

SYSTEMATIC REVIEW

Skin adverse events related to personal protective equipment: a systematic review and meta-analysis

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Abstract

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a global pandemic that has spread all over the world. To avoid the virus transmission, healthcare workers must wear adequate personal protective equipment (PPE). PPE is associated with several side events, including skin reactions. The objective of this study was to summarize the prevalence, type and risk factors for cutaneous adverse events related to PPE and prevention measures to avoid them. A systematic review and meta-analysis was conducted using MEDLINE, Scopus and EMBASE databases from conception to 21 January 2021. All types of epidemiological studies regarding skin adverse events related to PPE were included. The literature search identified 1007 references, 35 of them met the eligible criteria and were included for analysis, representing 31 453 participants. The media of skin side events related to PPE was 75.13%. The rate of cutaneous adverse events related to mask was 57.71%, and those associated with gloves and hand hygiene products was 49.16%. Most common skin adverse events were contact dermatitis, acne and itching. The most damaged anatomical regions were the nasal bridge, the cheeks and the hands. The duration of PPE wearing was the most common risk factor. Frequent handwashing, gloves and masks were the agents most frequently related to skin reactions. N95 respirators were the most harmful mask type for the skin. Hydrocolloid use prevented from developing skin adverse events related to masks. In conclusion, the rate of cutaneous adverse events related to PPE use is high. A longer duration of PPE wearing was the most common risk factor. Using hydrocolloid could prevent from skin injuries related to mask use.

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Conflicts of interest

The authors declare no conflict of interest.

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Introduction

In December 2019, a novel virus, called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and causal agent of the novel coronavirus-2019 disease (COVID-19), emerged in Wuhan, China Popular Republic, and rapidly spread around the world. Currently, more than 90 million people have been infected, with up to 2 million of deaths worldwide.¹

To fight against the pandemic and avoid the virus transmission, healthcare workers (HCWs) must wear adequate personal protective equipment (PPE), including medical masks, goggles or face shields, plastic gowns and gloves, and perform frequent handwashing.² The long-term working sessions and the daily use

of the PPE can lead to physical and psychological disturbances among HCWs.^{3,4} Moreover, several cutaneous adverse events have been related to PPE.⁵ Nevertheless, the prevalence of skin cutaneous adverse events related to PPE ranges between different studies,^{6,7} it is not known the type of material most likely to cause skin damage, and there is scarce evidence regarding preventive measures to avoid adverse skin events related to PPE.^{8,9}

The aims of this study were to summarize the prevalence, type and risk factors for cutaneous adverse events related to PPE and to evaluate preventive measures taken to avoid cutaneous adverse events related to PPE in HCWs and the general population.

Material and methods

Design

A systematic review and meta-analysis were conducted (Supplementary Material).

Research questions:

- 1 What is the prevalence of skin adverse events related to PPE?
- 2 Which are the most common skin adverse events associated with PPE and which are the most affected regions?
- 3 What are the risk factors for developing skin side events related to PPE?
- 4 What is the prevalence and what kind of side events are related to mask use?
- 5 What is the prevalence and what kind of side events are related to gloves and handwashing?
- 6 What prevention measures could be taken to avoid skin adverse events related to PPE?

Search strategy

A literature search was performed using MEDLINE, Scopus and EMBASE databases from conception to 21 January 2021, following PRISMA Guidelines (Supplementary Material). The following search algorithm was used: ((PERSONAL PROTECTIVE EQUIPMENT) OR GLOVES OR MASK OR FACEMASK OR (RESPIRATORY EQUIPMENT) OR (ALCOHOL-BASED HAND RUB) OR SOAP OR ALCOHOL) AND (SKIN OR CUTANEOUS OR DERMATOLOGY OR (SKIN REACTION) OR (SKIN ADVERSE EVENTS)) AND (COVID-19 OR (CORONAVIRUS DISEASE 2019)).

Inclusion and exclusion criteria

The search was limited to: (i) human data, (ii) *in vivo* studies, (iii) skin adverse events related to PPE and (iv) articles written in English. All types of epidemiological studies (clinical trials, cohort studies, case-control studies and cross-sectional studies) regarding skin adverse events related to PPE were included and analysed. Reviews, guidelines, protocols, case series, case reports and conference abstracts were excluded.

Study selection

Two researchers (TMV and CCB) independently reviewed the titles and abstracts of the articles obtained in the first search to assess relevant studies. The full texts of all articles meeting the inclusion criteria were reviewed, and their bibliographic references were checked for additional sources. The articles considered relevant by both researchers were included in the analysis. Disagreements about inclusion or exclusion of articles were subjected to discussion until a consensus was reached. If not reached, resolution was achieved by discussion with a third researcher (AMLo).

Variables

The variables assessed were study design, rate and type of skin adverse events related to PPE, risk factors for developing skin manifestations, number of participants, author, country, age, sex, assessment tools, anatomical regions damaged and kind of preventive measures.

Statistical analysis

The overall prevalence of skin cutaneous events related to PPE was calculated by a random effect meta-analysis weighted by the study sample size. Forest plots were constructed to summarize the prevalence estimates and their 95% CIs. These figures present measures of heterogeneity across studies (Cochrane Q statistic, noted the I² statistic). Microsoft Excel version 2016, Redmond, WA, USA, was used to run these data.¹⁰

Results

The literature search identified 1007 references, 668 after removing duplicated papers. After reviewing the title and abstract, 136 records underwent full-text review. A total of 101 records were excluded because they did not investigate skin adverse events associated with PPE. Other reasons for exclusion along with the flow chart are shown in Fig. S1 (Supporting Information). Finally, 35 studies, representing 31 453 participants, met the eligible criteria and were included and fully reviewed.

What is the prevalence of skin adverse events related to general personal protective equipment?

The media of skin side events related to PPE was 75.13%, after conducting a random effect meta-analysis weighted by the study sample size (Fig. S1, Supporting Information). Thirteen studies explored cutaneous adverse events related to PPE.^{5-7,11-20} Seven studies evaluated the prevalence of skin side events related to PPE.^{5-7,11-14} All the reports were cross-sectional studies that evaluated the presence of skin side events with self-administered questionnaires. 1912 out of 2424 participants had skin side events, with high female:male ratio, and an age ranged from 20 to 65 years (Table 1).

Which are the most common skin adverse events associated with PPE and which are the most affected regions?

Contact dermatitis, acne and eczema were the most frequent disorders;^{19,20} itching and burning the most common symptoms;²⁰ and erythema and papules the most frequent signs.²⁰ The prevalence and the type of specific skin conditions related to PPE and the features of skin side events were also investigated¹⁵⁻¹⁸ (Table S1, Supporting Information).

The most frequently damaged anatomical regions were the nasal bridge (67.22%), the cheeks (66.9%) and the hands (62.6%).^{5,12,13} Soap and water (56.4%), gloves (47.5%),

Table 1 Studies regarding prevalence of skin adverse events related to personal protective equipment

Study and site	Design	Participants	Age (years)	Sex (female: male ratio)	Assessment tools	Prevalence of skin side events	Most common adverse events	Anatomical regions most damaged	Risk factors
Yuan <i>N et al.</i> China	Cross-sectional study	129 HCWs	NS	NS	Online self-administered questionnaire	94.6% (122/129)	Facial indentation, rash, dermatitis	NS	NS
Swaminathan R <i>et al.</i> UK	Cross-sectional study	72 HCWs	NS	1.7:1	Online self-administer questionnaire	43.2% (31/72)	NS	NS	NS
Pei S <i>et al.</i> China	Cross-sectional study	484 HCWs	20–60	3.14:1	Online self-administer questionnaire	73.1% (354/484)	Pruritus, erythema, prurigo, blisters, rhagades, papule/oedema, exudation/crust, lichenification	Face, hand, limbs, trunk	High level of protection, higher working frequency, longer duration of wearing protective suits [†]
Lin P <i>et al.</i> China	Cross-sectional study	376 HCWs	NS	3.5:1	Questionnaire	74.5% (280/376)	NS	Hands, cheeks, nasal bridge	Female sex, working in hospitals with a more severe epidemic, working in inpatient wards, longer PPE wearing periods (>6 h) [‡]
Lan J <i>et al.</i> China	Cross-sectional study	542 HCWs	20–56	3.8:1	Online self-administer questionnaire	97.0% (526/542)	Symptoms: Dryness/lightness, tenderness, itching, burning/pain Signs: Desquamation, erythema, maceration, fissure, papule, erosion and ulcer, vesicle, wheal	Nasal bridge, cheek, hands, forehead.	Wearing a N95 mask or goggles, longer PPE wearing periods (>6 h), frequent hand hygiene (>10 times daily) [‡]
Daye M <i>et al.</i> Turkey	Cross-sectional study	440 HCWs	33.5 (21.0–65.0)	1.5:1	Questionnaire	90.2% (397/440)	Dryness, itching, flaking, tingling, spalling, peeling, lichenification	NS	Not using moisturizers, previous history of allergies or skin disease, using mask with metal nose bridge and located especially on the nose [§]
Battista RA <i>et al.</i> 2020. Italy	Cross-sectional study	381 participants (185 HCWs, 31 people with high public contact job, 165 with low public exposure)	35.0 ± 11.7	2:1	Email/phone questionnaires	53.02% (202/381)	Itching, acne, skin rash, pressure-related symptoms	NS	Longer PPE wearing periods (>6 h), using a N95/FFP2 mask [‡]

Continuous data are expressed as media ± SD or median (interquartile range), and categorical data are presented as relative(absolute) frequencies. HCWs, healthcare workers; L3PPE, level 3 barrier protection personal protective equipment; NS, not specified; PPE, personal protective equipment.

[†]Non-defining statistical test.

[‡]Logistic regression analyses.

[§]Chi-square (χ^2) test.

sanitizers (38.6%) and masks (20.8%) were the most frequent culprit agents.²⁰

What are the risk factors for developing skin side events related to PPE?

Longer duration of PPE wearing was the risk factor most frequently associated with skin side events.^{5,7,12–14,19,20} Other risk factors related to high rate of cutaneous adverse events were female sex,¹² non-use of moisturizers,¹⁴ a previous history of dermatitis¹⁶ or wearing a N95 mask compared with a surgical one.⁷

What is the prevalence and what kind of side events are related to mask use?

The media prevalence of skin side events related to mask use was 57.17% after conducting a random effect meta-analysis weighted by the study sample size (Fig. S2, Supporting Information). Eleven studies evaluated the skin effects related to mask wearing.^{21–31} Four studies analysed the overall prevalence of skin side events related to mask wearing^{21–24} (Table 2). All of them were cross-sectional studies assessing the prevalence by questionnaires. 5296 participants were included, 3900 non-HCWs and 1396 HCWs. 2430 participants reported cutaneous adverse events related to mask use. The prevalence of skin side events related to mask use was higher in HCWs (63.14%) than that in non-HCWs (42.38%) without statistically significant differences (Fig. S4, Supporting Information). Longer periods of mask wearing were a risk factor for skin adverse events,^{21,22} while controversial results were found regarding the type of mask. Most reports observed that wearing a surgical mask was a risk factor for developing skin side events compared with other kind of mask.^{21,23,24} Nevertheless, Matusiak *et al.*²² showed that surgical mask was a protective factor for sweating and itch. Acne and itching were the most common adverse events reported in these studies.^{21–23}

Moreover, two studies analysed itching related to mask wearing^{25,26} (Table 2). Itching was reported in 875 out of 4644 participants. The worst intensity of itch using a numeric rating scale was moderate in most cases. Sensitive skin, atopic predispositions, facial dermatoses (such as acne or seborrheic dermatitis) and longer periods of mask use were risk factors for developing mask-related itching.^{25,26} The frequency of itching was also higher in people wearing a N95/FFP2 mask compared with other types of masks.²⁵

In addition, five studies evaluated skin barrier function impairment due to mask wearing^{27–31} (Table 3). Temperature^{27,28,30,31} and redness or erythema^{28–30} were higher while stratum corneum hydration (SCH)^{28–30} was lower on the mask-covered area compared with the non-covered one. Controversial results were observed in other parameters. The effect in skin barrier function between surgical mask and N95 one has been evaluated in three studies.^{27,29,30} Two studies showed higher transepidermal water loss (TEWL) values on the mask-covered

area compared with the non-covered,^{29,30} while another two investigations did not report changes between both areas.^{28,31} Comparing different types of masks, it was observed that temperature increase was higher when using a N95 mask (1.2 vs. 0.7°C).²⁸ Nevertheless, greater TEWL increases were found when using a surgical mask (12.54 vs. 5.28 g/h/m², $P = 0.026$).³⁰ Other study did not report differences in skin homeostasis parameters between types of masks.³⁰

What is the prevalence and what kind of side events are related to gloves and handwashing?

The media prevalence of skin side events related to gloves and handwashing was 49.16% after conducting a random effect meta-analysis weighted by the study sample size (Fig. S5, Supporting Information). Skin effects related to gloves use and handwashing were evaluated in nine studies^{24,30,32–38} (Table 4). Three studies evaluated the general prevalence of skin adverse events associated with gloves use and hand hygiene in 3713 participants (3283 non-HCWs and 430 HCWs).^{24,32,33} 1475 participants reported skin side events. The prevalence of skin side events related to gloves and handwashing was higher in HCWs (68.16%) than in non-HCWs (36.88%; Fig. S6, Supporting Information).

One report also found that hand skin manifestations increased by 8.4% compared with the pre-pandemic period.³³ Most common adverse event was dryness, erythema, itching and fissures.^{24,32,33} Female sex,³³ working in unit with COVID-19 patients,³³ handwashing more than 10 times/day,²⁴ alcohol concentration >60%²⁴ and using gloves²⁴ were related to a higher rate of skin adverse event.³³

Furthermore, three studies evaluated the prevalence and risk factors of hand eczema in 7079 participants (6858 children and 221 HCWs).^{34,36,37} The prevalence of hand eczema in children was 38.3% (2627/6858) during the pandemic, and it increased by 26.2% compared with the pre-pandemic period. The prevalence of hand eczema in HCWs was between 14.9%³⁶ and 50.5%³⁷ without differences between HCWs working in COVID-19 intensive care units and HCWs without frequently contact with COVID-19 patients.³⁶ People in the first group were surgeons and nurses from a single surgical centre, and participants in the second group were physicians and nurses from an intensive care unit for COVID-19 patients. The median Hand Eczema Severity Index was 24 (range 3–84).³⁷ Female gender,³⁴ previous history of atopic dermatitis³⁴ or hand eczema³⁷ and high frequency of handwashing^{34,37} were risk factors associated with hand eczema. Its most frequent morphology was erythematous squamous (75.8%, 41/54), and the most common affected area was the hand dorsum (85.2%, 46/54).³⁷

Contact urticaria was observed in 8.2% (32/390) HCWs and was associated with the number of working hours and previous history of dermatological diseases.³⁵ Irritant contact dermatitis was reported in 42.4% (4496/6273) children. Female gender and

Table 2 Studies regarding the prevalence of skin adverse events related to mask wearing

Study and site	Design	Participants	Age (years)	Sex (female: male ratio)	Type of masks	Assessment tools	Prevalence of skin adverse events	Main adverse events	Risk factors
General skin adverse events									
Techasatian L <i>et al.</i> Thailand	Cross-sectional study	833 participants. 357 HCWs (42.9%) and 476 non-HCWs (57.1%)	32 (IQR 25–41)	2.75:1	-526 surgical masks (63.15%) -292 cloth masks (35.05%) -9 surgical masks covered by a piece of cloth (1.0%) -6 N95 masks (0.72%)	Questionnaire	54.5% (454/833)	Acne, rashes, itch, pigmentation and pressure-related skin injuries	Wearing a surgical mask compared with a cloth mask, longer periods of mask wearing (>4 h), mask reuse†
Matusiak, Ł <i>et al.</i> Poland	Cross-sectional study	876 HCWs	From 18 to 27	NS	NS	Online questionnaire	96.9% (849/876)	Warming/sweating, itch, skin irritation	Not wearing a surgical mask compared with the other types of masks†
Chaiyabutr C <i>et al.</i> Thailand	Cross-sectional study	1231 non-HCWs	NS	2.81:1	-1231 fabric masks (52.3%) -552 surgical masks (44.8%) -N95 mask (2.8%, n = 35)	Online self-administered questionnaires	62.3% (767/1231)	Acne, itching, greasy skin, erythematous rash, pain on mask border, dry skin, worsening of pre-existing dermatoses, abrasion	Surgical mask, female sex, age <40 years, having oily skin, having acne before starting to wear masks, longer periods of mask wearing (>4 h)†
Alsaïdan MS <i>et al.</i> 2020. Saudi Arabia	Cross-sectional study	2356 participants. HCWs (6.91%, n = 163) and non-HCWs (93.1%, n = 2193)	21 (IQR 18–26)	0.78:1	-1779 surgical/face masks (75.5%) -430 others (18.3%)	Online self-administer questionnaire	15.3% (360/2356)	Dryness, scaling, itchiness, redness, change in texture, change in colour, pain/burning, ulcer	Wearing a surgical mask compared with other types of mask‡
Itching									
Szepletowski <i>et al.</i> Poland	Cross-sectional study	2315 Polish students	20.2 ± 1.7	4.07:1	-755 three layers surgical mask (54.2%) -891 cloth mask (64%) -257 respirators (N95 + FFP) (18.4%) -16 half-face elastomeric respirator (1.1%) -8 full-face respirator: (0.4%)	Online questionnaire	19.6% (273/1393)	The WI-NRS was assessed as 4.07 ± 2.06 points (range 0–10 points), indicating itch of moderate severity	Sensitive skin, atopic predisposition, having atopic dermatitis, acne or seborrheic dermatitis and wearing face masks for longer periods (>5 h)†

Table 2 Continued

Study and site	Design	Participants	Age (years)	Sex (female:male ratio)	Type of masks	Assessment tools	Prevalence of skin adverse events	Main adverse events	Risk factors
Krajewski PK <i>et al.</i> , Poland	Cross-sectional study	2329 participants (1156 HCW and 1173 students)	HCW: 40.5 ± 11.8 Students: 20.9 ± 2.9	HCW: 4.48:1 Students: 2.79:1	-1363 surgical mask (58.52%) -591 cloth mask (25.37%) -221 respirators (N95/FFP2) (9.49%) -138 half-face mask: (5.93%)	Online questionnaire	All participants: 25.8% (602/2329) HCWs: 31.6% (365/1156) Students 20.2% (237/1173)	The WI-NRS was 4.6 ± 2.0 points for the whole population, 4.6 ± 2.0 points for HCWs and 4.7 ± 2.1 points for students, indicating a moderate itch severity	Sensitive skin, atopic predispositions, facial dermatoses, wearing face masks for longer periods (>4 h), wearing a N95/FFP2 mask compared with other types of masks§

Continuous data are expressed as media ± SD or median (interquartile range), and categorical data are presented as n or n/N (%).

AD, atopic dermatitis; FFP2, filtering respirator mask coded filtering facepiece 2; HCW, healthcare workers; NRS, numeric rating scale; SCH, stratum corneum hydration; TEWL, transepidermal water loss; WI-NRS, worst intensity of itch.

†Logistic regression analyses.

‡Chi-square (χ^2) test.

§Kruskal–Wallis one-way analysis of variance on ranks.

high frequency of handwashing were associated with high rate of irritant contact dermatitis.³²

Only one study reported objective impairment in skin barrier function associated with nitrile gloves use. They showed higher TEWL (31.11 vs. 14.24 g/h/m², $P < 0.001$), SCH (43.26 vs. 58.28 AU, $P < 0.001$), temperature (33.29°C vs. 32.57°C, $P < 0.001$) and erythema (243.97 vs. 215.55 AU, $P < 0.001$) at the area covered by gloves compared with the non-covered area.³⁰

What prevention measures could be taken to avoid skin adverse events related to PPE?

Hydrogel patch, small patches used in areas of pressure points of PPE, could be used to avoid skin injuries related to mask use. Four studies evaluated prevention measures for avoiding skin adverse events related to PPE^{8,39–41} (Table 5). All of them were focused on preventing skin injuries related to mask use. Zhou *et al.*³⁹ observed that hydrogel use decreased pain, itching and indentation both on cheeks and on nasal bridge in 26 HCWs wearing N95 masks. Moreover, Dong *et al.*⁴¹ observed that the use of hydrogel patch on one side of the face reduced overall skin reaction rate (including indentation, redness and pain) compared with the other side without hydrogel in 19 front-line HCWs using N95 masks. Dressing mask with extra-thin hydrocolloid was also compared with foam dressing in 88 HCWs without differences between groups in skin injuries.⁸ Furthermore, it was also observed that the use of prophylactic dressing and nasal strip reduced skin injuries by 2.5 times. Itching, erythema, papules, pustules and discomfort in breathing were also reduced, while satisfaction scores increased.⁴⁰

Moreover, it has been reported that the use of moisturizing hand cream might prevent from developing skin adverse events related to handwashing and gloves use (Table 4).

Discussion

In this systematic review, we have observed that the prevalence of skin adverse events related to PPE is high. Contact dermatitis, acne, eczema and itching were the most common skin adverse events. Masks and gloves are the agent most frequently related to cutaneous side events. Longer duration of wearing PPE was the most frequent risk factor for developing cutaneous reactions. Prevention measures were focused on skin injuries related to mask use.

Three out of four individuals could develop skin adverse events related to PPE. Nevertheless, this rate showed high variation between studies.^{5–7,11–14} Differences in participants (non-HCWs, HCWs in frequently contact with COVID-19 patients or HCWs not working in COVID-19 units) could explain these disparities.⁷ Moreover, the prevalence of skin adverse events was mainly evaluated by self-administered questionnaires. High variability rate was also observed in skin side events associated with masks,^{21–24} and gloves and handwashing.^{24,32,33} It was observed that the rate of skin side events related to both mask and gloves

Table 3 Studies regarding skin barrier dysfunction related to mask use

Study and site	Design	Participants	Age (years)	Sex (female: male ratio)	Type of masks	Assessment tools	Outcomes after mask removal	Outcomes comparing types of masks
Scarano A <i>et al.</i> Italy	Prospective observational crossover study	20 non-HCWs	NS	NS	- Surgical mask - N95 mask Wearing it for 1 h	Skin temperature, humidity, heat, discomfort, mask touching	Temperature increased at the perioral region and superior lip immediately after removal of the mask compared with baseline	Higher increases in temperature were observed with N95 wearing (1.2 ± 0.5) compared with surgical masks (0.7 ± 0.5°C). Humidity, heat, breathing difficulty, discomfort and mask touching were also higher under the N95
Park SR <i>et al.</i> Republic of Korea	Prospective observational study	21 non-HCWs	From 20 to 49	NS	Korea Filter 94 mask for 6 h	Temperature, redness, sebum secretion, SCH, TEWL, elasticity	Temperature and redness increased while SCH decreased on the mask-covered area compared with the non-covered area. Sebum secretion, TEWL and elasticity did not change	NS
Montero-Vilchez <i>et al.</i> Spain	Cross-sectional study	34 HCWs	44.97 ± 11.97	1.6:1	- Surgical masks (52.94%, n = 18) - FFP2 masks (47.06%, n = 16)	TEWL, SCH, temperature, erythema	TEWL, temperature and erythema were higher on the area covered by masks compared with the non-covered area while SCH was lower	TEWL was significantly greater at the area covered by a surgical mask than at the FFP2 one (12.54 vs. 5.28 g/h/m ² , P = 0.026)
Kim J <i>et al.</i> Korea	Prospective observational study	20 non-HCWs	28.10 ± 3.49	0.8:1	Korea Filter 94 mask for 6 h daily for 2 weeks	Temperature, redness, pore volume, texture, elasticity, TEWL, sebum content, pH	Temperature and pore volume increased after mask use. Elasticity and pH decreased. No differences in redness, roughness, TEWL and sebum were observed	NS
Hua W <i>et al.</i> China	A randomized crossover study with repeated measurements	20 non-HCWs	34.3 ± 11.5	10:1	- N95 respirators - Surgical masks	TEWL, SCH, erythema, pH and sebum secretion	SCH, TEWL, pH and erythema increased significantly after mask use and were higher at the area covered by the mask than at the non-covered area	There was no significant difference between the physiological values between the two types of masks. More adverse reactions and a higher score of discomfort and incompliance were reported following N95 mask use that following use of medical mask

Continuous data are expressed as media ± SD or median (interquartile range), and categorical data are presented as n or n/N (%). AD, atopic dermatitis; FFP2, filtering respirator mask coded filtering facepiece 2; HCW, healthcare workers; NRS, numeric rating scale, SCH, stratum corneum hydration, TEWL, transepidermal water loss; WI-NRS, worst intensity of itch.

Table 4 Skin adverse events related to gloves use and handwashing

Study and site	Design	Participants	Age (years)	Sex (female: male ratio)	Assessment tools	Aim	Main outcome	Other outcomes	Risk factors
Overall prevalence of skin adverse events									
Dindarloo K <i>et al.</i> Iran	Cross-sectional study	1090 non-HCWs	35.22 (range from 15 to 70)	1.12:1	Self-administered questionnaire	Overall prevalence of skin adverse events	41.4% (451/1090)	Most common skin adverse events: dryness, itching, redness and injuries	NS
Altuniski Toplu S <i>et al.</i> Turkey	Cross-sectional study	267 HCWs	35.0 ± 6.9	1.63:1	Self-administered questionnaire	Overall prevalence of skin adverse events	73.6% (203/267)	Most common skin adverse events: dryness, erythema, hand fissure, itching, burning-pain, vesicle	Female sex, working in units without COVID-19 patients¶
Alsaïdan MS <i>et al.</i> 2020. Saudi Arabia	Cross-sectional study	2356 participants. HCWs (6.91%, n = 163) and non-HCWs (93.1%, n = 2193)	21.00 (IQR: 18–26)	0.78:1	Online self-administered questionnaire	Overall prevalence of skin adverse events	34.85% (821/2356)	Most common skin adverse events: dryness, change in texture, scaling, itchiness, change in colour, redness, pain/burning, ulcer	Handwashing >10 times/day, alcohol concentration >60%, using hand gloves§
Prevalence of a specific skin condition									
Simonsen AB <i>et al.</i> Denmark	Cross-sectional study	6858 children using day care	3.4 ± 1.37	1:1	Parental self-administered questionnaire	Prevalence of hand eczema	38.3% (2627/6858)	The prevalence of hand eczema increased by 26.2% after the pandemic	Atopic dermatitis, female gender, older age, high frequency of handwashing;
Pourani MR <i>et al.</i> Iran	Cross-sectional study	390 HCWs	34.57 ± 9.41	2.9:1	Online self-administered questionnaire	Prevalence of hand contact urticaria	8.2% (32/390).	The rate of hypersensitivity to latex gloves was 32.6% (123/390) in all HCWs and 53.1% (17/32) in HCWs with contact urticarial	Longer work hours per week, history of dermatological diseases, allergic conjunctivitis, asthma, hypersensitivity to latex gloves†
Guertler A <i>et al.</i>	Cross-sectional study	114 HCWs: 35.9% (40/114) HCWs involved in intensive care and 64.91% (74/114) HCWs not involved	35.23 ± 10.78	1.59:1	Self-administered questionnaire	Prevalence of hand eczema	14.9% (17/114)	No differences in hand eczema between HCWs involved in intensive care of COVID-19 patients and HCWs without direct contact with COVID-19 patients were found	NS

Table 4 Continued

Study and site	Design	Participants	Age (years)	Sex (female: male ratio)	Assessment tools	Aim	Main outcome	Other outcomes	Risk factors
Erdem Y <i>et al.</i> Turkey	Cross-sectional study	107 HCWs	29.6 ± 6.3	2.06:1	Clinical evaluation	Prevalence of hand eczema	50.5% (54/107)	The median HECSI score was 24 (range 3–84)	The use of moisturizing hand cream in daily life, a previous history of hand eczema, handwashing frequency (>20 times/day)†
Borch L. Denmark	Cross-sectional study	6273 children	6.70 ± 3.12	1:1	Self-administered questionnaire	Prevalence of irritant contact dermatitis	42.4% (4496/6273)	NS	Female gender, schoolchildren compared with preschool, handwashing >7 times/day††
Assessment of skin barrier function parameters									
Montero-Vilchez T <i>et al.</i> Spain	Cross-sectional study	34 HCWs	44.97 ± 11.97	1.62:1	Skin homeostasis parameters: TEWL, SCH, temperature, erythema	To evaluate the effect of using nitrile gloves on epidermal barrier function	TEWL (31.11 vs. 14.24 g/h/m ² , <i>P</i> < 0.001), SCH (43.26 vs. 58.28 AU, <i>P</i> < 0.001), temperature (33.29°C vs. 32.57°C, <i>P</i> < 0.001) and erythema (243.97 vs. 215.55 AU, <i>P</i> < 0.001) were higher at the area covered by gloves compared with the non-covered area	NS	

Continuous data are expressed as media ± SD or median (interquartile range), and categorical data are presented as *n* or *n/N* (%). HCWs, Healthcare workers; HECSI, Hand Eczema Severity Index; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

†Analysis not specified.

‡Logistic regression analyses.

§Chi-square (χ^2) test.

¶McNemar test.

††Poisson regression with robust error variance.

Table 5 Prevention measures adopted to prevent skin adverse events related to personal protective equipment

Study and site	Design	Participants	Age (years)	Sex (female: male ratio)	Aim	Comparison groups	Follow-up	Assessment tools	Main outcomes
Zhou <i>N et al.</i> China	Clinical trial	26 HCWs wearing N95 masks	NS	NS	To explore whether hydrogel patches protect the nasal bridge and cheeks from skin injury by an N95 mask use	- Control Group ($n = 10$): operating without a W-shaped hydrogel patch - Experimental group ($n = 16$): operating with a W-shaped hydrogel patch over their cheeks and nasal bridge	2 weeks	Questionnaires NRS (from 0 to 5; 5 indicating most severe)	Hydrogel use decreased pain, itching and indentation both on cheeks and nasal bridge. Burning was only reduced on the nasal bridge
Yildiz A <i>et al.</i> Turkey	Clinical trial	48 HCWs using goggle, face shield, surgical mask and FFP3 mask together as standard PPE	34.21 ± 6.02	8.6:1	To determinate the effect of prophylactic dressing on the prevention of skin injuries due to the use of PPE in HCWs	- Control group ($n = 10$): non using prophylactic dressing - Experimental group 1 ($n = 20$): Using prophylactic dressing - Experimental group 2 ($n = 8$): Using prophylactic dressing and nasal strip	From 24 h to 5 days Mean duration: 3.79 ± 1.18 h	HCWs' satisfaction (VAS) Dermatological evaluation NPIAP PI staging system	Overall rate of skin injuries related to PPE was 47.9% (23/48). Skin injuries were 2.5 time higher in CG (100%) than in EG2 (12.5%) and in EG1 (10%). The mean number of skin injuries was higher in CG ($2.45 ± 0.24$) than in EG1 ($0.1 ± 0.06$) and EG2 ($0.13 ± 0.12$). Percentage of participants suffering from itching was higher in CG (40%, 8/20), than in EG2 (12.5%, 1/8) and EG1 (0%)
Gasparino RC <i>et al.</i> Brazil	Clinical trial	88 HCWs wearing N95 masks	38.0 ± 9.0	3.6:1	To compare foam and extra-thin hydrocolloid in preventing DRPI associated with PPE	- Group 1 ($n = 44$): foam - Group 2 ($n = 44$): extra-thin hydrocolloid	12 h	Participants discomfort reported	No participant developed DRPI. Four areas with erythema were observed in both groups. No differences in hyperaemia, itching, pain or discomfort were observed between groups
Dong L <i>et al.</i> China	Short-term, self-controlled study	19 HCWs	NS	NS	To assess whether hydrogel patch application relieve the skin damage caused by mask wearing	- Right side ($n = 19$): N95 mask - Left side ($n = 19$): N95 mask - with hydrogel patch	4 h	Photographs Questionnaire	Skin reactions rate reported in the control side ($13.32 ± 2.06$) was higher than in the intervention one ($3.47 ± 1.39$). Hydrogel application decreased indentation by 1.74, redness, and pain

Data are expressed as media ± SD or median (interquartile range).

DRPI, device-related pressure injury; CG, control group; EG, experimental group; HCWs, healthcare workers; NPIAP, National Pressure Injury Advisory Panel; PI, pressure injuries; PPE, personal protective equipment; NRS, numeric rating scale; visual analogue scale (VAS).

was almost double in HCWs and non-HCWs, what may be explained because HCWs need to wear longer periods mask or gloves. This fact makes it necessary to establish preventive measures in HCWs to avoid adverse events.

Most common adverse events were contact dermatitis, dryness, acne and eczema pressure-related symptoms and itching.^{13,23,32} Contact dermatitis, dryness and itching were related to masks, gloves and handwashing.^{24,32} Pressure-related symptoms were mainly associated with mask wearing.^{7,17} Other conditions were also reported, such as acne and related disorders, urticarial,³⁵ palmar hyperkeratosis¹⁹ or pigmentation.²¹ It has been proved that PPE use increases TEWL,³⁰ what could explain their dryness effect. Furthermore, the temperature raise creates a favourable environment for the development of some microorganisms, such as *Propionibacterium acnes*, favouring acne development.⁴²

The face and the hands were the most frequently damaged regions.^{5,12} Hand eczema was a frequent condition on the hands.³⁷ Face was a common location for developing skin injuries related to mask wearing, mainly on the nasal bridge and the cheeks.^{7,17,43} Acne was also frequent on mask-covered areas.^{21,31}

Studies agreed that longer PPE use and frequent handwashing were the main risk factor to develop skin adverse events.^{5,7,12,21,34,35,37} Having a previous history of atopy or hand eczema was also risk factors for developing hand problems.^{34,35,37} A previous history of acne or seborrheic dermatitis and having an oily skin were risk factors for developing acne aggravated by masks.²³ Nevertheless, there is controversial information regarding other kind of risk factors, such as sex or the mask type. Researches showed that female sex was a risk factor for the overall rate of skin adverse events associated with PPE,¹² skin adverse events related to mask use,²³ irritant contact dermatitis^{18,38} and hand eczema.³⁴ The prevalence of contact dermatitis and occupational dermatosis was also higher in female sex.^{44,45} However, female sex was considered a protective factor for skin injuries related to PPE in another research.¹⁷ Differences between sexes could be due to a greater rate of nurse, mainly women, that could use PPE longer than doctors, where the female:male ratio would be more homogeneous.

There are also controversial results concerning the type of mask. N95 respirators were a risk factor for the overall rate of skin adverse events related to PPE.¹³ Warming and sweating were less frequent with surgical masks than with other types,²² while acne rate did not differ between different kinds of masks.¹⁵ Higher temperature, a marker of inflammation,⁴⁶ was observed when using a N95 respirator compared with a surgical one. Moreover, surgical mask increased TEWL values more than FFP2,³⁰ a parameter indicating epidermal dysfunction when it is high.⁴⁷ Regarding the available data, it could be concluded that mask type that more damaged the skin, in descending order, was as follows: N95 respirators, surgical mask, FFP2 and cloth masks (Fig. S7, Supporting Information). These differences could be

due to the type of material they are made of. When deciding to wear a kind of mask, it should also be kept in mind that they might provide different protection for COVID-19 transmission. Similar rates of virus infection have been reported between N95, surgical mask and FFP2 one, while cloth masks are not recommended as PPE.⁴⁸

Regarding prevention measures, only studies using hydrocolloid to prevent skin injuries have been reported.^{8,39–41} Moisturizers use also reduced skin adverse events related to PPE and frequent handwashing.⁴⁹ As longer PPE wearing is a common risk factor to develop skin side events,^{5,7,12,34,35} permitting several daily rest periods could reduce skin damage. It would be also important to wash the face with non-comedogenic cleanser to avoid acne development.⁵⁰ The frequent use of emollient creams and the use of alcohol-based hand rubs instead of frequent handwashing would be also advisable to decrease side events on the hand,⁵¹ although it should be also considered that the use of hydro-alcoholic gels could have deleterious effect on the skin, particularly if there is a history of a previous eczema. Furthermore, developing educational programmes to teach people how to use PPE could be a recommendable measure to reduce the rate of skin side events.

Limitations

Most researches were cross-sectional studies, so their scientific evidence is limited. Most studies did not use validated questionnaires to assess skin cutaneous events. Furthermore, the absence of dermatological assessment makes it difficult to assess the real influence of previous history of acne, atopy or other dermatoses on the development of these adverse events. The population included vary between studies (HCWs, non-HCWs, students, children), and many selection biases may have affected these reports, as the samples came from hospital settings, schools or day care. Moreover, the absence of patch testing during COVID-19 pandemic did not allow to really distinguish irritative hand eczema from allergic hand eczema related to gloves, chemicals, disinfectants, preservatives, fragrances or handwashing soaps.

Recommendations for futures studies

A more accurate rate of skin side events related to PPE could be obtained if participants were evaluated by a dermatologist and not only by self-administered questionnaires. It would be also important that the studies included objective measure, such as TEWL, to evaluate precisely the epidermal dysfunction related to PPE. Further clinical trials should be carried out to compare different types of masks, gloves and handwashing products using objective parameters to find the less-aggressive PPE.

Conclusion

In conclusion, the rate of cutaneous adverse events related to PPE use is very high, and longer use periods were the most important risk factors for developing them. Most skin adverse

events were mild, being dryness, pressure-related symptoms and itching the most frequent. Frequent handwashing, gloves and mask use are important agents related to skin disorders. Hydrogel patches could be a protective measure against mask-related symptoms.

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Author contributions

SAS and TMV conceptualized the study; AMLo, CCB and TMV contributed to methodology; AMLe provided software; AMLe and SAS validated the study; AMLo and TMV involved in formal analysis; CCB, AMLo and TMV investigated the study; AMLe and SAS contributed to resources; CCB, AMLo and TMV curated the data; CCB, AMLo and TMV wrote—original draft preparation; AMLe and SAS wrote—review and editing; AMLe, SAS and TMV visualized the study, SAS involved in project administration; SAS involved in funding acquisition. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Supporting information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Flow chart of the studies included.

Figure S2. Metanalysis of the prevalence of skin side events related to PPE.

Figure S3. Metanalysis of the prevalence of skin side events related to mask use.

Figure S4. Metanalysis of the prevalence of skin side events related to mask use between HCWs and non-HCWs.

Figure S5. Metanalysis of the prevalence of skin side events related to gloves and hand-hygiene products.

Figure S6. Metanalysis of the prevalence of skin side events related to gloves and hand-hygiene products between HCWs and non-HCWs.

Figure S7. Type of masks.

Table S1. Studies exploring specific adverse cutaneous events related to personal protective equipment.