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A small suberythemal ultraviolet B dose every second week is sufficient to maintain summer vitamin D levels: a randomized controlled trial

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None declared.

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Summary

Background It is known that ultraviolet (UV) B radiation increases serum 25-hydroxyvitamin D_3 [25(OH)D] level. However, there is uncertainty about the relationship between the maintenance of vitamin D status and UVB.

Objectives To define the frequency of UVB exposure necessary for maintaining summer 25(OH)D levels during the winter.

Methods In total, 60 participants were included from October 2008 to February 2009 (16 weeks) and randomized for UVB exposure of 1 standard erythema dose (SED) to ~88% body area once a week (n = 15 completed), every second week (n = 14 completed) or every fourth week (n = 12 completed). The controls (n = 14 completed) had no intervention. Vitamin D was measured at baseline, every fourth week before exposure, and 2 days after the last UVB exposure.

Results The 25(OH)D levels (mean) after UVB exposure once a week increased significantly (from 71·9 to 84·5 nmol L^{-1}) ($P < 0{\cdot}0001$), whereas UVB exposure every second week maintained 25(OH)D levels ($P = 0{\cdot}16$). A significant decrease in mean 25(OH)D levels (from 56·4 to 47·8 nmol L^{-1}) ($P < 0{\cdot}0001$) was found after UVB exposure once every fourth week and for the control group (from 64·8 to 40·1 nmol L^{-1}) ($P < 0{\cdot}0001$). The development in 25(OH)D levels during the 16-week study period were negatively correlated with baseline 25(OH)D ($P < 0{\cdot}0001$). Further, the increase in 25(OH)D after the last UVB exposure was negatively correlated with the 25(OH)D level just before the last UVB exposure ($P < 0{\cdot}0001$).

Conclusions Exposure to a UVB dose of 1 SED every second week to ~88% body area is sufficient for maintaining summer 25(OH)D levels during the winter.

Vitamin D is essential for bone structure. Recently, several studies have suggested that vitamin D plays a role in other diseases such as cancer, autoimmune disorders and other aspects of health.[1–3] Ultraviolet (UV) B radiation (280–320 nm) is the only part of the solar UV radiation spectrum that causes formation of vitamin D.[4] However, solar UVB is also known to be an aetiological factor in the development of skin cancer.[5]

Health campaigns recommend a few short sun exposures in a week to keep a sufficient vitamin D level, but the UVB exposure frequency necessary for maintaining summer 25-hydroxyvitamin D_3 [25(OH)D] levels during winter is unknown.

Materials and methods

Design

A randomized, controlled trial was conducted from October 2008 to February 2009. The ethics committee approved the protocol (H-C-2008-072), which was carried out in accordance with the Declaration of Helsinki. ClinicalTrials.gov identifier: NCT01101243.

Participants

Of 60 participants included, 55 completed. Five were unable to comply with scheduled visits. Weight, height and body

mass index (BMI) were recorded and total body area was calculated.[6] Inclusion criteria were age 18–65 years; avoidance of sunbed exposure; travelling south of 45°N; and vitamin D supplementation. Exclusion criteria were pregnancy; skin or psychiatric disease; drug addiction; previous skin cancer; and intake of statins or photosensitive medicine.

Intervention

The participants were randomized to a UVB dose of one standard erythema dose (SED) to ~88% body surface area (full body except underwear)[7] once a week (17 UVB exposures, group 1, n = 15), every second week (nine UVB exposures, group 2, n = 14) or every fourth week (five UVB exposures, group 3, n = 12). The controls (group 4, n = 14) had no interventions. One standard erythema dose is defined as 100 J m^{-2} at 298 nm using CIE (*Commission Internationale de l'Eclairage*) erythema action spectrum.[8] The UVB source was a Waldmann UV-6 cabin (Waldmann, Villingen-Schwenningen, Germany) (Fig. 1). Pigment protection factor (range 1·0–24·0) was measured on back and buttocks at baseline and 2 days after last UVB exposure by remittance spectroscopy (Chromo-Light, Espergærde, Denmark).[9] This method has been described previously.[10] Blood samples were analysed for 25(OH)D at baseline and every month in all four groups. In the intervention groups (groups 1–3), the 25(OH)D was analysed a few minutes before irradiation and approximately 48 h after last UVB exposure. Parathyroid hormone, total calcium, total cholesterol and alkaline phosphatase were assessed at baseline. The analyses have been described previously.[11] Skin type according to Fitzpatrick was registered.[12]

Randomization, sample size and statistics

We used a computer-generated randomization list for sealed envelopes containing notes distributing the participants into four groups. Given a significance level of 5% and an assumed SD of 9 nmol L^{-1} for 25(OH)D analysis at 50 nmol L^{-1}, the study was designed to show a difference of at least 12 nmol L^{-1} between the groups with a power of 80% if a minimum of nine subjects per group completed.

SPSS 18.0 was used (SPSS Inc., Chicago, IL, U.S.A.). The correlations between the development in 25(OH)D level after UVB during the 16 weeks and the personal and biochemical baseline data were examined using analysis of variance. For all significant analyses ($P < 0·05$), linear regressions were performed.

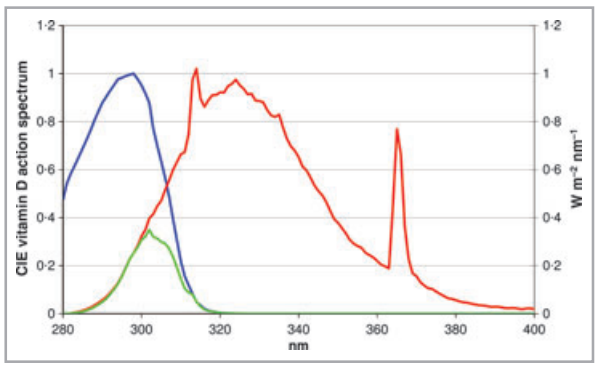

Fig 1. Blue line: action spectrum for the production of previtamin D_3 in humans.[4] Red line: ultraviolet (UV) spectrum for a Waldmann UV-6 cabin. Green line: CIE previtamin D_3 weighted UV action spectrum of the UV-6 lamp. The participants were exposed to 1 standard erythema dose (100 J m^{-2} using CIE erythema action spectrum[8]) once a week, every second week or every month.

Table 1 Baseline characteristics among the 55 participants divided into four groups. Groups 1–3 were the intervention groups and group 4 had no intervention (controls)

Baseline factors	Baseline	P-value[a]
Sex: women/men, n (%)	39 (71)/16 (29)	0·34
Skin type,[b] I/II/III/IV	3/24/23/5	0·83
Group 1	0/5/9/1	
Group 2	0/6/7/1	
Group 3	2/8/2/0	
Group 4	1/5/5/3	
PPF, buttocks[c]	5·4 ± 1·2 (3·6–9·7)	0·06
Age, years	36·0 ± 11·0 (20–60)	< 0·0001 (negative)
Weight, kg	73·4 ± 15·2 (50–120)	0·02 (positive)
Height, m	1·75 ± 0·09 (1·60–1·96)	0·28
BMI, kg m^{-2}	24·0 ± 4·4 (17·6–37·0)	0·04 (positive)
Total body area,[d] m^2	1·92 ± 0·23 (1·51–2·54)	0·02 (positive)
Serum 25(OH)D (> 50 nmol L^{-1})[e]	66·6 ± 28·3 (26–138)	< 0·0001 (negative)
Serum PTH (1·1–7·1 pmol L^{-1})[e]	4·9 ± 2·5 (0·6–13·3)	0·06
Serum total calcium (2·2–2·6 mmol L^{-1})[e]	2·38 ± 0·08 (2·22–2·60)	0·61
Serum alk. phos. (35–105 U L^{-1})[e]	60 ± 15 (33–117)	0·002 (positive)
Serum total chol. (2·9–7·1 mmol L^{-1})[e]	5·0 ± 1·0 (3·0–7·6)	0·68

Values are mean ± SD (range) unless stated otherwise. PPF, pigment protection factor; BMI, body mass index; PTH, parathyroid hormone; alk. phos., alkaline phosphatase; total chol., total cholesterol. [a]The P-values show the relation between the baseline factors and the development in 25-hydroxyvitamin D_3 [25(OH)D] after ultraviolet B exposure during the 16 weeks study period for the intervention groups. [b]According to Fitzpatrick.[12] [c]Constitutive skin type measured by remittance spectroscopy. [d]Total body area (in m^2) = $0·024 \times \text{height}^{0·40} \times \text{weight}^{0·54}$.[6] [e]Reference intervals for biochemical parameters.

Table 2 The 25-hydroxyvitamin D_3 [25(OH)D] level (nmol L^{-1}) (mean ± SD, range) for the four groups at baseline and after 4, 8, 12 and 16 weeks. The relation between the frequency of ultraviolet (UV) B exposure and the change in 25(OH)D is shown at the bottom

Week	Group 1[a] (n = 15)	Group 2[b] (n = 14)	Group 3[c] (n = 12)	Group 4 (control)[d] (n = 14)
0	71·9 ± 23·4 (32·7–100·4)	72·0 ± 31·3 (34·7–135·0)	56·4 ± 33·0 (26·2–136·6)	64·8 ± 26·5 (38·9–138·2)
4	90·1 ± 23·2 (46·4–137·9)	78·4 ± 28·3 (48·6–141·3)	56·5 ± 31·0 (30·8–127·7)	55·9 ± 28·5 (33·6–141·6)
8	85·6 ± 28·7 (32·6–160·3)	62·4 ± 25·7 (24·0–109·0)	42·0 ± 22·1 (16·9–99·9)	34·2 ± 13·8 (14·0–57·8)
12	76·3 ± 25·8 (54·7–151·2)	71·1 ± 23·5 (43·0–125·1)	47·9 ± 24·7 (19·3–98·3)	49·2 ± 31·2 (23·1–143·6)
16	84·5 ± 20·3 (53·3–124·4)	67·3 ± 18·2 (40·1–100·7)	47·8 ± 27·1 (20·7–113·8)	40·1 ± 26·5 (14·2–121·1)
P-value	< 0·0001 (increase)	0·16	< 0·0001 (decrease)	< 0·0001 (decrease)

[a]UVB once a week. [b]UVB every second week. [c]UVB every month. [d]No UVB.

Results

Baseline data

Baseline data are shown in Table 1. At baseline, 34 (62%) were vitamin D sufficient [25(OH)D > 50 nmol L^{-1}] and 21 (38%) were vitamin D insufficient [25(OH)D < 50 nmol L^{-1}]. The baseline 25(OH)D (mean) was 66·6 nmol L^{-1}. There were no significant differences in age, skin type or baseline 25(OH)D level between the groups.

Development of 25-hydroxyvitamin D_3 levels during the 16 weeks

The 25(OH)D (mean) after UVB exposure once a week, measured a few minutes before irradiation and approximately 48 h after last UVB exposure, increased significantly from 71·9 to 84·5 nmol L^{-1} ($P < 0·0001$), whereas UVB exposure every second week maintained 25(OH)D with no significant change during the 16 weeks ($P = 0·16$). The mean 25(OH)D after UVB exposure every fourth week decreased significantly from 56·4 to 47·8 nmol L^{-1} ($P < 0·0001$). The mean 25(OH)D for the control group decreased significantly from 64·8 to 40·1 nmol L^{-1} ($P < 0·0001$) (Table 2, Fig. 2a). The groups were analysed together in one combined linear regression model which includes different slopes for each group ($r^2 = 0·763$). Figure 2a is based on true data for each participant and Figure 2b shows the change in 25(OH)D (mean) during the 16 weeks adjusted for baseline 25(OH)D (mean 66·6 nmol L^{-1}). The changes in 25(OH)D during the 16 weeks were negatively correlated with baseline 25(OH)D ($P < 0·0001$; $r^2 = 0·763$) and age ($P < 0·0001$) in all groups. A significant positive relation was found between the change in 25(OH)D during the 16 weeks and weight ($P = 0·02$), BMI ($P = 0·04$), total body area ($P = 0·02$) and serum alkaline phosphatase ($P = 0·002$).

Analyses of the increase in 25-hydroxyvitamin D_3 after the last ultraviolet B exposure

We found a significant negative correlation between the 25(OH)D level before the last UVB exposure and the increase in 25(OH)D measured approximately 48 h after the UVB treatment ($P = 0·001$; $r^2 = 0·252$). We found no significant increase in 25(OH)D for group 1 ($P = 0·6$). However, 25(OH)D increased significantly for group 2 ($P = 0·03$) and group 3 ($P = 0·017$), by 4·4 and 6·9 nmol L^{-1}, respectively.

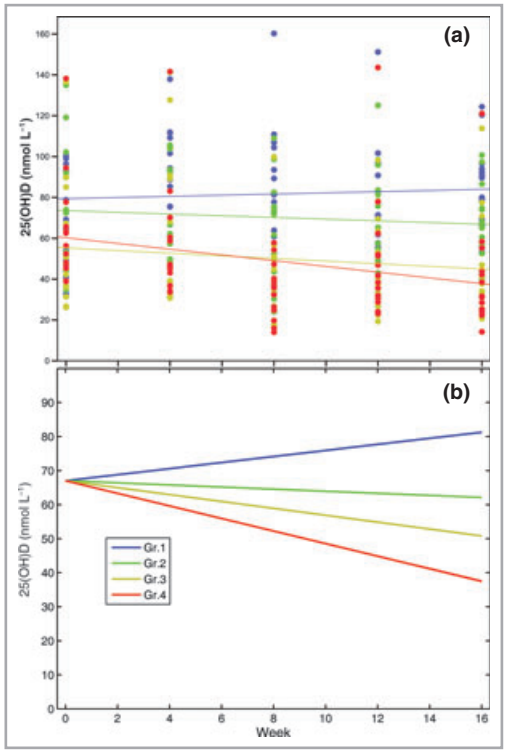

Fig 2. The development in 25-hydroxyvitamin D_3 [25(OH)D] levels (mean) between the four groups during the 16-week winter period, based on true data (a) and when adjusted for baseline 25(OH)D (mean 66·6 nmol L^{-1}, Table 1) (b). The 25(OH)D levels in (b) are linear adjusted according to the individual's baseline 25(OH)D level. The slope of the regression lines for each group is based on the development in 25(OH)D levels with a fixed intercept at baseline (week 0). For visual purposes, the mean baseline 25(OH)D for all the participants (66·6 nmol L^{-1}) is used as a fixed initial 25(OH)D level for each group, as there were no significant differences in baseline 25(OH)D between the groups ($P = 0·14$). Blue line (group 1): increase after weekly ultraviolet (UV) B exposure ($P < 0·0001$). Green line (group 2): maintenance with UVB exposure every second week ($P = 0·16$). Dark yellow line (group 3): decrease after monthly UVB exposure ($P < 0·0001$). Red line (group 4): decrease for the control group with no UVB exposure ($P < 0·0001$).

Discussion

A full body exposure to 1 SED (~10 min of sun exposure at zenith in summertime in Denmark at 56°N) every second week is sufficient to maintain summer vitamin D levels. However, our UVB cabin irradiates full body area simultaneously, whereas people lying in the sun are irradiated only from above lying supine or prone; therefore, vitamin D production would take longer in sunlight. Health campaigns recommend a few short sun exposures (5–15 min) a week to guarantee a sufficient vitamin D level. It has been shown that significant vitamin D can be produced by a few minutes of sun exposure in the summer on ~25% body area.[10] Our data show that a very small amount of UVB is sufficient to maintain summer vitamin D levels. We found a significant increase in 25(OH)D after weekly UVB exposure, but the 25(OH)D increase was reduced steadily during the course, suggesting a state of saturation in vitamin D production. In a recent study, saturation in vitamin D production was found for the higher UVB doses and body areas.[10] This has also been reported in other studies.[13,14] Our results were consistent with a linear model, which gave a strong correlation (r^2 = 0·763) and may be due to relatively long intervals between every UVB exposure and the small UVB dose of 1 SED. However, the 25(OH)D increase might have reached a plateau for group 1 if the UVB exposures had continued. The fact that we found no significant increase in 25(OH)D for group 1 after the last UVB exposure supports this theory. The change in 25(OH)D levels during the 16 weeks and the increase in 25(OH)D after the last UVB exposure were significantly negatively correlated with baseline 25(OH)D levels. This finding is consistent with previous studies.[11,15] The mechanisms are unknown, but 25(OH)D may act as a negative feedback to 25-hydroxylase in the liver, which prompts the hydroxylation of vitamin D_3 to 25(OH)D. In conclusion, a suberythemal UVB dose of 1 SED every second week to ~88% body area is sufficient for maintaining summer 25(OH)D levels during winter.

What's already known about this topic?

- Previous studies have shown that vitamin D insufficiency is common, especially during winter.
- However, relatively few studies exist on the photobiology of vitamin D, and the exposure frequency for maintenance of summer vitamin D status during winter remains to be clarified.

What does this study add?

- This study clarifies the frequency of ultraviolet (UV) B exposure necessary to maintain summer vitamin D levels during winter: a small UVB dose of 1 standard erythema dose every second week maintains summer vitamin D levels during winter.

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