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Measurement of Ultraviolet-B (UVB) Minimum Erythema Dosage (MED) Based on Sun Exposure as the Basis of Sunlight Phototherapy: Study of Skin Type III or IV at Various Altitudes in Indonesia

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ABSTRACT

Background: Phototherapy facilities for skin diseases are not widely available in Indonesia. No studies have yet measured the duration of sunbathing to achieve a minimal erythema dose (MED) in healthy volunteers at various altitudes. **Purpose:** This study calculates the duration of sunbathing to achieve the MED at various altitudes. **Methods:** This study was conducted in various regions of Yogyakarta, Indonesia, with latitude 7°15'-8°15' S and 110°5'-110°4' E, within the Yogyakarta equinox period by including three places with different altitude groups at 10:00 WIB (UTC+7). Forty-eight healthy individuals of skin type III or IV were exposed to sunlight using a photo-opaque template with 8 squares, each with 1 x 1 cm^2 holes. The squares will receive an increase in exposure duration of as many as 250 seconds. **Result:** There was a significant difference in the mean UVB intensity between all heights ($p < 0.05$). The average duration of sunbathing to reach MED at an altitude of 0-300 masl, > 300-600 masl, and > 600-950 masl are 22 minutes 40 seconds, 20 minutes 34 seconds, and 18 minutes 14 seconds, respectively. There is no significant difference in the duration of sunbathing between altitudes of 0-300 masl and 300-600 masl and between 300-600 masl and 600-950 masl ($p > 0.05$). However, there was a significant difference in the duration of sunbathing between the altitudes of 0-300 masl and 600-950 masl ($p < 0.05$). **Conclusion:** A difference exists in the duration of sunbathing required to achieve MED at altitudes greater than 600 masl.

Keywords: minimal erythema dose, sunlight phototherapy, sunbathing duration, ultraviolet-B.

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BACKGROUND

Indonesia is a tropical country that is exposed to sunshine throughout the year.[1] Exposure to ultraviolet (UV) radiation from sunlight can provide many health benefits, such as vitamin D synthesis and healing of several skin diseases[2]; on the other hand, prolonged sunlight exposure is often associated with photocarcinogenesis and other dermatological conditions.[3]

Currently, UV radiation has been filtered into medical phototherapy devices[4–5], but there are several problems related to phototherapy in Indonesia. The choice of phototherapy using sunlight is expected to reduce the problems mentioned above and optimize patient therapy[6], so it is necessary to know the optimal sunbathing time and duration.

The effect of UV light on human health depends on the type, intensity, and dose of UV radiation that reaches the human skin[7]. Ultraviolet-B (UVB) light consists of the most biologically active wavelengths that reach the earth's surface and are associated with erythema.[8,9]

The Meteorological and Geophysics Agency in many countries describes the level of UV intensity related to human health by using the Ultraviolet Index (UVI), which is expressed as a number without a unit.[10]

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The disadvantage of UVI is that it is unable to determine UV exposure that has reached the appropriate dose.[10]

Exposure to UV light, particularly UVB, causes erythema, which is an acute clinical effect that is visibly apparent and easily recognized. This reaction follows ultraviolet interaction with chromophores on the skin, resulting in DNA damage, which then triggers various cytokines and inflammatory mediators as well as changes in vascular perfusion in the dermis.[11,12] The sign of erythema is considered a clinical endpoint in human photobiology. Erythema, known as the minimal erythema dose (MED), is used as a basis for determining the initial dose of therapy for several skin disorders treated with UVB phototherapy.[13]

Measurement of MED based on natural sunlight in Indonesia incorporating healthy volunteers to find the optimal sunbathing duration has not been done. Therefore, this study was conducted to obtain the optimal sunbathing duration equivalent to MED at various DIY altitudes in the peak month of the equinox.

METHODS

This research utilized an experimental design and was conducted on Fitzpatrick skin types III and IV across various Yogyakarta Special Region at altitudes of 0-300 meters above sea level (masl), >300-600 masl, and >600-950 masl during the peak of the Yogyakarta equinox month. The equinox peaks occurred on 2 October 2020, 26 September 2020, and 28 September 2020 at 10:00 WIB under clear and cloudless conditions. Informed consent was obtained from every research subject, and ethical clearance was granted (Number: KE/FK/0517/EC/2020) by the Medical and Health Research Ethics Committee (MHREC) at the Faculty of Medicine, Public Health and Nursing, Gadjah Mada University, Dr. Sardjito General Hospital..

Forty-eight healthy individuals aged 20-35 years with skin type III or IV were included in this study. The exclusion criteria were pregnant women, breastfeeding, immunosuppressive conditions, a history of photodermatoses, lesions in the irradiated area, receiving medication suspected as a photosensitizer, and taking corticosteroids or nonsteroidal anti-inflammatory drugs.

On the first visit, the volar aspect of the forearm was exposed to sunlight using a photo-opaque template with 8 squares, each with 1 x 1 cm^2 holes. The exposure duration was increased by 250 seconds for each successive square, beginning at 500 seconds for the first square and reaching 2250 seconds for the 8th square.

Ultraviolet B intensity was measured at the time of exposure using the irradiance meter from Daavlin®, model X-96, USA. At the second visit (24 hours after irradiation), two observers visually assessed the area exposed to UV light that displays well-defined, uniform erythema 24 hours after exposure, along with the minimum duration of exposure, is regarded as the appropriate sunbathing duration to achieve the MED. The MED is obtained from the duration of sunbathing to achieve MED multiplied by the mean UVB intensity at the time of the measurement.

Comparative analysis of UVB intensity and sun duration to achieve MED and MED at various altitudes was done using ANOVA and Kruskal-Wallis tests. Results were considered statistically significant if $p<0.05$. Approval for the study was obtained from the Ethical Committee of the Medical and Health Research Ethics Committee's (MHREC) Faculty of Medicine, Public Health, and Nursing at Gadjah Mada University - Dr. Sardjito General Hospital (Ref. No. KE/FK/0517/EC/2020), issued on April 28th, 2020. Data confidentiality was maintained, and all information was used exclusively for research purposes.

RESULT

The measurement of sunbathing time was carried out by two observers. The interobserver reliability was analyzed using a paired t-test. There was no statistically significant difference, and the result was consistent between the observers (Table 1).

Table 1. Differences in time measurement by the two observers

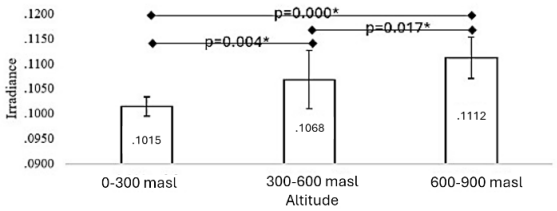
	Average time	Difference	P value
Obs1	1312.50 ± 322.75	62.5 ± ±322.75	0.451
Obs2	1250.00 ± 288.68		

*Statistical analysis was performed using a paired t-test

This study involved 48 subjects consisting of 23 males (47.9%) and 25 females (52.1%) with an average age of 23.7 ± 5.7 years. There were 24 subjects with skin type III and 24 subjects with skin type IV.

The results of this study indicate that the mean UVB intensity was 0.11 ± 0.01 mW/cm^2, the mean sunbathing duration was 1229.17 ± 317.21 seconds (20 minutes 29 seconds), and the MED is 130.48 ± 32.05 mJ/cm^2.

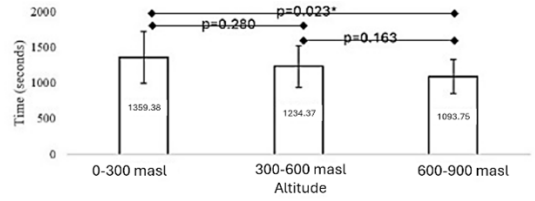
The highest average of UVB intensity was at an altitude of 600-900 masl, which was 0.111215 mW/cm^2, followed by an altitude of 300-600 masl, which was 0.106831 mW/cm2, and lowest at an altitude of 0-300 masl, namely 0.101456 mW/cm^2. There was a significant difference in the mean UVB intensity between all altitudes (p <0.05) (Figure 1).



*Statistical analysis was performed using advanced ANOVA post hoc LSD

Figure 1. Difference in UVB intensity (irradiance) based on the altitude of the area.

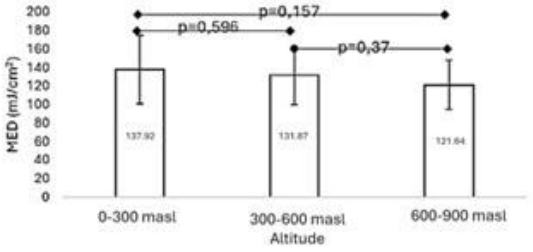
The highest average duration of sunbathing occurred at an altitude of 0-300 masl, which was 22 minutes 40 seconds, followed by an altitude of 300-600 masl, which was 20 minutes 34 seconds, and lowest at an altitude of 600-900 masl, which was 18 minutes 14 seconds. There is no significant difference in the duration of sunbathing between altitudes of 0-300 masl and 300-600 masl, and between >300-600 masl and >600-900 masl. However, there was a significant difference in the duration of sunbathing between altitudes of 0-300 masl and >600-900 masl (p <0.05) (Figure 2).



*Statistical analysis was performed using the Kruskal Wallis test followed by Mann-Whitney tes

Figure 2. The difference in sunbathing duration based on the area's altitude.

The findings of this study reveal that the highest average MED was recorded at an altitude of 0-300 masl, measuring 137.92 mJ/cm². This value was followed by an altitude of 300-600 masl, which recorded 131.87 mJ/cm², while the lowest average MED was observed at an altitude of 600-900 masl, at 121.64 mJ/cm². No significant difference in MED exists between the altitudes of 0-300 masl and 300-600 masl, 300-600 masl and 600-900 masl, as well as 0-300 masl and 600-900 masl (p>0.05) (Figure 3 and Figure 4).



*Statistical analysis was performed using ANOVA and Post Hoc LSD teets

Figure 3. Differences in MED based on the area's altitude

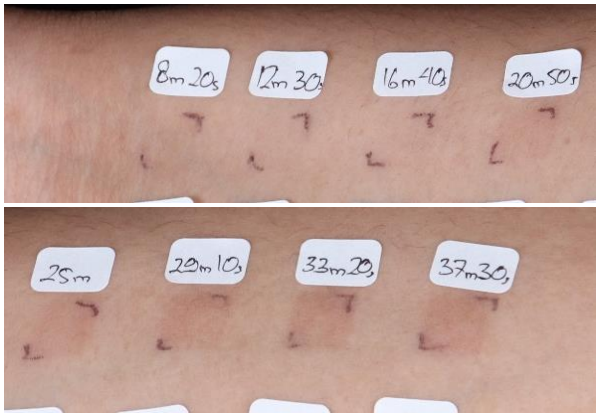


Figure 4. Squares showing the duration of sunbathing with MED reached at 20 minutes 50 seconds.

DISCUSSION

The effect of UV rays on health depends on the total dose of UV radiation, which consists of the intensity and duration of UV exposure.[14] In this study, the highest mean UVB intensity occurred at an altitude of >600-900 masl, followed by an altitude of >300-600 masl, and the lowest at an altitude of 0- 300 masl. There was a significant difference in the mean UVB intensity between all altitudes (p<0.05). One of the factors that influence UV intensity is the altitude of the region. Ultraviolet increases by about 4% per 300 kilometers.[15] In general, as the altitude increases, so will the solar radiation. Such a pattern is due to smaller optical air masses. Compared to low-altitude places, the intensity of sunlight at high-altitude places will pass a shorter path through the atmosphere so that it will experience less light scattering and absorption. The increasing UV intensity at higher places is known as the altitude effect (AE).[15,16] The increase in sunlight intensity (especially UV light intensity) along with the altitude of a place has been studied by various studies.

In this study, the average sunbathing duration at all altitudes was 20 minutes 29 seconds ± 317.21 seconds. Higher results obtained from research conducted by Miyauchi et al.[17] in Japan found the duration of sunbathing to reach MED for skin type III with a very high UV index category was 20-25 minutes.[17] This difference can be attributed to variations in latitude. The duration of sunbathing to receive the right dose of UV is influenced by geographic conditions (latitude and altitude).[18] Japan has a higher latitude than Indonesia. Areas with lower latitudes have the potential to receive higher UV radiation than areas at high latitudes, so the sunbathing duration will be shorter.[19]

In this study, it was found that the highest average sunbathing duration occurred at an altitude of 0-300 masl, namely 22 minutes 40 seconds, followed by an altitude of >300-600 masl, which was 20 minutes 34 seconds, and the lowest at an altitude of >600-900 masl which was 18 minutes 34 seconds. Guzikowski's research (2018)[18] in Canada obtained similar results, showing there was a reduction in sunbathing duration as the latitude of the area increased.[18] In their study, it was found that the duration of sunbathing with an altitude of 180 masl and 570 masl was 28 minutes 40 seconds and 22 minutes 30 seconds, respectively, based on spectrophotometer data.[18]

In our study, there was no significant difference in the duration of sunbathing between altitudes of 0-300 masl and >300-600 masl, as well as between >300-600 masl and >600-950 masl. Nevertheless, there was a significant difference in the duration of sunbathing between altitudes of 0-300 masl and >600-950 masl ($p < 0.05$). Blumthaler's study found as the altitude increases by 1000 masl, the erythema after UVB exposure increases by 23.7%, measured using a sunburn UV meter.[16] Based on this study, it can be assumed that the great altitude difference is able to make the duration of sunbathing significantly different. Research by Poon et al. showed a shorter sunbathing duration difference on the third day at the same measurement site due to the increase in wind speed that day. Meteorological factors such as climate, weather, air temperature, and wind speed influence the duration of sunbathing, in addition to geographical factors. Research by Sanjaya (2016) from the UGM Metrology and Instrumentation division found that the highest wind speed occurs at the highest altitude. Based on data from the Meteorology, Climatology, and Geophysics Agency (BMKG) of Sleman Climatology Class IV Station, wind speeds were obtained at 10.00 WIB at an altitude of 0-300 masl, >300-600 masl, and >600-950 masl and were 04 knots, 05 knots, and 06 knots, respectively. The highest wind speed was obtained at an altitude of >600-950 masl, so the shorter sunbathing duration at an altitude of >600-950 masl may also be affected by the wind speed at that location.

The results of our study indicate that the mean MED is 130.48 ± 32.05 mJ/cm2. This MED result is higher than the MED that has been determined using artificial broadband UVB for skin types III and IV, which is around 30-50 mJ/cm^2.[22] Similar results were presented in a study by Poon et al.[21] in Japan, which showed the mean MED for Fitzpatrick's skin types I and II using natural sun exposure was higher than the MED using artificial UVB. This variation was due to the difference in spectrum between artificial UV and natural sunlight.[20]

The study's limitation is that there is no reference for the intervals of closing time between irradiation squares. This limitation is due to the fact that this study is the first to find the optimal sunbathing time using the method of increasing the duration of exposure in healthy volunteers.

There is a difference in UVB intensity between altitudes; however, the difference in duration of sunbathing for achieving MED is only shown in different altitudes of more than 600 masl.

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