

# Thermal discomfort in healthcare workers during the COVID-19 pandemic

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## SUMMARY

**Introduction:** Due to the COVID-19 pandemic, healthcare workers are now required to use additional personal protective equipment (PPEs) to protect themselves against the virus. That led to an increased clothing insulation which is negatively affecting the perceived healthcare workers' thermal sensation. **Objectives:** While demonstrating through software simulations the potential level of thermal discomfort healthcare workers involved in the COVID-19 emergency can be subjected to, this work aims at identifying measures to improve thermal sensation perception and acceptable thermal conditions for medical personnel. **Methods:** After having obtained the insulation values of individual clothing used by staff during COVID-19 emergency through the use of a thermal well-being evaluation software, the Fanger indexes (PMV - Predicted Mean Vote and PPD - Predicted Percentage of Dissatisfied) were calculated in order to estimate staff satisfaction to microclimatic conditions. **Results:** The use of COVID-19 additional PPEs with an air temperature equal to 22 °C (normally considered optimal) brings the PMV index equal to 0.6, which corresponds to 11.8 % being unsatisfied (PPD) due to perceived heat. **Discussion:** The use of additional protective devices significantly increases the clothing insulation level, facilitating the onset of conditions of thermal discomfort in the health workers. Workers engaged in the execution of nasopharyngeal swabs were most affected by the summer weather conditions and certainly represent the most critical category, for which it would be recommended to implement a higher turnover of service to reduce individual exposure time and consequent discomfort.

## INTRODUCTION

The recent COVID-19 pandemic has forced healthcare workers to use additional personal protective equipment (PPE) throughout their shift to protect against the COVID-19 virus. According to INAIL data, updated August 2020, there are approximately 52,209 reported cases of contagion in the workplace for health care professional and un-

fortunately about 65 of these have led to the death of the worker (1). Critical situations have occurred in health facilities, due to the high number of hospitalizations, which forced those responsible to allocate beds to infected patients even in wards that had not been organized until then to treat infectious diseases. The difficulty in identifying the infected, often asymptomatic, has also forced all health workers to adopt preventive protection measures. The adapta-

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tion of personal protective equipment has resulted in an increase in insulation due to clothing, negatively affecting the thermal sensation perceived by healthcare workers. In this study, the contribution of the thermal insulation for healthcare personnel clothing, when engaged in activities in close contact with suspected or confirmed COVID-19 patients was quantified. Knowing the insulation value of the clothing ( $I$  is measured in Clo; 1 Clo = 0,155 m<sup>2</sup>K/W) and metabolic activity ( $M$  is measured in Met; 1 Met = 58 W/m<sup>2</sup>), simulations were carried out through a software to evaluate thermal well-being in order to identify maximum acceptable temperature level. The purpose of this work was not only to demonstrate through software simulations the level of thermal discomfort to which healthcare workers involved in the COVID-19 emergency can easily be subjected to, but also to propose measures to improve the perception of thermal sensation and guarantee acceptable thermal conditions to that personnel.

## MATERIALS AND METHODS

### Personal protective equipments

From the beginning of the epidemic it became clear that the main route of contagion of the SARS CoV-2 virus is constituted by the droplets of saliva (Droplet) spread even at a distance by symptomatic or asymptomatic patients through mainly coughing, sneezing or, in particular, during semi-invasive or invasive diagnostic or assistance maneuvers (bronchoscopy, intubation, broncho-pharyngeal aspiration, etc.) or the connection of the patient to pulmonary ventilators that can release bioaerosol into the air. As a result attention has been focused in protecting the airways: mouth, nose and conjunctiva (2-4). Furthermore, sick subjects can release droplets of infected saliva on objects and surfaces and other people can become infected by touching these surfaces with their hands and subsequently touching mouths, noses and eyes, making it necessary to protect the rest of the body as well (5-7).

Healthcare personnel who carry out screening or direct assistance to COVID-19 suspected or confirmed patients are required to adapt protective

equipment using disposable overalls / gown, hood or headgear, disposable footwear, gloves, goggles or visor and FFP2 filter mask or FFP3 (8).

### Microclimatic parameters and ventilation

The current legislation provides that the values established by the Presidential Decree of 14 January 1997 (9) should have a temperature range between 20-24°C and relative humidity between 40-60%.

In departments that treat infectious diseases, the ventilation system provides air exchange without recirculation and is suitably calibrated to obtain a negative pressure in the rooms in order to avoid the transmission of pathogens in adjacent environments. In intensive care units and operating rooms, on the other hand, positive pressure is maintained to avoid the introduction of untreated external air.

In the wards, only in the recently built structures is there an air conditioning system that is otherwise obtained by opening windows. The air temperature, according to the regional regulations concerning accreditation of healthcare facilities, must be close to 20 degrees.

To deal with the emergency, almost all healthcare facilities had to reorganize their spaces and in addition to the spaces already dedicated to infectious diseases and intensive care, it was necessary to identify other beds by converting entire departments.

The management of the air conditioning systems has been modified when possible by increasing the external air flow, avoiding any recirculation or installing absolute filters (10).

### Thermal insulation of clothing ( $I$ ) and metabolic activity ( $M$ ) of personnel involved in the COVID-19 emergency

Table 2 shows the isolation value of the basic items used by a nurse in the intensive care ward or wards before the pandemic emergency. From the analysis of previous studies (11, 12) and referring to the tables of the Technical Standard ISO 9920 (13) it was possible to obtain the insulation values of the individual garments used by healthcare personnel (Table 1). As required by the Technical Standard, the sum of the values ( $I_{clu}$  - Effective thermal

**Table 1** - Isolation values of the individual clothing used by healthcare workers

Clothing	Insulation value (Clo)
Underwear	0.04
Headgear	0.01
Glasses	0.01
Coat	0.24
Trousers	0.26
Socks	0.02
Clogs	0.02
Gloves x 1	0.02
Surgical mask	0.02
<b>Effective insulation (<math>I_{cln}</math>)</b>	<b>0.64</b>
<b>Basic insulation (Icl)</b>	<b>0.69</b>

insulation) has been corrected to compensate for the energy losses due to the discontinuity between the various items, obtaining the new value ( $I_{cl}$  – Basic Insulation). Overall, the value calculated for the combination of garments used under normal conditions was equal to 0.69 Clo.

Table 2 shows the isolation values of the individual garments generally used by healthcare personnel, integrated with those necessary to prevent contagion from COVID-19.

Overall, the obtained value of corrected insulation, for the combination of the garments used, was equal to 0.97 Clo.

The metabolic activity was estimated at a value of 1.6 met corresponding, according to the indications of the Technical Standard UNI EN ISO 8996 (14), to a not excessively burdensome job in which the handling of the patient is not very assistance activities mainly consist in monitoring the patient’s condition and administering therapies. This value allows you to obtain information on the average effort throughout the work shift.

**Simulation of the thermal sensation**

Through the use of a software for the evaluation of the thermal well-being Delta OHM -DeltaLog10, by entering the values of insulation of the clothing

**Table 2** - Isolation values of individual clothing generally used by healthcare workers, integrated with those necessary to prevent contagion from COVID-19

Clothing	Insulation value (Clo)
Underwear	0.04
Headgear	0.01
Glasses	0.01
Coat	0.24
Trousers	0.26
Socks	0.02
Clogs	0.02
Gloves x 2	0.012 (0.024)
Disposable sterile gown	0.31
Semi facial mask FFP2/FFP3	0.02
Shoes	0.04
<b>Effective insulation (<math>I_{cln}</math>)</b>	<b>0.98</b>
<b>Basic insulation (Icl)</b>	<b>0.97</b>

(I) and of metabolic activity (M) hypothesized and setting the environmental parameters of relative humidity and increasing air speed it was possible to calculate the Fanger indexes PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) (15) as required by the technical standard UNI EN ISO 7730 (16) in the temperature range 18 – 31 °C. These indexes allow to estimate the satisfaction of workers in respect to microclimatic conditions by quantifying the percentage of subjects who are deemed satisfied. The standard provides for three comfort classes (A, B, C) but, in the case examined, a condition in which the percentage of dissatisfied staff members does not exceed 10% corresponding to class B was considered optimal.

**RESULTS**

Tables 3 and 4 show the results of the calculation of thermo-hygrometric comfort for healthcare workers when they use, respectively, normal clothing and integrated clothing to protect themselves from contagion. To simplify the modeling calculation, the air temperature and overall temperature values were standardized in an equivalent way, assuming that

**Table 3** - Calculation of thermo-hygrometric comfort with standard clothing

Ta °C	Tg °C	UR %	Va m/s	I Clo	M Met	PMV	PPD %
18	18					-0,5	10.5
19	19					-0,3	7.1
20	20					-0.1	5.3
21	21					0.1	5.1
22	22					0.3	6.4
23	23					0.5	9.3
24	24					0.6	13.8
25	25	45	0.10	0.69	1.60	0.8	19.9
26	26					1.0	27.7
27	27					1.2	36.9
28	28					1.4	47.3
29	29					1.6	58.2
30	30					1.8	68.9
31	31					2.0	78.6

I Clo = Insulation value of the clothing; M Met = Metabolic activity; PMV = Predicted Mean Vote;  
PPD = Predicted Percentage of Dissatisfaction

**Table 4** - Calculation of thermo-hygrometric comfort with integrated anti-contagion PPE clothing

Ta °C	Tg °C	UR %	Va m/s	I Clo	M Met	PMV	PPD %
18	18					-0.1	5.1
19	19					0.1	5.1
20	20					0.2	6.3
21	21					0.4	8.5
22	22					0.6	11.8
23	23					0.7	16.4
24	24					0.9	22.2
25	25	45	0.10	0.97	1.60	1.1	29.1
26	26					1.2	37.2
27	27					1.6	54.1
28	28					1.7	62.1
29	29					1.8	64.5
30	30					1.9	73.3
31	31					2.1	81.1

I Clo = Insulation value of the clothing; M Met = Metabolic activity; PMV = Predicted Mean Vote;  
PPD = Predicted Percentage of Dissatisfaction

there were no significant radiant heat sources, that the air velocity was not particularly high and that the relative humidity value was within the comfort limits.

From the comparison between the two tables it emerges that in the range of 20–24°C standard clothing allows to maintain a condition of comfort, while with the use of additional PPE already with an air temperature equal to 22°C (temperature considered normally optimal) the PMV index is equal to 0.6 corresponding to 11.8% of dissatisfied (PPD) from heat. As can be seen from Table 4, the percentage of dissatisfied people tends to double for a temperature of 24°C.

## DISCUSSIONS AND CONCLUSIONS

As can be deduced from the modeling performed, healthcare personnel who carry out screening or direct assistance to suspected or confirmed COVID-19 patients could manifest a condition of thermal discomfort already for temperatures equal to or higher than 22°C, despite these being the level normally foreseen within the assistance structures. Therefore, in environmental conditions considered normal, staff can be easily exposed to conditions of thermal discomfort, with consequences of both physical and perceptual-psychic aggravation with the onset of potential health effects due to thermal stress, and potential relapses in welfare activities with an increase in clinical errors due to reduced concentration due to psycho-physical stress that could derive from it. During the pandemic, various health facilities also installed external tents with the aim of providing a first triage / screening for patients who presented respiratory issues, as well as detection procedures through nasopharyngeal and / or molecular swabs were organized rapid tests in open spaces of car parks in so-called drive-ins, in external environmental conditions correlated to seasonal thermo-hygrometric variables. In this case it is evident how complicated it is to guarantee acceptable thermal comfort levels. Workers engaged in the execution of nasopharyngeal swabs were most affected by the summer weather conditions and certainly represent the most critical category. The use of minimum additional protective devices such as the disposable apron / gown, double gloves

and FFP2 / FFP3 filter masks significantly increase the level of insulation of clothing, facilitating the onset of thermal discomfort conditions in workers, without considering the potential dermatological, cardio-cerebrovascular effects for inductive processes of vasodilation-constriction (17–25). The FFP2 / FFP3 filtering half-mask compared to the surgical mask certainly entails greater overheating of the face while the influence on the heat exchange through the exhaled air seems to be insignificant. A specific study has shown that the internal temperature of a subject does not undergo significant increases during the use of filter half masks (25), but a slight increase in the temperature of the skin in the face area has been observed. The feeling of comfort is also influenced by other components that can affect the perception of the thermal sensation by the workers such as the stress of working with an impending danger, the anxiety of giving the best assistance quickly and the physical limitations that inevitably entails having to wear additional garments play an important role. The management of the air conditioning systems was an unknown factor from the beginning due to the scarce information available on the ways of spreading the virus. One study reported how SARS-CoV-2 can spread through the air over large distances (26). The measure implemented immediately was the strengthening of the number of external air changes and the use of absolute air filtration systems. The frequency of filter replacement and the sanitation of at least the most accessible parts of the system had to be more frequent than those expected before the pandemic (7). A recent study also demonstrated through a computer simulation how the use of a localized suction system positioned above the patient's bed can increase the dilution capacity of viral particles in the environment (27), without prejudice to the consideration of particle "drag" effect that this could induce. One of the critical aspects in order to guarantee thermal comfort for healthcare workers is the management of temperatures and humidity in the hospital rooms, which must in any case take into account the presence and needs of patients, or at least must be considered by the doctor who must evaluate the need to check the patient's thermal balance during treatment. During the epidemic there were not rare cases

in which staff, in order to optimize the resources available and in rooms with more patients affected by COVID-19, wore PPE continuously for the entire work shift. It is clear that ensuring an adequate level of thermal comfort for healthcare workers who are required to use the PPE required for the COVID-19 emergency is not an easy task. Maintaining a temperature below 22°C would certainly allow staff to be able to carry out their business in more comfortable conditions. Limiting the staff stay time in hospital rooms and the related use of devices is certainly a suitable measure for improvement, although it must be considered that the dressing / undressing areas of the staff are those in which it is detected in the air and on the surfaces the higher concentration of SARS-CoV-2, so it should increase the staff's attention to the related procedures, making continuous activities of partial or total undressing-rest-dressing of the PPE stressful and difficult (28, 29). An increase in artificial ventilation in the environment could also achieve multiple objectives both by increasing the degree of dilution of SARS-CoV-2, and by reducing the surface temperature of the PPE worn with improved thermal transfer, without prejudice to not increasing the effect of remote "dragging" of the virus determined by the higher speed of the air. Finally, it is good to consider that workers engaged in the execution of nasopharyngeal swabs certainly represent the most critical category as they carry out this activity even in an external environment where it is difficult to guarantee acceptable thermal conditions and, therefore, a turnover would be desirable for them greater service to reduce individual exposure time and consequent discomfort.

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