

Impact of Gloves and Mask Use on Epidermal Barrier Function in Health Care Workers

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Background: Coronavirus disease 2019 has rapidly spread all over the world. Personal protective equipment (PPE) including masks and gloves is needed to avoid transmission. Adverse skin reactions associated with PPE have been described, but there is no information regarding objective measures to assess skin impairment related to PPE.

Objective: The aim of the study was to evaluate the impact of using facial mask and nitrile gloves on epidermal barrier function and skin homeostasis.

Methods: A cross-sectional study was designed. Thirty-four health care workers wearing nitrile gloves and a mask for 2 hours were included. Transepidermal water loss, stratum corneum hydration, erythema, and temperature were measured.

Results: Transepidermal water loss (31.11 vs 14.24 $\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$), temperature (33.29°C vs 32.57°C), and erythema were significantly greater at the area covered by gloves compared with the noncovered area. Transepidermal water loss (22.82 vs 13.69 $\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$), temperature, and erythema (411.43 vs 335.52 arbitrary units) were significantly increased at the area covered by mask, whereas stratum corneum hydration was lower. Transepidermal water loss was greater at the area covered by a surgical mask than at a filtering respirator mask coded filtering facepiece 2 (27.09 vs 18.02 $\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$, $P = 0.034$).

Conclusions: Skin homeostasis and epidermal barrier function may be impaired by gloves and mask use. High-quality PPE should be provided, and adequate skin prevention measures should be implemented to reduce epidermal barrier damage.

In December 2019, a new virus initially called “novel coronavirus 2019-nCoV” and later renamed to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) rapidly emerged in Wuhan, Hubei Province, China, and quickly spread in China and other countries around the world. At the time of this writing, the total number of cases worldwide has exceeded 20 million people, affecting 188 countries, with more than 730,000 deaths.¹ Spain has been one of the most heavily affected countries, with more than 320,000 cases and 28,000 deaths.¹

To stop the spread of the outbreak, thousands of health care workers (HCWs) have been working tirelessly taking care of infected and suspected patients. This effort has made HCWs have a high risk of infection, especially while providing care to coronavirus disease 2019 (COVID-19) patients with inappropriate personal

protective equipment (PPE).² In fact, during the SARS pandemic in 2003, HCWs made up 21% of global cases.³ To date, more than 50,000 HCWs have been infected in Spain, up to 20% of Italian HCWs have developed COVID-19, and an early report in a single-center case series in Wuhan found that 29% of hospitalized patients were HCWs.^{4,5}

Health care workers should protect themselves from the virus by performing adequate handwashing and wearing adequate PPE, including medical masks, goggles or face shields, plastic gowns, and gloves. The long-term working sessions and the daily use of PPEs can lead to physical and psychological disturbances among HCWs,⁶ such as headache or exacerbation of their preexisting disorder.⁷ In fact, the prevalence of PPE-related skin injuries has been estimated between 42.8% and 74%.^{8,9} Facial masks, goggles, and face shields can lead to erosion, abrasion, maceration, and ecchymosis in the cheeks, forehead, and nasal bridge.¹⁰ Moreover, a recent study reported an overall 21% of work absenteeism due to these facial lesions.¹¹ The frequent use of handwashing alcoholic or chlorine-based disinfectants could also cause skin injuries, leading to desquamation and even irritative or allergic contact dermatitis,¹⁰ and the prolonged use of gloves could cause irritant and allergic contact dermatitis, glove-related hand urticaria,¹² pompholyx, or secondary infections.¹⁰

The skin damage associated with PPE could be evaluated objectively by the measurement of some parameters. Assessment of epidermal barrier function usually involves measurements of transepidermal water

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loss (TEWL),¹³ the quantity of condensed water that diffuses across a fixed area of stratum corneum to the skin surface per unit time.¹⁴ Higher TEWL is often associated with skin barrier impairments.¹⁵ Stratum corneum hydration (SCH) is another important parameter,¹⁶ and a lower value is frequently associated with skin barrier dysfunction.¹⁷ Erythema and temperature may also influence epidermal barrier function and skin homeostasis.^{18,19}

Although many PPE-related skin injuries have been described in the literature, to date the impairment of the skin barrier has not been measured by objective methods. Thus, the aim of this study is to evaluate the effect of using a facial mask and nitrile gloves on epidermal barrier function and skin homeostasis.

MATERIAL AND METHODS

A cross-sectional study was designed. It was conducted between April 2020 and May 2020 in the Dermatology Department of the Hospital Universitario Virgen de las Nieves in Granada, Spain. Healthy HCWs, men or women older than 18 years, and volunteers who were wearing for at least 2 hours nitrile gloves and a mask (a surgical mask or a filtering respirator mask coded filtering facepiece 2 [FFP2]) were included in the study. The exclusion criteria of the study population were as follows: (1) having a previous personal history of any inflammatory skin disease (psoriasis, atopic dermatitis, hidradenitis suppurativa, acne, or seborrheic dermatitis), (2) presence of a clinical infection on the measured area, (3) a history of allergy, or (4) not signing the informed consent form.

Information regarding sex, age, occupational category, kind of mask and gloves being worn was gathered during the clinical interview. Homeostasis parameters related to epidermal barrier function were measured. Transepidermal water loss (in gram per hour per m², using Tewameter TM 300), SCH (in arbitrary units [AU], using Corneometer CM 825), erythema (in AU, using Mexameter MX 18), and skin temperature (in degree Celsius, using Skin-Thermometer ST 500) were measured by a Multi Probe Adapter (Courage + Khazaka Electronic GmbH, Germany). All variables were measured at least 2 hours (ranging from 2 to 3 hours) after the participants were wearing gloves and mask into their shift varying days of their work schedule. All participants did not change the mask during this period, whereas

glove change was allowed if needed. The new gloves were to be immediately replaced without use of any products on the hands and arms. Measurements were taken at 4 anatomic areas: the distal right volar forearm where covered by glove and a noncovered area 2 cm from the covered site (Fig. 1), a right cheek site covered by the mask and another area 2 cm from the covered site. All parameters were measured 10 times at each area, using their average for analysis. Measurements were taken in the same room, and ambient air temperature was measured with the TFA Lab Thermometer IP65 LT-101. The average ambient air temperature at the time of the study was 22°C ± 1°C, and the average ambient air humidity was 45% ± 3%.

Descriptive statistics were used to present the sample characteristics. Continuous data were expressed as mean ± SD. The absolute and relative frequency distributions were estimated for qualitative variables. Shapiro-Wilk test was used to check the normality of data distribution. Student *t* test for paired samples or Wilcoxon test was used to compare homeostasis parameters between areas. Student *t* test for independent samples or Mann-Whitney *U* test was applied when necessary to compare independent continuous data. Cohen *d* was calculated to assess effect size, using the SD of the baseline measure. A *P* value of less than 0.05 was considered statistically significant. Statistical analyses were performed using the SPSS package (SPSS for Windows, version 24.0; SPSS, Inc, Chicago, IL).

This study was approved by the ethics committee of Hospital Universitario Virgen de las Nieves (epidermal barrier function and skin homeostasis project). The nature of the study was explained to all the participants, who agreed to participate. All measurements were noninvasive, and patient data were kept confidential.

RESULTS

Thirty-four participants, 61.76% (21/34) women and 38.24% (13/34) men, were included in the study. The mean age was 44.97 (SD, 11.97) years: 46.33 (SD, 11.33) years for women and 42.77 (SD, 13.08) years for men. A total of 47.06% (16/34) were doctors, 26.47% (9/34) were nurses, and 26.47% (9/34) were miscellaneous HCWs, including nurses' assistant and cleaners.

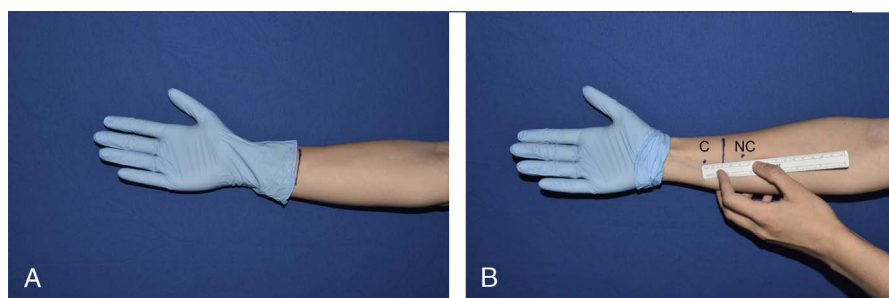


Figure 1. A, Area covered by gloves. B, Measurement location on the right volar forearm. C, Glove-covered area. NC, non-glove-covered area.

TABLE 1. Homeostasis Parameters at Areas Covered and Noncovered by Gloves

	Distal Forearm Noncovered by Gloves (n = 34)	Distal Forearm Covered by Gloves (n = 34)	Cohen <i>d</i>	<i>P</i> *
TEWL, g·m ⁻² ·h ⁻¹	14.24 (9.84)	31.11 (18.34)	0.92	<0.001*
SCH, AU	43.26 (12.31)	58.28 (17.08)	0.88	<0.001*
Temperature, °C	32.57 (0.81)	33.29 (0.86)	0.84	<0.001*
Erythema, AU	215.55 (38.69)	243.97 (44.97)	0.65	<0.001*

**P* value after using Student *t* test for paired samples to compare homeostasis parameters between the forearm covered and noncovered by gloves.

AU, arbitrary units; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

Skin Homeostasis Analysis Between Areas Covered and Noncovered by Gloves

Epidermal barrier function parameters between the distal volar forearm covered and noncovered by the nitrile gloves were compared (Table 1). Transepidermal water loss was greater at the glove-covered area (31.11 vs 14.24 g·m⁻²·h⁻¹, *P* < 0.001, *d* = 0.92). Stratum corneum hydration was also increased at the area covered (43.26 vs 58.28 arbitrary units, *P* < 0.001, *d* = 0.88). Moreover, temperature (33.29°C vs 32.57°C, *P* < 0.001, *d* = 0.84) and erythema (243.97 vs 215.55 AU, *P* < 0.001, *d* = 0.65) were also higher at the area covered by gloves when compared with the noncovered area.

Skin Homeostasis Analysis Between Areas Covered and Noncovered by Mask

Homeostasis parameters were also different in the areas covered and noncovered by a mask (Table 2). Transepidermal water loss was significantly greater on the area covered by mask (22.82 vs 13.69 g·m⁻²·h⁻¹, *P* < 0.001, *d* = 0.73), whereas SCH was lower (53.87 vs 59.50 AU, *P* = 0.058, *d* = 0.37). Temperature (33.19°C vs 32.54°C, *P* < 0.001, *d* = 0.80) and erythema (411.43 vs 335.52 AU, *P* < 0.001, *d* = 0.88) were both increased at the area covered by mask.

TABLE 2. Homeostasis Parameters at Areas Covered and Noncovered by Mask

	Cheek Noncovered by Mask (n = 34)	Cheek Covered by Mask (n = 34)	Cohen <i>d</i>	<i>P</i> *
TEWL, g·m ⁻² ·h ⁻¹	13.69 (4.66)	22.82 (12.59)	0.73	<0.001*
SCH, AU	59.50 (14.76)	53.87 (15.30)	0.37	0.058
Temperature, °C	32.54 (0.85)	33.19 (0.81)	0.80	<0.001*
Erythema, AU	335.52 (80.50)	411.43 (86.20)	0.88	<0.001*

**P* value after using Student *t* test for paired samples to compare homeostasis parameters between the forearm covered and noncovered by gloves.

AU, arbitrary units; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

TABLE 3. Homeostasis Parameters at Areas Covered by Different Types of Masks

	Surgical Mask (n = 18)	FFP2 Mask (n = 16)	Cohen <i>d</i>	<i>P</i> *
TEWL, g·m ⁻² ·h ⁻¹	27.09 (15.30)	18.02 (6.09)	0.59	0.034*
SCH, AU	49.70 (16.73)	58.56 (12.39)	0.53	0.092
Temperature, °C	33.25 (0.86)	33.13 (0.78)	0.14	0.674
Erythema, AU	429.85 (91.23)	390.70 (77.78)	0.43	0.190

**P* value after using Student *t* test for independent samples or Mann-Whitney *U* test to compare homeostasis parameters between the cheek covered by a surgical mask and that covered by an FFP2 mask.

AU, arbitrary units; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

The Influence of Mask Type on Skin Homeostasis

Differences in homeostasis parameters were found depending on the type of mask (Table 3). Stratum corneum hydration was less at the surgical mask-covered area (49.70 vs 58.56 AU, *P* = 0.092, *d* = 0.53) when compared with FFP2 mask-covered area. No difference in temperature was found (33.25°C vs 33.13°C, *P* = 0.674, *d* = 0.14).

Transepidermal water loss was significantly greater at the area covered by a surgical mask than at the FFP2 one (27.09 vs 18.02 g·m⁻²·h⁻¹, *P* = 0.034, *d* = 0.59). Moreover, surgical mask had a greater power in increasing TEWL (*P* = 0.026; Table 4). Although the cheek covered by surgical mask increased 12.54 (SD, 2.14) g·m⁻²·h⁻¹ compared with the noncovered area, the FFP2 area covered was only 5.28 (SD, 2.27) g·m⁻²·h⁻¹ greater than the noncovered area.

The Influence of Age and Sex on Skin Homeostasis Covered Areas

To evaluate the impact of age in skin homeostasis-covered areas, participants were grouped as individuals 45 years and younger or those older than 45 years (Table 5). It was observed that mask impact was similar between age groups. Nevertheless, it was found that

TABLE 4. Mean Differences Between Covered and Uncovered Mask Areas for Homeostasis Parameters

	Surgical Mask (n = 18)	FFP2 Mask (n = 16)	Cohen <i>d</i>	<i>P</i> *
TEWL, g·m ⁻² ·h ⁻¹	12.54 (11.40)	5.28 (5.30)	0.64	0.026*
SCH, AU	-8.99 (18.94)	-1.85 (13.37)	0.57	0.218
Temperature, °C	0.61 (0.42)	0.69 (0.53)	0.19	0.615
Erythema, AU	80.28 (65.06)	70.98 (46.95)	0.14	0.640

**P* value after using Student *t* test for independent samples or Mann-Whitney *U* test to compare changes in mask covered and noncovered homeostasis parameters between the type of masks.

AU, arbitrary units; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

TABLE 5. Mean Differences Between Covered and Uncovered Areas for Homeostasis Parameters Between Age Groups

	Gloves				Mask			
	Age ≤45 y (n = 18)	Age >45 y (n = 16)	Cohen <i>d</i>	<i>P</i> *	Age ≤45 y (n = 18)	Age >45 y (n = 16)	Cohen <i>d</i>	<i>P</i> †
TEWL, g·m ⁻² ·h ⁻¹	14.11 (11.61)	19.97 (15.46)	0.50	0.218	7.93 (5.96)	10.48 (12.70)	0.43	0.45
SCH, AU	9.34 (9.14)	12.29 (19.66)	0.32	0.571	-6.92 (21.55)	-4.19 (9.13)	0.13	0.640
Temperature, °C	0.53 (0.47)	0.93 (0.39)	0.85	0.013*	0.71 (0.32)	0.59 (0.60)	0.38	0.471
Erythema, AU	15.47 (28.14)	43.00 (44.31)	0.98	0.036*	70.42 (57.29)	82.08 (57.04)	0.20	0.557

**P* value after using Student *t* test for independent samples or Mann-Whitney *U* test to compare changes in glove-covered and noncovered homeostasis parameters between participants 45 years or younger and older than 45 years.

†*P* value after using Student *t* test for independent samples or Mann-Whitney *U* test to compare changes in mask-covered and noncovered homeostasis parameters between participants 45 years or younger and older than 45 years.

AU, arbitrary units; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

gloves have a different impact depending on the age. The older group had higher temperature increase between the covered and noncovered areas than did the younger group (0.93°C vs 0.53°C, *d* = 0.85, *P* = 0.013). Moreover, the erythema increase in glove-covered areas was also greater in the older group (43.00 vs 15.47 AU, *d* = 0.98, *P* = 0.036). A positive correlation between age and temperature increase (*r* = 0.34, *P* = 0.051) was found. No differences between sexes were found.

DISCUSSION

This study shows that epidermal barrier function and skin homeostasis may be impaired by gloves and mask. An increased TEWL, temperature, and erythema in the area covered by gloves and an increased TEWL, temperature, and erythema but a decreased SCH in the area covered by masks were observed. Moreover, surgical masks are more harmful for the skin than FFP2 masks, showing greater TEWL in areas covered by surgical masks. Epidermal barrier function integrity is important to prevent SARS-CoV-2 infection, as previous reports have shown.^{11,20}

The hands are the most common site affected by PPE-related adverse skin reactions during the COVID-19 outbreak.⁹ This is due to excessive handwashing, hydroalcoholic solutions, and glove use.²¹ Medical gloves are mostly made of different polymers such as latex and nitrile,¹² nitrile being the preferred gloves during the COVID-19 pandemic because of their high protection and durability.²² Many adverse skin reactions have been described associated with their use, such as irritant contact dermatitis, allergic contact dermatitis, and contact urticaria.¹² Glove use often causes skin maceration presenting as softening, whitening, wrinkling of the skin, and, sometimes, skin peeling.²³ This study showed higher SCH values at the glove-covered area, which may be explained in part by increased sweat production in the covered area.¹³ Nevertheless, the difference in TEWL between 2 near areas, glove covered and noncovered, reflects skin barrier damage related to glove use. This may explain the increased cases of hand eczema, allergic contact dermatitis, secondary superficial fungal infection, and pompholyx seen in HCW glove users.^{23,24} Previously, higher TEWL values during 30 minutes of glove use have also been described.²⁵ Nevertheless, the effects of glove

occlusion are controversial in the literature.²⁶ This study also shows high erythema and temperature at the area covered by gloves. This is in agreement with previous reports, as erythema is the second most reported skin adverse sign among HCWs.²⁷

Moreover, the high erythema and temperature are markers of inflammation and increased skin permeability.²⁸ Although SARS-CoV spreads mainly via the respiratory route, other possible pathways of infection have been proposed, including skin surface.^{20,29} Thus, the permeability increased by gloves, added to the abundant presentation of angiotensin-converting enzyme 2, the cell receptor for SARS-CoV-2, in the basal layer of the epidermis and the blood vessels of the skin, may increase the risk of being infected with SARS-CoV-2.^{20,29} Transepidermal transmission of this virus is, however, still theoretical. Possible solutions to prevent PPE and hand hygiene-related injuries have been described, such as increased protective skincare measures after washing hands or using gloves³⁰ and alcohol-based disinfectant solutions containing glycerin as moisturizer.²¹

The cheeks are the second area most affected by PPE-related adverse skin reactions during the COVID-19 outbreak.⁹ In fact, masks are the most common culprit among all PPEs that cause skin damage,²⁷ leading to indentations, ecchymosis, maceration, abrasion, and erosion.¹⁰ This study observed high TEWL values at the mask-covered area, revealing skin impairment associated with mask use. This may explain some skin reactions associated with mask use such as allergic contact dermatitis or urticarial facial eruption.³¹ In contrast to gloves, mask-covered areas showed lower SCH values than noncovered. This may be explained because of lower density of eccrine sweat glands on the cheek.³² Moreover, this study shows that mask-covered areas have higher temperature and more erythema than nearby noncovered areas, relating to increased permeability.²⁸ This could also explain mask-induced itch³³ and may be a risk factor to get SARS-CoV-2, because frequent face touching may increase the exposure and entry of SARS-CoV-2 infection.¹¹ Moreover, the increased temperature is also a contributor to developing acne and seborrheic dermatitis.^{31,34} To the best of our knowledge, there is no previous information regarding epidermal barrier function and skin homeostasis with mask use.

This report also shows TEWL increased more at areas covered by the surgical mask than at FFP2 mask-covered areas. This may mean that surgical masks are more harmful for the skin barrier. Filtering facepiece 2 masks have more filter efficiency,³⁵ meaning that they are more protective to avoid COVID-19 transmission.³⁶ Nevertheless, no differences in skin damage between different types of masks have been reported to date. A possible explanation for the differences in TEWL values may be the different materials the masks are made from.³⁷

This study also found greater increase in erythema and temperature at glove-covered areas in people older than 45 years. It has been previously pointed out that these parameters may be associated with a high permeability.²⁸ Moreover, elderly people are more susceptible to skin damage³⁸ and more frequently experience itch,³⁹ causing face touching and increasing the exposure to SARS-CoV-2. This is an important fact, as old people have a high risk of developing critical or mortal COVID-19 disease.⁴⁰

Although the reference values for homeostasis parameter are still controversial, our study shows similar values on the noncovered areas to those of a previous report in healthy people. In our population, the mean TEWL was 14.24 g·m⁻²·h⁻¹ on the distal volar forearm and 13.69 g·m⁻²·h⁻¹ on the cheek, in agreement with reference values in a meta-analysis (reference values ranging from 9.84 to 17.96 g·m⁻²·h⁻¹ on the distal right volar forearm and ranging from 12.92 to 14.91 g·m⁻²·h⁻¹ on the right cheek).¹⁵ Stratum corneum hydration values were also similar to previous reports.⁴¹ Erythema values on noncovered areas were also within the reference values on healthy skin: 215.55 AU on the volar forearm (reference values = 222.7–288.4 AU) and 335.52 AU on the cheek (reference values = 294.2–409.4 AU).⁴²

Limitations of this study include the small sample size and the lack of follow-up to assess skin barrier dysfunction over a long period. Moreover, the distal volar forearm may not be the area primarily affected by glove use, meaning that the effect of glove use may be underestimated in this study. This location was selected instead of the palm to increase similarities between skin properties in the covered and noncovered areas. Nonetheless, this pioneering study provides insights into the objective measures for glove and mask skin damage during the COVID-19 outbreak.

Skin homeostasis and epidermal barrier function may be impaired by glove and mask use. Surgical mask use is associated with greater TEWL values than FFP2 mask. Although before the COVID-19 pandemic, only HCWs wore gloves and masks, and only for limited periods, now the whole population uses them for a long period. High-quality PPE should be provided, and adequate skin prevention measures should be implemented to reduce epidermal barrier damage.

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