

Personal Protective Equipment for Health Workers During a Pandemic: A Literature Review of Evaluation of Discomfort and Physiological Response

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Abstract

Personal protective equipment must be used by health workers to prevent transmission while handling COVID-19 patients. However, its usage causes side effects in the form of discomfort. This study aimed to conduct a systematic literature review of the discomfort and physiological responses experienced by health workers when using PPE for handling COVID-19. The method of collecting articles in this systematic literature review used search engines such as Science Direct, Springer Link, Proquest, PubMed, Taylor & Francis Online and google scholar. The search results obtained 396 articles, then a checking process was carried out so that 19 articles were reviewed thoroughly. The discomfort experienced by health workers when carrying out activities using PPE for handling COVID-19 includes physical, psychological, and cognitive discomfort. The physiological responses experienced include end-tidal CO₂, heart rate, oxygen saturation and perfusion index. Risk factors for discomfort include demographic factors, habits, time of use and work environment. This literature review provides information on the level of discomfort, physiological responses and risk factors experienced by health workers when using PPE for handling COVID-19. The results of this review can be used as a direction by interested parties to support the performance of health workers when treating patients.

Keywords:

COVID-19, health workers, personal protective equipment, discomfort, physiological responses

1. Introduction

The outbreak of coronavirus disease 19 (COVID-19) as a pandemic was announced by the World Health Organization (WHO) on March 11, 2020 (Morabito et al. 2020). COVID-19 is caused by infection with a new type of corona virus that causes respiratory problems. This pandemic is very difficult to handled, so it is still ongoing today. The official WHO website (World Health Organization 2021) provides data on global COVID-19 cases, namely: 163,312,429 people confirmed positive, 3,386,825 people died, and 515,104 new cases. According to the same source, the data on domestic COVID-19 cases are as follow, namely: 1,744,045 people were confirmed positive, 48,305 people died, and 4,295 new cases.

Health workers are people who directly handle COVID-19 patients have a very high risk of contracting this disease. The risk is getting higher along with the increasing intensity of the relationship between health workers and patients due to the large number of patients, but this has not been accompanied by adequate numbers of health workers and care facilities. The risk of contracting COVID-19 is also getting higher because the virus is very contagious and spreads exponentially. COVID-19 spreads through droplets, aerosols, human contact, contact with contaminated surfaces, and the fecal-oral routes of transmission (Meng et al. 2020, Donà et al. 2020).

Personal protective equipment (PPE) must be used by health workers to reduce the risk of contracting or transmitting the COVID-19 disease when interacting with patients. PPE is defined as equipment designed to protect individuals from explosion, chemical, biological, radiological, and nuclear (O'Brien et al. 2011). Generally, PPE for handling COVID-19 includes head cap, eye protection, goggles, face masks, scrubs, coveralls, gloves, and boots (World Health Organization 2020). PPE for handling COVID-19 functions to prevent contamination that may occur due to droplets when coughing or sneezing from an infected person or activities that produce aerosols during clinical service or when accidentally touching contaminated areas (Tumram 2020).

The use of PPE when handling patients COVID-19 causes an increase in overheating (Morabito et al. 2020) thereby increasing the occurrence of heat stress for health workers (Global Heat Health Information Network 2020, Daanen et al. 2021). This PPE has properties that are impermeable to air and encapsulation that hinders heat transfer, when added to the additional burden of PPE and limited movement, the rate of heat stress will increase which results in thermal strain which is characterized by symptoms of increased skin temperature and core body temperature (Coca et al. 2017). The body's metabolic heat transfer outage is limited by PPE for handling COVID-19 which has about twice as much evaporation resistance as compared to standard medical scrubs (Foster et al. 2020). Furthermore, this resistance can be increased by more than 10 times with additional coating and with full cover on the head and neck (Potter et al. 2015).

Based on the description above, the use of PPE by health workers can prevent transmission of COVID-19. However, there are side effects that are felt by health workers, namely thermal discomfort and the emergence of a physiological response when used. There has been a lot of research completed to investigate the inconvenience of using PPE for handling COVID-19. However, not many have systematically reviewed these literatures. Therefore, a systematic literature review will be carried out on the level of discomfort and physiological response and risk factors for using PPE for handling COVID-19 based on published literature.

1.1 Objective

This systematic literature review investigated the discomfort felt by health workers, the physiological responses experienced by health workers when using PPE for handling COVID-19 and the risk factors that cause it. This systematic literature review used literature that has been published in the last two years (2020-2021). The study results were expected to provide information about the side effects of using PPE for handling COVID-19 so that it can be used as a basis for decision making by interested parties to support the performance of health workers in serving patients. Furthermore, the results of this study can be used as a research basis to design PPE that meets technical requirements and has better thermal quality.

2. Literature Review

The level of PPE protection according to the PPE Standards for Handling COVID-19 is divided into 3 levels (Liang 2020). The level of PPE protection is based on the level of danger faced by health workers. The lowest level of protection is level I and the highest level of protection is level III. PPE at protection level I consists of a 3ply surgical mask and disposable rubber gloves. PPE protection level II consists of a 3ply surgical mask, gown (at risk of splashing body fluids), disposable rubber gloves, eye protection / face shield (at risk of splashing body fluids), and a head cap. PPE protection level III consists of N95 mask or equivalent, coverall / gown, boots / rubber boots with shoe protection, eye protection, face shield, sterile disposable rubber surgical gloves, head cap, and apron (Tumram 2020). PPE at protection level III is a complete PPE that is used for activities that have the highest risk.

The usage of PPE in handling COVID-19 causes side effects in the form of thermal discomfort and the emergence of a physiological response. According to Li (2001) thermal comfort is a subjective perception of the thermal sensations of psychological processes, body-clothing interactions, and the effects of the external environment. Physiological response is a physical individual response characterized by increased heart rate, blood pressure, and respiratory system. One of the symptoms that occur is symptom of heat stress. Heat stress is an event when the body acquires higher heat than losing heat. It is caused by several factors, namely: environmental factors (air temperature, air speed, radiant temperature, and humidity), activities and clothing (Song 2011). Heat stress will have an impact on cognitive impairment, fatigue, reduced productivity and work accidents (Wondmagegn et al. 2019). In more severe conditions, it can cause heat stroke and the possibility of fainting while on duty (Tumram 2020).

PPE discomfort for handling COVID-19 can be caused by many factors. The human thermal environment is determined by six fundamental factors. These factors consist of air temperature, emission temperature, air movement and humidity, as well as metabolic heat generated by human activities and the clothes worn (Song 2011). The human body generates heat because of physical activity. The heat produced by the body will increase significantly when there is intense work activity (Kjellstrom et al. 2009). The body must dispose of excess heat that is acquired into the environment through sweat evaporation, convection, and conduction (Lee et al. 2020). The body's metabolic heat transfer to the environment is limited by the PPE for the treatment of COVID-19 which has about twice the evaporation resistance compared to standard medical scrubs (Foster et al. 2020). PPE has the properties of impermeable to air and encapsulation that hinders heat transfer (Coca et al. 2017). Limited heat transfer and increased sweating cause rapid

fatigue and thermal discomfort (Liu et al. 2020) resulting in critical health conditions such as hyperthermia and dehydration. The use of PPE for the handling of COVID-19 in the long term and in a hot environment can result in worse effects such as skin reactions (Yuan 2020), breathing difficulty queasiness, uncomfortable digestion, and headache (Ong et al. 2020) and mental health (Shaukat et al. 2020, Muller et al. 2020).

3. Method

3.1 Literature Search and mangement

The literature search for this literature review was conducted using five electronic search databases, namely Science Direct, Springer Link, Proquest, PubMed, Taylor & Francis Online and Google Scholar from 2020 to 2021. The search used the keyword "discomfort personal protective equipment covid-19". The literature review procedure was carried out using the rules of University of Edinburgh's systematic literature review (Piper, 2013).

3.2 Included and Excluded Criteria

In this paper, the evaluation of the use of PPE for handling COVID-19 by health workers was focused on discomfort and the physiological response that occurs. The criteria for articles were selected as follows:

1. Year of publication of the articles 2020-2021.
2. Connected to the usage of PPE for handling COVID-19.
3. Reporting the occurrence of risk of discomfort (heat stress) and physiological responses.
4. Using one of the investigative tools to get the risk of discomfort and the emergence of a physiological response, such as experiments and surveys.

3.3 Screening Process

Articles were collected through search sites using keywords in the advanced search feature. The collected articles were then checked, and then ensured that there are no duplicate articles. The screening process was carried out by examining the abstract because the abstract of the paper describes the objectives, methods, results, and conclusions of the study. Based on the abstract of the article, it could be determined whether an article has the potential to be included in the accepted criteria or not in this systematic literature review.

3.4 Evaluation Process

The factors of discomfort and physiological responses to the use of PPE for handling COVID-19 were evaluated based on the significance of the study. The criteria are categorized as having a strong relationship if they have an odds ratio (OR) value of at least 1.0. In addition, the classification of risk factors for discomfort also uses a significance value (p-value) (Kusmasari et al. 2017). Risk factors for discomfort and physiological responses to the use of PPE for handling COVID-19 are classified into 3 groups namely:

1. Strong evidence ($OR > 3$ or $P < 0.001$)
2. Reasonable evidence ($OR = 1 - 3$ or $P < 0.05$)
3. Insufficient evidence ($OR < 1$ or $P > 0.05$)

The results of the discomfort survey generally do not include OR and p-value, therefore the classification of discomfort in using PPE for handling COVID-19 is classified by dividing 4 groups based on the respondent's answer quartile, namely:

1. Quartile 1 (Q1) percentage of respondents' answers 0% -25%
2. Quartile 2 (Q2) percentage of respondents' answers 26% -50%
3. Quartile 3 (Q3) percentage of respondents' answers 51% -75%
4. Quartile 4 (Q4) percentage of respondents' answers 76% -100%

4. Data Collection

4.1 Literature Search and Evaluation

A literature search related to discomfort and physiological responses and risk factors experienced by health workers when using PPE for handling COVID-19 with the publication year 2020-2021 resulted in 396 articles from five online search sites as shown in Figure 1. Search results from website databases online searches included: Science Direct 151, Taylor & Francis Online 153, Proquest 19, Springer Link 28, and Pubmed 45. The total number of articles collected was 396 articles and there were 14 duplicated articles leaving 382 articles. The examination was continued by studying the title and abstract of the article and the result was that there were 351 articles that did not match the criteria and 1 article could not be downloaded so that there were 30 articles left. Examination of the full text of 30 articles found 11

articles that did not meet the criteria. As a result, this literature study used 19 articles that examine discomfort and physiological responses to the use of PPE for handling COVID-19 by health workers.

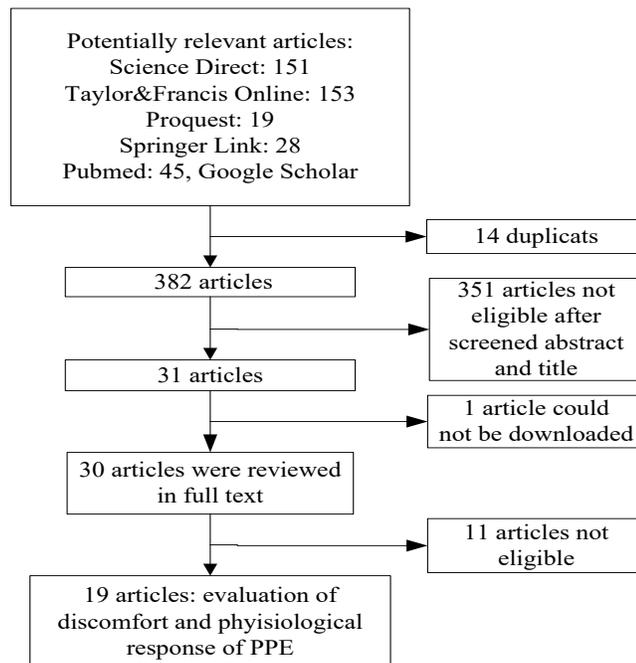


Figure 1. Systematic literature review stage

4.2 Investigation Tools for Discomfort and Physiological Response

Investigation of the occurrence of discomfort and physiological responses to the use of PPE for handling COVID-19 was carried out using several methods including survey and experimental methods. The use of these methods in research has advantages and disadvantages.

a. Experiment

The experimental method was used to investigate the occurrence of discomfort and physiological responses to the use of PPE for handling COVID-19 by health workers. One of the advantages of the experimental method is that all parameters for physical variables can be controlled properly so that the research objectives can be achieved well, while the drawback is that the psychological factors of the research subject do not match the actual conditions. Experiments were carried out using volunteers who work as health workers. The experimental protocol was determined to be close to the real conditions when health workers used complete PPE. Several volunteers were chosen with a certain age range, and no comorbid such as hypertension, diabetes mellitus, and chronic obstructive airway disease (Arif et al. 2021, Choudhury et al. 2020). After obtaining informed consent, demographic variables including gender, age, comorbidity, height, weight, BMI, smoking habits, and activity levels were documented (Arif et al. 2021). Environmental conditions were regulated according to real conditions including ambient air temperature and humidity. The experiment was carried out with a protocol that was determined according to the activities carried out by health workers at work.

b. Survey

Generally, the survey was conducted using a cross sectional study method. The survey to obtain data on the occurrence of discomfort and physiological responses to the use of PPE for handling COVID-19 was carried out by distributing questionnaires using the internet media (online / web survey). Respondents were health workers who use PPE for handling COVID-19 with certain demographic factors. The parameters that were asked in the questionnaire consist of physical, psychological, cognitive task, and risk factors related to discomfort. One of the advantages of the survey is that it has a high ability to eliminate the subjectivity of the researcher, while the weakness is that the researcher must ensure that the respondent gives a bias-free response.

5. Results and Discussion

5.1 Physiological Response to The Use of PPE for Handling COVID-19

Experiments had been carried out to determine the physiological response to the use of PPE for handling COVID-19 (Arif et al. 2021, Choudhury et al. 2020) with the results presented in table 1.

Table 1. Physiological response to the use of PPE for handling COVID-19

Symptom group	Symptom	Strong evidence	Reasonable evidence	Insufficient evidence	References
Physiological response	End-tidal CO ₂		√		Arif et al. 2021
	Heart rate	√	√		Arif et al. 2021, Choudhury et al. 2020
	Respiratory rate			√	Arif et al. 2021
	Blood pressure			√	Arif et al. 2021
	Oxygen saturation	√		√	Arif et al. 2021, Choudhury et al. 2020
	Perfusion index	√			Choudhury et al. 2020

The experiment was carried out by comparing the observed data from the physiological response between at rest and after carrying out activities on 12 volunteers using PPE for handling COVID-19 and carrying out the prescribed protocol. The exclusion results showed a significant difference in end-tidal CO₂ ($p = 0.002$), heart rate ($p = 0.002$) and no significant difference in the rate of respiratory, blood pressure, and oxygen saturation (Arif et al. 2021). The next study was conducted by observing 75 health workers aged 18 years to 50 years who carried out activities in the intensive care unit (ICU). Then after four hours of wearing PPE showed a significant difference in heart rate ($p < 0.001$); oxygen saturation ($p < 0.001$); perfusion index ($p < 0.001$) (Choudhury et al. 2020). Based on the two estimates above, it is concluded that the use of PPE causes changes in the user's physiological response which can cause headaches, dizziness, and respiratory problems which result in inhibition of the performance of health workers (Arif et al. 2021, Choudhury et al. 2020).

5.2 The Discomfort of Using PPE for Handling COVID-19

The results of the survey regarding the symptoms of discomfort experienced by health workers when using PPE for handling COVID-19 can be divided into 3 major parts, namely physical discomfort, psychological discomfort, and cognitive discomfort.

5.2.1 Physical Discomfort

The physical discomfort experienced by health workers when using PPE for handling COVID-19 is shown by the appearance of various symptoms. The diversity of these symptoms occurs because of the different risk factors that trigger them so that the symptoms experienced are different from each study (Çağlar et al. 2021). Sometimes a complaint or several complaints affect other complaints, for example condensation on the face shield, dry mouth and difficulty breathing contribute to stress, while headaches and difficulty breathing contribute to fatigue (Thiagarajan 2021). The results of the survey on the physical discomfort symptoms of using PPE for handling COVID-19 are presented in table 2.

Table 2. Symptoms of physical discomfort when using PPE for handling COVID-19

Discomfort group	Symptom	Q4	Q3	Q1	Q1	References
Physical Discomfort	Increase heat	√	√√√			Davey et al. 2021, Messeri et al. 2021, Yuan et al. 2020, Lembo et al. 2021
	Increase sweating	√	√√			Davey et al. 2021, Lee et al. 2020, Messeri et al. 2021
	Breathing difficulty	√	√√√	√√	√	Çağlar et al. 2021, Duan et al. 2021, Jegodka et al. 2021, Yuan et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020

Table 2. Symptoms of physical discomfort when using PPE for handling COVID-19 (continued)

Discomfort group	Symptom	Q4	Q3	Q1	Q1	References
Physical Discomfort	Dermatitis / allergic dermatitis / skin reaction / face acne		√√	√	√√	Çağlar et al. 2021, Duan et al. 2021, Messeri et al. 2021, Yuan et al. 2020, Xia et al. 2020
	Device-related pressure injuries	√		√	√	Duan et al. 2021, Tabah et al. 2020, Xia et al. 2020
	Hand maceration or foot erosion				√	Duan et al. 2021
	Trunk or limbs heat rash				√	Duan et al. 2021
	Conjunctivitis or keratitis				√	Duan et al. 2021
	Perineal maceration				√	Duan et al. 2021
	Dryness of mouth				√	Thiagarajan et al. 2021
	Thirst	√	√	√		Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020
	Dizziness		√	√√		Davey et al. 2021, Yuan et al. 2020, Xia et al. 2020
	Nausea			√	√	Yuan et al. 2020, Xia et al. 2020
	Fatigue/ exhaustion	√√√	√√√	√	√√	Davey et al. 2021, Duan et al. 2021, Jegodka et al. 2021, Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020
	Headache	√√	√	√√√√	√	Çağlar et al. 2021, Davey et al. 2021, Hajjij et al. 2020, Messeri et al. 2021, Tabah et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020
	Hearing difficulty		√			Parush et al. 2020
	Seeing difficulty	√√	√	√		Parush et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020
	Communication difficulty		√			Singh et al. 2021
Doffing difficulty	√				Parush et al. 2020	
inability to use the bathroom			√		Tabah et al. 2020	

Based on table 2, it can be identified that the occurrence of complaints of physical discomfort experienced by health workers when using PPE for handling COVID-19 with survey results above 75% (Q4), namely:

1. Increase heat (Davey et al. 2021, Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020, Yuan et al. 2020, Lembo et al. 2021).
2. Increase sweating (Davey et al. 2021, Lee et al. 2020, Messeri et al. 2021)
3. Breathing difficulty (Çağlar et al. 2021, Duan et al. 2021, Gordon et al. 2021, Jegodka et al. 2021, Yuan et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020).
4. Device-related pressure injuries (Duan et al. 2021, Tabah et al. 2020, Xia et al. 2020)
5. Thirst (Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020)
6. Fatigue/exhaustion (Davey et al. 2021, Duan et al. 2021, Gordon et al. 2021, Jegodka et al. 2021, Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Wang et al. 2021, Choudhury et al. 2020)
7. Headache (Çağlar et al. 2021, Davey et al. 2021, Gordon et al. 2021, Hajjij et al. 2020, Messeri et al. 2021, Tabah et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020)
8. Seeing difficulty (Parush et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021)
9. Doffing difficulty (Parush et al. 2020)

The symptoms of discomfort experienced when carrying out activities using PPE for handling COVID-19 vary widely. An increase in body temperature when using PPE for handling COVID-19 for a long time in a hot environment results in symptoms of heat stress and heat related illness that interfere with physical and cognitive performance (Davey et al. 2021, Lee et al. 2020). Heat stress experienced causes symptoms of increased sweat and thirst (Davey et al. 2021, Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020). One part of PPE for handling COVID is a mask that is used to filter viruses from the air that is inhaled by the nose. The very small size of the virus (0.08-0.12) microns (Vajda et al. 2016) requires the mask pore size to be smaller, resulting in users having difficulty breathing (Çağlar et al. 2021, Duan et al. 2021, Gordon et al. 2021, Jegodka et al. 2021, Yuan et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020). Another discharge caused by masks is dry mouth due to change from nasal to oral breathing (Harber et al. 1997).

Several complaints related to the skin are experienced by health workers when using PPE for handling COVID-19. The first complaint was hand dermatitis as a result of wearing gloves (Çağlar et al. 2021). Prolonged use of PPE plus a hot environment can exacerbate the effects of skin reactions (Messeri et al. 2021). PPE in contact with the skin, pressure on the skin, activity, and duration of use significantly resulted in injury to the skin of maceration of the hands or feet erosions, heat rash on the trunk or legs, conjunctivitis or keratitis, maceration of the perineum, or tinea corporis (Duan et al. 2021, Tabah et al. 2020, Xia et al. 2020).

PPE for handling COVID-19 protects the body from viral infections which are very small in size, and it is easily and quickly transmitted so that the PPE for handling COVID-19 is designed to cover almost the entire body so that it significantly causes users to experience difficult in doing activities in the toilet (Tabah et al. 2020) and difficulty changing PPE clothes (Parush et al. 2020). Another consequence is hearing loss (Parush et al. 2020, Singh et al. 2021), vision (Parush et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Choudhury et al. 2020) resulting in communication problems. (Parush et al. 2020, Singh et al. 2021). The use of PPE by health workers with different professions and work experiences has a significant effect on the level of dizziness (Davey et al. 2021, Yuan et al. 2020) and nausea (Yuan et al. 2020). Fatigue / exhaustion and headaches are symptoms that have been widely reported from many surveys and has met a large percentage (Q4) (Çağlar et al. 2021, Davey et al. 2021, Duan et al. 2021, Gordon et al. 2021, Hajjij et al. 2020, Jegodka et al. 2021, Lee et al. 2020, Messeri et al. 2021, Tabah et al. 2020, Singh et al. 2021, Thiagarajan et al. 2021, Wang et al. 2021, Choudhury et al. 2020).

5.2.2 Psychological Discomfort

The results of a survey on symptoms of psychological discomfort in using PPE for handling COVID-19 are presented in table 3.

Table 3. Symptoms of psychological discomfort when using PPE for handling COVID-19

Symptom group	Symptom	Q4	Q3	Q2	Q1	References
Psychological discomfort	Discomfort	√√√√√				Duan et al. 2021, Messeri et al. 2021, Yuan et al. 2020, Parush et al. 2020, Singh et al. 2021
	Insomnia / sleep disturbances		√		√	Duan et al. 2021, Yildiz et al. 2020
	Impact on working performance	√√				Çağlar et al. 2021, Messeri et al. 2021
	Anxiety / stress / depression		√		√	Duan et al. 2021, Singh et al. 2021

The impact of discomfort experienced by health workers is not only physical discomfort, but also psychological discomfort. The results of the investigation show that 54% of health workers reported that physical pressure and psychological pressure were both disturbing and 39% of health workers reported that psychological stress was greater than physical pressure while serving COVID-19 patients (Duan et al. 2021). Health workers experience discomfort while using PPE for handling COVID-19, it is proven that the survey results are in Q4 (Duan et al. 2021, Messeri et al. 2021, Yuan et al. 2020, Parush et al. 2020, Singh et al. 2021). Symptoms of psychological discomfort experienced

by health workers are anxiety, insomnia, depression, and sleep disorders / insomnia (Duan et al 2021, Yildiz et al 2020). In addition, emotionally, respondents feel anxiety, worry, fear, helplessness, and empathy because of transmitting COVID-19 and because of limited interventions in caring for patients in isolated environments (Gordon et al. 2021). Discomfort can negatively affect productivity, judgment, and emotions according to research showing that heat stress reduces work capacity (Chinnadurai et al. 2016) and increases errors (Hancock and Vasmatazidis 2003).

5.2.3 Cognitive Discomfort

The results of a survey on symptoms of cognitive discomfort by health workers when using PPE for handling COVID-19 are presented in table 4.

Table 4. Symptoms of cognitive impairment in the use of PPE for handling COVID-19

Symptom group	Symptom of cognitive tasks adversely	Q4	Q3	Q2	Q1	References
Cognitive tasks adversely	Making decisions			√	√	Davey et al. 2021, Parush et al. 2020
	Solving complex problems			√		Davey et al. 2021
	Retrieving information from short-term memory				√	Davey et al. 2021
	Difficulties to focus / concentrating	√	√	√√		Davey et al. 2021, Jegodka et al. 2021, Messeri et al. 2021, Parush et al. 2020

The use of PPE for handling COVID-19 affects the cognitive aspects of health workers in doing work. Cognitive discomfort in the form of difficulty focusing / difficulty concentrating reported from survey results is a high percentage and is in 2nd – 3rd quartiles (Davey et al. 2021, Jegodka et al. 2021, Messeri et al. 2021). This shows that the use of PPE for handling COVID-19 greatly affects health workers in concentrating or focusing on doing work taking care of the patients. Therefore, it requires special attention because it can affect the quality of service to patients. Other symptoms related to cognitive impairment reported were disturbances in solving problems and making decisions which were in the 2nd quartile and disturbances in retrieving information from short term memory which were in the 1st quartile (Davey et al. 2021, Parush et al. 2020).

5.3 Risk Factors for The Discomfort of Wearing PPE

The results of a survey on risk factors that affect the occurrence of discomfort / heat stress in using PPE for handling COVID-19 are presented in table 5.

Table 5. Risk factors for thermal stress / heat stress discomfort

Risk factors group	Risk factors	Strong evidence	Reasonable evidence	Insufficient evidence	Reference
Demografi	Gender		√√	√	Çağlar et al.2021, Xia et al. 2020, Yildiz et al. 2020
	Age		√√		Çağlar et al. 2021, Yildiz et al 2020
	Body mass		√√		Çağlar et al. 2021, Messeri et al. 2021
	Workplace, profesion (docter, nurse)		√√√√√√	√	Çağlar et al. 2021, Messeri et al. 2021, Yuan et al. 2020, Wang et al. 2021, Xia et al. 2020
Habit	Smooking		√		Çağlar et al. 2021
	Experience		√		Yuan et al. 2020
Use of PPE	Frequency of PPE use	√	√		Çağlar et al. 2021, Lee et al. 2020
	PPE duration	√√	√√√√√√		Çağlar et al. 2021, Hajjij et al. 2020, Messeri et al. 2021, Lee et al. 2020, Tabah et al. 2021, Wang et al. 2021, Xia et al. 2020, Yuan et al. 2020

Table 5. Risk factors for thermal stress / heat stress discomfort (continued)

Risk factors group	Risk factors	Strong evidence	Reasonable evidence	Insufficient evidence	Reference
Working environment	Ambient temperatures	√	√		Davey et al 2021, Lee et al. 2020
	Designated hospital		√		Xia et al. 2020
	Dedicated rest area		√		Lee et al. 2020
	Time taken to put on PPE		√		Lee et al. 2020
	Remove PPE on breaks		√		Lee et al. 2020

The risk factors for the occurrence of discomfort / thermal stress / heat stress in using PPE for handling COVID-19 are reported in the survey results. The risk factors are grouped into 4 groups of risk factors, namely demographics, habits, use of PPE and work environment. The risk factors reported as having strong evidence which influence thermal stress / heat stress, namely: frequency of PPE use (Çağlar et al. 2021 / Lee et al. 2020), duration of PPE use (Çağlar et al. 2021, Hajjij et al. 2020, Messeri et al. 2021, Lee et al. 2020, Tabah et al. 2021, Xia et al. 2020), and the temperature of the working environment (Davey et al. 2021, Lee et al. 2020). While the risk factors that have reasonable evidence are: gender (Çağlar et al. 2021, Xia et al. 2020), age (Çağlar et al. 2021), body weight index (Çağlar et al. 2021, Messeri et al. 2021), profession and workplace (Çağlar et al. 2021, Messeri et al. 2021, Yuan et al. 2020, Xia et al. 2020), hospital / workplace design (Xia et al. 2020), rest area design (Lee et al. 2020), the time required to wear PPE (Lee et al. 2020), and the time required to undress the time required to undress the PPE at rest (Lee et al. 2020). The risk factors mentioned above need to be considered for intervention so that they can support the safety, health, and comfort of workers in carrying out their duties.

The uncomfortable complaints felt by male and female respondents show a significant difference. Gender, duration of work, also reported significantly are different fatigue and anxiety (Wang et al. 2020). Physical complaints felt by women are higher than men. The number of physical complaints also differed significantly by age range, that aged between 41 to 50 years is lower than the age between 20 to 30 years old and those between 31 and 40 years old (Yildiz et al. 2020). Being overweight (BMI ≥ 25 kg / m²) cause a significant difference in complaints (Çağlar et al. 2021). Complaints from health workers are also significantly affected by the frequency and duration of PPE use, the longer and the more frequent of PPE use, the more discomfort it will be (Hajjij et al. 2020, Messeri et al. 2021, Yuan et al. 2020). Similarly, the type of occupation (profession) of health workers determines the level of complaints experienced (Hajjij et al. 2020, Yuan et al. 2020). Health workers who work in intensive care and who work in non-intensive care in Wuhan reported significantly different complaints (Wang et al. 2021). Working conditions with different temperatures result in different levels of discomfort. The wet bulb globe temperature (WBGT) in India is higher than Singapore resulting in a significant difference in discomfort (Lee et al. 2020).

Broadly speaking, the results of the systematic literature review are illustrated in Figure 2.

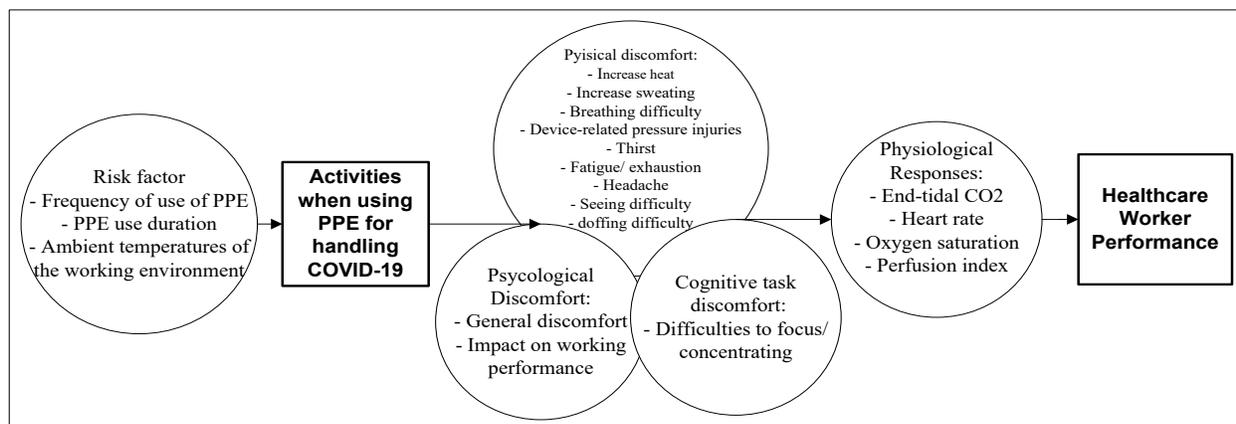


Figure 2. Mapping of risk factors, discomforts, and physiological responses

Risk factors in the form of frequency of use of PPE, PPE use duration, and Ambient temperatures of the working environment affect the activities of health workers when using PPE for handling COVID-19. Disruption of the activities of health workers when using PPE causes physical, psychological, and cognitive discomfort. The discomfort felt is responded by the body with the emergence of physiological responses in the form of a decrease in end-tidal CO₂, an increase in heart rate, a decrease in oxygen saturation, and a decrease in the perfusion index. The discomfort and physiological response experienced by health workers when using PPE will affect the performance of health workers when serving patients. Based on the picture above, there are risk factors that have not been studied, namely textile materials and PPE design, and physiological responses that have not been studied are changes in core body temperature and skin temperature.

6. Conclusion

Health workers must use PPE to prevent contracting or transmitting COVID-19 while serving patients. However, the use of PPE has side effects in the form of physical, psychological, and cognitive discomfort. The survey results reported discomfort with a very high number of respondent complaints experienced by health workers, namely increasing body temperature, increasing amount of sweat, breathing difficulty, pressure injury related to devices, thirst, fatigue, headaches, seeing difficulty, and difficulty in changing PPE clothes. Physiological responses with very strong evidence resulting from the use of PPE are heart rate, blood pressure, oxygen saturation, end-tidal CO₂, and perfusion index. Risk factors that have very strong evidence of the discomfort experienced by health workers when using PPE are duration of use, frequency of use and working conditions. This literature review provides information on side effects and risk factors for using PPE for handling COVID-19. The results of this study can be used as a basis and direction for researchers, designers, and manufacturers to produce PPE that meets requirements, supports performance and has better thermal comfort. Based on the results of this literature review, there are also opportunities for further research, namely the effect of PPE materials and designs on discomfort and a more complete physiological response with the addition of testing for core body temperature, skin temperature, and air temperature and humidity between the skin and PPE.

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