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Prevalence and correlates of sun protections with sunburn and vitamin D deficiency in sun-sensitive individuals

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Abstract

Background—Sun sensitivity is an inherent risk factor for skin cancer. Sun protection is important in sun-sensitive individuals to reduce sunburns for skin cancer prevention. However, concerns have arisen regarding the possible impact of sun protection on vitamin D deficiency.

Objective—To examine the prevalence and correlates of sun protective behaviors (staying in the shade, using sunscreen, and wearing long sleeves) with sunburn and vitamin D deficiency in sun-sensitive individuals

Methods—This was a cross-sectional study of 2,390 US non-Hispanic white adults aged 20–59 years in the National Health and Nutrition Examination Survey 2011–2014. Sun-sensitivity was defined as self-reported tendency to severe sunburn when exposed to the sun for half an hour after months of non-sun exposure and single serum 25(OH)D levels less than 50 nmol/L was determined as vitamin D deficiency. We calculated adjusted odds ratios (aORs) and 95% confidence intervals (95% CIs) using multivariable logistic regression taking into account the complex survey design.

Results—Sun-sensitive individuals had higher odds of frequently staying in the shade (aOR=3.08; 95% CI 2.19–4.33) and using sunscreen (aOR=1.93; 1.44–2.59) but not with sun exposure time (aOR=0.91; 0.62–1.32). Yet, sun-sensitive individuals had significantly higher likelihood of sunburns (aOR=1.93; 1.45–2.55), and no increased likelihood of vitamin D deficiency (aOR=1.15; 0.84–1.58). Among sun-sensitive individuals, being younger, male, and spending more time outdoors were associated with increased odds of sunburns and the risk of sunburn was reduced with frequently staying in the shade and engaging in multimodal sun protections.

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IRB review status: This study used deidentified data and was therefore exempt from review by the Johns Hopkins University Institutional Review Board.

Conclusion—Sun-sensitive individuals more frequently used sun protection methods yet they still were significantly more likely to experience sunburns and the risk of vitamin D deficiency was not increased. Education on proper application of sunscreen combined with other sun protective techniques is important to reduce sunburn in sun-sensitive populations.

Keywords

sun sensitivity; sun protection; sunburn; vitamin D; sunscreen

Introduction

Ultraviolet (UV) radiation is the predominant predisposing factor for skin cancer. Melanoma and non-melanoma skin cancer (NMSC) risk increases with UV radiation from sunlight¹. White populations have higher incidence of NMSC and melanoma, which account for 40% of all neoplasms in whites², but these cancers remain significantly lower in people of color (2–5%)³. Sunburns are implicated in the pathogenesis of NMSCs and melanoma⁴. Furthermore, even one sunburn every 2 years can triple the risk of melanoma⁵. The World Health Organization and the American Academy of Dermatology Association advise seeking shade in the midday hours, wearing protective clothing including a wide brimmed hat and UV-blocking sunglasses, and using broad-spectrum sunscreen of sun protection factor (SPF) 30+ liberally to prevent skin cancer^{6,7}.

However, recent findings on the benefits of vitamin D have led to concerns that rigorous sun protection may compromise vitamin D levels^{8,9}. Studies evaluating photodermatoses with light skin type had higher prevalence of vitamin D deficiency compared to controls, potentially due to the strict sun protection required in these patients^{10–13}. Cutaneous vitamin D synthesis from UVB in sunlight is the major source of vitamin D with few foods containing substantial amounts. Vitamin D is important not only for musculoskeletal health, but also for prevention of autoimmune diseases and reducing mortality from some cancers¹⁴.

Sun sensitivity is a profound risk factor for skin cancer along with fair skin, red or blonde hair, light colored eyes, and freckles^{15–17}. Distinct from photodermatoses which are pathologic, sun sensitivity is physiologic, indicating a tendency to sunburn easily after sun exposure with low minimal erythral dose (MED)^{18,19}. For sun-sensitive people, sun protection is even more important to prevent skin cancer but concerns remain whether photoprotection may block the beneficial effects of UVR such as vitamin D synthesis and photoadaptation^{19,20}. Yet the prevalence and correlates of sun protective behaviors and sunburn, and vitamin D deficiency in individuals with sun sensitivity have not been well studied. Thus, we aimed to address the use of different types of sun protective behaviors (staying in the shade, using sunscreen, and wearing long sleeves) in individuals with sun sensitivity and their impact on sunburn and vitamin D deficiency using a dataset from National Health and Nutrition Examination Survey (NHANES) 2011 to 2014. Herein, we defined sun sensitivity as self-reported tendency to develop severe sunburns (blisters or few days of skin peeling) with half an hour of sun exposure after several months of non-sun exposure. Serum 25(OH)D is the best indicator of vitamin D status. Although there is no international consensus on optimal levels of serum 25(OH)D, we defined vitamin D

deficiency as a serum 25(OH)D concentration less than 50 nmol/L (20 ng/mL) which is widely recommended by most experts¹⁴.

Methods

Study population

The NHANES is a biennial, nationally representative survey of the US non-institutionalized civilian population that involves a complex survey design and population-based weights. It includes data collected via household interviews and standardized physical examinations conducted in specially equipped mobile examination centers. We pooled self-reported data from two cycles of NHANES, 2011–2012 and 2013–2014, with a total of 19,931 participants. We restricted our study population to non-Hispanic whites ($N=6,647$) because of the high prevalence of sun-sensitive skin types and skin cancer in white people. Among them, 2,865 participants, aged 20–59 years, were administered the dermatology questionnaire and 2,794 individuals completed the survey. Of these, 2,606 had serum 25(OH)D levels. Our final study population included 2,390 participants who had complete data on all covariates representing US non-Hispanic white adults aged 20–59 years. This study was waived from review by the Johns Hopkins Institutional Review Board because the data were deidentified.

Sun sensitivity

Sun sensitivity was characterized based on the effect of going out in the sun for half an hour without sun-protection after several months of not being in the sun. Responses were identified as sun-sensitive (i.e., “severe sunburn with blisters”, “severe sunburn for a few days with peeling”) or non-sun-sensitive (i.e., “mild burn with some tanning”, “turn darker without a sunburn” and “nothing would happen”).

Covariates

We selected covariates known to be associated with vitamin D deficiency and UV exposure behaviors. Age, gender, education (highest level of schooling or degree), body mass index (BMI), physical activity, alcohol consumption, milk intake, vitamin D supplementation, season (winter–spring, summer–fall), and survey year were included. Physical activity level was categorized as none, 0–<180, 180–<360, and ≥360 minutes/week using the sum of reported minutes of moderate and vigorous recreational activity per week. Alcohol consumption was categorized as heavy drinking (history of drinking 4 or more drinks for females and 5 or more drinks for males of any kind of alcoholic beverage almost daily) or normal (less than heavy drinker). Vitamin D supplement use in the past 30 days was categorized as yes/no. Possible responses to milk intake in the past 30 days included never, rarely, varied, sometimes, and often, and we categorized it as rare (never, rarely), sometimes (varied, sometimes) and frequent (often).

Dependent variables: Sun protection, sun exposure time, sunburn and vitamin D deficiency

For sun protection use, participants were asked three questions regarding how often they (1) stay in the shade, (2) wear a long-sleeved shirt, and (3) use sunscreen on a very sunny day.

For each of the three questions, possible responses included “always”, “most of the time”, “sometimes”, “rarely”, and “never”. Responses were recoded to three categories: rare (never or rarely), moderate (sometimes), and frequent (most of the time or always). We defined individuals with frequent multimodal sun protection as those who reported frequent use of at least two of the three examined sun protective methods. Recent sunburn was characterized as number of sunburns within the past 12 months. Multiple sunburns were identified as two or more sunburns during last year. For sun exposure time, we summed the reported minutes of time spent outdoors between 9 am to 5 pm per week and created categories of time spent outdoors as 0–59, 60–119, 120–179, and 180 minutes/week. Serum samples were obtained at the same time as the questionnaire was administered. Serum 25(OH)D levels (nmol/L) were measured by radioimmunoassay (RIA) (DiaSorin, Stillwater NM) by the National Center for Environmental Health, Centers for Disease Control (CDC). The results were not available to the participants thus subjects’ behaviors were not biased by the test results. Vitamin D deficiency was defined as 25(OH)D levels < 50 nmol/L as the Institute of Medicine concluded that to maximize bone health, the level of serum 25(OH)D should be higher than 50 nmol/L (20 ng/mL)²¹.

Statistical analyses

Data analysis was conducted using SAS 9.4 (SAS Institute, Inc., Cary, North Carolina, USA) reflecting complex survey design. Sample weights were adjusted by dividing each sample weight by 2 (the number of pooled cycles)²². We performed multivariable logistic regression to estimate the odds ratios (ORs) for the dependent variables including sun protective behaviors, sun exposure time, sunburns and vitamin D deficiency. We adjusted for age, gender, education, BMI, physical activity, season, and survey year for sun protective behaviors, sun exposure time, and sunburns. In the second model for calculating OR of sunburns, we additionally included sun protective behaviors and sun exposure time as covariates. For vitamin D deficiency, we adjusted for age, gender, education, BMI, physical activity, season, and survey year as well as additional covariates that have been reported to affect serum 25(OH)D levels, including vitamin D supplement, milk intake, and alcohol consumption. Also, to account for the effect of sun protective behaviors and sun exposure time on vitamin D deficiency, we adjusted for these factors in the second model for vitamin D deficiency. Further analysis was performed in a subpopulation restricted to subjects who were sun sensitive. We computed the *P* for trend treating ordinal variables as continuous. All tests were two-sided and significance was set at *P*-value < 0.05.

Results

Descriptive characteristics of all participants and with versus without sun sensitivity are presented in Table 1. Of the 2390 participants, 424 (17.6%) were sun-sensitive. Females compared to males (62.1% versus 37.9%, *P* < 0.001) and participants who were obese (BMI ≥ 30 kg/m²) compared to non-obese (BMI: 25.0–29.9 and <25.0 kg/m²) (39.0%, 29.9%, 31.1%, respectively, *P* = 0.002) were more likely to be sun-sensitive. The prevalence of vitamin D deficiency was not significantly different between sun-sensitive and non-sun-sensitive individuals (19.3% versus 15.7%, *P* = 0.12).

The percentages of frequently using sunscreen (50.3% versus 34.3%), seeking shade (45.8% versus 20.7%), and multimodal sun protections (31.4% versus 12.6%) were significantly higher in sun-sensitive individuals than those without sun-sensitivity, whereas wearing long sleeves (9.6% versus 6.3%) was not significantly different between the two groups. However, sun-sensitive participants significantly more frequently suffered from two or more episodes of sunburn during the last year (44.2% versus 30.7%). Sun exposure time was not significantly different between individuals with and without sun sensitivity (Table 2).

Sun-sensitive individuals had higher odds of frequent sunscreen use (aOR=1.93; 95% CIs 1.44–2.59), staying in the shade (aOR=3.08; 2.19–4.33), but not with wearing long sleeves (aOR=1.58; 0.98–2.55). Sun-sensitive individuals were more likely to use multimodal protections (aOR=3.14; 2.23–4.40) than non-sun-sensitive individuals while sun exposure time was not limited (≥ 180 min/week) (aOR=0.91; 0.62–1.32). Yet still, sun-sensitive individuals had higher odds of multiple sunburns in the past year (aOR=1.93; 1.45–2.55), which was not substantially altered after additionally adjusting for sun protection behaviors and sun exposure time (aOR=1.90; 1.44–2.50). Individuals with sun sensitivity did not have higher odds of vitamin D deficiency (aOR=1.15; 0.84–1.58) even after additionally adjusting for sun protection and sun exposure time (aOR=1.14; 0.85–1.52) (Table 3).

Among sun-sensitive individuals, younger age ($P_{\text{trend}} < 0.001$), male sex ($P = 0.02$), and increased time spent outdoors ($P_{\text{trend}} = 0.03$) were associated with higher odds of suffering multiple sunburns (Table 4). Among the three sun protection methods, frequently seeking shade ($\beta = -0.38$, $R^2 = 0.23$, $P_{\text{trend}} = 0.02$) was associated with lower odds of having multiple sunburns while neither frequently using sunscreen ($\beta = -0.15$, $R^2 = 0.21$, $P_{\text{trend}} = 0.35$) nor wearing long sleeves ($\beta = -0.30$, $R^2 = 0.22$, $P_{\text{trend}} = 0.07$) was associated with multiple sunburns in sun-sensitive individuals. Above all, engaging in more methods of frequent sun protection ($\beta = -0.26$, $R^2 = 0.22$, $P_{\text{trend}} = 0.04$) was associated with lower odds of multiple sunburns (Table 5).

Discussion

We found that sun-sensitive individuals more frequently engaged in sun protective behaviors, especially via staying in the shade and using sunscreen compared to non-sun-sensitive individuals among the non-Hispanic white US population. However, their sun-protective behaviors remained inadequate in preventing sunburns. In this study, sun-sensitive individuals had approximately twice the odds of suffering multiple sunburns during the past year compared to non-sensitive individuals, which is consistent with a recent US population study²³. Notably, prevalence of vitamin D deficiency was not different between individuals with and without sun sensitivity and the odds of vitamin D deficiency was not associated with sun sensitivity, implying that better sun protection behaviors in this population did not compromise vitamin D status.

In our study of the US non-Hispanic white population, 18% were estimated to be sun sensitive. Among them, 44% reported multiple sunburns in the previous year. Considering sunburn is a well-known risk factor for skin cancers, this is a concerning number^{15,16}.

Persons with sun sensitivity have been highlighted in recent studies as being at high risk of

getting sunburns^{23,24}. A study suggesting a decision tree model to predict sunburn risk placed sun sensitivity as the first decision point followed by sun protective behaviors²⁴. Interestingly, those who used only sunscreen had the highest likelihood of sunburns (62.4%) whereas the group that engaged in other sun protective behaviors (seeking shade, wearing protective clothes and hat) without using sunscreen had the lowest likelihood of sunburns (24.3%) among sun-sensitive individuals²⁴. The health benefits of using sunscreen are well established^{25,26}. However, solely using sunscreen did not seem to provide enough sun protection in the sun sensitive population.

In contrast to reports on the higher incidence of vitamin D deficiency and lower serum 25(OH)D levels in photodermatoses and skin cancer patients to whom strong sun protection is required^{10–13,27}, we found that frequent sun protective behaviors among sun-sensitive individuals did not compromise their vitamin D status. This is mostly attributed to the finding that in fair skinned individuals, maximum possible vitamin D synthesis occurs rapidly, within a few minutes of summer sun exposure and longer exposures do not provide further benefit^{8,9}. Regular moderate sun exposure, even while using consistent photoprotection, still leads to sufficient amount of UV reaching the skin to synthesize vitamin D²⁷. No differences in lifestyle habits including physical activity, milk intake, and vitamin D supplementation between individuals with and without sun sensitivity may also contribute to the lack of difference in vitamin D deficiency between individuals with and without sun sensitivity. However, the odds ratio for having vitamin D deficiency remained insignificant even after adjusting for sun protective behaviors and sun exposure time, indicating that sun protection in sun-sensitive individuals seemed to be less intense than for patients with photodermatoses or history of skin cancer. In a recent review of published articles, international experts concluded that sunscreen use for daily and recreational photoprotection does not compromise vitamin D synthesis even when applied under optimal conditions²⁸. Broad-spectrum sunscreens that prevent erythema are unlikely to compromise vitamin D status in healthy populations and vitamin D screening and supplementation are only recommended in patients with photodermatoses²⁸. Another possible explanation is that sun-sensitive individuals may require lower levels of UV radiation to synthesize vitamin D. An interventional study found that equivalent vitamin D is generated according to fractional minimal erythral doses (MEDs) of respective skin types²⁹. Thus, sun-sensitive individuals who might have lower MEDs can produce comparable dose of vitamin D with less sun exposure, thereby less likely to develop vitamin D deficiency.

Many studies investigated the consequence of UV exposure in order to develop best sun protective strategies for the optimal balance between skin cancer risk and the benefits of vitamin D because UVB is responsible for both effects. Experimental studies in humans have shown that cutaneous vitamin D production quickly reached equilibrium within a few minutes of summer sun exposure in whites although epidermal DNA damage is initiated in tandem even at low dose of UV radiation^{8,28}. A study reported that increase in 25(OH)D and detection of cyclobutane pyrimidine dimers (CPDs) with carcinogenic potential were induced from 0.2 MED²⁹. CPD was detected in whole epidermis in fair skin types while only superficial damage (sparing the basal layer of the skin) was seen in dark skin types as the higher melanin content serve as a better protection to CPD formation²⁹. This potentially explains the higher incidence of skin cancer in fair skin types, thus requiring greater caution

even at low levels of UV exposure. Studies conducted at summer camps or skiing holidays among whites have shown that the increase in vitamin D was accompanied by much greater increase in DNA damage, further suggesting the importance of rigorous sun protection to prevent skin cancer^{30,31}. Therefore, neglecting sun protection practices out of concern for vitamin D deficiency is a poor trade-off for preventing photoaging and skin cancer⁹.

Among sun-sensitive individuals, younger age, male sex, and sun exposure time were associated with sunburns. Given that severe sunburns in childhood and adolescence increased the risk of melanoma¹⁶, public education targeting the youth population who are actively engaging in outdoor activity is warranted. Sunburns were decreased with frequently staying in the shade but not with sunscreen use, demonstrating different efficacies of sun protective behaviors³². Several reasons for the lack of association with reduced sunburn risk with sunscreen use were suggested by previous studies, including using insufficient amounts (less than 2mg/cm²), not re-applying often enough or following exercise and not applying to all exposed skin^{33–35}. Sunscreen use might also be linked to more sun exposure since people intentionally use sunscreen when they expect intense or longer sun exposure^{36–38}. Multimodal sun protections combining two or more methods were associated with decreased sunburns in our study. Given that people using multimodal protections was only 31.4% of the sun-sensitive population, there is room for improvement to lower sunburn in sun-sensitive individuals.

One limitation of our study is that the cross-sectional study design cannot infer causal relationships. The data are based on self-reported outcomes, hence recall bias may exist. Likert scales on the responses can be interpreted differently between responders which can decrease the study sensitivity. In addition, the database did not provide details of sun protection behaviors including sunscreen reapplication, SPFs of sunscreen, and sun exposure intensity at varying time points throughout the year. Another potential limitation is the single measurement of serum 25(OH)D may not give fully representative vitamin D levels over a year. Nonetheless, we addressed this by controlling for seasons and this cross-sectional measurement could be a better reflection of long-term vitamin D status compared with short-term intervention trials. Also, given the large sample size, the data provides valuable information regarding this cohort's sun protective behaviors and vitamin D status.

In conclusion, while staying in the shade and using sunscreen were the more commonly utilized sun protection methods among sun-sensitive individuals in our study, individuals with sun sensitivity remained twice as likely of suffering from multiple sunburns. Of note, this group did not have higher prevalence of vitamin D deficiency. Solely using sunscreen does not provide adequate protection for patients with sun sensitivity and additional methods are required such as staying in the shade. Taken together, proper sunscreen use under the greater umbrella of multimodal sun protection is recommended for sun-sensitive individuals to reduce sunburns in order to prevent skin cancer. In sun-sensitive individuals, this point of adequately using sun protection cannot be over-emphasized given their inherent higher risk for sunburns. Targeted interventions in this high risk population are needed to reduce the morbidity and mortality associated with skin cancer.

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Table 1

Characteristics of the non-Hispanic white study participants overall and stratified by sun sensitivity

Characteristic	All study participants, No. (Wt %)	Non-sun-sensitive participants, No. (Wt %)	Sun-sensitive participants, No. (Wt %)	P-value
No. of participants	2390	1966 (82.4)	424 (17.6)	
Age, years				
20–29	561 (23.4)	447 (23.0)	114 (25.4)	0.79
30–39	653 (21.9)	542 (22.1)	111 (20.8)	
40–49	584 (25.2)	477 (25.1)	107 (25.5)	
50–59	592 (29.5)	500 (29.8)	92 (28.3)	
Sex				
Male	1219 (50.5)	1053 (53.2)	166 (37.9)	<0.001
Female	1171 (49.5)	913 (46.8)	258 (62.1)	
Education				
High School or lower	814 (28.8)	681 (29.3)	133 (26.4)	0.53
Some college	836 (33.8)	677 (33.3)	159 (36.1)	
College degree or higher	740 (37.4)	608 (37.4)	132 (37.5)	
Body mass index, kg/m ²				
<25.0	835 (35.3)	702 (36.2)	133 (31.1)	0.002
25.0–29.9	795 (34.8)	667 (35.8)	128 (29.9)	
30.0	760 (29.9)	597 (28.0)	163 (39.0)	
Physical activity, min/week				
None	1010 (38.3)	820 (37.7)	190 (40.9)	0.23
1–179	523 (23.4)	430 (23.1)	93 (25.3)	
180–359	469 (21.3)	397 (22.1)	72 (17.5)	
360	388 (17.0)	319 (17.1)	69 (16.3)	
Alcohol consumption				
Heavy drinking	440 (15.7)	376 (16.2)	64 (13.1)	0.13
Normal	1950 (84.3)	1590 (83.8)	360 (86.9)	
Milk intake				
Rare	785 (34.0)	631 (33.3)	154 (37.2)	0.34
Sometimes	693 (28.7)	574 (28.9)	119 (28.0)	
Frequent	912 (37.3)	761 (37.8)	151 (34.8)	
Vitamin D supplement				
No	1496 (59.3)	1224 (58.9)	272 (61.1)	0.31
Yes	894 (40.7)	742 (41.1)	152 (38.9)	
Seasonal variation				
Winter–Spring	1037 (41.4)	846 (41.0)	191 (43.5)	0.51
Summer–Fall	1353 (58.6)	1120 (59.0)	233 (56.5)	
Survey year				
2011–2012	1048 (49.0)	865 (49.2)	183 (48.1)	0.73
2013–2014	1342 (51.0)	1101 (50.8)	241 (51.9)	

Characteristic	All study participants, No. (Wt %)	Non-sun-sensitive participants, No. (Wt %)	Sun-sensitive participants, No. (Wt %)	P-value
Vitamin D deficiency (<50 nmol/L)				
No	1958 (83.7)	1618 (84.3)	340 (80.7)	0.12
Yes	432 (16.3)	379 (15.7)	93 (19.3)	

Abbreviations: weighted, Wt; Chi-square test was performed.

Table 2

Sun protective behaviors and recent sunburns for all non-Hispanic white participants and stratified by sun sensitivity

Variable	All participants, No. (Wt %)	Non-sun-sensitive participants, No. (Wt %)	Sun-sensitive participants, No. (Wt %)	P-value
No. of participants	2390	1966 (82.4)	424 (17.6)	
Sunscreen ^a				
Rare	1013 (37.4)	872 (39.3)	141 (28.1)	<0.001
Sometimes	580 (25.5)	492 (26.4)	88 (21.6)	
Frequent	797 (37.1)	602 (34.3)	195 (50.3)	
Stay in the shade ^a				
Rare	689 (27.9)	615 (30.5)	74 (15.9)	<0.001
Sometimes	1091 (47.0)	934 (48.8)	157 (38.3)	
Frequent	610 (25.1)	417 (20.7)	193 (45.8)	
Long sleeve ^a				
Rare	1730 (71.3)	1427 (71.5)	303 (70.2)	0.14
Sometimes	493 (21.8)	415 (22.2)	78 (20.2)	
Frequent	167 (6.9)	124 (6.3)	43 (9.6)	
Frequent protection methods ^b				
0	1239 (49.6)	1095 (53.5)	144 (31.1)	<0.001
1	795 (34.5)	642 (33.9)	153 (37.5)	
2	289 (13.0)	186 (10.3)	103 (25.9)	
3	67 (2.9)	43 (2.3)	24 (5.5)	
Recent sunburns ^c				
0	956 (39.1)	836 (41.1)	120 (30.0)	<0.001
1	658 (27.8)	549 (28.2)	109 (25.8)	
2	776 (33.1)	581 (30.7)	195 (44.2)	
Time spent outdoors (min/wk) ^d				
0–59	883 (38.1)	714 (37.5)	169 (40.7)	0.27
60–119	578 (25.8)	469 (25.7)	109 (26.5)	
120–179	364 (14.7)	298 (14.6)	66 (15.3)	
180	565 (21.4)	485 (22.2)	80 (17.5)	

Abbreviations: weighted, Wt; Chi-square test was performed.

^aSelf-reported frequency of the sun-protective practices on a warm sunny day

^bNumber of the three examined sun protection techniques that sun-exposed participants reported frequently using on a warm sunny day

^cNumber of sunburns reported in the last year

^dAverage number of minutes spent outdoors in a day

Table 3

Sun sensitivity as a predictor of sun protective behaviors, sun exposure, recent sunburns and vitamin D deficiency

Variable (N=2390)	Unadjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Sun protection ^a				
Sunscreen use ^b	1.94 (1.49–2.52)	<0.001	1.93 (1.44–2.59)	<0.001
Stay in the shade ^b	3.24 (2.32–4.54)	<0.001	3.08 (2.19–4.33)	<0.001
Long sleeves ^b	1.58 (0.99–2.53)	0.06	1.58 (0.98–2.55)	0.06
Multiple sun protection ^c	3.18 (2.35–4.32)	<0.001	3.14 (2.23–4.40)	<0.001
Sun exposure ^a				
Time spent outdoors(min/wk) ^d	0.74 (0.52–1.05)	0.09	0.91 (0.62–1.32)	0.61
Recent sunburns ^e				
Model 1 ^a	1.79 (1.37–2.32)	<0.001	1.93 (1.45–2.55)	<0.001
Model 2 ^f			1.90 (1.44–2.50)	<0.001
Vitamin D deficiency				
Model 1 ^g	1.29 (0.95–1.75)	0.11	1.15 (0.84–1.58)	0.36
Model 2 ^h			1.14 (0.85–1.52)	0.39

^a Adjusted for age group (20–29, 30–39, 40–49, 50–59), gender (male, female), education (less than high school, high school diploma, college degree or higher), BMI (<25.0, 25.0–29.9, 30.0 kg/m²), physical activity (None, 1–179, 180–359, 360 min/wk), season (winter–spring, summer–fall), and survey year (2011–2012, 2013–2014)

^b Frequent use versus rare or sometimes use on a very sunny day

^c Frequent use of at least two of the three sun protection methods versus fewer than two methods

^d 180 or more minutes per week spent outdoors between 9 am and 5pm

^e At least two sunburns in the last year versus none or one

^f Adjusted for covariates included in 'a' (model 1) plus sun protection/sun exposure time

^g Adjusted for age group (20–29, 30–39, 40–49, 50–59), gender (male, female), education (less than high school, high school diploma, college degree or higher), BMI (<25.0, 25.0–29.9, 30.0 kg/m²), physical activity (None, 1–179, 180–359, 360 min/wk), alcohol consumption (heavy drinking, less than heavy drinking), milk consumption (rare, sometimes, frequent), vitamin D supplement (yes/no), season (winter–spring, summer–fall), and survey year (2011–2012, 2013–2014)

^h Adjusted for covariates included in 'g' (model 1) plus sun protection/sun exposure time

Table 4

Weighted percentage (Wt %) and odds ratios of recent sunburns by characteristic for the non-Hispanic white participants with sun sensitivity ($N=424$)

Characteristic	No recent sunburns, No. (Wt %)	Recent sunburns ^a , No. (Wt %)	OR (95% CI)	P-value
No. of sun-sensitive participants	229 (55.8)	195 (44.2)		
Age, years				
20–29	41 (16.1)	73 (37.0)	5.78 (3.00–11.15)	<0.001 ^b
30–39	58 (20.1)	53 (21.7)	2.72 (1.40–5.31)	
40–49	61 (25.2)	46 (25.9)	2.60 (1.26–5.33)	
50–59	69 (38.6)	23 (15.4)	1.0 (Reference)	
Sex				
Male	79 (31.1)	87 (46.4)	1.92 (1.15–3.23)	0.02
Female	150 (68.9)	108 (53.6)	1.0 (Reference)	
Education				
High School or Lower	77 (29.5)	56 (22.5)	1.0 (Reference)	0.77 ^b
Some college	77 (31.0)	82 (42.6)	1.81 (1.08–3.02)	
College degree or higher	75 (39.5)	57 (34.9)	1.16 (0.67–2.01)	
Physical activity level, min/wk				
None	113 (45.6)	77 (35.1)	1.0 (Reference)	0.15 ^b
0– <180	50 (24.7)	43 (26.0)	1.36 (0.67–2.77)	
180– <360	33 (14.0)	39 (21.9)	2.03 (1.03–4.00)	
360	33 (15.7)	36 (17.0)	1.42 (0.66–3.06)	
Body mass index, kg/m ²				
<25.0	67 (30.3)	66 (32.2)	1.0 (Reference)	0.36 ^b
25.0–29.9	63 (26.9)	65 (33.7)	1.18 (0.64–2.17)	
30.0	99 (42.8)	64 (34.1)	0.75 (0.39–1.45)	
Seasonal variation				
Winter–Spring	100 (41.1)	91 (46.6)	1.0 (Reference)	0.37
Summer–Fall	129 (58.9)	104 (53.4)	0.80 (0.48–1.33)	
Survey year				
2011–2012	92 (44.9)	91 (52.2)	1.0 (Reference)	0.23
2013–2014	137 (55.1)	104 (47.8)	0.75 (0.46–1.21)	
Time spent outdoors ^c , min/wk				
0–59	105 (47.9)	64 (31.7)	1.0 (Reference)	0.03
60–119	59 (27.5)	50 (25.2)	1.11 (0.61–2.05)	
120–179	31 (11.2)	35 (20.5)	2.50 (1.12–5.61)	
180	34 (13.4)	46 (22.6)	1.88 (0.86–4.10)	

^a 2 or more sunburns reported in the last year

^b P-value for linear trend was computed using the Wald statistic, treating the categorized exposure variable as a continuous variable.

^cAdjusted for age group (20–29, 30–39, 40–49, 50–59), gender, education (less than high school, high school diploma, some college, college degree or higher), BMI (<25.0, 25.0–29.9, ≥30.0 kg/m²), physical activity level (None, 1–179, 180–359, ≥360 min/wk), season (winter–spring, summer–fall), and survey year (2011–2012, 2013–2014)

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Table 5

Weighted percentage (Wt %) and odds ratios of recent sunburns by sun protection behaviors and sun exposure time for the non-Hispanic white participants with sun sensitivity ($N=424$)

Behavior	No recent sunburns, No. (Wt %)	Recent sunburns ^a , No. (Wt %)	Adjusted OR ^b (95% CI)	β^c	R ^{2d}	P for trend ^e
No. participants	229 (55.8)	195 (44.2)				
Sunscreen use						
Rare	78 (30.1)	63 (25.6)	1.0 (Reference)	0.15	0.21	0.35
Sometimes	42 (20.1)	46 (23.5)	1.46 (0.66–3.25)			
Frequent	109 (49.8)	86 (50.9)	1.41 (0.72–2.76)			
Stay shade						
Rare	32 (13.0)	42 (19.6)	1.0 (Reference)	−0.38	0.23	0.02
Sometimes	76 (33.5)	81 (44.3)	0.97 (0.53–1.76)			
Frequent	121 (53.5)	72 (36.1)	0.52 (0.27–1.01)			
Long sleeves						
Rare	159 (68.6)	144 (72.3)	1.0 (Reference)	−0.30	0.22	0.07
Sometimes	39 (18.4)	39 (22.4)	1.11 (0.64–1.93)			
Frequent	31 (13.0)	12 (5.3)	0.37 (0.14–0.96)			
Multiple sun protections ^f						
0	66 (27.4)	78 (35.8)	1.0 (Reference)	−0.26	0.22	0.04
1	83 (36.2)	70 (39.1)	0.77 (0.45–1.32)			
2	62 (29.0)	41 (22.0)	0.69 (0.34–1.42)			
3	18 (7.4)	6 (3.1)	0.31 (0.08–1.23)			

^a 2 or more sunburns reported in the last year

^b Adjusted for age group (20–29, 30–39, 40–49, 50–59), gender, education (less than high school, high school diploma, some college, college degree or higher), BMI (<25.0, 25.0–29.9, 30.0 kg/m²), physical activity level (None, 1–179, 180–359, 360 min/wk), season (winter–spring, summer–fall), survey year (2011–2012, 2013–2014), and sun exposure time (<180, 180 min/wk)

^c β for linear trend was computed using Wald statistic, treating the categorized exposure variable as a continuous variable

^d R², coefficient of determination, for each sun protection method model for Wald statistic

^e P-value for linear trend was computed using the Wald statistic, treating the categorized exposure variable as a continuous variable

^f Number of the three examined sun protection techniques that sun-exposed subjects reported frequently using on a warm sunny day