SUN SENSITIVITY AND SUN PROTECTIVE BEHAVIORS DURING SUN

EXPOSURE IN INDOOR OFFICE WORKERS IN THE MIDWESTERN UNITED

STATES

by

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ABSTRACT

Background: Sun exposure is strongly associated with skin cancer. Sun protection to reduce harmful effects of sun exposure, including skin cancer, is encouraged. However, sun sensitivity, a possible confounder of the association between sun exposure and sun protection, is often overlooked.

Objectives: This study examined how sun exposure and sun protection behaviors among indoor workers vary between sun sensitive and less sun sensitive individuals.

Methods: Diaries over 45 days (August and September of 2009) from indoor workers in the Midwest were examined. Diaries included daily sun exposure, sun protection, and sun sensitivity. Sun sensitivity was measured by determination of fair and non-fair complexion, categorized based on inability to tan and tendency to sunburn. Sun exposure was compared between fair and non-fair complexion. Total exposure (sunrise to sunset) was examined, along with exposure between 10 am and 4 pm, and long exposure between 10 am and 4 pm (at least 60 minutes). Percentages of time in the sun spent practicing sun protection were reported by study participants with fair and non-fair complexion. Logistic regression was used to determine odds ratios between fair complexion and mean sun exposure and mean sun protection times.

Results: Fair complexioned individuals spent less time in the sun than non-fair complexioned individuals. In addition, fair complexioned individuals spent greater percentages of time practicing sun protection behaviors while they were in the sun. They were more likely to practice sun protection behaviors related to sunscreen application and protective clothing, notably, wearing a long-sleeved shirt.

Conclusion: Fair complexioned individuals spend less time in the sun and practice more sun protective behaviors than non-fair complexioned individuals. These interrelations between sun sensitivity, sun protection and amount of sun exposure suggest that controlling for potential confounding when examining one of these factors and skin cancer may be challenging.

INTRODUCTION

Ultraviolet radiation (UVR) has been found to be strongly associated with skin cancer.[1,2] Solar UVR exposure is typically categorized as either chronic or intermittent.[3,4] Solar UVR is the main source of UVR exposure for most individuals.[3] Artificial UVR is a less common source of UVR exposure that is emitted from various lamps used in medicine, industry, research or for cosmetic purposes. The harmful effects of UVR can be reduced or prevented by practicing sun protection behaviors. Sun protection behaviors can be generalized to four strategies: reducing or eliminating deliberate tanning by artificial or natural UVR, avoiding intense UVR outdoor between 10 am and 4 pm, the practice of wearing protective clothing to cover exposed skin when in the sun and the application of broad-spectrum sunscreen with a sun protection factor (SPF) greater than 30 when in the sun.[5] The International Agency for Research on Cancer has suggested that more specific sun protection behaviors should include wearing tightly woven clothing covering the arms, torso and legs, wearing a hat that provides shade to the entire head, and seeking shade when outside whenever possible[6], which is similar to recommendations from other agencies such as the Centers for Disease Control and Prevention, United States Environmental Protection Agency, Occupational Health and Safety Administration and the Shade Foundation.[4,7] Both sun exposure and sun protection behaviors may vary by skin color and other measures of sun sensitivity.

Skin color can be objectively measured using narrow-band reflectance spectrophotometry using instruments such as colorimeters and spectrophotometers. Color is determined by

measuring the intensity of light of a particular wavelength that has been reflected off of a surface.[8] This technique measures erythema and melanin index values based on the differences in the absorption of red spectrum light by hemoglobin and green spectrum light by melanocytes that are present in the skin surface.[9]

When skin is exposed to both solar and artificial UVR, melanin, a pigment with protective effects against UVR DNA damage, is produced and the skin darkens, or tans.[10] However, individuals who have an inadequate amount of melanin production tend to develop little or no tan and instead develop a moderate to severe sunburn to the exposed skin areas when exposed to UVR. This difference in the reaction to UVR exposure or skin sensitivity to the sun, often referred to as sun sensitivity, has been studied by researchers and led to the development of sun sensitivity factors.

Sun sensitivity is typically measured through self-report of skin color, inability to tan and tendency to sunburn. These factors have been shown to be reliable.[11-14] Fitzpatrick skin type is a classification system typically used by dermatologists to determine risk.[15] Fitzpatrick skin types were initially proposed to classify Caucasian individuals into one of four categories (skin types I, II, III or IV) and later expanded to six categories to include darker skinned populations.[15] Dermatologist determined Fitzpatrick skin type is currently the gold standard measurement of sun sensitivity. Proxy measurements of sun sensitivity such as eye color, hair color and freckling tendency have also been linked to development of nevi and risk of melanoma, but may be less meaningful in mixed populations such as the United States.[16]

Sun sensitivity factors are risk factors for skin cancers.[17-19] People with lighter skin phenotypes (tendency to sunburn, inability to tan and light skin color) are more at risk of cutaneous malignant melanoma than people with other phenotypes.[20,21] Similar associations between lighter phenotypes and basal cell carcinoma possibly have been reported.[22-24] Additionally, sun sensitivity factors have been found to be associated with benign melanocytic nevi, which itself is associated with an increased risk of melanoma and generally thought to be a precursor lesion.[25,26]

Skin cancer is recognized as a major public health issue by *The Surgeon General's Call to Action to Prevent Skin Cancer.[4]* Sun protection behaviors are intended to reduce the harmful effects of sun exposure, mainly skin cancer. However, the associations between sun protection behaviors and skin cancer risk are not well understood due to complex confounding by sun sensitivity and amount of sun exposure. It is therefore important to understand the relationship between sun sensitivity, sun exposure and sun protection behaviors. In this study, the association between sun sensitivity and sun protection behaviors in a group of Caucasian indoor office workers is examined within the context of their overall sun exposure.

METHODS

Study Population

Adults were recruited from the University of Iowa in Iowa City, Iowa (latitude 41.66°N).
All participants were employed by the university in indoor office worker positions as
faculty or staff. One participant was found to be retired. Participants were restricted to
Fitzpatrick skin-type ranging from I to IV based on assessment by the principal
investigator using a colorimeter. Of these 50 participants, 44 who had recorded skin
color (via a colorimeter), sun sensitivity information and recorded sun exposure and sun
protection diary information during the analysis period (August 6, 2009 – September 19,
2009) were included. A screening questionnaire was administered to exclude individuals
who reported artificial UVR use during the prior month. During the study, participants
were not allowed to have artificial UVR exposure due to concerns that recent artificial
UVR would influence the melanin values in unexposed body locations. Recruitment was
conducted using a university listserv email. Approval to conduct the study was obtained
from the Institutional Review Board from the University of Iowa.

Monthly Visits and Monthly Diaries

Participants attended monthly in-person visits with study personnel. During these visits
skin color measurements (melanin and erythema) were taken at three locations (upper
inner arm, inner wrist, and outer forearm) and they were provided with dairies on sun
exposure and sun protection for the following month. During their subsequent visits,
diaries from the previous month were collected by study personnel and participants were

given diaries for the upcoming month to record their daily sun exposure and sun

protection. Appendix A displays an example of the diary given to participants to record

daily sun exposure and sun protection.

Sun Exposure

Participants were asked to record their daily UVR sun exposure as minutes of sun

exposure during peak UVR hours (between 10 am and 4 pm) and minutes of sun

exposure during non-peak UVR hours (before 10 am or after 4 pm). Total sun exposure

was determined by summing minutes of sun exposure between 10 am and 4 pm and

minutes of sun exposure before 10 am or after 4 pm. Mean time engaged in a sun

protection behavior was determined by calculating the average daily amount of time a

participant engaged in a sun protection behavior while in the sun.

Sun Protection Behaviors

Participants recorded their daily sunscreen application behaviors including: if

sunscreen(s) were applied, the SPF of the applied sunscreen(s), the amount of

sunscreen(s) applied, if they applied the sunscreen(s) at least 20 minutes prior to sun

exposure and if they reapplied their sunscreen(s) according to standard industry

application rules (every 2 hours after initial application). Participants were also asked to

record types of clothing worn during sun exposure. Clothing categories included hats,

shirts, pants, bathing suits and sunglasses.

Sunscreen application, clothing protection and wearing a brimmed hat were considered for sun protection behaviors. For sunscreen application, using at least one (1+) ounce of sunscreen for the day (the commonly estimated amount to cover the arms, legs, face and neck of an average sized adult body[27]) and use of SPF sunscreen of at least 30 (30+) were examined separately and together. The use of SPF sunscreen of at least 15 (15+) was also examined, since SPF 15+ is the SPF level recommended by the Food and Drug Administration to protect against sunburns and to reduce skin cancer risk and signs of early aging when used as directed with other measures of sun protection.[28] SPF 15+ is also a commonly recommended SPF rating by agencies such as the International Agency for Research on Cancer, Centers for Disease Control and Prevention and Environmental Protection Agency.[3] For clothing protection, wearing a long-sleeved shirt and wearing long pants were evaluated separately and together. Wearing a brimmed hat, defined as wearing a hat with at least a two inch brim all the way around, was examined.

Fair and Non-Fair Complexion Determination

Self-reported sun sensitivity information was obtained from the screening questionnaire that asked about tendency to sunburn, inability to tan, skin color (fair, medium or dark), hair color and eye color. Tendency to sunburn, after exposure to strong sunlight for an hour for the first time each spring or summer with no protection, had responses of severe, moderate, mild or no burn. Whereas inability to tan, after repeated and prolonged sun exposure, had responses of no tan, mild, moderate or deeply tan. Self-reported un-tanned skin color was classified as fair, medium and dark. Natural hair color at age 20 was

classified as blond, red, brown or black. Eye color was classified as blue, green, hazel or brown or black.

We stratified responses for tendency to sunburn by responses for inability to tan. Across these 16 combinations, we compared mean melanin values from a Cortex Technology DSM II Colorimeter (Hadsund, Denmark) (an objective measure of skin color).[29] The instrument provided melanin and erythema index values for these body sites. When comparing average melanin values to responses for tendency to sunburn and inability to tan, instead of seeing a clear pattern of four groups as defined by Fitzpatrick[15], in our population two distinct groups were seen. Based on this pattern, individuals with fair complexion were defined by self-report of tendency to sunburn, quantified as moderate or severe, and inability to tan, quantified as no tan or mild tanning. All other responses of inability to tan and tendency to sunburn were categorized as non-fair complexion.

Statistical Analysis

Individuals with fair complexion were compared to those with non-fair complexion. Three categories of minutes of sun exposure over 45 days are considered in the analysis: total sun exposure that occurs between sunrise and sunset, sun exposure that occurs between 10 am – 4 pm, and sun exposure 10 am – 4 pm for at least 60 (60+) minutes.

Logistic regression analyses were used to examine the associations between fair complexion and mean sun exposures and mean sun protection times for the three categories of sun exposure. Odds ratios (ORs) and 95% confidence intervals (CIs) were

determined using maximum likelihood estimates from the logistic regression analyses.[30]

For meaningful interpretations as sun protection behavioral modifications, ORs for mean

amount of sun exposure and mean times wearing a brimmed hat, wearing clothing

protection and applying sunscreen were calculated for increments of 10 minutes per day.

Age, gender, mean time spent protected by clothing, mean time spent wearing a brimmed

hat while in the sun and mean time in sun while using sunscreen were considered as

potential confounders. Confounders were determined by a 20% change in the OR of

interest and were included in the final adjusted model. All analyses were performed

using SAS version 9.4 (SAS Institute, Cary NC).

RESULTS

The 44 participants were Caucasian adults who ranged in age from 25 to 66 years and included 8 males and 36 females. For sun sensitivity classification, 16 participants were determined to have fair complexion and 28 to have non-fair complexion. All comparisons are between individuals with fair complexion to those without fair complexion. No differences were seen between those with fair complexion and those with non-fair complexion for female sex (p=0.69) or age (p=0.27) (Table 1) and there was no association between fair complexion and female sex (OR=1.91, 95% CI: 0.34, 10.82) or between fair complexion and age (OR= 0.97, 95% CI: 0.92, 1.02). The mean number of minutes described in Table 1 suggested a large portion of individuals in the sun between 10 and 4 pm were in the sun for an hour or more (greater than 80% of sun exposure 10 am – 4 pm is also sun exposure that lasts at least an hour).

Table 1. Characteristics of fair and non-fair complexion indoor office workers in the Midwest

	Fair (N=16)		Non-fair (N=28)		
	N *(%)*		N *(%)*		Fisher's exact test p-value
Gender					0.6895
Male	2 *(12.5)*		6 *(21.4)*		
Female	14 *(87.5)*		22 *(78.6)*		
	Mean (*sd*)	**Range**	**Mean (*sd*)**	**Range**	**t-test p-value**
Age (years) at time of entry into study*	40.8 *(11.91)*	[26, 60]	44.8 *(11.00)*	[25, 66]	0.2739
Daily average sun exposure (min/day) August 6, 2009 – September 19, 2009					
	Mean (*sd*)	**Range**	**Mean (*sd*)**	**Range**	
Total sun exposure**	60.94 *(46.6)*	[5.9, 188.4]	72.44 *(33.3)*	[18.9, 135.6]	
Sun exposure 10am - 4pm	28.05 *(22.3)*	[3.4, 93.3]	42.34 *(21.2)*	[10.4, 93.7]	
Sun exposure 10am - 4pm 60+ min***	23.28 *(22.1)*	[0, 88.7]	34.27 *(20.8)*	[2.7, 82.8]	

N= frequency; *(%)*= column percentage; *(sd)*= standard deviation; min= minutes.
* July 15, 2009 - August 6, 2009
** Sun exposure that occurs anytime between sunrise and sunset
*** Days with less than 60 minutes of sun exposure between 10 am – 4 pm set to zero minutes

Table 2: Prevalences and percentages of sun protection behaviors among fair and non-fair complexion indoor office workers in the Midwest over a 45-day period*

	All (N=44)	Fair (N=16)	Non-fair (N=28)
Prevalence of use more than 50% of time outside			
Wore long-sleeved top	2.2%	5.9%	0%
Wore long pants	26.1%	41.2%	17.2%
Wore long-sleeved top and long pants	2.2%	5.9%	0%
Wore hat with brim	2.2%	5.9%	0%
Applied 1+ oz sunscreen	8.7%	17.6%	3.4%
Applied sunscreen with SPF 15+	23.9%	35.3%	17.2%
Applied sunscreen with SPF 30+	10.9%	17.6%	6.9%
Applied 1+ oz sunscreen with SPF 30+	4.3%	11.8%	0%
Percentages per minutes spent outdoors			
Total sun exposure			
Average amount of sun exposure (hours/person) **	50.9	45.3	54.1
Time wore long-sleeved top	11.0%	19.8%	6.8%
Time wore long pants	29.3%	39.7%	24.4%
Time wore long-sleeved top and long pants	7.9%	14.8%	4.6%
Time wore hat with brim	3.5%	6.2%	2.2%
Applied 1+ oz sunscreen	17.0%	30.6%	10.4%
Applied sunscreen with SPF 15+	32.9%	47.9%	25.8%

Applied sunscreen with SPF 30+	20.3%	33.7%	13.9%
Applied 1+ oz sunscreen with SPF 30+	12.4%	23.7%	7.0%
Sun exposure 10am - 4pm			
Average amount of sun exposure (hours/person) **	27.7	20.9	31.6
Time wore long-sleeved top	8.4%	13.6%	8.2%
Time wore long pants	25.4%	33.7%	22.3%
Time wore long-sleeved top and long pants	6.1%	9.2%	5.0%
Time wore hat with brim	3.1%	5.4%	2.2%
Applied 1+ oz sunscreen	17.7%	35.7%	10.9%
Applied sunscreen with SPF 15+	33.3%	50.5%	26.8%
Applied sunscreen with SPF 30+	22.7%	39.7%	16.3%
Applied 1+ oz sunscreen with SPF 30+	13.6%	27.9%	8.2%
	All	**Fair**	**Non-fair**
	(N=43)	**(N=15)**	**(N=28)**
Sun exposure 10am - 4pm, ≥60 min*			
Average amount of sun exposure (hours/person) **	23.1	18.4	25.6
Time wore long-sleeved top	7.8%	15.6%	4.8%
Time wore long pants	21.5%	33.0%	17.1%
Time wore long-sleeved top and long pants	5.6%	10.9%	3.6%
Time wore hat with brim	3.1%	4.4%	2.5%
Applied 1+ oz sunscreen	20.1%	38.3%	13.1%
Applied sunscreen with SPF 15+	34.2%	50.6%	27.9%
Applied sunscreen with SPF 30+	25.4%	43.6%	18.4%
Applied 1+ oz sunscreen with SPF 30+	16.0%	32.5%	9.7%

N = number of participants; min = minutes; oz = ounce; SPF = sun protection factor.
* Minutes spent engaging in sun protection behavior per total minutes of sun exposure from August 6, 2009 - September 19, 2009
** Calculated as sum of hours of sun exposure / number of people with sun sensitivity type who had sun exposure
*** Days with less than 60 minutes of sun exposure between 10 am – 4 pm set to zero minutes

Table 2 describes the average amount of hours of sun exposure per person over the 45-day period. Percentages of sun exposure time spent engaging in sun protection behaviors for those with fair complexion were higher than those with non-fair complexion for all categories (Table 2). For total sun exposure during the 45 days, fair complexion individuals had a total of 43,499 minutes of sun exposure, averaging to 45.3 hours of exposure per individual. Non-fair complexion individuals had a total of 90,955 minutes of sun exposure, averaging to 50.9 hours of sun exposure per individual. For sun exposure between 10 am – 4 pm during the 45 days, fair complexion individuals had a

total of 20,061 minutes of sun exposure, averaging to 20.9 hours of exposure per individual; while non-fair complexion individuals had a total of 53,127 minutes of sun exposure, averaging to 31.6 hours of sun exposure per individual. Average hours of sun exposure for fair and non-fair complexion individuals for exposure 10 am – 4 pm for 60+ minutes are shown in Table 2. While non-fair complexion individuals on average had more sun exposure than fair complexion individuals, in general, fair complexion individuals spent a higher percentage of their sun exposure time practicing sun protection behaviors. The frequency of wearing long pants was greater than the frequency of wearing long-sleeved tops regardless of sun sensitivity. Wearing both long pants and a long-sleeved top had the lowest frequency of the measures of protective clothing. Wearing long-sleeved shirts had a stronger association with fair complexion than did wearing long pants. Wearing a long-sleeved shirt and long pants at the same time had an OR of similar magnitude as wearing a long-sleeved shirt (Table 3).

Sunscreen use during total sun exposure was more common among fair complexion individuals than non-fair complexion individuals. When considering use of 1+ ounces of sunscreen regardless of SPF, those with fair complexions spent 30.6% of time in the sun using sunscreen compared to 10.4% of the time in the sun for those with non-fair complexions. When considering use of SPF 30+ sunscreen regardless of amount of sunscreen, fair complexioned individuals spent 33.7% of time spent in sun using sunscreen versus 13.9% of the time in the sun for non-fair complexioned individuals. When considering use of 1+ ounces of 30+ SPF sunscreen, fair complexion individuals spent 23.7% of time in sun using sunscreen versus 7.0% of the time in sun for non-fair

complexioned individuals. Similar comparisons were seen for sunscreen use during 10

am – 4 pm. Use of SPF of 30+ was a more commonly used behavior than use of 1 +

ounces of sunscreen for both fair and non-fair complexion individuals.

Table 3: Odds ratios of fair complexion sun protection behaviors in the Midwestern United States, shown for 10 minutes per day with sun exposure

	Crude		Adjusted	
	OR	95% CI	OR	95% CI
Total sun exposure				
Mean amount of sun exposure	0.92	(0.77, 1.09)	0.69*	(0.50, 0.94)
Mean time wore long-sleeve top	1.44	(0.87, 2.34)	2.89**	(1.24, 6.73)
Mean time wore pants	1.17	(0.87, 1.58)		
Mean time wore long-sleeve top and pants	1.39	(0.81, 2.36)	1.99**	(1.02, 3.88)
Mean time wore hat with 2-inch brim	1.73	(0.60, 4.96)		
Mean time used 1+ oz sunscreen	1.15	(0.89, 1.50)		
Mean time used sunscreen with SPF 15+	1.08	(0.91, 1.29)		
Mean time used sunscreen with SPF 30+	1.14	(0.89, 1.46)	1.36**	(0.98, 1.87)
Mean time used 1+ oz sunscreen with SPF 30+	1.27	(0.76, 2.11)		
Sun exposure 10 am – 4 pm				
Mean amount of sun exposure	0.69	(0.48, 1.01)	0.46*	(0.25, 0.84)
Mean time wore long-sleeve top	1.28	(0.52, 3.15)	5.56**	(1.24, 24.97)
Mean time wore pants	1.00	(0.58, 1.73)	1.38**	(0.71, 2.71)
Mean time wore long-sleeve top and pants	1.12	(0.43, 2.91)	2.97**	(0.82, 10.75)
Mean time wore hat with 2-inch brim	1.75	(0.25, 12.33)		
Mean time used 1+ oz sunscreen	1.30	(0.80, 2.09)	2.27**	(1.16, 4.46)
Mean time used sunscreen with SPF 15+	1.08	(0.77, 1.54)	1.70**	(1.01, 2.85)
Mean time used sunscreen with SPF 30+	1.19	(0.79, 1.80)	2.06**	(1.12, 3.77)
Mean time used 1+ oz sunscreen with SPF 30+	1.26	(0.77, 2.06)	2.10**	(1.08, 4.10)
Sun exposure 10 am – 4 pm, ≥ 60 min				
Mean amount of sun exposure	0.76	(0.53, 1.07)	0.45*	(0.24, 0.84)
Mean time wore long-sleeve top	1.68	(0.56, 5.04)	10.25**	(1.24, 84.77)
Mean time wore pants	1.23	(0.64, 2.38)	1.85**	(0.82, 4.15)
Mean time wore long-sleeve top and pants	1.47	(0.49, 4.41)	4.17**	(0.89, 19.65)
Mean time wore hat with 2-inch brim	1.22	(0.14, 10.44)		
Mean time used 1+ oz sunscreen	1.26	(0.78, 2.02)	2.11**	(1.06, 4.19)
Mean time used sunscreen with SPF 15+	1.08	(0.74, 1.58)	1.74**	(0.96, 3.13)
Mean time used sunscreen with SPF 30+	1.19	(0.77, 1.84)	2.09**	(1.07, 4.06)
Mean time used 1+ oz sunscreen with SPF 30+	1.16	(0.85, 1.56)	2.03**	(1.03, 4.02)

OR= odds ratio; CI= confidence interval; yr= year; min= minute; oz= ounce; SPF= sun protection factor.
 * Adjusted for minutes of wearing long sleeve top
** Adjusted for minutes of sun exposure

Table 3 displays the association between sun sensitivity and sun protection behaviors. It describes that when fair complexion individuals are in the sun, they are more likely than those with non-fair complexions to have increased sun protection. Their higher levels of sun protection included spending less time in the sun, spending more time wearing protective clothing (long-sleeved shirt, long-sleeved shirt and pants together) and spending more time with sunscreen applied (using SPF 15+ or 30+, using 1+ ounce, using 1+ ounce of SPF 30+). Wearing a brimmed hat and wearing pants were not associated with fair complexion.

Individuals with fair complexion spent less time in the sun than non-fair individuals regardless of the definition/categories of sun exposure after adjustment for wearing a long-sleeved top. The magnitude of the ORs for sun exposure between 10 am – 4 pm and sun exposure 10 am – 4 pm that lasted 60+ minutes were greater than ORs for total sun exposure. ORs for fair complexion and sun exposure between 10 am – 4 pm (OR=0.46, 95% CI: 0.25, 0.84) and sun exposure 10 am – 4 pm for 60+ minutes (OR=0.45, 95% CI: 0.24, 0.84) had similar magnitudes showing less sun exposure among fair complexioned individuals than non-fair individuals.

Increased associations between fair complexion and wearing a long-sleeved top were seen after adjustment for amount of sun exposure. For wearing a long-sleeved top, ORs > 2.0 were seen for all categories of sun exposure (Table 3). ORs of similar magnitudes

for applying sunscreen with SPF 30+ were also seen for sun exposure between 10 am – 4 pm (OR=2.06, 95% CI: 1.12, 3.77) and sun exposure 10 am – 4 pm for 60+ minutes (OR=2.09, 1.07, 4.06). Increased associations between fair complexion and other sun protection behaviors (described in Table 3) were also seen. Notably, the OR of fair complexion individuals who use sunscreen with SPF 30+ was similar in magnitude as the OR to use 1+ ounce of SPF 30+.

DISCUSSION

Among Caucasian Midwestern indoor workers, compared to non-fair complexioned individuals, fair complexioned individuals spent less time in the sun and a higher percentage of time engaged in sun protection behaviors while in the sun, most noticeably sunscreen-related behaviors. In other words, individuals with greater sun sensitivity, who are at greater risk of skin cancer, more frequently practice sun protection when they are in the sun. These findings address a goal published by Surgeon General to support skin cancer prevention by contributing information to improve our understanding of skin cancer prevention.[4]

Previous studies have also found that indoor workers and sun sensitive individuals have less sun exposure. Two Danish studies found that those with Fitzpatrick skin type I were exposed to less sun exposure per day than those with skin type II, III and IV, in a general population[31] as well as indoor workers specifically[32]. This is consistent with our study findings of less sun exposure among fair complexioned indoor workers compared to non-fair indoor workers. As with our study, the participants of the two Danish studies were all Caucasian. Another study in Danish indoor workers examined sun exposure and found that subjects had greater sun exposure during holiday periods compared to working periods and greater exposure during holiday periods to Southern Europe compared to Northern Europe.[32] This would represent greater amounts of intermittent sun exposure. A Netherlands case-control study of melanoma patients and control patients (with non-melanoma malignancies) found that indoor workers and sun-sensitive individuals are

more likely to engage in indices of intermittent sun exposure (sunbathing, water sports, sunny vacations or have a history of sunburns).[33] However neither of the previously mentioned studies stratified indoor workers by sun sensitivity.[32,33]

Table 4: Prevalence of practice of sun protection behaviors among adults when in the sun for at least an hour compared to similar prevalence from the 2010 National Health Interview Survey

Description of prevalence	2010 NHIS* Non-Hispanic white adults (18+ years) who responded they used a sun protection behavior "most of the time" or "always) when in the sun for at least an hour	Our study Midwestern Caucasian adults (25+ years) who used a sun protection behavior at least 50% of the time they were in sun at least an hour	Our study Average minutes of sun exposure** during study period Midwestern Caucasian adults (25+ years) used a sun protection behavior
Sun protective apparel***	36.2%	39.1%	26.7%
Sunscreen (SPF 15+)	36.6%	28.3%	34.2%
Sunscreen (SPF 30+)	NA	17.6%	25.4%

*NHIS= National Health Interview Survey
** Sun exposure between 10 am - 4 pm for 60+ minutes
*** Brimmed hat and/or long pants and/or long skirt and/or long-sleeved shirt, our study did not record wearing long skirts

Our findings on sun protection behaviors support previous findings that the practice of sun protection behaviors is low among adults in general, but were higher among more sun sensitive individuals.[34-38] When comparing prevalence of sun protection behaviors of Caucasian adults from our study to results of non-Hispanic white adults from the 2010 National Health Interview Survey (NHIS) (Table 4), we find both similarities and differences. The 2010 NHIS reported that 36.6% of adults 18 years and older most of the

time or always applied sunscreen with SPF 15+ when outside on a sunny day for at least an hour.[34] In our study, 28.3% of participants reported applying sunscreen with SPF 15+ more than half the time (minutes) they were in the sun at least an hour, but during sun exposure subjects reported application for 34.2% of their sun exposure minutes. The 2010 NHIS reported that 36.2% of adults wore protective clothing (a wide brimmed hat and/or long sleeves and/or long pants and/or long skirt) when outside on a sunny day for at least an hour.[34] In our study, 39.1% wore protective clothing (by the same definition). There are several possible reasons why the results of our study differed from results of the 2010 NHIS. In our study, data was collected during the end of summer while the 2010 NHIS was conducted throughout the year. Our study described indoor workers from a specific Midwestern city, while the 2010 NHIS contained nationally aggregated data of individuals from various occupations. Also, the 2010 NHIS data is age adjusted to the 2000 United States standard population, while the data from our study has not been age adjusted. An earlier study observed a significant linear trend between sun sensitivity and sun protection behaviors, such that protection behaviors were greater among those with a higher tendency to sunburn[38], which is similar our study where prevalence of sun protection practice among fair complexion individuals were higher compared to non-fair complexion individuals.

In 2005, a study reported that 39% of Danish indoor workers used sunscreen at least 50% of the time when they were outside[31], which is greater than our findings, but similar to application of sunscreen with SPF 15+ among those with fair complexions (35.3% applied SPF 15+ more than half of the time in the sun). This difference may be because

the Danish indoor workers all were of Scandinavian ancestry. Blond hair, a measure of

greater sun sensitivity, can be found in the highest frequencies in Nordic countries.[39] A

study examining Danish individuals found that the most common pigmentary

characteristics for males and females were blond hair and blue eyes.[40] Fitzpatrick skin

type II has been found to be the most prevalent skin type among Danes and combined,

skin type I and II have been found to comprise over 50% of two different Danish study

populations.[23,40] The 2005 Danish study also found that Fitzpatrick skin types I and II

used sunscreen with a higher SPF than those of skin type III and IV.[31] Our study found

43.6% fair complexion individuals compared to 18.4% among non-fair complexion

individuals used sunscreen with SPF 30+ during sun exposure lasting at least 60 minutes

between 10 am – 4 pm.

Several studies have reported on the use of short term diaries to record sun exposure

and/or sun protection behaviors. These studies focus on research with recent sun

exposure defined as within the last day or week or within the last few weeks or months.

Such exposure includes summer sun exposure[41-43], occupational outdoor exposure[41,44],

sun exposure during sunny vacations[45,46] or the association between sun exposure and

vitamin D status[45,47,48]. Our study differs from these short term diary studies in several

ways. Other studies often supplement self-reports with use of personal UVR dosimeters,

which provide objective measurements of ambient UVR exposure. Several studies

assessing the relationship between self-reported and objective measurements of sun

exposure found statistically significant fair to moderate correlations.[49-51] This suggests

that our findings on sun exposure would not have been significantly different if personal

UVR dosimeters were used instead of self-reported sun exposure diaries. Also, our study period was longer than those of many other studies mentioned above. In our study six individuals were excluded due to failure to turn in one or both of the monthly diaries for the months of August and September. This loss to follow up may have resulted in information bias if the six individuals lost to follow up differed from the forty-four individuals included in the analysis. However, the six lost to follow up appeared to be similar in baseline characteristics to the 44 in our study. Of those lost to follow up, 83% had non-fair complexions, 17% had a fair complexion, 83% were female and 17% were male. Ages ranged from 30 to 52 years old, and the median age was 40 years with a standard deviation of 9.6 years.

In general, sun sensitive individuals have an increased risk of developing skin cancer. Results from several reviews and meta-analyses indicate that sun sensitive individuals have an increased risk of developing melanoma[52] and basal cell carcinoma.[17] When used properly, sun protection behaviors should reduce risk of skin cancers. The evidence between sun sensitivity and squamous cell carcinomas is not clear due to few published research studies in the area, but assumed to be similar. Studies examining sun exposure and different types of skin cancer have reported inconsistent associations. Evidence demonstrates that this association is stronger with squamous cell carcinoma[1,53] compared to melanoma and basal cell carcinoma.[19,54] The inconsistencies in reported associations may be due to the different types of sun exposure studied. Although increased melanoma risk due to intermittent exposure (sporadic and often in bursts of exposure) has been shown, no or inconsistent associations have been seen for chronic sun exposure (extended

and repeated exposure) and melanoma. However consistent positive associations between squamous cell carcinoma and total and chronic sun exposure have been seen[55,56], suggesting different patterns of sun exposure are important for different skin cancers.

In our study, the differences in amounts of sun exposure between participants with fair and non-fair complexions suggest that studies on skin cancer should consider sun sensitivity as an effect modifier or negative confounder of sun exposure, meaning that the observed association is attenuated. The implications of these observed differences were first described in an article published in 1988, when Armstrong[57] suggested a complex association of sun exposure interacting with sun sensitivity for risk of melanoma. His theory stated that because of their sun sensitivity, persons with sun sensitive skin tended to avoid sun exposure or protect themselves when in the sun. This would result in negative confounding between sun sensitivity and sun exposure, where a positive association between sun exposure and melanoma (unadjusted for sun sensitivity) may appear weaker than it actually is. Armstrong also suggested that darker complexioned individuals may appear to be minimally protected at low sun exposure levels but have risk of melanoma at higher sun exposure levels.[57] Future studies need to attempt to clarify the complex interactions between sun sensitivity and different patterns and amounts of UVR exposure.

Sun exposure intensity can vary depending on a number of factors, including the time of day and the time of the year. The intensity of ambient UVR at a specific place and time can be measured on a standardized scale of 0-11+ on a UV Index.[58] UVR is greatest

during the hours around midday and peaks during the spring and summer (April-August) due to the fact that the travel of UVR is greatly affected by the incident angle of sunlight.[58,59] Information from the National Weather Service's Climate Prediction Center indicate that in 2009 in Iowa City, UV Index readings ranged roughly from 6 (high) to 9 (very high) between August and September.[60] In our study, fair and non-fair complexion individuals spent a similar amount of their total sun exposure outside between the hours of 10 am and 4 pm, when the UV Index is highest. This suggests that even though they carry greater risk for sun exposure related skin cancer, fair complexion individuals are still being exposed to the same amount of high intensity sun exposure as non-fair complexion individuals.

The strengths of this study include the length of the study period and the many categories of sun protection behaviors collected via the diary. Other studies that have used sun exposure and sun protection diaries have collected information for periods of several days to a week.[41,42,45,46,48] The longer than average collection of sun exposure and sun protection information increases the chance that the behaviors recorded and averaged over the 45-day period are less influenced by extreme outlying behaviors. This study is also unique in the regard that a great variety of sun protection behaviors were recorded. Providing participants with the option to record different types of clothing protection (various shirts and pants) and sunscreen related behaviors allowed us to consider various measures of clothing protection and sunscreen application.

The main limitation of this study is a small sample size, similar to other studies of indoor workers.[32,44,46] The small sample size of our study restricted the categorization of individuals to only two levels of sun sensitivity (fair and non-fair complexion) rather than the four categories (I-IV) of Fitzpatrick skin type. As a result of the study's small sample size, we also could not divide sun exposure and sun protection behaviors into multiple categorical levels. Measurement error is always a concern in epidemiological studies. The use of daily diaries places a high burden on participants, so this is likely to have affected who participated. Detailed diaries can only be sustained over a relatively short period before subject compliance decreases, while less detailed diaries can be used for longer periods.[61,62] Types of clothing worn in the sun and whether the individual sought shade were recorded daily as either "yes" or "no". When used with the daily minutes of recorded sun exposure, the assumption was made that individuals engaged in each sun protection behavior for the full amount of recorded sun exposure, leading to some measurement error. The diary also lacked a method for recording the site of sunscreen application. For amounts 1+ ounce, the assumption could be made that sunscreen was applied to all exposed skin.[27]

The results from our study suggest that sun sensitivity is related to sun exposure and sun protection behaviors. The associations seen here and elsewhere suggest that when examining sun protection and skin cancer it is important to not only control for sun sensitivity but to also consider the amount of sun exposure as a possible confounder. Some studies of skin cancer and UVR or UVR protection are still not adjusting for strong measures of sun sensitivity. Even fewer studies adjust for amounts of sun exposure when

examining sun protection behaviors. The results of this study add to previous works that call for increasing the practice of effective sun protection behaviors, in particular around midday, among all individuals to meet the goals laid out by the Surgeon General to reduce the occurrence of skin cancer.

Vitamin D and Sun Exposure Study

		Monday 24-Aug	Tuesday 25-Aug	Wednesday 26-Aug	Thursday 27-Aug	Friday 28-Aug	Saturday 29-Aug	Sunday 30-Aug
UV Exposure								
Outdoor sun exposure:								
between 10 am- 4pm	minutes							
before10 am or after 4pm	minutes							
Sunscreen used while outdoors								
SPF level: ____								
SPF level: ____								
SPF level: ____	oz							
How much did you apply*								
applied >20 minutes before going out	Y/N							
re-applied at least every 2 hours	Y/N							
Clothing worn while in the sun								
Sun glasses								
Hat with at least 2 inch brim all around								
Hat - baseball cap								
Shirt-none/halter	shirt							
Shirt-sleeveless	shirt							
Shirt-short sleeves	shirt							
Shirt-3/4 sleeves	shirt							
Shirt-long sleeves	shirt							
Pants-shorts	shorts							
Pants-cropped (below knee)	pants							
Pants-long	pants							
Bathing suit- 1 piece/trunks								
Bathing suit- 2 piece								
While in the sun								
Did you seek shade?	Y/N							
Artificial UV tanning:	minutes							

* Sunscreen: 1 oz is a palmful is recommended to cover the arms, legs, face neck of an average adult

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