Received: 1 January 2021 | Revised: 6 June 2021 | Accepted: 18 July 2021

DOI: 10.1002/hsr2.350

RESEARCH ARTICLE

Health Science Reports Open Access WILEY

An evaluation of the course of facial sunscreen coverage and sustainability over an 8-hour workday among outdoor workers

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Abstract

Background: Reapplication of sunscreen every 2 hours is recommended, especially after swimming, sweating, or working outdoors. However, the sustainability of sunscreen during the workday among outdoor workers is still unclear.

Objective: To evaluate the course of facial sunscreen coverage and sustainability over an 8-hour workday among outdoor workers.

Materials and Methods: This open-label trial included 20 healthy subjects who spend at least 80% of their workday outdoors. All volunteers applied 2 mg/cm^2 of provided broad-spectrum sunscreen mixed with the invisible blue fluorescent agent to all parts of their face in the morning. A VISIA-CR camera was used to capture facial fluorescence intensity every 2 hours, and digital image analysis software was used to quantify fluorescence intensity at six areas of the face at each time point for 8 hours.

Results: Sunscreen coverage declined most rapidly during the first 2 hours with a mean reduction of 18.31%. By the end of the 8-hour study workday, the mean decrease in sunscreen coverage was 31.63% (range: 17.39%-45.29%).

Conclusion: Reapplication of sunscreen is essential among outdoor workers. After 4 hours, the amount of sunscreen remaining on the face may not be sufficient for protecting the skin from harmful ultraviolet radiation.

KEYWORDS
fluorescent, outdoor, reapplication, sun protection factor, sunscreen

1 | INTRODUCTION

Solar ultraviolet radiation (UVR) is responsible for many skin conditions, including sunburn, skin discoloration, photoaging, and nonmelanoma skin cancers.[1] Sunscreen is one of the effective methods used to prevent UVR exposure. The World Health Organization (WHO), the American Academy of Dermatology (AAD), and Canadian Dermatology Association jointly recommend the application of sunscreen 30 minutes prior to sun exposure, and reapplication every 2 hours when outdoors, and immediately after sweating or swimming. The recommendation suggests using a broad-spectrum sunscreen with a sun protection factor (SPF) of 30 or higher, and the amount applied should be 2 mg/cm^2 to achieve the labeled level of sun protection.[2-4] However, the range of sunscreen applied in a real-life setting was reported to be only 0.39 to 0.79 mg/cm^2.[5,6]

People that work outdoors are at higher risk for UVR exposure and its related adverse effects, and the sun protection strategies of outdoor workers were reported to be often inadequate.[7] To achieve

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adequate photoprotection throughout the day, the initial amount of sunscreen applied must be appropriate, and the reapplication of sunscreen is necessary in certain settings. However, the reapplication of sunscreen during the workday among outdoor workers can be inconvenient, and that inconvenience often leads to sunscreen reapplication compliance failure. There were previous studies on the durability of sunscreen.[2,8,9] However, data specific to the time of day when sunscreen needs to be reapplied are both scarce and unclear.[10] We hypothesize that the sunscreen reduction in outdoor worker is continuously declined overtime. Therefore, the aim of this study was to evaluate the course of facial sunscreen coverage and sustainability over an 8-hour workday among outdoor workers.

2 | MATERIAL AND METHODS

2.1 | Study population

This single-center, open-label trial was conducted at the Department of Dermatology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand during January 2019 to October 2019. This study was approved by the Siriraj Institutional Review Board. Twenty healthy subjects aged more than 18 years whose work involved being outdoors for at least 80% of their working day were recruited (Table 1). Patients informed consents were obtained. All volunteers were available to be photographed every 2 hours from 8 AM to 4 PM (for a total of 5 times including the baseline photograph). Subjects with photodermatoses, active facial dermatitis, prior or current use of photosensitizing agents, previous history of sunscreen or topical fluorescent allergy, or pregnant and/or breastfeeding women were excluded.

TABLE 1 Sociodemographic characteristics and sunscreen use history of included subjects

Characteristics	n (%)
Gender	
Male	11 (55)
Female	9 (45)
Age (years), mean (range)	40.2 (24-59)
Fitzpatrick skin phototype	
IV	3 (15)
V	17 (85)
Occupation	
Security guard	14 (70)
Delivery messenger	5 (25)
Motorcycle driver	1 (5)
Level of education	
Primary school	1 (5)
Middle school	7 (35)
High school	12 (60)
Type of daily sun protection	
Sunglasses	1 (5)
Mask	5 (25)
Hat	4 (20)
Sunscreen	9 (45)
Long-sleeved shirt	9 (45)
Trousers	13 (65)
Having history of sunscreen use	9 (45)
Frequency of sunscreen use	
Every day	6 (30)
3–5 days/week	1 (5)
1–2 days/week	2 (10)
Amount of sunscreen applied on face (n = 9)	
Less than 1 fingertip	7 (77.78)
About 1 fingertip	2 (22.22)

2.2 | Sunscreen

The sunscreen used in this study was a broad-spectrum SPF50+ PA+++ sunscreen (SpectraBAN, Stiefel, GSK company, Brentford, Middlesex, UK) that is commercially available in Thailand. That sunscreen was homogenously admixed with a 2% invisible blue fluorescent agent (Swada, Dane Color UK Ltd., Houthalen-Helchteren, Limburg, Belgium) at the Pharmacy Department of Siriraj Hospital. The 2% invisible blue fluorescent agent used in this study was first used at our center as an agent to be combined with hand cleansing cream for teaching proper handwashing technique to patients. This fluorescent agent is stable under artificial indoor light and daylight. It becomes visible under Wood's light examination. The study sunscreen of 1 g and fluorescence preparation were then packaged in a sachet.

2.3 | Photography

A VISIA-CR camera booth (Canfield Scientific Inc., Parsippany, New Jersey) in UV mode with broad-pass filter (365 ± 40 nm) was used to photograph all volunteers. This camera has the ability to detect and photographically demonstrate the fluorescent agent in the sunscreen. Photographs were taken in 3 angles 5 times in the same day using the same background for all subjects.

2.4 | Digital image analysis program

The Regional Center of Robotics Technology, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand designed a software analysis program to analyze the brightness of the facial fluorescence photographed by the VISIA-CR camera. Fluorescence intensity was a gray scale measured using a range from 0 to 255. The areas measured were forehead, left cheek, right cheek, nose, upper cutaneous lip, and

chin. The mean brightness of each area represented the amount of sunscreen remaining on the volunteer's face.

2.5 | Day of study

All subjects were interviewed to determine their job-related details. Those whose work satisfied the inclusion criteria were given information about the study and invited to join the study. Written informed consent to participate was obtained from all volunteers. On a study day, subjects were given a questionnaire specially designed to elicit background information, work history, work description, the length of time they spent outdoors each working day, and their sun protection methods. Subjects were then first photographed by VISIA-CR camera in three angles (straight, left 45°, and right 45°) with a cleansed face, and then the volunteer was instructed to evenly apply one sachet of sunscreen to his/her entire face. Subjects were instructed that all of the sunscreen in the sachet must be used. Subjects were then photographed immediately after applying the sunscreen at 8 AM, and then at 10 AM, 12 PM, 2 PM, and 4 PM in three angles using the same background for all participants. Each photography session took about 5 minutes. During the workday, subjects were encouraged to engage in normal daily outdoor activities and to wear the protective garments or accessories that they normally use. Subjects were allowed to wipe their face, as needed, but they were not allowed to wash their face, reapply sunscreen, or apply any cosmetic products (Figure 1).

2.6 | Statistical analysis

Data are presented as number and percentage or mean and range. All continuous data were evaluated for normality by Shapiro-Wilk test. All *P*-values above .05 represent the normality of the data. Multivariate regression model was used to measure the reduction of sunscreen over time. Paired *t* test was used to analyze the mean reduction of sunscreen between different confounding factors. A *P*-value of less than .05 was considered to be statistically significant. All statistical analyses were performed using SPSS Statistics software program version 18.0 (SPSS, Inc., Chicago, Illinois).

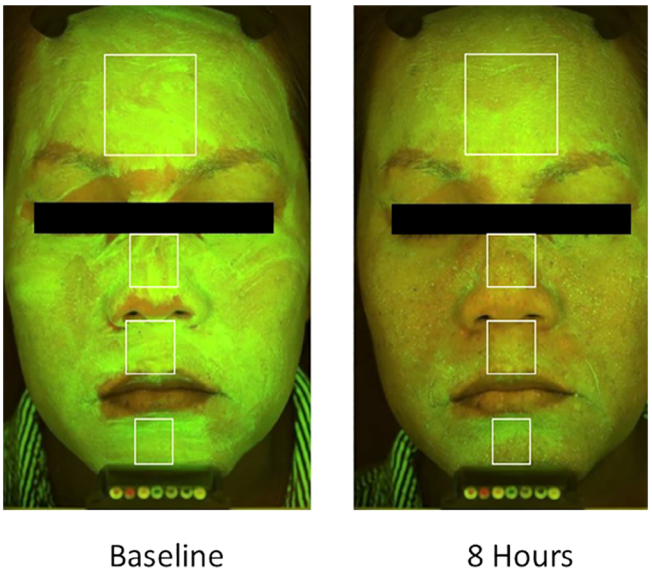

FIGURE 1 UV-mode photographs of facial sunscreen at baseline and 8 hours

3 | RESULTS

Twenty volunteers who spend at least 80% of their normal workday outdoors were enrolled. A majority (55%) of subjects were male, and the mean age of all participants was 40 years (range: 24-59). The number of working days was 4 (25%), 5 (70%), and 7 (5%) days a week. The mean amount of time spent outdoors per day was 7 hours (range: 6-12). Nine (45%) subjects had a history of previous sunscreen use (8 females and 1 male), and only 6 (66.7%) of those reported daily sunscreen use. The amount of sunscreen used was less than one fingertip in 7 (77.8%) subjects, and one fingertip in 2 (22.2%) volunteers. No study volunteers reapplied sunscreen during the workday (Table 1).

On the day of study, the UV index ranged from 9 to 11. At baseline, eyelids and ear pinna were common areas that were left without sunscreen application. Mean brightness reduction from digital image analysis at each area of the face showed significant declines in brightness at every 2-hour time point (Figure 2). The greatest decline in sunscreen coverage occurred during the first 2 hours at all six measured areas of the face. Table 2 demonstrates the mean reduction in sunscreen brightness, the estimated amount of sunscreen remaining, and the estimated SPF at every 2-hour time point. The mean reduction in sunscreen coverage after 8 hours was 31.63% (range: 17.4%-45.3%). The chin was found to be most susceptible to sunscreen reduction (40.0%), followed by above the lip (38.0%). The cheek was the area of the face with the least amount of sunscreen reduction throughout the workday (Figure 3). No significant difference in sunscreen reduction

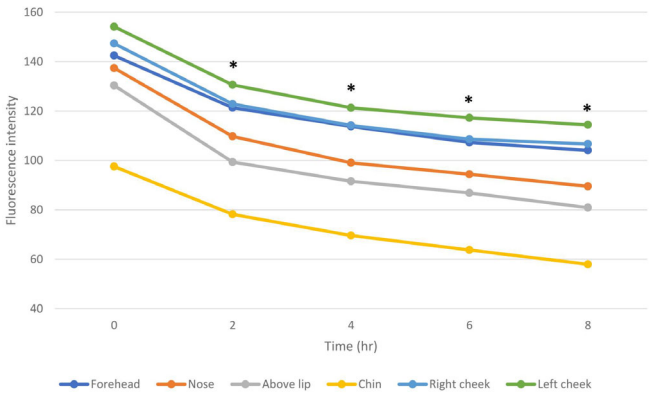

FIGURE 2 Mean fluorescence intensity (sunscreen brightness) from digital image analysis at each area of face compared among time points. (*indicates statistically significant change from the baseline at every area of the face)

TABLE 2 Mean reduction in sunscreen brightness, the estimated amount of sunscreen remaining and the estimated sun protection factor (SPF) at every 2-hour time point

Time point	Mean reduction in brightness % (range)	Estimated amount of remaining sunscreen (mg/cm^2)	Estimated SPF
Baseline	0.0 (0–0)	2.00	50+
2 hours	18.31 (4.21-36.31)	1.63	>30
4 hours	24.77 (11.12-38.97)	1.50	<30
6 hours	28.63 (14.25-39.69)	1.43	<25
8 hours	31.63 (17.39-45.29)	1.37	<25

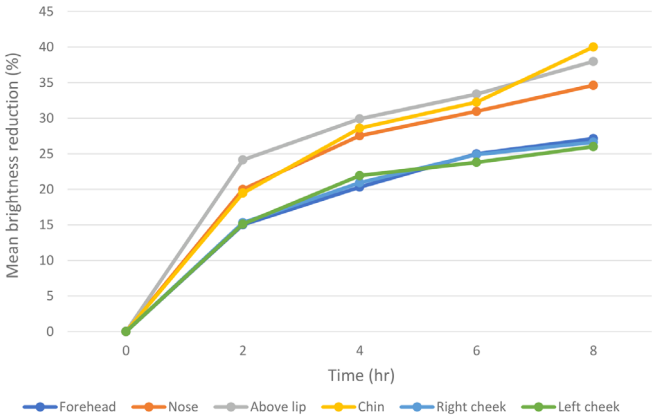

FIGURE 3 Mean brightness reduction compared among different areas of the face at each 2-hour time point

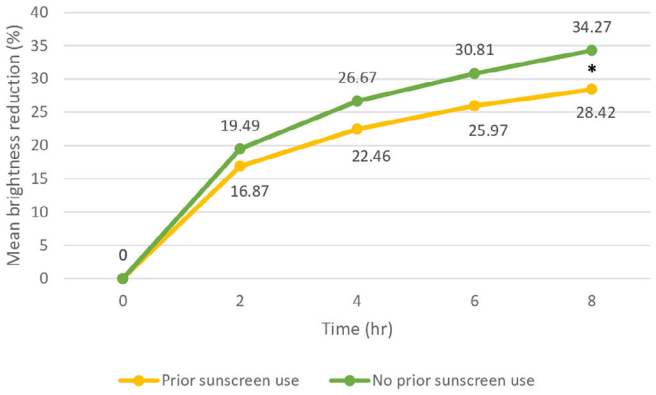

FIGURE 5 Percentage of brightness reduction compared between those with and without prior use of sunscreen. (*indicates statistically significant change from the baseline)

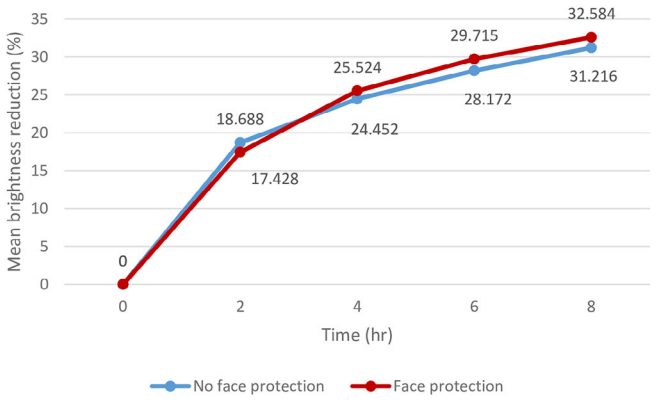

FIGURE 4 Percentage of brightness reduction compared between those who did and did not wear face protection (sunglasses or masks)

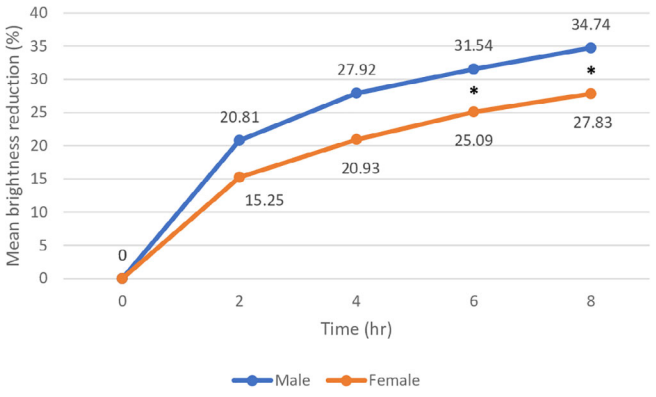

FIGURE 6 Percentage of brightness reduction compared between male and female participants (*indicates statistically significant change)

was observed compared between those who wore sunglasses or masks and those who did not (Figure 4). Interestingly, subjects who reported previous use of sunscreen during their workday showed a significantly lower reduction of sunscreen coverage at the 8-hour time point compared to those with no previous history of sunscreen use during their workday ($P = .05$) (Figure 5). Males showed a significantly higher rate of sunscreen decline after 4 hours compared to females (Figure 6).

4 | DISCUSSION

Our study confirmed a low level of sunscreen awareness, which was reflected in the 45% rate of previously inadequate use of sunscreen, and only 30% of participants wore sunscreen regularly. Outdoor workers are more prone to developing both acute and chronic effects of ultraviolet radiation. Reinau D, et al. conducted a systematic review of sun-related knowledge, attitudes, and protective behaviors among

outdoor workers, and they found the sun-protective behaviors of outdoor workers to be largely inadequate. The sunburn rate and risk of developing nonmelanoma skin cancer were high among outdoor workers when compared with indoor workers.[7] The hot and humid weather in Thailand could be a barrier to wearing thick sunscreen, long-sleeved shirt, and/or trousers. Lack of sun protection knowledge, and the discomfort associated with wearing protective garments were likely to contribute to the inadequate sun protection observed among outdoor workers in this study.

Previous studies reported a correlation between sunscreen thickness and the sunscreen SPF level.[11-13] Wulf, et al. used a mathematical model to demonstrate an exponential relationship between sunscreen thickness and the sunscreen SPF level. Wei Liu, et al. found a linear correlation between sunscreen thickness and SPF value in low SPF (4, 15) sunscreens, and an exponential correlation in high SPF (30, 55) sunscreens.[14] When the application thickness decreased to 1.5 mg/cm^2, the protection factor remained 50%.[14] As a result, we hypothetically assumed that the initial sunscreen thickness should be 2 mg/cm^2. After 2 hours, we found an 18.31% reduction in sunscreen, which we calculated to be equivalent to a sunscreen thickness of 1.63 mg/cm^2. We further estimated that this sunscreen thickness would deliver sun protection of greater than SPF 30. At 4 hours, the sunscreen remaining was 1.5 mg/cm^2, which reflects sun protection of less than SPF 30. The estimated SPF level at both 6 and 8 hours was less than SPF 25. The rapid decline within the first 2 hours can be explained by the migration of sunscreen into the follicular ostia.[15] However, the decline in sunscreen thickness continued at all subsequent 2-hour time points. This may be explained by sweat and sebum washing that is produced during the day, and even waterproof or water-resistant sunscreens can only withstand water for 40 to 80 minutes according to the 2011 US Food and Drug Administration regulations.[16] The rapid declination of sunscreen in the first 2 hours was similar even in indoor workers.[9] This hypothesis that sebum combined with sweat enhanced the degradation of sunscreen is supported by the observed greater decline of sunscreen at the nose, above the lip, and chin, all of which have greater sebum production, and less degradation at the cheek, which has less sebum production. Interestingly, our study showed no effect of sunscreen decline from wearing a surgical mask or sunglasses. This finding emphasizes the necessity of sunscreen reapplication even when subjects wear protective accessories. Subjects who reported no previous use of sunscreen had a significantly greater reduction of sunscreen at 8 hours compared to those who reported previous use of sunscreen. Moreover, females tended to have more remaining sunscreen than males at the 8-hour time point. These may be explained by that almost all of subjects who use sunscreen were female and the fact that females are more used to having make-up and treatments applied to their face compared to men. As such, men may be more uncomfortable and more likely to rub or wipe their face.

The findings of this study suggest that a start of the workday proper application of 2 mg/cm^2 of SPF50+ PA+++ sunscreen will degrade to an SPF level of less than 30 at 4 hours after sunscreen application. Therefore, reapplication of sunscreen every 4 hours will confer the necessary added benefit for sun protection. A public health campaign should be developed and implemented to inform outdoor workers of sun-related risks, and the ways that those risks can be mitigated.

4.1 | Limitations

The small number of included subjects is the main limitation of this study. Our study also restricted applicants from washing their faces and applying other cosmetic products (eg, powder, blush, and concealer) during the study period, and this may not reflect actual typical real-life behavior, especially among female outdoor workers. We did not measure the rate of sweating of each subject and this might also the affect the durability of the sunscreen. Other limitations were that we do not have information of baseline fluorescence with sunscreen without blue fluorescence and whether the blue fluorescence and the sunscreen filters declines equally with time.

4.2 | Conclusion

Reapplication of sunscreen is essential among outdoor workers. After 4 hours, the amount of sunscreen remaining on the face may not be sufficient for protecting the skin from harmful UV radiation.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the individuals who participated in this study, and Professor Viboon Sangveraphunsiri of the Regional Center of Robotics Technology, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand for his assistance with digital image analysis; and Mr. Suthipol Udompunthurak for assistance with statistical analysis.

CONFLICT OF INTEREST

All authors declare no personal or professional conflicts of interest, and no financial support from the companies that produce and/or distribute the drugs, devices, or materials described in this report.

AUTHOR CONTRIBUTIONS

Dr. Kobwanthanakun: conceptualization (supporting), data curation (lead), formal analysis (lead), writing- original draft preparation (lead).
Dr. Silpa-archa: conceptualization (equal), data curation (supporting), formal analysis (supporting), validation (lead), supervision (equal), writing- review & editing (equal).
Dr. Wongpraparut: conceptualization (equal), data curation (supporting), supervision (equal), writing- review & editing (equal).
Dr. Pruksaekanan: data curation (supporting), formal analysis (supporting), validation (supporting), writing- review & editing (supporting).
Dr. Manuskiatti: writing- review & editing (supporting).

All credited authors have read and approved the final version of the manuscript.

The corresponding author confirms to have had full access to all of the data in this study and takes complete responsibility to the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT

The authors affirm that this manuscript is an honest, accurate, and transparent account of the study being reported. No important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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REFERENCES

1. Watson M, Holman DM, Maguire-Eisen M. Ultraviolet radiation exposure and its impact on skin cancer risk. *Semin Oncol Nurs*. 2016;32:241-254.
2. Ouyang H, Meyer K, Maitra P, et al. Realistic sunscreen durability: a randomized, double-blinded, controlled clinical study. *J Drugs Dermatol*. 2018;17:116-117.
3. Gorig T, Schneider S, Seuffert S, Greinert R, Diehl K. Does sunscreen use comply with official recommendations? Results of a nationwide survey in Germany. *J Eur Acad Dermatol Venereol*. 2019;34:1112-1117.
4. Li H, Colantonio S, Dawson A, Lin X, Beecker J. Sunscreen application, safety, and sun protection: the evidence. *J Cutan Med Surg*. 2019;23:357-369.
5. Heerfordt IM, Philipsen PA, Larsen B, Wulf HC. Long-term trend in sunscreen use among beachgoers in Denmark. *Acta Derm Venereol*. 2017;97:1202-1205.
6. Petersen B, Wulf HC. Application of sunscreen—theory and reality. *Photodermatol Photoimmunol Photomed*. 2014;30:96-101.
7. Reinau D, Weiss M, Meier CR, Diepgen TL, Surber C. Outdoor workers' sun-related knowledge, attitudes and protective behaviours: a systematic review of cross-sectional and interventional studies. *Br J Dermatol*. 2013;168:928-940.
8. Bodekaer M, Faurschou A, Philipsen PA, Wulf HC. Sun protection factor persistence during a day with physical activity and bathing. *Photodermatol Photoimmunol Photomed*. 2008;24:296-300.
9. Rungananchai C, Silpa-Archa N, Wongpraparut C, Suiwongsa B, Sangveraphunsiri V, Manuskiatti W. Sunscreen application to the face persists beyond 2 hours in indoor workers: an open-label trial. *J Dermatol Treat*. 2019;30:483-486.
10. Diffey BL. When should sunscreen be reapplied? *J Am Acad Dermatol*. 2001;45:882-885.
11. Wulf HC, Stender IM, Lock-Andersen J. Sunscreens used at the beach do not protect against erythema: a new definition of SPF is proposed. *Photodermatol Photoimmunol Photomed*. 1997;13:129-132.
12. Faurschou A, Wulf HC. The relation between sun protection factor and amount of suncreen applied in vivo. *Br J Dermatol*. 2007;156:716-719.
13. Kim SM, Oh BH, Lee YW, Choe YB, Ahn KJ. The relation between the amount of sunscreen applied and the sun protection factor in Asian skin. *J Am Acad Dermatol*. 2010;62:218-222.
14. Liu W, Wang X, Lai W, et al. Sunburn protection as a function of sunscreen application thickness differs between high and low SPFs. *Photodermatol Photoimmunol Photomed*. 2012;28:120-126.
15. Draelos ZD. Degradation and migration of facial foundations. *J Am Acad Dermatol*. 2001;45:542-543.
16. Jansen R, Osterwalder U, Wang SQ, Burnett M, Lim HW. Photoprotection: part II. Sunscreen: development, efficacy, and controversies. *J Am Acad Dermatol*. 2013;69:867 e861-814; quiz 881-862.

How to cite this article: Kobwanthanakun W, Silpa-archa N, Wongpraparut C, Pruksaekanan C, Manuskiatti W. An evaluation of the course of facial sunscreen coverage and sustainability over an 8-hour workday among outdoor workers. *Health Sci Rep*. 2021;4:e350. https://doi.org/10.1002/hsr2.350