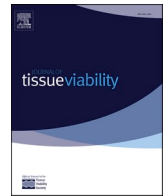




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# Protective equipment-related pressure ulcers in healthcare workers during COVID-19 pandemic: A systematic review

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## ABSTRACT

**Aim:** This systematic review was carried out to examine pressure ulcers in healthcare staff due to the use of protective equipment during COVID-19 pandemic and the precautions taken to prevent these injuries.

**Method:** Relevant studies were retrospectively searched. Seven English keywords identified from MESH were used while searching. The search was carried out in five international databases by trying various combinations of these words during February 15–25, 2021. This systematic review was updated by rescanning databases on December 20, 2021 and a total of 611 studies were attained.

**Results:** 17 studies which met the study inclusion criteria, which were conducted mostly through online survey method in different study designs and which included a total of 24,889 healthcare professionals were examined. The incidence of PPE-related pressure ulcers was found to be between 30% and 92.8%. Grade I pressure ulcers were the most common (44.1%–82%). The incidence of skin problems except PPE-related pressure ulcers such as itching, redness and dry skin was found to be between 42.8–88.1%. Risk factors that frequently played a role in the development of PPE-related pressure ulcers and other skin problems were longer use of PPE and sweating. PPE-related pressure ulcers and other skin problems were more frequent over the nose (nasal bone/nasal bridge), ears, forehead and cheeks. PPE-related itching, redness and dry skin mostly occurred. Several dressing applications were found to be effective in the prevention of PPE-related pressure ulcers and other skin problems that might develop especially on the facial region.

**Conclusion:** PPE-related pressure ulcers and other skin problems were found to be higher among healthcare professionals. Data regarding the sealing of dressing applications against viral transmission in the prevention of PPE-related pressure ulcers and other skin problems are limited. It is estimated that future studies will be performed to prevent device-related pressure ulcers in healthcare workers. It is suggested that there is a need to conduct studies with larger samples where expert researchers make observations for pressure ulcers in order to determine the prevalence and incidence of PPE-related pressure ulcers.

## 1. Introduction

Today, all countries are struggling with new type of coronavirus (COVID-19) which has become a global pandemic [1]. COVID-19, that spreads around the whole world rapidly, is highly infectious and some isolation studies have been carried out worldwide in order to prevent the spread of this disease which has a high mortality rate [2,3]. Healthcare staff are working on the frontline as well as performing isolation applications to protect their patients during this period [4]. During isolation, it is important for the healthcare workers to use personal protective equipment (PPE) while providing care to COVID-19 patients. The PPEs

such as gloves, N95 masks and protective clothes are the precautions taken for minimizing viral transmission risk. Healthcare professionals comply with the policies regarding the use of PPEs in many countries. The use of PPEs in healthcare systems has increased during this period and their usage time by healthcare professionals has prolonged [32]. Long working hours and extended use of PPE increase the risk for PPE-related pressure ulcers in the healthcare workers [5].

These PPE-related skin injuries are not new. In a study which was carried out in an acute care hospital in Singapore during Severe Acute Respiratory Syndrome (SARS) epidemic (n = 109), staff who used a mask regularly reported acne (59.6%), itching on face (51.4%) and

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redness (35.8%) [33]. In a recent study examining the effect of surgical face masks and N95 masks on physiological parameters, it was found that surgical face masks applied a lower pressure and facilitated the return of facial temperature to basal level. Due to these characteristics, surgical face masks were found to irritate skin less than N95 masks. Moreover in this study, it was reported that dressing cuts which were applied under N95 mask decreased localized force significantly. The results of this study were emphasized to form a basis for improving PPE designs since it described physiological test methodologies for quantitative comparison of the effects of several PPE types on facial skin [34].

Before COVID 19 pandemic, device-related pressure ulcers (DRPUs) were mostly examined and specific precautions were taken. An increase has been reported in DRPUs with the increased need for intensive care, increased use of prone position during the treatment and the use of PPE by the healthcare workers [4]. Together with the pandemic, healthcare professionals have begun to need help to prevent facial pressure ulcers which are DRPUs that have increased with the use of PPE. These ulcers, which are primarily caused by facial masks and eyegoggles, may lead to skin damage in the armpits, pubic region and extremities [4]. Some cases have been examined to identify and prevent the risk factors for PPE-related DRPUs in the literature [6–12]. In the literature, it has been emphasized that PPE-related pressure ulcers and skin lesions may affect life quality and operability of healthcare professionals and thus; they may unwillingly violate PPE protection while getting rid of such symptoms and lead to an increase in COVID-19 transmission risk [32]. Therefore, there is a need for emergency solutions for preventing PPE-related skin ulcers. A few number of studies have been conducted to examine data retrieved from the studies investigating the prevention of PPE-related skin ulcers. Based on this, this study was carried out to examine pressure ulcers due to the use of protective equipment in healthcare workers during COVID-19 pandemic and the precautions taken to prevent them.

## 2. Materials and methods

### 2.1. Study design and setting

This study was conducted by searching and reviewing relevant studies in a retrospective and systematic manner.

### 2.2. Study questions

1. What is the incidence of protective equipment-related pressure ulcers in healthcare workers during COVID-19 pandemic?
2. Which body parts are more exposed to these protective equipment-related pressure ulcers in the healthcare workers during COVID-19 pandemic?
3. What are the factors associated with protective equipment-related pressure ulcers in healthcare workers during COVID-19 pandemic?
4. Which treatments are used to prevent protective equipment-related pressure ulcers in the healthcare workers during COVID-19 pandemic?

### 2.3. Time of the study

The studies to be included were collected and identified between February 15–25, 2021. This systematic review was updated by rescanning databases on December 20, 2021.

### 2.4. Sample

Literature review was performed by using various combinations of the keywords including “COVID-19”, “healthcare workers”, “healthcare staff”, “protective equipment”, “personal protective equipment”, “pressure injury” and “pressure ulcer” in Cochrane Library, Web of Science, Pubmed, ScienceDirect and Wiley Online Library databases. The search

was made in English language.

The studies which have been published since the onset of COVID-19 pandemic in 2019 were examined in the study. The search was made during the time period until February 2021 including 2019. Databases were rescanned on December 20, 2021 and the studies conducted since February 2021 were also included in the systematic review. Randomized controlled studies, meta analyses, descriptive and cross-sectional studies examining protective equipment-related pressure ulcers in the healthcare workers were identified as the inclusion criteria.

The studies which did not meet the criteria above were excluded.

A total of 611 studies were found at the end of literature search. The studies were examined according to the titles and abstracts. 594 studies, which did not meet inclusion criteria, were excluded (Fig. 1). “Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-2009” guideline was admitted during the examination of the studies [13]. Studies, which met the inclusion criteria, were examined by the researchers independently by preparing a list in order to minimize the risk of bias. No ethics approval was taken since studies were found in open-access databases.

## 3. Results

### 3.1. Characteristics of the included studies

When the included studies were examined, it was seen that six studies were published in 2020 and 11 studies were published in 2021 in peer-reviewed journals. The studies were carried out by using different study designs. Nine studies were conducted as multicentric.

Sample sizes of the studies were different. All studies were carried out with healthcare workers. More than 4000 healthcare workers were accessed in two multicenter studies. It was seen that sample size was at least 10 [14], and up to 10287 [35]. In 15 studies [14–20,35–40,42], majority of the sample was composed of nurses. The results of the relevant studies were given in Table 1.

### 3.2. PPE-related pressure ulcers among healthcare professionals

The studies included in the review reported PPE-related pressure ulcers at ratios between 30% and 92.8%. Grade I pressure ulcers were the most common one (at ratios between 44.1% and 82%). In a study examining pressure ulcers based on PPE types, the incidence of DRPUs was found to be various. The studies examining PPE-related pressure ulcers among healthcare professionals have shown that the most affected body parts are nose (nasal bone/nasal bridge), ears, forehead and cheeks. In this study, it was found that at least one DRPU was developed in 77.1% of the nurses providing care to COVID-19 patients during their shifts, that 92.8% of the nurses experienced pain while using PPE and that the first DRPU occurred following the use of PPE for an average of 3 h [37].

The studies included have shown that the most common risk factors that play a role in the development of pressure ulcers are PPE usage time, sweating and lack of precautions for skin protection. Other risk factors were found as the age range of 20–29 years old, being older than 35 years old, being male, length of working hours, severe pain during the use of PPE and using PPE with the highest protection. It was found in the studies that PPE use resulted in many skin reactions [39] and sweating increased the risk of injury [38].

### 3.3. Other PPE-related skin problems and risk factors among healthcare professionals

In the studies examining PPE-related skin problems among healthcare professionals, such skin problems were reported to occur at varying rates between 42.8% and 88.1%. The most affected body parts were found to be nose, ears, cheeks and forehead. Healthcare professionals were found to experience PPE-related itching, redness and dry skin

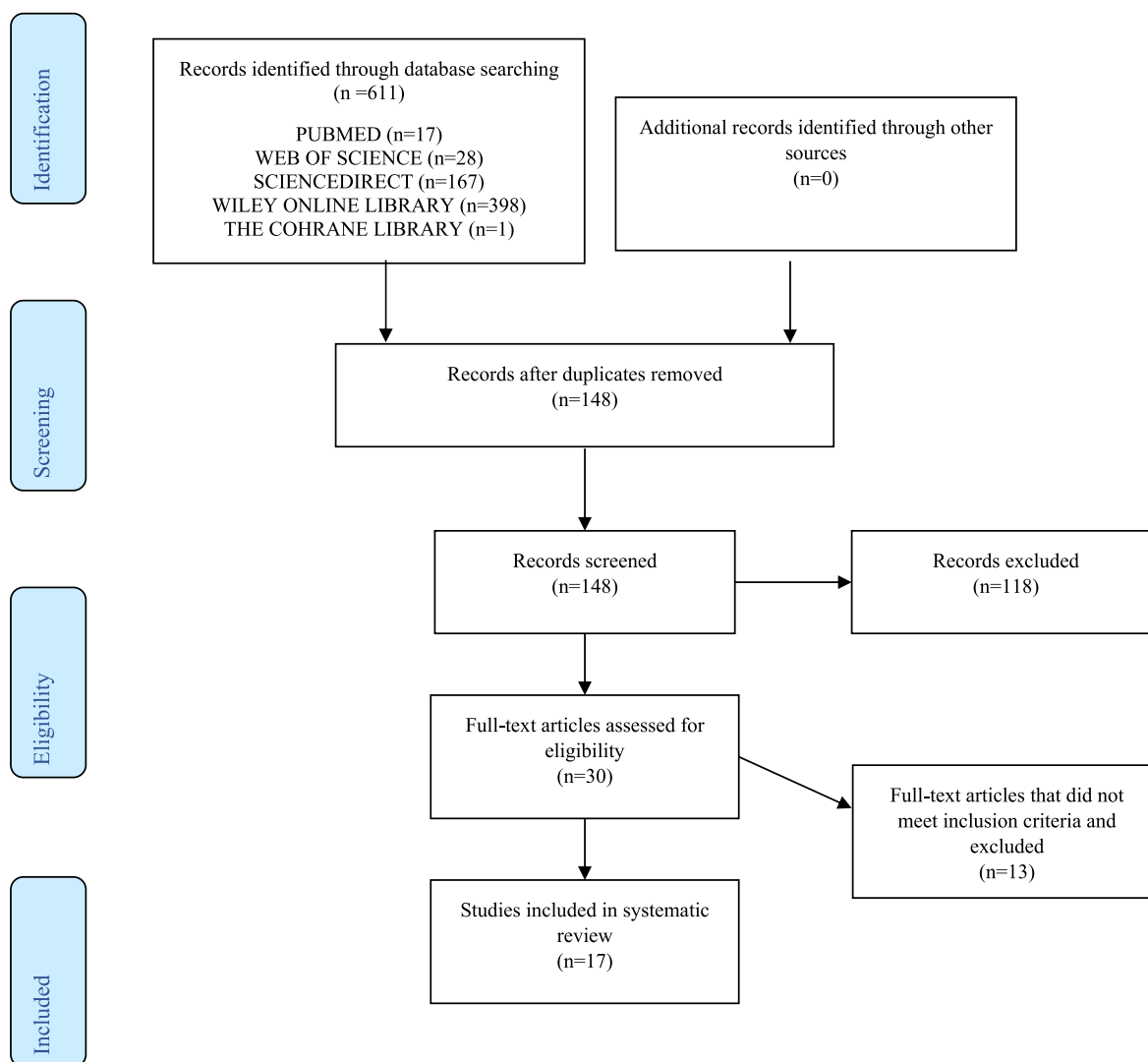


Fig. 1. Flow diagram of the study selection and exclusion process.

mostly. The most common risk factors for the development of skin problems have been reported as longer use of PPE [41], the use of PPE with the highest protection, being female and sweating. The other risk factors were chronic skin diseases and a history of allergy, frequent hand washing and being a nurse. In a study including more than a thousand healthcare professionals, skin lesions were observed among the nurses more significantly [17]. In another study with a sample size more than a thousand individuals, doctors (35.8%) were found to develop more DRPUs compared to the nurses (29.2%); but the difference was not statistically significant. Three types of injuries were observed including DRPUs, moist-related skin damage and skin tear. Sweating and daily PPE usage time were found to be correlated with skin injuries [15]. It was also indicated that healthcare professionals using F-PPE for more than 6 h per day had four-times higher ASR risk compared to those using less than 3 h [35].

### 3.4. The precautions taken to prevent PPE-related pressure ulcers and other skin problems among healthcare professionals

When the results of the studies included were examined, it was seen that several dressing applications were found to be effective in preventing PPE-related pressure ulcers especially on facial region and other skin problems. In a study comparing the use of foam and extra-thin hydrocolloid in the prevention of PPE-related DRPUs among

healthcare professionals, an hyperemia area was found to develop on the forehead, nose and nasal bridge in foam application. Hyperemia site was developed on the forehead, nose and nasal bridge at foam application and on the nasal bridge, right ear and left ear at hydrocolloid application. DRPUs were not developed in the healthcare staff. Among the healthcare workers using foam, itching was observed in 14.3%, detachment was observed in 66.7%, mask issues were observed in 14.3% and heating was observed in 4.8%. Pain, uncomfortable use, difficulty in removing dressing, stretched skin and other skin problems were not seen in this group. Among the healthcare workers using hydrocolloid, itching was seen in 21.9%, pain was observed in 12.5%, mask issues were observed in 6.3%, uncomfortable use was seen in 12.5%, difficulty in removing dressing occurred in 31.3%, stretched skin was found in 9.4% and other skin problems were seen in 6.3%. Detachment and heating were not seen in this group [19].

In another study, it was observed that skin injury occurred 10-times more in the group which did not use prophylactic dressing compared to the ones who did [18]. Moreover, in a study examining the efficiency of barrier film and hydrocolloid dressing, pressure ulcers only developed in 36.2% of the healthcare professionals using hydrocolloid dressing. Grade I pressure ulcer was developed in 19.8% of the healthcare staff who used hydrocolloid dressing and barrier film together [21]. In the study investigating the efficiency of respiratory liner application, respiratory liner was found to decrease pressure ulcers from 84.7% to

**Table 1**  
PPE-related pressure ulcers and other skin problems.

Study	Method	N	Intervention/Application	Results	Risk Factors	Outcome
Coelho et al., 2020	A cross-sectional study	1.106 healthcare workers	<ul style="list-style-type: none"> <li>Defining the incidence and risk factors of PPE-related pressure ulcers</li> </ul>	<ul style="list-style-type: none"> <li>The incidence of PPE-related pressure ulcer was 69.4%</li> <li>An average of 2.4 ulcers were seen per healthcare worker.</li> <li>Grade I (67%)</li> <li>Grade II (8.4%)</li> <li>DTI (0.4%)</li> <li>Nasal bone (31.7%)</li> <li>Forehead (18.5%),</li> <li>Ear (18.4%),</li> <li>Zygomatic (12.1%),</li> <li>Cheeks (11.5%) and</li> <li>Nasal wings (7.8%)</li> </ul>	<ul style="list-style-type: none"> <li>Using PPE for more than 6 h per day,</li> <li>Lack of precaution for skin protection,</li> <li>The length of working hours</li> <li>Being older than 35 years old.</li> </ul>	DRPUs showed a high prevalence among the healthcare worker population.
Jiang et al., 2020(a)	Multicenter, cross-sectional study	4.306 healthcare workers	<ul style="list-style-type: none"> <li>Examining the incidence, characteristics and preventive practices of PPE-related skin injuries</li> </ul>	<ul style="list-style-type: none"> <li>Overall prevalence of skin injuries was 42.8%</li> <li>17.7% of the staff took precautions.</li> <li>45.0% of the skin injuries were treated.</li> </ul>	<ul style="list-style-type: none"> <li>Longer use of PPE</li> <li>Using PPE with the highest protection</li> <li>Being male</li> <li>Over sweating</li> </ul>	It was emphasized that this was the first cross-sectional study which was carried out to recognize PPE-related skin injuries in healthcare workers and where adequate precautions were not taken.
Jiang et al., 2020(b)	Multicenter, cross-sectional study	4.306 healthcare workers	<ul style="list-style-type: none"> <li>Examining the prevalence and characteristics of PPE-related DRPUs</li> </ul>	<ul style="list-style-type: none"> <li>The prevalence of DRPUs was 30%.</li> <li>Nasal bridge (24.4%)</li> <li>Cheeks (23.4%),</li> <li>Auricles (20.3%),</li> <li>Forehead (10.9%)</li> <li>Other anatomical regions (chin, pubic region, neck, etc.) (1.09%)</li> <li>Grade I (82.90%)</li> <li>Grade II (15.94%)</li> <li>Grade III (0.49%)</li> <li>DTI (0.67%)</li> </ul>	<ul style="list-style-type: none"> <li>Being male</li> <li>Over sweating</li> <li>PPE with the highest protection</li> <li>The use of PPE for more than 4 h</li> </ul>	It was suggested to implement comprehensive prevention interventions.
Hu et al., 2020	A quantitative descriptive study	61 healthcare professionals	<ul style="list-style-type: none"> <li>Examination of adverse skin reactions (ASR) among the healthcare professionals using PPE</li> </ul>	<ul style="list-style-type: none"> <li>The incidence of N95 mask-related ASR was 95.1%, the most commons were scar on nasal bridge (68.9%) and itching on face (27.9%)</li> <li>The incidence of latex glove-related ASR was 88.5%; the most common ones were dry skin (55.7%), itching (31.2%) and redness (23.0%)</li> <li>The incidence of protective clothes-related ASR was 60.7%; the most common ones were dry skin (36.1%) and itching (34.4%)</li> </ul>	<ul style="list-style-type: none"> <li>Being female</li> <li>Age range of 20–29 years old</li> </ul>	ASR showed a high incidence among the healthcare professionals.
Kong et al., 2021	A cross-sectional study	207 healthcare workers	<ul style="list-style-type: none"> <li>Comparison of the psychological states and personal characteristics of healthcare workers who had PPE-related pressure ulcers</li> </ul>	<ul style="list-style-type: none"> <li>PPE-related pressure ulcer in 92.8%</li> <li>Erythema in 91.6%</li> <li>Complete serous blister in 8.4%</li> </ul>	<ul style="list-style-type: none"> <li>Age range of 20–29 years old</li> <li>Presence of severe pain due to the use of PPE</li> </ul>	Healthcare workers wearing PPE were susceptible to nasal and facial pressure injuries that increase their concerns about social appearance.
Bambi et al., 2021	A descriptive study	266 nurses	<ul style="list-style-type: none"> <li>Examination of PPE-related pressure ulcers among the Italian nurses providing care to COVID-19 patients</li> </ul>	<ul style="list-style-type: none"> <li>PPE-related pain (92.8%)</li> <li>The development of first DRPUs occurred within an average of 3 h hours</li> <li>PPE-related DRPUs (77.1%)</li> <li>The most common ulcers were seen on the nose and ears</li> <li>The ratio of DRPUs greater than Grade II (6.9%)</li> <li>Mostly hydrocolloid wound dressing (56.3%)</li> <li>Headache (27.8%)</li> <li>Itching (15.8%)</li> </ul>	<ul style="list-style-type: none"> <li>Lack of transparent dressings, softening creams and dressing were associated with DRPUs.</li> </ul>	Results have shown that PPE-related DRPUs may occur earlier at high rates.
Skiveren et al., 2021	A descriptive study	10287 healthcare professionals	<ul style="list-style-type: none"> <li>Examining ASR among the healthcare professionals using F-PPE</li> </ul>	<ul style="list-style-type: none"> <li>ASR prevalence (61.9%)</li> <li>Spots and pimples were commonly observed in surgical masks (37.2%)</li> </ul>	<ul style="list-style-type: none"> <li>Chronic skin diseases</li> <li>Sensitive skin</li> <li>Healthcare professionals using F-PPE for more than 6 h</li> </ul>	Different F-PPE types caused various skin reactions.

(continued on next page)

Table 1 (continued)

Study	Method	N	Intervention/Application	Results	Risk Factors	Outcome
Jiang et al., 2021	A cross-sectional study	1.611 healthcare professionals	<ul style="list-style-type: none"> <li>Investigating the relationship between wearing protective mask and goggles and skin ulcers.</li> </ul>	<ul style="list-style-type: none"> <li>Red and irritated skin were the most common ones among those wearing FFP3 masks (27.3%)</li> <li>ASR were higher among the ones who had chronic skin diseases (71.6%)</li> <li>Surgical mask-related DRPUs (1.7%)</li> <li>FFP3 mask-related DRPUs (2.7%)</li> <li>Face shield-related DRPUs (0.6%)</li> <li>Goggles-related DRPUs (0.3%)</li> <li>The prevalence of skin ulcers (79.5%)</li> <li>DRPUs (56.5%); grade I (44.1%), grade II (12.0%), grade III (0.2%) and DTI (0.3%)</li> <li>MASD (19.4%)</li> <li>ST (3.5%; all types 1).</li> <li>Multiple skin injuries (68.5%)</li> <li>Most damage was observed on nasal bridge, cheeks, ears and forehead.</li> </ul>	<ul style="list-style-type: none"> <li>Using goggles and N95 mask together</li> <li>Usage for more than 4 h</li> <li>sweating</li> </ul>	The importance of the prevention and management of sweating among the healthcare professionals wearing protective mask and goggles for more than 4 h was underlined.
Abiakam et al., 2021	A prevalence study and a prospective study	Prevalence study n = 108 Prospective study n = 307	<ul style="list-style-type: none"> <li>Investigating 24-hour prevalence of the effect of PPE on skin health and multicentric forward-looking formation</li> </ul>	<ul style="list-style-type: none"> <li>The most common ones were nasal bridge (69%) and ears (30%) in the prevalence study.</li> <li>In the prospective study, there were six adverse skin reactions with the most commons such as redness (33%), itching (22%) and pressure damage (12%).</li> </ul>	<ul style="list-style-type: none"> <li>Daily average PPE usage time</li> <li>Uninterrupted PPE usage time</li> <li>Type and model of PPE</li> <li>The number of consecutive days of using PPE</li> </ul>	It was concluded that there was a compelling need for improving PPE usage guidelines and their production materials/design to ensure worker safety.
Yuan et al., 2021	A cross-sectional study	275 healthcare professionals	<ul style="list-style-type: none"> <li>Examining skin damage reported by the healthcare professionals</li> </ul>	<ul style="list-style-type: none"> <li>Overall prevalence of skin reactions (77.09%)</li> <li>Regions under pressure;</li> <li>Under nose (78.54%)</li> <li>Cheeks (70.55%),</li> <li>Forehead (55.63%)</li> <li>Auricles (52.36%)</li> <li>ASR;</li> <li>Nasal bridge (54.25%)</li> <li>Cheeks (52.83%)</li> <li>Forehead (55.25%)</li> <li>Auricles (21.70%)</li> <li>Hands (37.45%)</li> <li>Preventive strategies such as prophylactic dressing (54.55%)</li> <li>Lack of information about dressing was more than 75%</li> </ul>	<ul style="list-style-type: none"> <li>Gender,</li> <li>Protection level</li> <li>Daily average usage time</li> </ul>	It was recommended to take more attention to skin safety, to apply suitable protective strategies and to have training.
Etgu and Onder, 2021	A cross-sectional study	1142 healthcare professionals	<ul style="list-style-type: none"> <li>Investigating skin problems associated with the use of PPE and personal hygiene measures.</li> </ul>	<ul style="list-style-type: none"> <li>Adverse skin reactions due to PPE and personal hygiene precautions (88.1%)</li> <li>Skin problems due to gloves (54.4%)</li> <li>Due to surgical mask (47%)</li> <li>Due to N95 mask (34.6%)</li> <li>Due to FFP3 masks (22.5%),</li> <li>Due to the goggles (18%)</li> <li>Due to face shields (12.4%)</li> <li>Erythema (64.4%)</li> <li>Dryness (57.9%)</li> <li>Acne (35,6%)</li> <li>Ulcer (34.7%)</li> <li>Peeling (28.2%)</li> <li>Running nose (21,1%)</li> <li>Lichenification (16.5%)</li> </ul>	<ul style="list-style-type: none"> <li>Being female,</li> <li>Working as a nurse, wearing PPE for more than 6 h per day</li> <li>Working for more than 3 days per week</li> <li>Frequent hand washing,</li> <li>History of allergic disease</li> <li>Washing hands with alcohol-based products</li> </ul>	Suitable protective precautions should be taken to prevent PPE-related skin problems.

N: Number of samples, Personal Protective Equipments- PPE, Device-Related Pressure Ulcers- DRPUs, Deep Tissue Injury-DTI, Moisture-Associated Skin Damage- MASD, Skin Tear-ST, Respiratory Protective Equipment-RPE, Adverse Skin Reactions-ASR. Face Personal Protective Equipment- F-PPE.

11.1% and reduced PPE usage-related discomfort from 91.6% to 6.3%. PPE-related pain was alleviated by the application of respiratory liner [22]. It was also emphasized in another study that 54.5% of the healthcare professionals applied prophylactic dressing and more than 75% had a limited knowledge about dressing [42].

A study showed that applying both types of thin dressings (light silicone foam dressing or soft silicone perforated tape dressing) under nanofiber bacterial surgical respirators would not endanger face sealing needed to protect healthcare professionals from viral transmission. The results of the studies investigating the precautions taken to prevent PPE-related pressure ulcers and other skin problems among healthcare professionals were given in Table 2.

#### 4. Discussion

Coronavirus disease, that has become a global pandemic affecting whole world, does not affect only frontliner healthcare staff, but also all hospital workers including cleaning and maintenance areas significantly. PPEs are used not only by healthcare workers who have contact with COVID-19 patients, but also by all staff working in the healthcare institution. During this period, the incidence of ulcers and lesions has been increased due to the intense use of PPE. While precautions to prevent DRPUs among the patients were investigated previously, DRPU prevention methods against the use of PPE in healthcare workers have been searched during the pandemic [4]. Based on this, studies investigating PPE-related pressure ulcers were examined in line with the study

questions.

In the studies examining PPE-related pressure ulcers among healthcare professionals, such ulcers were reported to occur at various rates. Grade I pressure ulcers were found to be the most common one. The incidence of pressure ulcers was found to vary depending on the PPE types. The most affected body parts were found as nose (nasal bone/nasal bridge), ears, forehead and cheeks. PPE-related itching, redness and dry skin frequently occurred in healthcare professionals. Several dressing applications were found to be effective in the prevention of PPE-related pressure ulcers and other skin problems that might develop especially on the facial region. However, the evidence of these applications regarding face sealing needed to protect healthcare professionals from viral transmission are limited. In one study, the sealing of both types of dressings applied under the mask (light silicone foam dressing or soft silicone perforated tape dressing) against viral transmission was proved. More evidence is needed for safe dressing application under PPE.

In a study examining DRPUs in the patients before COVID-19 pandemic, ulcers were found to develop on the ears by 29%, feet by 12% and nose by 10%. At the same time, it was reported in this study that ulcers were due to nasal oxygen cannula in 26%, splints in 12% and continuous positive airway pressure in 9% [23]. It has been seen that face is the anatomical region that is most affected by medical device-related pressure ulcers both in the healthcare workers and the patients. In the literature, it has been emphasized that the type of material from which device is made (solid material), placement of the

**Table 2**  
Precautions taken to prevent PPE-related pressure ulcers and other skin problems.

Study	Method	N	Intervention/Application	Results	Outcome
Smart et al., 2020	Observational cohort study	10 healthcare workers	<ul style="list-style-type: none"> <li>Application of a silicone-based dressing under N95 mask</li> </ul>	<ul style="list-style-type: none"> <li>It was seen that oxygen levels were improved, comfort was increased and mask gasket was not impaired at the end of applying silicone dressing for 4 h.</li> </ul>	It was emphasized that silicone dressing was effective in skin protection significantly.
Yildiz et al., 2021	Comparative observational study	48 healthcare workers CG: n = 20 EG1: n = 20 EG2: n = 8	<ul style="list-style-type: none"> <li>CG was applied PPE procedure of the institution.</li> <li>EG 1 was applied prophylactic dressing</li> <li>EG 2 was applied prophylactic dressing and single-sided adhesive nasal strip</li> <li>Daily evaluation</li> </ul>	<ul style="list-style-type: none"> <li>The rate of PPE-related skin injury was 47.9%.</li> <li>Injury was present in two healthcare workers in EG1, one worker in EG2 and all workers in CG.</li> <li>Healthcare workers who used nasal strip and prophylactic dressing together did not experience difficulty in breathing (<math>p &lt; 0.001</math>).</li> </ul>	It was recommended to use prophylactic dressing under PPE.
Zhang S. et al., 2021	Self-controlled study	116 healthcare workers	<ul style="list-style-type: none"> <li>Phase I: application of a hydrocolloid wound dressing for the first two weeks</li> <li>Phase II: application of hydrocolloid dressing and barrier film at weeks 3 and 4.</li> </ul>	<ul style="list-style-type: none"> <li>Facial pressure ulcer in Phase II was less than Phase I (<math>p &lt; 0.05</math>).</li> <li>Facial skin comfort in Phase II was higher than Phase I (<math>p &lt; 0.05</math>).</li> </ul>	It was underlined that using barrier film and hydrocolloid wound dressing together might decrease facial pressure ulcers and increase comfort level of the skin.
Zhang W. et al., 2021	Multicenter self-controlled study	1161 healthcare workers	<ul style="list-style-type: none"> <li>Application of respiratory liner by using polyurethane foam</li> </ul>	<ul style="list-style-type: none"> <li>The rate of pressure ulcer: 11.1%</li> <li>IQR: 1</li> <li>Discomfort of use: 6.3%</li> </ul>	It was emphasized that application of a respiratory liner by using polyurethane foam might alleviate facial pressure ulcers.
Gasparino et al., 2021	A randomized clinical trial	88 healthcare workers Using foam n = 44 Using hydrocolloid n = 44	<ul style="list-style-type: none"> <li>Comparison of the use of foam and extra thin hydrocolloid in the prevention of PPE-related pressure ulcers</li> </ul>	<ul style="list-style-type: none"> <li>No pressure ulcer was developed.</li> <li>No significant difference was found between groups in terms of discomfort and skin condition (<math>p &gt; 0.05</math>).</li> </ul>	It was indicated that foam and extra thin hydrocolloid were effective in preventing PPE-related pressure ulcers.
Yip and Yip, 2021	Experimental study (not randomized controlled)	24 healthcare professionals Light silicone foam dressing n = 12 Soft silicone perforated tape dressing n = 12	The efficiency of two different dressings applied under FFRs was investigated. Quantitative fit testing was done.	<ul style="list-style-type: none"> <li>No skin reactions were observed in 23 healthcare professionals at the end of 240-min application.</li> </ul>	<ul style="list-style-type: none"> <li>The study showed that applying both types of thin dressings (light silicone foam dressing or soft silicone perforated tape dressing) under nanofiber bacterial surgical respirators would not endanger face sealing needed to protect healthcare professionals from viral transmission.</li> </ul>

N: Number of samples, Control Group-CG, Experimental Group-EG, Personal Protective Equipments-PPE, Pain scores are median-IQR, Disposable Filtering Facepiece Respirators-FFRs.



device on the body parts with small amount of adipose tissue, methods used to fix the device and shear forces caused by the device are effective in the development of DRPUs [24]. The devices keep skin tissue under risk for irritation, pressure and disruption especially when their rigidity and flexibility are combined with the difficulties in their adjustment and fixation. The moist derived from the secretions, drainage and/or sweating around the device may make the skin more susceptible to the injury. Moist and heat occurring between the device and skin changes microclimate of the skin [25,24]. Moreover, the tools used to fix the devices (bands/strips) make it difficult to examine the skin. The lack of awareness among healthcare professionals regarding the examination of body parts under the medical devices increases the risk of injury. The ulcer may progress rapidly when medical devices are placed on the body parts with less amount of adipose tissue [26,25]. When the included studies were examined, it was seen that the facial region including less amount of adipose tissue was mostly affected also in healthcare staff due to the use of mask.

Most of the studies included in this systematic review were cross-sectional and descriptive studies conducted online through surveys. In the studies, healthcare professionals were asked to report PPE-related pressure ulcers or skin problems themselves. Since skin was not evaluated by the researchers in terms of non-whitening erythema, there were limitations to the fact that skin damage was a confirmed pressure ulcer. The skin of healthcare professionals was observed by the experts in four studies which were planned as observational and experimental [14,18,19,36]. It is suggested that there is a need to conduct studies with larger samples in order to determine the prevalence and incidence of PPE-related pressure ulcers. At the same time, observation of the healthcare professionals for pressure ulcers by expert researchers will help to confirm the prevalence or incidence of PPE-related pressure ulcers among healthcare professionals.

The important points in preventing skin injuries associated with the use of PPE were determined also for the healthcare workers by National Pressure Injury Advisory Panel (NPIAP) that conducts studies for the prevention of pressure ulcers. They recommended healthcare staff to clean the skin before and after wearing PPE, to treat PPE-related ulcers, to decrease the pressure caused by PPE and to get training about personal hygiene. In addition to this, NPIAP does not suggest a strategy on the dressings used under PPE [27]. In their 2019 guideline, NPIAP introduced evidence-based recommendations for the prevention of DRPUs in the patients, at the same time they made important warnings about them to be applied on healthcare workers during COVID-19 pandemic [28,27]. NPIAP reviewed the evidence on the prevention of pressure ulcers and the effective use of PPE. After reviewing the data, they underlined the presence of uncertainties regarding prophylactic dressings used under N95 mask [4,27]. There are some studies in the literature that prove the utility of thin prophylactic dressings in the patients to prevent DRPUs [29–31]. It has been also determined that these data would provide indirect evidence for PPE masks, but there are no studies proving the safety of mask against viral penetration and comparing the fit of the mask on the face [27]. NPIAP also emphasized the need for more data regarding the prevention of PPE-related pressure ulcers without increasing the infection risk in healthcare workers [27].

## 5. Strengths and limitations

This systematic review was limited to 17 studies which met the inclusion criteria.

## 6. Conclusion

During COVID-19 pandemic, healthcare staff may be exposed to PPE-related pressure ulcers mostly on the facial region. Healthcare workers should use PPE for this disease which has a high risk of viral transmission in order to protect their patients as well as themselves. PPE-related pressure ulcers and other skin problems may cause difficulties

for healthcare professionals in patient care. The body parts where the pressure ulcers are frequently seen must be protected in order to decrease the incidence of PPE-related pressure ulcers and to alleviate the skin problems such as itching and erythema. Healthcare workers should be provided an evidence-based prevention training for DRPUs. It has been estimated that more studies will be conducted to prevent the development of DRPUs among the healthcare professionals in the future.

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## Declaration of competing interest

The authors declare that they have no conflict of interests.

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