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Association between sun-protective behaviours and psoriasis in US adults in the National Health and Nutrition Examination Survey, 2009–2014: a cross-sectional study

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ABSTRACT

Objective To evaluate the association between sun-protective behaviours and psoriasis in a nationally representative sample of US adults.

Design Analysis of cross-sectional data.

Setting National Health and Nutrition Examination Survey (NHANES), 2009–2014.

Participants A total of 9735 participants aged 20–59 years with available data on psoriasis, sun-protective behaviours and covariates were included in the analysis.

Outcome measures Information on sun-protective behaviours (staying in the shade, wearing long sleeves and using sunscreen) and psoriasis was obtained from questionnaires in the NHANES database. Logistic regression models and subgroup analyses were employed to investigate the association between sun-protective behaviours and psoriasis.

Results After adjusting for sociodemographic variables, body mass index (BMI), alcohol drinking status, smoking status, sun sensitivity and time spent outdoors in the multivariable logistic regression model, moderate wearing of long sleeves was negatively associated with psoriasis (OR, 0.55; 95% CI 0.33 to 0.90, p=0.02), while frequent wearing showed no significant relationship. There was no significant association between staying in the shade and psoriasis, regardless of frequency. Subgroup analyses stratified by age, gender, race/ethnicity and smoking status revealed no significant associations in most groups, but moderate wearing of long sleeves was found to be negatively associated with psoriasis among those aged 20–39 years (OR, 0.42; 95% CI 0.18 to 0.98, p=0.04), among non-Hispanic white individuals (OR, 0.52; 95% CI 0.28 to 0.97, p=0.04) and among non-smokers (OR, 0.49; 95% CI 0.25 to 0.95, p=0.04), as it was among women in terms of overall sun protection (OR, 0.58; 95% CI 0.35 to 0.97, p=0.04). However, among non-Hispanic white individuals (staying in the shade: OR, 1.69; 95% CI 1.00 to 2.84, p=0.049) and former/current smokers (overall: OR, 3.28; 95% CI 1.41 to 7.63, p=0.009), frequent sun protection was positively associated with psoriasis.

Conclusions Moderate sun-protective behaviours among US adults were found to be negatively associated with psoriasis. However, among non-Hispanic white individuals and former/current smokers, frequent sun protection was positively associated with psoriasis. Future studies with rigorous study design could further explore and validate the potential reasons for these associations to better inform evidence-based behavioural recommendations that protect human health.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Data from the National Health and Nutrition Examination Survey database are nationally representative and collected under strict control.
⇒ This study adjusted for a variety of confounding variables.
⇒ In this study, subgroup analyses were employed in addition to logistic regression to explore the relationships between sun-protective behaviours and psoriasis in specific subgroups.
⇒ Due to the cross-sectional study design, only associations and no causal links could be determined.
⇒ Self-reported psoriasis and sun-protective behaviours may be subject to recall bias and reporting bias.

INTRODUCTION

Psoriasis is a prevalent chronic inflammatory skin disease that causes a decline in quality of life, sleep impairments, psychological problems and other consequences.[1] Its prevalence is anticipated to increase,[2] with a current prevalence of about 3% among US adults, affecting over 7.5 million US adults.[3]

A range of therapeutic interventions exist for psoriasis, including pharmacotherapy, psychotherapy and rapidly developing biological therapies. Phototherapy modalities (broadband ultraviolet B, narrowband ultraviolet B and heliotherapy) are endorsed as effective and safe treatment options by the Joint American Academy of Dermatology–National Psoriasis Foundation guidelines.[4] Phototherapy is commonly used for psoriasis due to its efficacy and safety. Empirical evidence indicates that ultraviolet B (UVB)

contributes to faster lesion clearance, fewer episodes of excessive erythema and longer remission periods in psoriasis[5] by inducing apoptosis in keratinocytes,[6] CD4+ T cells and CD8+ T cells[7]; inhibiting mast cell degranulation and histamine release[8]; immunosuppression; and changing the level of cytokines such as interleukin (IL) 10 and IL-17A.[9 10] Furthermore, there are several pieces of evidence supporting the notion that UVB therapy or heliotherapy enhances vitamin D levels and reduces the severity of psoriasis.[11 12] An association between low levels of serum 25-hydroxyvitamin D (25(OH)D) and increased risk of developing psoriasis has been observed.[13] In addition, psoriasis tends to manifest more frequently in winter than in summer,[14 15] which suggests that ultraviolet (UV) radiation might influence this seasonal variation.

In the USA, some health organisations and clinicians advocate for use of sunscreen and other sun protection measures to reduce the risk of developing melanoma and other skin cancers, as well as to prevent premature skin ageing. This raises concerns regarding whether sun protection hinders the cutaneous synthesis of vitamin D, diminishes the beneficial effects of UV radiation on the skin, and is thus detrimental to cardiovascular health, metabolism, bone and skeletal health, and skin health.[16 17] Thyssen *et al* have proposed that reduced environmental UV exposure may be a potential driver of the current epidemic of atopic dermatitis.[18] As for the prevalence of psoriasis, there is considerable variation across different geographical locations.[19] Research has shown that higher latitudes generally correspond with increased prevalence rates.[20 21] Both genetic and environmental factors probably contribute to the correlation, but variation in UV exposure must also be touched on. Therefore, given UV radiation's therapeutic role in psoriasis and the geographical differences in UV exposure, it is pertinent to explore whether sun-protective behaviours may cause or aggravate psoriasis. Despite having found that using sunscreen for both daily and recreational photoprotection has no impact on the synthesis of vitamin D,[22] data are scarce on whether sunscreen use and other sun-protective behaviours affect the prevalence of psoriasis.

To address this research gap, this cross-sectional study analysed data from the 2009–2014 cycles of the National Health and Nutrition Examination Survey (NHANES) to explore the association between multimodal sun-protective behaviours and the prevalence of psoriasis among US adults.

METHODS

Data source

We used NHANES data from 2009 to 2014 to investigate the association between multimodal sun-protective behaviours and the prevalence of psoriasis among US adults.[23] The NHANES is a nationally representative survey that captures statistics of the US non-institutionalised civilian population on a biennial basis based on complex survey design and population-specific sample weights in order to assess their health or nutritional status.

Study design and population

This was a population-based, cross-sectional study. Our analyses were based on data collected from participants during three 2-year NHANES cycles (2009–2010, 2011–2012 and 2013–2014).

The total number of initial NHANES participants from 2009 to 2014 was 30 468. Of 11 842 participants aged 20–59 years, 6 were excluded due to unavailable self-reported psoriasis data and 168 excluded due to unavailable information on three kinds of sun-protective behaviours. Additionally, 1933 participants with missing data on covariates, including age, gender, race or ethnicity, education level, marital status, country of birth, body mass index (BMI), alcohol drinking status, smoking status, sun sensitivity and time spent outdoors, were excluded, resulting in 9735 individuals included in the final analysis (figure 1).

To our knowledge, all participants provided informed consent for data collection and for the data to be publicly disseminated in a de-identified format.

Psoriasis

Data on psoriasis were obtained from the medical conditions section of the questionnaire data in NHANES. Participants aged 20 years and older were asked if they had ever been told by a doctor or other healthcare professionals that they had psoriasis. If the answer is 'yes', the participant is considered to have psoriasis.

Sun-protective behaviours, sun sensitivity and time spent outdoors

We assessed three different sun-protective behaviours from the NHANES dermatology questionnaire section, for which the target group included participants aged 20–59 years. The question asked for sun-protective behaviours was: 'When you go outside on a very sunny day, for more than one hour, how often do you (1) stay in the shade, (2) wear a long-sleeved shirt, (3) use sunscreen?' Valid answers can be 'always', 'most of the time', 'sometimes', 'rarely', 'never' and 'don't go out in the sun'. We reclassified these different answers into three categories: frequent (always or most of the time), moderate (sometimes) or rare (never, rarely or do not go out in the sun). Furthermore, overall sun protection was classified into three levels according to the total score for three sun-protective behaviours. The total score for sun protection ranging from 3 to 9 was further divided down into rare (3–4), moderate (5–7) and frequent (8–9) categories[24] after every behaviour was scored 1, 2 or 3 depending on their frequency of use (rare, moderate and frequent).

Sun sensitivity was defined based on the question about skin reaction to the sun without sunscreen or protective clothing for half an hour after several months of not being exposed to the sun. According to their responses, survey participants were then divided into three groups: no sun sensitivity ('nothing would happen in half an hour'), mild

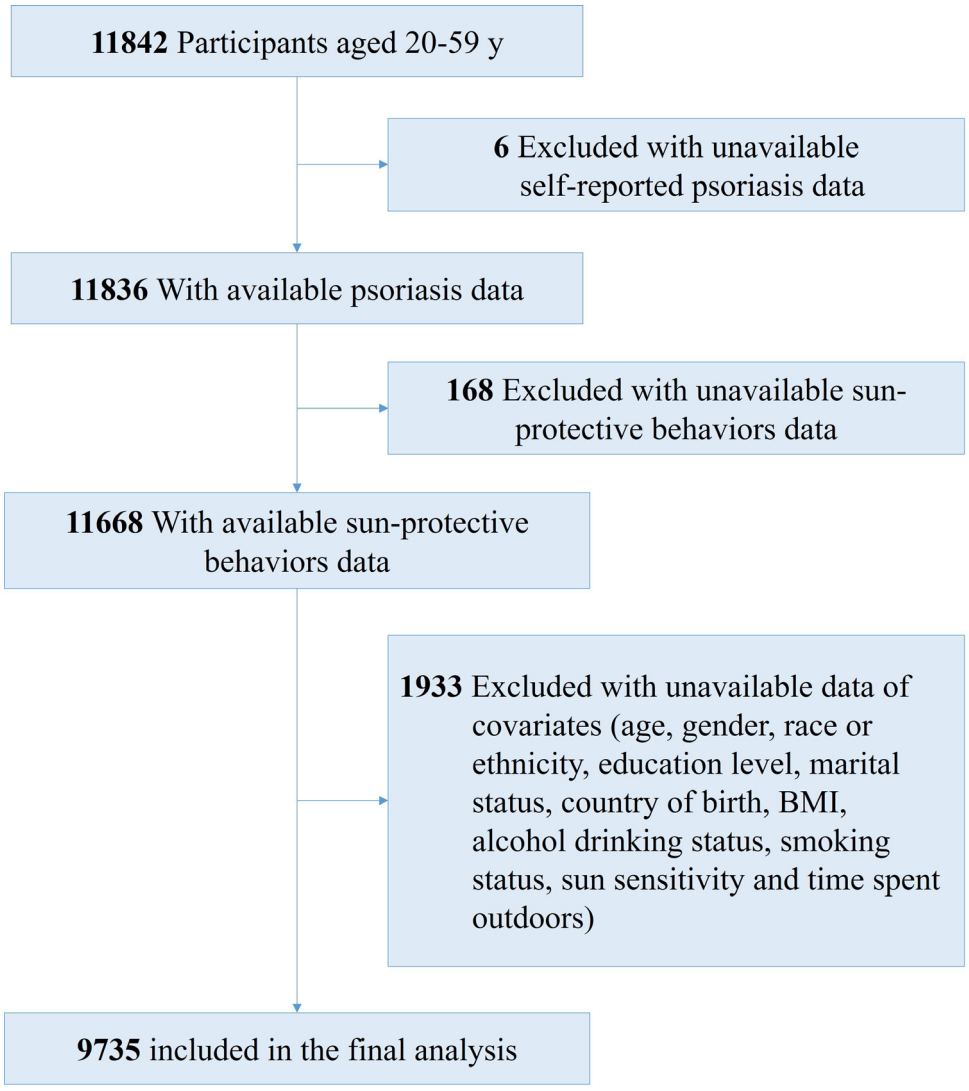

Figure 1 Flow diagram of the screening process for participant selection. Sun-protective behaviours include staying in the shade, wearing long sleeves and using sunscreen. BMI, body mass index.

sun sensitivity ('mildly burned with some tanning' or 'turning darker without a sunburn') and severe sun sensitivity ('severe sunburn with blisters' or 'a severe sunburn for a few days with peeling').

In NHANES 2009–2014 cycles, participants were questioned how many minutes they spent outdoors over the previous 30 days between 09:00 and 17:00 on workdays and non-workdays. Considering a week with 5 working days and 2 days off, we calculated the average time (minutes per day) spent outdoors using the following formula: (minutes outdoors 09:00–17:00 on working days × 5 + minutes outdoors 09:00–17:00 on non-working days × 2)/7. If the response is 'does not work or go to school' for the working day or 'at work or at school 9 to 5 seven days a week' for the non-working day, the counterpart will be regarded as the final average time.

Other covariates

In addition to sun sensitivity and time spent outdoors, other covariates included age, gender, race or ethnicity, education level, marital status, country of birth, BMI, alcohol drinking status and smoking status. Race or ethnicity was derived from responses to the survey questions on race and Hispanic origin in the demographics file. Respondents were reclassified into four groups: non-Hispanic white, non-Hispanic black, Hispanic and other (Mexican American or other race, including multiracial). Marital status was categorised into the following three groups: never married, married or living with a partner, and widowed, divorced or separated. Country of birth was encoded as a binary variable (0=born in another country; 1=born in the USA). BMI was calculated as weight in kilograms divided by height in metres squared and then was analysed as a three-categorical variable (BMI <25, 25 ≤ BMI <30, BMI ≤30) in the multivariable models. The survey question 'In any 1 year, have you had at least 12 drinks of any type of alcoholic beverage?' was used to establish participants' alcohol drinking status. Participants who responded 'yes' were considered alcohol drinkers. Smoking status was divided into three categories: non-smoker (smoked <100 cigarettes in a lifetime),

former smoker (smoked ≥100 cigarettes in a lifetime but has quit) and current smoker (smoked ≥100 cigarettes in a lifetime and still smoking), according to data on cigarette use in the questionnaire.

Statistical analysis

All analyses were conducted in accordance with the NHANES analytic guidelines,[25 26] taking into consideration the complex sample design and appropriate sampling weights. In this study, we extracted three cycles of NHANES; thus, the sampling weight was calculated using the following equation: full sample 6-year mobile examination centre (MEC) exam weight=full sample 2-year MEC exam weight/3. Continuous data were reported as mean, SD and 95% CI, while categorical data were expressed as numbers, weighted percentage frequencies and 95% CIs. To compare the baseline characteristics by presence of psoriasis, t-tests were used to compare continuous data and χ^2 tests for categorical data. Unadjusted and multivariable adjusted logistic regression analyses were performed to calculate weighted ORs and 95% CIs to explore the association between sun protection and psoriasis. The multivariable model was adjusted for potential confounders (ie, age, gender, race or ethnicity, education level, marital status, country of birth, alcohol drinking status, smoking status, sun sensitivity and time spent outdoors). Subgroup analyses stratified by age, gender, race or ethnicity and smoking status were conducted to determine the association in specific subgroups. Notably, in all models, staying in the shade, wearing long sleeves, using sunscreen and overall sun protection were modelled separately. In all tests, p values of less than 0.05 (two-sided) were considered statistically significant. All statistical analyses were conducted in Stata V.17 (StataCorp).

Patient and public involvement

None.

RESULTS

Characteristics of the population

Baseline characteristics and comparisons of the included and excluded participants are shown in online supplemental table 1. Of 9735 participants who were finally included in our study, 255 (2.6%) had psoriasis, while 9480 (97.4%) did not. As shown in table 1, 50.3% of the participants were male, and the weighted mean age of the participants was 39.6 years (95% CI 39.3 to 39.9). Compared with participants without psoriasis, those with psoriasis were more likely to be older (+3.2 years), non-Hispanic white, USA-born and former smokers; however, they did not differ significantly in gender, education level, marital status, BMI and alcohol drinking status. Additionally, participants with psoriasis had a lower prevalence of severe sun sensitivity, but no difference existed in the time spent outdoors. In terms of frequent staying in the shade, wearing long sleeves, using sunscreen and overall sun protection, the corresponding percentages were 31.0% (95% CI 29.8% to 32.1%), 9.0% (95% CI 8.3% to 9.7%), 29.8% (95% CI 28.6% to 31.0%) and 6.8% (95% CI 6.2% to 7.5%), respectively. There were significantly different distributions in wearing long sleeves (p=0.002), sunscreen use (p=0.04) and overall sun protection (p<0.001) between the psoriasis group and the non-psoriasis group. Additionally, we presented the characteristics of participants by the frequency of sun-protective behaviours, including staying in the shade, wearing long sleeves, using sunscreen and overall sun protection, as shown in online supplemental tables 2–5, respectively.

Multivariable regression analyses

Based on the limited information from NHANES and our understanding of related factors for psoriasis[27] and sun-protective behaviours,[28] we included some covariates such as some sociodemographic variables, smoking status, BMI and sun sensitivity in the regression models to control for confounding effects. In table 2, the results of an unadjusted and a sample-weighted adjusted regression model to evaluate the association between sun-protective behaviours and psoriasis are presented. In the unadjusted one, moderate wearing of long sleeves was associated with a decreased prevalence of psoriasis (OR, 0.55; 95% CI 0.34 to 0.89). After adjustment for covariates, the association remained statistically significant (p<0.05). However, overall sun protection had a positive association with psoriasis in the unadjusted model (OR, 1.91; 95% CI 1.08 to 3.39), but the relationship disappeared after adjustment. Meanwhile, the other two behaviours were not significantly associated with psoriasis in the unadjusted or adjusted model.

Subgroup analyses

The results of the subgroup analyses, stratified by age, gender, race or ethnicity and smoking status, are presented in table 3. Among participants aged 20–39 years (OR, 0.42; 95% CI 0.18 to 0.98), non-Hispanic white individuals (OR, 0.52; 95% CI 0.28 to 0.97) and non-smokers (OR, 0.49; 95% CI 0.25 to 0.95), moderate wearing of long sleeves was associated with a lower prevalence of psoriasis, as it was among women in terms of overall sun protection (OR, 0.58; 95% CI 0.35 to 0.97).

However, among former or current smokers, those with frequent stays in the shade (OR, 2.05; 95% CI 1.11 to 3.78), those who wear long sleeves (OR, 3.02; 95% CI 1.57 to 5.79) or overall sun protection (OR, 3.28; 95% CI 1.41 to 7.63) had a higher prevalence of psoriasis. There were also slightly significant and positive relationships between frequent shade-seeking behaviour and psoriasis among non-Hispanic white participants (OR, 1.69; 95% CI 1.00 to 2.84).

DISCUSSION

To our knowledge, this is the first report to investigate the associations between sun-protective behaviours and psoriasis in a population-based setting, specifically in the US

Table 1 Characteristics of participants with and without psoriasis

Characteristic	Participants			P value
	Total (N=9735)	Without psoriasis (n=9480)	With psoriasis (n=255)	
Age (years), mean±SD (95% CI)	39.6±11.7 (39.3 to 39.9)	39.5±11.7 (39.2 to 39.8)	42.7±11.3 (40.9 to 44.5)	**<0.001**
Gender				
Female	4882 (49.7) (48.4 to 50.9)	4750 (49.7) (48.4 to 50.9)	132 (50.0) (42.2 to 57.8)	0.91
Male	4853 (50.3) (49.1 to 51.6)	4730 (50.3) (49.1 to 51.6)	123 (50.0) (42.2 to 57.8)	
Race or ethnicity				
Non-Hispanic white	4030 (64.5) (63.5 to 65.6)	3883 (64.2) (63.1 to 65.2)	147 (77.4) (72.0 to 82.0)	**<0.001**
Non-Hispanic black	2048 (11.9) (11.3 to 12.4)	2021 (12.0) (11.5 to 12.6)	27 (5.4) (3.6 to 8.0)	
Hispanic	938 (6.2) (5.8 to 6.6)	915 (6.2) (5.8 to 6.7)	23 (5.3) (3.4 to 8.2)	
Other*	2719 (17.4) (16.7 to 18.2)	2661 (17.6) (16.8 to 18.4)	58 (11.9) (8.7 to 16.1)	
Education level				
<9th grade	645 (4.0) (3.6 to 4.4)	631 (4.0) (3.7 to 4.4)	14 (2.3) (1.3 to 4.1)	0.06
9th–11th grade	1363 (10.9) (10.2 to 11.6)	1336 (11.0) (10.3 to 11.7)	27 (6.7) (4.3 to 10.5)	
High school graduate/GED or equivalent	2137 (21.1) (20.1 to 22.1)	2080 (21.1) (20.1 to 22.1)	57 (21.5) (15.8 to 28.6)	
Some college or AA degree	3115 (33.1) (31.9 to 34.3)	3035 (33.1) (31.9 to 34.3)	80 (33.0) (26.0 to 40.9)	
College graduate or above	2475 (31.0) (29.8 to 32.2)	2398 (30.8) (29.6 to 32.1)	77 (36.4) (29.1 to 44.4)	
Country of birth				
Not USA-born	2793 (18.5) (17.7 to 19.3)	2745 (18.7) (17.9 to 19.5)	48 (9.9) (7.1 to 13.6)	**<0.001**
USA-born	6942 (81.5) (80.7 to 82.3)	6735 (81.3) (80.5 to 82.1)	207 (90.1) (86.4 to 92.9)	
Marital status				
Never married	2563 (24.1) (23.1 to 25.2)	2507 (24.2) (23.1 to 25.2)	56 (22.9) (17.0 to 30.1)	0.64
Married or living with partner	5719 (62.1) (60.8 to 63.3)	5571 (62.1) (60.9 to 63.3)	148 (61.4) (53.6 to 68.7)	
Widowed or divorced or separated	1453 (13.8) (13.0 to 14.7)	1402 (13.8) (12.9 to 14.7)	51 (15.7) (10.9 to 22)	
BMI (kg/m^2)				
<25	3043 (31.4) (30.2 to 32.6)	2977 (31.5) (30.4 to 32.7)	66 (26.2) (20.0 to 33.5)	0.17
≥25–<30	3071 (32.8) (31.6 to 34.0)	2991 (32.7) (31.5 to 34.0)	80 (35.4) (28.1 to 43.4)	
≥30	3621 (35.8) (34.6 to 37.0)	3512 (35.7) (34.5 to 37.0)	109 (38.5) (31.3 to 46.2)	
Alcohol drinkers				
No	2279 (18.6) (17.7 to 19.5)	2226 (18.6) (17.7 to 19.5)	53 (17.7) (12.8 to 23.9)	0.70
Yes	7456 (81.4) (80.5 to 82.3)	7254 (81.4) (80.5 to 82.3)	202 (82.3) (76.1 to 87.2)	
Smoking status				
Non-smokers	5670 (57.8) (56.6 to 59.1)	5547 (58.1) (56.8 to 59.3)	123 (49.2) (41.4 to 57.0)	**<0.001**
Former smokers	1647 (19.2) (18.2 to 20.3)	1587 (18.9) (17.9 to 20.0)	60 (30.1) (23.0 to 38.2)	
Current smokers	2418 (22.9) (21.9 to 24.0)	2346 (23.0) (22.0 to 24.1)	72 (20.8) (15.7 to 27.0)	
Sun sensitivity†				
None	956 (12.7) (11.9 to 13.7)	923 (12.7) (11.8 to 13.6)	33 (15.4) (10.3 to 22.4)	**0.006**
Mild	4667 (52.1) (50.8 to 53.3)	4524 (51.9) (50.6 to 53.2)	143 (58.4) (50.6 to 65.9)	
Severe	4112 (35.2) (34.0 to 36.3)	4033 (35.4) (34.3 to 6.6)	79 (26.2) (20.1 to 33.3)	
Time spent outdoors‡ (minutes per day)				
<60	3891 (38.8) (37.6 to 40.1)	3790 (38.9) (37.7 to 40.2)	101 (35.2) (28.1 to 42.9)	0.21
≥60	5844 (61.2) (59.9 to 62.4)	5690 (61.1) (59.8 to 62.3)	154 (64.8) (57.1 to 71.9)	
Staying in the shade				
Rare	2546 (27.2) (26.0 to 28.3)	2489 (27.2) (26.1 to 28.4)	57 (24.8) (18.6 to 32.2)	0.07
Moderate	3776 (41.9) (40.6 to 43.1)	3677 (42.0) (40.7 to 43.3)	99 (37.9) (30.7 to 45.7)	
Frequent	3413 (31.0) (29.8 to 32.1)	3314 (30.8) (29.6 to 31.9)	99 (37.3) (30.0 to 45.2)	

Continued

Table 1 Continued

Characteristic	Participants			P value
	Total (N=9735)	Without psoriasis (n=9480)	With psoriasis (n=255)	
Wearing long sleeves				
Rare	6742 (70.9) (69.8 to 72.1)	6557 (70.8) (69.6 to 71.9)	185 (76.0) (68.8 to 81.9)	**0.002**
Moderate	1941 (20.1) (19.1 to 21.1)	1907 (20.3) (19.3 to 21.4)	34 (12.0) (7.9 to 17.9)	
Frequent	1052 (9.0) (8.3 to 9.7)	1016 (8.9) (8.2 to 9.6)	36 (12.0) (7.9 to 17.9)	
Using sunscreen				
Rare	5579 (48.5) (47.2 to 49.7)	5449 (48.7) (47.4 to 50.0)	130 (41.8) (34.5 to 49.5)	**0.04**
Moderate	1819 (21.8) (20.7 to 22.9)	1763 (21.6) (20.5 to 22.7)	56 (27.2) (20.5 to 35.2)	
Frequent	2337 (29.8) (28.6 to 31.0)	2268 (29.7) (28.5 to 31.0)	69 (31.0) (24.2 to 38.8)	
Overall sun protection§				
Rare	3249 (31.9) (30.8 to 33.1)	3174 (31.9) (30.8 to 33.1)	75 (31.4) (24.5 to 39.1)	**<0.001**
Moderate	5850 (61.3) (60.0 to 62.5)	5698 (61.4) (60.2 to 62.6)	152 (56.1) (48.2 to 63.7)	
Frequent	636 (6.8) (6.2 to 7.5)	608 (6.7) (6.0 to 7.4)	28 (12.5) (7.9 to 19.3)	

Data are presented as unweighted number (weighted percentage) (95% CI) unless otherwise indicated.
Boldface indicates statistical significance.
BMI is calculated as weight in kilograms divided by height in metres squared.
*Included Mexican American and multiracial participants.
†Sun sensitivity was determined by the answer to the skin reaction to the sun without sunscreen or protective clothing for half an hour: none ('nothing would happen in half an hour'), mild ('mildly burned with some tanning' or 'turning darker without a sunburn') and severe ('get a severe sunburn with blisters' or 'a severe sunburn for a few days with peeling').
‡Time spent outdoors refers to the average minutes spent outdoors from 09:00 to 17:00 on each day of the week considering that there are 5 working days and 2 non-working days in a week.
§Overall sun protection reflects the general condition of sun protection, including staying in the shade, wearing long sleeves and using sunscreen.
AA, associate degree; BMI, body mass index; GED, general equivalency diploma.

adult population. The findings revealed that moderately wearing long sleeves had a statistically significant association with a lower prevalence of psoriasis, even after adjusting for some potential confounders. However, no associations were found between psoriasis and either staying in the shade, using sunscreen or overall sun protection. In a subsequent subgroup analysis, significant relationships between moderate sun-protective behaviours and a lower prevalence of psoriasis were observed among younger adults aged 20–39, women, non-Hispanic white individuals and smokers. Remarkably, among smokers, frequent staying in the shade, wearing of long sleeves and overall sun protection were associated with an increased prevalence of psoriasis, whereas moderate use was not. Among non-Hispanic white participants, frequent

Table 2 Association between sun-protective behaviours and psoriasis

Model	Presence of psoriasis by sun-protective behaviours			
	Staying in the shade	Wearing long sleeves	Using sunscreen	Overall sun protection
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Unadjusted				
Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Moderate	0.99 (0.66 to 1.50)	**0.55 (0.34 to 0.89)***	1.47 (0.98 to 2.20)	0.93 (0.65 to 1.32)
Frequent	1.33 (0.88 to 2.02)	1.26 (0.77 to 2.03)	1.22 (0.84 to 1.76)	**1.91 (1.08 to 3.39)***
Adjusted†				
Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Moderate	0.95 (0.62 to 1.45)	**0.55 (0.33 to 0.90)***	1.25 (0.82 to 1.91)	0.90 (0.62 to 1.31)
Frequent	1.42 (0.92 to 2.18)	1.36 (0.82 to 2.26)	0.96 (0.62 to 1.50)	1.67 (0.90 to 3.12)

Boldface indicates statistical significance.
*P<0.05, **P<0.01.
†Adjusted for sociodemographic variables, body mass index, alcohol drinking status, smoking status, sun sensitivity and time spent outdoors.

Table 3 Association between sun-protective behaviours and psoriasis, stratified by age, gender, race or ethnicity and smoking status

Subgroup	Frequency	Staying in the shade OR (95% CI)	Wearing long sleeves OR (95% CI)	Using sunscreen OR (95% CI)	Overall sun protection OR (95% CI)
Overall					
Unadjusted	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	0.99 (0.66 to 1.50)	**0.55 (0.34 to 0.89)***	1.47 (0.98 to 2.20)	0.93 (0.65 to 1.32)
	Frequent	1.33 (0.88 to 2.02)	1.26 (0.77 to 2.03)	1.22 (0.84 to 1.76)	**1.91 (1.08 to 3.39)***
Adjusted	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	0.95 (0.62 to 1.45)	**0.55 (0.33 to 0.90)***	1.25 (0.82 to 1.91)	0.90 (0.62 to 1.31)
	Frequent	1.42 (0.92 to 2.18)	1.36 (0.82 to 2.26)	0.96 (0.62 to 1.50)	1.67 (0.90 to 3.12)
Age (years)					
20–39	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	0.71 (0.40 to 1.25)	**0.42 (0.18 to 0.98)***	1.21 (0.66 to 2.19)	0.91 (0.53 to 1.55)
	Frequent	1.14 (0.61 to 2.13)	0.86 (0.31 to 2.42)	1.23 (0.66 to 2.29)	1.27 (0.41 to 3.93)
40–59	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	1.24 (0.67 to 2.27)	0.64 (0.34 to 1.20)	1.28 (0.73 to 2.27)	0.92 (0.55 to 1.53)
	Frequent	1.77 (0.96 to 3.24)	1.75 (0.97 to 3.16)	0.84 (0.46 to 1.53)	1.97 (0.92 to 4.20)
Gender					
Female	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	0.63 (0.35 to 1.16)	0.56 (0.28 to 1.12)	0.88 (0.48 to 1.59)	**0.58 (0.35 to 0.97)***
	Frequent	1.33 (0.74 to 2.39)	1.37 (0.62 to 3.03)	0.56 (0.31 to 1.02)	1.23 (0.55 to 2.76)
Male	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	1.28 (0.72 to 2.29)	0.53 (0.26 to 1.07)	1.71 (0.95 to 3.09)	1.32 (0.78 to 2.23)
	Frequent	1.40 (0.74 to 2.64)	1.30 (0.68 to 2.48)	1.75 (0.97 to 3.15)	1.95 (0.74 to 5.11)
Race or ethnicity					
Non-Hispanic white	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	0.93 (0.56 to 1.55)	**0.52 (0.28 to 0.97)***	1.28 (0.78 to 2.11)	0.80 (0.50 to 1.26)
	Frequent	**1.69 (1.00 to 2.84)***	1.43 (0.71 to 2.86)	0.83 (0.48 to 1.43)	1.73 (0.82 to 3.66)
Other	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	1.14 (0.64 to 2.03)	0.68 (0.37 to 1.22)	1.10 (0.59 to 2.06)	1.39 (0.83 to 2.32)
	Frequent	0.92 (0.52 to 1.61)	1.20 (0.68 to 2.12)	**1.94 (1.09 to 3.44)***	1.66 (0.72 to 3.82)
Smoking status					
Non-smokers	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	0.76 (0.42 to 1.35)	**0.49 (0.25 to 0.95)***	1.71 (0.93 to 3.14)	0.74 (0.43 to 1.26)
	Frequent	1.00 (0.55 to 1.82)	**0.42 (0.19 to 0.93)***	1.14 (0.58 to 2.21)	0.87 (0.36 to 2.09)
Smokers†	Rare	1 (reference)	1 (reference)	1 (reference)	1 (reference)
	Moderate	1.20 (0.66 to 2.20)	0.62 (0.31 to 1.25)	1.00 (0.53 to 1.89)	1.12 (0.67 to 1.85)
	Frequent	**2.05 (1.11 to 3.78)***	**3.02 (1.57 to 5.79)****	0.91 (0.49 to 1.70)	**3.28 (1.41 to 7.63)****

Each stratification was adjusted for age, gender, race or ethnicity, country of birth, education level, marital status, body mass index, smoking and alcohol drinking status, sun sensitivity, and time spent outdoors except the stratification factor itself. All ORs and 95% CIs are based on data weighted to represent the US population.
Boldface indicates statistical significance.
*P<0.05, **P<0.01.
†Smokers refer to current smokers and former smokers.

sunscreen use was associated with an increased prevalence of psoriasis, but moderate use was not.

Psoriasis is a chronic and immune-mediated skin disorder attributed to various genetic and environmental factors. As reported by previous studies, physical trauma,[29] lifestyle and habits,[30] infections such as *Streptococcus* infection[31] and medications[32 33] are risk factors or triggers of psoriasis. The observed relationship between sun protection and a lower prevalence of psoriasis might be due to sun protection preventing the traumatic effects of excessive UV rays on the skin, or that people practising moderate sun protection possess higher health awareness, thereby reducing psoriasis triggers related to infections, unhealthy lifestyles or medication habits. Natural sunlight, with a wide variety of bands, is more likely to cause negative skin effects in contrast to narrowband UVB and targeted UVB with specific spectrum and controlled doses in the clinic.

Additionally, although a sizeable portion of patients with psoriasis respond well to phototherapy (mainly at a UV wavelength of 311 nm), excessive UV exposure can lead to side effects such as erythema, blistering and even deterioration of psoriasis. It was reported that approximately 5.5% of psoriasis cases worsen or develop new lesions post-sun exposure due to genetics, gender (female) and abnormal UV response, and some even experience symptoms after prolonged sunbathing.[34 35] They are collectively referred to as photosensitive psoriasis (PP). Consequently, it is necessary for patients with PP to take some daily sun-protective measures. Meanwhile, the association remained after adjustment for gender, race or ethnicity and sun sensitivity in our study, which may suggest the protective effects of moderate sun protection on the general population as well as the potential predisposing effect of sunlight on psoriasis. However, further research is warranted to explore the conjecture and the underlying mechanism of these associations.

In the past few years, the pathogenesis of psoriasis has been unveiled gradually. The persistence of skin inflammation due to cutaneous immune disorder is a hallmark of psoriasis. Dendritic cells (DCs), macrophages, different T-cell sets and other cell types via various cytokines, such as *cathelicidin* leucine-leucine-*37* (*LL-37*), tumour necrosis factor-alpha (TNF-α) and ILs, play a major role in the initiation and maintenance phases,[36] causing higher levels of IL-17, IL-23 and TNF-α, lower levels of IL-4 and IL-10, and other dysregulation of cytokine secretion.[37] In many studies, it has been found that sunlight or UV radiation can reduce the number of DCs,[38] CD4+ T cells and CD8+ T cells, as well as modulate immune homeostasis and cytokine levels, in psoriasis.[7] In our study, there was no difference in the prevalence of psoriasis between individuals with rare and frequent sun protection, potentially due to excessive sun protection inhibiting UV's beneficial effects. The negative impact of insufficient sun protection, combined with excessive protection, links moderate sun protection to a lower prevalence of psoriasis.

The results of the subgroup analyses indicated an opposing association between different frequencies of sun protection use and psoriasis. Among people aged 20–39, women, non-Hispanic white individuals and smokers, moderate sun protection was linked to a lower prevalence of psoriasis. Conversely, frequent sun protection was linked to a higher prevalence among non-Hispanic white individuals and among smokers. The stronger association observed in younger adults and women may stem from greater attention to sun protection factor (SPF) in products. Unfortunately, the NHANES database did not record details on sunscreen, such as SPF and usage per time. As for race or ethnicity, previous research discovered that sun-protective behaviours may significantly reduce the level of 25(OH)D in white individuals compared with black and Hispanic individuals.[24] Currently, notable associations between low vitamin D status and psoriasis have been systematically found, and oral vitamin D supplementation is deemed an effective treatment for psoriasis.[39] Therefore, the decrease in vitamin D caused by frequent sun protection may exacerbate the adverse skin effects brought on by insufficient UV exposure, which is speculated to be more obvious among white people.

Regarding smoking status, frequent sun protection was positively associated with psoriasis among smokers, whereas wearing long sleeves was negatively associated with psoriasis among non-smokers. It is widely accepted that smoking can increase the risk of developing psoriasis[40 41] through several mechanisms,[42] including oxidation, inflammation and genetics. Therefore, when combined with the absence of UV immunosuppressive and anti-inflammatory properties due to excessive use of sun protection, the difference in the risk of developing psoriasis may be amplified.

We also found that over 30% of US adults aged 20–59 rarely engaged in sun protection practices. Especially when it comes to wearing long sleeves, less than 30% of participants opted to wear them while being outside in the sun for an hour. Although this phenomenon has been proven to improve from 2010 to 2020,[43] pent-up demand for travel and holidays is driving rapid growth in the USA following the full lifting of COVID-19 lockdown measures, which poses a new challenge to Americans' awareness of sun protection. We hope that our findings can draw public attention to appropriate sun protection measures and encourage further research for convincing evidence in this area.

This study has several strengths that deserve mentioning. The principal strength of this study is that this is the first attempt to explore the relationship between sun-protective behaviours and psoriasis. Furthermore, the NHANES database boasts a large and nationally representative sample size, with data collected under strict control, ensuring that the results are generalisable to the adult population in the USA. There are some limitations that need to be acknowledged. First and foremost, this is a cross-sectional study that can only suggest association but not causation. Psoriasis may have been

diagnosed years ago, and some sufferers may choose to conceal visible skin lesions through long sleeves or other means due to shame over their appearance.[44 45] However, the collection of information on the frequency of wearing long sleeves has clear sun protection targeting under specific contexts, which possibly minimises such reverse causality bias. Therefore, additional results from well-designed cohort studies are required. Second, our data were from the 2009–2014 cycles of NHANES and thus might not provide a precise representation of present-day circumstances. To ensure that our analyses and conclusions are aligned with the most recent trends and conditions, further studies that incorporate more recent data are recommended. Third, data on psoriasis diagnosis and sun-protective behaviours were all obtained in the form of questionnaire surveys, which are prone to recall bias and reporting bias. Fourth, variations in geographical locations, data collection timing, sun exposure intervals and sunscreen type were not captured, which hindered our capacity to accurately evaluate the association between frequency of sun protection and prevalence of psoriasis among individuals with varying UV exposure levels. Similarly, there may be other covariates that were not considered. Thus, future studies ought to collect and evaluate more detailed information on geographical location and sun protection, as well as other important covariates, so as to better elucidate the potential relationship. Fifth, UV's dual effects at ~305 nm (sunburn) and 311 nm (psoriasis therapy) further complicate assessments of sun protection effects, which cannot be clearly distinguished in our study. Lastly, multiple tests may raise the probability of obtaining a significant result by chance.

CONCLUSION

The findings of this cross-sectional study suggested that moderate sun protection was negatively associated with psoriasis in the adult population of the USA, particularly in white women aged 20–39 years and in non-smokers, while frequent sun protection was linked to a higher prevalence of psoriasis in white individuals and smokers. Additional research is required to reach more convincing conclusions and propose practical recommendations on sun protection.

Contributors YX had full access to all the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. YX and WL were involved in study concept and design. All authors were involved in the acquisition, analysis or interpretation of data. YX, WW, YF and FR were involved in drafting the manuscript. WW, WL and XH were involved in the critical revision of the manuscript for important intellectual content. YX and FR were involved in statistical analysis. WL acted as guarantor. YX, WW and WL provided administrative, technical or material support. WW, WL and YF were involved in supervision.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval This study involves human participants. All NHANES protocols have been approved by the National Center for Health Statistics Research Ethics Review Board. The specific protocol numbers involved in the study are #2005-06 and #2011-17. All participants in NHANES presented informed consent for data collection and publication. Since the study uses publicly accessible and anonymised NHANES data, it is exempt from additional ethical review by the Ethics Committee of Shuguang Hospital Affiliated to Shanghai University of TCM.

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Data availability statement Data are available in a public, open access repository. Open access data are available on the NHANES website at https://www.cdc.gov/nchs/nhanes/index.htm.

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