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INVESTIGATIVE REPORT

Narrowband Ultraviolet B Exposures Maintain Vitamin D Levels During Winter: A Randomized Controlled Trial

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Exposure to solar ultraviolet B radiation during the summer months is the main source of vitamin D (VD) for people living in northern latitudes. The aim of this study was to determine whether artificial narrowband ultraviolet B (NB-UVB) whole-body exposures could maintain VD levels in winter. The intervention group received 2 standard erythema doses (SEDs) of NB-UVB exposures every second week from October 2013 to April 2014. In October 2013 serum 25-hydroxyvitamin D concentrations were 78.3 nmol/l in the intervention group (n=16) and 76.8 nmol/l in the control group (n=18). By April 2014 the concentrations had increased by 11.7 nmol/l (p=0.029) in the intervention group and decreased by 11.1 nmol/l (p=0.022) in the control group. The baseline VD concentration showed a negative correlation (p=0.012) with body mass index (BMI). In conclusion, a suberythemal NB-UVB dose of 2 SED every second week maintains and even increases serum VD concentrations during the winter. A high BMI seems to predispose subjects to low levels of VD. Key words: 25-hydroxyvitamin D; ultraviolet B; narrow-band ultraviolet B; body mass index.

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Vitamin D (VD) insufficiency is a worldwide issue (1). VD is synthesized from 7-dehydrocholesterol in response to ultraviolet B (UVB) radiation and its key role is in adjusting the serum calcium level to enable metabolic functions, signal transduction and neuromuscular activity (2). VD insufficiency has been linked to chronic skeletal (3) and extra-skeletal diseases, such as obesity and type 2 diabetes mellitus (4, 5). The best indicator of VD status is its circulating form, 25-hydroxyvitamin D [25(OH)D] (2). Levels above 50 nmol/l are thought to be sufficient for calcium and bone homeostasis, but the optimal level for extra-skeletal effects is unclear (6). The Institute of Medicine (Washington DC, USA) recommends a dietary intake of VD supplements of 15 µg daily for people aged 1–70 years and 20 µg daily for those older than 70 years (7). In addition to VD supplements, artificial ultraviolet B (UVB) light treatments increase VD concentrations (8). Narrowband ultraviolet B (NB-UVB) exposures given 3 times a week increase serum 25(OH)D concentrations even more than does 20 µg or 40 µg oral cholecalciferol daily (9, 10). Bogh et al. (11) showed that 1 standard erythema dose (SED) of broadband ultraviolet B (BB-UVB) every second week can be used to maintain serum 25(OH)D concentrations during the winter (11). On the other hand, as NB-UVB is better tolerated (12), widely used (13), and provides a higher vitamin D action spectrum-weighted irradiance dose (14), we examined its ability to maintain summer levels of vitamin D throughout the winter period.

MATERIALS AND METHODS

Subjects

Thirty-seven healthy volunteers were randomized to an intervention group (n=18) or a control group (n=19). Inclusion criteria were: age 18 years or older; and avoidance of solarium visits, phototherapy, sunny holidays and vitamin D supplementation during a 1-month washout period prior to the trial and during it. Exclusion criteria were: pregnancy, skin disease, previous skin cancer, intake of photosensitizing drugs; and Fitzpatrick’s skin reactive type 1 (15). Recruitment began on 1 September 2013 and the trial was carried out at the Department of Dermatology of Tampere University Hospital from 7 October 2013 to 5 May 2014. The principal investigator assessed the skin types of the volunteers. VD intake at the onset was estimated by means of a 3-day food frequency questionnaire. Altogether 34 subjects completed the trial (Table I). Two intervention subjects were disqualified for failing to follow the irradiation schedule and one control subject was disqualified for taking VD supplements. All 3 were excluded from the analyses. The protocol was approved by the ethics committee of Tampere University Hospital, and all the volunteers gave their informed consent in advance.

Randomization and sample size calculation

Volunteers were randomized to the intervention and control groups in blocks of 2 using a web-based validated program (Research Randomizer (http://www.randomizer.org)). The primary investigator randomized and enrolled all the participants. The trial was designed to show an inter-group difference in 25(OH)D of at least 12 nmol/l, with an α-value of 0.05 and a β-value of 0.90. An assumed standard deviation (SD) of 9 nmol/l for the
Narrowband ultraviolet B treatment

The intervention group received a total of 13 NB-UVB whole-body exposures, given every other week for 24 weeks with a Waldmann UV 7002 cabin equipped with 42 TL01 tubes (Schulze & Böhm, Brühl, Germany). The first NB-UVB non-weighted total UV dose was 170 mJ/cm² (1 SED), which was subsequently increased to 340 mJ/cm² (2 SED). One SED is equivalent to an erythemal effective radiant exposure of 10 mJ/cm² (1 SED). The intervention group received 13 NB-UVB exposures over 24 weeks, implying a cumulative NB-UVB dose of 25 SED, which corresponds to a physical dose of 4.25 J/cm².

RESULTS

Vitamin D intake and NB-UVB exposures

The mean ± SD daily VD intake at onset was 7.0 ± 3.7 µg in the intervention group and 6.7 ± 2.2 µg in the control group (p = 0.78) (Table I). The intervention group received 13 NB-UVB exposures over 24 weeks, maintaining daily VD intake at onset and at week 14 were 3.7 ± 1.1 µg and 4.7 ± 1.1 µg, respectively (p = 0.78) (Table I). The intervention group had a mean increase of 11.7 nmol/l (p = 0.001) and that in the control group by 2.7 nmol/l (p = 0.32), while those at week 26 (Fig. 1), and had a mean increment of 11.7 nmol/l (p = 0.022) by the end of the intervention period, in April (week 26), at which point the mean for the control group had decreased by 11.1 nmol/l (p = 0.022, Fig. 1, Table II). The difference between the groups was statistically highly significant (p < 0.001) when adjusted for the baseline value, BMI and Fitzpatrick’s skin type. During the 1-month follow-up period the mean concentration of VD in the intervention group decreased by 10.6 nmol/l (p < 0.001) and that in the control group by 2.7 nmol/l (p = 0.18, Fig. 1, Table II).

Serum 25-hydroxyvitamin D concentrations

The mean baseline serum VD concentration in October was 78.3 nmol/l in the intervention group and 76.8 nmol/l in the control group (p = 0.78) (Table I), which peaked at 104.5 ± 40.2 nmol/l in February, i.e. in week 20 (Fig. 1), and had a mean increment of 11.7 nmol/l (p = 0.029) by the end of the intervention period, in April (week 26), at which point the mean for the control group had decreased by 11.1 nmol/l (p = 0.022, Fig. 1, Table II). The difference between the groups was statistically highly significant (p < 0.001) when adjusted for the baseline value, BMI and Fitzpatrick’s skin type. During the 1-month follow-up period the mean concentration of VD in the intervention group decreased by 10.6 nmol/l (p < 0.001) and that in the control group by 2.7 nmol/l (p = 0.18, Fig. 1, Table II).

Parathyroid hormone concentrations

The mean ± SD initial PTH levels were 3.8 ± 1.1 pmol/l in the intervention group and 4.2 ± 1.2 pmol/l in the control group (p = 0.32), while those at week 14 were 3.7 ± 1.4 pmol/l and 4.7 ± 1.8 pmol/l, respectively (p = 0.11) (Table I).
DISCUSSION

The results of this study show that an artificial NB-UVB exposure of 2 SED every second week maintained VD concentrations throughout the winter, whereas levels in the control group decreased. No adverse effects were observed. The NB-UVB dose was small, given that an average Dane receives 1.5 SED of solar UV radiation daily in July (19). Bogh et al. (11) have shown that a BB-UVB exposure of 1 SED every second week will maintain summer levels of VD. They gave 9 BB-UVB exposures over 16 weeks and observed a non-significant maintenance of VD (16 SED). The NB-UVB dose was small, given that an average Dane receives 1.5 SED of solar UV radiation daily in July (19). Bogh et al. (11) have shown that a BB-UVB exposure of 1 SED every second week will maintain summer levels of VD. They gave 9 BB-UVB exposures over 16 weeks and observed a non-significant maintenance of VD (16 SED).

We found a moderate negative correlation between BMI and baseline VD status in our volunteers. A meta-analysis has confirmed the occurrence of low VD concentrations among obese subjects, suggesting that the reason for this may be volumetric dilution of 25(OH)D in the fat tissue (29). A high BMI therefore seems to predispose subjects to VD insufficiency, which in turn increases the risk of contracting VD-related diseases (3–5). The dietary VD intake was 7.0 µg in the intervention group and 6.7 µg in the control group. These intakes were approximately the same as in our previous study with healthy subjects (8), but remained lower than in the recent national survey carried out in Finland (30). Only a few of the present volunteers were receiving the estimated average requirement of 10 µg dietary VD daily, and none had reached the recommended dietary allowance of 15 µg (7). It seems that an additional 10 µg VD supplement is needed to ensure adequate VD status in the adult population (7, 31).

We have shown previously that regular NB-UVB exposures increase serum VD concentrations more than 20 µg of oral cholecalciferol daily (9). In addition, NB-UVB exposures increased the mean VD concentration by as much as 58% in patients with psoriasis who were receiving a 20 µg oral cholecalciferol supplement daily (32). Laganova et al. (33) compared the effect of VD supplementation (50 µg oral cholecalciferol daily) and 10 UVB exposures to a total dose of 23.8 SED on VD concentration in a 1-month study. Both interventions increased serum 25(OH)D concentrations similarly, by

![Fig. 1. 25-Hydroxyvitamin D concentrations in the narrow-band ultraviolet B (NB-UVB)-treated and control groups during the intervention (weeks 0–26) and follow-up periods (weeks 26–30).](image-url)
20–25 nmol/l. The total UVB dose was comparable to the 25 SEDs given in our study, but the intervention period was only 5 weeks compared with our 24 weeks. In the following commentary, UV dose-response studies with more careful and possibly safer exposure protocol were warranted (34). The strengths of our study are the randomized and controlled design, the long time-frame covering all winter, and the similarity of the groups. A limitation of our study is the need to standardize further the analytical methods for 25(OH)D, as suggested by Volmer et al. (35).

Our goal was to examine the capacity of low-dose NB-UVB exposures to maintain VD concentrations during the winter. The results confirmed that the 2 SED dose given every second week from October to April was enough to maintain the baseline concentrations of VD and even to increase them, suggesting that a NB-UVB dose of 1 SED might be appropriate for this purpose. A parallel comparison of continuous NB-UVB exposures and the recommended oral VD supplementation of 10 µg daily during the winter should be carried out (7, 31).

In conclusion, a suberythemal dose of NB-UVB of 2 SED given to healthy subjects every second week over the winter months can maintain and even increase VD concentrations, and even to increase them, suggesting that a NB-UVB dose of 1 SED might be appropriate for this purpose. A parallel comparison of continuous NB-UVB exposures and the recommended oral VD supplementation of 10 µg daily during the winter should be carried out (7, 31).

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