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Sun exposure questionnaire predicts circulating 25-hydroxyvitamin D concentrations in Caucasian hospital workers in southern Italy☆

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ABSTRACT

Introduction: Recent sun exposure should correlate with circulating 25-hydroxyvitamin D [25(OH)D] due to ultraviolet B (UVB)-catalyzed cutaneous synthesis of vitamin D.
Methods: A Sun Exposure Score was calculated for healthy adults using a recall questionnaire assessing daily Time in Sun (<5 min, 5–30 min, >30 min) and Skin Exposure (face/hands; face/hands and arms; face/hands and legs; and "bathing suit") for 1 week in each of the winter and summer ($n = 47$ and 23, respectively; $n = 18$ participated in both). Concentrations of 25(OH)D were measured by DiaSorin RIA on end-of-week sera.
Results: Mean serum 25(OH)D was higher in summer than winter (58.6 ± 16.5 nmol/L *vs.* 38.8 ± 29.0 nmol/L, respectively, $P = 0.003$ unpaired). The calculated Sun Exposure Score correlated strongly with serum 25(OH)D during summer (Spearman's rho = 0.59, $P = 0.003$); based on the Pearson coefficient of determination, summer Sun Exposure Score explained 38% of the variability in summer serum 25(OH)D. The Sun Exposure Score did not correlate with 25(OH)D in the winter (rho = 0.19, $P = 0.210$). The summer correlation was largely explained by the Time in Sun (rho = 0.58, $P = 0.004$) rather than area of Skin Exposed (rho = 0.10, $P = 0.660$). Although there was a correlation between winter and summer Sun Exposure Scores (rho = 0.63, $P = 0.005$), there was no summer *vs.* winter correlation in serum 25(OH)D (rho = 0.08, $P = 0.76$).
Conclusion: This simple 1-week sun exposure recall questionnaire predicted summer serum 25(OH)D concentrations, accounting for 38% of the variability in 25(OH)D among healthy Italian adults.

1. Introduction

In humans, vitamin D is primarily derived through the interaction of the sun's ultraviolet B (UVB) radiation with a cutaneous cholesterol precursor, 7-dehydrocholesterol. Vitamin D from both cutaneous synthesis and dietary or supplemental intake undergoes hepatic hydroxylation to form 25-hydroxyvitamin D (25(OH)D), the circulating concentrations of which are the objective biomarker of vitamin D status. A further renal hydroxylation produces the active metabolite, $1,25(OH)_2D$.

The importance of sun exposure for vitamin D status is highlighted by the observations from temperate regions where circulating 25(OH)D concentrations fluctuate annually, lagging approximately 2 months behind the incident solar radiation [1–3]. Interestingly, serum 25(OH)D concentrations among those living in temperate regions are commonly below the established range for optimal vitamin D status [4], not only during winter and early spring, but also throughout much of the year [2,5,6]. It is possible that algorithms may be developed that will direct serum 25(OH)D analyses towards those at highest risk of impaired vitamin D status. We hypothesize that people spending little time outdoors during the day or exposing very little skin to the sun are at an elevated risk of having low serum 25(OH)D concentrations. The present study evaluates this hypothesis by evaluating the relationship between responses to a simple sun exposure recall questionnaire and concurrent serum 25(OH)D concentrations during the winter and summer seasons in healthy adults living in Southern Italy.

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2. Materials and methods

2.1. Participants

Healthy adult Italian Caucasian hospital workers in southern Italy (latitude: 40°N) volunteered for this study, providing signed informed consent. Participants were eligible if physical examinations and routine laboratory tests of renal and hepatic function were normal. Participants were excluded if they had conditions associated with impaired vitamin D metabolism or used medication(s) known to affect calcium metabolism. The ethics committee of the "Casa Sollievo della Sofferenza" Hospital, San Giovanni Rotondo (FG), Italy, approved this study.

2.2. Data collection

The study was carried out during January and February 2003 ("winter" visit), and July and August 2003 ("summer" visit). Fasting blood and random urine samples were collected between 07.00–09.00 h, and stored at −70 °C until assayed as part of the assessment of the biochemical parameters related to bone and mineral metabolism. Serum 25(OH)D concentrations were analyzed by radioimmunoassay (RIA; DiaSorin, Stillwater, MN, USA) with intra- and inter-assay CVs <7.2% and <12%, respectively. Serum ionized calcium (iCa) was assessed via ion-specific electrode (AVL LIST GmbH Medizintechnik, Graz, Austria).

During the sample collection visit, participants' recollection of daily sun exposure over the previous week was assessed via a questionnaire administered during the sample collection visit (Fig. 1). There were three choices for the amount of time spent outdoors each day (0 = ≤5 min, 1 = 5–30 min, and 2 = ≥30 min) and four choices for clothing or skin exposure while outdoors (1 = face and hands only; 2 = face, hands and arms; 3 = face, hands and legs; and 4 = "bathing suit"). A score to estimate of their mean weekly sun exposure was calculated: The product of the amount of time spent outdoors and the amount of skin exposed was calculated for each day to create a daily Sun Exposure Score (min = 0, max = 8). All seven days' Sun Exposure Scores were summed to equal the weekly Sun Exposure Score (min = 0, max = 56). Similarly, the weekly Time in Sun Score and weekly Skin Exposure Score were each calculated by summing the seven daily scores (respectively, min = 0, max = 14 and min = 7, max = 28).

2.3. Statistics

All statistical analyses were carried out using SPSS 13.0 (SPSS Inc., Chicago, IL). Means and standard deviations describe parametric data; medians and interquartile ranges describe non-parametric data. The Pearson coefficient of determination and Spearman rho describe relationships between the weekly Scores and 25(OH)D, separately for each season. Paired *t*-tests (for comparisons of parametric variables between winter and summer for the $n = 18$ participants completing both visits), unpaired *t*-tests (for comparisons of all participants, $n = 43$ in winter and $n = 27$ in summer) and the Fisher exact test were used to evaluate categorical variables. $P < 0.05$ was set as the limit of significance.

3. Results

Participant characteristics are presented in Table 1. Mean serum 25(OH)D concentrations were higher in summer than winter (respectively, 58.6 ± 16.5 and 38.8 ± 29.0 nmol/L, $P = 0.003$ unpaired). The correlation between the serum 25(OH)D and weekly Sun Exposure Score was significant in summer but not winter (respectively, Spearman rho = 0.59 and 0.19, $P = 0.003$ and 0.212; Fig. 2A). Interestingly, all 47 participants reported Skin Exposure only in the lowest category (face and hands) during winter; hence the uneven distribution in Fig. 2C.

Table 1
Participant characteristics at the winter and summer visits.

	Winter ($n = 47$)	Summer ($n = 23$)	*P*-Value
Mean age (y)[†]	45.6 ± 13.5	42.2 ± 9.0	0.288
Sex (males:females)	17:30	10:13	0.607
Body Mass Index (kg/m^2)	25.5 ± 4.5	24.0 ± 3.4	0.126
Serum ionized calcium (mmol/L)	1.21 ± 0.03	1.24 ± 0.2	<0.001
Vitamin D Status			
Mean serum 25(OH)D (nmol/L)	38.8 ± 29.0	58.6 ± 16.5	0.003
25(OH)D < 75 nmol/L (*n*, %)	41 (87%)	18 (78%)	0.485
25(OH)D < 30 nmol/L (*n*, %)	25 (53%)	1 (4%)	<0.001

[†] Results presented as means ± SD or n participants with percent (in brackets).

In summer, the correlation between the weekly "Time in Sun" score was almost as strongly correlated with serum 25(OH)D as the weekly Total Sun Exposure Score (rho = 0.58, $P = 0.004$; Fig. 2B). In contrast, the amount of skin exposed to the sun (Skin Exposure) did not correlate significantly with serum 25(OH)D (rho = 0.10, $P = 0.66$).

A subgroup of 18 participants (9 males and 9 females) attended both study visits. In these 18 participants, there was no significant correlation between seasons for serum 25(OH)D concentrations (rho = 0.08, $P = 0.76$). The weekly Sun Exposure Scores and Time in Sun Scores were, however, correlated between the summer and winter (respectively, rho = 0.63, $P = 0.005$ and rho = 0.84, $P < 0.001$).

4. Discussion

The present study demonstrates that a simple questionnaire assessing both the amount of time spent outdoors and amount of skin exposed in a given week for healthy Caucasian adults living at latitude 40°N offers a good prediction of 25(OH)D concentrations in summer. This questionnaire involves minimal participant burden but includes a timeframe long enough to estimate typical activity for an individual. This questionnaire could serve as a screening tool to identify patients at increased risk of low sun exposure who might benefit from a serum 25(OH)D determination.

The strength of the relationship detected between sun exposure in the summer and serum 25(OH)D, highlights the key role of summer sun exposure in determining vitamin D status in a Caucasian population at 40°N latitude. The present study did not collect information regarding type of clothing worn, use of sunscreens, or vacation travel, nor was dietary or supplemental intake assessed to quantify exogenous sources of vitamin D. While the relationship might have been improved by inclusion of such additional measures, it also would have increased the complexity of the questionnaire, making routine clinical use less feasible and recall less accurate. Furthermore, skin pigmentation affects the rate of cutaneous vitamin D synthesis, and thus, the relationship between the Sun Exposure Score and circulating 25(OH)D may vary with skin pigmentation. Since all participants were native Italians, future use of this questionnaire in ethnically diverse populations should also objectively query participant skin pigmentation to evaluate its potential influence on the relationship between sun exposure and serum 25(OH)D.

A comparable study of men working outdoors in Nebraska USA focused more intently on the type and quality of clothing in addition to time spent outdoors [7]. Despite more precise description of Skin Exposure in that study, the correlation between sun exposure and serum 25(OH)D concentrations was weaker than in the present study. The stronger summertime correlation observed in the present study may be partly explained by the relative eth-