Research Article

Negative Association Between Sun Exposure and Depression: A Cross-Sectional Analysis of the NHANES 2011-2018 In the United States

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Abstract

Background: As a mental disorder, depression can have a negative impact on people's thoughts and behaviors and cause adverse consequences for people's mental health and physical health. Analyzing the causes and potential influencing factors of depression is the key to preventing and treating depression effectively.

Purpose: The purpose of this study was to analyze the relationship between sunlight exposure and depression to provide reference for the prevention and treatment of depression.

Methods and Materials: This study is based on a stratified sample of the representative population aged 20-59 from the National Health and Nutrition Examination Survey (NHANES) in the United States from 2011 to 2018, with a total of 11682 people. Sun exposure data were extracted from the Dermatology Questionnaire (DEQ) and depression data were extracted from the Depression Screening Questionnaire (DPQ). Chi-square test was used for counting variables, and rank sum test was used for measuring variables. Binary Logistic regression model was used to analyze the relationship between "sun exposure" and "depression".

Result: In binary Logistic regression analysis, after excluding all confounding variables, the odds ratio (OR) was 0.945(95% Cl: 0.906-0.985, P<0.05).

Conclusion: Sun exposure is a protective factor for depression, and sun exposure can effectively reduce a person's risk of developing depression.

Keywords: Sun exposure, Depression, Mental health, American adult, Cross-sectional survey

Keywords: NHANES: National Health and Nutritional Examination Survey; CAPI: Computer-Assisted Personal Interviewing; MEC: Mobile Examination Centre; OR: Odds Ratio; CI: Confidence Interval; P: P-Value; U.S.: The United States of America; SPSS: Statistical Package for Social Sciences; PHQ-9: Patient Health Questionnaire; WHO: World Health Organization; DEQ: Dermatology Questionnaire; DPQ: Depression Screening Questionnaire

Background

According to the World Health Organization (WHO), more than 350 million people worldwide have symptoms of depression, and people with depression deserve more care. As reported in a study by Munoz, *R F, et al.,* depression is expected to become the second largest community health problem in the world [1]. Depression, as a mental disorder, can have a negative impact on people's thinking and behavior, and cause adverse consequences for people's mental health and physical health. For example, people with depression

have mental health problems such as suicidal thoughts and loss of interest in things, and physical health problems such as obesity and insomnia [2].

Depression, as a serious disabling disease, exists widely in the world. The United States is greatly affected by major depressive disorder, and its direct consequence is an increased socio-economic burden [3]. In 2012, the socioeconomic burden of major depression in the United States exceeded the economic burden of cancer ($131 billion) and diabetes ($173 billion) in the United States, amounting to an estimated $188 billion [4]. In addition to the United States, other countries in the world also face the health challenge of depression [5]. The German Social Insurance Agency has reported an increase in early retirement and medical service provision, an increase in the frequency of depression, and an increase in healthcare costs, influenced by the loss of working days [6,7]. Therefore, analysis of the causes and potential influencing factors of depression is the key to effective prevention and treatment of depression.

In recent years, due to the destruction of the atmospheric ozone layer, the ultraviolet rays reaching the surface have increased, and too much or too long sunlight exposure may cause skin diseases [8,9], resulting in excessive sun protection and reduced outdoor activities. However, studies have reported negative effects on cardiovascular disease, bone disease, and autoimmune diseases due to insufficient sun exposure or vitamin D intake [10-13]. At the same time, insufficient sun exposure can also lead to mental health disorders such as depression and anxiety. Sun exposure has been used as a way to alleviate a variety of conditions, such as lowering blood pressure, improving brain function and treating skin diseases. Sunlight exposure is beneficial to mental health. Sansone, *R A, et al.,* [14] have discussed the relationship between psychopathology and sunlight.

In this study, we designed a cross-sectional study using data from the National Health and Nutrition Examination Survey (NHANES) to analyze the association between sun exposure and depression in order to provide advice on depression prevention and treatment for public health and health issues.

Methods and Materials

Objects

The National Health and Nutrition Examination Survey (NHANES) is a cross-sectional survey designed to assess the health and nutrition status of adults and children in the United States [15]. In this study, a total of 11682 representative samples of NHANES aged between 20 and 59 from 2011 to 2018 were selected. NHANES covers about 15,000 households, all of which are U.S. residents who have lived in the United States for at least two months. The protocol and secondary analysis of the data were approved by the NCHS Ethics Review Board, and all participants were informed of the study's purpose, risks, and benefits and provided written notice of consent [16].

Covariables

In this study, we included demographic variables such as gender, age, race, education, marital status, income-poverty ratio, and current health status. Among the counting variables, gender is divided into male and female; Ethnically divided into Mexican Americans, other Hispanics, non-Hispanic whites, non-Hispanic blacks, non-Hispanic Asians, and other races; The education level is divided into high school education, high school education and high school education; Marital status is divided into cohabitation, married living alone (widowed, divorced, separated) and never married; Current health status is classified as excellent, good or poor. The age range of the measurement variables is 20-59 years old; The income-poverty ratio, which ranges from 0.00 to 5.00, is a poverty guideline divided by household income for the year surveyed. In this study, the poverty ratio was used to create two income conditions, poor (<1.3) and middle income (≥1.3) [17].

Sunlight Exposure Assessment

Sun exposure data were extracted from the Dermatology Questionnaire (DEQ), which included data from individual interviews about sun exposure and sun protection behaviors. We took the question "On a sunny day, when you go out for more than an hour, how much time do you spend in the shade?" (DEQ034A) "to assess the intensity of participants' sun exposure levels. Participants responded on a scale of six: 1= never going out in the sun, 2= always, 3= most of the time, 4= sometimes, 5= rarely, and 6= never.

Depression Assessment

Depression data were extracted from the Depression Screening Questionnaire (DPQ), also known as the Patient Health Questionnaire. These included nine depression screening questions to assess the frequency of depressive symptoms in the sample over the past two weeks. Scores for each question response category "not at all," "some days," "more than half," and "almost every day" ranged from 0 to 3 points [18,19]. For those who answered the question completely, a total score (ranging from 0 to 27) was calculated. In this study, we defined depression as a counting variable and divided it into two groups, 1= non-depressed group (0-4 points) and 2= depressed group (5-27 points). (19)

Quality Control

To ensure data quality, the data obtained by NHANES is presented by trained interviewers in a mobile Test Center (MEC), using a computer Assisted Personal Interview (CAPI) system as part of the MEC interview. CAPI systems are programmed with built-in consistency checks to reduce data entry errors.

Statistical Analysis

In this study, Microsoft Excel2010 was used to extract and merge the original data, excluding missing and useless (rejected, unknown) data. The database included information on demographics, sun exposure, and depression among U.S. adults aged 20 to 59

years (5,681 males, 6,601 females, mean age 39.32±11.523). According to the purpose of the study, we tested the statistical significance of covariates between the "non-depressed" and "depressed" groups. Chi-square test was used for counting variables and rank sum test was used for measuring variables. We used a binary Logistic regression model to analyze the relationship between "sun exposure" and "depression." All data were analyzed using Statistical Product and Service Solutions (SPSS) version 26.0, with P<0.05 considered statistically significant (two-sided test). Variables that were statistically significant in the univariate analysis were included in the stepwise binary Logistic regression analysis. A-entry=0.05 and a-exit=0.10 were used to select and exclude confounding variables.

With sun exposure as the independent variable and depression as the dependent variable, all covariables (P<0.001) were statistically significant in the univariate analysis. In analyzing the relationship between sun exposure and depression, the following models were established to exclude the influence of confounding variables: Model I: Only the independent variable sun exposure was adjusted. Model II: Demographic variables (gender, age, race, education, marital status, income-poverty ratio, and current health status) were adjusted for the independent variables in Model I.

Results

Demographic Characteristics

The study included 11,682 adults aged 20 to 59 years from the National Health and Nutrition Examination Survey during the 2011-2018 cycle. They completed data collection on demographics, sun exposure and depression. The depressed and non-depressed groups were statistically significant in terms of sex (P<0.001), age (P<0.001), race (P<0.001), education level (P<0.001), marital status (P<0.001), income-poverty ratio (P<0.001), and current health status (P<0.001) (See Table 1).

Table 1: Demographic characteristics of adults aged 20-59 years with depression.

Characteristics, n%	Sample Capacity N=11682	Depression n=8726	No depression n=2956	Test statistics	P
Gender				125.890a	<0.001***
Male	5681	4507 (79.3)	1174 (20.7)		
Female	6001	4219 (70.3)	1782 (29.7)		
Age				18.886b	<0.001***
20-39	5894	4505 (76.4)	1389 (23.6)		
40-59	5787	4220 (72.9)	1567 (27.1)		
Race				124.879a	<0.001***
Mexican American	1639	1262 (77.0)	377 (23.0)		
Other Hispanic	1108	803 (72.5)	305 (27.5)		
Non-Hispanic White	4270	3099 (72.6)	1171 (27.4)		
Non-Hispanic Black	2602	1910 (73.4)	692 (26.6)		
Non-Hispanic Asian	1539	1306 (84.9)	233 (15.1)		
Other	524	346 (66.0)	178 (34.0)		
Education				92.168b	<0.001***
Below high school	2028	1383 (68.2)	645 (31.8)		
High school	2558	1830 (71.5)	728 (28.5)		
Post high school	7095	5512 (77.7)	1583 (22.3)		
Marital Statues				246.527a	<0.001***
Cohabitation	6951	5510 (79.3)	1441 (20.7)		
Married living alone	1684	1037 (61.6)	647 (38.4)		
Not married	3047	2179 (71.5)	868 (28.5)		
Income to Poverty				422.198b	<0.001***
Impoverished	3857	2504 (64.9)	1353 (35.1)		
Moderate income	7824	6221 (79.5)	1603 (20.5)		
Current health status				1004.131b	<0.001***
Excellent	9221	7479 (81.1)	1742 (18.9)		
Good	2137	1166 (54.6)	971 (45.4)		

Poor	323	80 (24.8)	243 (75.2)		
Sunlight exposure				47.603a	<0.001***
Don't go out in the sun	113	76 (67.3)	37 (32.7)		
Always	1177	793 (67.4)	384 (32.6)		
Most of the time	3009	2164 (71.9)	845 (28.1)		
Sometimes	4741	3651 (77.0)	1090 (23.0)		
Rarely	1725	1336 (77.4)	389 (22.6)		
Never	916	705 (77.0)	211 (23.0)		

Note*: a Chi-square test, b Rank sum test, *P<0.05, **P<0.01, ***P<0.001.

Relationship Between Sunlight Exposure and Depression

In logistic regression analysis, model I (without excluding any confounding variables) showed that the odds ratio (OR) of sun exposure to depression was 0.866(95%Cl :0.833-0.900, P < 0.001).

Model II (excluding demographic variables) showed an odds ratio (OR) of 0.945(95%Cl :0.906-0.985, P < 0.05). The findings suggest that after adjusting for confounders, sun exposure is a protective factor for depression, and sun exposure can effectively reduce people's risk of developing depression (See Table 2).

Table 2: Logistic regression analysis results of sun exposure and depression.

Mode	b	SE	Wald	P	OR (95%Cl)
I[a]	-0.144	0.02	52.57	<0.001***	0.866(0.833-0.900)
II[b]	-0.057	0.021	7.261	0.007	0.945(0.906-0.985)

A Only the independent variable of sunlight exposure was adjusted. b Adjustments were made for independent variables in Model I plus demographic variables (sex, age, race, education, marital status, income-poverty ratio, and current health status).

Discussion

Using a binary Logistic regression analysis of NHANES data from 2011-2018, we found an independent association between sun exposure and depression in American adults aged 20-59 years. For every increase in the intensity of sunlight exposure, the risk of depression was reduced by 5.5%. We discuss the relationship between sun exposure and depression in more depth below.

Sun Exposure and Depression

Our findings are consistent with many previous studies showing that the longer the time spent in the sun, the lower the risk of depression. In a cross-sectional study of Chinese college students, the longer the reported duration of sun exposure or outdoor activity, the lower the score on the Depression Scale (CES-D) [20] In a cross-sectional survey of older Chinese women assessed using the Zung Self-rated Depression Scale (SDS), increased sun exposure was associated with a lower prevalence of depressive symptoms in older women in a logistic regression model [21]. In prospective follow-up of middle-aged people with multiple sclerosis in Australia, sun exposure was reported to be negatively associated with depression scores [22]. In a study of sun exposure and psychosocial stress in Korean adults, it was shown that the less time participants were exposed to sunlight, the higher psychosocial stress was, which predicted an increased likelihood of developing depressive mood [23]. In the study of a special group of people who are not exposed to

sunlight at work, researchers studied the sun exposure and mental health of operating room nurses and found that operating room nurses showed worse mental health than other groups, which also means that the risk of depression symptoms is higher. Our results are consistent with previous research on sun exposure and depression. However, we cannot limit ourselves to the findings and would like to explore further why sun exposure is positively associated with depression.

The relationship between sunlight exposure and depression was analyzed from the biological perspective. Proper sun exposure will stimulate the skin to synthesize vitamin D3, and vitamin D3 has an improving effect on human immune function, can regulate inflammatory response, affect calcium homeostasis [24,25]. Insufficient sunlight exposure leads to decreased production of vitamin D3, and insufficient levels of vitamin D3 in the human body are associated with a variety of diseases, such as cardiovascular disease, metabolic syndrome, osteoporosis, rickets, immune diseases, kidney diseases, and psychiatric disorders [26-29]. Exposure to sunlight stimulates intrinsically sensitive retinal ganglion cells, thereby affecting melatonin secretion and balancing the circadian rhythm. In a study by *Dowling, et al.,* [30] researchers used artificial light therapy that mimics sunlight in Alzheimer's patients and reported significant improvements in insomnia, sleep disturbances, and sleepwalking. Therefore, we believe that sun exposure also has an important effect on sleep cycle and sleep quality [31], and sleep cycle and sleep quality may have an impact on the prevention or treatment of depression. Sun exposure has an impact on serotonin [32], a mood-boosting neurotransmitter, and a lack of sun exposure leads to decreased serotonin production, which can lead to negative

emotions such as depression. In the rehabilitation training using light therapy, *Tsai, et al.,* 's research report showed that it can alleviate depression in the elderly, which means that a variety of light waves of sunlight have a positive effect on depression [33].

The relationship between sunlight exposure and depression was analyzed from the perspective of psychology. In psychological research, we can find that self-denial, negative emotions and low emotional clarity are related to depression. When it comes to depression, one of the determinants that has received a lot of attention in mental health research is rumination. Rumination refers to when an individual experiences stress or is negatively affected, he spontaneously thinks repeatedly about the causes and consequences of emotions, instead of actively facing and solving problems. It is a mediating factor and risk factor for depression [34]. Leanne *Trick, et al.,* 's findings suggest that rumination is an important independent predictor of depression, and that the relationship between rumination and depression has been explained in part by "inadequate problem solving skills" and "inadequate social support" [35]. Outdoor sports, rock climbing, surfing, cliff downhill and other challenging and exciting extreme sports can stimulate people's resilience and perseverance, give people a sense of accomplishment and satisfaction. This kind of outdoor exercise helps people reduce depression and anxiety, and has a positive effect on mental and spiritual status. We think that people with more sun exposure are more likely to be willing to participate in these kinds of extreme outdoor activities. Not only are they exposed to sunlight during these outdoor activities, but they are also able to develop their problem-solving skills, gain social support, and experience positive emotions, thereby reducing the risk of depression.

The relationship between sunlight exposure and depression was analyzed from a sociological perspective. Sociological factors, including the factors people experience in life, entertainment, study and work [36], such as social status, different life experiences, educational background and economic pressure, are all related to depression. From a sociological perspective, interpersonal relationship difficulties are associated with depression [37], and good social relationships are protective factors for depression. Outdoor team sports such as football, rugby and beach volleyball are conducive to the establishment of good interpersonal relationships between people. Therefore, we recommend that whether or not people with depression should carry out appropriate physical activity in the sun in their daily life. On the one hand, it can physiologically ensure that mood-boosting neurotransmitters and vitamin D are maintained at healthy levels; On the other hand, it can establish good interpersonal relationships to prevent or improve depression. For the relationship between sun exposure and depression, we can explain to some extent that the lack of outdoor activities and sedentary behavior for a long time, resulting in lack of sun exposure and depression. Less outdoor activity leads to less sunlight exposure, which also means less physical activity. In the systematic review and meta-analysis of the association between physical activity and depression by *Pearce M, et al.,* significant benefits of physical activity on mental health were noted, even at levels below public health recommendations [38].

After discussion, this study suggests that depression can be prevented or treated with appropriate sunlight exposure. In particular, participation in outdoor physical activities to increase sunlight exposure is a more advocated way.

Limitations

There are some limitations in this study. First of all, the data of this study came from the National Health and Nutrition Examination Center of the United States, and the samples were all American citizens, so the applicability of the current research results to other countries and regions remains to be studied. In future studies, we will collect data from other countries and regions to demonstrate the results of this study. Second, this study only analyzed data from adults aged 20-59 in the United States, and we will expand the study population to include children, adolescents, and the elderly in future studies. Finally, we mentioned that outdoor physical activity may be a protective factor for the prevention or treatment of depression in the discussion of the article. In future studies, we hope to list physical activity as a separate factor and discuss the relationship between sunlight exposure, physical activity and depression in more depth and detail.

Conclusions

As a serious disabling disease, depression has caused harm to many citizens in the world. The aim of this study was to determine the effect of sun exposure on depression in American adults and to conclude that sun exposure is a protective factor for depression. Future studies need to consider the feasibility of increasing sun exposure by engaging in outdoor physical activity to prevent or treat depression.

Declarations

Ethics Approval and Consent to Participate

All procedures performed in the study were in accordance with the Declaration of Helsinki. The study protocols for NHANES were approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board (Protocol#2017-1). All adult participants provided written notification of consent before participating in the study.

Consent for Publication

Not applicable.

Availability of Data and Materials

The datasets generated and/or analysed during the current study are available in the [NHANES] repository, [NHANES Questionnaires, Datasets, and Related Documentation (cdc.gov)]. Raw data supporting the obtained results are available at the corresponding author.

Author Contributions

YC and JZ conceived and designed the study. YC organized the

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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