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PAPER

The effects of a mid-winter 8-week course of sub-sunburn sunbed exposures on tanning, vitamin D status and colds†‡

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Like UV irradiation, which generates vitamin D_3 in the skin, the hormonally active metabolite, 1,25-dihydroxyvitamin D_3, boosts innate immunity against viruses and bacteria. Epidemiologic studies have found high vitamin D levels to be associated with lower risk of infections of the upper respiratory tract (colds). We have therefore performed an intervention study in 105 young adults (ages 18–30 years; 91% female) over a mid-winter 8-week period (January–March 2010). The participants were randomised to 3 groups: (A) subjected to 3 times a week sub-sunburn sunbed exposure ($n = 35$), (B) daily vitamin D supplementation, @ 1000 IU ($n = 37$), and (C) a control group without any intervention ($n = 33$). The mean serum level of 25-hydroxyvitamin D (25(OH)D) dropped from 62 to 55 nmol l^{-1} in group C, while these levels rose from 62 to 109 and from 58 to 93 nmol l^{-1} in groups A and B, respectively ($p < 0.001$). The skin on the chest darkened significantly in group A (mean difference in lightness, L^*, equalled −5.7, $p < 0.001$), correlating significantly, but weakly, with increases in 25(OH)D (3.3 nmol l^{-1} per unit drop in L^*, $R^2 = 0.17$, $p = 0.014$). The percentage of self-reported colds with proper signs and symptoms was only slightly and not significantly reduced in groups A and B in comparison to group C: 57 and 51 *versus* 67%, respectively. Hence, the sub-sunburn sunbed treatment was effective in tanning and increasing the 25(OH)D serum level, more so than 1000 IU per day, but had no appreciable effect on colds.

Introduction

UVB irradiation is effective in producing (pre-)vitamin D_3 from 7-dehydrocholesterol in the skin. Next to the canonical function of vitamin D, or rather its hormonal metabolite 1,25-dihydroxy-vitamin D (1,25(OH)2D), in bone health (regulating calcium and phosphate levels), many non-calciotropic functions have been discovered in recent decades. The number of papers on the subject grew explosively. Importantly, it has been hypothesized that the vitamin D status has a strong bearing on common infections like "the flu" or "colds". The winter lows in vitamin D could contribute to winter-time prevalence of these infections, *e.g.*, the "R. Edgar Hope-Simpson hypothesis" on influenza.[1] The biologic plausibility can be found in the upregulation by 1,25(OH)2D of anti-microbial proteins (AMPs, *e.g.*, defensins and cathelicidins) that directly kill infectious agents like bacteria and viruses.[2,3] UV irradiation was similarly found to increase levels of AMPs from keratinocytes.[4]

There has been a long-standing suspicion that (solar) UV exposure may be effective against various infections. In 1929 the Medical Research Council stated, however, that "no evidence could be found … of a better resistance to infective illnesses" by ultraviolet light. This was based on two small studies in a children's ward and a lack of further studies (the children were given cod liver oil for vitamin D). An earlier study showed that whole blood was more bactericidal (by 20%) after a person had been exposed to a moderately erythemal UV dose.[5,6] More recently, it was found that a high single dose (2.5 mg) of vitamin D reduced the survival of *Mycobacterium bovis* Bacille Calmette Guérinin (BCG) significantly, on average by 20%, in whole blood drawn after 6 weeks.[7]

In investigating a possible immunosuppressive effect of solar UV exposure on cellular immunity in babies (children < 1 year old), it was indeed found that sunburns were associated with ear infections. On the other hand, respiratory tract infections surprisingly turned out to be associated with little sun exposure (less than 17 *versus* more than 85 h over a 4-week period resulted in an odds ratio of 2.2).[8] The authors speculated that the latter effect may have been attributable to low vitamin D levels. In a comment on Cannel *et al.*,[1] Alioa and Li-Ng[9] pointed out that in a study of theirs – although it was not designed for that purpose and therefore not optimal – year-long vitamin D supplementation (20 or 50 μg per day) was found to reduce significantly winter-time colds and flues. Less than 5% of supplemented post-menopausal Afro-American women reported to have suffered the symptoms *versus* 23% of non-supplemented controls. In a Finnish study it was found that a low vitamin D status (serum level of 25-hydroxyvitamin D, 25(OH)D < 40 nmol l^{-1}) was associated with more days of absence from military duty due to

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respiratory tract infections.[10] Data from a nutritional survey in the US showed that the chance of self-reported recent upper respiratory tract infections ("colds") showed a significant negative trend with 25(OH)D levels.[11]

These studies may provide the explanation for an effect on colds we found in a user test of a new type of UV lamp, the "Sunshower". This lamp was designed to be used while showering to maintain a tan at low UV dosages (in 5–10 min maximally about 1/3 to 2/3 of a Standard Erythemal Dose, *i.e.* 33–66 J m^{-2} of CIE erythemally weighted UV, *i.e.*, well below the average threshold for a sunburn). These lamps were installed in the showers of two student dorm units in September 2006: one unit with a slightly UVB-enriched output of the lamp at a face–chest level. Skin color measurements after the winter showed students from this latter unit to have a significantly darker tan than students from the other unit. Although the study was not designed for the purpose, and inadequately controlled for confounders (especially the chance of infection per dorm-unit), we inquired about the occurrences of colds. The group with the UVB-enriched lamp and darker skin reported significantly fewer colds in January and February than students from two control dorm units (1/11 *vs.* 8/18 controls; $p = 0.04$), whereas the other UV group with a lesser tan showed no difference in colds with controls (5/10 *vs.* 8/18).

Although inadequate and possibly a fluke, this result was intriguing and led us to set up the present controlled follow-up study on moderate (sub-sunburn) artificial UV exposures, the effects on skin tan, vitamin D status and colds. In close collaboration with a sunbed salon and a sunbed manufacturer we were able to carry out this intervention study over a mid-winter 8-week period. Instead of daily UV exposure, the volunteers used the sunbed at sub-erythemal dosages 3 times a week. Going by the results of Thieden *et al.*[12] with similar commercial sunbeds, we expected the volunteers to approximate their final 25(OH)D levels already in the second week. Next to the sunbed users, we introduced a group with daily vitamin D_3 supplementation, and a control group ('business as usual') without sunbed use or vitamin D supplementation. Volunteers were not informed on the main objective of the study, and were told that the aim was to find an optimal method to correct the winter low in vitamin D status. We collected blood samples from all volunteers, and measured skin color in the sunbed users, before and after the 8-week intervention period. After the 8-week intervention we inquired about colds.

Materials and methods

Study population

The legally required permission for this (non-medicinal) study on healthy volunteers was granted by the Medical Ethical Committee of the Leiden University Medical Center January 2009, registered under investigation number P07.035 (amended). Volunteers, 18–30 years of age, were recruited in November 2009. Respondents were mainly female students: 22 of the initial 133 dropped off because of the exclusion criteria, logistical problems or withdrawals because of unknown personal reasons. Besides age, exclusion criteria were: any use of a sunbed, or a sun or skiing vacation, in 2 months preceding the start of the study on January 11, 2010, or any such vacation planned during the study period, and specific vitamin D supplementation in the months preceding the study. Volunteers were randomly assigned to one of the three study groups (using the entry numbers and www.randomizer.org) and invited for the intake procedure in the week preceding the start of the study (January 4 through 7 before dinner between 17 : 00 and 20 : 00 h). After this intake procedure 106 volunteers (9 males) entered the study, and only one dropped out because she did not attend the final evaluation. Volunteers in each of the groups were given written instructions and a diary to keep track of their compliance and any special (health) event. All participants were asked to abstain from vacationing, sunbathing, sunbed use (other than for the study), and vitamin D supplementation (other than provided for the study) during the study period. After ending the intervention on March 7, 2012, the intake procedure was repeated on March 8 through 11, 2012, with a final questionnaire for assessment of the intervention.

Questionnaires

At the start of the study participants had to fill out a questionnaire to record their particulars: gender, birth date, body weight and height, color of hair and eyes, ethnicity (NW or E European, Mediterranean, Asian, African), sun sensitivity (burns easily – never), abnormal reactions to sun exposure (itch, rash, eczema, or never any), use of vitamin supplements (ever and in the previous 2 months), use of sunbeds (ever and in previous 2 months), and fish consumption.

At the end of the study the participants filled out a form with questions on their compliance (also checked in the diaries they handed in), fish consumption, vitamin supplements (to guard against other significant vitamin D intake), and catching a cold after Sunday January 17 (with proper signs and symptoms: sore throat, cough, runny nose, clogged-up nose, sneezing), or the flu (with proper signs and symptoms: fever, muscle ache, tiredness, dry deep cough, stomach or intestinal problems, sneezing), and any other health complaint that might have arisen during the study period.

The sunbed

The collaborating sunbed salon had two sunbeds of the type Megasun 7900α available (compliant with EU Standard EN 60335-2-27). One was especially installed and mainly dedicated to the study (courtesy KBL-Solarien AG, Dernbach, Germany) and the other mainly used by the regular patrons. The irradiance mid-canopy to the body (from fluorescent tubes) was 164 W m^{-2} UV with 0.8% UVB (280–315 nm; or 1.3% in 280–320 nm) and from facial lamps (filtered metal halide lamps switched to low output) 280 W m^{-2} UV with 0.8% UVB (280–315 nm; 1.2% 280–320 nm); see Fig. 1a. This amounted to 230 mW m^{-2} CIE erythemally weighted UV (66% in UVB band) mid-canopy, and 273 mW m^{-2} (50% UVB) to the face; see Fig. 1b (effectiveness spectra according to the CIE vitamin D action spectrum are given in the ESI, Fig. S1;‡ amounting to effective irradiances of 348 mW m^{-2} mid-canopy and 327 mW m^{-2} to the face). The spectral measurements were done at the start of the study with a Bentham DMc150 double monochromator and a CL7 Bentham

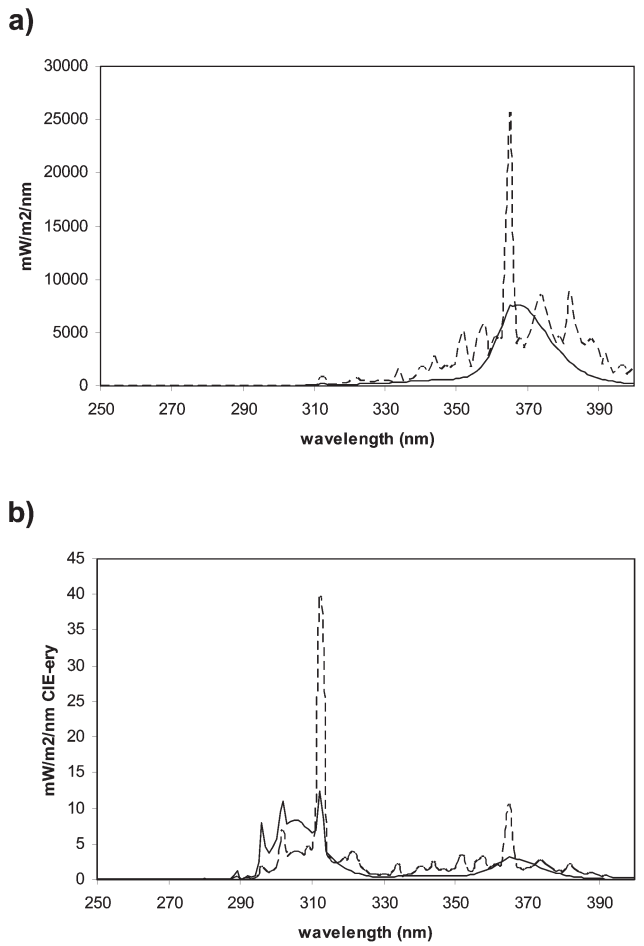

Fig. 1 Plots of spectral irradiances from the Megasun 7900α mid canopy (solid lines) and facial tanner (dashed lines): panel (a) the absolute spectra, and panel (b) the CIE erythemal effectiveness spectra.

calibration lamp (traceable to the National Physical Laboratory in Teddington, UK).

Three groups

Group (A) with 35 volunteers attended the sunbed salon 3 times a week. They received a personal card for access and automatic registration of their sunbed use. The aim was to have the exposures below the threshold for erythema. The volunteers started at 6 min exposure (0.8 SED mid-canopy; 1.0 SED to the face). They were instructed to increment the exposure by 2 min each time if no sign of sunburn, *i.e.* reddening of skin 8–24 h after exposure, had occurred, to a maximum of 12 min exposure (1.7 SED mid-canopy; 2.0 SED to the face) (patrons of the salon usually started at 10 min). Participants were instructed to repeat the last exposure time if a skin reaction (erythema) had occurred, and increase the exposure time when the skin no longer reacted, or lower the exposure time by 2 min if the reaction persisted after repeating the same exposure time. Thirteen volunteers missed one day of sunbed exposure due to illness. Seven volunteers complained about rashes on the pressure points where their skin touched the sunbed. This was apparently due to irritation by the cleaning and disinfecting agent used. Before switching to a different cleaning agent (after about 4 weeks) the affected volunteers were advised to insert small rolled-up towels between the bed and the pressure points (shoulder and/or buttocks) or to rinse off the sunbed extra carefully with water. Exposure times were not affected. Skin color on inner upper right arm and mid-chest was measured at the start and end of the study period with a Minolta CR-200 chromameter with readings in CIE color coordinates: L^* for 'lightness' (with values between 0 and 100), and the hue coordinates a^* (negative for green, positive for magenta/red), and b^* (negative for blue and positive for yellow) (each measurement was the average of 3 repeated readings).

Group (B) with 37 volunteers (excluding one drop-out) took daily 1000 IU (25 μg) of vitamin D_3 orally in gel capsules (Solgar Vitamins, Haarlem, The Netherlands); one Muslim woman got halal vitamin D pills (@ 1000 IU) to be taken with meals (also of Solgar Vitamins). If a day was missed, the volunteers were asked to note this in their dairy and take an extra capsule the next day. Sixteen volunteers never missed a day and 21 people reported missing a day (one more than 7 times, and 5 volunteers 3 to 7 times) but – as instructed – they had always compensated with an extra capsule the next day.

Group (C) was the control group with 33 volunteers who were asked to "go about their usual business", without sunbed use and/or vitamin D supplementation.

Vitamin D status

At the start and end of the study period blood was drawn, 2 tubes @ about 4–6 ml per person, one gel tube for serum and one with EDTA for plasma (coded anonymously, without information on the group, but with birth date for verification). After overnight storage at 4 °C, the blood was processed and distributed in aliquots of 0.5 ml over several tubes for storage at −80 °C. Later on, at a suitable time for the receiving laboratory, a complete set of frozen serum samples (*i.e.*, an initial and end sample from each volunteer) was sent to determine 25-hydroxy-vitamin D levels. A complete set was first sent to the research Lab of Calcium and Bone Metabolism of the Erasmus Medical Center in Rotterdam, where the RIA method with the DiaSorin kit (Minnesota, USA) was used. The pre-intervention values came out rather high for mid-winter readings. On re-inspection, the measurements including calibration were, however, found to be correctly executed. Subsequently, we also sent a complete set of serum samples to a central certified Hematologic Lab for hospital services (Sanquin, Amsterdam) that used a chemiluminescent IDS-isys kit. The measurements (210 pairs) of the two laboratories correlated reasonably well (R^2 = 0.80) and highly significantly ($p < 0.001$), resulting in the linear regression formula 'Sanquin reading' = 0.93 (SE 0.03) × 'ErasmusMC reading' −4.9 (SE 2.9), where readings were in nmol l^{-1} and SE stands for standard error. The intercept did not differ significantly from zero (p = 0.09). A regression through the origin yielded: 'Sanquin reading' = 0.87 (SE 0.01) × 'ErasmusMC reading', *i.e.*, the Sanquin readings came out 13% lower on average than the readings of the Erasmus Medical Center. In the results we present the measurements by the Sanquin Lab; the results were essentially the same as with the measurements by the Erasmus Medical Center.

Table 1 Group characteristics

	Group		
	A	B	C
Group size	35	37	33
Males	3	4	2
Ethnicity other than NW European	2 Females part Asian	1 E European female and 1 Mediterranean	1 African female
Age, mean ± SD (in years)	21.6 ± 2.1	21.9 ± 2.3	21.5 ± 2.1
BMI, mean ± SD (in kg m^{-2})	22.1 ± 2.2	22.4 ± 2.7	22.3 ± 2.7
Sunburns, *n* (%)			
Never	0 (0)	0 (0)	1 (3)
Rarely	11 (31)	15 (40)	12 (36)
Sometimes	18 (51)	18 (49)	16 (48)
Easily	6 (17)	4 (11)	4 (12)
Ever experienced rashes after sun exposure, *n* (%)	17 (48)[a]	6 (16)	8 (24)
Ever used sunbed, *n* (%)	9 (26)	8 (22)	7 (21)
Never uses vitamin supplements, *n* (%)	28 (80)	23 (62)	22 (66)
Eats fish at least once a week, *n* (%)	14 (40)	17 (46)	16 (48)

[a] $p < 0.01$ (chi-square = 9.35, df = 2); from instructions and all documents handed out as one package at intake the participants knew their assigned groups before filling out questionnaires.

Statistics

A power analysis showed that a reduction from 45 to 10% with colds, as found in the poorly controlled pilot, would be detectable at group sizes of 20 volunteers per group with (two-sided) $p < 0.05$ and a power equal to 0.80. Hence, group sizes over 30 appeared to be adequate, and large enough to cope with possible drop-outs.

Categorical data on colds (and symptoms) from the 3 groups were tested for significant differences by Chi-square statistics. The paired *t*-test was used to assess differences in pre- *versus* post-intervention measurements. Significant correlations were established as part of linear regression analyses. The SPSS (formerly PASW) Statistics 17.0 package (IBM SPSS, Chicago, IL) was used. Two-sided *p*-values < 0.05 were considered significant.

Results

Groups

Characteristics of the groups in this study are given in Table 1. The majority was female (91.5%) and of NW European descent (93.3%). The one female of African descent (in group C) was the only one that never sunburned. Overall, 30% reported to have ever experienced rashes from sun exposure. Surprisingly however, this percentage was significantly higher in group A, the "sunbed group", than in groups B and C (see footnote to Table 1).

Course of sunbed exposures and skin reactions

In group A 20 of 35 volunteers (57%) did not report any sign of sunburn (erythema), and started the second week (4th exposure) with the maximum of 12 min exposure (1.7–2 SEDs). Another 5 volunteers (14%) reached this stage without any skin reaction but sunburned after this first 12 min exposure. Three (9%), 4 (11%) and 3 (9%) volunteers reported sunburns upon 10, 8 and 6 min exposure, respectively (*i.e.* after the 3rd, 2nd and 1st exposure, respectively); overall less than 5% of the exposures evoked signs of sunburn. Ultimately, the majority (30 out of 35, 86%) ended with 12 min exposure times; 4 volunteers (11%) ended at 10 min exposure and 1 (3%) at 8 min exposure. Minimum and maximum cumulative exposures thus amounted to about 26 and 39 SEDs over an 8-week period. Seven volunteers (20%) reported to have developed a rash on a limited skin area (*e.g.* either shoulders/upper back, cheeks, breast or legs) at some stage, indicative of sun allergy (mild polymorphic light eruption); after moderating the next 1 or 2 exposures, the rash disappeared and the exposure schedule could be resumed.

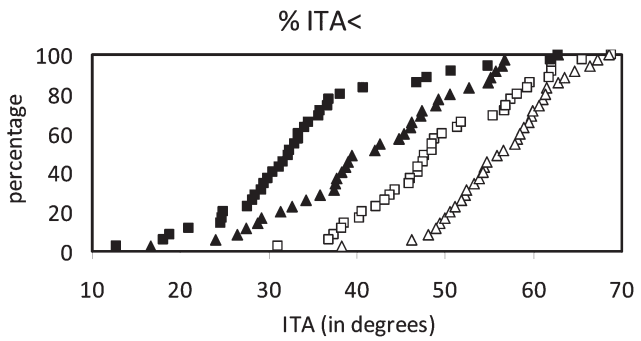

Fig. 2 Cumulative distribution of people in group A with ITA smaller than a certain value (in degrees) on the *X* axis: high ITA implies a light skin. Over 55° is 'very light' skin (MED ≈ 0.5–1.5 SEDs), 55–41° 'light' (MED ≈ 0.5–2 SEDs), 41–28° 'intermediate' (MED ≈ 1–2.5 SEDs), 28–10° 'tanned' (MED ≈ 1.5–3 SEDs), and below 10° 'brown' skin (MED ≈ 2.5–6.5 SEDs).[13] Squares for measurements on the chest and triangles for measurements on the upper inner arm; open symbols measured before intervention and solid symbols after intervention. Median ITA on breast changed from 48° before to 32° after intervention, and median ITA on the inner upper arm from 56° to 41°.

As a representation of skin color (and an indication of initial sunburn sensitivity) Fig. 2 depicts the cumulative distribution of ITA (Individual Typology Angle in degrees = Arctangent(L^* – 50)/b^*)[13] measured on the chest and upper inner arm before and

after the sunbed course. The average change in ITA over the 8-week sunbed exposures was −15.6° (SD 8.6°) on the chest and −14.7° (SD 7.8°) on the upper inner arm. A significant skin darkening ($p < 0.001$) could also be measured simply as a decrease in skin 'lightness', L^*: on the chest the mean L^* dropped from 66.5 (SD 3.4) to 60.8 (SD 3.7), and on the inner upper arm from 68.5 (SD 2.2.) to 63.8 (3.8).

Vitamin D status

The mean serum concentrations of 25(OH)D before and after the 8-week intervention period are presented in Table 2. The changes are greater for smaller initial levels (as shown in ESI, Fig. S2‡). The increase in the 25(OH)D level in group A is significantly, but weakly ($R^2 = 0.17$), correlated with skin darkening on the chest, see Fig. 3. A similar, but weaker ($R^2 = 0.12$), correlation is found between the increase in vitamin D status and change in ITA (data not shown).

Colds

The results from final questionnaire on self-reported colds, together with signs and symptoms, are given in Table 2 (colds were apparently commonly ignored in the daily routine, or not considered a "special health event", as they were most often not noted down in the diaries). All reported colds were accompanied by at least 2 of the signs and symptoms. Although fewer colds occurred in the groups A and B compared with control group C, the difference was not significant. The initial 25(OH)D levels in the volunteers that caught a cold ($n = 61$) was not significantly different from those who did not ($n = 44$): mean of 61 (SD 21) *versus* 61 (SD 20) nmol l^{-1} (nor were the final levels different: mean of 86 (SD 31) *versus* 86 (SD 32) nmol l^{-1}). Interestingly, the female of African descent had the lowest vitamin D status (initially 17.4 nmol l^{-1}) but did not catch a cold. As expected the number of flues was too low for significance testing: 7 in total, 4 in group A, 1 in group B and 2 in group C (all with gastrointestinal problems, except 1 in group C with only fever and muscle ache).

Table 2 Serum levels of 25(OH)D before and after the 8-week intervention period in the three groups. And the numbers and percentages of volunteers with self-reported colds during the intervention. Reported colds were accompanied by at least 2 of the self-reported signs and symptoms. There were no significant differences in colds (or in signs and symptoms) between the groups, $p = 0.43$ (chi-square = 1.7, df = 2)

	Group		
	A	B	C
Group size:	35	37	33
25(OH)D levels, mean ± SD (in nmol l^{-1})			
Before	62 ± 20	58 ± 18	62 ± 24
After	109 ± 25	93 ± 20	55 ± 21
Difference	47 ± 23	35 ± 19	−7 ± 11
p	<0.001	<0.001	<0.001
Colds, *n* (%)	20 (**57**)	19 (**51**)	22 (**67**)
>1 Episode, *n* (%)	4 (11)	5 (14)	7 (21)
Sore throat, *n* (%)	14 (40)	8 (22)	12 (30)
Coughing, *n* (%)	10 (29)	12 (32)	8 (24)
Runny nose, *n* (%)	17 (49)	17 (46)	21 (63)
Clogged-up nose, *n* (%)	13 (37)	13 (35)	17 (52)
Sneezing, *n* (%)	12 (34)	11 (30)	11 (33)

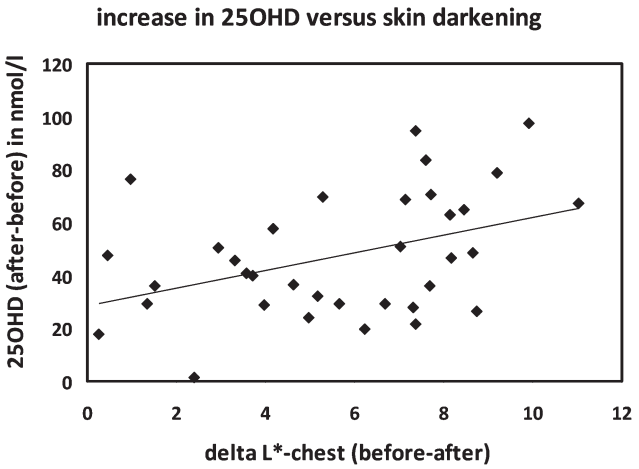

Fig. 3 Increase in vitamin D status *versus* skin darkening (L^* before – L^* after 8 weeks of sunbed exposures). The line is the result of linear regression according to the formula Y = slope. X + intercept, with slope = 3.3 (SE 1.3) nmol l^{-1} per unit drop in L^* ($p = 0.014$) and intercept = 28.4 (SE 8.2) nmol l^{-1} ($p = 0.001$), $R^2 = 0.17$.

Discussion

The present study confirms that sub-sunburn dosages from a commercial sunbed are effective in tanning the skin[14] and in elevating the 25(OH)D serum level of a person.[12] Serum levels on average increased by more than 40 nmol l^{-1} to high levels only attained in summer. The present sunbed regimen – despite a relatively low UVB and high UVA irradiance – proved more effective in raising the 25(OH)D level than an oral supplementation by 1000 IU (25 μg) of vitamin D per day. However, the 8-week courses of sunbed exposures and of vitamin D supplementation were ineffective against colds, although earlier epidemiologic studies indicated that a raised vitamin D status could be effective against colds.[9] Individuals that did not catch a cold during our intervention study did not show higher initial levels of 25(OH)D either (nor higher final levels).

On the whole, our study failed to find any significant link between vitamin D status and the risk of catching a cold. This is very much in line with recent intervention studies by Laaski *et al.*[15] and Li-Ng *et al.*[16] in follow-up of their earlier studies that did show a clear inverse correlation between 25(OH)D levels and risk of colds (an observational study[10] and an intervention study not designed to assess impact on colds[9]). The vitamin D supplementation in the intervention study in Denmark by Laaski *et al.*[15] was rather low, at 400 IU per day, but successful in maintaining the average 25(OH)D level just over 70 nmol l^{-1} from October through March (in the control group the mean level dropped to 51 nmol l^{-1}). The main endpoint measured was the average number of days of absence because of self-reported colds (2.2 (SD 3.2) *vs.* 3.0 (SD 4.0) days, $p = 0.10$). The vitamin D supplementation in the intervention study by Li-Ng *et al.*[16] was considerably higher, at 2000 IU

per day over a period of 12 weeks. Volunteers were recruited on Long Island, NY, from December 2006 through March 2007 and the study ended in June 2007. Average levels in the vitamin D supplemented group rose from 64 to 89 nmol l^{-1} and dropped slightly from 63 to 61 nmol l^{-1} in the placebo group. The vitamin D supplemented group showed a marginally, not significantly, lower frequency of self-reported colds than the placebo group. These two intervention studies may not have been optimal in either vitamin D supplementation dosage or timing in relation to the season. Although our study appeared to be better on these aspects, it also failed to show any significant relationship between vitamin D status and the risk of colds or flu-like symptoms. Moreover, the UV treatment appeared to offer no improvement over vitamin D supplementation in an effect on colds.

The reason for the discrepancies between the earlier (observational and intervention) studies and more recent intervention studies is unclear. Considering the seasonal timing of the recent intervention studies and our preliminary observation on a lowered prevalence of colds among users of UV lamps while showering, one could envisage that maintaining high levels of vitamin D immediately following the summer is most effective against colds, and that correcting a winter low in 25(OH)D while it is developing is not very effective – possibly because the immune system requires time (months?) to become adjusted to a certain vitamin D level. In this respect a recent Danish study[17] is of special note. It showed that very little UV exposure is needed to maintain summer levels of 25(OH)D: 1 SED every other week to 88% of the body surface from medical broadband UVB lamps suffices (amounting to monthly SEDs even lower than estimated for the users of the UV lamp while showering). Alternatively, Li-Ng *et al.*[16] pointed out that base line 25(OH)D levels in their first intervention study among post-menopausal Afro-American women (on average 47 nmol l^{-1}) were much lower than in their follow-up study among mainly white Caucasians (64 nmol l^{-1}). A very low initial 25(OH)D level may be a prerequisite to detect any effect of vitamin D supplementation on seasonal infections such as colds. This also agrees with the first study by Laaski *et al.*,[10] who found more days of absence due to colds among subjects with 25(OH)D levels below 40 nmol l^{-1}. As only a small minority (18%) of subjects in our study had initial 25(OH)D levels below 40 nmol l^{-1}, our study could be insensitive if effects were restricted to this subgroup. However, a very high percentage of the volunteers caught a cold in our study, and most of them with 25(OH)D levels > 50 nmol l^{-1}. We found no indication that colds were more prevalent with low initial levels of 25(OH)D, nor that volunteers with low initial levels (and larger increases in 25(OH)D) caught less colds with UV treatment or vitamin D supplementation.

A large uncertainty surfaced in our study in determining the 25(OH)D levels: two commonly used methods differed substantially in absolute levels (DiaSorin on average 13% higher than IDS-isys); very much in line with the earlier reported differences.[18] Moreover, the correlation between the two measurements was not very tight either (R^2 = 0.80). This finding clearly underlines the difficulties in comparing different studies on absolute levels of 25(OH)D, and consequently, difficulties in setting norms on 25(OH)D levels.

The present sunbed regimen was aiming for sub-erythemal exposures, and was by and large successful in avoiding sunburns. Nevertheless, this regimen still resulted in clear tanning responses (see Fig. 2). Sunburns are a well known risk factor for melanomas, but the common occurrence of 'sunbed burns' among users[19] is underappreciated and clearly an important risk factor (>5 burns gave an OR = 4 with 95% CI 2.5–6.5).[20] There seems to be a tendency among many sunbed users to get "their money's worth" and have the skin reacting as soon as possible, even if it is a sunburn. Such use of sunbeds should be strongly discouraged, and is evidently not required for tanning.

The induced tan, the darkening of the skin (decrease in lightness L^*), showed a significant positive correlation with the increase in 25(OH)D, but the correlation was far too weak to be predictive (R^2 = 0.17), *i.e.* a large increase in tan does not necessarily imply a large increase in 25(OH)D (see Fig. 3). As reported earlier, we also observed a highly significant negative correlation between the initial level of 25(OH)D and the increase in 25(OH)D over the 8-week intervention period (ESI Fig. S2a,b‡), but again the correlation was too weak to be predictive. The control group C showed a highly significant trend toward larger decreases in 25(OH)D with increasing initial levels of 25(OH)D (ESI Fig. S2c‡), but also this correlation was far too weak to be predictive.

Seven of 35 (20%) volunteers in group A had transiently suffered photo-allergic skin reactions at some point in the course of moderate UV exposures. This percentage is actually very similar to those of people reported to have ever experienced such skin reactions after sun exposure in groups B and C (Table 1), and in a pan-European survey.[21] Surprisingly, this *a priori* percentage was significantly higher in group A (48%); very remarkable, after randomly assigning the volunteers to the 3 groups. As the volunteers knew to which groups they were assigned before filling out the intake questionnaire (see footnote to Table 1), the higher percentage in group A is to be attributed to an unanticipated recall bias induced by the prospect of a protracted UV challenge over an 8-week period.

Overall, our study showed sub-sunburn sunbed treatment to be effective in tanning and in increasing the 25(OH)D serum level, more so than oral vitamin D supplementation by 1000 IU per day. Despite earlier results suggesting a possible beneficial effect on colds, this 8-week mid-winter course of sunbed exposures had, however, no appreciable effect on colds.

Abbreviations

25(OH)D	25-hydroxyvitamin D
1,25(OH)2D	1,25-dihydroxyvitamin D
CI	confidence interval
CIE	Commission International de l'Éclairage
IU	international unit, 25 ng 25(OH)D
MED	minimal erythemal dose
OR	odds ratio
SD	standard deviation
SED	standard erythemal dose (100 J m^{-2} CIE erythemally weighted UV)
UV	ultraviolet (radiation).

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