Effects of regional average sunny days and other risk factors on the prevalence of skin cancer: A United States nationwide population-based study

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Abstract

Totaling over 5.4 million cases each year, skin cancer is the most common form of cancer in the US. Skin cancer generally develops from exposure to UV rays, however it is also attributed to various occupational and risk behaviors. Data collected in the 2014 Behavioral Risk Factor Surveillance System (BRFSS) (n=463,283) and the North America Land Data Assimilation System Daily Insolation were used to evaluate skin cancer history with UV exposure, demographic characteristics, and risk behaviors. Weighted multiple logistic regression and generalized linear mixed modeling were used for data analysis. A history of skin cancer was most prevalent among those over age 65 (22.2%), men (11.2%), and Whites (12.9%). Odds of reporting a history of skin cancer increased with educational attainment (AOR=1.34, 95% CI [1.21, 1.48] for college graduates), veterans (AOR=1.30, 95% CI [1.21, 1.39]), among those who had ever had another type of cancer (AOR=1.91, 95% CI [1.80, 2.03]), and as sun exposure increased (AOR=1.47, 95% CI [1.40, 1.55]). BRFSS data provide a unique look at all skin cancer in the US. Older Whites are most susceptible to skin cancer and results show a correlation between average levels of sun exposure and prevalence of skin cancer history. Associations between demographic characteristics, risk behaviors, and sun exposure help identify at risk populations and target prevention efforts and interventions.

Keywords: Skin cancer, BRFSS

Background

Skin Cancer Overview

Skin cancer is the most common form of cancer, so prevalent that the number of cases diagnosed annually exceeds the number of all other cancer diagnoses combined. The two most common forms of skin cancer, basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), are classified as non-melanoma skin cancers, are highly curable, and rarely spread to other parts of the body (Howlader et al., 2015). Due to the large number of cases seen and treated each year in the United States, estimated at 5.4 million cases of BCC and SCC in approximately 3.3 million people, skin cancer is associated with substantial morbidity costs and is the 5th most costly malignancy to treat at around $4.8 billion each year (Rogers et al., 2015). Despite high incidence, BCC and SCC are not required to be reported to cancer registries and thus are not included in national estimates for skin cancer incidence and death, making true estimates of prevalence difficult. The most accurate estimate of non-melanoma skin cancer prevalence in the United States has been through analyses of Medicare databases in an attempt to help allocate prevention and treatment strategies for the most vulnerable population (Rogers et al., 2015).

Melanoma is the third most common form of skin cancer and, as it is more likely to spread and metastasize, causes the most deaths (CDC, 2014). The Surveillance, Epidemiology, and End Results Program (SEER) estimated that 76,380 new cases of melanoma were diagnosed and 10,130 people died from the disease in 2016. In 2013 it was estimated that 1,034,460 people in the US were living with melanoma (Howlader et al., 2015), and national incidence rates have been rising an average of 1.4% each year for the last 10 years (SNDPBH, 2015). Rates for melanoma are derived from information sent to state cancer registries from diagnosing physicians, however reporting rates between physicians and states varies so estimates of national incidence and prevalence of melanoma may be low. The potential for melanoma to be underreported is very high since melanoma is commonly diagnosed and treated in outpatient facilities and the requirements for skin cancer reporting are complicated and time consuming (Harris et al., 2015). Additionally, since not all skin cancers are required to be reported to the state cancer registries, this leads to confusion, omission of cases, and creates a barrier for physicians to report all incident cases they diagnose. For example, in 2012 Arizona noticed significantly lower rates of melanoma incidence than the national rates and after a detailed investigation found that 33% of incident melanoma cases from 2009 to 2012 had not been reported to their state registry (Harris et al., 2015).

Additional forms of skin cancer include Kaposi sarcoma, lymphoma of the skin, skin adnexal tumors, sarcomas, and Merkel cell carcinoma, however these are uncommon and combined account for less than 1% of all skin cancers (ACS, 2016). These cancers will not be discussed further in this paper.

Etiology of Skin Cancer

Skin cancer generally develops after sun exposure causes skin cells and their DNA to become damaged. The cells will attempt to repair the damaged DNA, though if repaired incorrectly the cell can become defective and over time may grow into a tumor (TCPC, 2010). Melanoma occurs when malignant cells form in melanocytes, the cells present in epidermal tissue that produce melanin and pigment skin. Melanoma can develop anywhere on the body but is most likely to occur on the face, neck, hands, and arms as these areas of skin are most often exposed to ultraviolet (UV) rays through sun exposure and tanning beds (Howlader et al., 2015). An image of skin histology is provided in Appendix 1 for reference. People with fair complexions, light colored-eyes, red or blonde hair, a history of blistering sunburns, or having several large or many small moles are more susceptible to developing melanoma.

Research has shown UV exposure, either from direct contact with sunlight or through tanning beds, to be the major risk factor for the development of skin cancer. Ultraviolet B (UVB) radiation is the most significant causal factor in developing non-melanoma skin cancers (Moan, Grigalavicius, Baturaite, Dahlback, & Juzeniene, 2014). While SCC is impacted more by total lifetime exposure to UVB, development of BCC is impacted by both total exposure and exposure pattern to UVB, meaning those who have continuous UV exposure from an occupational setting may have different outcomes than those with intermittent intense exposure during the summer. The etiology of melanoma is less clear, however it is thought to develop in conjunction with both UVB and Ultraviolet A (UVA) radiation and is more correlated with exposure pattern than lifetime exposure. Additional factors that influence the development of skin cancer after exposure to UV radiation include one's sensitivity to exposure (if the skin tans, burns, or blisters), number of painful sunburns as a child, and lifetime exposure to UV radiation (Barton et al., 2016). While UV radiation is the major environmental carcinogen for melanoma, chemical exposures and other risk factors can also play a part in development of disease.

There are several links to skin cancer seen through behavioral habits. A link to melanoma has been seen through consumption of citrus food like oranges or grapefruits. These foods are rich in psoralens, compounds that readily absorb UV light while in the body and induce carcinogenic processes (Wu et al., 2015; Feskanich, Willett, Hunter & Colditz, 2003; Bram et al., 1980). Alcohol consumption has been associated with melanoma and non-melanoma skin cancers, potentially through a mechanism that reduces the skin's defenses against UV light (Rivers, 2014; Kubo et al., 2014; Jensen et al., 2012; Freedman, Sigurdson, Doody, Mabuchi, &

Linet, 2003). There is also a link between smoking and the development of SCC, with a dose-response relationship seen as the number of cigarettes smoked increases (Rollinson et al., 2012; Freedmanet al., 2003; De Hertog et al., 2001). This could be due to a carcinogenic property of tobacco on the skin, lowered immune functioning due to smoking, or possibly greater exposure to intermittent UV radiation from smoking outside. Further, this relationship appears to be only associated with SCC, as no significant associations have been noted for BCC, and appears to be stronger among women when compared with men (Rollinson et al., 2012; Freedman et al., 2003; De Hertog et al., 2001).

People who work in occupational settings where they are exposed to the sun, such as farmers, firemen, construction workers, or Military personnel, are at an increased risk of developing skin cancer. Occupational UV exposure has been shown to be a substantial risk factor for development of non-melanoma skin cancers (Diepgen, Fartasch, Drexler, & Schmitt, 2012). Employers may not enforce sun protective behaviors among their employees, so it is often up to the individual to continuously apply sunscreen throughout the day, wear sun protective clothing, or seek shade while working. If these habits are not socially acceptable or easy to do, these workers could be putting themselves at risk for skin cancer. Additional effects of hazardous air pollutants or occupational exposure to chemicals can enhance the carcinogenic process and development of skin cancer (Suarez et al., 2007). Increased risk of SCC has been seen among workers exposed to insecticides, herbicides, fungicides, seed treatments, petroleum products, grease, and other occupational exposures (Gallagher et al., 1996). Several studies have shown that veterans have an increased risk of skin cancer, especially melanoma, as they are often deployed in climates and latitudes much different than found in the United States (Powers et al., 2015; Lea, Efird, Toland, Lewis, & Phillips, 2014; Zhou et al., 2011). A study conducted by the

US Armed Forces Health Surveillance Center (2014) found service members to be at risk of excessive sun exposure due to working, training, and deployment environments. This study found 19,172 incident cases of clinically significant sunburn among active component service members from 2002 to 2013, 80.2% of which were first degree sunburns. Like the outdoor workers mentioned previously, Military personnel may have low awareness of and accessibility to sun safety measures while deployed, or may feel social pressure from their peers to not wear protection, putting them at a higher risk for developing skin cancer.

Lastly, genetics plays a role in development of melanoma, with 5% to 12% of melanomas associated with family history (Ransohoff et al., 2016). There is some evidence that suggests people with the BRCA1 or BRCA2 gene, commonly associated with development of breast cancer, are also at an increased risk of developing melanoma (Gumaste et al., 2014; Ransohoff et al., 2016). Some studies have suggested an association between a diagnosis of non-melanoma skin cancer with other primary cancers, especially when the skin cancer occurred at a young age (Ong, Goldacre, Hoang, Sinclair, & Goldacre, 2014; Jaju, Ransohoff, Tang, & Sarin, 2016), suggesting non-melanoma skin cancer could trigger a genetic change that increases the chance for cell mutations and tumor development. Among people with a history of non-melanoma skin cancer, an increased risk of developing subsequent lung and breast cancer has been seen among women, and an increased risk of melanoma in both men and women (Song et al., 2013; Ong et al, 2014). Long-term infection with human papillomavirus (HPV), more commonly in the etiologic pathway for cervical cancer, has been linked to development of SCC, likely through facilitating or enhancing the carcinogenic processes initiated by UV radiation or environmental exposures (Bavinck, Plasmeijer, & Feltkamp, 2008).

Skin Cancer Incidence and Mortality

As BCC and SCC data are not maintained by national cancer registries, melanoma alone serves as an indicator for skin cancer incidence and mortality in the US. Nationally, between the years 1999-2013, the age-adjusted incidence rate for melanoma was reported at 18.9 per 100,000 and the age-adjusted death rate was 2.7 per 100,000 (USDHHS, 2016). While the five-year survival rate for melanoma is high at 91.5%, there were 125,456 reported deaths from melanoma during that timeframe, making it the 16th most common cancer-related cause of death (USDHHS, 2016).

The median age of death from melanoma is 69, however the highest death rates are seen among people aged 75 to 84 (Howlader et al., 2015). Melanoma is most commonly diagnosed between the ages of 55 and 64, with the median age at diagnosis of 63 (Howlader et al., 2015). Men have higher incidence and death rates when compared to women, with 57% of incident cases and 64% of melanoma-related deaths seen among men. In the United States, melanoma is most commonly seen among those identifying as White race and non-Hispanic ethnicity (CDC, 2014).

The states with the highest age-adjusted incidence rate for melanoma based on national cancer data are Vermont, Utah, New Hampshire, Oregon, and Washington, with 29.5, 29.0, 27.3, 25.7, and 24.8 cases per 100,000 residents, respectively. These states have high numbers of White residents who are likely get most of their sun exposure in intense intervals and not continuously throughout the year, consistent with results published by Moan et al. (2014) that showed intense intermittent exposure to UV radiation to be associated with development of melanoma. The lowest incidence rates occur in Washington DC, Alaska, and Louisiana, with age-adjusted incidence rates of 8.3, 12.3, and 13.5 cases per 100,000 people, respectively

(USDHHS, 2016). Full data on incidence and mortality rates for melanoma by state are provided in Appendix Table 2 and Figures 4 and 5.

The Behavioral Risk Factor Surveillance System

This paper utilizes data collected in the 2014 the Behavioral Risk Factor Surveillance System (BRFSS) to assess factors associated with self-reported melanoma and non-melanoma skin cancer diagnoses. The BRFSS is an annual survey conducted over the telephone in each state that collects data from noninstitutionalized US residents about their health-related risk behaviors, chronic health conditions, and preventive services use (CDC, 2015). It is the largest continuously conducted health survey system in the world, with over 400,000 adults aged 18 and older from all 50 states, the District of Columbia, and 3 US territories surveyed each year. The 2014 survey collected basic demographic information from each participant, including age, race, ethnicity, gender, education level, and veteran status, and assessed behavioral risk factors that included tobacco and alcohol use, exercise habits, immunization status, health status, access to care, chronic health conditions, cancer screening, and several other issues. In the chronic health conditions section, participants were asked about their history of skin cancer, and these responses will be used for analysis in this paper.

North America Land Data Assimilation System Daily Sunlight

The North America Land Data Assimilation System (NLDAS) Daily Sunlight (Insolation) data provides the average daily sunlight in kilojoules per square meter (kJ/m^2) of each county in the contiguous Unites States from 1979 to 2011 (NLDAS, 2012). The NLDAS calculated daily insolation, the amount of solar radiation reaching a given area per minute, as the average value of all the daily insolation measurements in kJ/m^2 (CDC, 2012). As the BRFSS data is available on the state level, the average insolation for each state will be used to map solar radiation levels with the self-reported skin cancer prevalence data from the BRFSS dataset. Alaska and Hawaii will be excluded from analyses that use sunlight data since insolation data are not available for these states.

Study Purpose

This study utilizes data provided in a large, nationally representative data set to observe prevalence and behavioral, demographic, and occupational associations among all skin cancer types in residents of the United States. Further, it looks to provide additional evidence on the impact of sun exposure in the development of skin cancer among people of different races.

Skin cancer is largely attributed to UV exposure but is also associated with several other risk factors through both direct and indirect pathways. The first objective of this paper will be an ecological study that combines the 2014 BRFSS data set on skin cancer prevalence with the North America Land Data Assimilation System (NLDAS) Daily Sunlight (Insolation) for years 1979-2011 to assess potential relationships between UV exposure and reported risk factors in those with a history of skin cancer. An assessment of risk of skin cancer by gender, race, and age will be done to verify that results are consistent with the literature. Further analysis will be done on additional health risk factors, including tobacco use and military history, as these have previously been associated with increases in skin cancer. Additionally, as the literature shows a correlation between non-melanoma skin cancer and development of other cancers, including melanoma, breast, and lung cancers, associations will be tested to determine if the population-based data from the BFRSS is consistent with the literature.

The second objective of this study will map the associations between UV exposure and cancer prevalence as reported to the BRFSS by state. The United States population lives at diverse altitudes, latitudes, and experiences different weather patterns. Modeling the distribution of average levels of sunlight in each state with prevalence of self-reported skin cancer is a valuable tool for understanding how these factors play into the role of skin cancer development in each state. As the most common forms of skin cancer, BCC and SCC, are not reported to state cancer registries, these maps can show the distribution of these skin cancers across the US.

Methods

Study Population

Participants from Hawaii, Alaska, Guam, and Puerto Rico were excluded from analysis due to lack of sunlight data for these states. In 2014, participants of the BRFSS survey were asked if a doctor, nurse, or other health professional had ever told him or her that they had skin cancer. Participants could answer with yes, no, or don’t know/not sure. Of a total survey population of 464,663, 20,140 were from Alaska, Hawaii, Guam, or Puerto Rico, limiting the study population to 444,523. A total of 41,988 reported a history of skin cancer, 401,189 reported no history of skin cancer, and data were missing for 1,346 participants. Only respondents who selected yes or no are included in this analysis, for a total study population of 443,177. Respondents represented the 48 contiguous US states and Washington DC. Table 1 shows the demographic characteristics of the participants of the 2014 BRFSS survey who had responded to having a history of skin cancer.

A total of 41,988 participants of the 2014 BRFSS survey reported a history of skin cancer, making up 5.83% of the study population. Participants in the study ranged in age from 18 years to over 65 years, with the majority of participants over 65 years old. Slightly more females than males took the survey (51% vs 49%), and 65% of the population identified as White only, Non-Hispanic. Most participants attended or graduated from college, and over 45% of participants had annual household incomes greater than $50,000 per year. A large majority, 85.9% of participants, reported currently having health insurance at the time of the survey.

Table 1. Characteristics of respondents of the 2014 BRFSS survey who responded to having a history of skin cancer

Characteristic	n	*Weighted %*		n	*Weighted %*
History of Skin cancer	41,988	*5.83%*	Education		
Age group, Categorical			Did not graduate High School	34,784	*14.62%*
18-24	22,606	*12.93%*	Graduated High School	125,517	*28.47%*
25-34	40,898	*17.31%*	Attended College	119,922	*30.96%*
35-44	51,598	*16.50%*	Graduated College	159,413	*25.94%*
45-54	73,798	*17.68%*	*Missing*	3,541	
55-64	101,037	*16.51%*	Income		
65+	153,240	*19.07%*	Less than $15,000	40,205	*12.59%*
Gender			$15,000 to less than $25,000	64,633	*17.77%*
Male	183,600	*48.63%*	$25,000 to less than $35,000	42,335	*10.94%*
Female	259,577	*51.37%*	$35,000 to less than $50,000	55,112	*13.70%*
Race			$50,000 or more	172,513	*45.01%*
White only, Non-Hispanic	349,962	*64.96%*	*Missing*	*68,379*	
Black only, Non-Hispanic	34,877	*11.90%*	Insurance Coverage		
Other race only, Non-Hispanic	15,388	*6.39%*	Has health insurance	405,611	*85.90%*
Multiracial, Non-Hispanic	6,471	*1.21%*	Does not have health insurance	35,833	*14.10%*
Hispanic	28,933	*15.55%*	*Missing*	1,733	
Missing	*7,546*				
Veteran Status					
Veteran	59,291	11.23%			
Non-Veteran	382,963	88.77%			
Missing	*923*				

Measures

Outcome variables. To understand associated risk factors with development of skin cancer, this study will utilize self-reported skin cancer diagnosis as the outcome of interest. Respondents were prompted: Has a doctor, nurse, or other health professional ever told you that you had skin cancer? Tell me “Yes,” “No,” or you’re “Not sure.” Those who responded “Yes” will be analyzed in comparison to those who said “No”, and those who responded “Not sure” were excluded from analysis. Age-adjusted prevalence was calculated by the CDC and was separately pulled from the 2014 database.

Exposure variables. Exposure to ultraviolet light is closely associated with skin cancer development. This study will model the effects of average state-level sunlight exposure collected by the NLDAS on skin cancer history.

Covariates. As many factors contribute to the development of skin cancer, several demographic and behavior variables will be evaluated and included in the adjusted effect measures of the relationship between sun exposure and skin cancer. Demographic indicators will include age, race, gender, education level, income, and insurance status. Behavioral, occupational, and other risk factors will include smoking, history of other cancer diagnoses, and veteran status.

Data Analysis

Weighted descriptive statistics were used to report demographic characteristics for the study population. Chi-square testing was performed for all variables and t-testing was performed for age as a continuous variable to determine if the distribution of values or difference of means differed between those who reported a history of skin cancer and those who did not report a history of skin cancer. Weighted crude and multiple logistic regression analyses were conducted for the exposure variable and all demographic and behavioral variables, simultaneously adjusting for all other factors.

For all analysis, a p-value of 0.05 was used as the cutoff for statistical significance. All analysis was conducted using SAS 9.4 software.

Mapping. Maps were created using PROC GMAP in SAS. County code was provided from the NLDAS data set and state averages were calculated to obtain a single average for sun exposure in each state. Crude and age-adjusted data on skin cancer history from the BRFSS were imported and mapped to each state.

Generalized Linear Mixed Modeling. Every individual within a state was assigned the same sun exposure level, however this does not account for the variability of the individuals within the state. To address this issue, hierarchical generalized linear mixed modeling with PROC GLIMMIX was used to analyze a 2-level nested source of variability to consider the variability within a state that impacts individual exposure levels.

First, an unconditional model with no covariates was used to calculate the intraclass correlation coefficient (ICC) and predicted probabilities (Ene et al., 2015). This model provides an overall estimate of the rate of skin cancer in a typical state, as well as provides information about the variability of skin cancer between states. Secondly, the best fitting model was assessed to understand the relationship between sun exposure and the likelihood of reporting history of skin cancer, while controlling for state and individual characteristics. The data collected for sun exposure were very large numbers, so they were divided by 1000 to improve the readability of the model.

Ethical Considerations

This study utilized publically available datasets with no individually identifiable components. Therefore, formal review by an institutional review board or ethics committee is not applicable.

Results

Skin Cancer and Behavioral Factors

Table 2 shows the prevalence of self-reported skin cancer by demographic variable, veteran status, or risk behavior. Results from chi square analyses showed significance for all variables at a $p<0.001$ significance level. Over 17.5% of those ages 65 or older reported a history of skin cancer, and there is a significant dose-response trend for reporting a history of skin cancer as age increased (p <0.0001, results of trend test not shown). Males reported a higher prevalence of skin cancer when compared to females, at 6.05% and 5.63%, respectively. Whites had the highest prevalence of skin cancer, with 8.51% of the population reporting a history, with those identifying as multiracial, Non-Hispanic having the second highest prevalence at 4.13%.

Proxies for socioeconomic status (SES) indicated as SES increased, prevalence of skin cancer history increased as well. Those in the two lowest income categories had the lowest prevalence of skin cancer, and once respondents earned more than $25,000 per year, incidence was relatively stable, between 6.0 -6.6%. Prevalence of skin cancer history increased with educational attainment, from 3.84% among those who did not graduate high school to 7.18% among those who graduated from college. Additionally, prevalence among those who had health insurance was 6.6%, compared to only 1.31% of those without health insurance.

Veterans had a much higher prevalence of skin cancer when compared with non-veterans, at 12.79% and 5.0%, respectively. Similarly, those who reported having another cancer diagnosis had a skin cancer prevalence of 18.15%, compared with 4.97% of those who had never had another cancer diagnosis. Interestingly, former smokers had the highest skin cancer prevalence, at 9.77%, followed by never smokers (4.93%) and current smokers (3.91%).

Table 2. Prevalence of self-reported skin cancer by characteristic in respondents of the 2014 BRFSS survey

Characteristic	History of skin cancer n=41,988	No history of skin cancer n= 401,189	Prevalence	X^2 ⌗ (d.f.)*	*p-value*
Mean age, years, continuous (SD)	68.1 (11.1)	54.3 (16.8)	---	---	**<0.0001**^
Age group, Categorical				8308.3 (5)	**<0.0001**
18-24	84	22,522	0.34%		
25-34	331	40,567	0.60%		
35-44	1,032	50,566	1.67%		
45-54	3,477	70,321	4.27%		
55-64	8,748	92,289	8.00%		
65+	28,316	124,924	17.50%		
Gender				14.73 (1)	**<0.0001**
Male	18,962	164,638	6.05%		
Female	23,026	236,551	5.63%		
Race				1900.6 (4)	**<0.0001**
White only, Non-Hispanic	39,869	310,093	8.51%		

Table 2. Prevalence of self-reported skin cancer by characteristic in respondents of the 2014 BRFSS survey

Characteristic	History of skin cancer	No history of skin cancer	Prevalence	X^2 ‡ (d.f.)*	*p-value*
	n=41,988	n= 401,189			
Black only, Non-Hispanic	217	34,660	0.44%		
Other race only, Non-Hispanic	423	14,965	1.00%		
Multiracial, Non-Hispanic	423	6,048	4.13%		
Hispanic	435	28,498	1.02%		
Missing	*621*	*8,271*			
Education				304.6 (3)	**<0.0001**
Did not graduate High School	2,501	32,283	3.84%		
Graduated High School	11,123	114,394	5.59%		
Attended College	10,990	114,062	5.96%		
Graduated College	17,152	142,261	7.18%		
Missing	*222*	*3,319*			
Income				302.7 (4)	**<0.0001**
Less than $15,000	2,669	37,536	3.48%		
$15,000 to less than $25,000	5,687	58,946	4.84%		
$25,000 to less than $35,000	4,370	37,965	6.04%		
$35,000 to less than $50,000	5,730	49,382	6.64%		
$50,000 or more	16,296	156,217	6.43%		
Missing	*7,236*	*61,143*			
Insurance Coverage				779.2 (1)	**<0.0001**
Has health insurance	41,007	364,604	6.60%		
Does not have health insurance	893	34,940	1.31%		
Missing	*88*	*1,645*			
Veteran status				2040.1 (1)	**<0.0001**
Veteran	9,986	49,305	12.79%		
Not a veteran	31,940	351,023	5.00%		
Missing	*62*	*861*			
Smoking Status				1295.4 (2)	**<0.0001**
Current smoker	3,752	59,655	3.91%		
Former smoker	16,377	107,030	9.77%		
Never smoker	20,327	215,741	4.93%		
Missing	*1,532*	*18,763*			
Other cancer diagnoses				3685.1 (1)	**<0.0001**
Ever had another type of cancer	9,034	33,603	18.15%		
Never had another cancer	32,814	366,865	4.97%		
Missing	*140*	*721*			

* Chi-square d.f. = degrees of freedom; ^ T-test p-value from Satterthwaite Method; ‡ Chi-square test excludes missing data

Table 3 shows the crude and adjusted odds ratios by logistic regression analyses of characteristics of participants who reported having a history of skin cancer. Results show that as sunlight levels increase, the odds of self-reporting skin cancer increase by 48% for those with high exposure, and by 11% for those with medium exposure when compared to those with low average levels of sunlight. Unsurprisingly and as with most cancers, as age increases, the odds of reporting skin cancer increase. Those identifying as White, Non-Hispanic had 17 times the odds of reporting skin cancer when compared to Blacks, and males had 1.09 times the odds of reporting skin cancer when compared with females.

Several SES indicators were tested, including education, income, and insurance status. Results show that as education and income increase, the odds of reporting a history of skin cancer increase. Those who graduated college had 1.34 times the odds of reporting a history of skin cancer when compared to those who did not graduate from high school. Those with current health insurance had 1.63 times the odds of reporting a history of skin cancer than those who did not currently have health insurance. Results were borderline non-significant for income level, but may suggest as income increases, odds of reporting a history of skin cancer increases.

Veterans showed a 30% increased odds of reporting skin cancer history when compared to non-veterans. Participants who reported history of cancer other than skin cancer had 1.91 times the odds of reporting a history of skin cancer when compared to those with no other cancer diagnoses.

Table 3. Crude and adjusted logistic regression analysis of characteristics of participants in the 2014 BRFSS survey who reported a history of skin cancer

Characteristic	Crude Odds Ratio	95% C.I.†	p-value‡	Adjusted Odds Ratio	95% C.I.†	p-value‡
Sunlight exposure (continuous, per 1000 kJ/m^2 increase)	1.07	(1.06, 1.08)	<0.0001	1.11	(1.10, 1.12)	<0.0001
Sunlight exposure (categorical)			<0.0001			<0.0001
Low (Reference)	1.00	---		1.00	---	
Medium	1.04	(1.00, 1.08)		1.11	(1.06, 1.17)	
High	1.12	(1.07, 1.17)		1.48	(1.41, 1.56)	
Age group			<0.0001			<0.0001
18-24 (Reference)	1.00	---		1.00	---	
25-34	1.75	(1.20, 2.56)		1.57	(1.00, 2.46)	
35-44	4.94	(3.45, 7.07)		4.06	(2.65, 6.24)	
45-54	12.95	(9.16, 18.31)		9.75	(6.39, 14.89)	
55-64	25.13	(17.85, 35.38)		17.26	(11.36, 26.21)	
65+	61.68	(43.87, 86.71)		35.49	(23.374, 53.88)	
Gender			<0.0001			0.005
Female (Reference)	1.00	---		1.00	---	
Male	1.08	(1.04, 1.12)		1.09	(1.03, 1.16)	
Race			<0.0001			<0.0001
Black only, Non-Hispanic (Reference)	1.00	---		1.00	---	
White only, Non-Hispanic	20.95	(15.87, 27.65)		17.13	(12.72, 23.07)	
Hispanic	2.32	(1.63, 3.31)		3.57	(2.41, 5.30)	
Other race only, Non-Hispanic	2.28	(1.51, 3.44)		2.92	(1.84, 4.66)	
Multiracial, Non-Hispanic	9.71	(6.879, 13.72)		10.68	(7.43, 15.36)	
Education			<0.0001			<0.0001
Did not graduate High School (Reference)	1.00	---		1.00	---	
Graduated High School	1.48	(1.36, 1.62)		1.05	(0.95, 1.16)	
Attended College	1.59	(1.46, 1.74)		1.17	(1.05, 1.30)	

Table 3. Crude and adjusted logistic regression analysis of characteristics of participants in the 2014 BRFSS survey who reported a history of skin cancer

Characteristic	Crude Odds Ratio	95% C.I.†	p-value‡	Adjusted Odds Ratio	95% C.I.†	p-value‡
Graduated College	1.94	(1.78, 2.11)		1.34	(1.21, 1.48)	
Income			<0.0001			0.0553
Less than $15,000 (Reference)	1.00	---		1.00	---	
$15,000 to less than $25,000	1.41	(1.27, 1.57)		0.99	(0.88, 1.10)	
$25,000 to less than $35,000	1.78	(1.59, 1.99)		1.05	(0.94, 1.18)	
$35,000 to less than $50,000	1.97	(1.77, 2.19)		1.08	(0.97, 1.21)	
$50,000 or more	1.90	(1.73, 2.10)		1.09	(0.98, 1.22)	
Insurance Coverage			<0.0001			<0.0001
No current health insurance (Reference)	1.00	---		1.00	---	
Has health insurance	5.32	(4.66, 6.06)		1.63	(1.39, 1.90)	
Veteran status			<0.0001			<0.0001
Not a veteran (Reference)	1.00	---		1.00	---	
Veteran	2.81	(2.68, 2.95)		1.30	(1.21, 1.39)	
Smoking Status			<0.0001			0.0059
Never smoker (Reference)	1.00	---		1.00	---	
Current smoker	0.78	(0.73, 0.85)		0.96	(0.88, 1.05)	
Former smoker	2.09	(2.00, 2.18)		1.07	(1.02, 1.12)	
Other cancer diagnoses			<0.0001			<0.0001
Never had another cancer (Reference)	1.00	---		1.00	---	
Ever had another type of cancer	4.24	(4.04, 4.46)		1.91	(1.80, 2.03)	

* Adjusted simultaneously for all other factors; † C.I. Confidence interval; ‡ Likelihood Ratio Chi-square Test; Excludes AK, HI, PR, Guam

Because individuals were assigned to a single exposure variable based on the state they lived in at the time of the survey, this is unable to account for the variability within the states themselves that could impact an individual's exposure to the sun. Hierarchical generalized linear mixed modeling was used to analyze this nested variability. This shows if skin cancer diagnoses of individuals in the same state are more alike due to their common environment than an individual chosen at random from the entire population, and shows the relationship between one's state of residence and the likelihood of reporting skin cancer while controlling for individual-level characteristics.

First, using an unconditional model for skin cancer with no predictive variables, the overall estimate for the rate of skin cancer in a typical state was calculated. Using the estimate for the log odds of reporting a history of skin cancer in a typical state, the probabilities of reporting a history of skin cancer and not reporting a history of skin cancer were calculated:

$$P_{\text{skin cancer history}} = \Phi_{ij} = \frac{e^{nij}}{1+e^{nij}} = \frac{e^{-2.3556}}{1+e^{-2.3556}} = 0.0866$$

$$P_{\text{no skin cancer history}} = 1 - \Phi_{ij} = 1-0.0866 = 0.9134$$

Next, using the covariance parameter estimates provided by SAS, the intraclass correlation coefficient (ICC) was calculated to indicate how much of the total variation in the probability of having skin cancer is accounted for by a state. This model assumes no error at level-1 and that the dichotomous outcome comes from an unknown latent continuous variable with a level-1 residual that follows a logistic distribution with a mean of 0 and a variance of 3.29 (Ene et al., 2015), which was used to calculate the ICC:

$$ICC = \frac{\tau_{00}}{\tau_{00}+3.29} = \frac{0.1511}{0.1511+3.29} = 0.0439$$

The ICC indicates that approximately 4% of the variability in the skin cancer history is accounted for by the state, leaving 96% of the variability to be accounted for by the individuals or other unknown factors. The output also indicates that there is a statistically significant amount of variability in the log odds of having a history of skin cancer between states [τ_{00} =.1511; $z(52) = 4.79$, $p<0.001$].

In summary, the unconditional model results revealed that the probability of reporting a history of skin cancer in a typical state is 0.0866, however the probability of reporting a history of skin cancer varies considerably across states.

To assess the relationship between sun exposure and the likelihood or reporting a history of skin cancer while controlling for state and individual characteristics, the model building process began by adding sun as a fixed effect, and then in an addition model, adding sun, race, gender, and age as fixed effects. A summary of the model estimations is provided in Table 4.

Table 4. Estimates for Two-level Generalized Linear Dichotomous Models of Skin Cancer History, BRFSS 2014 and NLDAS 2011

Fixed Effects	Model 1	Model 2 [a]	Model 3
Intercept	-2.36* (0.05)	-3.21* (0.29)	-6.62* (0.20)
Sun		0.06* (0.02)	0.10* (0.01)
Race			-0.58* (0.01)
Sex			-0.29* (0.01)
Age Group			0.77* (0.01)
Error Variance			
Level-2 Intercept	0.15* (0.03)	0.035* (0.007)	0.015* (0.003)
Model Fit			
-2LL	283453.4	276223.8**	239411.6**

Note: *p< .05; **=likelihood ratio test significant; ICC = .0439; Values based on SAS PROC GLIMMIX. Entries show parameter estimates with standard errors in parentheses; Estimation Method = Laplace. a Best fitting model

The best fitting model was selected by conducting a deviance test, comparing the difference in the -2 Log Likelihood values between models. Through this process, Model 2, a model containing level-1 fixed effects of sun exposure only, was found to be the best fitting model for this data.

Using the parameter estimate for the sun exposure variable generated by Model 2, the relationship between sun exposure and the likelihood of reporting a history of skin cancer was evaluated. While this does not control for other individual level factors, this relationship is both significant and positive (b=0.06, p=0.0011), indicating that as sun exposure increases, the predicted log odds of reporting a history of skin cancer increases. Using the odds ratio estimates (data not shown), it appears that for every unit increase in sun exposure, the odds of reporting a history of skin cancer increases by 1.06.

Mapping of Skin Cancer Prevalence across the US

Figure 1 below shows the average distribution of sunlight in the United States in kJ/m^2. States to the north show the lowest amount of daily sunlight, with increasing levels of sunlight seen in the south. The state with the lowest amount of sunlight, Vermont, receives an average of 13,457 kJ/m^2 per day, while the state with the highest average sunlight, Arizona, received 19,869 kJ/m^2 per day. For a detailed map of average sunlight by US County, see Figure 2 in the Appendix.

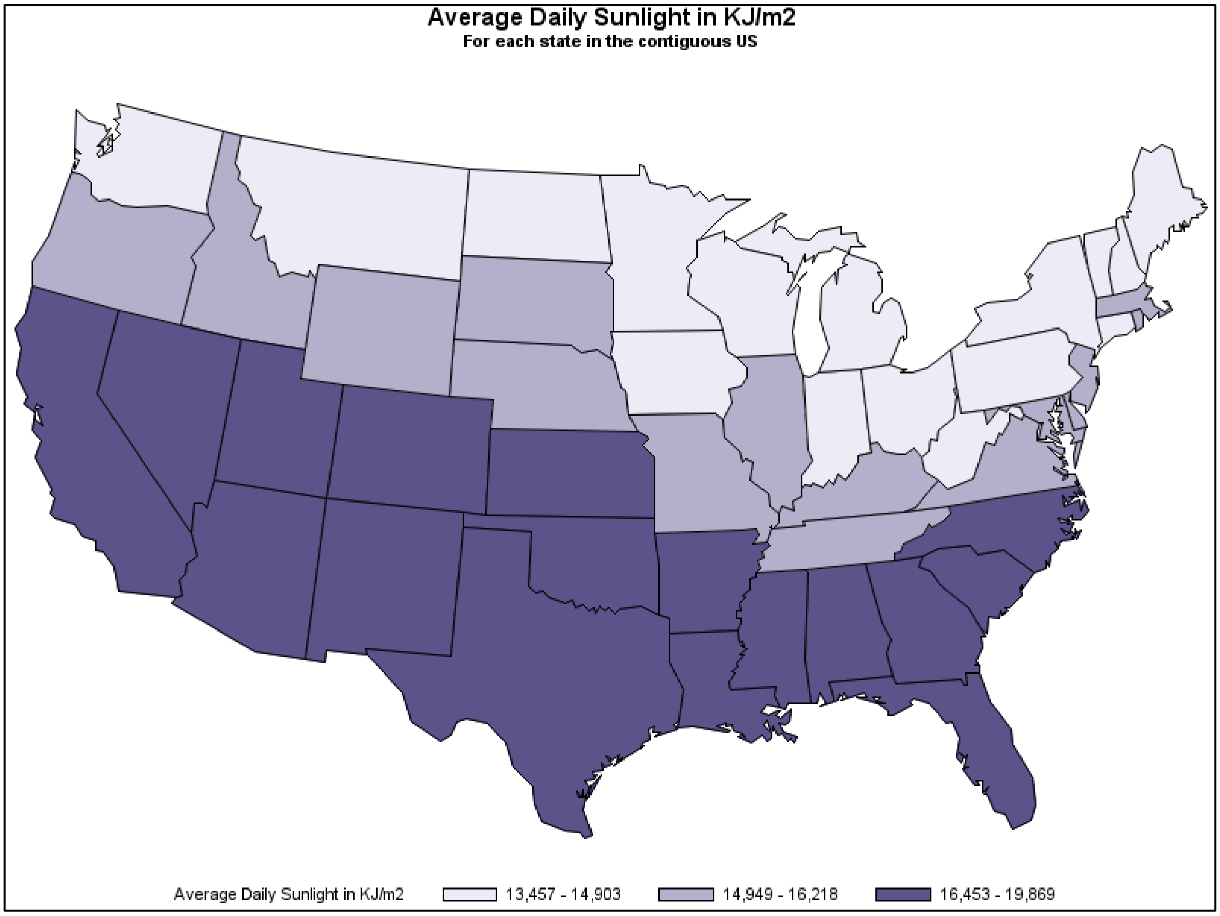

Figure 1: Average Daily Sunlight in kJ/m2 for states in the contiguous US, NLDAS 2012

Figure 2 shows the same sunlight distribution seen in Figure 1, however crude prevalence of skin cancer has been imposed on each state in block graphs as reported by respondents of the 2014 BRFSS survey. The lowest crude prevalence of skin cancer occurs in Delaware, with only 2.91% of respondents from this state reporting a history of skin cancer. The highest crude prevalence occurs in Florida, with 8.85% of respondents reporting a personal history of skin cancer. For a breakdown of crude, age-adjusted, and racial prevalence numbers by state, please reference Table 1 in the Appendix.

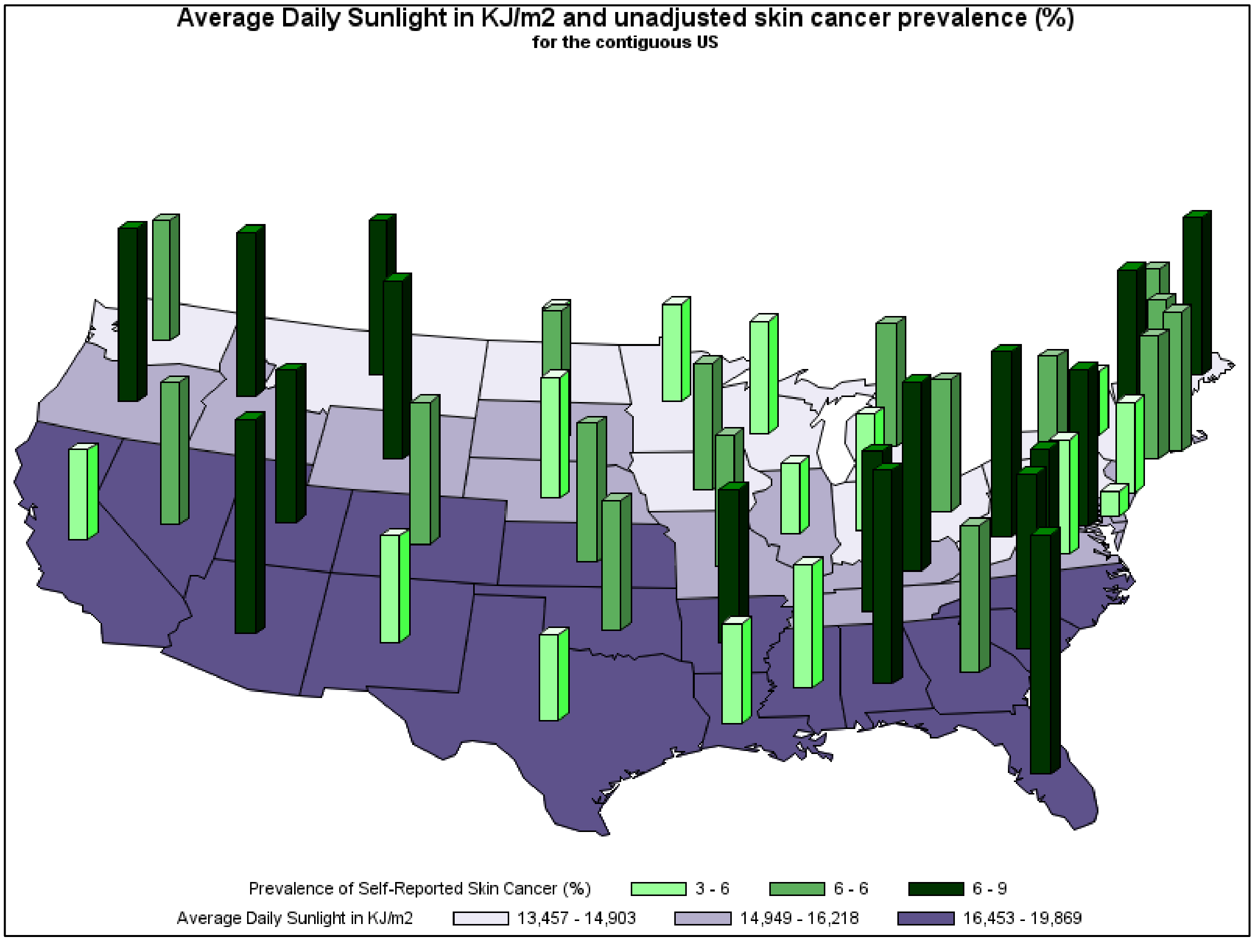

Figure 2: Unadjusted skin cancer prevalence as reported to the BRFSS, 2014, in relation to average sunny days of each state, NLDAS 2012

Figure 3 maps the age-adjusted skin cancer prevalence as reported to the 2014 BRFSS survey by average daily sunlight exposure. In this map, Washington DC has the lowest reported skin cancer prevalence, at 3.10% of respondents. Delaware, the state with the lowest crude prevalence, has an age-adjusted prevalence of 5.8%, and Arizona remains at the highest prevalence, with 7.4% of the survey population reporting a history of skin cancer.

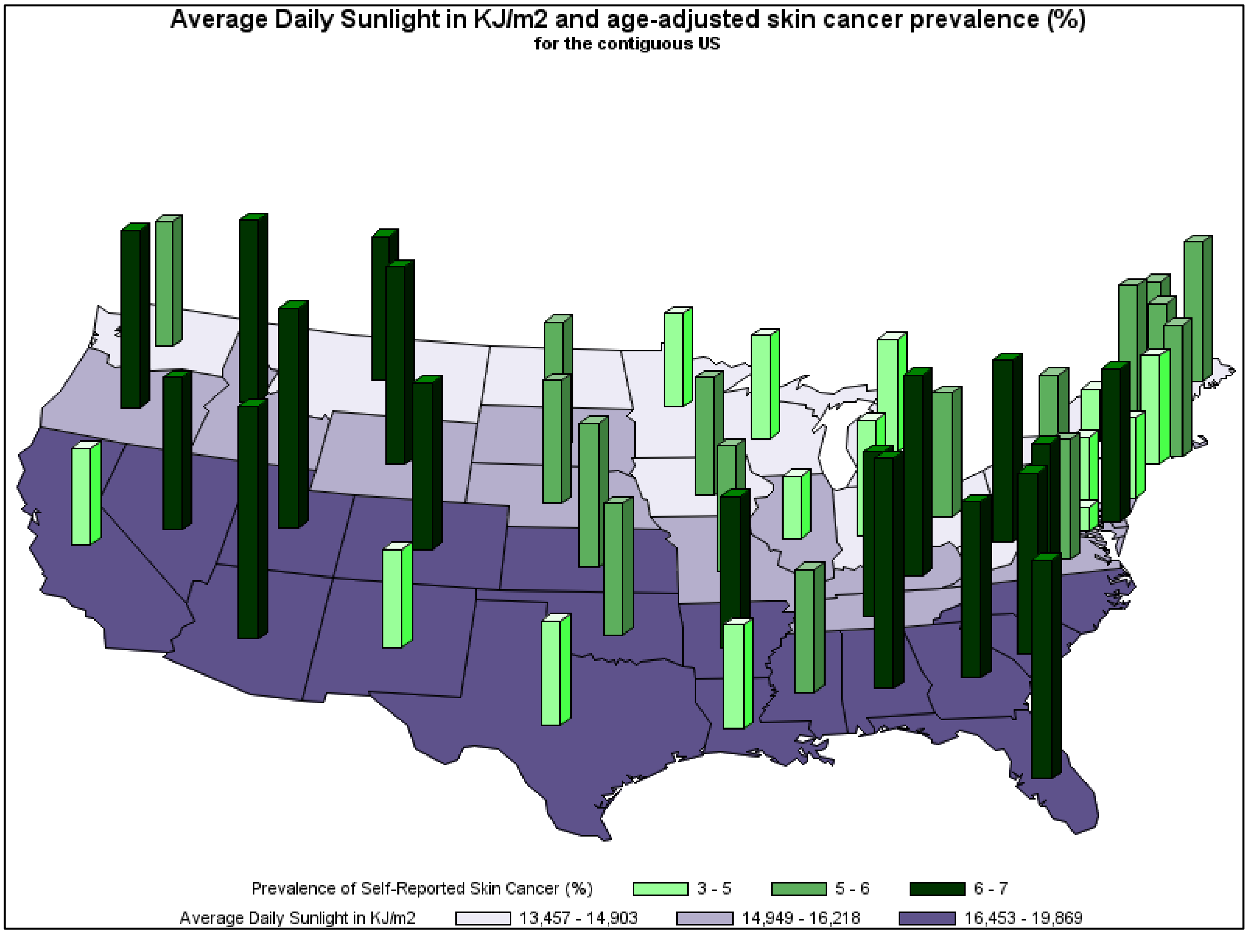

Figure 3: Age-adjusted skin cancer prevalence as reported to the BRFSS, 2014, in relation to average sunny days of each state, NLDAS 2012

Lastly, Figures 4 and 5 provide mapping of crude prevalence of self-reported history of skin cancer for White respondents and respondents of all other races, respectively. Although data are not age-adjusted, Whites show a much higher prevalence of skin cancer when compared with other races. For example, over 14% of White respondents in Florida reported a history of skin cancer, compared to only 1.6% of non-White residents. Maine shows the highest prevalence for non-White skin cancer history, at 5.8% of non-White residents, with a comparable prevalence of 7.0% among White residents in Maine. Prevalence among White respondents aligns well with the gradient of sun exposure, with the highest prevalence rates seen in the South, and the lowest prevalence seen in the Northeast, while those of other races have a prevalence pattern that does not match exposure patterns.

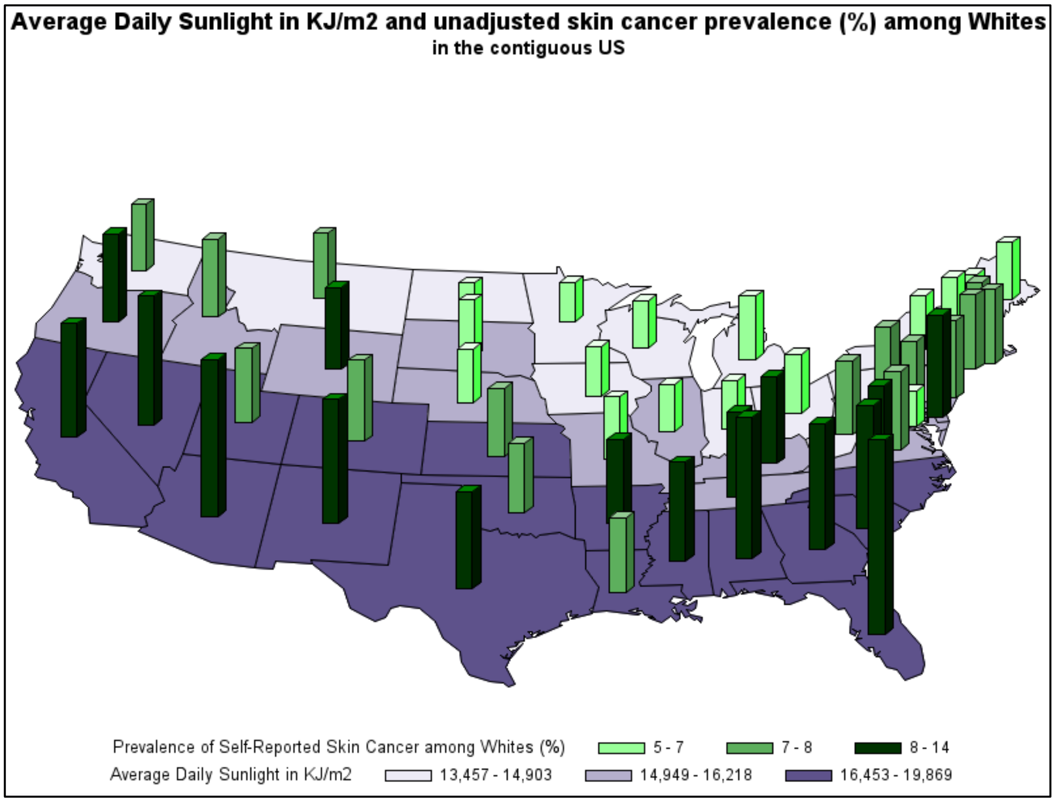

Figure 4: Unadjusted skin cancer prevalence (%) among White respondents, BRFSS, 2014

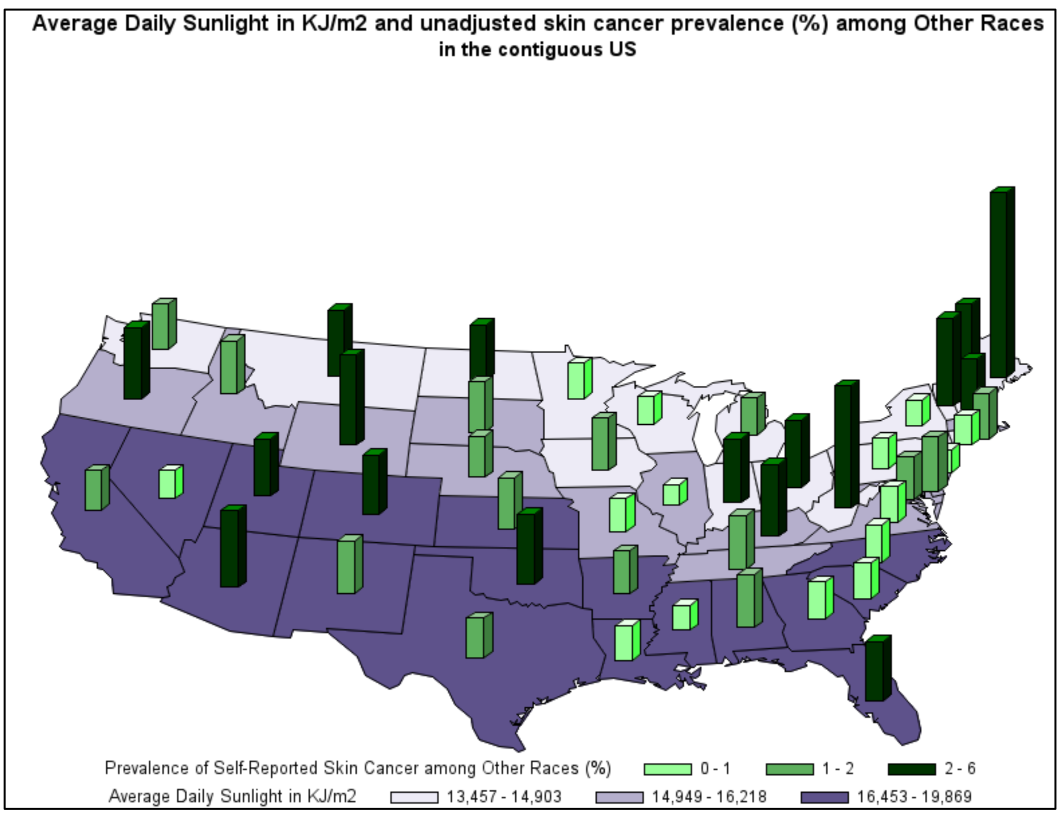

Figure 5: Unadjusted skin cancer prevalence (%) among respondents of all other races, BRFSS, 2014

Discussion

Using previous literature as a guideline, this study evaluated population-level data to provide additional evidence of associations between skin cancer prevalence and state-level sun exposure, demographic characteristics, and risk behaviors. This study found consistency with SEER data on melanoma (USDHHS, 2016) and existing literature on trends seen among types skin cancer (Hoejberg et al, 2015; Orkic et al., 2015; Perez-Gomez et al., 2004; Salvaggio et al., 2016), finding a history of all types of skin cancer to be most prevalent among men, those identifying as White, and those above age 65, with 6.05%, 8.51%, and 17.50% of the population, respectively. Notably, Whites had 17 times the odds of reporting a history of skin cancer when compared to Blacks, and those 65 years and older had 35 times the odds of reporting skin cancer history when compared with those younger than age 24. In many of the variables analyzed, adjusted odds ratios dropped, sometimes significantly, from the crude odds ratio, highlighting the strong influence that covariates like race and age have on the development of skin cancer.

This study is unique in that average daily sun exposure for each state was matched to individual skin cancer history in each state. As state-level sun exposure increased both continuously and categorically, the odds of reporting a history of skin cancer increased. When analyzed continuously, the odds of reporting history of skin cancer were 1.11 for each 1000 kJ/m^2 increase in exposure. When analyzed categorically, those who had high levels of exposure had 48% increased odds and those with medium exposure had 11% increased odds of reporting a history of skin cancer when compared to those with low levels of exposure. Additional testing from multilevel modeling found a significant but less impactful estimate for this relationship, showing as sun exposure increased, the odds of reporting a history of skin cancer increased by 6%. This modeling also found that 96% of variability in skin cancer history was accounted for by the individual as opposed to the state they reside in, and the probability of reporting a history of skin cancer varied considerably across states.

Interestingly, current smokers had a 4% reduced odds when compared with never smokers, and former smokers had 7% higher odds of reporting a history of skin cancer when compared to never smokers. Research by De Hertog et al. (2001) found a dose-response relationship between the number of cigarettes smoked and development of SCC, so former smokers in this study could represent those with the most lifetime exposure to cigarettes. Though temporality of diagnoses was not obtainable due to the nature of the survey, those who reported a history of skin cancer had 1.91 times the odds of reporting a history of having other types of cancer. This is consistent with previous research that showed associations among skin cancer diagnoses and other primary cancers, including lung, breast, and cervical cancers (Ong et al., 2014; Song et al., 2013; Bavinck, Plasmeijer, & Feltkamp, 2008; Shack, Jordan, Thomson, Mak, & Moller, 2008).

The race-adjusted prevalence map shows as sun exposure increases, prevalence of skin cancer among Whites increases, though this relationship is not seen among non-Whites. It provides additional evidence that those with fair skin are more likely to develop skin cancer in general; the lowest prevalence of skin cancer among Whites is 4.7% in North Dakota, whereas the highest prevalence among non-Whites is 5.8% in Maine, followed by 3.6% in West Virginia. This highlights the differences in skin cancer etiology between races, showing while sun exposure patterns may influence development of skin cancer among Whites, those of other races may develop skin cancer more commonly from other causes.

Strengths and Limitations

While this study shows consistency with previous research, there are several limitations to the study design and analysis. First, the BRFSS is a cross sectional study and only captures information from one point in time and in this study, so temporality and thus causality are not evaluable. Also, individuals were assigned to sun exposure in the state where they lived at the time of the survey. Skin cancer, like many other cancers, has a long latency period which could mean that most of a person's sun exposure occurred in a state other than the one where they took the survey. Additionally, county-level data for the BRFSS was unable to be obtained for this study so sun exposure was averaged for each state. While this provides a reasonable estimate for sun exposure for each individual living within a state, some states have large ranges of exposures. For example, levels of sun exposure in Oregon range from 13,779 kJ/m^2 to 17,490 kJ/m^2, a difference of 3,711 kJ/m^2. However some states, such as Delaware, have much less variability and there is only a 600 kJ/m^2 difference in exposure across the state. To address this issue, mixed modeling was performed and found approximately 4% of the variability in the skin cancer history is accounted for by the state itself however the probability of reporting skin cancer varies considerably across states.

Lastly, information bias could be a concern since people were asked to self-report a history of skin cancer. This could lead to both over- and under-reporting a previous diagnosis. Since BCC and SCC can be easily removed during a physician visit with very simple procedures, someone might not realize they are having a cancer taken off them. Conversely, someone could assume that just because they had a mole removed, it was skin cancer. However, due to the large overall sample size and high number of people who reported a history of skin cancer, it is unlikely that this self-report bias will have a large impact on the results.

Despite these limitations, the BRFSS does have many strengths, a significant one being that it provides data from a large, representative sample of US adults. Additionally, since most skin cancers are highly survivable, it is unlikely that survival bias was present in this data set, and those represented in this study should be representative of most people who develop skin cancer in the United States. Sun exposure is something that everyone experiences in some form, and the methodology used in this study accounts for sun exposure at the individual and state levels. Results showed that the probability of reporting a history of skin cancer varies considerably across states, however most of the factors that influence a person's history of skin cancer are on the individual-level rather than the state-level.

Policy and Practice Implications

This study adds to the growing body of evidence that shows skin cancer impacts Whites, males, and the older population most significantly. These populations may benefit from targeted prevention education and increased diligence from their physicians to reduce not only the incidence of skin cancer but also the cost to the medical system. Additionally, it provides evidence that increased UV exposure is associated with an increased history of skin cancer through several analytical techniques, especially among Whites in the South.

The SES indicators tested in this study may indicate gaps in receiving care for skin cancer. Those with health insurance had 63% increased odds of having a history of skin cancer, and as education level and income increases, odds of reporting a history of skin cancer increases as well. This indicates that people with better access to care, more money, and higher education are the ones who are receiving skin cancer diagnoses. Those with lower SES may not understand the risks and signs of skin cancer and thus do not or may not be able to prioritize it in their health care. Education on skin cancer from their physician, and increased awareness of this gap among health providers, may benefit those of lower SES who may be undertreated for this disease.

This study used veteran status as a proxy for occupational or military exposure to excess UV rays. Consistent with research done by Powers et al. (2015), veterans in this study had 1.30 times the odds of reporting a history of skin cancer when compared to non-veterans. This may be attributed to increased sun exposure while deployed and compounded by lack of motivation or resources to use barriers like sunscreen or protective clothing. This highlights a need for improved sun-safety education and implementation of policies in military and occupational settings that encourage and promote sun protective behaviors.

Future work in skin cancer should involve preventive efforts and promotion of sun safety education and behaviors to schools, community centers, and occupations settings. Sun exposure is preventable and reducing this, even in the presence of other behavioral risk factors, may reduce one's risk for developing skin cancer. Future generations will be at a higher risk of skin cancer due to climate change; with stratospheric ozone depletion, more UVA and UVB radiation will come through the atmosphere (Maxwell, 2014). Research has shown that younger children are more apt to adopt new practices, and early education can impact long-term behaviors (CDC, 2014; Townsend et al., 2011), so requiring schools to provide adequate shade and promote the use sunscreen may be able to impact the incidence of skin cancer for younger generations. Recreational centers such as parks, ski resorts, or stadiums should also adopt sun safety policies and provide sunscreen to customers. Lastly, those employed in occupational settings where sun exposure is common should be given education about their risk and access to sun protection.

One of the benefits to using BRFSS data to study skin cancer is that it provides data on all skin cancer, and not just melanoma. Melanoma currently serves as the only indicator for skin cancer in the US since BCC and SCC are not reportable cancers, though reporting rates are inconsistent between states and among physicians. Future research could use this population-level data to look at the impact on individual states and counties to inform policy in that state. Additionally, BRFSS county data is available with proper approval, so future research could further delve into the issue of SES through comparisons of skin cancer in rural and urban counties.

Conclusion

This study identified several demographic characteristics, risk behaviors, and geographic associations with skin cancer in the US, providing additional evidence to the growing body of research on what influences the development of skin cancer. There are large variations in skin cancer prevalence between states, and they are positively associated with increasing exposure to UV rays. Knowing what risk behaviors, occupational exposures, and demographic variables contribute to the increases in skin cancer prevalence across the US can help states and physicians identify at risk populations and target prevention and interventions.

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Figure 1
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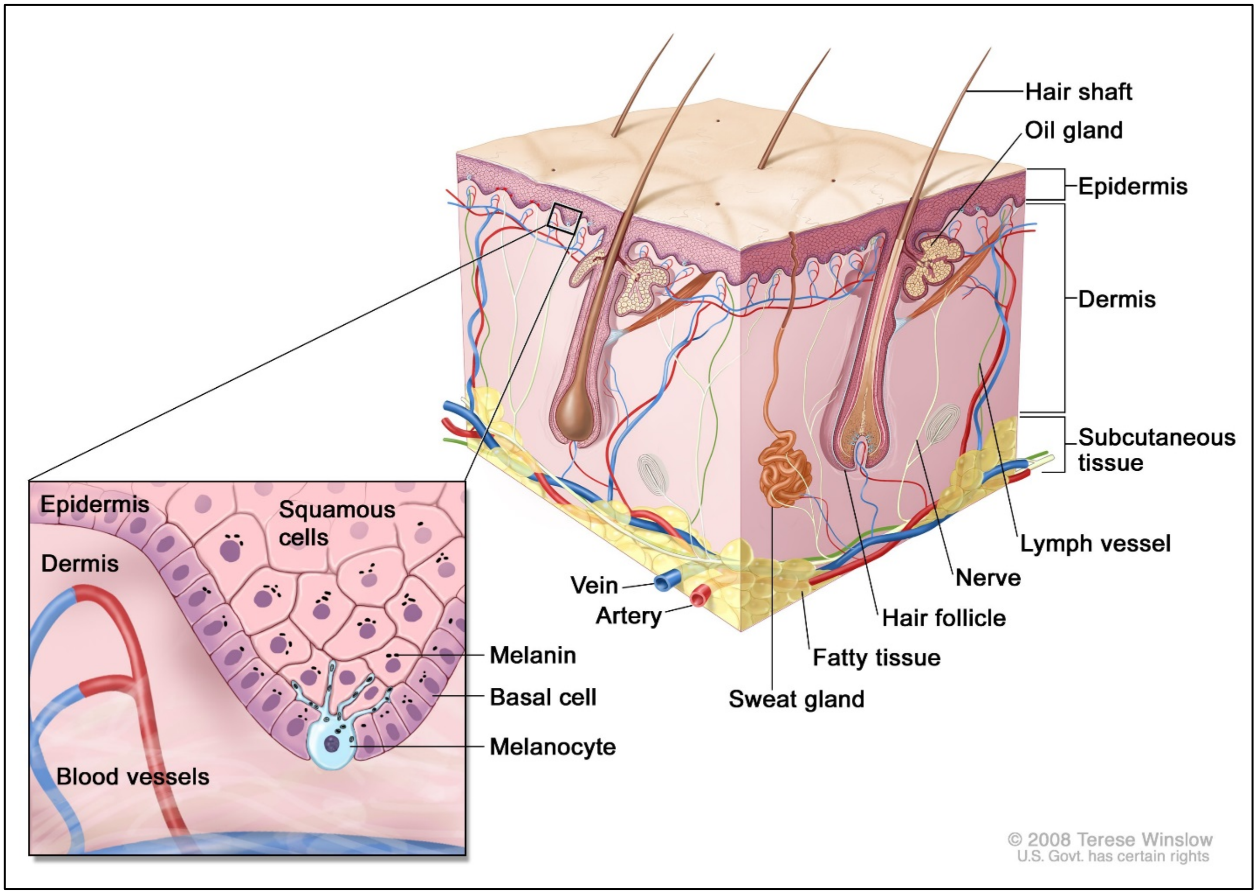
Appendix



Appendix Figure 1: Skin with Melanocyte Anatomy

Table 1: Crude and Age-Adjusted prevalence of all self-reported skin cancer by state, and stratified for Whites and Other Races, BRFSS 2014

State	Average Daily Sunlight (kJ/M2)	Crude Prevalence (%)	Age-Adjusted Prevalence (%)	Prevalence among Whites (%)	Prevalence among Non-Whites (%)
Alabama	16921.28	8.22	7.30	11.488	1.4315
Arizona	19869.21	8.31	7.40	12.477	2.1768
Arkansas	16494.09	6.55	5.70	8.3272	1.1494
California	19032.34	4.79	4.60	10.1071	1.0675
Colorado	17344.84	6.31	6.10	8.2572	1.6737
Connecticut	14902.9	5.80	4.90	7.9518	0.7539
Delaware	15693.66	2.91	5.80	9.5158	1.525

Table 1: Crude and Age-Adjusted prevalence of all self-reported skin cancer by state, and stratified for Whites and Other Races, BRFSS 2014

State	Average Daily Sunlight (kJ/M2)	Crude Prevalence (%)	Age-Adjusted Prevalence (%)	Prevalence among Whites (%)	Prevalence among Non-Whites (%)
District of Columbia	15265.36	6.74	3.10	5.618	1.1647
Florida	18515.04	8.85	7.00	14.2758	1.5893
Georgia	17227.59	6.36	6.20	10.6229	0.9527
Idaho	16014.62	7.08	6.50	8.1701	1.5221
Illinois	15046.53	4.22	3.90	6.3525	0.4594
Indiana	14862.75	5.56	5.00	6.4188	1.82
Iowa	14700.88	5.91	5.10	6.4646	1.4745
Kansas	16538.8	6.20	5.60	7.4842	1.4039
Kentucky	15211.45	7.66	6.80	8.5593	2.052
Louisiana	17520.24	5.02	4.70	7.6932	0.879
Maine	13888.87	6.91	5.60	6.9854	5.7969
Maryland	15489.89	4.88	4.50	8.3044	0.8897
Massachusetts	14948.91	6.29	5.60	7.7368	2.0453
Michigan	14325.79	5.84	5.00	7.3159	0.9972
Minnesota	14225.19	5.11	4.60	5.924	0.949
Mississippi	17030.67	5.67	5.10	9.1308	0.5879
Missouri	15595.46	5.98	5.20	7.1659	0.8487
Montana	14799.63	6.80	5.70	7.4776	1.9634
Nebraska	15699.7	5.74	5.20	6.6868	1.1093
Nevada	18178.95	6.33	5.80	11.0142	0.7019
New Hampshire	14132.25	6.29	5.40	6.6156	2.9773
New Jersey	15245.17	4.84	4.30	8.0704	0.5366
New Mexico	19152.1	5.22	4.60	10.5732	1.4316
New York	14259.11	4.07	3.70	6.7887	0.632
North Carolina	16452.81	6.62	6.00	9.5332	0.9765
North Dakota	14519.54	4.36	3.90	4.7495	1.604
Ohio	14567.14	6.03	5.20	7.0377	1.939
Oklahoma	17007.25	5.89	5.30	7.5273	1.9749

Table 1: Crude and Age-Adjusted prevalence of all self-reported skin cancer by state, and stratified for Whites and Other Races, BRFSS 2014

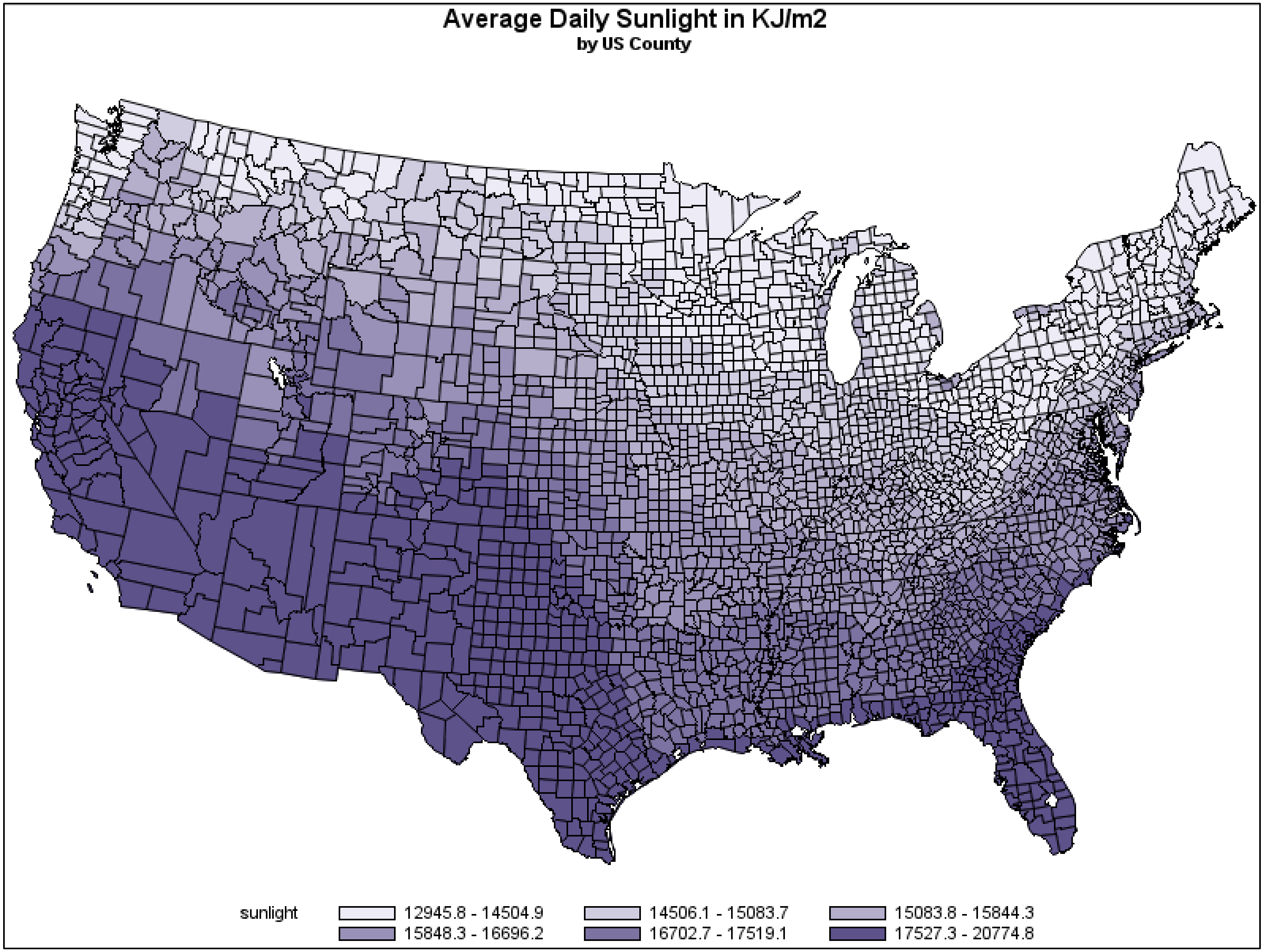
State	Average Daily Sunlight (kJ/M2)	Crude Prevalence (%)	Age-Adjusted Prevalence (%)	Prevalence among Whites (%)	Prevalence among Non-Whites (%)
Oregon	15618.75	7.37	6.40	8.7739	2.1158
Pennsylvania	14206.38	6.06	5.10	7.4833	0.7716
Rhode Island	15111.87	6.32	5.40	7.8974	1.2604
South Carolina	17323.88	7.16	6.30	10.5549	0.9208
South Dakota	15023.32	6.11	5.30	6.9022	1.428
Tennessee	15787.32	6.78	6.00	8.448	1.474
Texas	18155.28	4.62	4.70	8.9966	1.0071
Utah	17521.76	6.61	7.20	7.8594	1.6256
Vermont	13457.03	6.40	5.40	6.6911	2.6507
Virginia	15844.06	5.51	5.10	8.0717	0.9458
Washington	14472.9	5.81	5.30	7.5195	1.2692
West Virginia	14580.96	7.56	6.40	7.8555	3.6473
Wisconsin	14275.39	5.52	4.80	6.3971	0.7102
Wyoming	16217.66	7.45	6.80	8.3728	2.6877

Table 2: Age-Adjusted Incidence and Mortality rates among Whites in the US for melanoma only, CDC Wonder 2013

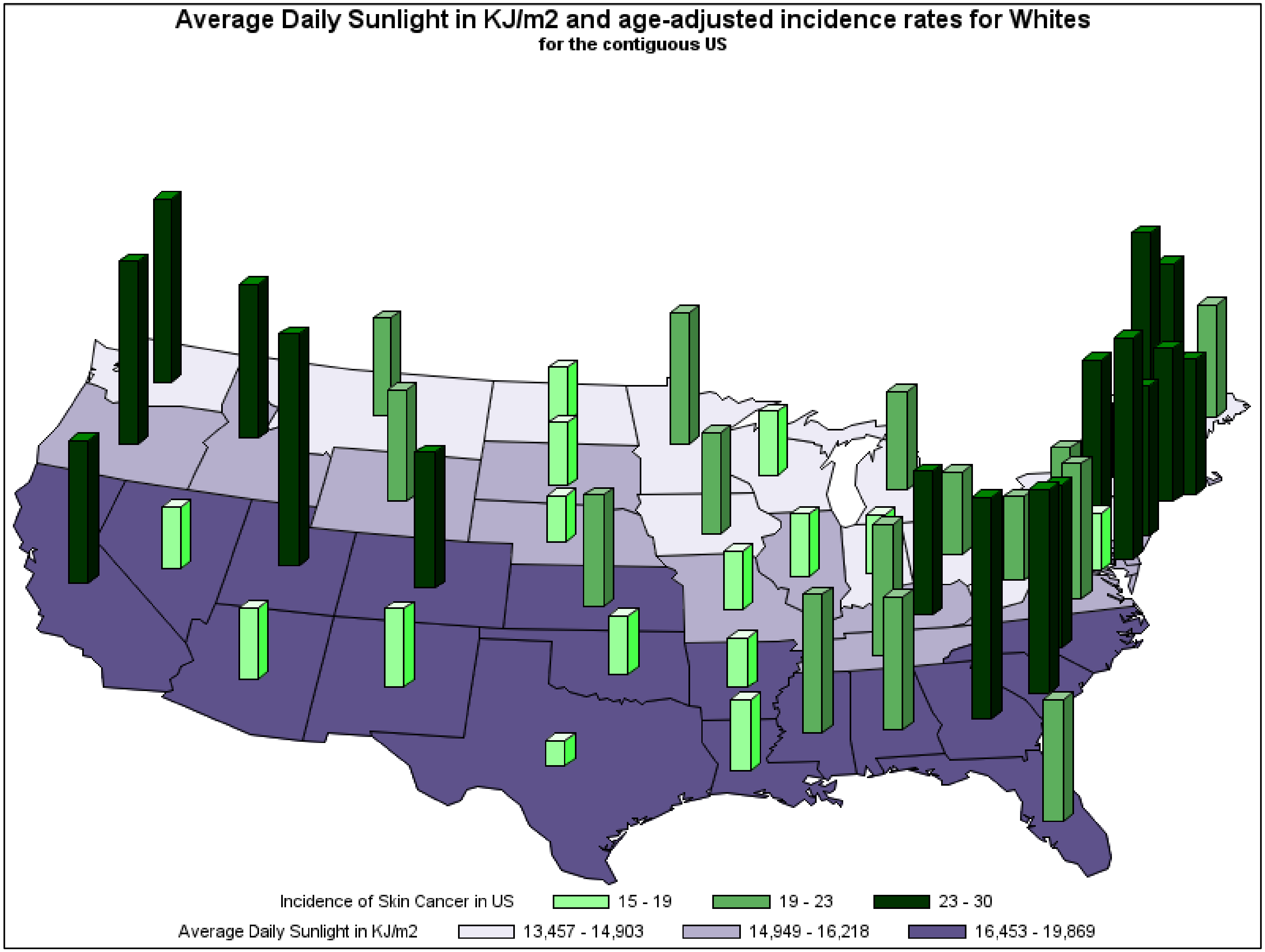
State	Average Daily Sunlight (kJ/M2)	Age-Adjusted Incidence Rate	Age-Adjusted Death Rate
Alabama	16921.28	22.6	3.4
Arizona	19869.21	18.4	3.1
Arkansas	16494.09	16.9	3
California	19032.34	23.6	3.1
Colorado	17344.84	23.1	3.3
Connecticut	14902.9	24.5	2.8
Delaware	15693.66	29.3	3.5
District of Columbia	15265.36	17.5	2.7
Florida	18515.04	21.7	3.3
Georgia	17227.59	28.8	3.3
Idaho	16014.62	24.7	3.4
Illinois	15046.53	17.9	2.8
Indiana	14862.75	17.6	3.1

Table 2: Age-Adjusted Incidence and Mortality rates among Whites in the US for melanoma only, CDC Wonder 2013

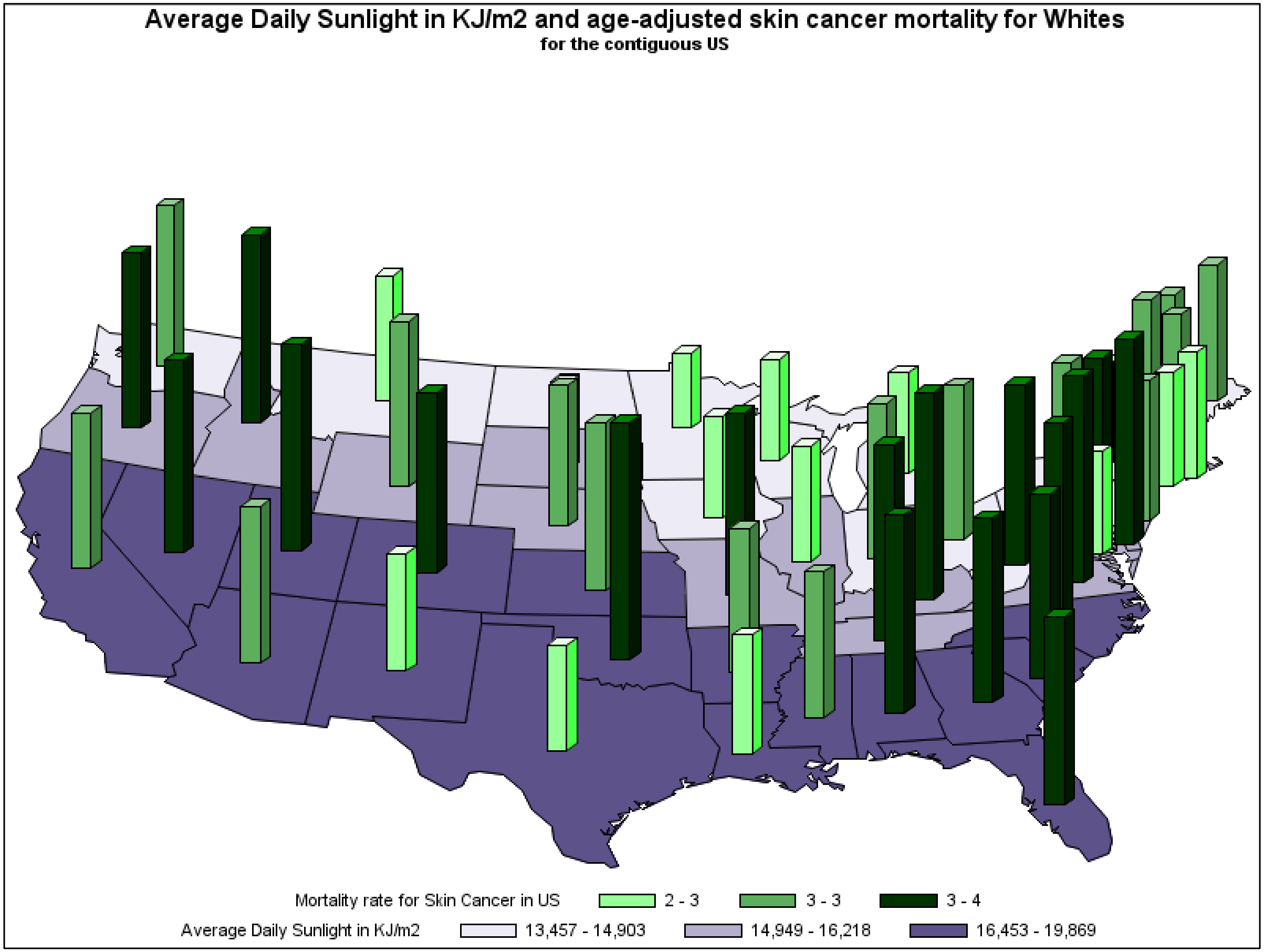
State	Average Daily Sunlight (kJ/M2)	Age-Adjusted Incidence Rate	Age-Adjusted Death Rate
Iowa	14700.88	20.7	2.7
Kansas	16538.8	21.3	3.2
Kentucky	15211.45	23.6	3.5
Louisiana	17520.24	18.3	2.8
Maine	13888.87	21.7	3
Maryland	15489.89	28.2	3.4
Massachusetts	14948.91	22.3	3.1
Michigan	14325.79	20.5	2.7
Minnesota	14225.19	23	2.5
Mississippi	17030.67	23	3
Missouri	15595.46	17.6	3.3
Montana	14799.63	20.6	2.9
Nebraska	15699.7	16.7	3
Nevada	18178.95	17.8	3.4
New Hampshire	14132.25	26.9	3
New Jersey	15245.17	24.2	3
New Mexico	19152.1	18.9	2.8
New York	14259.11	18.9	2.7
North Carolina	16452.81	24.9	3.5
North Dakota	14519.54	17.4	2.1
Ohio	14567.14	19.3	3.1
Oklahoma	17007.25	17.5	3.7
Oregon	15618.75	26.8	3.3
Pennsylvania	14206.38	19.4	3.1
Rhode Island	15111.87	23.2	2.9
South Carolina	17323.88	27.7	3.3
South Dakota	15023.32	18	2.6
Tennessee	15787.32	22.7	3.4
Texas	18155.28	15.2	2.7
Utah	17521.76	30	3.5
Vermont	13457.03	29.5	3
Virginia	15844.06	23	3.5
Washington	14472.9	27	3.2
West Virginia	14580.96	19.4	3.3
Wisconsin	14275.39	18.1	2.7
Wyoming	16217.66	21.5	3.2



Appendix Figure 2: Average levels of sunlight in kJ/m² by US county, NLDAS 2012



Appendix Figure 3: Age-adjusted incidence rate of Melanoma among Whites in the US, CDC Wonder 2013



Appendix Figure 4: Age-adjusted mortality rate of Melanoma among Whites in the US, CDC Wonder 2013