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## Effect of Body Site and Surface on Vitamin D and 25-Hydroxyvitamin D Production after a Single Narrowband UVB Exposure



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### TO THE EDITOR

Skin color, body surface area (BSA) exposed to UVB, ability to tan, latitude, altitude, season, solar zenith angle, clothing, age, moment of the day, and use of sunscreen influence the cutaneous synthesis of vitamin D (Chen et al., 2007; Holick, 2003; Libon et al., 2013; Rizzoli et al., 2013; Touvier et al., 2015). There are still many controversies concerning the impact of the UV-exposed anatomical region and BSA on cutaneous vitamin D production.

This study was performed in accordance with the Declaration of Helsinki (World Medical Association, 2013) and approved by the university hospital ethics committee. All study procedures were explained to the volunteers. All participants signed an informed consent form.

To determine whether various anatomical regions exhibit different vitamin D production capacities, assessed as production per percentage of BSA, this study initially measured cholecalciferol (vitamin D<sub>3</sub>, representing cutaneous synthesis) and 25(OH)D<sub>3</sub> (the circulating form of vitamin D) levels before and on days 1, 2, and 5 in 72 young healthy volunteers, recruited from among medical students (male = 25, female = 47, mean age = 23.0 ± 2.3 years, age range = 19–29 years, body mass index = 21.6 ± 1.9 kg/m<sup>2</sup>,

body mass index range = 18–25 kg/m<sup>2</sup>, Fitzpatrick's phototype III) after a single narrowband (310–315nm) UVB exposure of 0.8 minimal erythematous dose (mean = 0.22 ± 0.08 J/cm<sup>2</sup>) to different BSAs. BSAs were determined according to real-life clothing habits: group I (n = 15): head, neck, and hands (BSA = 9%); group II (n = 15): head, neck, arms, and hands (BSA = 23%); group III (n = 15): head, neck, arms, hands, legs, and feet (BSA = 50%); group IV (n = 15): the total body (BSA = 96%), as well as a non–UVB-exposed control group (group 0, n = 12). The BSA percentages were calculated according to Wallace's rule (Hettiaratchy and Papini, 2014).

25(OH)D<sub>3</sub> analysis was performed using liquid chromatography/tandem mass spectrometry kits for 25(OH)D<sub>3</sub> measurement (MassChrom 25-OH-Vitamin D3/D2 [LC-MS/MS], Chromsystems, Gräfelfing, Germany) (Cavalier et al., 2014). Cholecalciferol was determined with an in-house developed liquid chromatography/tandem mass spectrometry method.

Statistics were expressed as mean and standard deviation for continuous variables and as frequency tables for categorical variables. On graphs, mean values were plotted with their standard error. The general linear mixed model was used to analyze the evolutions of vitamin D and 25(OH)D<sub>3</sub>

over time and test for group differences. A linear regression was used to compare the area under the curve of vitamin D and 25(OH)D<sub>3</sub> with respect to BSA. Results were considered significant at the 5% critical level ( $P < 0.05$ ). Calculations were done with SAS, version 9.4 (SAS Institute, Cary, NC).

Vitamin D level increased with peak levels on day 1 for groups I and II and on day 2 for groups III and IV, and it decreased subsequently in all groups except in the control group (Figure 1). In contrast, 25(OH)D<sub>3</sub> increased steadily at all time points in all groups but not in the control group (Figure 1). The larger the exposed area was (group IV > III > II > I), the higher the increase (Figure 1).

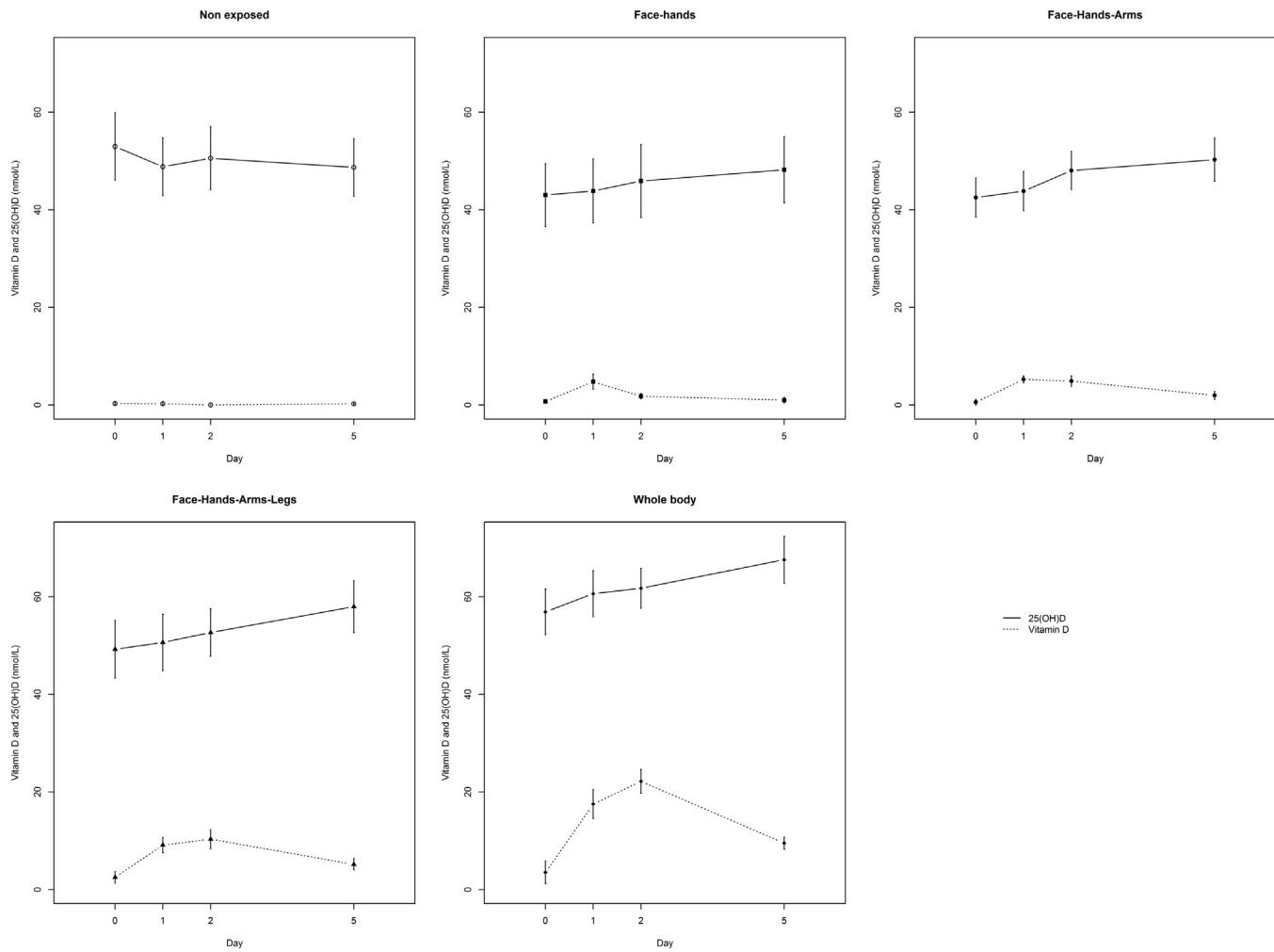
Expressed as area under the curve, no difference in 25(OH)D<sub>3</sub> level was observed between the groups ( $P = 0.29$ ) at day 0. After UVB irradiation, a steady increase in vitamin D and 25(OH)D<sub>3</sub> levels was observed in groups I through IV, with a constant increase according to the body surface exposed (Table 1).

This study gave evidence that the vitamin D production capacities of various skin regions are not similar at all. In fact, the relative mean vitamin D production expressed as area under the curve for the entire body (group IV) was 314 nmol/L, corresponding to 96% of BSA. Hence, the production per percentage of BSA was 3.3 nmol/L. Consequently, the production in group I was 25.4 nmol/L; in group II, 10.3 nmol/L; and in group III, 5.36 nmol/L.

Abbreviations: 25(OH)D<sub>3</sub>, 25-hydroxyvitamin D; BSA, body surface area

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**Figure 1. Vitamin D (nmol/L) and 25(OH)D3 (nmol/L) levels.** Mean and standard error of mean for every study group.

In brief, the head and hands area produced 7.84 more vitamin D per percentage of UV-exposed skin surface; the head, hands, and arms area, 3.17 times more; and the head, hands, arms, and limbs area, 1.64 more compared with the entire body surface.

The importance of BSA on cutaneous vitamin D synthesis remains debated. One study irradiated different BSAs of 27 subjects with a short-term suberythematous single UVB dose ([Matsuoka et al., 1990](#)). An increase in

vitamin D serum level was found in subjects exposing the trunk, the legs, and the entire body ( $13.7 \pm 3.2$  ng/ml vs.  $11.2 \pm 3.2$  ng/ml vs.  $12.6 \pm 2.8$  ng/ml, respectively), representing 32%, 40%, and 100% of irradiation, with a similar response between these groups. This suggests a steady state beyond 33% of surface exposed. In contrast, no increase was observed with the exposition of the head and neck or the arms, which represent, respectively, 9% and 19% of BSA. The authors suggested that

at least 19% of BSA should be exposed to induce an increase in cholecalciferol ([Matsuoka et al., 1990](#)). A short course of three consecutive suberythematous UVB exposures of the upper body or the whole body was associated with a higher concentration of serum cholecalciferol in 10 volunteers compared with face and head irradiation only ([Osmancevic et al., 2015b](#)). Similar results suggested that hands and face exposure was associated with a smaller cholecalciferol production compared

**Table 1. Mean AUC values of vitamin D (nmol/L) and 25(OH)D<sub>3</sub> (nmol/L) and according to the various study groups**

AUC	Nonexposed, Group 0 (n = 12)	Face-Hands, Group I (n = 15)	Face-Hands-Arms, Group II (n = 15)	Face-Hands-Arms-Legs, Group III (n = 15)	Whole Body, Group IV (n = 15)
Vitamin D	$0.73 \pm 2.14$	$10.20 \pm 8.37$	$18.20 \pm 13.60$	$38.70 \pm 28.30$	$77.90 \pm 37.40$
25(OH)D <sub>3</sub>	$249.0 \pm 107.0$	$229.0 \pm 135.0$	$237.0 \pm 78.7$	$268.0 \pm 101.0$	$314.0 \pm 84.7$

Abbreviations: AUC, area under the curve; 25(OH)D<sub>3</sub>, 25-hydroxyvitamin D.

with exposition of larger skin areas (Osmancevic et al., 2015a). However, direct comparison of literature data remains complicated by different study designs.

In this study we showed that not all the skin areas display identical capacities of cutaneous vitamin D synthesis. A previous study showed that the increase in 25(OH)D<sub>3</sub> after narrowband UVB exposure of the entire body was almost the same after head and arms irradiation (mean of 11.4 nmol/L and 11 nmol/L, respectively) (Vähäviu et al., 2010). They hypothesized that certain skin areas have potential adaptive capacities to produce vitamin D. This could be the consequence of different molecular distributions of cholecalciferol precursors. Indeed, animal studies showed that the amount of 7-dehydrocholesterol was 30 times higher in chicken legs, exposed to sunlight, compared with the back (Osmancevic et al., 2015b). Our study clearly showed higher production capacities of the anatomical regions that are usually light-exposed compared with commonly light-hidden areas. This might represent an evolutionary adaptation to clothing habits.

In conclusion, the larger the UVB-exposed skin area, the higher the production levels of cholecalciferol and, subsequently, 25(OH)D<sub>3</sub>. The face and the hands are proportionally more

potent producers of cholecalciferol than other body areas, hypothetically representing an evolutionary adaptation for preventing vitamin D deficiency given the dress habits in Western Europe.

#### CONFLICT OF INTEREST

The authors state no conflict of interest.

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