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Original article

Association of sunlight exposure with 25-hydroxyvitamin D levels among working urban adult Filipinos

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A B S T R A C T

Objectives: To determine the association of different levels of sunlight exposure, measured using the Filipino sunlight exposure questionnaire (SEQ) with 25-hydroxyvitamin D (25-OHD) levels among working urban adult Filipinos.
Methods: Seventy-five adult participants, living and working in Metro Manila, for at least 1 year, were grouped according to their perceived sunlight exposure pattern: low sunlight exposure (mostly indoor work); moderate sunlight exposure (both indoor and outdoor work); and high sunlight exposure (mostly outdoor work). After completion of the self-administered Filipino SEQ, they underwent serum 25-OHD level determination. Strength of correlation between the SEQ scores and 25-OHD levels was computed.
Results: Serum 25-OHD levels generally increased with increasing sunlight exposure levels. The overall Pearson's correlation between the SEQ scores and 25-OHD levels of the participants was 0.396 ($P = 0.001$). The correlation for the individual domains was 0.342 for intensity of sunlight exposure ($P = 0.003$), 0.321 for factors affecting sunlight exposure ($P = 0.005$), and 0.256 for sun protection practices ($P = 0.027$).
Conclusions: The sunlight exposure of working urban adult Filipinos, as measured by the Filipino SEQ, has an overall significant, direct and moderate association with serum 25-OHD levels. This Filipino SEQ can serve as a valuable clinical tool for sunlight exposure assessment to identify individuals at risk for vitamin D deficiency.

1. Introduction

Although vitamin D can be obtained from the diet, dermal synthesis through ultraviolet ray (UVB) exposure remains the main source in humans. Vitamin D_3 is rapidly converted to 25-hydroxyvitamin D (25-OHD) in the body. Since serum 25-OHD has a long plasma half-life, it is an excellent reflection of vitamin D status [1]. Vitamin D deficiency (VDD) is a global health burden, with increased risks of osteoporosis, cardiovascular diseases, diabetes, cancers and infections [2]. VDD has become prevalent even in tropical countries known to have abundant sunlight all year long [3], probably due to lifestyle changes preventing adequate outdoor sunlight exposure, such as urbanization and air pollution, as seen in a study in Thailand [4]. Similarly, in the Philippines, sun exposure of working urban adults is reduced due to increased indoor occupations, use of more protective clothing and sunscreen, and increased cloud cover from air pollution [5]. The 2013 Philippine National Nutrition Survey revealed that among 1446 participants in the National Capital Region (Metro Manila), 52.2% had deficient (< 50 nmol/L) and insufficient (50 to <75 nmol/L) vitamin D levels, with the highest prevalence among 20-39 year-old females and the lowest among ≥ 60 year old male elderly adults [6]. Moreover, a study among 365 Metro Manila office employees in 2013 showed that 58% had VDD, while 30% had vitamin D insufficiency [5].

Questionnaires are the most cost-effective population-based sunlight exposure measurement, and compared with observation, colorimeters, UV dosimeters that are exorbitantly expensive, and sunlight diaries that do not take into account other important factors [3,7]. Recently, a culturally-appropriate Filipino (Tagalog) sunlight exposure questionnaire (SEQ) was formulated and

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validated in an urban adult population in Metro Manila, Philippines. This 25-item, self-administered questionnaire, answerable through a 4-point Likert scale, had adequate content validity (at least 0.86 for each item). Domains identified using exploratory factor analysis, as seen in Table 1, were intensity of sunlight exposure (items 1–7), factors affecting sunlight exposure (items 8–19), and sun protection practices (items 20–25), which had satisfactory internal consistency generally and independently (Cronbach alpha > 0.7). Good test-retest reliability was established when all 260 adult participants completed the first and second testing with no significant differences from their responses 2 weeks apart [8].

There are 2 other SEQs validated in Asian populations, one of which employed criterion and concurrent validity assessment using objective methods to measure sunlight exposure [3,7]. The short-term and long-term SEQs developed in Pakistan were shown to have good correlation with UV dosimeter readings and fair correlation with serum 25-OHD levels using electrochemiluminescence immunoassay [3]. It is quintessential that the newly developed Filipino SEQ be evaluated for clinical use. This study aims to determine the association of different levels of sunlight exposure, measured using the SEQ locally developed by Yu et al [8], with 25-OHD levels among working urban adult Filipinos.

2. Methods

The study was reviewed and approved by the UP Manila Research Ethics Board (UPMREB 2018-209-01) and was conducted in accordance with the Declaration of Helsinki regarding biomedical research. Those who agreed to participate in the study were asked to sign the informed consent form and were identified only using number codes.

2.1. Study design and setting

This was a cross-sectional analytic study done at the University of the Philippines Manila-Philippine General Hospital (UP-PGH).

2.2. Sample population

Individuals 19–60 years old, who were able to read and write independently, fluent in the Filipino (Tagalog) language, with different socioeconomic backgrounds, living and working in Metro Manila for at least 1 year to account for seasonal changes, were recruited. Exclusion criteria were: admitted patients, pregnant or lactating women, active skin disorders, immunocompromised conditions (eg, malignancy, HIV/AIDS), current intake of vitamin D supplements and medications known to alter vitamin D metabolism (eg, statins, rifampicin, isoniazid, anti-epileptic drugs, glucocorticoids, cyclosporine, tacrolimus, chemotherapeutic agents, highly active anti-retroviral agents, cimetidine), hepatic, renal, and malabsorptive conditions (eg, celiac disease, Crohn's disease, chronic pancreatitis, cystic fibrosis).

2.3. Sample size estimation

A sample size of 75 was computed based on the correlation coefficient of 0.363 between the sunlight exposure measurement score and 25-OHD level seen in the study of Humayun et al, with level of significance of 0.05 and 90% power [3,9].

2.4. Sampling design

Participants with different levels of sunlight exposure were needed to capture the range of responses using the SEQ and their respective 25-OHD measurements, so purposive sampling was employed for our study. The investigators first identified occupations traditionally associated with each level of sunlight exposure. Potential subjects were then recruited from their respective workplaces after voluntary consent for participation. They were grouped according to their perception of their sunlight exposure: low sunlight exposure (indoor daytime workers, eg, physicians, office employees), moderate sunlight exposure (both indoor and outdoor daytime workers, eg, maintenance/utility workers, security officers/guards), high sunlight exposure (outdoor daytime workers, eg, construction site workers/laborers) before completing

Table 1
SEQ Domains and Items (English version).

SEQ Domains	SEQ Items
1. Intensity of sunlight exposure	1. How do you describe your skin when it is exposed to the sun?
	2. What part of your body is usually exposed to the sun?
	3. How long do you usually spend under the sun on a weekday?
	4. How long do you usually spend under the sun on a weekend?
	5. How long do you usually spend under the sun during sunny weather?
	6. How long do you usually spend under the sun during cloudy weather?
	7. What time of the day are you usually exposed to the sun?
2. Factors affecting sunlight exposure	8. How often do you go out in the sun due to work or daily routine?
	9. How often do you walk or use public transport to do the above activities?
	10. How often do you engage in outdoor activities such as jogging, cycling, and swimming?
	11. How often do you take calcium with vitamin D or multivitamins?
	12. How likely are you to be exposed to the sun to get stronger bones and better health?
	13. How likely are you to be exposed to the sun to get happier and livelier?
	14. How likely are you to be exposed to the sun to get more beautiful skin?
	15. How likely are you to avoid sun exposure due to the influence of family, friends, and coworkers?
	16. How likely are you to avoid sun exposure due to the influence of TV, radio, and internet?
	17. How likely are you to avoid sun exposure due to sunburn, skin cancer, skin allergy, and rashes?
	18. How likely are you to avoid sun exposure due to heat stroke, hypertension, and dizziness?
	19. How likely are you to avoid sun exposure due to sweating and fear of darker skin?
3. Sun protection practices	20. When going out in the sun, how often do you wear a hat?
	21. When going out in the sun, how often do you use an umbrella?
	22. When going out in the sun, how often do you walk under the shade?
	23. When going out in the sun, how often do you use sunscreen containing at least SPF (sun protection factor) 30?
	24. When do you usually apply sunscreen?
	25. How much sunscreen do you usually apply?

SEQ, sunlight exposure questionnaire.

the questionnaire and undergoing 25-OHD level determination. Thus, we believe that our sample is generally representative of the population in terms of capturing a wide range of occupations and sunlight exposure levels.

2.5. Scoring system for the sunlight exposure questionnaire

Responses to the items under each domain were rated on a 4-point scale, from “never” to “always”. Mean scores for each domain were computed and interpreted as follows: scores ranging from 1.0 to 2.0 represented low sunlight exposure; >2.0 to 3.0 represented moderate sunlight exposure; and >3.0 to 4.0 represented high sunlight exposure. A total of 4 scores was generated for each participant: 1 for each of the 3 domains and an overall score.

2.6. Sunlight exposure questionnaire completion and 25-hydroxyvitamin D determination

After completing the self-administered SEQ, the participants underwent venous blood extraction for in-vitro determination of total serum 25-OHD using Chemiluminescent Microparticle Immunoassay with Abbott ARCHITECT analyzer (Abbott, Abbott Park, Illinois, USA), with coefficients of variation of 5.6% for low control, 5% for medium control and 5% for high control [10]. This is sufficient for the study’s purposes, since a maximum coefficient of variation of 10% for 25-OHD analysis is recommended [10,11]. Vitamin D levels were then classified as follows: sufficient ≥ 30 ng/mL; insufficient 20–29 ng/mL; deficient < 20 ng/mL [3,12]. Those with vitamin D deficency and insufficiency were referred to an endocrinologist at the outpatient department of UP-PGH for proper education and appropriate treatment.

2.7. Statistical analysis

Descriptive statistics was used to summarize the general and clinical characteristics of the participants. Frequency and proportion were used for nominal variables; median and range for ordinal variables; mean and standard deviation for interval and ratio variables. One-way ANOVA, Kruskal-Wallis test and Fisher’s exact/Chi square test were employed to determine the differences in mean, median, and frequency, respectively. Since data were normally distributed, Pearson’s correlation was computed to determine the association between the SEQ scores and 25-OHD measurements. Strength of correlation was interpreted as follows: >0.1 to < 0.3, small correlation; >0.3 to < 0.5, medium/moderate correlation; >0.5, large/strong correlation [13]. Missing variables were neither replaced nor estimated. Null hypotheses were rejected at 0.05 α-level of significance. STATA 15.0 software (StataCorp LLC, College Station, Texas, USA) was used for data analysis.

3. Results

Seventy-five respondents were included in the analysis, distributed equally to various categories of sunlight exposure based on the nature of employment as seen in Table 2. The median age was 33 years (range 22–60). Males comprised roughly three-fourths of the recruited participants. Mostly male participants were recruited in the moderate (88%) and high sunlight exposure groups (100%) as compared to the low sunlight exposure group (36%). The median durations of residence and work in an urban area were 14 (range 1–60) and 4 (range 1–40) years, respectively. Participants in the low and moderate sunlight exposure categories lived significantly longer in an urban area as compared to those with high sunlight exposure (25 years versus 3 years, P < 0.001). While most participants were high school graduates or lower (32%), more low sunlight exposure participants received postgraduate education as compared to those with moderate or high sunlight exposure (76%, 4%, 0%, respectively, P < 0.001). Most respondents had monthly household incomes of ≥ PHP 10,000/USD 192.71 (PHP 51.89 = USD 1) (73.33%).

The mean (± SD) scores of participants for SEQ domains 1, 2, and 3 were 2.04 ± 0.52, 2.52 ± 0.47, and 3.05 ± 0.49, respectively. The overall score was 2.51 ± 0.38 as shown in Table 3. Participants in all groups scored lower in the intensity of sunlight exposure domain and higher in the sun protection practices domain. The average scores for any domain and for overall showed an increasing trend as perceived sunlight exposure moved from low to high, notably for the domains on intensity of sunlight exposure (P = 0.022) and sun protection practices (P = 0.008). When the participants’ SEQ scores were interpreted using the devised scoring system, majority were classified as having moderate sunlight exposure (80%).

As seen in Table 4, the average 25-OHD levels of the different groups significantly increased as sunlight exposure moved from low to high (P < 0.001). Most participants with sufficient 25-OHD had high perceived sunlight exposure (64.71%); those with insufficient levels mostly had moderate perceived sunlight exposure (39.47%); while majority of those with deficient levels had low perceived sunlight exposure (80%).

The Pearson’s correlation between the SEQ scores and 25-OHD levels of the participants was 0.342 for intensity of sunlight exposure domain (P = 0.003), 0.321 for factors affecting sunlight exposure domain (P = 0.005), and 0.256 for sun protection practices domain (P = 0.027). Overall r was 0.396 (P = 0.001). SEQ domain scores, as well as the overall score, correlated significantly, directly and moderately with participants’ 25-OHD levels, save for sun protection practices domain, which had lower correlation as shown in Table 5.

4. Discussion

To date, there is no standard, universally-accepted questionnaire available for approximate measurement of sunlight exposure and vitamin D. Further research is advocated in developing valid and cost-effective tools for sun exposure estimation and its importance to human health [14].

The first SEQ developed for use in urban adult Filipinos was found to have sufficient content validity, construct validity and test-retest reliability. This Filipino SEQ was further evaluated for its association with serum 25-OHD in order to become clinically applicable. 25-OHD is an objective reflection not only of recent sun exposure, but of several years’ duration [15]. In this study, the overall SEQ scores of the participants with different levels of sunlight exposure correlated significantly, directly, and moderately with 25-OHD levels as revealed by a correlation coefficient of 0.396 (P = 0.001).

Similar validation studies that also included small numbers of participants had varied findings as shown in Table 6. There was no significant correlation between the questionnaire measures during weekdays, weekends or cumulative time outdoors and 25-OHD in a study by Cargill et al in Australia [16]. Conversely, weekly sun exposure score was significantly and strongly associated with 25-OHD in summer (r = 0.59), but not in winter, in a study by Hanwell et al in Southern Italy [17]. Among a South Asian population in Pakistan, Humayun et al found that the mean short-term SEQ scores (r = 0.36) and long-term SEQ scores in summer (r = 0.43) and winter (r = 0.48) had fair correlation with serum 25-OHD levels. Furthermore, the average serum 25-OHD was lower in each of the sunlight exposure group as compared to our findings (low sunlight exposure group 9.8 ng/mL; moderate sunlight exposure group 11.1 ng/mL; high sunlight exposure group 17 ng/

Table 2
Socio-demographic characteristics of study participants.

	Total (n = 75)	Perceived sunlight exposure			*P*-value
		Low (n = 25)	Moderate (n = 25)	High (n = 25)	
	Frequency (%); mean ± SD; median (range)				
Age, yr	33 (22–60)	31 (25–59)	42 (24–60)	30 (22–58)	0.044[a]
Sex					< 0.001[b]
Male	56 (74.67)	9 (36)	22 (88)	25 (100)	
Female	19 (25.33)	16 (64)	3 (12)	0	
Duration of urban living, yr	14 (1–60)	25 (2–44)	25 (2–60)	3 (1–40)	< 0.001[a]
Duration of urban work, yr	4 (1–40)	4 (1–38)	13 (1–40)	3 (1–31)	0.003[a]
Educational attainment					< 0.001[c]
Elementary graduate or less	7 (9.33)	0	0	7 (28)	
High school graduate or lower	24 (32)	0	12 (48)	12 (48)	
Some college or vocational	9 (12)	2 (8)	6 (24)	1 (4)	
College graduate	15 (20)	4 (16)	6 (24)	5 (20)	
Post–graduate	20 (26.67)	19 (76)	1 (4)	0	
Monthly household income (PHP/USD)					0.274[b]
< PHP 10,000/USD 192.71	20 (26.67)	4 (16)	7 (28)	9 (36)	
≥ PHP 10,000/USD 192.71	55 (73.33)	21 (84)	18 (72)	16 (64)	

PHP, Philippines Peso; USD, United States Dollar.
[a] Kruskal-Wallis test.
[b] Chi-square test.
[c] Fisher's exact test.

Table 3
Sunlight exposure questionnaire scores of study participants.[a]

SEQ domains	Perceived sunlight exposure				*P*-value
	Total (n = 75)	Low (n = 25)	Moderate (n = 25)	High (n = 25)	
	mean ± SD				
1. Intensity of sunlight exposure	2.04 ± 0.52	1.81 ± 0.35	2.13 ± 0.48	2.18 ± 0.62	0.022
2. Factors affecting sunlight exposure	2.52 ± 0.47	2.19 ± 0.33	2.61 ± 0.46	2.76 ± 0.43	0.283
3. Sun protection practices	3.05 ± 0.49	2.77 ± 0.60	3.21 ± 0.37	3.18 ± 0.34	0.008
Overall	2.51 ± 0.38	2.22 ± 0.29	2.62 ± 0.32	2.70 ± 0.36	0.613

[a]For each score, interpretation of sunlight exposure is as follows: 1.0 to 2.0, low; > 2.0 to 3.0, moderate; > 3.0 to 4.0, high.
One-way ANOVA.
SEQ, sunlight exposure questionnaire.

Table 4
Mean serum 25-OHD and classification of study participants grouped according to perceived sunlight exposure.

Perceived sunlight exposure	Serum 25-OHD (ng/mL)	P-value	Serum 25-OHD level[d]			P-value[c]
	mean ± SD		Sufficient (n = 17)	Insufficient (n = 38)	Deficient (n = 20)	
			Frequency (%)			
Low	17.51 ± 5.96	< 0.001[a]	0	9 (23.68)	16 (80)	< 0.001
Moderate	26.78 ± 6.55		6 (35.29)	15 (39.47)	4 (20)	
High	30.97 ± 5.88		11 (64.71)	14 (36.84)	0	
Pairwise comparison						
Low vs moderate		< 0.001[b]				
Low vs high		< 0.001[b]				
Moderate vs high		0.047[b]				

[a] One-way ANOVA.
[b] Tukey's HSD test.
[c] Chi-square test.
[d] Classification for serum 25-OHD level: sufficient if ≥ 30 ng/mL; insufficient if 20 to <30 ng/mL; deficient if < 20 ng/mL.

Table 5
Correlation of sunlight exposure questionnaire scores with 25-OHD Levels.

	Pearson's r[a]	Relationship	P-value
SEQ domains			
1. Intensity of sunlight exposure	0.342	Direct, moderate relationship	0.003
2. Factors affecting sunlight exposure	0.321	Direct, moderate relationship	0.005
3. Sun protection practices	0.256	Direct, weak relationship	0.027
Overall SEQ score	0.396	Direct, moderate relationship	0.001

SEQ, sunlight exposure questionnaire.
[a] Correlation coefficient.

Table 6
Correlation studies between sunlight exposure questionnaire and 25-OHD.

Sunlight exposure domain	Hanwell et al 2010 (Italy) Summer n = 23 Winter n = 47	Humayun et al 2012 (Pakistan) n = 54	Cargill et al 2012 (Australia) n = 46	Present study Mansibang et al 2019 (Philippines) n = 75
Time spent outdoors	Yes	Yes	Yes	Yes
Skin type	-	Yes	Yes	Yes
Amount of skin exposed or type of clothing	Yes	Yes	–	Yes
Type of activities outdoors	-	–	–	Yes
Sunscreen application	-	Yes	–	Yes
Sun protection behaviors (shade-seeking, umbrella, hat and eyeshade use)	-	Yes	–	Yes
Sunlamp use	-	–	–	–
Sunbed use	-	–	–	–
Current weather or season	-	Yes	–	Yes
Travel to place with another season	-	–	–	–
Use of glass windows of vehicle	-	Yes	–	–
Multivitamin use	-	Yes	–	Yes
Use of weighted or ordinal scores	Yes	Yes	–	Yes
Correlation with 25-OHD levels	Strong in summer (r = 0.59) Not significant in winter (r = 0.19)	Moderate ST (r = 0.36) LT summer (r = 0.43) LT winter (r = 0.48)	Not significant	Moderate (r = 0.396)

SEQ, sunlight exposure questionnaire; ST, short-term SEQ; LT, long-term SEQ.

mL), and values were mostly in the deficient range [3]. Though both the Philippines and Pakistan are situated in Asia, differences in latitude, time of day, season, and other environmental influences determine the solar zenith angle, which largely affects the quality of UVB rays that reach the skin and thus, cutaneous vitamin D synthesis [2,14,18]. Based on the Köppen climate classification, Metro Manila has a tropical wet and dry climate [19], while Karachi, Pakistan has a tropical and subtropical desert climate [20]. To note, our study had the largest sample size (n = 75) out of these different validation studies, and is also the first study correlating SEQ and serum 25-OHD levels in a tropical setting.

Evidently, the findings in our study are consistent with the previous research done in Pakistan that showed moderate correlation between self-reported SEQ and serum 25-OHD. As measurement of sunlight exposure is a complex process, questionnaires may not fully assess certain variables like skin pigmentation, age, sun protection behavior and practices (eg, time spent outdoors, clothing, sunscreen use) that greatly affect vitamin D status; hence, low correlation may be expected [14]. This may also be the reason explaining the lower correlation between SEQ scores and domain 3 of this study ($r = 0.256$), which evaluated the participants' sun protection practices. Revision of the SEQ to include actual duration of sun exposure instead of categorical responses is suggested, for this may result in a stronger correlation with 25-OHD as observed by Hanwell et al [17]. Nutritional vitamin D intake and genetic variations in the activity of the 25-hydroxylase enzyme and polymorphisms in the vitamin D-binding protein are other parameters that affect 25-OHD concentration [18]. A limitation of the study was that the diet, e.g. intake of vitamin D-rich foods, of the participants was not assessed, as the enteral route is traditionally not a good source of vitamin D unless foods are fortified [21]. In a local study by Zumaraga et al among post-menopausal Filipino women, a single nucleotide polymorphism rs141114959 in the vitamin D receptor (VDR) gene was associated with low serum 25-OHD levels. Additional research on these VDR sequence variants and VDD is warranted [22].

The participants of this study were required to have been living and working in Metro Manila for at least a year to account for seasonal variations. They were recruited according to their perceived sunlight exposure, which was primarily dependent on their occupation. The UP-PGH is an acceptable study setting since it is an urban community, composed of workers with different levels of sun exposure. Each perceived sunlight exposure group was somehow appropriately represented by the participants as reflected in the results. The mean SEQ scores for any domain and overall increased as the perceived sunlight exposure moved from low to high, especially for the domains on intensity of sunlight exposure and sun protection practices. The average serum 25-OHD levels of respondents with perceived low, moderate, and high sunlight exposure were interpreted as deficient, insufficient, and sufficient, respectively. Workers with deficient 25-OHD more likely had low perceived sunlight exposure, while those with sufficient 25-OHD mostly had high perceived sunlight exposure. On the other hand, Table 3 shows that the classification of the participants' perceived sunlight exposure, which was the basis for grouping during recruitment, may not always be similar to the classification of their eventual SEQ scores. For example, the results showed that for domains 2 and 3 and overall, the mean SEQ scores of the participants in the low perceived sunlight exposure group fall under moderate sunlight exposure. Most participants were actually classified as having moderate sunlight exposure when the SEQ scoring system was used (80%). A limitation of this study was that participants were mostly males and belonged to the middle-aged group. Jobs that entail moderate to high sunlight exposure such as machinery and construction work are frequently designated to men in the Philippines. An important difference in 25-OHD levels of Filipino adults based on gender was revealed by the 2013 Philippine National Nutrition Survey. Insufficient and deficient 25-OHD levels were found more in females (62.5%) than in males (32.1%) [6,23]. A more evenly distributed sample in terms of gender and age could have captured a wider range of SEQ responses and 25-OHD levels. Future studies applying the SEQ with 25-OHD determination in larger urban and also rural communities are proposed.

Another limitation of this study is the lack of data on correlation with UV dosimeters, which quantitatively measure overall ambient radiation exposure that accounts for latitude, season, time of day, cloud cover and ground surface [14]. The short-term SEQ ($r = 0.601$) and long-term SEQ in summer ($r = 0.582$) and winter ($r = 0.613$) developed by Humayun et al demonstrated strong correlation with UV dosimeter readings [3]. In a Danish population study by Køster et al, strong correlation was also determined between exposure scale from questionnaire and standard erythema dose readings on dosimetry ($r = 0.54$) [24]. Unfortunately, personal UV dosimetry is not readily available in the Philippines and is expensive to procure. A validation study on the association of the Filipino SEQ with UV dosimetry is recommended to evaluate if there is a significant and stronger correlation between the 2 measurements.

5. Conclusions

The Filipino (Tagalog) SEQ developed by Yu et al has an overall significant, direct and moderate association with serum 25-OHD levels. In resource-limited and tropical settings, this Filipino SEQ can serve as a valuable clinical tool for sunlight exposure assessment to identify individuals at risk for VDD.

Conflicts of interest

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CRediT author statement

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