (18)	0.97, 0.92-1.02,0.65	5 (4)	1,0.17-5.7,1.0

Table 3. Association between workers heat exposure (WBGT°C) and self-reported Productivity Loss (PL) and Thermal comfort (TC)

No	Study variables	X^2	COR$^{\neq}$(95% CI);p-value*
I.	**WBGT VS parameter**		
1.	Work category	5.78	4.4 (1.215-15.75);0.016*
2.	Thermal comfort	6.12	10.87(1.082-109.32); 0.013*
3.	Productivity loss	4.12	0.40 (0.166-0.982);0.042*
4.	Number of PPEs (nos. 3)	0.432	14.7 (0.77 to 280.24);0.07
II	**Work category VS parameter**		
5.	Thermal comfort	7.02	0.905(0.820-.998); 0.007*
6.	Productivity loss	9.70	0.226(0.08-0.602);0.002*

Note: *$^{\neq}$COR Crude Odds ratio more than 1 denotes the presence of odds, *p-value<0.05 is*

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significant

Discussion

Workplace thermal discomfort profiles

During this COVID-19 pandemic, additional personal protective equipment (PPEs) is now essential for healthcare professionals to safeguard themselves from the infection. This could result in increased clothing insulation, which has a negative impact on the heat sense of healthcare professionals.[16]In the present study, the number of PPEs worn by the worker was high enough that the thermal discomfort was high, the same finding from other similar studies.[17] Workplace heat profiles prevailing in the HC canters showed high occupational thermal stress exposures (Figure 1) that exceeded the recommended TLVs, a scenario similar to other studies conducted in India and internationally.[18-19] Apart from the environmental heat imposed on the workers that subjects them to thermal discomfort, the high metabolic workload on workers also adds to the additional burden of heat stress on the workers' comfort, as proven by experimental studies.[20] Similar to the finding in the present study, workers engaged in heavy physical work throughout their shifts were at a high risk of thermal discomfort and thermal stress, which have been commonly reported in many studies .[21]Thermal discomfortmay therefore negatively impact their roles as HCWs, which require considerable amounts of attentionand commitment.

Worker's perception of PPE usage on productivity loss

For most regions in Tamilnadu, South India, rising temperatures and increased environmental and process heat in workplaces would have major productivity and economic impacts, especially during the hot season (May).[22] Then the temperature rises above 25 degrees Celsius, studies reveal a 2% decrease in job performance for every degree Celsius.[23] In the present study, just 37% of HCWs said that thermal stress had a negative impact on their productivity, judgement, or emotions. This is supported by other research.[7 24] Although no statistical significance was found due to the small sample size and few perception biases because the study was based solely on self-reported questionnaires, a large number of HCWs (97 percent) who reported a productivity loss also reported thermal discomfort, which is a positive outcome of the current study. Several studies have demonstrated that wearing additional PPEs can increase the risk of PL,[17 25] which was reported by

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23% of the HCWs in our study. The findings of this study show that workers' productivity declines when they are thermally exposed and have a severe workload, which could further damage them monetarily as well as physically and mentally.[26]

Conclusion

The study's main goal was to see how indoor workplace heat, PPE use, and HCW workload affected their thermal stress and PL. We found that during the COVID pandemic in India, HCWs experienced thermal discomfort and PL, in addition to working in poorly ventilated facilities, a problem that is predicted to worsen with the projected rising temperature scenario due to climate change. Wearing PPE while working in hot and humid situations might cause thermal stress and PL in HCWs, especially doctors and nurses, as well as help to manage increased energy needs and avoid thermal stress. Personal cooling intervention, as well as passive cooling technologies, could be a realistic and long-term option to avoid occupational health and high-energy hazards in the face of a changing climate scenario. We believe that the findings of this study will aid in the better understanding of the levels of thermal stress experienced by HCWs and the identification of appropriate strategies to protect their health and safety while wearing PPEs.

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Author Contribution

Dr. VV conceived in writing, interpreting and finalizing the manuscript&Dr.PK contributed in data collection, data analysis and data interpretation

Data availability

Not applicable

Competing of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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