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Photoprotection Practice and Skin Health Habits on the Incidence of Pigmentation

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Abstract

The skin is susceptible to intrinsic and extrinsic factors — including sun exposure, diet, and lifestyle — which can disrupt homeostasis and induce pigmentation. This pilot study evaluated photoprotective behaviors and skin health habits and their association with pigmentation incidence among medical students at Sam Ratulangi University, Indonesia (February–April 2024). Using a self-administered questionnaire, 94 valid respondents were included (mean age 21.4 ± 1.7 years; response rate 37.6%). Pigmentation was reported by 34.0% of respondents, predominantly female (59.8%). Associated factors included irregular sunscreen use, history of sunburn, passive smoking, prolonged sun exposure, poor dietary habits, insufficient sleep, limited exercise, and elevated stress. Statistically significant associations ($P < 0.05$) were identified for daily sunscreen use, sunscreen use during outdoor activities, history of sunburn, and daily stress. Although pigmentation incidence was relatively low, concerning gaps in photoprotective and skin health behaviors were observed. As future healthcare providers, medical students represent a critical target population. Early education on sun-related damage, photoprotection, and skin health habits is recommended to improve knowledge, attitudes, and practices in this group.

Introduction

The skin is the body's largest organ and serves as a barrier between the internal environment and the external environment. It serves as both a physical shield and as an immunological and metabolic organ, responding to internal and external changes. Among the environmental factors affecting skin homeostasis, solar radiation—especially ultraviolet (UV) radiation—is most significant. UV radiation is the most energetic and potentially harmful form of light, aside from visible and infrared light. The atmosphere filters some UV (UVA: 320-400 nm, UVB: 280-320 nm) and visible light, but a substantial amount reaches the Earth's surface and impacts skin through DNA damage and oxidative stress pathways (Chung, 2019; Solano, 2020).

Short-term exposure to UV radiation can lead to acute skin damage, *e.g.*, sunburn and tanning. Subsequently, long-term exposure to UV radiation may lead to chronic skin diseases, *e.g.*, hyperpigmentation, premature skin aging, altered immunological responses in the skin, disturbances of skin barrier function, photodermatoses, and the development of skin cancer (Bahashwan, 2024). The pathogenesis of UV-induced pigmentation is complex and involves melanocyte activation, increased tyrosinase activity, and enhanced melanosome transfer to keratinocytes, often mediated by reactive oxygen species (ROS) and inflammatory cytokines (Yardman-Frank & Fisher, 2021).

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Prevention of pigmentation and skin cancer has been closely related to photoprotection practice and skin health habits. These strategies include the regular use of sunscreen, protective clothing (e.g., wearing a wide-brimmed hat and sunglasses), behavioral modifications, and environmental awareness (Chung, 2019; Roren *et al.*, 2022). Despite well-established guidelines from dermatological associations, adherence to photoprotective practices remains suboptimal, even among populations with medical knowledge (Chavez *et al.*, 2025; Roren *et al.*, 2022).

Several studies have identified poor photoprotection practices among students, *e.g.,* infrequent sunscreen use (Rodriguez-Gambetta *et al.*, 2016; Amin *et al.*, 2023; Upadhyay *et al.*, 2021). In addition to UV exposure, lifestyle-related factors, such as improper sleep and diet, tobacco smoking, and physical inactivity, have also been identified as contributing factors towards unhealthy skin through oxidative stress or chronic psychological stress, which may subsequently amplify UV-mediated damage through shared molecular pathways (Jhonvini *et al.,* 2025; Nelson *et al.*, 2023). It is noteworthy that many students are in adolescence (Sawyer *et al.*, 2018). Adolescence and childhood involve greater exposure to sunlight than in most adults due to outdoor recreational activities and sports. This social behavior is linked to an increased risk of developing skin cancer in adulthood. Furthermore, the likelihood of photoaging and the development of sunspots or skin pigmentation increases with extensive sun exposure during childhood (Andreola *et al.*, 2018). Among Indonesians, particularly medical university students, photoprotection practices, skin health habits, and their perceptions of UV radiation exposure and photodermatoses have rarely been reported. This population is important because they are future healthcare professionals who will advise their patients on photoprotection measures and skin health habits (Amin *et al.*, 2023). This pilot study aimed to evaluate photoprotective practices and skin health habits and their incidence of pigmentation among medical students in East Indonesia, providing preliminary data to inform future larger-scale studies and targeted educational interventions.

Method

This cross-sectional observational study was conducted from February 1 to April 30, 2024, at Sam Ratulangi University, Manado, North Sulawesi, Indonesia. Ethics approval was granted by the Faculty of Medicine's Ethics Committee (Ref. No: DP.04.03/D. XV/1366/2024). All participants, who were medical students (including clerks and interns), provided informed consent. Sampling was purposive and consecutive. Data were collected using an online questionnaire. The questions were developed for this study and modified based on recent updates to theories, recommendations, and specific circumstances to align with the characteristics of our sample. The self-report questionnaire comprised 17 questions, each with two-choice options. The questionnaire underwent a preliminary content validity review by two board-certified dermatovenereologists before distribution. It was divided into three sections: the first focused on demographic characteristics; the second section assessed photoprotective behaviors (*e.g.*, the frequency of sunscreen use, application during outdoor activities, and duration of sun exposure) and skin health habits (*e.g.*, smoking status, dietary intake [fruits and vegetables], antioxidant supplementation, sleep duration, physical activity, psychological stress, and sugar consumption]; and the third section evaluated the self-reported participants' incidence of pigmentation.

Data collected through the questionnaires were exported to Excel files (Microsoft Excel, Microsoft Corp., Redmond, WA, USA) and analyzed using the Statistical Package for the Social Sciences (SPSS) for Mac Version 25.0 (IBM, Armonk, NY, USA). Frequency and percentage were used to describe participant characteristics. Photoprotective practices and skin health habits were categorized into two groups. To determine the potential association between photoprotective practices and skin health habits and the incidence of pigmentation, the chi-square test was used. P values < 0.05 were considered statistically significant, and odds ratios with 95% confidence intervals were used to assess the strength of associations and precision. Given the pilot nature of the study and the small sample size, multivariate analysis

was not conducted; however, the findings were interpreted cautiously, with consideration of potential confounders.

Result and Discussion

An estimated 400 surveys were distributed, and 94 medical students

Table 1. Photoprotection Practice and Skin Health Habits on the Incidence of Pigmentation

Variable	Pigmented (n = 32)	Non-pigmented (n = 62)	OR (95% CI)	P value
Sex				
Male	13 (37.1)	22 (62.9)	1.0 [Reference]	0.625
Female	19 (32.2)	40 (67.8)	1.244 (0.518 – 2.989)	
Daily sunscreen use				
Yes	16 (47.1)	18 (52.9)	1.0 [Reference]	0.045
No	16 (62.7)	44 (73.3)	2.444 (1.010 – 5.915)	
Sunscreen use during outdoor activity				
Yes	13 (50.0)	13 (50.0)	1.0 [Reference]	0.043
No	19 (27.9)	49 (72.1)	2.579 (1.014 – 6.560)	
Active smoking				
No	31 (33.7)	61 (66.3)	1.0 [Reference]	0.630
Yes	1 (50.0)	1 (50.0)	1.968 (0.119 – 32.531)	
Passive smoking				
No	9 (40.9)	13 (59.1)	1.0 [Reference]	0.437
Yes	23 (31.9)	49 (68.1)	1.475 (0.551 – 3.945)	
Direct sun exposure				
No	11 (42.3)	15 (57.7)	1.0 [Reference]	0.296
Yes	21 (30.9)	47 (69.1)	1.641 (0.646 – 4.171)	
Average duration of weekly sun exposure				
< 3 hours/ week	16 (40.0)	24 (60.0)	1.0 [Reference]	0.294
≥ 3 hours/ week	16 (29.6)	38 (70.4)	0.632 (0.267 – 1.494)	
History of sunburn				
No/ Never	12 (57.1)	9 (42.9)	1.0 [Reference]	0.011
Yes	20 (27.4)	53 (72.6)	3.533 (1.292 – 9.660)	
Daily antioxidant supplementation				
Yes	12 (37.5)	20 (62.5)	1.0 [Reference]	0.611
No	20 (32.3)	42 (67.6)	0.794 (0.325 – 1.937)	
Daily fruits and vegetables intake				
Yes	9 (47.4)	10 (52.6)	1.0 [Reference]	0.170
No	23 (30.7)	52 (69.3)	0.491 (0.176 – 1.371)	
Average duration of daily sleep				
> 7 hours/ night	4 (50.0)	4 (50.0)	1.0 [Reference]	0.319
≤ 7 hours/ night	28 (32.6)	58 (67.4)	0.483 (0.112 – 2.073)	
Average duration of daily stress				
< 2 hours/ day	12 (21.4)	44 (78.6)	1.0 [Reference]	0.002
≥ 2 hours/ day	20 (52.6)	18 (47.4)	4.074 (1.654 – 10.037)	

Frequency of high sugar content				
< 3 times/ week	8 (47.1)	9 (52.9)	1.0 [Reference]	0.211
≥ 3 times/ week	24 (31.2)	53 (68.8)	0.509 (0.175 – 1.481)	
Frequency of weekly exercise				
≥ 3 hours/ week	17 (36.2)	30 (63.8)	1.0 [Reference]	0.663
< 3 hours/ week	15 (31.9)	32 (68.1)	0.827 (0.352 – 1.944)	

CI = confidence interval; OR = odds ratio

responded, yielding a 37.6% response rate. The study included 94 respondents with no refusal to participate. Hence, the total number of respondents eligible for the study was 94. The respondents comprised 94 medical students, with a mean age of 21.4 ± 1.7 years. Pigmentation incidence was reported by 32 respondents (34.0%), predominantly female (59.8%). Statistically significant factors related to pigmentation were irregular daily sunscreen use, lack of sunscreen during outdoor activities, history of sunburn, and daily stress ($P < 0.05$). Other observed factors among those with pigmentation included active smoking (3.1%), passive smoking (71.9%), direct sun exposure (65.6%), ≥3 hours/week sun exposure (50.0%), irregular antioxidant use (62.5%), low fruit/vegetable intake (71.9%), ≤7 hours/night sleep (87.5%), <3 hours/week of exercise (46.9%), ≥2 hours/day stress (62.5%), and ≥3 times/week high-sugar intake (75.0%) (see **Table 1**).

This study demonstrated that inconsistent sunscreen use and lack of sunscreen application during outdoor activities were significantly associated with a higher incidence of pigmentation. These findings reinforce the pivotal role of UV exposure in melanogenesis and align with existing recommendations emphasizing sunscreen as the cornerstone of photoprotection. Interestingly, while direct sun exposure and duration of exposure were not statistically significant, this may reflect variability in individual protective behaviors, such as intermittent sunscreen use or physical barriers (*e.g.*, clothing or hat), which were not fully captured in this study.

The physiological response of skin against solar radiation depends on the production, distribution, type, and quantity of melanin synthesized in melanocytes and transferred to keratinocytes (Solano, 2020). Pigmentation incidence is associated with the accumulation of melanin pigment produced by melanocytes (Ashar & Riyaningrum, 2022). The association between UV radiation and pigmentation observed in this study can be explained by the role of UV-induced inflammation in melanogenesis. UV radiation stimulates keratinocytes to release pro-inflammatory mediators, such as α-melanocyte-stimulating hormone, endothelin-1, and prostaglandins, which in turn activate melanocytes. Additionally, oxidative stress generated by UV exposure increases tyrosinase activity, a key enzyme in melanin synthesis (Jia & He, 2025). In this study, although not statistically significant, 32 respondents (34.0%) reported pigmentation, predominantly females (59.8%). It has been established that the female sex hormones estrogen and progesterone, which boost melanin production when the body is exposed to solar radiation, are the culprits behind the pigmentation that is prevalent in women (Thawabteh *et al.*, 2023).

The effort to reduce UV radiation-induced skin damage and skin cancers is called photoprotection. Photoprotection includes sunscreen, clothing, hats, makeup, sunglasses, and windshields (Gabros *et al.*, 2023). In this study, daily sunscreen use and sunscreen use during outdoor activity had statistically significant associations with pigmentation; however, to our surprise, neither direct sun exposure nor≥3 hours of weekly sun exposure was statistically significant. In support of photoprotection practice, specifically sunscreen use, the American Academy of Dermatology has recommended the ideal times of sunscreen application; amount of sunscreen to be applied; level of protection (sun protection factor [SPF]) required; frequency, methods, and sites of application; and reapplication of sunscreen (American Academy of Dermatology, 2024).

Mechanically, the effects of UV radiation

on target cells and tissues are triggered by molecular and cellular damage pathways that are induced when chromophores in the skin absorb UV radiation. UV radiation can broadly induce reactive oxygen species by affecting cellular components or through photosensitization mechanisms. UV radiation may also damage DNA, leading to cell cycle arrest and apoptosis. Among the various components of solar radiation, UVA radiation frequently leads to ROS accumulation in the skin, causing alterations in gene and protein structure and function. This process results in reduced and fragmented collagen and elastic fibers in the dermis, ultimately leading to deep wrinkles, skin laxity, and hyperpigmentation, *i.e.*, characteristic of photoaged skin (Tang *et al.*, 2024).

In this study, skin health habits (*e.g.,* avoidance of smoking, history of sunburn, daily antioxidant supplementation, daily fruits and vegetables intake, >7 hours daily sleep, ≥3 hours weekly exercise, <2 hours daily stress, and <3 times weekly high sugar contents) were also evaluated. Smoking and UV radiation are represented as environmental triggers of exogenous sources, which may contribute to the increase of reactive oxygen species production in cells (Sharifi-Rad *et al.*, 2020). Antioxidant supplementation coupled with daily fruit and vegetable intake containing antioxidants (vitamins A, C, E, β- and α-carotene, and glutathione) will help to counteract the oxidative stress (Jideani *et al.,* 2021; Arias *et al.*, 2022). One proposed function of sleep may be mitigating oxidative stress in both brain and peripheral tissues, contributing to the clearance of reactive species that accumulate during wakefulness (Davinelli et al., 2024). Yet, nowadays, increased internet access via smartphone technology poses a significant challenge to sleep quality as it prolongs the duration required to sleep, disrupts circadian rhythms, diminishes melatonin hormone levels that facilitate sleep, affecting the quality and duration of rapid eye movement sleep, and alters morning alertness, aligning with a study in 2023 by Wijaya & Megawati.

Regular exercise enhances the body's antioxidant capabilities and overall redox balance, contributing to reducing oxidative damage (Meng & Su, 2024). Chronic psychological stress has also been reported to induce oxidative stress in the skin. The effect of chronic psychological stress could be mediated through the autonomic nervous system, renin-angiotensin system, and hypothalamus-pituitary-adrenal system (Chen *et al.*, 2021). Consumption of high sugar contents may lead to hyperglycemia and, subsequently, promote collateral glucose metabolism through protein kinase C, polyols, and hexosamine routes, and facilitate spontaneous glucose auto-oxidation and the formation of advanced glycation end products (González et al., 2023). UV-induced oxidative stress and DNA damage in skin cells. DNA damage repair initiates cellular signals through the overproduction of reactive oxidants, *e.g.*, H_2O_2 and reactive nitrogen species, promoting melanogenesis (Chen *et al.*, 2021).

In this study, two variables, *i.e.*, history of sunburn and average duration of daily stress, were statistically significant. The physiological response to solar radiation through solar pigmentation (tanning) or the production of erythema (sunburn) is genetically determined by ethnic characteristics of individuals. Fairer-skinned individuals respond predominantly with sunburn, while darker-skinned individuals will experience a more intense pigmentation rather than erythema (Schalka *et al.*, 2014). Interestingly, Indonesian skin types are mainly classified as Fitzpatrick skin types 4 and 5, never-to-rarely burn, and are prone to tanning, increasing the risk of pigmentation (Ashar & Riyaningrum, 2022). It is also crucial to emphasize that this study sampled only medical students. A previous study by Roren *et al.* highlighted that medical students had a significantly higher level of photoprotection knowledge than non-medical students (P-value = 0.00). This finding may be attributed to the different curricula in each faculty, yielding different photoprotection behavior and skin health habits (Roren *et al.*, 2022).

Concurrently, most medical students also represent adolescents (10-24 years old), in which critical developmental periods are characterized by evolving autonomy, identity formation, and health-related decision-making, which significantly influence health-seeking

behavior and overall well-being (Sawyer *et al.*, 2018). This age period is prone to involvement with health risk problems, *e.g.*, smoking, drinking alcohol, drugs, and/ or lower physical exercise (Shaluhiyah *et al.*, 2021). Medical students also often demonstrate a discrepancy between knowledge and practice, particularly in preventive health behaviors, such as photoprotection (Chavez *et al.*, 2025). However, previous studies have shown that adolescent health behavior may be addressed through a psychological approach of self-compassion, participation, and life skills education (Hedo & Katmini, 2022; Shaluhiyah *et al.*, 2021). Earlier introduction of photoprotection from junior to senior high school through adolescent-friendly health services (PKPR) and the health promotion model may benefit the adolescents, as supported by a previous study about anemia and changes in health behavior intentions during the COVID-19 pandemic among adolescents (Arifah *et al.*, 2025; Lutfhiani *et al.*, 2023).

This study has some limitations. First, this is a pilot study with a relatively small sample size. Second, responses were collected through a questionnaire, which might have subjected the participants to recall bias, particularly regarding their behaviors. Finally, this study was conducted at one university in an urban area of East Indonesia and hence did not explore the differences between universities as well as those between urban and rural areas. Further studies could extend our findings to the assessment of knowledge and attitude toward photoprotection as well as to other faculties, universities, and geographical regions.

Conclusion

This pilot cross-sectional study demonstrated that pigmentation incidence among medical students at Sam Ratulangi University, East Indonesia, was 34.0%, with a predominance in female respondents (59.8%). Statistically significant associations ($P < 0.05$) were identified between pigmentation incidence and irregular daily sunscreen use, absence of sunscreen use during outdoor activities, history of sunburn, and prolonged daily stress exposure of ≥2 hours/day. Additional behavioral risk factors, including passive smoking, extended sun exposure, poor dietary habits, insufficient sleep, and high sugar intake, were observed among pigmented respondents, though these did not reach statistical significance, likely owing to the pilot nature and limited sample size of the study. These findings collectively underscore the presence of notable gaps in photoprotective practices and skin health behaviors within this population, despite their medical background. Given that medical students represent future healthcare providers with a critical role in patient education, the integration of early, structured photoprotection and skin health education into medical curricula is strongly warranted to bridge the gap between theoretical knowledge and health-promoting practice.

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