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Investigating the Optimal Duration of the Sun Exposure for Adequate Cutaneous Synthesis of Vitamin D3 in Baghdad City: Depending on Fitzpatrick Skin Classification for Different Skin Types

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Abstract

Vitamin D3 deficiency is regarded as a public health issue in Iraq, particularly during the winter. Sun exposure is the main source of vitamin D3, where the surface ultraviolet (UV) radiation plays an important role in human health. The amount of time that must be spent in the sun each day was determined for the amount of exposed skin, for all skin types, with and without sunscreen under clear sky conditions in the city of Baghdad (Long 44.375, Lat 33.375). UV index data was obtained by TEMIS satellite during the year 2021. From data analysis, we found that most days during the year were within the high level of ultraviolet radiation values in the city of Baghdad, and most of them were during the summer, where the person needed less time of exposure to sunlight to obtain vitamin D3 in the case of exposing the face and hands or the whole body. As a result, it can be concluded that the amount of UV radiation is affected by several factors: depending on latitude, day of the year, time of day and the season, body area exposed to the radiation, and use of sun protection factor. These factors influence the time of sun exposure required to initiate cutaneous vitamin D3 synthesis.

Keywords: Vitamin D3, Sun exposure, UV index, Ultraviolet (UV), Sun protection factor, Skin type.

المدة المثلى للتعرض لأشعة الشمس من أجل تخليق جلدي مناسب لفيتامين D3 في مدينة بغداد: اعتمادًا على تصنيف الجلد فيتزباتريك لأنواع البشرة المختلفة

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الخلاصه

يعتبر نقص فيتامين D3 من مشاكل الصحة العامة في العراق ، وخاصة خلال فصل الشتاء. يعتبر التعرض لأشعة الشمس المصدر الرئيسي لفيتامين D3 ، حيث تلعب الأشعة فوق البنفسجية السطحية دورًا مهمًا في صحة الإنسان. تم تحديد مقدار الوقت الذي يجب أن تقضيه في الشمس كل يوم لمدة عام مع حساب كمية الجلد المكشوف ، لجميع أنواع البشرة ، مع وبدون واقي من الشمس لظروف السماء الصافية لمدينة بغداد (Long

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44.375، Lat 33.375) . تم الحصول على بيانات مؤشر الأشعة فوق البنفسجية بواسطة القمر الصناعي TEMIS. لقد وجد أن معظم الأيام خلال العام تكون ضمن المستوى العالي لقيم الأشعة فوق البنفسجية لمدينة بغداد ، ومعظمها خلال فصل الصيف ، حيث يحتاج الشخص إلى وقت أقل من التعرض لأشعة الشمس للحصول على فيتامينD3 في حالة تعريض الوجه واليدين أو الجسم كله لأشعة الشمس ، يمكن الاستنتاج من ذلك أن كمية الأشعة فوق البنفسجية تتأثر بعدة عوامل ، حسب خط العرض ، واليوم من السنة ، والوقت من اليوم والموسم ، والمنطقة المعرضة للإشعاع من الجسم، واستخدام عامل الحماية من أشعة الشمس. تؤثر هذه العوامل على وقت التعرض للشمس المطلوب لبدء تكوين فيتامين D3 الجلدي.

1.Introduction

Solar Ultraviolet (UV Radiation) is part of the electromagnetic spectrum with wavelengths shorter than 400nm [1]. It is divided into three regions: UVA 400-315nm, UVB 315-280nm, UVC 280-100nm [2]. UV radiation is approximately 9.3% of the total solar radiation at the top of the atmosphere. The total amount of UV reaching the Earth's surface is approximately 6-7% and less than 1% in the UVB band, while UVC is completely absorbed by ozone and oxygen in the upper atmosphere. [3]. The large variability of UV radiation is controlled by a combination of several factors: Earth-sun distance, solar zenith angle, absorption and scattering due to atmospheric molecules (mainly ozone), absorption, scattering and reflection by aerosols, and clouds [4] .The Ultra Violet Index (UVI), which ranges from 0 to 20, is a fundamental indicator of the risk of exposure to solar radiation. It is calculated by multiplying solar erythemal irradiance (Erythemal is the amount of energy received by a horizontal plane within a time interval dimension is Jm-2) by 40 (Wm-2), which takes into account the spectrum of erythematic action as a function of solar UV irradiance[5]. For average photosensitivity, the UVI distribution is classified into five categories: low (0-2), moderate (3-5), high (6-7), extremely high (8-10), and extreme (>11). Each class is represented by a different color: low (green), moderate (yellow), high (orange), very high (red), and extreme (red) (violet); see table 2[6]. According to a survey, prolonged exposure to UV radiation can harm the environment, as well as cause erythema, premature aging and skin harm, dangerous skin sensitivities, eye issues, and sunburn[7]. UV radiation, on the other side, promotes the body's generation of vitamin D and raises calcium and phosphorus levels, which is beneficial to bone health [8]. The sunshine vitamin, vitamin D, is essential for keeping healthy bones and regulating calcium and phosphorus absorption [9]. The main sources of vitamin D3 are casual sun exposure and, to a lesser extent, food consumption [10]. Sunlight's UVB photons (290 - 315nm) permeate the epidermis of human skin when exposed to sunlight. The 7-dehydrocholesterol in the plasma membrane subsequently absorbs them[11]. In addition to the factors that affect the ultraviolet rays that affect the production of vitamin D, the production of vitamin D3 is influenced by skin melanin content, use of sun protection, age, and clothing covering the body [12]. Many researchers have taken up the topic of examining changes in UVI and its impact on the production of vitamin D3. A study was conducted to detect the best time for short exposure to sunlight at high latitudes appears to be midday. There was a fine line between adequate UV exposure and the cutaneous synthesis of vitamin D3 [13]. The results showed that reduced solar intensity, cold and temperatures in temperate to high latitudes inhibit skin exposure during mid-winter. These factors led to reduced exposure to solar radiation, which significantly impaired vitamin D3 synthesis in this population [14]. The study determined the best period for sun exposure and whether the incidence of vitamin D3 deficiency among Saudi children and adolescents in the Kingdom of Saudi Arabia was related to the level of sun exposure. The results revealed that the generation of vitamin D3 was significantly influenced by the geographical location, time of the day, sun exposure, and physical activity, that could be quite efficient at preventing vitamin D3 deficiency [15] [16]. The sun exposure time was calculated for each day of the year, taking into account 10% of the exposure to the sun and the V type (dark skin) of skin for 10 Indian stations and applying the minimum doses of erythema and the Holick rule. The results showed a change in the time of sun exposure depending on latitude and seasonal variation. The seasonality was high, and about 75% of the days were suitable for exposure to sunlight in the studied stations [17]. The objective of the present work is to estimate the sun exposure duration required for cutaneous synthesis of vitamin D3 in the city of Baghdad employing TEMIS UVI daily data.

2. Methodology

2.1 Data Acquisition and Study Area

Throughout this study, we used data from Tropospheric, Emission, Monitoring, Internet, Service (TEMIS) of European Space Agency platforms, UVI was computed in the city of Baghdad, it was located in the central part of Iraq between Latitude 33.375^{o}; longitude 44.375^{o}.

2.2 Calculation Approaches

The optimal time for sun exposure is required to receive adequate UV for vitamin D3 production while avoiding erythema. In this section, we generate methods for determining time by using UVI. The time taken (TvitD3 in min) can be determined by using eq.1 and eq. 2:

$$Tvit = 8 * \frac{MED.SPF}{UVI.R.A} \quad \ldots\ldots\ldots\ldots\ldots.. \ (1)$$

$$UVI = 40 * UVEry \quad \ldots\ldots\ldots\ldots\ldots\ldots.. \ (2)$$

UVI is the UV Index, and Minimum Erythema Dose (MED) is a factor that accounts for variations in skin color. According to the Fitzpatrick skin classification, it is represented as the number of Standard Erythemal Dose (SED) needed to cause erythema (see Table 1.) and Sun Protection Factor (SPF) for any sunscreen used (1,50,80) and Ultraviolet erythemal (UVery) [18].The amount of exposed skin represented as a percentage of the total body area (A) was taken into consideration while calculating the exposure time necessary to produce sufficient vitamin D (TvitD3):

- Full body is equal to 100% (A = 1).
- Face, hands, arms and legs are equal to 63% (A = 0.63).
- Face, hands and arms are equal to 27% (A = 0.27).
- Face and hands are equal to 10% from the body area (A = 0.10).
- R = 2 (the maximum value for R is (SZA, total ozone), where SZA is Solar Zenith Angle [19]

While Fitzpatrick Skin Types (FST) is now used by dermatologists to evaluate sun sensitivity [20], it was originally developed in 1975 to determine the safe initial dose of UVA. The Fitzpatrick scale depends on the sensitivity to sunburn and ability to tan[21]. The skin of white individuals was categorized into Types I-VI, ranging from pale skin that always burns and never tans, to white to light brown skin that usually does not burn and tans easily and deeply (Table 1). Since that time, the classification has expanded to include darker skin types (V-VI.) (Table 1) [22]

Table 1: Skin phototype classification according to Fitzpatrick scales [22].

FST	Properties	Minimum dose for erythema (SED)
I	white skin, extremely sensitive (always burns)	2-3
II	white skin, overly sensitive (burns easily)	2.5-2.3
III	light brown skin, moderately sensitive (may burn)	3-5
IV	light brown skin (burns rarely)	4.5-6
V	brown skin, variable sensitivity (rarely burns)	6-10
VI	black skin (rarely burns)	10-20

3. Results

Figure 1. Displays the yearly variation of the daily UVI values at noon for central Iraq, Baghdad, from 1 January to 31 December 2021

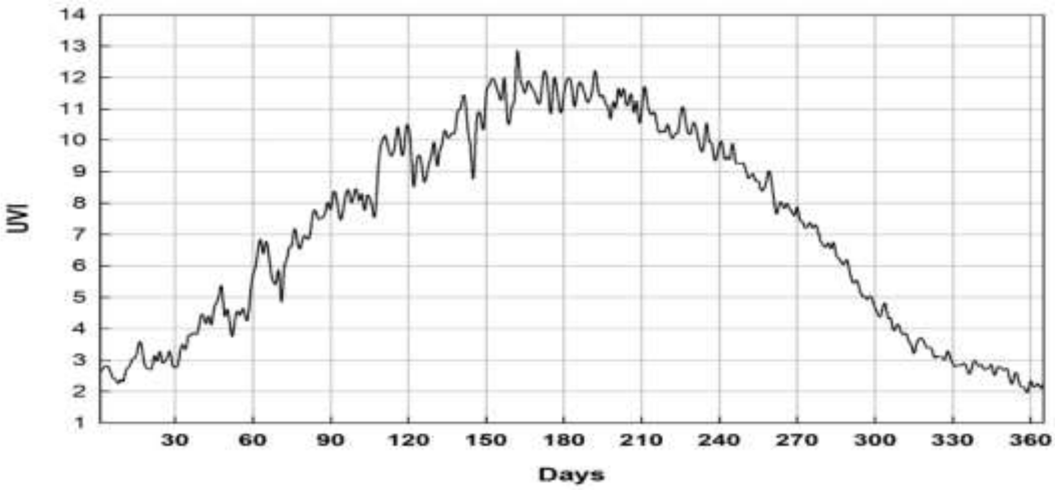

Figure 1: UV index at local noon in the city of Baghdad for the year 2021.

The UVI at solar noon is shown to have a different maximum in the city of Baghdad curve in the summer, while UVI levels are at their lowest in the winter. Important statistical analysis was used in this work to look into the discrepancies in the outcomes. There were discoveries in the area for which the variations in the data are shown in Table 2.

Table 2: Number of UV index days in the city of Baghdad during the year 2021[6].

UVI	Number of days
0_2	17
3_5	118
6_7	43
8_10	109
11+	78

Table 2. Tabulated values of the UVI for each season of the year, where the high levels appear in summer days whereas the lowest levels are shown in winter season, which suggests that during winter season, UV exposures will be relatively low. The UVI at solar noon data was used to determine the annual cumulative dosages for each phototype to produce vitamin D3 for the different types of skin. It is important to note that these results indicate the cumulative dose from a continuous exposure to the sun in this position during all the year. The values of the time

required to produce vitamin D3 decrease the time required for exposure during the summer season. These exposure situations are depicted in Figures (2-4) shown below.

The resulting times are shown in Figure 2. when there is sufficient UV to keep effective vitamin D3 levels, for different skin types, without using a sun protection factor for full body area exposures. The other three figures represent the estimated exposure times required to keep vitamin D3 levels in various areas of the exposed body for UV radiation. For full-body exposures, there is a large window between sufficient and excessive UV exposure time. As the fraction of the body exposed decreases, so does the window of optimum UV exposure times. There is typically only a tiny window between receiving adequate UV for vitamin D3 generation and too much UV for skin harmful if only hands and face are exposed. It becomes increasingly difficult to synthesis adequate vitamin D3 without causing skin damage as the UVI increases over 5. Winter season can make it difficult to expose large sections of skin, making it difficult to get enough UV radiation for the best vitamin D3 synthesis. When exposures to the hands and face are limited, there is a comparatively small limit of error between getting enough UV for vitamin D production and not getting too much for sunburn.

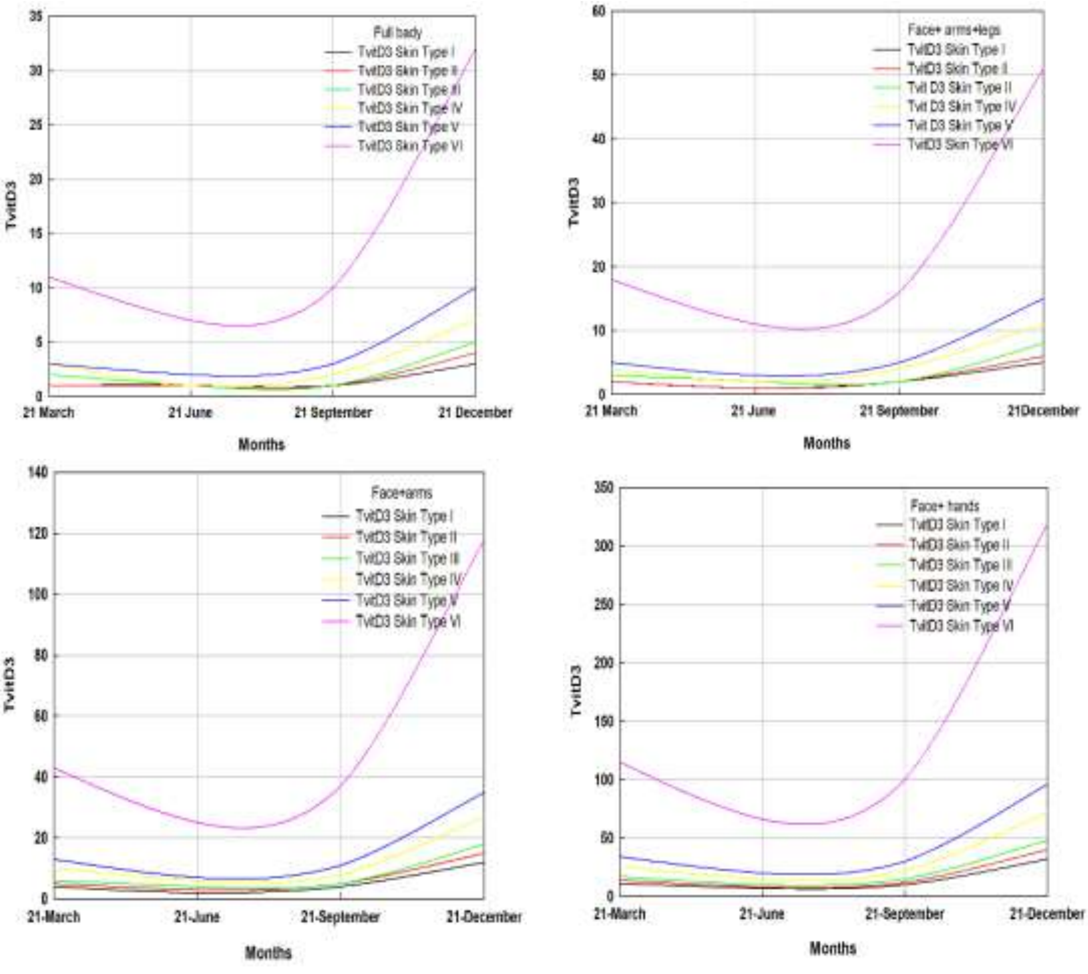

Figure 2 : Sun exposure times (in minutes) for synthesis of vitamin D as indicator of sun protection factor 1, date, time, and skin type.

In Figure 3, when using sun protection factor 50, the time required to start producing vitamin D3 increases for the same sun exposure conditions. Especially during the winter, when solar UV is low and insufficient for vitamin D3 synthesis. This makes it difficult to start producing vitamin D3 for the different areas of skin exposed to the sun, specifically when exposure is limited to the hands, face, and skin type VI. Where this sun protection factor is appropriate when the area of skin exposed to the sun is large and the types of skin are (I-IV), so that vitamin D is produced without exposure to burn when the UV radiation is higher than 5 in the summer.

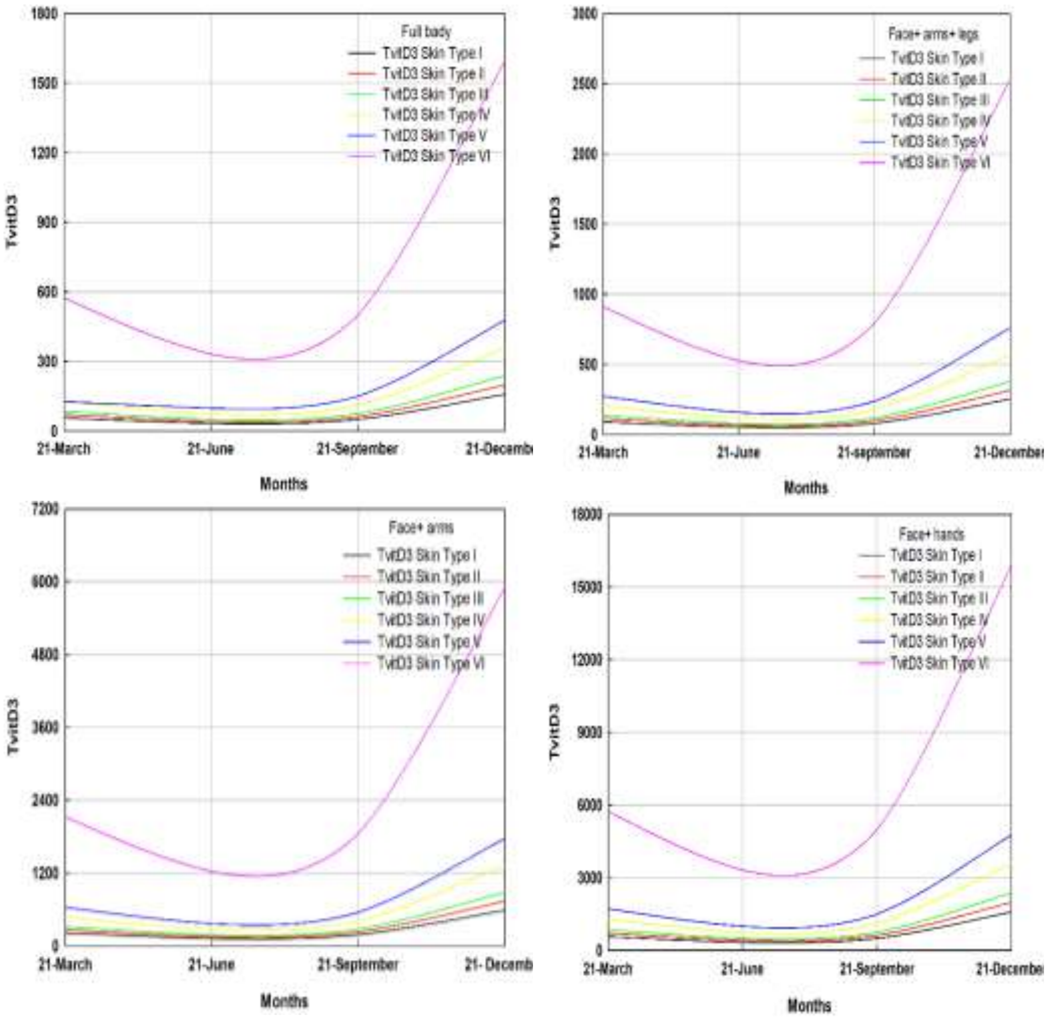

Figure 3: Sun exposure times (in minutes) for synthesis of vitamin D as indicator of sun protection factor 50, date, time, and skin type.

Figure 4 shows applying a higher sun protection factor than before. The time required for exposure to ultraviolet radiation to benefit from it to start the synthesis of vitamin D3 in the skin during all seasons of the year, is long. As well as, putting sun protection factor 80, as individuals of all skin types, especially those with dark skin, need a time that reaches more than 3 days of continuous exposure to sunlight.

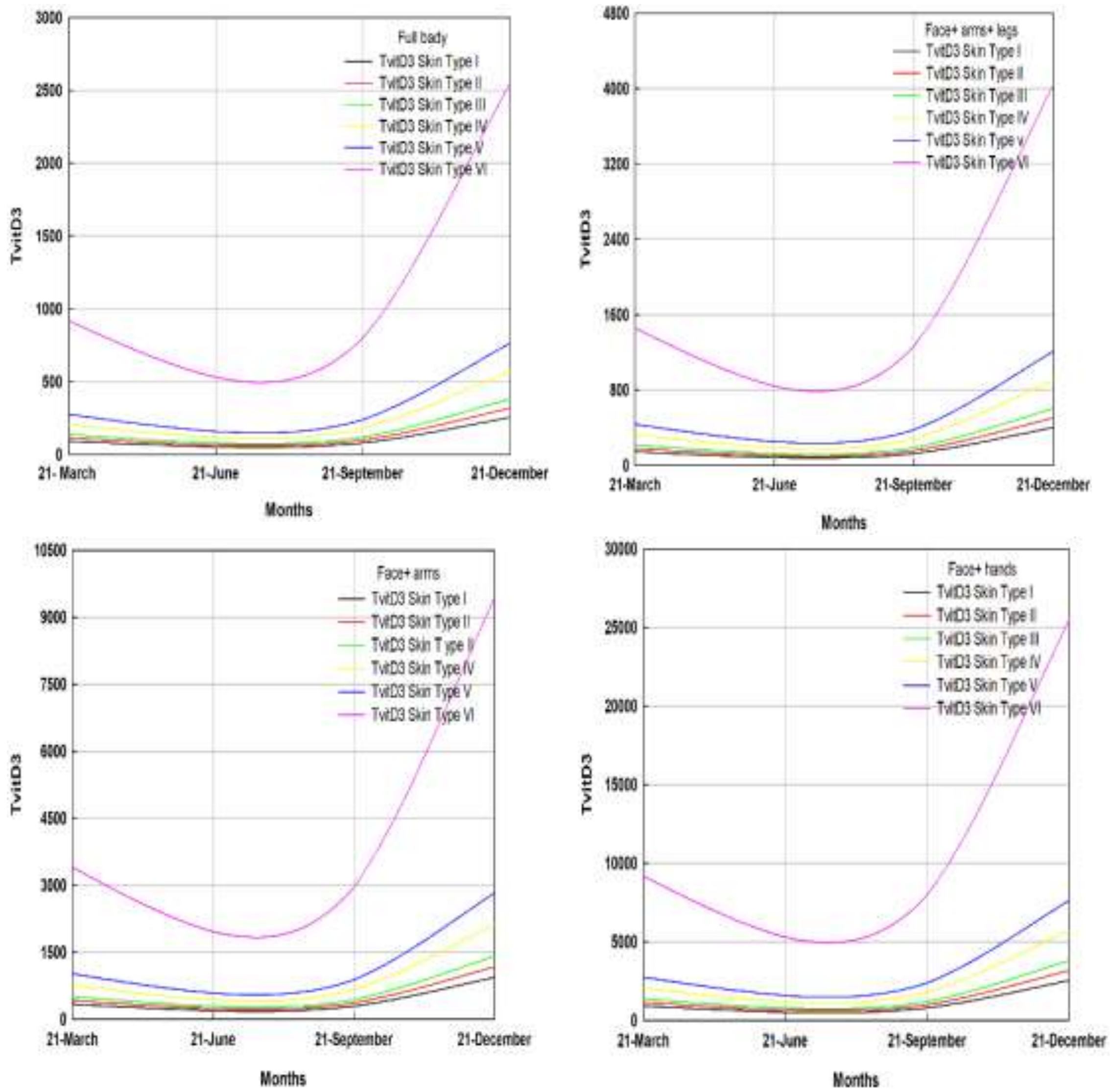

Figure 4: Sun exposure times (in minutes) for synthesis of vitamin D as indicator of sun protection factor 80, date, time, and skin type.

As a result, after 20 minutes of full-body exposure without the use of sunscreen, the body should have produced enough vitamin D3. The exposure time needed for brown skinned people would be more, but the quantity of vitamin D3 created cannot be zero. Indeed, there is the issue of whether people would be able to expose a large enough portion of their bodies for religious, cultural or environmental reasons at low temperatures in winter. They probably would not. Even with modest exposures, vitamin D3 production would still be present.

4. Conclusion

According to the curve of UVI, the highest value of UVI is during June and July 13, and the lowest value is 2 during December. Whereas, according to the results shown in Figure 1 and discussed in Table 2, the number of days with a UVI severity of high to very high is very large (230) days including (78) extreme days, as it is possible to compensate for a vitamin D deficiency on these days in a shorter time than on the rest of the days. During the time of exposure, vitamin D3 generation from UVI shows that the afternoon time window, when UV values are at their peak, controls the creation of vitamin D from sunshine. A few minutes in the sun on the hands and face can produce enough vitamin D when the sun is directly overhead, such as at midday in the summer. A good tactic would be to expose more of the body area in a shorter amount of time, when the sun is inclined in the sky. Adequate vitamin D3 is produced for light-skinned individuals more quickly than for dark-skinned individuals under the same conditions of sun exposure. People who wear concealing clothes for religious, cultural or environmental reasons need more time to be exposed to sunlight to take advantage of the UV radiation to produce vitamin D3, where the exposed areas are the face and hands. The time required to produce a vitamin is affected by several factors, including the use of sun protection, as well as the area exposed to UV radiation, in addition to UV intensity. Whereas the time required to benefit from UV radiation to produce vitamin D3 decreases as the area exposed and intensity of UV radiation increases, so does the use of SPF.

References

[1] D. Mohania *et al.*, "Ultraviolet Radiations: Skin Defense-Damage Mechanism," *Adv Exp Med Biol*, vol. 996, pp. 71–87, 2017, doi: 10.1007/978-3-319-56017-5_7.

[2] A. Alwan, A. Hameed, and N. Hamad, "Analyzing of UV Index with the Time Variation for Baghdad," *Iraqi Journal of Industrial Research*, vol. 8, no. 1, pp. 50–54, Jun. 2021, doi: 10.53523/ijoirvol8i1id32.

[3] A. Serrano, M. Antón, M. L. Cancillo, and V. L. Mateos, "Daily and annual variations of erythemal ultraviolet radiation in Southwestern Spain," 2006. [Online]. Available: www.ann-geophys.net/24/427/2006/

[4] B. K. Ahmed, G. G. Younis, and Z. Abdalwahid, "Estimation and Analysis of Solar Radiation on Horizontal and Inclined Surface for Baghdad City," *Iraqi Journal of Science*, vol. 62, no. 11, pp. 4249–4259, Dec. 2021, doi: 10.24996/ijs.2021.62.11(SI).5.

[5] A. Cede, E. Luccini, L. Nuñez, R. D. Piacentini, and M. Blumthaler, "Monitoring of erythemal irradiance in the Argentine ultraviolet network," *Journal of Geophysical Research Atmospheres*, vol. 107, no. 13, p. AAC 1-1-AAC 1-10, 2002, doi: 10.1029/2001JD001206.

[6] S. Modesti, "Characterization of biologically effective UV radiation at mid-latitudes sites: innovative method for the calculation of the human vitamin D exposure," 2008.

[7] R. Rendell, M. Higlett, M. Khazova, and J. O'hagan, "Public Health Implications of Solar UV Exposure during Extreme Cold and Hot Weather Episodes in 2018 in Chilton, South East England," *J Environ Public Health*, vol. 2020, doi: 10.1155/2020/2589601.

[8] T. Dietrich, K. J. Joshipura, B. Dawson-Hughes, and H. A. Bischoff-Ferrari, "Association between serum concentrations of 25-hydroxyvitamin D 3 and periodontal disease in the US population 1-3," 2004. [Online]. Available: https://academic.oup.com/ajcn/article/80 /1/108 /4690265

[9] "Overview of general physiologic features and functions of vitamin D 1-4 Hector F DeLuca," 2004. [Online]. Available: https://academic.oup.com/ajcn/article/80/6/1689S/4690513

[10] R. L. McKenzie, J. ben Liley, and L. O. Björn, "UV radiation: Balancing risks and benefits," *Photochem Photobiol*, vol. 85, no. 1, pp. 88–98, Jan. 2009, doi: 10.1111/j.1751-1097.2008. 00400 .x.

[11] M. F. Holick, "Vitamin D: A millenium perspective," in *Journal of Cellular Biochemistry*, Feb. 2003, vol. 88, no. 2, pp. 296–307. doi: 10.1002/jcb.10338.

[12] "Photosynthesis of vitamin D in the skin: effect of environmental and life-style variables - PubMed." https://pubmed.ncbi.nlm.nih.gov/3030826/ (accessed Nov. 03, 2022).

[13] A. R. Webb and O. Engelsen, "Calculated Ultraviolet Exposure Levels for a Healthy Vitamin D Status," *Photochem Photobiol*, vol. 82, no. 6, p. 1697, 2006, doi: 10.1562/2006-09-01-ra-670.

[14] O. Engelsen, "The relationship between ultraviolet radiation exposure and vitamin D status," *Nutrients*, vol. 2, no. 5. MDPI AG, pp. 482–495, 2010. doi: 10.3390/nu2050482.

[15] F. Alamri, "Optimum Sun Exposure Times for Vitamin D Status Correction in Saudi Arabia," *European Journal of Preventive Medicine*, vol. 3, no. 5, p. 147, 2015, doi: 10.11648/j.ejpm. 2015 0305.14.

[16] A. Al-Othman *et al.*, "Effect of physical activity and sun exposure on vitamin D status of Saudi children and adolescents," *BMC Pediatr*, vol. 12, Jul. 2012, doi: 10.1186/1471-2431-12-92.

[17] B. Kulkarni, "Optimal Duration of Sun Exposure for Adequate Cutaneous Synthesis of Vitamin D in Indian Cities: An Estimate Using Satellite-Based Ultraviolet Index Data," *Biomed J Sci Tech Res*, vol. 6, no. 2, Jun. 2018, doi: 10.26717/bjstr.2018.06.001313.

[18] R. L. McKenzie and J. ben Liley, "Balancing the risks and benefits of ultraviolet radiation," *UV Radiation in Global Climate Change: Measurements, Modeling and Effects on Ecosystems*, pp. 21–47, 2010, doi: 10.1007/978-3-642-03313-1_2.

[19] R. L. McKenzie, J. ben Liley, and L. O. Björn, "UV radiation: Balancing risks and benefits," *Photochem Photobiol*, vol. 85, no. 1, pp. 88–98, Jan. 2009, doi: 10.1111/j.1751-1097.2008.00400.x.

[20] T. B. Fitzpatrick, "The validity and practicality of sun-reactive skin types I through VI," *Arch Dermatol*, vol. 124, no. 6, pp. 869–871, Jun. 1988, doi: 10.1001/ARCHDERM.124.6.869.

[21] S. Eilers *et al.*, "Accuracy of self-report in assessing Fitzpatrick skin phototypes I through VI," *JAMA Dermatol*, vol. 149, no. 11, pp. 1289–1294, Nov. 2013, doi: 10.1001/JAMADERMATOL.2013.6101.

[22] S. Eilers *et al.*, "Accuracy of self-report in assessing Fitzpatrick skin phototypes I through VI," *JAMA Dermatol*, vol. 149, no. 11, pp. 1289–1294, Nov. 2013, doi: 10.1001/jamadermatol.2013.6101.