Major Article

Medical masks' and respirators' pattern of use, adverse effects and errors among Portuguese health care professionals during the COVID-19 pandemic: A cross-sectional study

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ABSTRACT

Background: During COVID-19 pandemic, a shortage of surgical masks (Mask) and respirators (Resp) was experienced worldwide. We aimed to assess its pattern of use, adverse effects and user errors by Portuguese health care professionals (HCP).
Methods: A cross-sectional study was conducted through snowball convenience sample, collected by email/ social media to health care organizations. Participants answered an online anonymous survey in March 2021.
Results: Mean age of 3052 respondents was 42.1 years old, 83.6% were female and 77.8% provided direct health care to COVID-19 patients. Mean time of use per shift was 6-8 hours in 40.8% of the participants. 28.0% reported never changing it during their shift. Resp use (vs Mask) was more associated with discomfort (58.2% vs 26.8%), affecting task performance (41.5% vs 18.9%) and communication (55.0% vs 40.9%), dyspnea (36.0% vs 14.4%), skin rash (37.5% vs 19.4%) and headache (37.5% vs 19.4%). Frequent user errors included touching the front while in use (70.1% Mask vs 66.3% Resp) and omitting hand hygiene before (61.8% Mask vs 55.0% Resp) or after use (61.3% Mask vs 57.0% Resp). Average number of errors was higher for Mask (4.3), than for Resp (3.2) (all: $P < .001$).
Conclusions: Most HCP admitted an extended use of Mask/ Resp. Resp were more prone to adverse effects and Mask more prone to errors. Strategies to reinforce good practices should be considered.

BACKGROUND

A range of personal protective equipment (PPE) is available for HCP. In most clinical scenarios where PPE is required, it will comprise either a surgical mask (Mask) or a particulate respirator (Resp), with or without eye protection. In the majority of situations that require respiratory and facial protection, a surgical mask will be adequate. For a very small number of pathogens that are transmissible via the airborne route, or when aerosol-generating procedures (AGP) are conducted, a respirator will be required.[1,2]

A surgical mask (Mask) is defined as a loose-fitting, disposable device that creates a physical barrier between the mouth and nose of the wearer and potential contaminants in the immediate environment. It may come with or without a face shield. These are often referred to as face masks, although not all face masks are regulated as surgical masks. If worn properly, a surgical mask is meant to help block user exposure to large-particle droplets, splashes, sprays, or splatter that may contain microorganisms (viruses and bacteria), keeping it from reaching the user's mouth and nose. Surgical masks may also help reduce exposure of the user's saliva and respiratory secretions to others.[3] On the other hand, a particulate respirator (Resp), as known as filtering face-piece respirator, is a disposable (and intended for single-use) personal protective device worn by HCP, over the nose and mouth, to protect them from acquiring airborne infectious diseases due to inhalation of infectious airborne particles that are <5 μm in size. The N95 filtering facepiece respirator is the type used most commonly by HCP.[4] In Europe the equivalent to N95 is the FFP2 Resp.

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In the context of the Coronavirus Disease 2019 (COVID-19) pandemic (in which a contingency capacity strategy was in place), the World Health Organization and European Center for Disease Control and Prevention, considered that Resp can be used for 4-6 hours for multiple patients without removing it, unless the Resp is damaged, soiled or contaminated.[5,6] In consequence of this global public health emergency, facial and respiratory protection became essential both inside and outside health care environments, and their use is currently recommended by health authorities in health care and other contexts, as a means for containing and reducing the spread of this infection.[7-9]

In response to the pandemic, health systems had to quickly adapt to the growing requests, inherent to the evolution of the epidemiological situation. In this scenario, health care units are at risk of nosocomial outbreaks becoming important local amplifiers. Health care professionals (HCP) are at increased risk of becoming infected, with studies describing 3.8% of cases being in HCP in China, 10% in Italy and 20% in Spain.[10] Considering the high risk of HCP exposure, health care facilities should ensure that PPE is available and appropriately used to safeguard those providing patient care.[11,12] In order to assure its adequate provision, several strategies have been proposed.[13-17]

PPE adherence and training are an infection control pillar against viral respiratory pathogen exposure because if PPE is used incorrectly or is improperly maintained, the wearer is unlikely to receive adequate protection.[1,12]

In this study, we aimed to assess the pattern of use, adverse effects and frequent user errors of Mask and Resp by Portuguese HCP, working in emergency first response, in primary, acute and postacute health care, during the COVID-19 pandemic.

MATERIAL AND METHODS

Study design

A cross-sectional, descriptive and analytical study was conducted with the study population consisting of HCP working in Portugal in the areas of emergency first response, primary, acute and postacute health care. The following exclusion criteria were applied: use of community masks, surgical masks or respirators by general population in a non-health care environment.

A snowball convenience sampling was used. Email messages were sent to Portuguese management staff of emergency first responders (National Medical Emergency Institute) and all the primary, acute and postacute national health care facilities, as well as, HCP civic associations (Portuguese medical, nursing, physiotherapy and pharmaceutical associations). Messages were posted on Facebook and disseminated via WhatsApp in Portuguese groups associated with HCP. Participants were asked to answer an online anonymous questionnaire-based survey, available between February 27 and March 31, 2021. At the time of the questionnaire, Portugal showed a consistent reduction in number of cases and hospital admissions due to COVID-19.

The questionnaire was divided into 3 parts, namely: (1) sociodemographic characteristics; (2) pattern of use of respiratory protection during the COVID-19 pandemic and (3) experience in its use (including adverse effects and user errors). The first part consists of 7 questions of multiple choice type and short answer. The "pattern of use" was evaluated through 3 questions of multiple choice type and short answer. The last part was subdivided in Mask vs Resp experience (with the same questions for each of the subgroups). In this part, the participants were invited to express their degree of agreement with 9 statements (according to a Likert scale) and to answer 3 additional multiple choice questions.

This study was approved by the Ethics Committee of Matosinhos Local Health Unit (reference code 14/CES/JAS).

Statistical analysis

The questionnaire was developed using the Google Forms platform (©Google). Descriptive and analytical analysis was performed using software R 3.5.19. Considering continuous variables, the difference in means between the Mask and Resp groups was assessed using paired samples t-test, considering only those with experience in both Mask and Resp use. Multivariate analysis for the association between the outcomes "difficulty in task performance" or "remove Mask/Resp due to discomfort" and "adverse effects" was performed using linear regression. A significance level of 5% was considered.

RESULTS

A total of 3052 filled questionnaires were eligible for this study. The mean age of respondents was 42.1 years old (SD 11.0) and 83.6% were female. Medical doctors represented 28.3%, nurses 47.7%, technicians 15.5% and other HCP 8.5%. Concerning workplace areas, 1.5% were emergency first responders, 25.6% worked in primary care, 67.0% in hospitals and 5.9% in postacute health care facilities. Their average work experience was 17.4 years (SD 11.0), with almost 30% with more than 25 years of work as a HCP (Table 1).

Regarding Mask/ Resp pattern of use, 77.8% of study participants had at some time during the pandemic provided health care to suspected or confirmed COVID-19 patients. A great majority had experience with both Mask and Resp use (80.6%) and the remaining 592 participants with Mask use only. The mean total time of use per shift was 6-8 hours in 40.8% and 8-10 hours in 30.5% of the participants, with 41.6% of them using it continuously 3-4 hours and 25.8%, 5-6 hours. A total of 28.0% reported never changing the Mask/ Resp

Table 1
Participants sociodemographic characterization and their Mask/ Resp pattern of use (n = 3052)

| Participants characterization	N (%)	Pattern of use	N (%)
Gender		**Experience with:**	
Female	2550 (83.6)	COVID-19 patients	2375 (77.8)
Male	500 (16.4)	Mask use only	592 (19.4)
Other/ Rather not say	2 (0.1)	Mask and Resp use	2460 (80.6)
Age group (years old)		**Mean time of use (h)**	
18-24	100 (1.8)	[2-4]	50 (1.6)
25-34	756 (3.3)	[4-6]	192 (6.3)
35-44	969 (31.8)	[6-8]	1241 (40.8)
45-54	730 (23.9)	[8-10]	929 (30.5)
55-64	441 (14.5)	[10-12]	371 (12.2)
≥65	56 (1.8)	>12	261 (8.6)
Professional group		**Continue use time (h)**	
Doctors	864 (28.3)	0-2	203 (6.7)
Nurses	1456 (47.7)	3-4	1269 (41.6)
Technicians	474 (15.5)	5-6	787 (25.8)
Others	258 (8.5)	7-8	229 (7.5)
		>8	560 (18.4)
Work Experience (y)		**Mask/Resp change in a work shift**	
<5	414 (13.6)	0	854 (28.0)
5-9	429 (14.1)	1	1024 (33.6)
10-14	511 (16.8)	2	694 (22.7)
15-19	415 (13.6)	3	297 (9.7)
20-24	390 (12.8)	4	121 (4.0)
≥25	891 (29.2)	≥5	62 (2.0)
Level of Health care			
Pre-Hospital Emergency	46 (1.5)		
Primary Care	781 (25.6)		
Hospital	2045 (67.0)		
Long-Term Care	180 (5.9)		

Mask, Surgical Mask; *Resp*, Respirator.
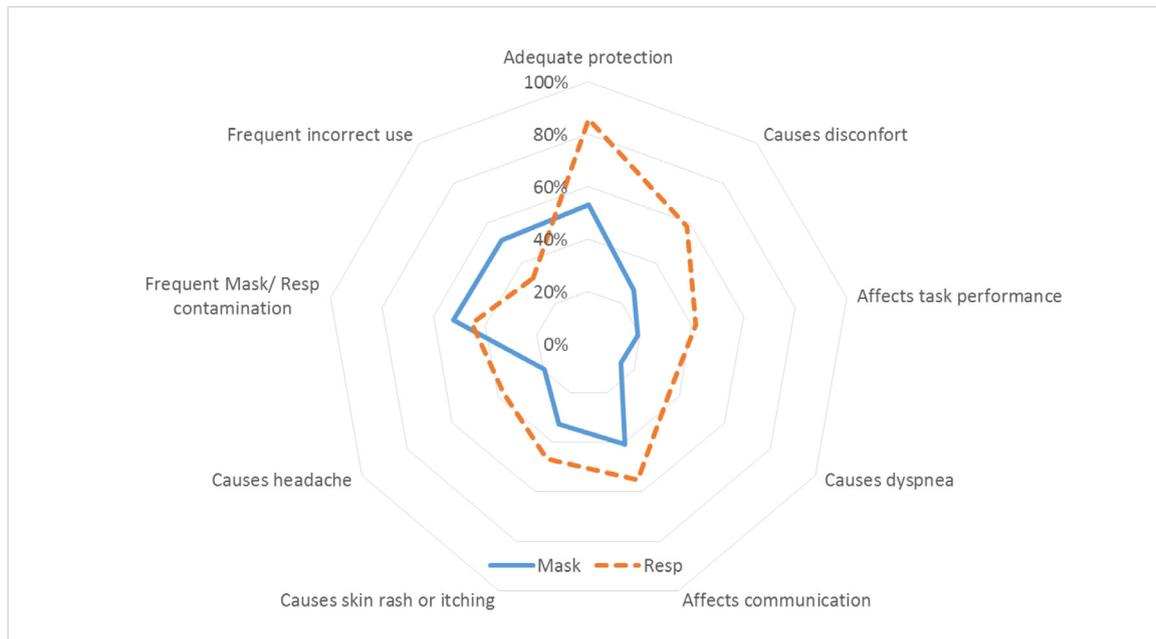
Fig 1. Participants experience of surgical mask (Mask) vs respirator (Resp) use, including adverse effects (n = 2460, *P* < .001).

during their work shift and one third changed it once. On the other hand, 2.0% changed 5 or more times (Table 1).

Concerning participant's experience, several statistically significant differences between Mask and Resp use were found: 53.0% of participants agreed that Mask provided adequate protection against COVID-19 but, when asked about Resp, this proportion rose to 85.6% (*P* < .001) (Fig 1). In general, Resp use (compared with Mask) was more associated with HCP reporting discomfort (58.2% vs 26.8%, *P* < .001), affecting negatively task performance (41.5 vs 18.9%, *P* < .001) and communication (55.0 vs 40.9%, *P* < .001), causing dyspnea (36.0 vs 14.4%, *P* < .001), skin rash or itching (37.5 vs 19.4%, *P* < .001) and headache (37.5 vs 19.4%, *P* < .001).

When asked about "When used, Mask/ Resp are frequently contaminated with organic material," 45.2% of Resp users and 52.3% of Mask users agreed with the sentence (*P* < .001). Frequent incorrect use was reported by 32.7% of the participants for Resp, compared with the 51.4% who reported the same for Mask (*P* < .001) (Fig 1).

The most frequent user errors reported were touching the front of the equipment while using it (70.1% Mask vs 66.3% Resp, *P* < .001), omitting hand hygiene before (61.8% Mask vs 55.0% Resp, *P* < .001) or after use (61.3% Mask vs 57.0% Resp, *P* < .001), putting or keeping the used equipment inside the pocket (62.0% Mask vs 46.0% Resp, *P* < .001), putting the equipment in the neck or forehead (52.0% Mask vs 31.2% Resp, *P* < .001) and using it only covering the mouth (56.5% Mask vs 11.9% Resp, *P* < .001). Other reported errors included crossing straps or only using 1 strap (38.6% Mask vs 15.9% Resp, *P* < .001), not using it when is recommended (13.3% Mask vs 25.6% Resp, *P* < .001) and using it only covering nose (13.0% Mask vs 4.2% Resp, *P* < .001). Average number of user errors reported was higher for Mask (4.3), than for Resp (3.2) (*P* < .001).

Regarding the multivariate analysis (Table 2), the factors which had the most effect on work performance were communication difficulty (estimate 0.044 for Mask and 0.043 for Resp, *P* < .001) followed by dyspnea (estimate 0.024 for Mask and 0.034 for Resp, *P* < .001) and headache (estimate 0.024 for Mask and 0.007 for Resp, *P* < .05).

Considering the need to take off the Mask/ Resp due to discomfort, the variables most associated with it were dyspnea (estimate 0.051 for Mask and 0.051 for Resp, *P* < .001), followed by skin adverse effects for Mask (estimate 0.026, *P* < .001) and communication difficulty for Resp (estimate 0.022, *P* < .001).

DISCUSSION

Pattern of use

Considering the current SARS-CoV-2 pandemic, most of the HCP who participated in this study had experience dealing with suspected or confirmed COVID-19 patients (77,8%), as well as using both Mask and Resp (80,6%). These results are in accordance to the guidelines of the Centers for Disease Control and Prevention and European Center for Disease Control and Prevention, which recommend that HCP should wear an N95 Resp (or a Mask, if Resp is not available) and eye protection, while taking care of suspected or confirmed COVID-19 patients and that Resp should be prioritized for AGP.[18,19] In fact, most hospitals responding to a recent North-American survey, were using N95 Resp when caring for COVID-19 patients and when AGP were performed.[20]

Radonovich et al studied the tolerance of HCP to respiratory protection and described that the median reported tolerance is 7.7 hours for a Mask and 5.8-6.6 hours for a Resp.[21] Another study found that 10% of Mask worn over a 6-8 hour shift, in a high risk Chinese hospital ward, were contaminated with a range of respiratory viruses, and there was a significantly higher rate of contamination on Mask worn for more than 6 hours.[22] In our study, 40.8% of the sample used the Mask/ Resp for 6-8 hours and 30.5% used them up to 8-10 hours, which indicates an overuse of this type of PPE. In fact, 28.0% reported never changing the Mask/ Resp during their work shift (Table 1). One possible explanation for these results is the variation in local policies and the need to adapt to the inconstant supply of PPE during the pandemic. In a British study developed during the COVID-19 pandemic, involving 224 participants, Davey et al reported one third using this PPE 4-8 hours and other third, 8-11 hours.[23]

Table 2
Multivariate analysis for the association between the outcomes "difficulty in task performance" or "remove Mask/Resp due to disconfort" and adverse effects

Outcome	Adverse effect	Mask		Resp	
		Estimate	P value	Estimate	P value
Difficulty in task performance	Dyspnea	0.024	‡	0.034	‡
	Headache	0.012	*	0.007	*
	Skin adverse effects	0.004	NS	0.010	†
	Communication difficulty	0.044	‡	0.043	‡
Remove Mask/ Resp due to disconfort	Dyspnea	0.051	‡	0.051	‡
	Headache	0.022	‡	0.011	*
	Skin adverse effects	0.026	‡	0.014	†
	Communication difficulty	0.021	‡	0.022	‡

Mask, Surgical Mask; *NS*, Non Significant; *Resp*, Respirator.
*$P < .05$
†$P < .01$
‡$P < .001$

Adverse effects

A recent systematic review and meta-analysis, including 37 studies, concluded there was insufficient data to quantify all of the adverse effects that might reduce the acceptability, adherence and effectiveness of facial or respiratory protection.[24] Nonetheless, World Health Organization warns about the potential harms and risks that should be carefully taken into account when using this type of PPE, namely: self-contamination due to the manipulation of the Mask/Resp by contaminated hands or not changing the Mask/Resp when wet, soiled or damaged; possible development of facial skin lesions, irritant dermatitis or worsening acne; uncomfortable sensation; false sense of security (leading to less adherence to well recognized preventive measures, such as physical distancing and hand hygiene); risk of transmission of droplets or splashes to the eyes (if Mask/ Resp use is not combined with eye protection); difficulty wearing this PPE by specific vulnerable populations (mental health disorders, developmental disabilities, the deaf and children) or in hot and humid environments.[25] Several studies addressed specific adverse effects, such as Davey et al that described the experience of several heat-related illness symptoms (such as 40.2% dizziness, 63.4% fatigue, 79,0% headache and 54.5% profuse sweating), and heat stress that impairs both cognitive and physical performance (such as 22.3% making decisions, 26.8% solving complex problems, 20.1% retrieving information from short-term memory and 59.8% attentional focus). The majority of these British HCP stated that wearing PPE made their job more difficult.[23] Another study, involving surgeons from several countries, described that more than half (54%) felt that their surgical performance was hampered with this type of PPE. Visual impairment was reported by 63%, whereas 54% had communication impediments. Less than half (48%) felt protected with its use, and the same proportion perceived that it influenced their decision making. Decreased overall comfort was cited by 66% of the surgeons and 82% experienced increased surgical fatigue.[26]

Another study discussed how N95 Resp and Mask induces significantly different temperature and humidity in their microclimates, which have profound influences on heart rate and thermal stress and subjective perception of discomfort.[27] Heider et al described that during the universal masking in COVID-19 pandemic, HCP of high-risk units were at risk of voice disorders.[28] A German study reported 46 patients with rhinitis-like symptoms strongly associated to the use of Resp.[29]

In our study we found statistically significant differences between Resp and Mask use. In fact, participants were more likely to associate Resp use to discomfort, affecting negatively task performance and communication, causing dyspnea, skin adverse effects and headache (Fig 1). This is according to a Scarano et al study, that suggested that N95 Resp are able to induce an increased facial skin temperature, greater discomfort and lower wearing adherence when compared to the Mask.[30] On the other hand, respondents in the present study felt safer using Resp and had the perception that this type of PPE was associated with less probability of being contaminated with organic material or used incorrectly.

In the multivariate analyses the factor which had the most effect on work performance was communication difficulty and, regarding the need to take off the Mask/ Resp due to discomfort, the variable most associated with it was dyspnea.

User errors

In our study, user errors questions were formulated using a neutral grammatical form ("please report the most frequent errors" instead of "please report your most frequent errors") in order to minimize self-reporting bias. Results showed that the most frequent error was touching the front of the equipment while using it (E1 in Fig 2). In fact, Rebmann et al described a study, involving 10 North American intensive care nurses, in which they found these HCP touched their face 2 to 3 times per hour, their Resp 5 times per hour and their eyes once every 2 hours.[31] We found that omitting hand hygiene before or after Mask/Resp use was an important user error too. In another study, 25% of the HCP wore masks only covering their mouth.[32] According to Figure 2, this error was the fifth and the sixth more frequently reported for Mask and Resp use, respectively. Other errors were strapping incorrectly and "cover only mouth." In a Singaporean study only 12% passed the visual N95 Resp fit test, with the strap placement as the most common criteria performed incorrectly.[33] A recent experimental study reported that it is important to maximize good fit for Resp as well as for Masks. The authors concluded that many simple ways to improve fit have been demonstrated as effective, and continued innovative efforts merit attention.[34]

Despite a facility-wide mandate for universal masking during the COVID-19 pandemic, its compliance remained sub-optimal among HCP in a tertiary-care center. The implementation of a multi-modal intervention (consisting of audit and passive feedback, active discussion, and increased communication from leadership) was effective in increasing Mask compliance among HCP.[35] This contrasts with our study, in which the lack of Mask/ Resp compliance was not one of the most important reported errors (E8 in Fig 2). Overall, the average number of errors reported was higher for Mask (4.3), than for Resp (3.2) ($P < .001$).

As Conly et al refers, "PPE used by HCP caring for patients with COVID-19 must be used with attention to detail and precision of execution, which involves selecting the proper PPE and being trained in how to correctly don, doff and dispose of it − without self-contaminating oneself in the process."[36] Adequate provision of PPE, as well as, training of HCP in its correct use, is highly recommended to ensure safety of care.[37,38]
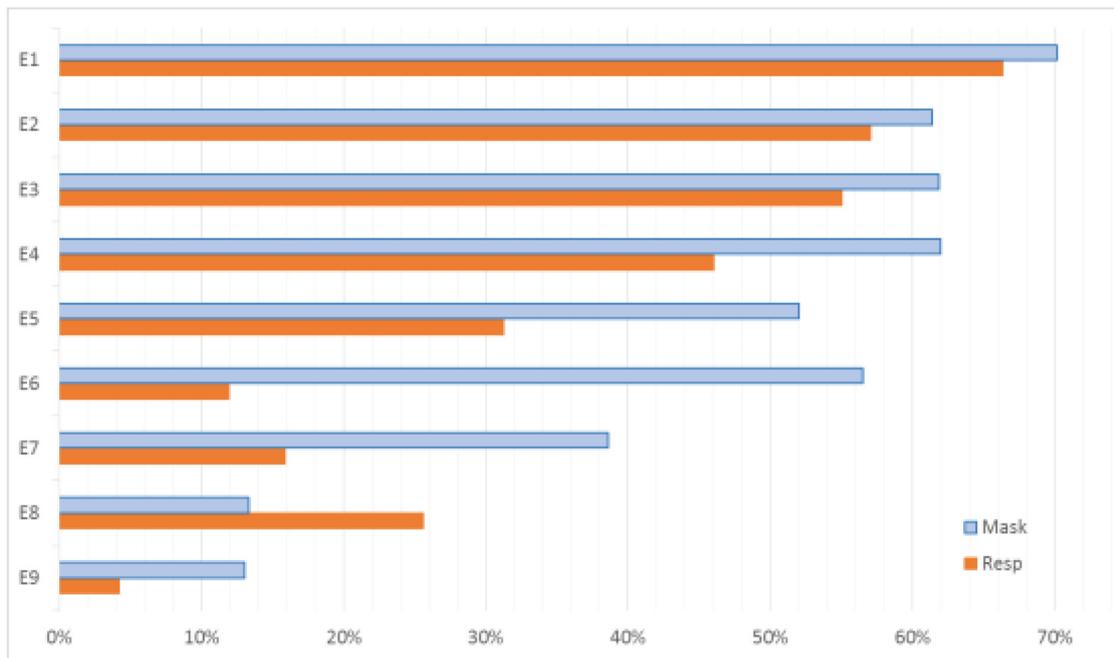
User error
E1	Touch the front of the equipment while using it
E2	Omit hand hygiene after use
E3	Omit hand hygiene before use
E4	Put or keep the equipment in the pocket
E5	Put the equipment in the neck or forehead
E6	Wear it only covering the mouth
E7	Cross straps or only using one of it
E8	Not wear it when is recommended
E9	Wear it only covering the nose

Fig 2. Most frequently reported surgical mask (Mask) vs Respirator (Resp) user errors (n = 2460, $P < .001$).

Study limitations

To our knowledge, this is the first study in Portugal addressing this specific question. Portugal has a public national health system with approximately 131800 HCP.[39] Since global emails were sent to the health care units/ associations (and not individual messages to each HCP), it is not possible to calculate the total sample size or response rate. Other limitation of the study is the response bias (the perception of the participants can differ, consciously or not, from their real practice) and the participation bias (the HCP that use correctly Mask or Resp and that didnt experience any adverse effect can be underrepresented). It should be mentioned that the HCP vaccination status was not collected and that this variable could have an effect on the pattern of use of Mask or Resp.

CONCLUSIONS

Protecting all HCP from infection and mortality must be a core element of any pandemic response. Their protection is essential for the welfare of the HCP themselves, as well as health care systems more generally, because of the critical role they play during pandemic responses. Mask and Resp use are recommended for HCP in their work activities and their choice is task risk dependent. Their use is part of a comprehensive package of measures

to limit the spread of many respiratory viral diseases, including COVID-19. In this study, we identified Resp as more prone to adverse effects, affecting communication and increasing task struggle, when compared to Mask. On the other hand, respondents felt safer using Resp and had the perception that this type of PPE was associated with a lower risk of being contaminated or used incorrectly. In COVID-19 pandemic many PPE practices had to be adapted, due to its inconsistent supply. Infection Preventionists should formulate strategies to reinforce PPE best practices in a post-crisis scenario.

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