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Influence of quarantine mask use on skin characteristics: One of the changes in our life caused by the COVID-19 pandemic

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Abstract

Background: The influence of various environmental factors on skin properties is well known. However, there is a lack of research into the effect of quarantine masks on skin properties, even though the use of masks has significantly increased after the COVID-19 outbreak. Therefore, this study aimed to investigate the influence of mask use on skin properties.

Materials and Methods: Twenty subjects were enrolled in this study. The subjects used approved quarantine masks for 6 hours a day for 2 weeks. We measured eight skin biophysical parameters: temperature, redness, pore volume, texture, elasticity, trans-epidermal water loss (TEWL), sebum content, and pH, and evaluated acne lesions before and after using quarantine masks. The evaluation was performed on the mask-wearing area of the face.

Results: Skin temperature, redness, and TEWL increased significantly after a 6-hour mask use, while the sebum content increased marginally. Skin elasticity was reduced by the use of masks over 1 and 2 weeks, whereas the pore volume and the number of acne lesions increased after a 2-week mask use. The skin changes caused by mask use showed sex-based differences in the skin elasticity (after 6 hours), redness, and roughness (after 2 weeks).

Conclusions: The use of quarantine masks causes a change in the skin temperature, redness, and TEWL in the short term and in skin elasticity, pores, and acne in the long term. This study revealed that prolonged mask use could have negative effects on the skin.

KEYWORDS

COVID-19, face mask, prolonged mask use, quarantine mask, skin changes, skin properties

1 | INTRODUCTION

As the outermost layer of the body, the skin has many functions to maintain constant conditions in response to variable external factors. Despite these functions, the skin may be altered by various environmental factors such as temperature and humidity. In particular, skin barrier recovery is reduced when relative humidity is high.[1] According to Tsukahara et al,[2] in dry environments, skin elasticity is decreased and wrinkles form easily. Several studies have reported that sudden changes in humidity can cause abnormalities in the skin

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barrier function and increase skin roughness.[3,4] Changes in temperature are also known to affect the skin. Many studies have shown that the skin temperature rises due to a high environmental temperature, thereby increasing the trans-epidermal water loss (TEWL).[5,6]

A variety of skin changes in response to occlusion have been studied. Aly et al[7] reported that the microbial flora (as described using bacterial counts and composition), TEWL, and pH changed after 5 days of skin occlusion. In addition, prolonged occlusion can induce skin barrier damage[8] and higher susceptibility to sodium lauryl sulfate irritation.[9] In case of patients with atopic dermatitis, skin condition may be worsened by the use of occlusive gloves, athletic equipment, or fabrics.[10]

Moreover, skin irritation and changes in the skin characteristics can be caused by different types of contact. Due to contact of the skin with fabrics, a variety of skin responses such as alterations in nonvisual skin characteristics (hydration, water evaporation, neural response, percutaneous absorption, and skin microflora) and eczematous dermatitis may occur.[11] The use of surgical masks has also been reported to cause various dermatologic conditions, including contact/irritant dermatitis, acne, and moisture-associated skin irritation.[12,13] Raymond et al[14] showed that low-to-moderate working activities performed for 1 hour while wearing a surgical mask cause physiological responses such as an increase in the respiratory rate, partial pressure of transcutaneous carbon dioxide, and temperature of the skin covered by the mask.

Most of these studies have focused on case reports from healthcare workers. Although Hua et al[15] recently reported adverse skin reactions caused by wearing N95 respirators and medical masks, they showed only short-term effects of several parameters. In recent months, due to the COVID-19 pandemic and its high risk of infection, the use of personal quarantine masks by the general public, often on a daily basis, has increased significantly. Although people who frequently wear masks often experience skin problems and discomfort, there is a lack of research on the effects of long-term use of personal quarantine masks on skin characteristics.

Therefore, in this study, we investigated the changes in skin biophysical parameters under controlled use of quarantine masks, reflecting the actual use of the mask. This study aimed to shed light on the effects of mask use on skin characteristics during the pandemic.

2 | MATERIALS AND METHODS

2.1 | Study population and design

Twenty healthy Korean volunteers (11 male and 9 female; mean age: 28.10 ± 3.49 years) were enrolled in this study. All subjects used the quarantine mask (KF94 mask) approved by the Korean Food and Drug Administration for 6 hours/day for 2 weeks. During the study, the subjects did not use any medications on their facial skin, and their cosmetic use remained unchanged. The study was conducted in accordance with the ethical standards of the Helsinki Declaration and was approved by the Institutional Review Board. All subjects were informed about the purpose of the study and provided written consent prior to participation.

2.2 | Biophysical measurements

Before the measurements, the subjects cleaned their faces and acclimated for 20 min in an air-conditioned room (temperature 22 ± 2°C; relative humidity 50 ± 10%) without the application of any cosmetics. Skin measurements were carried out on the mask-wearing area of the face at baseline and after 6 hours of mask use. As a control, skin measurements were performed on the same subjects at baseline and after 6 hours without wearing the mask to investigate the natural changes in biophysical parameters before mask use was initiated. Follow-up evaluations were performed at 1 and 2 weeks of using the mask for 6 hours every day.

High-quality digital photographs of the subjects were taken using Janus® (PIE Co., Ltd., Suwon, Korea), which is a facial image analysis device with a high-resolution digital camera, to capture the whole face and acquire three images under three light sources (normal, polarized, and ultraviolet light).

Eight biophysical parameters of the skin, namely temperature, redness, pore volume, texture, elasticity, TEWL, sebum content, and pH, were measured using multiple devices with noninvasive methods. Skin temperature was recorded using an infrared laser thermometer (Fluke® Corp., Washington, USA). Skin redness was measured using a Chromameter CR-400 (Konica Minolta, Osaka, Japan) and expressed as a^*, that is, the value representing the level between red (positive) and green (negative). Skin pores and texture were measured using Antera 3D® (Miravex, Dublin, Ireland). We analyzed the overall volume of pores and the average of skin roughness (Ra) in the image using a medium filter and a small filter, respectively. Skin elasticity was indicated as R2, R5, and R7 (gross, net, and biological skin elasticity, respectively), and was measured using a Cutometer® MPA 580 (C + K electronic GmbH, Cologne, Germany). TEWL was measured with a Tewameter® TM300 (C + K electronic GmbH), which is a device that measures water evaporation from the skin. Sebum content was measured using a Sebumeter® SM815 (C + K electronic GmbH) to analyze the sebum level absorbed on a special mat tape using the light transmission principle. Surface pH was measured using a Skin pH-meter® PH905 (C + K electronic GmbH). In addition, the evaluation of acne lesion counts on each subject's face through visual assessment was independently performed by three trained assessors.

2.3 | Statistical analysis

The collected data were analyzed using IBM SPSS Statistics, version 25 (IBM Corp., New York, USA). The normality of the measured data was tested using the Shapiro-Wilk test. Statistical

comparisons between the results before and after 6 hours of mask use were performed using a paired t test or the Wilcoxon signed-rank test. Repeated-measures ANOVA (*post hoc* comparison: Bonferroni correction) or the Friedman test (*post hoc* comparison: Wilcoxon signed-rank test with Bonferroni correction) was used to statistically compare the results between 0, 1, and 2 weeks of mask use. To statistically compare the results between sexes, an independent t test or the Mann-Whitney *U* test was performed. *P*-values < .05 were considered statistically significant, while the statistical significance level of *post hoc* analysis for multiple comparisons following the Friedman test was set at a *P*-value < .017 (0.05/3 comparisons).

3 | RESULTS

3.1 | Skin changes after mask use

Table 1 shows the skin biophysical parameters before and after a 6-hour mask use for over 1 week and 2 weeks, respectively (control data shown in supplementary data 1).

There were significant differences in the skin temperature, redness, TEWL, sebum content, and pH before and after mask use (Figure 1). The skin temperature, redness, and TEWL increased by 2.09°C ($P < .001$), 8.57% ($P < .01$), and 19.38% ($P < .001$), respectively, after a 6-hour mask use. While the sebum content increased by 135.49% ($P < .001$) and the pH decreased by 3.24% ($P < .05$) after a 6-hour mask use, there was no significant difference compared with the control. There were no significant differences in the skin pores, roughness, and elasticity (R2, R5, and R7) after a 6-hour mask use.

After a 1-week mask use, there was significant difference in the skin elasticity. Skin elasticity R5 and R7 decreased by 9.90% ($P < .05$) and 7.12% ($P < .01$), respectively. After using the mask over 2 weeks, there were significant differences in the skin pores, elasticity, and acne (Figure 2). The volume of the pores increased by 73.16% ($P < .05$), skin elasticity (R7) decreased by 7.44% ($P < .01$), and the mean acne lesion count increased by 1.65 after using the mask over 2 weeks ($P < .001$). Figure 3 presents a participant's facial skin images showing changes in the acne before and after mask use over 2 weeks. There were no significant differences in the skin temperature, redness, roughness, TEWL, sebum content, and pH.

TABLE 1 Skin biophysical parameters before and after using the mask for 6 hours a day over 1-week and 2-week periods

Variables	Baseline	After 6 hours	*P*-value	1 week	*P*-value	2 weeks	*P*-value
Temperature (°C)	31.77 (±1.19)	33.86 (±0.88)	.000***	31.83 (±1.07)	.000	31.90 (±1.05)	.000
Redness (a*)	12.03 (±2.76)	12.85 (±2.54)	.005**	12.18 (±2.34)	.000	12.24 (±2.30)	.994
Pore (mm^3)	0.14 (±0.11)	0.15 (±0.12)	.287	0.17 (±0.12)	.032	0.18 (±0.14)	.014†
Roughness (Ra)	5.02 (±1.10)	5.01 (±1.00)	.794	5.11 (±1.28)	.575	5.14 (±1.17)	.247
Elasticity (R2)	0.73 (±0.05)	0.74 (±0.06)	.794	0.71 (±0.05)	.040	0.71 (±0.05)	.117
Elasticity (R5)	1.02 (±0.15)	0.98 (±0.17)	.292	0.91 (±0.13)	.012*	0.94 (±0.11)	.204
Elasticity (R7)	0.42 (±0.05)	0.41 (±0.05)	.215	0.39 (±0.04)	.008**	0.39 (±0.03)	.006**
TEWL ($g/h/m^2$)	18.73 (±5.76)	21.98 (±5.94)	.001***	17.85 (±6.92)	.211	18.32 (±5.40)	.955
Sebum (a.u.)	107.43 (±58.69)	177.72 (±44.42)	.001***	87.05 (±44.68)	.232	103.42 (±64.05)	.575
pH	5.81 (±0.45)	5.62 (±0.51)	.024*	5.76 (±0.38)	.709	5.56 (±0.25)	.048
Acne	2.70 (±3.01)	-	-	3.55 (±3.24)	.037	4.35 (±2.70)	.001††

Note: Results are expressed as mean (± standard deviation); n = 20

Skin temperature, redness, and R5 and R7 elasticity were compared using a paired t test (after 6 hours) and repeated-measures ANOVA (at 1 and 2 weeks). Pore volume, roughness, R2 elasticity, trans-epidermal water loss (TEWL), sebum content, pH, and acne lesion counts were compared using the Wilcoxon signed-rank test (after 6 hours) and the Friedman test (at 1 and 2 weeks).

Statistical significance denoted by; *$P < .05$, **$P < .01$, and ***$P < .001$ (paired t test, repeated-measures ANOVA, and Wilcoxon signed-rank test), †$P < .017$ and ††$P < .003$ (Friedman test with *post hoc* comparison).

R2, gross elasticity; R5, net elasticity; R7, biological elasticity, a.u., arbitrary unit.

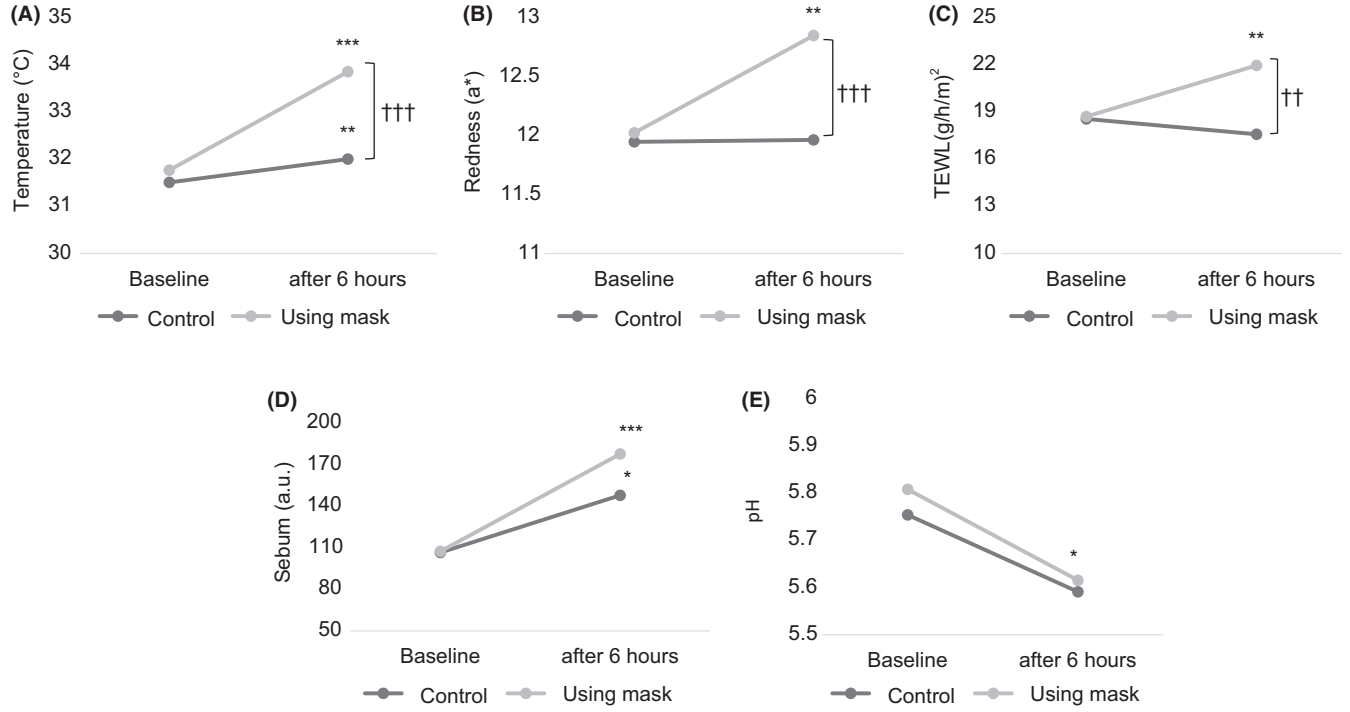

FIGURE 1 Comparison of skin parameters after using the mask for 6 hours. (a) Skin temperature, (b) redness, (c) trans-epidermal water loss (TEWL), (d) sebum content, and (e) pH were measured with a laser thermometer. The results represent mean ± SE. Paired t test and Wilcoxon signed-rank test (as compared to baseline: $^{*}P < .05$, $^{**}P < .01$, $^{***}P < .001$, and as compared to control: $^{\dagger\dagger}P < .01$, $^{\dagger\dagger\dagger}P < .001$) were used for statistical comparison. a.u., arbitrary unit

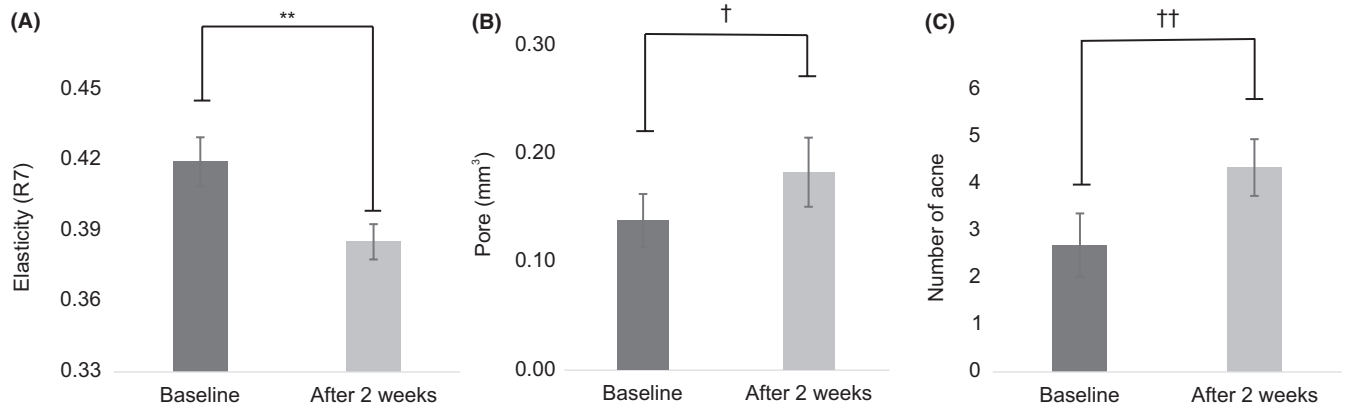

FIGURE 2 Comparison of skin parameters after a daily 6-hour mask use over 2 weeks. (a) Skin elasticity, (b) pore volume, and (c) the number of acne lesions were evaluated. The results represent mean ± SE. Repeated-measures ANOVA ($^{**}P < .01$) and the Friedman test ($^{\dagger}P < .017$, $^{\dagger\dagger}P < .003$) were used for statistical comparison. R7, biological skin elasticity

3.2 | Sex-based differences in skin changes

Several sex-based differences were observed in the rates of change of skin biophysical parameters after mask use. While the rate of change of skin elasticity (R7) was 0.03% in men, it decreased by 6.62% in women after a 6-hour mask use ($P < .05$) (Figure 4). There were no sex-based differences in the rates of change in skin temperature, redness, pore, texture, TEWL, sebum, and pH after a 6-hour mask use (all data shown in supplementary data 2).

Figure 5 shows a comparison of the rates of change of skin redness (a*) and roughness (Ra) before and after a 2-week mask use. The skin redness in women increased by 8.59% after 2 weeks of mask use, while it changed by −0.97% in men ($P < .05$). The rate of change of skin roughness in men and women after 2 weeks of mask use was 6.32% and −2.39%, respectively, showing a significant difference ($P < .05$). There were no sex-based differences in the rates of change of all skin biophysical parameters after a 1-week mask use and in the rates of change of the skin temperature, pores, elasticity, TEWL,

FIGURE 3 Participant's facial skin images showing changes in acne lesions. (a) Before and (b) after a daily 6-hour mask use over 2 weeks [Colour figure can be viewed at wileyonlinelibrary.com]

sebum, and pH after a 2-week mask use (all data are shown in supplementary data 2).

4 | DISCUSSION

The recent COVID-19 outbreak has changed the life behaviors of people worldwide. Among the lifestyle changes caused by the COVID-19 pandemic is the use of quarantine masks in everyday life. Therefore, we investigated the influence of mask use on skin characteristics using noninvasive methods. To the best of our knowledge, this is the first study to quantitatively evaluate skin biophysical parameters related to what people experience with prolonged mask use.

After a 6-hour mask use, the skin temperature, redness, and TEWL significantly increased as compared to under control conditions. The elevation of skin temperature seems to be caused by the increased temperature inside the mask due to exhalation. Skin temperature usually maintains at a relatively constant level, but can change slightly depending on environmental conditions such as ambient temperature.[5] Cherrie et al[16] have stated that the temperature inside masks is closely related to the exhaled breath temperature (EBT). Mansour et al[17] have further reported that the EBT ranges from 31.4 to 35.4°C, which is relatively higher than the mean temperature of the skin (31.77°C) in our study. The increase in skin redness seems to be associated with the pressure and contact of the mask. According to Visscher et al,[18] the areas that receive frequent contacts with the mask are prone to skin erythema, and blanchable erythema indicates the potential to develop into pressure ulcers. In addition, skin redness appears to be influenced by changes in the skin temperature. Some studies have shown that redness on the cheek has a strong positive correlation with the skin temperature, because both the capillary blood vessels and the blood flow change with ambient temperature.[19,20] The change in TEWL might also be influenced by skin temperature because there is a relationship between skin temperature and TEWL. Grice et al[6] have reported that the rate of TEWL doubles when the skin temperature rises by 7-8°C. Moreover, it seems that the evaporation of sweat caused by the increased skin temperature affects TEWL.

The sebum content and pH also changed significantly after mask use. However, there were no significant differences compared with the control, because these two parameters also

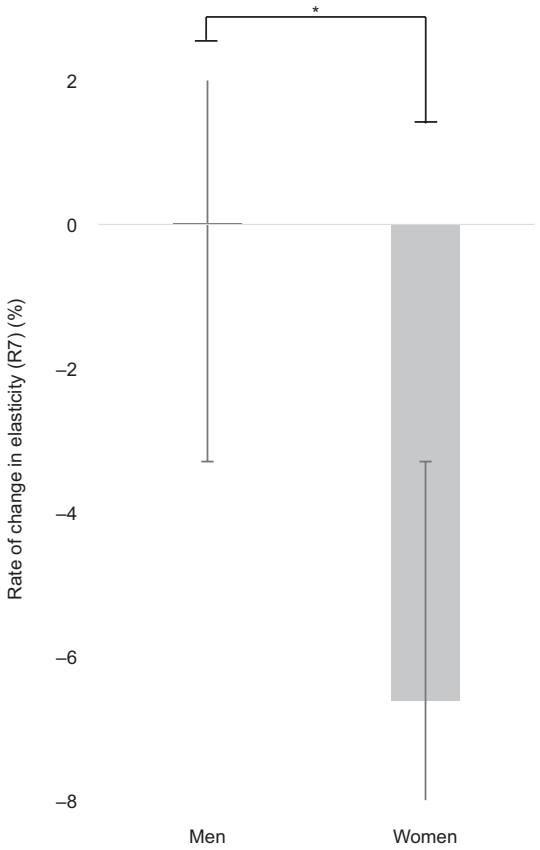

FIGURE 4 Comparison of the change rate of skin elasticity after using the mask for 6 hours. Skin elasticity was measured before and after mask use. The rates of change in men (n = 11) and women (n = 9) were expressed as mean ± SE. Results were statistically compared using the Mann-Whitney *U* test (*$P < .05$). R7, biological skin elasticity

changed in the control condition. In general, sebum continues to be secreted throughout the day,[21] so skin sebum content is higher in the afternoon than in the morning. This factor may explain why, in our study, sebum increased even in the control without a mask. However, according to Cunliffe et al,[22] sebum secretion increases by 10% with every 1°C rise in local temperature. It is likely that mask use increases the temperature around the skin, which promotes sebum secretion. Indeed, although not significant, the use of masks was associated with a tendency to secrete more sebum than in the control condition, suggesting that mask use might have an additional effect of promoting sebum production. Furthermore, the skin pH is generally slightly acidic due to the presence of fatty acids and lactic acid in the sebum and sweat, respectively.[23] Therefore, when the secretion of sweat and sebum increases, the skin surface becomes more acidic. There was no significant change in the skin pH after 6 hours in the control condition; however, the pH was significantly decreased after a 6-hour mask use, contrary to the recent report by Hua et al.[15] A likely explanation is that the pH was lowered because mask use promoted sebum and sweat secretion.

After prolonged use of the mask for 6 h a day, there were statistically significant differences in the skin elasticity (after 1 and

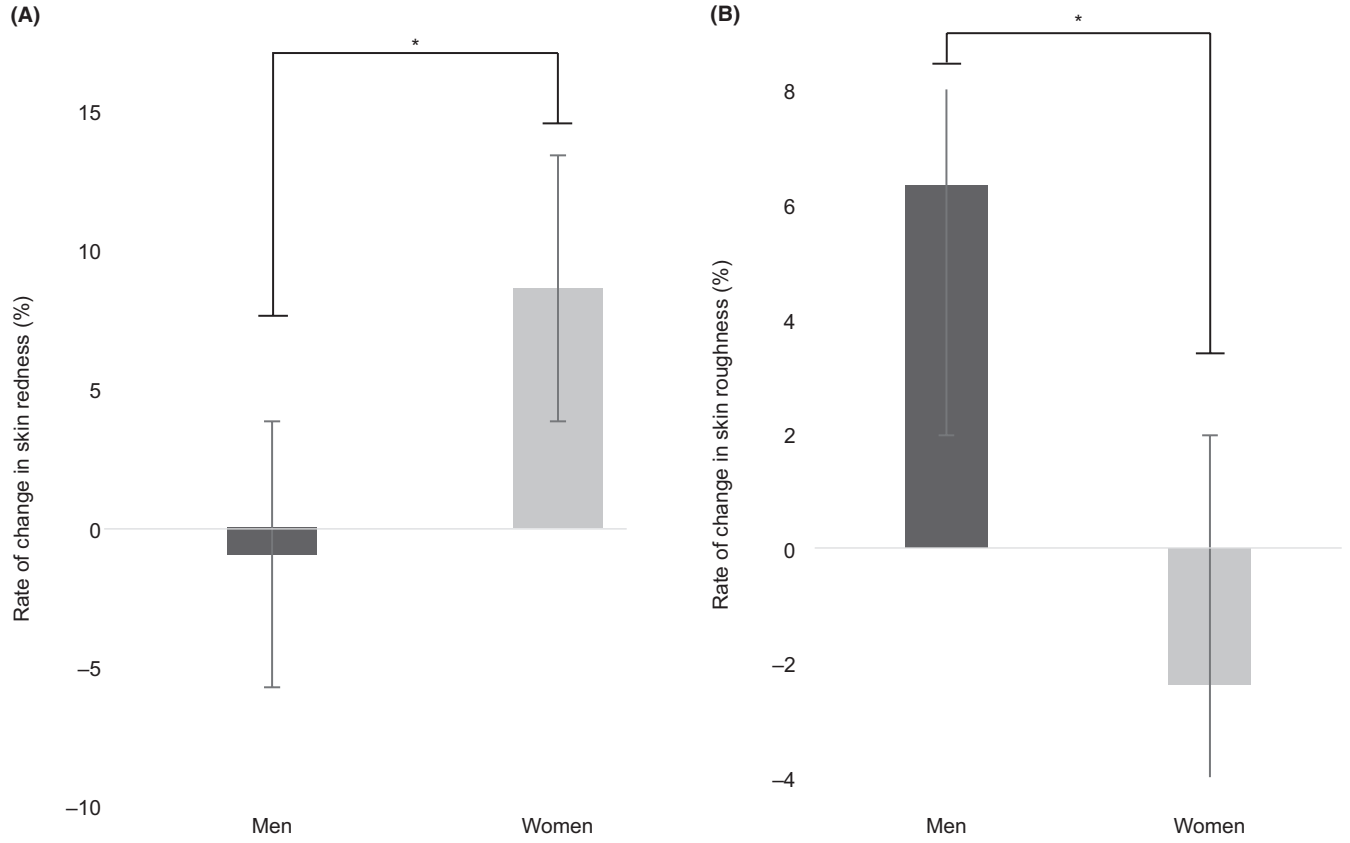

FIGURE 5 Comparison of the rates of change of skin redness and roughness after a daily 6-hour mask use for over 2 weeks. (a) Skin redness and (b) roughness were measured before and after mask use. The rates of change in men (n = 11) and women (n = 9) were expressed as mean ± SE. Results were statistically compared by an independent t test (*$P < .05$)

2 weeks), pores, and acne (after 2 weeks). Numerous studies have shown that skin elasticity generally increases under high temperature and humidity.[24] However, the skin elasticity was significantly reduced after 1 and 2 weeks of using the mask. It is thought that although mask use increases the temperature and humidity around the skin, it simultaneously gives rise to repetitive physical stimulation and an environment disconnected from the outside. This, in turn, may lead to increased skin fatigue and eventually decreased skin elasticity. Additionally, the increase in pore volume seems to be caused by frequent and prolonged exposure to relatively high temperature and humidity due to continuous mask use. According to Song et al,[25] skin pores tend to be larger in summer, during which the temperature and humidity are higher than in the winter in South Korea. This suggests that the increased temperature and humidity caused by masks may result in enlarged pores and eventually increase in acne lesions. Indeed, Narang et al[26] have found that with its higher temperatures and humidity, there is more acne production during summer in India (Northern Hemisphere) than winter.

Skin differences between men and women have been extensively documented. Tur[27] has reported a range of physiological differences in the skin of men and women, including structural and anatomical characteristics, biochemical composition, mechanical properties, functional differences, and skin color. In this study, we found several differences in the skin changes caused by external factors between men and women. There was sex-based difference in the rate of change of skin elasticity after a 6-hour mask use. Shuster et al[28] reported that skin thickness is greater in men than in women, and skin collagen content is lower in women than in men at all ages. This could explain our results, in which the reduction in skin elasticity in women could have been greater because of structural differences. There was a sex-based difference in the skin redness after a 2-week mask use. According to Goh et al,[29] the female skin is more irritable, as measured using the irritation index after sodium lauryl sulfate treatment. It is possible that the increase in skin redness was significantly greater in women than in men because skin irritation often increases skin redness. In addition, after using the mask for 2 weeks, we found that the rate of increase in skin roughness in men was significantly greater than in women. There was also a high possibility of a difference in the pore changes between men and women ($P = .131$). Larger pores make the skin furrows deeper, which might affect the increase in skin roughness.[30] Greater changes in the pores of men could be explained by the tendency of the male skin to produce more sebum as compared to the female skin.

In addition to sex, age affects various skin biophysical parameters. Several studies have reported that age has an effect on the skin elasticity, melanin index, wrinkles, and hydration.[31,32] Because the

age range of the subjects in this study was small, further research is needed to compare skin changes according to age.

While we conducted 1-day control experiments to investigate the natural changes in the skin properties after 6 hours, we could not perform a control study for long-term natural skin changes, that is, over 1 and 2 weeks, because of the requirement to wear a mask every day during the COVID-19 pandemic. Therefore, we controlled subjects for what could cause sudden skin changes, such as outdoor activities. Furthermore, because this study focused on the resultant phenomenon, further studies from a skin physiological viewpoint are needed.

5 | CONCLUSION

In conclusion, the use of facial masks for a short period led to an increase in the skin temperature, redness, and TEWL, and marginally increased the sebum content. Using masks for 6 hours every day over a long period of time reduced skin elasticity and increased the pore volume and number of acne lesions. In addition, regarding skin changes caused by mask use, there were sex-based differences in the skin elasticity, redness, and roughness. Therefore, prolonged mask use, especially under circumstances such as the COVID-19 outbreak, may unfavorably affect the skin.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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