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Skin Color Is Relevant to Vitamin D Synthesis

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Key Words
Vitamin D · 25-Hydroxyvitamin D · Skin color · Phototype · UVB exposure · Skin pigmentation

Abstract
Background: Whether dark skin produces less vitamin D after UVB radiation than fair skin remains controversial. ***Objective:*** To compare 25-hydroxyvitamin D [25-(OH)-D] levels after a single UVB exposure in fair (phototype II–III) and black-skinned (phototype VI) volunteers. ***Methods:*** Fair-skinned volunteers (n = 20, 4 males/16 females, mean age: 23.2 years) and black-skinned (n = 11, 6 males/5 females, mean age: 23.8 years) received a single total body UVB exposure (0.022 J/cm^2). The 25-(OH)-D levels were measured on days 0, 2 and 6. ***Results:*** On day 0, all volunteers were severely vitamin D deficient. On day 2, 25-(OH)-D levels of fair-skinned volunteers increased significantly (median: 11.9–13.3 ng/ml, $p < 0.0001$), but not in black-skinned people (median: 8.60–8.55 ng/ml, $p = 0.843$). Again, on day 6, 25-(OH)-D levels of fair-skinned volunteers increased significantly (median: 11.9–14.3 ng/ml, $p < 0.0001$), but not in black-skinned people (median: 8.60–9.57 ng/ml, $p = 0.375$). ***Conclusion:*** This study suggests that skin pigmentation negatively influences vitamin D synthesis.

Introduction

It is well known that UV transmission is hindered by melanin, hence it seems logical to think that black-skinned people are less capable of vitamin D synthesis compared to fair-skinned subjects. However, there is no absolute proof in the literature and the subject still remains debated.

Vitamin D_3 is produced by a photochemical reaction from 7-dehydrocholesterol in the epidermis, especially in the basal layer and in the stratum spinosum [1–3]. In fact, UVB irradiation of the skin converts 7-dehydrocholesterol to previtamin D_3, followed by a thermal reaction to produce vitamin D_3. Consequently, the production is, at least, determined by the amount of radiation and is influenced by sunscreens [4, 5], clothing [6] and skin pigmentation [7]. Skin pigmentation is largely determined by the concentration and type of melanin in epidermal keratinocytes. Melanin is a large opaque polymer that is produced constitutively. In response to UV radiation, melanin distribution alters and synthesis increases in the skin. Melanin effectively absorbs and scatters electromagnetic radiation across the entire UV and visible light range and thus competes with 7-dehydrocholesterol for UVB photons.

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Table 1. Skin color does not influence vitamin D synthesis

Subject number	Phototype/ skin color	UVB dose	Frequency of exposure	Body surface exposed, %	25-(OH)-D level	Ref.
28	18 light (I–IV) 10 dark (V–VI)	3 standard erythema doses	Iterative (4 sessions with 2- or 3-day interval, i.e. 1 week)	24	Baseline 48 h after last exposure	8
20	13 light 7 dark	<MED	Iterative (biweekly for 6 weeks)	100	Baseline Weekly	9
7	2 Asians 4 light 1 dark	? 1-min increase every day	Iterative (standard course; increased by 1 min every successive day, during about 20 days)	100	Baseline Daily	10
16	I–IV	27 mJ/cm^2	Single (1×)	100	Baseline Day 1	11
10	6 dark (VI) 4 light (II–III)	1.5 MED	Single (1×)	100	Baseline Days 1, 2, 3, 6, 9	12

Table 2. Skin color influences vitamin D synthesis

Subject number	Phototype/ skin color	UVB dose	Frequency of exposure	Body surface exposed, %	25-(OH)-D level	Ref.
Not available	II–V	0.75 MED	Iterative (3×/week, 36 sessions)	100	Baseline During treatment End	3
72	Lighter vs. darker skin	Light skin: 20–40 mJ/cm^2 Dark skin: 50, 60, 80 mJ/cm^2	Iterative (3×/week, 4 weeks)	90	Baseline Weekly (8 weeks)	13
31	II–VI	0.8 MED	Single (1×)	100	Baseline Day 1	14
5	2 light (III) 3 dark (VI)	1.5 MED	Single (1×)	100	Baseline Daily for 3 weeks	15

Earlier studies demonstrated no differences in vitamin D synthesis between phototypes [8–12] (table 1) whereas others showed that dark skin results in less 25-hydroxyvitamin D [25-(OH)-D] compared with fair skin [3, 13–15] (table 2). In sum, the relation between constitutive skin color, inducible skin color (tanning), phototype and cutaneous vitamin D synthesis remains controversial.

In order to answer this question, this study compared serum levels of 25-(OH)-D after controlled UVB exposure in fair and black-skinned volunteers.

Materials and Methods

This study was performed according to the Declaration of Helsinki and was approved by the local university hospital ethic committee. All the volunteers signed an informed consent.

Patients

Volunteers with fair skin [4 males/16 females, mean age: 23.2 years, min.: 20 years, max.: 41 years, mean body mass index (BMI): 20.3, phototype II: n = 19, phototype III: n = 1] and black skin (6 males/5 females, mean age: 23.8 years, min.: 19 years, max.: 40 years, mean BMI: 21.45, phototype VI: n = 11) were selected among medical students, in order to have a homogeneous population in terms of age, BMI and dietary behavior. The phototypes were determined according to Fitzpatrick's classification (Fitzpatrick II–III: fair skin, VI: black skin). The study was performed in February to avoid the influence of solar UVB exposure. Volunteers with oral vitamin D supplementation, BMI <20 and >25, vitamin D-rich diet, photosensitive drug intake, photosensitive diseases, liver insufficiency and recent sun holidays or sunbed use were excluded.

Minimal Erythema Dose Testing

MED (minimal erythema dose) testing was performed in all the 20 fair phototype volunteers using a handheld UVB device (Philips TL-01 lamp, wavelength 311–313 nm, Cosmedico Medizintechnik

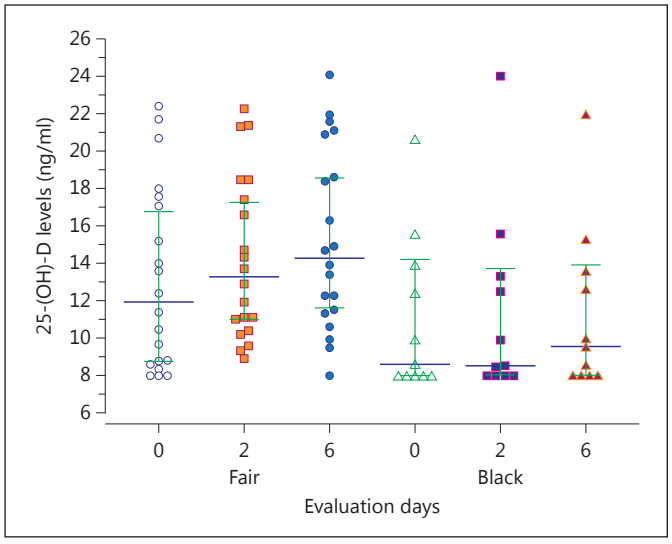

Fig. 1. Individual 25-(OH)-D levels (median: long horizontal bars, 95% confidence intervals: short horizontal bars) on days 0, 2 and 6 for fair-skinned and black-skinned volunteers.

GmbH, Schwenningen, Germany). The test was evaluated at 30 min (to avoid the inclusion of patients with solar urticaria) and after 24 h. The mean MED of the fair-skinned volunteers was 0.028 J/cm^2. MED testing was not performed in the dark skin group.

UV Irradiation

The total body UVB exposure was performed in a standard UVA/UVB phototherapy device by selecting broad-band UVB (290–320 nm) only (Waldmann 8001 K, Herbert Waldmann GmbH & Co., Villingen-Schwenningen, Germany) with a dose of 0.022 J/cm^2 for all the participants, corresponding to 0.8 of the mean fair-skinned MED in order not to sunburn the fair-skinned volunteers. Output was verified by dosimetry.

25-(OH)-D Analysis

25-(OH)-D measurements were performed using the DiaSorin® Liaison Total Vitamin D method (Stillwater, Minn., USA). Blood samples were taken on day 0 (before UVB exposure) as well as on days 2 and 6. All 25-(OH)-D determinations were performed in duplicate.

Statistical Analysis

The Mann-Whitney test was used to compare the independent samples (fair vs. dark), whereas the Wilcoxon test compared the differences between paired samples (fair before vs. fair after, dark before vs. dark after).

Results

On day 0, both the fair- and black-skinned volunteers were severely vitamin D deficient. The fair-skinned volunteers presented a median 25-(OH)-D value of 11.9 ng/ml and the black-skinned volunteers presented a median value of 8.6 ng/ml. There was no statistically significant difference in 25-(OH)-D levels between both groups ($p = 0.102$). On day 2, 25-(OH)-D levels of fair-skinned volunteers increased significantly (median: 11.9–13.3 ng/ml, $p < 0.0001$), whereas no statistically significant difference was observed in black-skinned people (median: 8.60–8.55 ng/ml, $p = 0.843$). Again, on day 6, 25-(OH)-D levels of fair-skinned volunteers increased significantly (median: 11.9–14.3 ng/ml, $p < 0.0001$), but not in dark-skinned subjects (median: 8.60–9.57 ng/ml, $p = 0.375$). The fair-skinned people continued a steady increase in 25-(OH)-D levels. Furthermore, on day 6, a statistically significant difference in 25-(OH)-D levels was observed between fair-skinned (median: 14.3 ng/ml) and black-skinned volunteers (median: 9.57 ng/ml) ($p = 0.02$). All individual 25-(OH)-D values of both groups according to the sampling days are summarized in figure 1.

Discussion

Both fair and black phototypes present a vitamin D deficiency, as previous studies have shown [1, 3, 15, 16]. Furthermore, this study clearly demonstrated that, after an identical amount of UVB radiation, fair-skinned volunteers increased their 25-(OH)-D levels on day 2 and even more so on day 6, whereas black-skinned subjects did not present statistically significantly increments.

Skin pigmentation is partially determined by a constitutive content and type of melanin [17]. Fair-skinned and black-skinned individuals have similar numbers of melanocytes in the basal cell layer of the skin (12.2–12.8 melanocytes/mm) [18].

Upon UV radiation there are different racial responses. The densities of melanocytes at the dermoepidermal junction in different types of human skin are remarkably similar and do not change significantly within 1 week after a single 1-MED UV exposure [18]. Chronic exposure, however, doubles the number of melanocytes [19]. The total amount of melanin is about 4-fold higher in black skin compared to fair skin. This amount did not change 1 day after UV exposure but increased significantly (10–14%) after 1 week [18]. The total amount of melanin in all layers increased in all 3 races (Caucasian, Asian and Afro-American) 1 week after exposure. The distribution of melanin was shifted from the lower epidermal layers to the middle layers and these differences were more dramatic in dark skin [18].

Variations in study designs may explain some of the highly discrepant results of the selected studies.

As more than 150 genes have currently been identified that directly or indirectly affect the color of the skin [20], the small number of subjects may partially account for study variations. There was no clear-cut difference between the findings of small [9, 12, 15] and large studies [13, 14].

No correlation was observed between studies using a single dose [11, 12, 14, 15] versus iterative UVB exposures [3, 8–10, 13] on the vitamin D production according to skin type. Another study increased the UVB dose with every exposure [10]. The most sensible way to investigate the role between UV exposure and cutaneous vitamin D synthesis is to use a single UVB dose. In fact, iterative exposures induce immediate pigmentation, increase melanogenesis and increase the number of melanocytes, potentially interfering with incident light and probably vitamin D synthesis.

The number and timing of the determination of vitamin D serum levels after exposure are also variable between different studies. Although most studies used 24 h postexposure vitamin D levels as a main outcome, significant discrepancies among studies were observed. One study evaluated vitamin D levels during 6 weeks. Hence potential biases are possible by UV exposures, food or supplement intake [9].

The surface exposed to UVB radiation provides another potential confounding factor. Some used partial exposure [8, 13] whereas others used whole-body exposure [3, 9–12, 14, 15]. To what extent different parts of the body contribute to cutaneous vitamin D synthesis is unknown. As the density of melanocytes is variable among different body sites, summer tanning may significantly shift the major sites of cutaneous vitamin D production.

Furthermore, phototype VI skin may react differently to UV radiation depending on the amount of total sun exposure, i.e. on the latitude where the volunteer is living.

A study performed in the summer determined the association between natural and sun-induced skin color and 25-(OH)-D in a group of 87 Pacific people and 255 New Zealand Europeans by reflectance colorimetry. The mean 25-(OH)-D level was significantly higher in Europeans than in Pacific people (88 vs. 75 nmol/l). The inducible color of the skin at the forearm but not the natural skin color was a significant predictor of 25-(OH)-D. Each 10-degree lower skin color value at the forearm (more tanning) was associated with 5 nmol/l higher 25-(OH)-D. These results suggest that tanning was a more important determinant of 25-(OH)-D levels than natural skin color was [21].

It is curious to see that participants exposed according to their measured MED did not react differently in terms of vitamin D synthesis from those exposed to 1 standard erythema dose [22].

Other variables could be the dietary 25-(OH)-D intake, polymorphism, enzyme activity, scarred skin, burned skin, BMI, vitamin D supplementation, different 25-(OH)-D serum level measurement techniques, nonconsistent or autoevaluations of phototypes, etc. The age-related decline of cutaneous 7-dehydrocholesterol content and skin temperature influence vitamin D synthesis and represent other potential confounding factors in these studies. Whether baseline vitamin D levels influence the capacities of cutaneous vitamin D synthesis remains undetermined.

Conclusion

The results clearly indicate that a single UVB exposure increases 25-(OH)-D levels on days 2 and 6 in fair-skinned volunteers but not in black-skinned subjects. Consequently, skin pigmentation hinders the transformation from 7-dehydrocholesterol to vitamin D_3. The role of iterative exposure, the influence of inducible skin pigmentation and the eventual influence of baseline 25-(OH)-D serum levels merit further investigation.

Disclosure Statement

The authors have no conflicts of interest to declare.

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