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When personal protective equipment for health workers during COVID-19 outbreaks is missing: conclusions from the Catalan COVID-19 Workgroup

Cuando falta el equipo de protección personal para los trabajadores sanitarios durante los brotes de COVID-19: conclusiones del Grupo de trabajo catalán COVID-19

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Abstract

Objectives: Frontline healthcare workers (HCWs) are at high risk of SARS-CoV-2 infection. The aim of this study is to ensure risk-based protection when there is a lack of personal protective equipment (PPE).

Materials and methods: At the beginning of the pandemic, it was suggested that PPE were necessary to protect HCWs from COVID-19. However, given supply shortage, PPE had to be replaced in some situations. Three levels of protection were established depending on the risk level of exposure to SARS-CoV-2. Best practices were reviewed and analysed, and subsequently implemented in all hospitals in Catalonia. As the first COVID-19 wave progressed, we became more knowledgeable with the behaviour of the virus, so PPE procedure tables and algorithms were modified and adapted to the changing scenarios. After airborne transmission was demonstrated as the main route of the virus transmission, we emphasized new measures to ensure respiratory tract protection.

Results: Three general tables were established based on low, medium, and high risk of infection for HCWs. These three scenarios are a subgroup of the very high-risk category, according to OSHA's pyramid of SARS-CoV-2 risk characterization. The most appropriate PPE for each task or job were identified and alternatives were given amid the shortage of PPE.

Conclusions: Specific PPE are required for the healthcare sector. Many studies on PPE are based on the characteristics of industrial jobs, and do not consider the specificities of the healthcare sector, which requires close and prolonged contact with patients.

Keywords: COVID-19, SARS-CoV-2, Personal protective equipment (PPE), Healthcare workers.

Resumen

Objetivos: Los trabajadores sanitarios de primera línea tienen un alto riesgo de infección por SARS-CoV-2. El objetivo de este estudio es garantizar la protección según el nivel riesgo cuando falta el equipo de protección personal (EPI).

Métodos: Al comienzo de la pandemia, se sugirió que el EPI era necesario para proteger a los trabajadores de la salud del COVID-19; pero dada la escasez, el EPI tuvo que ser reemplazado en algunos escenarios. Se establecieron tres niveles de protección dependiendo del nivel de riesgo de exposición al SARS-CoV-2. Se analizaron las mejores prácticas para su posterior implantación en todos los hospitales de Cataluña. A medida que avanzaba la primera ola, nos familiarizamos mejor con el comportamiento del virus y los procedimientos en formato de tablas se modificaron y adaptaron a los nuevos escenarios. Se produjo un punto de inflexión después de que se confirmara que la mayoría de las infecciones se debían a la transmisión por vía aérea. Este avance mostró la importancia de identificar nuevas medidas que pudieran garantizar la protección de las vías respiratorias.

Resultados: Se han establecido tres tablas generales con según el riesgo bajo, medio y alto de contagio de los trabajadores de la salud. Estos tres escenarios son un subgrupo de la categoría de riesgo muy alto, de acuerdo con la pirámide de caracterización del riesgo de SARS-CoV-2 de OSHA. Se ha identificado el EPI más adecuado para cada tarea o trabajo y se han dado alternativas ante la escasez de EPI.

Conclusiones: Se requieren EPI específicos para el sector sanitario. Muchos estudios realizados sobre EPI se basan en las características de los trabajos industriales y no consideran las especificidades del sector sanitario, que requiere un contacto cercano y prolongado con los pacientes.

Palabras clave: COVID-19, SARS-CoV-2, Equipo de protección individual (EPI), trabajadores sanitarios.

Introduction

"Pla EPI" [Catalan acronym for Personal Protective Equipment (PPE) plan], was created by a Catalan COVID-19 Workgroup to ensure the safety and health of healthcare workers (HCWs), and ensure risk-based protection in all Catalan healthcare institutions and activities when dealing with lack of protective equipment. This initiative also provides new measures and tools to manage the shortage of PPEs, as well as adaptations for the permanent use of PPE and surgical masks during the COVID-19 pandemic. During the first wave of COVID-19, the demand for PPE (face-filtering piece (FFP)2 and FFP3 respirators and gloves, among others) increased substantially. Global supply chains, especially those providing single use respirators, were severely affected, impacting the European Union (EU) market[1][2]. The shortage of PPE and the use of low-quality equipment may have contributed to the high infection rates among HCWs.

This shortage posed the need to identify those activities and workers to be prioritized in terms of protection. Thus, occupational risk factors due to SARS-CoV-2 exposure during the outbreaks were divided into four risk categories by the United States Occupational Safety and Health Administration (OSHA) and accepted by the World Health Organisation (WHO): very high, high, medium, and low, and the risk level depended on the type of task performed and on extended or close contact with possible COVID-19 cases[3].

Occupational health services (OHS) had to assess the risk of these groups as established in the "*The action procedure for occupational risk prevention services against exposure to SARS-CoV-2*" from the Spanish Ministry of Health, and the "*Guide to action and collaboration of occupational risk prevention services to deal with the COVID-19 pandemic*" of the Catalan Health Department[4][5].

Methods

The work methodology had two main parts. First, setting up a participatory team of experts - the Catalan COVID-19 Workgroup– to conceptualize, design and guide the implementation of proposed recommendations. The working group was composed and led by the Catalan Association of Occupational Health (Associació Catalana de Salut Laboral - ACSL), made up of a number of well-respected experts in the field from different hospitals of the region and other external advisors. Second, strategizing the implementation of preventive measures based on location, worker exposure and occupational risk factors, best summarized in tables. The recom-

mendations were put in place through consensus among all participating experts of the group, based on what was being evidenced first-hand and on the front lines, and by cumulatively learning more about SARS-CoV2 transmission and the behaviour of the pandemic.

Given the lack of PPE during the first wave of the pandemic, alternatives to the optimal equipment were proposed to protect HCWs even when PPE shortage did not allow them to follow recommendations. The resolution of April 23rd 2020 (issued by the Spanish Ministry of Industry and Commerce, together with the Spanish National Institute for Safety and Health at Work (INSST), established alternative certifications to the European CE for PPE under similar health and safety environments. Given the exceptional situation, it was considered sufficient for international certifications to have similar requirements and functionality as the CE certification. Acknowledging legal and accessibility limitations and in the context of the COVID-19 pandemic, the European Union established Regulation 2020/403 with the aim of guaranteeing the availability of PPE equipment[6][7].

The protective equipment was to be used only when the risks could not be avoided or sufficiently limited by methods of collective protection or by organizing work differently. This management plan focused on the following lines of action:

1. Reducing the number of HCWs who need to use respiratory protection.
2. Establishing engineering and administrative controls.
3. Minimizing the reuse of respiratory protective equipment.
4. Prioritizing the use of FFP2 or FFP3 respirators in workers exposed to an increased risk of infection.

For this reason, public health and occupational and environmental health must work together (Figure 1) when selecting PPEs, functionality, suitability, capacity of decontamination, disposability, while also considering costs. When a HCW has to use PPE repeatedly for an extended period, a more expensive high quality PPE becomes more cost-effective. Each health center or hospital must select the combination of specific PPE that will suit the needs of their workers.

At the beginning of the crisis, workers were instructed on donning and doffing PPE to avoid cross contamination in addition to implementing a system for HCWs to have access to PPE and hydroalcoholic solution. Price also became an important factor. public health and occupational health worked together to address different new challenges, such as funding, the usage of non-medical masks and alternative measures and tools to face PPE shortages which were far from suitable[4] . Some of these alternatives were reuse and reprocessing extended use. Extended use is the practice of using the same material for repeated close contact encounters with several patients[9]. Limited reuse (extended use with limited number of reuse times) was also recommended as an option to save FFP2 and FFP3.

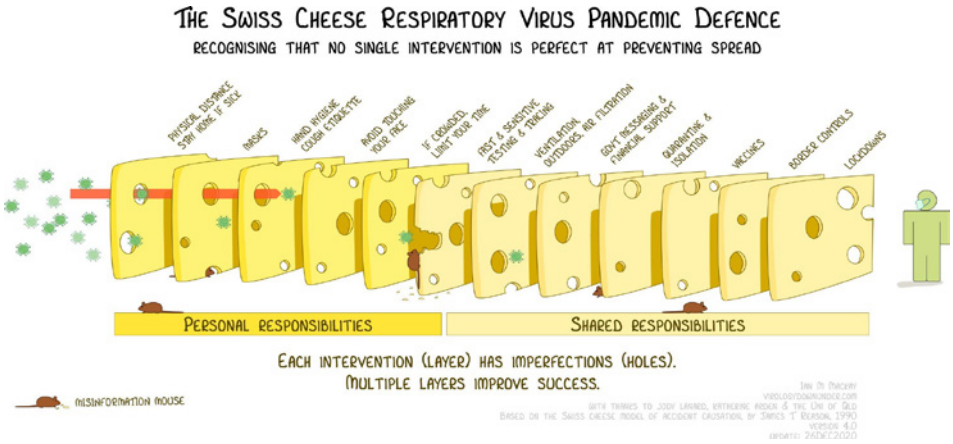

Figure 1. Illustration showing how all measures against a disease complement each other. Figshare - Ian M. Mackay. Available from. https://figshare.com/authors/Ian_M_Mackay/490154

In COVID-19 units, extended use was recommended when caring for several patients with the same masks. In every shift (every 8 hours) masks had to be discarded and replaced by new ones. They also had to be disposed of whenever they were visibly dirty, deformed or did not adjust correctly[9].

The following protocol was implemented when using uniforms: HCWs had to change their uniform daily, all work uniforms had to be washed in the health care center, hospital or in a laundry room related to the centre; work uniforms could not be worn over street clothes if HCWs were in contact with the virus, and jackets were required to have a front opening and not be removed over the head to avoid cross-contamination with the outer part.

In other hospital areas a limited usage following the criteria below was recommended[9-12]:

- Respiratory protection equipment had to be stored in a paper bag with identification of each HCW in a limited and well-ventilated space (a new bag was required each time).
- Gloves had to be worn when donning previously used respiratory protection equipment, and the gloves had to be discarded thereafter together with hand hygiene with alcohol-based lotion.
- The use of masks or other PPE such as gowns and homemade screens did not guarantee protection. The ability to act as a barrier and containment of PPE was determined by the material, the form of placement and its certification.
- FFP2 and FFP3 (respiratory protection equipment) masks for medical use had to be dually-approved as PPE and as a medical product without a valve.
- FFP3 protective masks provided a slightly higher level of protection than FFP2, but without an exhalation valve.

- If FFP2 or FFP3 masks with a CE marking could not be obtained, some equivalent approvals could be used according to the April 23 Resolution of the Ministry of Industry, Trade and Tourism, on alternative specifications to masks with European CE PPE labelling.

Three types of surgical masks were classified according to the compromise between bacterial filtration efficiency and respiratory resistance (expressed as differential pressure). Wearing a type IIR mask requires more effort to breathe than type I or II. [9]

Type 1 surgical masks were only recommended for use by patients (to prevent the risk of spreading infections). HCWs had to use type II or IIR masks.

The PPE had to be comfortable and adaptable to each worker's personal characteristics. It had to be used whenever the risks could not be avoided or sufficiently lowered by technical means of collective protection or organizational measures. Hence the need to implement all possible organizational and technical measures to minimize their use. It was necessary to foresee the supply needs for every healthcare center in order to meet its requirements regarding the selection, quantity and availability of suitable equipment by promoting an adapted delivery service and avoiding reuse as much as possible. Adequate planning could not only guarantee the supply. Once the specific characteristics of each protective equipment had been established, it was necessary to avoid supply interruptions as much as possible to prevent HCWs from being distracted when patient care pressure was extreme.

As described in the OSHA risk pyramid (Figure 2), HCWs are considered as exposed to high risk or very high risk. The Catalan Workgroup COVID-19, focusing on HCWs, created three levels of protection within these two risk categories.

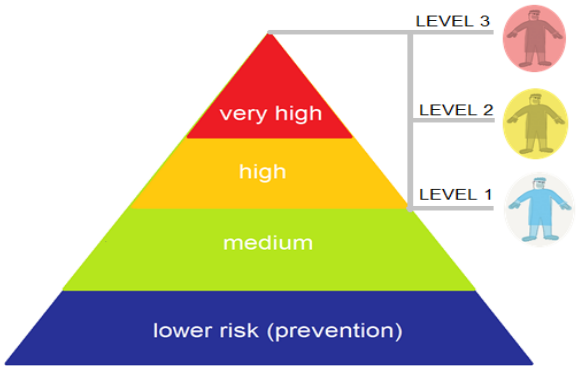

Figure 2. Categories proposed by Occupational Safety and Health Administration (OSHA) and accepted by World Health Organisation (WHO)[3].

Basic PPE were established for each level. HCWs were assigned a different level depending on the tasks they performed, and only minor changes were implemented among the four published versions of the document.

A colour was assigned to each of the published versions of the original document. Changes among the versions have been indicated with the colour of the version in which they happened.

Three levels of protection were proposed, corresponding to three colours: blue (level 1), yellow (level 2) and red (level 3). The aim was to give continuity among levels of protection at all times facilitating moving from one level to another in order to deal with the complexity of real time situations of exposure to SARS-CoV-2, which cannot be categorized in a simple way. Therefore, the Catalan COVID-19 Workgroup proposed the use of different PPE in different workplaces in order to avoid collapsing of the supply system, by assessing which PPE would be most appropriate for each case with alternative proposals to ensure the safety and health of HCWs, and taking into consideration their two proposals, recommendations of WHO [9] and the experience in hospitals of the region.

Results

Once the COVID-19 outbreak had become a pandemic, official reports were scarce. On April 18th 2020, the COVID-19 pandemic revealed critical knowledge gaps in the traditional view of understanding the transmission pathways for respiratory viruses. The long-standing definitions of droplet and airborne transmission (Figure 3) do not account for the mechanisms by which virus-laden respiratory droplets and aerosols travel and lead to infection.

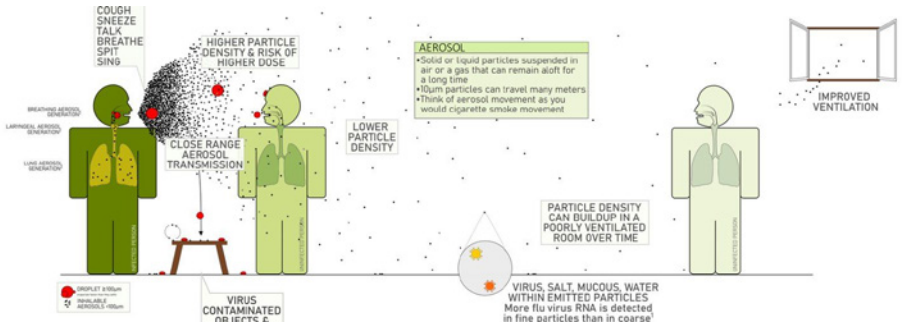

Figure 3. Airborne transmission paths. Figshare - Ian M. Mackay. Available from: https://figshare.com/authors/Ian_M_Mackay/490154.

Mathematical modelling of exposure to respiratory pathogens supports that transmission is dominated by short-range aerosol inhalation at most distances within 2 m of the infectious person, and droplets are only dominant when individuals are within 0.2 m when talking or 0.5 m when coughing.[14] The criteria used for recommendations reflected in the following result tables were a result of a participatory evaluation of the exposure to biohazard risk factors, location, duration and evidenced based protection through personal protective equipment.

In this new model of the transmission of airborne diseases, Tables 1-6 were proposed for all Catalan hospitals.

Table 1. Recommendations for personal protective equipment (PPE) for health care workers (HCW) in hospitals, as a result of a participatory expert evaluation of the exposure to biohazard risk factors, location, duration and evidenced based. Catalan COVID-19 Workgroup.

Type of HCW	Type of exposure	Level of protection[a]	PPE option 1	PPE option 2 if 1 not available
Direct patient care staff	Nonaerosol-generating procedures in patients with COVID-19.	Level 2	Single use cap	NA
			Integral protection goggles	Face shield
			FFP2 mask without valve[9]	FFP1 mask; if not available, surgical mask
			Liquid repellent gown.	NA
			Gloves	NA
			Shoe cover	NA
	Aerosol-generating procedures for patients with COVID-19.	Level 3	Single use cap	NA
			Integral protection goggles[14][15]	Face shield
			FFP2 or FFP3 mask without valve	FFP2 or FFP3 mask with valve and surgical mask on top
			Impermeable gown	Liquid repellent gown with impermeable apron or with coverall
			Gloves	NA
			Shoe cover	NA
Cleaning staff	Rooms for COVID-19 patients where aerosols are not generated.	Level 2	Single use cap	NA
			Integral protection goggles	Face shield
			FFP2 mask without valve	FFP1 mask or surgical mask
			Impermeable gown	Liquid repellent gown and impermeable apron
			Nitrile gloves	NA
			Shoe cover	NA
	Rooms for COVID-19 patients where aerosols are generated.	Level 2	Single use cap	NA
			Integral protection goggles	Face shield
			FFP2 mask without valve	FFP2 mask with valve and surgical mask on top
			Impermeable gown	1) liquid repellent gown and impermeable apron 2) coverall
			Nitrile gloves	NA
			Shoe covers	NA

[a]Levels of protection for HCWs based on the Catalan COVID-19 Workgroup evaluation; NA = not applicable.

Table 2. Recommendations for personal protective equipment (PPE) for health care workers (HCW) in primary care centers, as a result of a participatory expert evaluation of the exposure to biohazard risk factors, location, duration and evidenced based. Catalan COVID-19 Workgroup.

Type of Health Workers	Type of exposure	Level of protection[a]	PPE option 1	PPE option 2 if 1 not available
Direct patient care staff	With no risk of generating aerosols	Level 2	Single use cap	NA
			Integral protective goggles in procedures with risk of splashing[14][15]	Face shield
			Surgical mask	NA
			Impermeable gown in procedures with risk of splashing	Liquid repellent gown and impermeable apron
			Gloves	NA
			Shoe cover	NA
	With risk of generating aerosols.	Level 3	Single use cap	NA
			Integral protection goggles	Face shield
			FFP2 mask without valve	FFP2 mask with valve
			Impermeable gown	Liquid repellent gown and impermeable apron
			Gloves	NA
			Shoe cover	NA
Cleaning staff	In the primary care examination room when attending an infected or suspected to be infected with COVID-19 patient.	Level 2	Single use cap	NA
			Integral protective goggles in procedures with risk of chemical and/or biological splashes[14][15]	NA
			Surgical mask[9]	NA
			Gown	NA
			Nitrile gloves	NA
			Closed footwear	NA

[a]Levels of protection for HCWs based on the Catalan COVID-19 Workgroup evaluation; NA = not applicable.

Table 3. Recommendations for personal protective equipment (PPE) for health care workers (HCW) in patient transportation and home health care, as a result of a participatory experts' evaluation of the

exposure to biohazard risk factors, location, duration and evidenced based. Catalan COVID-19 Workgroup.

Type of Health Workers	Type of exposure	Level of protection[a]	PPE option 1	PPE option 2 if 1 not available
Direct patient care staff	In home health care when attending an infected or suspected to be infected with COVID-19 patient	Level 2	Single use cap	NA
			Single use face shield[14][15]	Integral protective goggles
			FFP2 mask without valve[9]	FFP2 or FFP3 with valve
			Impermeable gown and impermeable pants	Impermeable gown and coverall
			Gloves	NA
			Shoe cover	NA
	Transporting an infected or suspected to be infected with COVID-19 patient	Level 2	Single use cap	NA
			Integral protection goggles	Face shield with surgical mask
			FFP2 mask with valve	Face shield with surgical mask
			Coverall	Impermeable gown
			Gloves	NA
			Shoe cover	NA
Driver	Transporting an infected or suspected to be infected with COVID-19 patient	Level 2	Single use cap	NA
			Integral protective goggles	Face shield with surgical mask
			FFP2 mask with valve	Face shield with surgical mask
			Coverall	Impermeable gown
			Gloves	NA
			Shoe cover	NA
Cleaning staff	Patient transportation	Level 2	Single use cap	NA
			Integral protection goggles	Face shield with surgical mask
			FFP2 mask with valve	Face shield with surgical mask
			Coverall	Liquid repellent gown
			Single use rubber gloves	NA
			Shoe cover	NA

[a]Levels of protection for HCWs based on the Catalan COVID-19 Workgroup evaluation; NA = not applicable.

Table 4. Recommendations for personal protective equipment (PPE) for health care workers (HCW) in prevention services and private medical services, as a result of a participatory experts' evaluation of the exposure to biohazard risk factors, location, duration and evidenced based. Catalan COVID-19 Workgroup.

Type of Health Workers	Type of exposure	Level of protection[a]	PPE option 1	PPE option 2 if 1 not available
Health surveillance staff	Occupational medicine examination room when attending an infected or suspected to be infected with COVID-19 patient.	Level 3	Single use face shield	Integral protective goggles
			FFP2 mask without valve	Surgical mask
			Single use gown	Reusable gown
			Nitrile gloves	NA
Direct patient care staff	In the examination room when attending an infected or suspected to be infected with COVID-19 patient.	Level 3	Single use face shield	Integral protective goggles
			FFP2 mask without valve	Surgical mask
			Single use gown	Reusable gown
			Nitrile gloves	NA
	When moving for work	Level 1	Protective goggles	Nothing
			Surgical mask	Nothing
			Closed footwear	NA
Health&safety advisors	When visiting businesses	Level 2	Single use face shield	Integral protective goggles
			FFP2 mask without valve	Surgical mask
			Single use gown	Reusable gown
			Nitrile gloves	NA
	Moving for work	Level 1	Goggles	Nothing
			Surgical mask	Nothing
			Closed footwear	NA

[a]Levels of protection for HCWs based on the Catalan COVID-19 Workgroup evaluation; NA = not applicable.

Table 5. Recommendations for personal protective equipment (PPE) for health care workers (HCW) in morgue and thanatopraxy, as a result of a participatory experts' evaluation of the exposure to biohazard risk factors, location, duration and evidenced based. Catalan COVID-19 Workgroup.

Type of Health Workers	Type of exposure	Level of protection[a]	PPE option 1	PPE option 2 if 1 not available
Facultative and technic staff	Necropsy of the deceased if infected with COVID-19.	Level 3	Face shield	Integral protection goggles
			FFP2 or FP3 mask with valve	Mask FFP2 or FFP3 without valve
			Coverall	Impermeable gown, impermeable pants and boots
			Gloves	
Thanatopraxy HWs	Embalmers of COVID-19 infected corpses	Level 3	Face shield	Integral protection goggles
			FFP2 or FP3 mask with valve	Mask FFP2 or FFP3 without valve
			Liquid repellent gown and apron	NA
			Gloves	NA

[a]Levels of protection for HCWs based on the Catalan COVID-19 Workgroup evaluation; NA = not applicable.

Table 6. Recommendations for personal protective equipment (PPE) for health care workers (HCW) in maintenance, kitchen and laundry staff, as a result of a participatory experts' evaluation of the exposure to biohazard risk factors, location, duration and evidenced based. Catalan COVID-19 Workgroup.

Type of Health Workers	Type of exposure	Level of protection[a]	PPE option 1	PPE option 2 if 1 not available
Maintenance staff	In the morgue and in COVID-19 units	Level 3	Integral protection goggles	Face shield
			FFP2 or FFP3 mask with valve	FFP2 or FFP3 mask without valve
			Coverall	Gown
			Single use gloves	Nitrile gloves
	In autopsy rooms	Level 3	Face shield	Integral protection goggles
			FFP2 or FFP3 mask with valve	FFP2 or FFP3 mask without valve
			Coverall	Impermeable gown, impermeable trousers, and boots
			Single use gloves	Nitrile gloves
Kitchen staff	In tasks involving silverwhare of COVID-19 infected patients	Level 1	Single use of a gown	Plastic apron
			Gloves	NA
Laundry staff	In contact with COVID-19 infected patients	Level 1	Integral protection goggles	Face shield
			FFP2 or FFP3 mask with valve	FFP2 or FFP3 mask without valve
			Coverall	Impermeable gown
			Double gloves	NA

[a]Levels of protection for HCWs based on the Catalan COVID-19 Workgroup evaluation; NA = not applicable.

Conclusions

The proposed PPE guidelines were not only the result of the greater availability of equipment once the system started to adapt to the demands of the pandemic, but also due to the publication of new studies related to SARS-CoV-2 and its characteristics. All the alternatives ensure the protection of HCWs against the risk of exposure to SARS-CoV-2 according to the available scientific-technical evidence of health, safety, and environment (HSE) professionals.

The results are tailored to each specific HCW job, establishing different levels of risk and allowing a fluid transition among levels depending on the risk and the task. To avoid errors in the selection of PPE, it would be advisable to have a universal label with identical criteria in its evaluation.

The emergency situation experienced during the pandemic forced health institutions to prioritize the control of hygiene risks above all others. However, future success of its implementation needs to integrate other risks (ergonomic, psychosocial, etc.) that have been considered essential in this study. The human factors perspective in the use of PPE must not be forgotten by healthcare organizations, and some conclusions drawn from our study regarding their use include:

1. Improving the user-friendliness of PPE, in particular with regard to donning and doffing. This would not only improve the user experience but also reduce errors that lead to undesirable contamination.
2. Improving training in the use of PPE through learning by doing.
3. Proposing more adaptable facial adjustments to avoid undesirable face compression.
4. Conducting research on textiles that reduce overheating of workers wearing PPE.
5. Providing a solution to the reduced perception of the people who wear them. Some suggestions for implementation could be: specific communication protocols must be implemented with the use of PPE; communication with patients and/or between colleagues, the use of hands-free technology devices internal to the PPE should be used; and an integral full-face system could improve the field of vision and spatial awareness.

Disclosures

The authors declare they have no current or potential competing financial interests.

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