

# Heat stress and PPE during COVID-19: impact on healthcare workers' performance, safety and well-being in NHS settings

Davey, S. L., Lee, B. J., Robbins, T., Randeve, H. & Thake, C. D.

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**Heat Stress and PPE during COVID-19: Impact on health care workers' performance, safety and well-being in NHS settings.**

Sarah L Davey<sup>1\*</sup>, Ben J Lee<sup>1</sup>, Timothy Robbins<sup>2,3</sup>., Harpal Randeva<sup>2</sup>, C. Doug Thake<sup>1</sup>.

<sup>1</sup> Occupational and Environmental Physiology Group, Centre for Sport, Exercise and Life Sciences, (CSELS), Faculty of Health and Life Sciences, Coventry University, Coventry, United Kingdom.

<sup>2</sup> University Hospitals Coventry & Warwickshire NHS Trust, Coventry, United Kingdom.

<sup>3</sup> Institute of Digital Healthcare, WMG, University of Warwick, Coventry, United Kingdom

**Corresponding author:**

Sarah Davey

**E-mail:** ad4782@coventry.ac.uk

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## Abbreviations

<b>HCWs</b>	Health Care Workers
<b>PPE</b>	Personal Protective Equipment
<b>PFM</b>	Protective face mask
<b>NHS</b>	National Health Service

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## Summary

Personal protective equipment (PPE) can potentiate heat stress which may negatively impact wearer's performance, safety and well-being. In view of this, a survey was distributed to healthcare workers (HCWs) required to wear PPE during the COVID-19 pandemic in the UK to evaluate perceived levels of heat stress and its consequences. Respondents reported experiencing several heat-related illness symptoms and that heat stress impaired both cognitive and physical performance. The majority also reported PPE made their job more difficult. These, and additional responses, suggest that modification to current working practices is urgently required to improve HCWs' resilience to wearing PPE during pandemics.

## 1. Introduction

To reduce the risk of health care workers (HCWs) within the NHS workforce from contracting or transmitting COVID-19, they are required to wear personal protective equipment (PPE). The impermeable, encapsulating nature of some PPE impedes heat loss, which, when combined with the extra weight of PPE and restricted mobility, can increase the level of heat stress, and, consequently, thermal strain (i.e. raised skin and core temperatures) in HCWs<sup>1</sup>.

Heat stress increases the risk of heat-related disorders and is often associated with impaired cognition, particularly in complex mental tasks<sup>2</sup>. Combining these factors with reduced dexterity and impaired visibility through wearing PPE<sup>3,4</sup>, jeopardises the safety, performance and well-being of HCWs. In addition, the PPE related discomfort experienced by HCWs has caused concern around adherence to both wearing PPE and the appropriate doffing procedures as it endangers infection control<sup>5</sup>. Even though these issues were highlighted as an area of concern during the Ebola virus disease outbreak<sup>4</sup>, the same issues are clearly evident during the current COVID-19 pandemic. This study aimed to evaluate perceived levels of heat stress and its consequences in HCWs required to wear PPE during the COVID-19 pandemic in NHS health care settings with the objective to inform future interventions designed to mitigate the level of heat stress experienced.

## 2. Method

An online anonymous questionnaire-based survey was distributed within the University Hospital Coventry and Warwickshire NHS trust and other NHS settings (via social media: LinkedIn, Twitter) between May and August, 2020. Both Type 1 (i.e. filtering face piece class 3 (FFP3) respirator, disposable fluid repellent coveralls or long-sleeved gowns, full face shield or visor, and disposable gloves) and Type 2 (i.e. fluid-resistant (Type IIR) surgical masks (FRSM) or surgical mask with no integrated visor, full face shield/visor/polycarbonate safety spectacles or equivalent, disposable plastic aprons and gloves) PPE ensembles were assessed.

Perceptions of the level of heat stress experienced were evaluated by assessing, retrospectively, temperature sensation and thermal comfort when PPE was worn and comparing the change in sweating when PPE was worn to when PPE was not worn. The level and consequence of heat stress experienced by HCWs when wearing PPE was assessed by: (1) the number and type of heat-related illness symptoms experienced; (2) the number and type of cognitive tasks that were perceived to be adversely affected; (3) whether, and to what degree, physical performance at work was impaired; (4) whether PPE made their job easier or more difficult; and (5) whether, and how often, PPE was removed within a shift due to feelings of discomfort or overheating. All perceptions were assessed by Likert scales. The questionnaire also contained a free-text option where the respondent could provide

additional information of their experiences of wearing PPE. The questionnaire is available as online supporting information, Supplementary S1. Ethical approval was provided by Coventry University Ethics Committee. Data values are presented as median  $\pm$  IQR, range or percentages.

### 3. Results

The survey received 230 responses. As 6 of the respondents reported only wearing a protective face mask (PFM), 224 responses were included in the categorical data analysis (see Table I for demographic information).

*Insert Table I here*

The type of PPE ensemble reported on and how long the ensemble was worn in a shift is provided in Table I. Whilst wearing PPE, 72.3% respondents perceived they felt 'hot', with 89.7% feeling 'very uncomfortable' or 'uncomfortable' and 98.7% reported experiencing an increase in sweating. A median of 3 (IQR: 2,5; range 0-9) heat-related illness symptoms were reported, with headache being the most reported symptom, followed by fatigue (Table I). In a shift, 76.8% of respondents reported that they have removed the PPE in order to relieve discomfort or overheating. Of these respondents, 32.6% reported they removed the ensemble on five or more occasions in a shift.

Of the respondents, 76.2% reported PPE impaired their physical performance at work. A median of 1 (IQR: 0-3, range, 0-8) of the listed cognitive tasks were perceived as being affected. Attentional focus was the most frequently affected followed by solving complex problems (Table I). On the whole, 91.5% of respondents reported PPE made their job more difficult.

The additional comments highlighted issues related to individual items of PPE (i.e. the PFM and the visor negatively impacting breathing, visibility, and communication with patients and colleagues especially from vulnerable groups such as the elderly) and how heat stress was exacerbated by the level of PPE worn and by higher ambient temperatures of their working environment (such as the heatwaves experienced in the UK during the COVID-19 pandemic). The comments also drew attention to the severity of heat-related illness symptoms being higher in certain populations vulnerable to heat stress such as menopausal women. Several themes emerged on how these issues affected respondents' working-life such as increasing the difficulty in performing certain procedures (e.g. cannulation, CPR, and conducting physiotherapy assessments), contact dermatitis in the facial region and eye irritation due to wearing either the PFM or visor for extended periods of time. Further themes related to operating procedures or policies regarding PPE use in health care settings i.e. scheduling longer breaks, wearing less thermally stressful ensembles, increasing the opportunity to hydrate and working in cooler environments (Figure 1).

### 4. Discussion

Although the majority of survey respondents provided responses based on when the less thermally challenging Type 2 PPE ensemble was worn, the results demonstrate that there is a high prevalence of heat stress amongst respondents that negatively impacted respondents' performance, health, and well-being. In addition, to relieve feelings of overheating or discomfort, ~77% respondents reported removing their PPE in a shift, potentially increasing their risk of infection if not doffed and possibly

donned again appropriately<sup>5</sup>. Unfortunately, we can't ascertain which item of PPE was removed most frequently which may influence the level of risk of infection.

Approximately 65% of respondents reported one or more cognitive tasks being impaired when wearing PPE. This impairment in cognition may not only affect performance, but also compromises the health and safety of HCWs and patients. The prevalence of occupational heat stress has been strongly associated with workplace accident rates, with the majority of accidents reported in certain workplaces found to occur in wet-bulb globe temperatures > 25 °C<sup>6</sup>.

In the present study, respondents reported PPE impaired their physical performance at work (~76%) and made their job more difficult (~92%). Previous studies have highlighted that completing medical tasks can be adversely affected when PPE is worn, with the length of time taken to complete the task more often being affected rather than the successful completion of the task<sup>7</sup>. The increase in time taken to complete a task generally occurs as individuals regulate their pace of work to a lower intensity to reduce heat production and/or due to cognition being impaired by heat stress. Regardless, if tasks take longer to complete, the productivity of HCWs will be compromised.

The PFM and visor appeared to be the most problematic items of PPE in the present study, with compromised communication being the main complaint, especially when treating patients from vulnerable populations. The issues highlighted in this study with wearing a PFM or visor over long periods of time (i.e. thermal discomfort, contact dermatitis, reduced visibility) have been previously documented and can be associated with an increased levels of heat stress and temperature and/or relative humidity of the PFMs microclimate<sup>3,4</sup>. Increased levels of thermal discomfort with the use of PFM can be explained by the facial region being recognised as being highly thermosensitive<sup>8</sup>. Therefore, modifications in the design of the PFM to improve the PFMs microclimate may assist in reducing both overall discomfort and contact dermatitis related issues.

The comments provided by the respondents highlight the impact of wearing PPE on HCWs' health and well-being. Chronic exposure to heat stress (i.e. over a working day/week) have been associated with medical conditions such as acute kidney disease, especially if chronically dehydrated<sup>6</sup>. 'Hangover-like' symptoms have also been reported to occur amongst workers who are chronically exposed to thermally stressful conditions, which have the potential to affect individuals' sleep, appetite and relationships with friends and family<sup>9</sup>. Some respondents highlighted that they "dreaded going to work" due to the requirement of wearing PPE and some were unsure if they could cope with a subsequent wave in the COVID-19 pandemic if changes aren't made to PPE usage policy.

The present study had a number of limitations. The more thermally challenging PPE ensemble (i.e. Type 1) is underrepresented in the sample population, therefore the extent of the associated heat stress experienced and its impact on HCWs may not be evident. In addition, it is not understood whether respondents adhered to certain policies designed to alleviate heat stress when wearing PPE which may have influenced individuals' responses. Males are also underrepresented in the sample population. It is acknowledged that sex-related differences in thermoregulatory responses are present when PPE is worn<sup>10</sup>, therefore, male HCWs' experiences may differ to that represented in the present study.

In conclusion, responses from the survey highlight that modifications to the current design of PPE, or policies on the use of PPE, are urgently required to reduce the level of heat stress and prevalence of other issues that jeopardise the performance, safety and well-being of HCWs with potential consequences for patients. This requirement is reinforced by some HCWs indicating limited resilience to respond to another pandemic or a second wave in the current pandemic. Modifications in the design, or use, of the PFM and visor, alongside modifying the length of time PPE is required to be worn within a shift or providing cooler working environments, could be impactful in alleviating some of the discomfort and impaired performance experienced by HCWs when PPE is worn.

## Authors' contributions

The study was designed by SD, TR, CDT and HR. Data were collected by SD and TR. Data was analysed by SD and BL. Data interpretation and manuscript preparation were undertaken by SD, BL, TR and CDT. All authors approved the final version of the paper.

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## References

1. Coca, A., Quinn, T., Kim, J., Wu, T., Powell, J., Roberge, R., Shaffer, R. (2017). Physiological Evaluation of Personal Protective Ensembles Recommended for Use in West Africa. *Disaster Medicine and Public Health Preparedness*. 11: 1-7. doi: 10.1017/dmp.2017.13.
2. Gaoua, N., Racinais, S., Grantham, J., and El Massioui, F. (2011). Alterations in cognitive performance during passive hyperthermia are task dependent. *Int. J. Hyperthermia* 27: 1–9. doi: 10.3109/02656736.2010. 516305.
3. Morabito, M., Messeri, A., Crisci, A., Pratali, L., Bonafede, M., Marincho, A. (2020) Heat warning and public and workers' health at the time of COVID-19 pandemic. *Science of the Total Environment*. 738: 140347. <https://doi.org/10.1016/j.scitotenv.2020.140347>.
4. Den Boon, S., Vallenias, C., Ferri, M., Norris, S.L. (2018) Incorporating health workers' perspectives into a WHO guideline on personal protective equipment developed during an Ebola virus disease outbreak. *F1000Res.*, 7: 45. doi:10.12688/f1000research.12922.2.
5. Honda, H., Iwata, K. (2016) Personal protective equipment and improving compliance among healthcare workers in high-risk settings. *Curr Opin Infect Dis*. 29: 400–406. <https://doi.org/10.1097/QCO.000000000000280> PMID: 27257793.
6. Flouris, A.D., Dinas, P., Ioannou, L., Nybo, L., Havenith, G., Kenny, G., Kjellstrom, T (2018) Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. *The Lancet Planetary Health*. 2 (12), e521-e531. doi: [https://doi.org/S2542-5296\(18\)30237-7](https://doi.org/S2542-5296(18)30237-7).
7. Rissanen, S., Jousela, I., Jeong, J., Rintamäki, H (2008) Heat stress and bulkiness of chemical protective clothing impair performance of medical personnel in basic lifesaving tasks. *Ergonomics*, 51 (7): 1011-1022. doi: 10.1080/00140130701813160.
8. Cotter, J.D, Taylor, N.A. (2005) The distribution of cutaneous sudomotor and alliesthesial thermosensitivity in mildly heat-stressed humans: an open-loop approach. *J Physiol*, 565: 335–45. doi: 10.1113/jphysiol.2004.081562.
9. Carter, S., Field, E., Oppermann, E., Brearley, M. (2020) The impact of perceived heat stress symptoms on work-related tasks and social factors: A cross-sectional survey of Australia's Monsoonal North. *Appl Ergon*. 82: 102918. doi:10.1016/j.apergo.2019.102918.
10. McLellan, T. M. (1998) Sex-related differences in thermoregulatory responses while wearing protective clothing. *Eur J Appl Physiol Occup Physiol*. 78(1): 28-37. doi:10.1007/s004210050383.

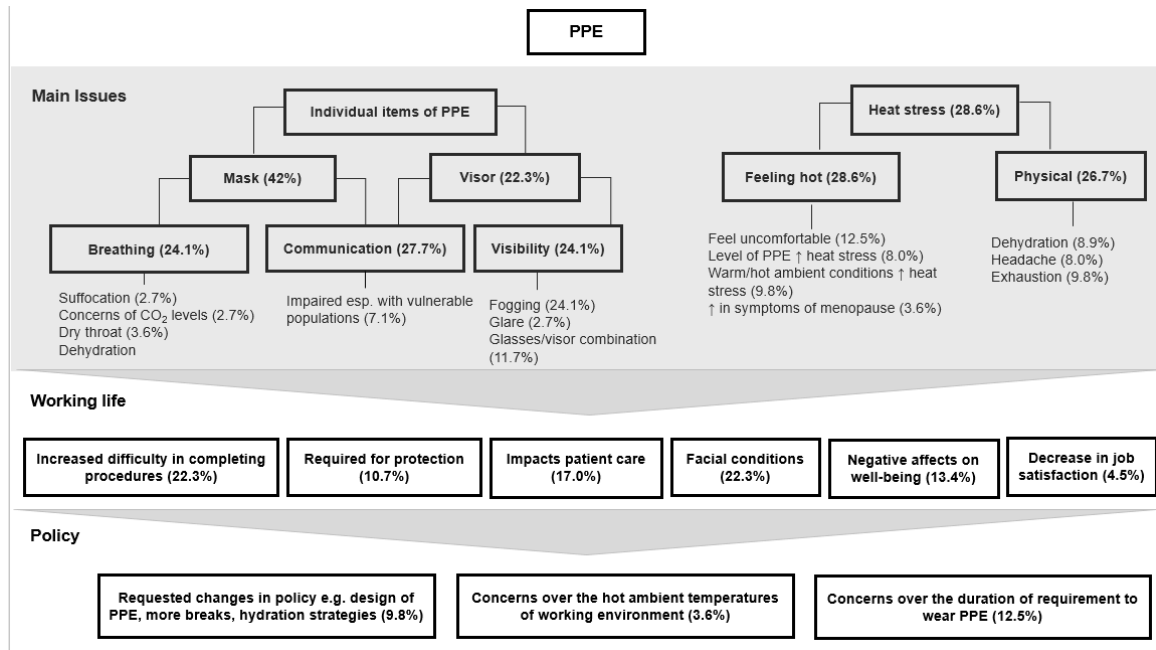
**Table I.** The demographics of respondents, the frequency of the type of personal protective equipment (PPE) ensemble reported on, the number of hours PPE is worn and the top 4 heat-related illness symptoms and cognitive tasks adversely affected when wearing PPE (n = 224).

	Frequency	Percentage (%)
<b>Sex</b>		
Females	192	85.7
Males	32	14.4
<b>Age (years)</b>		
18-29	55	24.6
30-39	65	29.0
40-49	50	22.3
50-59	43	19.2
60+	11	4.9
<b>Ethnicity</b>		
English/Welsh/Scottish/NI/British	187	83.5
Mixed ethnic background	7	3.1
Indian	7	3.1
Chinese	5	2.2
African	6	2.7
Other	12	5.4
<b>Role</b>		
Allied Health Practitioner*	48	21.4
Medic**	30	13.4
Nurse/Sister	78	34.8
Health Care Assistant	40	17.9
Admin/managerial/research	16	7.1
Other***	12	5.4
<b>Type of PPE ensemble</b>		
Type 1	63	28.1
Type 2	161	71.9
<b>Number of hours PPE is worn</b>		
0-4 hours	60	26.8
4-8 hours	76	33.9
8-12 hours	74	33.0
12+ hours	14	6.3
<b>Heat-related illness symptom</b>		
Dizziness	90	40.2
Fatigue	142	63.4
Headache	177	79.0
Profuse sweating	122	54.5
<b>Cognitive task</b>		
Making decisions	50	22.3
Solving complex problems	60	26.8
Retrieving information from short-term memory	45	20.1
Attentional focus	134	59.8



**Footnote:** \* includes physiotherapists, physiotherapist assistant, occupational therapists \*\* medic includes medical students, junior doctors, consultants, surgeons, general practitioner \*\*\* other services include radiographers, psychiatrists, and dieticians (all patient facing roles).

**Figures.**



**Figure 1** Main themes generated from the additional information provided regarding respondents experiences of wearing personal protective equipment (PPE) and how these experiences may have impacted their working-life (n = 112).