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ORIGINAL RESEARCH

Association Between Sedentary Lifestyle, Physical Activity, and Skin Cancer Among Outpatient US Adults: Evidence from NHANES

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Background: Sedentary behavior has been identified as a potential risk factor for various malignancies, whereas physical activity serves as a protective factor for certain cancers. The aim of this study was to explore the associations between these two factors and the prevalence of melanoma and non-melanoma skin cancers (NMSCs).

Methods: We collected cross-sectional data from 26,731 participants in the NHANES from 2007 to 2016. Multivariate logistic regression and subgroup analyses were used to assess the correlations between sedentary behavior, physical activity, and the prevalence of melanoma and NMSCs.

Results: Multivariable logistic regression indicated that sedentary behavior was not significantly associated with melanoma or NMSCs. The type and score of physical activity were not related to melanoma ($p > 0.05$). However, moderate-intensity physical activity (including both work and recreation activities) and physical activity scores in the 2001–4000 range were positively correlated with NMSCs. Subgroup analysis and interaction tests showed no significant differences in NMSC prevalence between participants with a physical activity score ranging from 2001–4000, suggesting that gender, Poverty Income Ratio (PIR), and education level were not significantly related to this positive correlation ($p < 0.05$). However, after adjusting for UV radiation as a covariate, the logistic regression results of the NMSCs were no longer significant.

Conclusion: Our study results indicate that, for individuals aged 20 and above in the US, SB is not associated with the prevalence of melanoma or NMSCs. There is no significant correlation between physical activity and the prevalence of melanoma, but a positive correlation exists with NMSCs'. However, this association was attenuated and lost statistical significance after adjustment for sunburn history as a proxy for UV exposure. We need more prospective and well-designed studies to validate our findings to promote early prevention and lifestyle interventions for high-risk populations of NMSCs.

Keywords: physical activity, sedentary behavior, melanoma, non-melanoma skin cancer, public health

Introduction

With the advancement of technology in human society, sedentary behavior (SB) has become an inevitable aspect of modern life, whether it is white-collar office work or modern people's dependence on the internet and television.[1,2] These factors contribute to an excessive amount of time spent in SB daily. Studies have shown that SB has become an independent risk factor for incidence rate and mortality of certain cancers.[3] Notably, the association between SB and the increased incidence of colorectal and endometrial cancers is particularly strong.[4,5] Prolonged SB is linked to a 54% increased incidence of colorectal cancer and a 66% increased incidence of endometrial cancer.[5,6]

Regular physical activity (PA) has been identified as a protective factor against various diseases, with the strongest evidence supporting its role in reducing the risk of colon and breast cancers.[7,8] Some studies also suggest that replacing SB with PA is beneficial for improving patients' disease prognosis.[9] Although PA serves as a protective factor for various cancers,[10] it is noteworthy that in melanoma patients—particularly those with acral melanoma—mechanical stimulation

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of the feet has been identified as a potential risk factor.[11] PA is theoretically believed to prevent malignant melanoma and non-melanoma skin cancers (NMSCs) through mechanisms such as inhibiting cancer cell proliferation,[12] inducing apoptosis, modulating metabolism or immunity[13] and promoting weight loss.[14] However, existing evidence indicates that the relationship between PA and melanoma prevalence may be positive[15] or nonsignificant.[16] Consequently, the association between PA and melanoma appears to be more complex and less definitive than previously hypothesized. Furthermore, research on the associations between PA and NMSCs is even rarer. To our knowledge, this study is the first to investigate the associations among SB, PA, and NMSCs, and to used the NHANES to further validate the association among SB, PA and melanoma.

Melanoma and NMSCs are common among skin cancer patients in the United States, and the incidence of these two diseases has increased in recent years.[17] Despite significant "milestone" advances in treatment, the emergence of tumor resistance and mutations has further exacerbated the burden on both patients and society.[18,19] The identification of new preventive strategies and risk factors for these two diseases has therefore become particularly important. Therefore, investigating whether SB and PA influence or predict the development of melanoma and NMSCs is crucial. Such insights could help provide early, personalized guidance for high-risk populations, aiming to prevent or minimize the impact of these diseases.

Methods

Study Population

All raw data and samples used in this research were obtained from the National Health and Nutrition Examination Survey (NHANES), the most comprehensive ongoing cross-sectional survey conducted by the National Center for Health Statistics (NCHS).[20] This survey aims to evaluate the health and nutritional status of people in the United States. After gaining informed consent from the subjects, specialists on NHANES team utilize telephone and mobile NHANES centers to conduct interviews, physical measurements and laboratory tests as well as complex, multistage probability sampling designs, which guaranteed the reliability and representativeness of the NHANES. The NHANES interview encompasses health-related, demographic, and socioeconomic questions, while the examination component consists of medical or physiological measurements, and laboratory tests administered by skilled medical professionals. NHANES plays a crucial role in many aspects, including evaluating the prevalence and potential risk factors for diseases and informing the development of evidence-based public health policies.

Study Sample, Inclusion and Exclusion Criteria

The detailed participant selection procedure is shown in Figure 1. Between 2007 and 2016, the NHANES cycles included 62,815 participants. First, we excluded participants who were aged <20 years old (n = 21,387) and those who previously had tumors other than melanoma and NMSCs (n = 2221). We subsequently removed participants with missing data on sedentary behavior, key covariates, and individuals without physical activity data (n = 12,476). Ultimately, a total of 26,731 participants were included in this study.

Assessment of SB&PA

Sedentary behavior (SB) was assessed using the NHANES Physical Activity Questionnaire (PAQ).[21] In response to the question (PAD680): "How much time do you usually spend sitting on a typical day?", participants provided self-assessments. Participants self-reported their average daily sitting time. Implausible values (eg, >18 hours per day or daily variation >3 hours) were flagged and verified following NHANES data processing recommendations. SB time was then categorized into three groups based on prior research: <5 hours/day, 5–8 hours/day, and >8 hours/day.[9] The information concerning PA in the NHANES questionnaire mainly consists of work and leisure activities, which can be classified according to intensity into moderate and vigorous activities. Regarding PA status, we referred to the NHANES PAQ questionnaire from 2007 to 2016 and obtained participants' daily activity information from PAQ620, PAQ605, PAQ650, PAQ665. And according to code PAQ610, PAQ625, PAQ655, and PAQ670, we obtain their PA frequency in a week. Using the data above, we were able to gather data related to participants' SB time and their engagement in varying levels

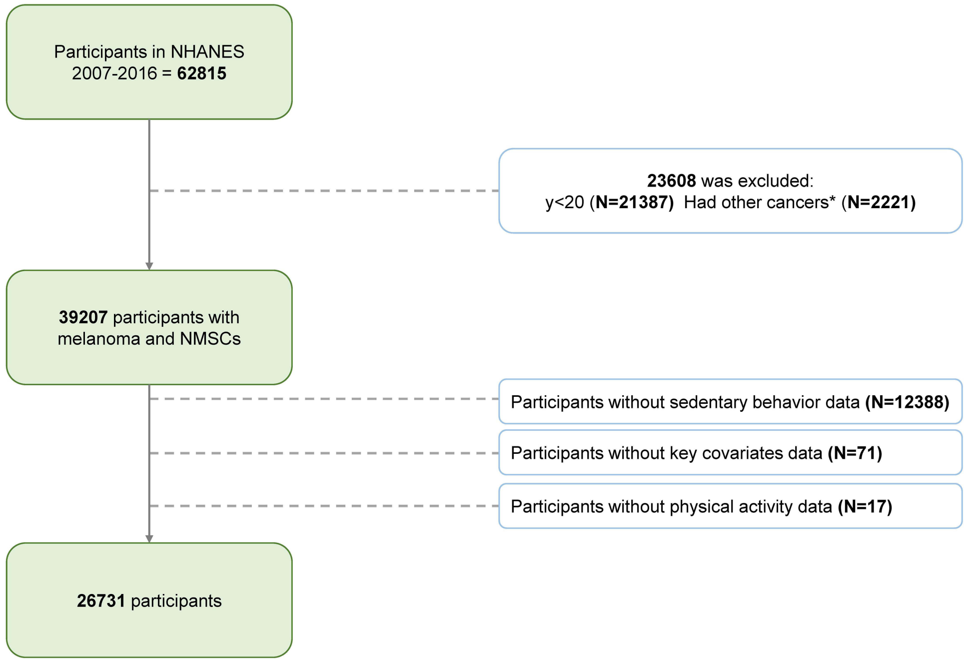

Figure 1 Flow chart of the participants' selection from NHANES 2007–2016 *Not melanoma or non-melanoma skin cancer.

of PA on a weekly basis. In accordance with the WHO analysis guidelines, the PA of each participant can be converted into metabolic equivalents (METs) for quantitative analysis. The MET values vary depending on the type of exercise, and NHANES has provided reference MET values for each type of PA. The PA score is calculated on the basis of PA type, frequency, and duration of activities in a typical week, via the following formula: MET*weekly frequency of each PA*active duration per day.[22] Following previous studies, the calculated MET values were transformed into categorical variables: <600, 601–2000, 2001–4000, and >4000 MET*min/week.[9,22,23]

Assessment of Participants with Melanoma or NMSCs

Information on melanoma and non-melanoma skin cancers (NMSCs) was obtained from the NHANES Medical Conditions Questionnaire (MCQ). Participants were first asked whether they had ever been told by a doctor or health professional that they had cancer (MCQ220). Those who responded "yes" were then asked to specify the cancer type (MCQ230A–D). Cancer types were coded according to NHANES coding guidelines, with 31 representing melanoma and 32 representing skin (non-melanoma). Participants reporting these codes were classified as melanoma or NMSC cases, respectively, while all others were treated as controls. The Dermatology Questionnaire (DEQ) was used as a supplementary source to confirm case status. By integrating information from both MCQ and DEQ questionnaires, we identified melanoma and NMSC cases according to established inclusion and exclusion criteria.

Covariables

Covariables in our study included age (year), gender (male/female), race (white/nonwhite), and the nonwhite category included Mexican American, other Hispanic, non- Hispanic Black, and other races.[24] Socioeconomic status was assessed through two dimensions: income and education. In terms of economy, the Poverty Income Ratio (PIR) was selected according to the Supplemental Nutrition Assistance Program (SNAP) eligibility criteria cited in NHANES analytic guidelines 1999–2010. This measure was subsequently categorized into three levels: 0–1.30 (lowest), 1.31–3.50 (middle), and 3.51–5.00 (highest).[25] With respect to education, we also obtained participants' educational information through the NHANES questionnaire and classified their educational levels into three categories based on relevant literature:≤High school, College/ AA degree, and ≥College graduate.[25] Additionally, personal-related covariates included smoking history (ever/never), hours of sleep, and Body Mass Index (BMI) measured in kg/m².

Statistical Analysis

All statistical analyses were conducted using appropriate NHANES sampling weights in accordance with CDC guidelines and taking into account complex multistage cluster surveys. The dependent variables were melanoma and NMSCs. The primary independent variables was SB time, PA type, and PA scores. We use survey-weighted percentages (95% Cl) to describe categorical variables. For all continuous variables, we use survey-weighted percentage (95% Cl) to describe them. Survey-weighted linear regression (continuous variable) or survey-weighted chi square test (categorical variable) were used to evaluate the differences between participants with and without melanoma. Similarly, we evaluate the differences between participants with and without NMSC. We use multiple logistic regression to explore the correlation between SB, different PA types, PA scores, and melanoma/NMSC. The covariates in the fully adjusted model include gender (male/female), age, race (white/non-white), and education level (≤ High school, College/AA degree, ≥ College graduate), PIR (0–1.30, 1.31–3.50, 3.51–5.00), smoking history (ever, never), sleep duration, and BMI. Age, gender, race, and PIR were included in the subgroup analysis of the correlation between PA scores and these two diseases. All statistical analyses were conducted using EmpowerStats 4.2 and R 4.4.1, with a significance threshold set at $P < 0.05$.

Results

In accordance with our inclusion and exclusion criteria, a total of 20,731 subjects from the NHANES were ultimately included in this study. The baseline characteristics of the participants are presented in Tables 1 and 2. In our analysis, The average age of melanoma patients was 61.67 years, while that of NMSC patients was 62.94 years, both significantly higher than the average ages of the respective control groups (without melanoma: 45.95 years; without NMSCs: 28.30 years). In this study, 144 cases of melanoma were identified, with a prevalence of 0.54%, while 405 cases of NMSC were observed, with a prevalence of 1.52%. For both melanoma and NMSCs, the proportion of male patients was higher (for melanoma: 57%; for NMSCs: 53.02%). However, this difference did not reach statistical significance. ($p > 0.05$). Participants with melanoma were more likely to identify as white individuals compared to

Table 1 Characteristics of Study Participants Aged ≥20, by Type of Skin Cancer (Melanoma) (N=26,731), National Health and Nutrition Examination Survey (NHANES), 2007–2016[a, b]

Characteristic	Melanoma		P-value [c]
	Yes	No	
N	144	26,587	
Age(y), mean (95% CI)	61.67 (59.12, 64.22)	45.95 (45.46, 46.44)	<0.01
Gender, percentage (95% CI)			0.13
Male	57.00 (45.63, 67.68)	48.64 (48.01, 49.28)	
Female	43.00 (32.32, 54.37)	51.36 (50.72, 51.99)	
Race, percentage (95% CI)			<0.01
White	94.40 (88.98, 97.24)	65.21 (61.85, 68.42)	
Non-white [d]	5.60 (2.76, 11.02)	34.79 (31.58, 38.15)	
Education level, percentage (95% CI)			0.01
≤High school	23.98 (15.54, 35.10)	39.56 (37.57, 41.57)	
College/ AA degree	40.86 (30.31, 52.34)	31.27 (30.23, 32.33)	
≥College graduate	35.16 (25.28, 46.49)	29.17 (27.19, 31.24)	
PIR [e], percentage (95% CI)			<0.01
0–1.30	7.00 (4.35, 11.08)	21.49 (20.01, 23.05)	
1.31–3.50	41.70 (31.67, 52.47)	39.94 (38.74, 41.16)	
3.51–5.00	51.30 (40.61, 61.87)	38.57 (36.42, 40.76)	
Smoking history, percentage (95% CI)			0.02
Ever	57.09 (44.51, 68.82)	43.53 (42.25, 44.82)	
Never	42.91 (31.18, 55.49)	56.47 (55.18, 57.75)	

(*Continued*)

Table 1 (Continued).

Characteristic	Melanoma		P-value [c]
	Yes	No	
Sedentary behavior (h/day), percentage (95% CI)			0.34
<5	42.51 (32.31, 53.38)	47.40 (46.14, 48.66)	
5–8	37.10 (26.76, 48.78)	29.48 (28.55, 30.42)	
>8	20.39 (12.09, 32.30)	23.13 (22.07, 24.23)	
BMI (kg/m^2), mean (95% CI)	28.88 (28.71, 29.05)	28.84 (27.81, 29.88)	0.95
Sleep hours, mean (95% CI)	7.05 (7.02, 7.07)	7.34 (7.14, 7.54)	<0.01

Notes: [a]Data source: Centers for Disease Control and Prevention. NMSCs, non-melanoma skin cancers. [b]Of 62815 participants in NHANES in 2007–2016, participants aged < 20 years or who had cancer other than melanoma and NMSCs history were excluded. [c]For continuous variables: survey-weighted mean (95% CI), P-value was by survey-weighted linear regression. For categorical variables: survey-weighted percentage (95% CI), P-value was by survey-weighted Chi-square test. [d]Includes Mexican American, other Hispanic, non-Hispanic Black, and other races. [e]According to the information from NHANES analytic guidelines 1999–2010, 0–1.30 indicates the lowest income, 1.31–3.50 indicates the middle income, and 3.51–5.00 indicates the highest income.

Table 2 Characteristics of Study Participants Aged ≥20, by Type of Skin Cancer (Non-melanoma skin cancer, NMSCs) (N=26,731), National Health and Nutrition Examination Survey (NHANES), 2007–2016[a, b]

Characteristic	NMSCs		P-value [c]
	Yes	No	
N	405	26,326	
Age(y), mean (95% CI)	62.94 (61.19, 64.68)	28.30 (27.54, 29.05)	<0.01
Gender, percentage (95% CI)			0.19
Male	53.02 (46.40, 59.54)	48.61 (47.96, 49.25)	
Female	46.98 (40.46, 53.60)	51.39 (50.75, 52.04)	
Race, percentage (95% CI)			<0.01
White	96.52 (93.36, 98.21)	64.70 (61.31, 67.94)	
Non-white[d]	3.48 (1.79, 6.64)	35.30 (32.06, 38.69)	
Education level, percentage (95% CI)			<0.01
≤High school	25.40 (20.04, 31.63)	21.69 (20.20, 23.25)	
College/ AA degree	31.81 (26.16, 38.06)	31.34 (30.27, 32.42)	
≥College graduate	42.79 (36.26, 49.58)	28.90 (26.91, 30.97)	
PIR [e], percentage (95% CI)			<0.01
0–1.30	8 36 (5.60, 12.32)	21.69 (20.20, 23.25)	
1.31–3.50	36.37 (29.98, 43.29)	40.04 (38.82, 41.27)	
3.51–5.00	55.26 (47.93, 62.37)	38.27 (36 16, 40.43)	
Smoking history, percentage (95% CI)			0.02
Ever	50.84 (44.33, 57.33)	43.46 (42.17, 44.77)	
Never	49.16 (42.67, 55.67)	56.54 (55.23, 57.83)	
Sedentary behavior (h/day), percentage (95% CI)			0.04
<5	39.81 (33.88, 46.06)	47.54 (46.29, 48.79)	
5–8	34.74 (29.21, 40.73)	29.41 (28.50, 30.34)	
>8	25.45 (19.91, 31.90)	23.05 (22.02, 24.12)	
BMI (kg/m^2), mean (95% CI)	28.30 (27.54, 29.05)	28.89 (28.72, 29.07)	0.12
Sleep hours, mean (95% CI)	7.04 (7.02, 7.07)	7.18 (7.02, 7.34)	0.10

Notes: [a]Data source: Centers for Disease Control and Prevention. NMSCs, non-melanoma skin cancers. [b]Of 62815 participants in NHANES in 2007–2016, participants aged < 20 years or who had cancer other than melanoma and NMSCs history were excluded. [c]For continuous variables: survey-weighted mean (95% CI), P-value was by survey-weighted linear regression. For categorical variables: survey-weighted percentage (95% CI), P-value was by survey-weighted Chi-square test. [d]Includes Mexican American, other Hispanic, non-Hispanic Black, and other races. [e]According to the information from NHANES analytic guidelines 1999–2010, 0–1.30 indicates the lowest income, 1.31–3.50 indicates the middle income, and 3.51–5.00 indicates the highest income.

those without melanoma (P < 0.01), and were also more likely to have a college degree or higher (P = 0.01), a same trend similarly observed in participants with NMSCs (P < 0.01 for race; P < 0.01 for education). However, no significant difference in sedentary behavior was identified between participants with melanoma (P = 0.34). Furthermore, the percentage of participants diagnosed with melanoma or NMSC increased significantly with increasing income levels (p < 0.01). Individuals with a history of smoking were significantly more likely to report melanoma (p = 0.02) or NMSC (p = 0.02).

Association Between SB with Melanoma and NMSCs

As illustrated in Table 3, our fully adjusted model revealed that there is no association between melanoma and SB time (OR = 1.09; 95% CI, 0.68–1.75 for SB time 5–8 h and OR = 0.72; 95% CI, 0.36–1.40 for SB time > 8 h). Similarly, in our fully adjusted model, no significant association was observed between SB time and the occurrence of NMSCs. (OR = 1.09; 95% CI, 0.82–1.44 for SB times of 5–8 h/day and OR = 1.01; 95% CI, 0.73–1.40 for SB time > 8 h/day).

Association Between PA Type and Melanoma and NMSCs

We included PA type as an independent variable in our fully adjusted model for logistic regression, and the results are shown in Table 4. Our analysis found that there is no statistically significant correlation between PA type and melanoma. However, among subjects with NMSCs, engaging in moderate intensity work activities and moderate intensity recreational activities are positively correlated with the prevalence of NMSCs (OR = 1.46; 95% CI, 1.11–1.91 for moderate work activity and OR = 1.36; 95% CI, 1.02–1.82 for moderate recreation activity). This result indicates that compared to participants who did not participate in these types of physical activities, were 46% and 36% more likely to develop NMSCs.

Table 3 Associations Between SB Time and Participants Aged ≥20 with Melanoma and with NMSCs (n=26731)[a]

Sedentary Time (h/day)	Melanoma	p-value	NMSCs	p-value
	OR[b] (95% CI [c])		OR[b] (95% CI [c])	
<5	Ref.		Ref.	
5-8	1.09 (0.70, 1.75)	0.72	1.08 (0.82, 1.44)	0.57
>8	0.72 (0.36, 1.40)	0.34	1.01 (0.73, 1.40)	0.95

Notes: [a]This model was fully adjusted for: age, gender, race (white and non-white, which includes: Mexican American, other Hispanic, non-Hispanic black, other race), educational level (≤high school, College/AA degree, ≥College graduate), PIR[d](0–1.30, 1.31–3.50, 3.51–5), BMI, smoking history (ever, never), sleep duration. NMSCs, non-melanoma skin cancer. [b]OR: Odds Ratio. [c]95% CI: 95% confidence interval.

Table 4 The Association Between Different PAs and Melanoma & NMSCs (n=26731)[a]

Characteristic	Melanoma, OR[b] (95% CI[c])	p-value	NMSC, OR[b] (95% CI[c])	p-value
Vigorous work activity		0.73		0.42
No	1.00 [ref.]		1.00 [ref.]	
Yes	1.10 (0.64, 1.87)		1.15 (0.82, 1.62)	
Moderate work activity		0.27		<0.01
No	1.00 [ref.]		1.00 [ref.]	
Yes	1.26 (0.84, 1.89)		1.46 (1.11, 1.91)	
Vigorous recreation activity		0.11		0.70
No	1.00 [ref.]		1.00 [ref.]	
Yes	0.57 (0.29, 1.13)		0.93 (0.65, 1.34)	

(*Continued*)

Table 4 (Continued).

Characteristic	Melanoma, OR[b] (95% CI[c])	p-value	NMSC, OR[b] (95% CI[c])	p-value
Moderate recreation activity		0.59		0.04
No	1.00 [ref.]		1.00 [ref.]	
Yes	1.14 (0.70, 1.86)		1.36 (1.02, 1.82)	

Notes: [a]This model was fully adjusted for: age, gender, race (white and non-white, which includes: Mexican American, other Hispanic, non-Hispanic black, other race), educational level (≤high school, College/AA degree, ≥College graduate), PIRd (0–1.30, 1.31–3.50, 3.51–5), BMI, smoking history (ever, never), sleep duration. NMSCs, non-melanoma skin cancer. [b]OR: Odds Ratio. [c]95% CI: 95% Confidence Interval.

Association Between PA Scores with Melanoma and NMSC

As previously mentioned, we calculated the PA scores (MET*min/week) for the subjects by using the methods from the previous studies and transformed them into categorical variables to explore their correlation with MM and NMSCs prevalence. The results, as shown in Table 5, indicate that subjects with PA scores >2000 and ≤4000 were positively correlated with the prevalence of NMSC (OR = 1.47; 95% CI, 1.00 −2.15 for NMSCs). This means that compared to subjects with PA scores ≤600, participants with PA scores in the range of 2001–4000 have a 47% higher probability of developing NMSCs.

Sensitivity Analysis Adjusting for Sunburn History

In order to address potential confounding by ultraviolet exposure, we further incorporated sunburn history as a proxy variable for UV exposure into the fully adjusted logistic regression models, with missing values imputed using multiple imputation. After additional adjustment, the previously observed positive association between PA and NMSC was attenuated and no longer statistically significant (eg, PA score 2001–4000 MET·min/week: OR = 0.87, 95% CI: 0.44–1.74, p = 0.69; PA score >4000 MET·min/week: OR = 0.63, 95% CI: 0.29–1.35, p = 0.22). Similarly, no significant associations were observed between PA and melanoma after adjustment for sunburn history (Table 6).

Subgroup Analysis

Subsequently, we further explored the relationship between PA scores ranging from 2001 to 4000 and the prevalence of NMSCs in different subgroups (gender, age, education level, PIR, smoking). The results are shown in Figure 2. Regarding the association between PA and NMSC prevalence, we observed a positive correlation among female participants (OR = 1.77, 95% CI: 1.04–3.01), those with lower education levels (OR = 1.58, 95% CI: 1.02–2.44), and individuals in the PIR range of 3.51–5.00. (OR = 2.01, 95% CI: 1.01–3.99). However, interaction tests indicated that the association between PA Score (2001–4000) and NMSCs prevalence did not vary significantly across different strata, suggesting that gender, education level, and PIR did not significantly influence this positive correlation.

Table 5 Relationship Between PA Score (MET-min/Week) with Melanoma and NMSCs (n=26731) [a]

Characteristic	Melanoma	P-value	NMSCs	P-value
PA Score (MET*min/week)	**OR[b] (95% CI[c])**		**OR[b] (95% CI[c])**	
≤600	1.00 [ref.]		1.00[ref.]	
601-2000	0.99 (0.58, 1.67)	0.96	1.38 (0.98, 1.93)	0.06
2001-4000	1.18 (0.60, 2.32)	0.64	1.47 (1.00, 2.15)	0.05
>4000	1.06 (0.59, 1.90)	0.84	0.97 (0.60, 1.57)	0.91

Notes: [a]This model was fully adjusted for: age, gender, race (white and non-white, which includes: Mexican American, other Hispanic, non-Hispanic black, other race), educational level (≤high school, College /AA degree, ≥College graduate), PIR (0–1.30, 1.31–3.50, 3.51–5), BMI, smoking history (ever, never), sleep duration. NMSCs, non-melanoma skin cancer. [b]OR: Odds ratio. [c]95% CI: 95% confidence interval.

Table 6 Association Between PA Categories and Skin Cancer Outcomes After Adjustment for Sunburn History [a, b]

Characteristic	Melanoma	P-value	NMSCs	P-value
PA Score (MET*min/week)	OR [c] (95% CI [d])		OR (95% CI)	
≤600	1.00 [ref.]		1.00 [ref.]	
601–2000	0.43 (0.16, 1.16)	0.11	0.90 (0.47, 1.74)	0.75
2001–4000	0.46 (0.11, 1.84)	0.30	0.87 (0.44, 1.74)	0.69
>4000	0.65 (0.23, 1.83)	0.43	0.63 (0.29, 1.35)	0.22

Notes: [a]Models were fully adjusted for age, gender, race (white and non-white, which includes: Mexican American, other Hispanic, non-Hispanic black, other race), education (≤High school, College/AA degree, ≥College graduate), PIR (0–1.30, 1.31–3.50, 3.51–5.00), BMI, smoking history (ever vs never), sleep duration and UV exposure. NMSCs, non-melanoma skin cancer. [b]Sunburn history was included as a proxy for UV exposure; missing values were imputed using multiple imputation (m=20). [c]OR: Odds ratio adjusted for covariates. [d]95% CI: 95% confidence interval.

Discussion

In this study, involving 26,731 noninstitutionalized participants from the United States, we observed no significant association between SB and the prevalence of melanoma or NMSCs. However, no statistically significant correlation was found between PA and melanoma prevalence. Interestingly, in NMSCs patients, we observed a positive association between daily moderate PA (including both work and leisure activities) and weekly moderate physical activity (with a PA score in the range of 2001–4000) and the prevalence of NMSCs. Our findings may reflect that individuals engaging in moderate or high levels of physical activity are more likely to spend time outdoors, thereby experiencing higher cumulative UV exposure. This mechanism has been highlighted in previous studies[26] and could partly explain the observed association between PA and NMSC.

Previous studies have explored the relationship between PA and melanoma, yet the findings remain controversial. A recent data analysis from the UK Biobank yielded results consistent with ours, showing no significant association

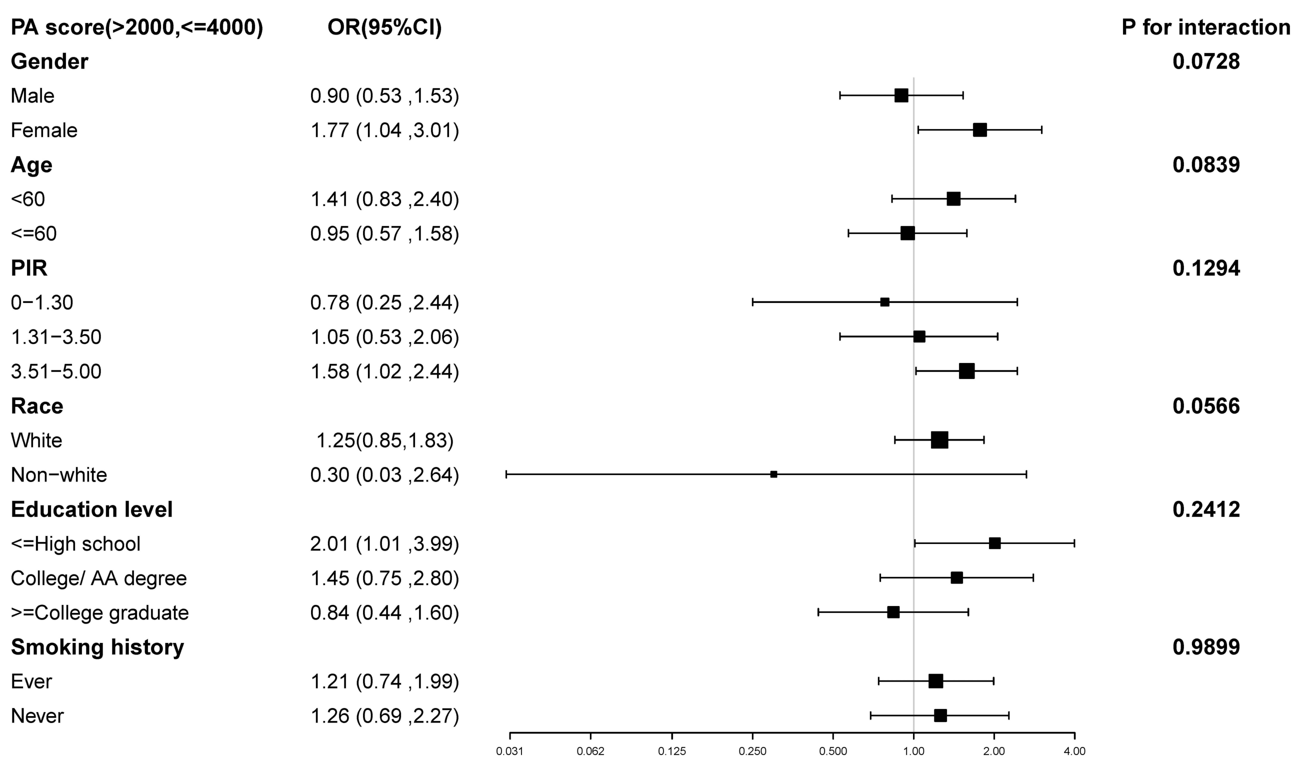

Figure 2 Subgroup analysis for the association between NMSCs and the PA score.

between PA, SB, and melanoma prevalence.[16] However, a large-scale epidemiological study involving 1.44 million adults found that leisure-time PA was positively associated with the risk of melanoma (HR = 1.27; 95% CI, 1.16–1.40).[27] Some studies have also suggested an inverse association between PA and melanoma incidence. However, this association was not statistically significant (RR = 0.85, 95% CI = 0.63–1.14).[15] A study conducted in Canada investigating the relationship between occupational PA and melanoma risk found that individuals with higher levels of PA had an increased risk of developing cutaneous malignant melanoma.[28] In the present study, no significant association was found between PA and melanoma prevalence. This is likely attributable to the use of sun protection measures in the US population, the diversity of available exercise venues, and the increasing preference for indoor physical activities.[29] As a result, UV exposure, a known risk factor for melanoma, may not necessarily coincide with physical activity simultaneously. Moreover, with the currently available data, it is challenging to fully adjust for all high-risk factors of melanoma as covariates. Consequently, any protective effect of physical activity on melanoma risk may be difficult to detect statistically, as it could be obscured by the influence of unaccounted risk factors.

To the best of our knowledge, the present investigation represents the inaugural cross-sectional study examining the correlation between PA and the prevalence of NMSCs. Consequently, the literature pertaining to this association is rather sparse. Utilizing data from the National Health and Nutrition Examination Survey, our analysis revealed a positive correlation between daily moderate-intensity PA, encompassing both occupational and recreational activities, and the prevalence of NMSCs. Furthermore, weekly moderate-intensity PA, quantified by a PA score within the range of 2001 to 4000, was also found to be positively associated with the incidence of NMSCs. A prospective Australian study has investigated the relationship between physical activity and squamous cell carcinoma of the skin (SCC) - a subtype of NMSC. Although a positive correlation between PA and the incidence of skin SCC was observed, statistical significance was not established.[30] A 14-year prospective Danish study has demonstrated a significantly increased risk of NMSC associated with PA, with an adjusted odds ratio of 1.72 (95% CI 1.23–2.40; p = 0.001), particularly in males.[31] In sensitivity analyses, we further incorporated sunburn history as a proxy for ultraviolet exposure, with missing values imputed using multiple imputation. After this additional adjustment, the previously observed positive association between PA and NMSC was attenuated and lost statistical significance. This attenuation suggests that the observed association may be partly explained by residual confounding from UV exposure.

Although physical activity can reduce cancer risk through various mechanisms, factors such as local pressure,[11] skin type,[32] and sun exposure may confound the relationship between exercise and skin tumors. Thus, the role of physical activity in melanoma and NMSCs may differ from its established protective effect observed in other types of cancers.[7,8]

The present study boasts several merits. Firstly, this study is based on data from the NHANES, which employs a nationally representative, standardized, protocol-based sampling of the United States population. All analyses incorporated the use of appropriate NHANES sampling weights, thereby strengthening the generalizability of the findings to the US population. Secondly, this study examined the associations between several common lifestyle factors and the risk of skin tumors, including melanoma and NMSCs. Based on previous studies and the literature, we used two metrics to assess physical activity: type of PA and PA scores, to qualitatively and quantitatively assess the impact of exercise on these diseases. Furthermore, common covariates were adjusted to ensure the reliability of the current results.

Nevertheless, the limitations of this study are not to be overlooked. Due to the cross-sectional nature of the data, establishing a causal relationship between outcomes and exposures is challenging. Additionally, the assessment of participants' physical activity was based on self-reported questionnaires, which are susceptible to potential recall bias. Despite the adjustment for numerous covariates, the possibility of confounding by unmeasured factors remains. In sensitivity analyses, we used sunburn history as a proxy for UV exposure to address potential confounding. While this variable provided some adjustment, it may not fully capture cumulative UV exposure in real-world conditions. Therefore, some degree of residual confounding by UV exposure cannot be entirely excluded. For participants diagnosed with NMSCs, the risks associated with moderate PA, such as increased sun exposure, fatigue, and environmental toxin exposure, may outweigh the benefits derived from exercise. The carcinogenic effects of PA are multifaceted, depending on energy expenditure and factors such as the age of the participants, as well as the frequency, intensity, and duration of PA. Based solely on data from the NHANES, the interplay between PA and the carcinogenic process is challenging to elucidate. Interpretation of the final results should be approached with caution, and further research is needed to validate or refute our findings.

Conclusion

Our study findings indicate that SB is not associated with the prevalence of melanoma or NMSCs. No significant correlation was observed between PA and melanoma. While the primary analysis suggested a positive correlation between moderate-intensity PA and the prevalence of NMSCs, this association was attenuated and lost statistical significance after adjustment for sunburn history as a proxy for UV exposure. These results suggest that the observed relationship between PA and NMSC may be partly attributable to residual confounding by UV exposure. Therefore, the findings should be interpreted with caution, and future longitudinal studies with more precise measures of UV exposure are warranted to clarify the true nature of this association.

Abbreviations

SB, Sedentary behavior; PA, Physical activity; NMSCs, Non-Melanoma Skin Cancers; NHANES, the National Health and Nutrition Examination Surveys; MET, Metabolic Equivalent; OR, Odds Ratio; CI, Confidence Interval; PIR, Poverty Income Ratio; US, United States.

Data Sharing Statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://wwwn.cdc.gov/nchs/nhanes.

Ethics Approval and Consent to Participate

Data collection for the NHANES was approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board (ERB), and all participants provided written informed consent. The NHANES datasets are publicly available and fully de-identified; therefore, separate ethical approval was not required for this secondary analysis. According to the Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects (China, 2023, item 1 and 2 of Article 32), studies based exclusively on publicly available and anonymized data are exempt from additional institutional review board (IRB) approval.

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Disclosure

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