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著者	UNOKI Takeshi, TAMOTO Mitsuhiro, OUCHI Akira, SAKURAMOTO Hideaki, NAKAYAMA Asami, KATAYAMA Yukiko, MIYAZAKI Satoko, YAMADA Toru, FUJITANI Shigeki, NISHIDA Osamu, Tabah Alexis, The Japan Society of Intensive Care Medicine PPE-SAFE In Japan Project, International Exchange Committee
著者別名	卯野木 健, 田本 光拓, 大内 玲, 櫻本 秀明, 中山 麻実, 片山 雪子, 宮崎 聡子, 山田 亨, 藤谷 茂樹, 西田 修, 日本集中治療医学会 国際交流委員会, PPE-SAFE In Japan Project
journal or publication title	Acute Medicine & Surgery
volume	7
number	1
page range	e584
year	2020-01
URL	http://id.nii.ac.jp/1127/00000833/

doi: <https://doi.org/10.1002/ams2.584>



Original Article

Personal protective equipment use by health-care workers in intensive care units during the COVID-19 pandemic in Japan: comparative analysis with the PPE-SAFE survey

Takeshi Unoki,¹  Mitsuhiro Tamoto,² Akira Ouchi,³ Hideaki Sakuramoto,³ Asami Nakayama,⁴ Yukiko Katayama,⁵ Satoko Miyazaki,⁶ Toru Yamada,⁷ Shigeki Fujitani,⁸  Osamu Nishida,⁹  and Alexis Tabah,¹⁰ PPE-SAFE in Japan Project, International Exchange Committee, the Japan Society of Intensive Care Medicine

¹Department of Acute and Critical Care Nursing, School of Nursing, Sapporo City University, Sapporo, ²Department of Nursing, Kyoto University Hospital, Kyoto, Kyoto, ³Department of Adult Health Nursing, College of Nursing, Ibaraki Christian University, Hitachi, Ibaraki, ⁴Department of Nursing, Dokkyo Medical University Hospital, Mibu, Tochigi, ⁵Department of Nursing, Nihonkai General Hospital, Sakata, Yamagata, Japan, ⁶Department of Nursing, Tokai University Hospital, Isehara, Kanagawa, ⁷Department of Nursing, Toho University Omori Medical Center, Tokyo, ⁸Department of Emergency and Critical Care Medicine, St. Marianna University School of Medicine, Miyamae, Kanagawa, ⁹Department of Anesthesiology and Critical Care Medicine, Fujita Health University School of Medicine, Toyoake, Aichi, Japan, and ¹⁰Intensive Care Unit, Faculty of Medicine, Redcliffe Hospital, University of Queensland, Brisbane, Australia

Aim: We investigated personal protective equipment (PPE) use and supply shortage, training, and adverse events among health-care workers (HCWs) in the intensive care unit (ICU) during the coronavirus disease (COVID-19) pandemic in Japan and compared the results with an international survey that used the same methodology.

Methods: This Web-based survey was carried out from 14 April to 6 May, 2020, in Japan and included HCWs directly involved in ICU management of COVID-19 patients. A survey invitation was emailed using the Japanese Society of Intensive Care Medicine's mailing list.

Results: We analyzed 460 valid responses from among 976 responses. The N95/FFP2 mask (77%) was the most frequently used, although half of our respondents reported reuse of single-use N95/FFP2 masks. The median duration (1 h) of uninterrupted PPE use per shift was less than that in the international study. The most common PPE-related adverse event was experiencing intense heat (75%). Logistic regression analysis revealed that being a nurse was independently associated with experiencing intense heat.

Conclusion: Shortage of PPE and frequent mask reuse were prevalent during the COVID-19 pandemic in Japan. Intense heat is the most significant symptom, especially for nurses, even with short-duration PPE use. Strategies to protect HCWs from dehydration and intense heatstroke are needed.

Key words: Health-care worker, heat, intensive care unit, personal protective equipment, safety

INTRODUCTION

THE GLOBAL DISEASE outbreak caused coronavirus disease (COVID-19) to emerge as a major public health

issue.¹ By 14 July, 2020, 570,288 COVID-19-related deaths were reported worldwide.² Health-care workers (HCWs) are at high risk for infection, and need personal protective equipment (PPE) to reduce the risk of disease transmission.³ Worldwide, the problems associated with PPE use include PPE shortage,⁴ inappropriate use,⁵ and adverse effects (AEs).⁶

The international PPE-SAFE survey⁶ was undertaken in April 2020 among HCWs directly involved in COVID-19 patient management in the intensive care unit (ICU). The majority of respondents were from Europe (61%), followed by Asia (16%).⁶ More than half of the survey's respondents (52%) reported the unavailability of at least

Corresponding: Takeshi Unoki, RN, PhD, Department of Acute and Critical Care Nursing, School of Nursing, Sapporo City University, Kita 11 Nishi 13, Chuo-ku, Sapporo, Hokkaido 060-0011, Japan. E-mail: iwwhyh1029@gmail.com.

Received 21 Jul, 2020; accepted 25 Sep, 2020

Funding information

Sapporo City University Research Grant (Grant/Award Number: '2020').

one PPE item; 30% reported reusing at least one single-use PPE item because of supply shortage.⁶ Personal protective equipment-related AEs, such as intense heat, thirst, and pressure, were frequently reported.⁶ Because PPE scarcity and unavailability varied widely between countries, region-specific representative data from Japan and a comparison of these data with that from the PPE-SAFE survey were considered necessary to generate important insights and implications.

Here, we aimed to describe the current practices, availability, training, confidence in PPE use, and AEs of extended PPE use by HCWs in Japan. We intended to provide an international comparison between these data and those from the international PPE-SAFE survey.⁶ As PPE failure and risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection are the main concerns of HCWs, we included survey items on the confidence in the available PPE to protect against SARS-CoV-2 exposure.

MATERIALS AND METHODS

THIS SURVEY WAS carried out as part of a previously reported international study⁶ using the same questionnaires. However, the data obtained here were not included or reported previously.⁶

An anonymous Web-based survey was undertaken to collect PPE-related data from HCWs directly involved in ICU management of COVID-19 patients. The Human Research Ethics Committee of the Royal Brisbane and Women's Hospital (Brisbane, Australia) approved the study protocol.

Instruments

The development of the survey instrument was described previously.⁶ The survey had two components. One was a questionnaire of the respondent's (e.g., age, ICU experience, position) or institution's characteristics (e.g., type of ICU and hospital). The other component included questions related to the usual practices of PPE use, current PPE availability, training, and PPE-related AEs, including heat and pressure areas, which were compressed areas on the PPE wearer that were distressed or injured. Respondents were asked to report only very significant PPE AEs. The research explanation, items, and choices were translated from English to Japanese by the authors.

Survey administration

An online survey was undertaken from 14 April to 6 May, 2020 using the SurveyMonkey (SVMK, San Metro, CA, USA) platform. Participants were informed of the survey's

length and purpose and that participation was voluntary. Health-care workers of all disciplines who were directly involved in the ICU-based management of COVID-19 patients were included in the survey. A mailing list of the members of the Japanese Society of Intensive Care Medicine was used to invite participation and was further shared through various mailing lists and on social media by the members.

Statistical analysis

We compared the results from our data with that of published data from the PPE-SAFE study.⁶ We used the χ^2 -test and the Mann–Whitney *U*-test to compare two or more categorical variables and continuous variables, respectively. To assess factors associated with PPE-related AEs, we used multivariable logistic regression. For analyses with gender as a variable, we excluded two subjects who responded “undisclosed” about their gender. *P*-values < 0.05 were considered to be statistically significant.

RESULTS

WE OBTAINED 976 responses, of which 516 were excluded for the following reasons: not involved in COVID-19 management (*n* = 345), incomplete questionnaires (*n* = 170), and working outside Japan (*n* = 1). Therefore, the final analysis dataset included information from 460 responses.

Characteristics of respondents

The participant characteristics are shown in Table 1. The majority of respondents (80.0%) reported working in a “mixed” ICU that included patients with and without COVID-19. Approximately half of the respondents were nurses (51.3%), followed by physicians (38.9%).

The proportion of respondents from the mixed ICU was significantly lower than that in the PPE-SAFE survey (80.0% versus 41.5%, *P* < 0.05). Furthermore, the proportions of respondents who reported a running capacity above and well above the usual capacity were significantly lower in Japan than in the PPE-SAFE survey (12.0% versus 47.1%, *P* < 0.05).

Shortages and reuse of single-use PPE

Table 2 presents responses regarding the shortages and reuse of single-use PPE. Approximately half of the respondents (52.4%) who used N95/FFP2 masks responded that they reused single-use N95/FFP2 masks. Only 16.5% of respondents reported that they were very confident or

Table 1. Comparison of characteristics and workplace attributes among respondents working in intensive care units (ICUs) in this survey as compared to PPE-SAFE survey

Variable	This survey	PPE-SAFE
<i>n</i>	460	2711
Age, years; median (IQR)	40 (34, 46)	41 (34, 49)
Female respondent, <i>n</i> (%)	210 (45.7)	1254 (46.3)
ICU experience, years; median (IQR)	10 (6, 15)	10 (4, 18)
COVID-19 dedicated or repurposed ICU, <i>n</i> (%)*	92 (20)	1585 (58)
Position, <i>n</i> (%)*		
Registered nurse	236 (51.3)	744 (27.4)
Physician	179 (38.9)	1797 (66.3)
Allied HCW	45 (9.8)	170 (6.3)
Specialty, <i>n</i> (%)*		
Emergency	103 (22.4)	72 (2.7)
Intensive care	289 (62.8)	2019 (74.5)
Anesthesia	35 (7.2)	430 (15.9)
Other	33 (7.2)	190 (7.0)
Hospital type, <i>n</i> (%)*		
Remote/regional	29 (6.3)	186 (6.9)
Private	25 (5.4)	237 (8.7)
Tertiary	247 (53.7)	1548 (57.1)
Community/urban	159 (34.6)	741 (27.3)
Running capacity, <i>n</i> (%)*		
Well above	11 (2.4)	690 (25.5)
Above	44 (9.6)	586 (21.6)
Below	227 (49.4)	663 (24.5)
Usual	173 (37.6)	699 (25.8)
Unsure	5 (1.1)	57 (2.1)

Type of ICU where the respondent worked the day of the survey
HCW, health-care worker; IQR, interquartile range.

* $P < 0.05$.

confident that the available PPE could protect them against SARS-CoV-2 exposure.

A significantly higher proportion of respondents in this study routinely used and reused N95/FFP2 compared with that in the PPE-SAFE survey (76.7% versus 57.5%, $P < 0.05$; and 52.4% versus 17.1%, $P < 0.05$, respectively).

Training and confidence of knowledge

The majority of respondents (81.3%) reported having received formal training on PPE use. Most respondents felt that additional training, including simulation (74.6%) or demonstration by infection control specialists (59.8%), and didactic training (43.3%) would be useful. Approximately

half of the respondents (42.4%) had never used the two-person technique when donning and doffing PPE. Only 23.0% of respondents reported that they were very confident or confident in their knowledge of the institutionally recommended PPE-use methods.

A significantly higher proportion of respondents reported never using the two-person technique for donning and doffing PPE in this study than in the PPE-SAFE survey (42.4% versus 23.6%, $P < 0.05$). The lack of confidence in the available PPE to protect against SARS-CoV-2 exposure was reported more frequently in this study than in the PPE-SAFE survey (23.5% versus 13.9%, $P < 0.05$).

Adverse effects

The results for the duration of PPE use in a shift and adverse reports are shown in Table 3. The median duration of a shift while wearing PPE without a break was 1 h (interquartile range [IQR], 1–3 h). The duration of PPE use for nurses (median, 2 h; IQR, 1–3 h) was longer than for physicians (median, 1 h; IQR, 1–2 h; $P < 0.05$). The median duration of a shift while wearing PPE in the mixed ICU and that in the COVID-19-dedicated ICU were not significantly different (1 h [IQR, 1–3 h] versus 2 h [IQR, 1–3 h]; $P = 0.09$).

The most frequent AE was intense heat (75.2%), followed by pressure areas caused by PPE (56.1%). A comparison of the characteristics and duration of PPE use in a shift between those with and without an experience of significant intense heat is shown in Table 4. After adjusting the confounding factors of position as a nurse, age, and consequent duration of PPE use in a shift by using logistic regression, being a nurse was the only independent factor associated with a feeling of intense heat during PPE use (Table 5). Additionally, we investigated the effect of different types of PPE and reuse of masks on the incidence of feeling intense heat (Table S1). Respondents with significant heat symptoms more frequently used full-sleeve waterproof gowns than those without this symptom (87% versus 77.2%; $P = 0.02$). Respondents with significant heat symptoms reused N95 masks more frequently than those without this symptom (43.4% versus 30.8%; $P = 0.02$).

A comparison of the duration of PPE use in a shift and AEs between this study and the PPE-SAFE survey is presented in Table 3. Most AEs were more frequently reported in this study than in the PPE-SAFE survey; however, the median duration of a shift while wearing PPE was significantly shorter in this study than in the PPE-SAFE survey (median, 1 h [IQR, 1–3 h] versus 4 h [IQR, 2–6 h]; $P < 0.05$).

Table 2. Shortages and reuse of single-use personal protective equipment in intensive care units during COVID-19 pandemic: comparison between this study and the PPE-SAFE survey

	This study			PPE-SAFE survey		
	Used for routine care	Reported as missing	Washed or reused	Used for routine care	Reported as missing	Washed or reused
Mask (<i>n</i> = 460)				Mask (<i>n</i> = 2,679)		
Surgical mask, <i>n</i> (%)	85 (18.5)*	7 (8.2)	16 (18.8)*	289 (10.5)	11 (3.8)	13 (4.5)
N95/FFP2 mask, <i>n</i> (%)	353 (76.7)*	41 (11.6)	185 (52.4)*	1557 (57.5)	127 (8.2)	267 (17.1)
FFP3 mask, <i>n</i> (%)	9 (2.0)*	2 (22.2)	0 (0.0)	649 (24.0)	78 (12.0)	107 (16.5)
PAPR, <i>n</i> (%)	12 (2.6)*	0 (0.0)	n/a	184 (6.8)	16 (8.7)	n/a
None, <i>n</i> (%)	1 (0.2)			32 (1.1)		
Gown (<i>n</i> = 460)				Gown (<i>n</i> = 2,432)		
Sleeveless apron, <i>n</i> (%)	20 (4.3)	1 (5.0)	0 (0.0)	193 (7.1)	3 (1.6)	5 (2.6)
Full sleeve waterproof gown, <i>n</i> (%)	389 (84.6)*	34 (8.7)	14 (3.6)*	1623 (60.0)	115 (7.1)	183 (11.3)
Hazmat suits, <i>n</i> (%)	28 (6.1)*	6(21.4)	3 (10.7)	616 (22.7)	73 (11.9)	66 (10.7)
None, <i>n</i> (%)	23 (5.0)*			279 (10.3)		
Eye protection (<i>n</i> = 460)				Eye protection (<i>n</i> = 2,519)		
Goggles, <i>n</i> (%)	122 (26.5)*	7 (5.7)	58 (47.5)*	945 (34.9)	28 (3.0)	326 (34.4)
Face shield or visor, <i>n</i> (%)	311 (67.6)*	25 (8.0)	67 (21.5)*	1574 (58.0)	131 (8.3)	820 (52.2)
None, <i>n</i> (%)	27 (5.9)			192 (7.1)		
Head protection (<i>n</i> = 460)				Head protection (<i>n</i> = 2,075)		
Hair cover, <i>n</i> (%)	350 (76.1)	6 (1.7)	8 (2.3)	1,636 (64.7)	43 (2.6)	41 (2.5)
Balaclava, <i>n</i> (%)	24 (5.2)*	1 (4.2)	0 (0.0)	317 (12.5)	26 (8.2)	8 (2.5)
Impervious hood, <i>n</i> (%)	3 (0.7)*	0 (0.0)	0 (0.0)	122 (4.8)	5 (4.1)	11 (9.0)
None, <i>n</i> (%)	83 (18.0)			452 (17.9)		

n/a, not applicable; PAPR, powered air purification respirator.

**P* < 0.05 compared with PPE-SAFE survey data.

DISCUSSION

THIS STUDY IS the first report of PPE availability, usage, training, and AEs related to PPE use during the COVID-19 outbreak in Japan. At this survey's commencement, the number of COVID-19 patients who needed mechanical ventilation was increasing and peaked at approximately 250 patients 7 days from the start of the survey.⁷ Therefore, these findings reflect a snapshot of the COVID-19 pandemic in Japan. Additionally, we compared the results with those of an international study and found important differences and implications.

Notably, disease spread and mortality varied among countries. In Japan, there were 3.6 deaths per a million population, lower than the 536.8 in Spain and 467.0 in Italy as of 2 May 2020.⁸ Thus, the running capacities of ICUs was significantly different between the two studies.⁶

In Japan, more than half of respondents reported the reuse of single-use N95/FFP2 masks, likely compensating for the higher rate of N95/FFP2 use than elsewhere.⁶

The frequency of PPE use is an indication of a shortage of N95/FFP2 masks when compared with other countries with a higher COVID-19 burden than Japan. This is possibly due to more frequent donning and doffing in this study as the majority of respondents worked in mixed ICUs and in shorter shifts under PPE, which could lead to more PPE being used. Supply issues could also differ from those in other countries. Additionally, the stock of PPE was inadequate. Therefore, sufficient stockpiling and establishing of domestic supply will be required in the future.

Formal training in PPE use might not be adequate in HCWs managing COVID-19 patients. Similar to worldwide results, most Japanese respondents reported having had formal training in PPE use. However, fewer reported confidence in their knowledge of PPE use. Moreover, most respondents required additional formal education. These responses indicate an issue with the content or delivery of the education. Leads for improvement include a recent study reporting the effectiveness of simulation training for PPE use.⁹

Table 3. Reported personal protective equipment (PPE) shift duration and significant adverse effects associated with wearing PPE in the present study compared to the PPE-SAFE survey

Variable	Overall	PPE-SAFE
<i>N</i>	460	2,476
PPE shift duration, h, [†] median (IQR)*	1 (1, 3)	4 (2, 6)
Adverse effects, <i>n</i> (%)*	430 (93.5)	1,986 (80.2)
Heat, <i>n</i> (%)*	346 (75.2)	1,266 (51.1)
Pressure areas, <i>n</i> (%)*	258 (56.1)	1,088 (43.9)
Exhaustion, <i>n</i> (%)*	198 (43.0)	492 (19.9)
Thirst, <i>n</i> (%)*	148 (32.2)	1174 (47.4)
Inability to use the bathroom, <i>n</i> (%)	127 (27.6)	661 (26.7)
Headaches, <i>n</i> (%)*	56 (12.2)	696 (28.1)

[†]Time the health-care worker remained dressed in PPE before being able to take a break.

IQR, interquartile range.

**P* < 0.05.

The two-person technique for both donning and doffing is recommended to prevent exposure.¹⁰ In Japan, 42% reported never using a two-person technique, which is twice that reported in the international study.⁶ This is likely multifactorial. First, the lower number of COVID-19-specialized ICUs in this study might have contributed to these results. Donning and doffing outside a patient's area could decrease the availability of human resources for assistance. Second, insufficient education could be a cause. Third, the minimum standard patient-to-nurse ratio is 2:1 in the ICU in Japan. Inadequate human resources could decrease compliance with procedures. This ratio might be inadequate, especially during the COVID-19 pandemic. Moreover, the participants might not necessarily have been nurses, but other HCWs who received adequate training. There is a need to resolve these issues at the personal, institutional, and governmental levels.

The duration of PPE use in a shift in mixed ICUs was significantly different from that in COVID-19-dedicated ICUs. This was because most of the respondents worked in mixed ICUs and managed COVID-19 patients in a private room. As mentioned above, the management of COVID-19 patients in a private room requires frequent donning and doffing and consumption of PPE.

It was noted that, despite the shorter duration of PPE use in Japan, three-quarters of the respondents reported significant problems with regard to a feeling of intense heat. This result was higher than in the previous international study.⁶

Table 4. Comparison of characteristics of health-care workers with or without symptoms of significant intense heat while wearing personal protective equipment (PPE)

Variable	With symptoms of significant intense heat	Without symptoms of significant intense heat	<i>P</i> -value
<i>n</i>	346	114	
Age, years; median (IQR)	40 (34–45)	40 (35–47)	0.049
Female sex, <i>n</i> (%)	170 (49.1)	40 (35.1)	0.009
Time wearing PPE, h; median (IQR)	1 (1–3)	1 (1–3)	0.539
Experience in ICU, years; median (IQR)	10 (6–15)	10 (6–16)	0.889
Position, registered nurse; <i>n</i> (%)	195 (56.4)	41 (36.0)	<0.001
Workplace, mixed ICU, COVID-19 ICU, or other; <i>n</i> (%)	273 (78.9)	95 (83.3)	0.346
Running capacity of ICU, <i>n</i> (%)			
Well above	11 (3.2)	0 (0.0)	0.192
Above	33 (9.5)	11 (9.6)	
Below	175 (50.6)	52 (45.6)	
Usual	123 (35.5)	50 (43.9)	
Unsure	4 (1.2)	1 (0.9)	

ICU, intensive care unit; IQR, interquartile range.

Table 5. Multivariate logistic regression analysis of factors associated with experiencing significant intense heat while using personal protective equipment (PPE)

Variable	Odds ratio (95% CI)	<i>P</i> -value
Time wearing PPE, /h	0.90 (0.81–1.01)	0.062
Age, /year	0.98 (0.96–1.01)	0.123
Female gender	1.27 (0.78–2.09)	0.338
Registered nurse	2.10 (1.26–3.52)	0.005

CI, confidence interval.

One reason for this difference could be the ambient temperature in the ICU. In Japan, the proportion of ICUs within a private room only was significantly low.¹¹ Thus, in many ICUs, the temperature might not have been individually adjusted but was maintained for the entire ICU. Another study¹² found that the ambient temperature of an ICU bedside was 26.3°C in a Japanese hospital. In contrast, the mean room temperature elsewhere was 23.3°C, even in a burns

ICU in Canada.¹³ This higher temperature in the Japanese ICU could have been associated with more frequent feelings of intense heat in this study.

Attention to dehydration and symptoms of intense heat is needed to avoid the risk for heatstroke, especially among nurses, even if they are wearing PPE for a short duration. The multivariable analysis revealed that the occupation of “registered nurse” was an independent factor for reporting significant problems with symptoms of intense heat. Because the activity of the nurse beside the patient was high, the body temperature tends to be high. A previous study¹⁴ suggested that under ambient temperatures of 29°C in a hospital, the mean body temperature of HCWs wearing PPE to treat or care for patients with Ebola increased by 0.07°C/10 min. In the study, the body temperature reached or exceeded 38.5°C in four of the 25 HCWs. We emphasize the need for administrators to develop prevention strategies for dehydration and symptoms of intense heat, including limiting the duration of PPE use and education on symptoms of dehydration and intense heat, especially for nurses and particularly in summer. Reuse of N95 masks was associated with significant feelings of intense heat. As methods of reuse were not investigated in our survey (i.e., rotation or decontamination), we cannot suggest the actual reasons for this association. Thus, further research is required to confirm the relationship and clarify the mechanisms.

This study has several limitations. First, from a methodological issue, the response rate could not be calculated. Thus, the results might not reflect findings from the entire target population. To investigate the rapidly evolving situations during the pandemic, a quick nationwide distribution of the survey is required, and a Web-based survey is suitable for obtaining a snapshot of the prevailing situation. Second, there were possible differences between respondents’ perceptions and actual practice. The survey content, including on the availability of PPE, perception of training, and symptoms of PPE AEs, were indicated by HCW, and this perception constitutes important information. Finally, there is the possibility of duplicate responses from a single unit; thus, we may have under- or overestimated the actual percentages.

CONCLUSION

THE COVID-19 pandemic in Japan was associated with a PPE shortage, and mask reuse was more frequently observed than in an international survey. Confidence in the PPE technique was insufficient among HCWs, and additional education or re-evaluation of the content of the training programs is highly recommended. Among PPE-related AEs, a feeling of intense heat is the most significant,

especially for nurses, despite short-duration PPE use. Therefore, prevention strategies need to be developed to prevent dehydration and heatstroke among HCWs, especially in summer.

ACKNOWLEDGMENTS

WE THANK MR. Tomoo Sato and Mr. Yuki Wakabayashi for translating the questionnaires.

DISCLOSURES

Approval of the research protocol: The study protocol was approved by the Royal Brisbane and Women’s Hospital Human Research Ethics Committee (LNR/2020/QrBW/63041), Brisbane, Australia.

Informed consent: N/A.

Registration and the registration no. of the study/trial: N/A.

Animal studies (if applicable): N/A.

Conflicts of interest: None.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Comparison of type and reuse of personal protective equipment with or without symptoms of significant heat.