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ORIGINAL PAPER

Higher Ultraviolet Radiation Exposure Among Rural-Dwelling Versus Urban-Dwelling Adults and Children: Implications for Skin Cancer Prevention

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Abstract

Ultraviolet radiation (UVR) exposure is a primary risk factor for the development of melanoma. However, adults and adolescents often do not engage in preventive behaviors to reduce UVR exposure. Rural residents may be at higher risk for melanoma due to lower use of sun protection strategies, which increases their overall UVR exposure compared to those who live in urban areas. The purpose of this study was to evaluate differences in UVR exposure between rural and urban residents in a geographic area with high incidence of melanoma. Children (aged 8–17 years) and adults (≥ 18 years) from rural and urban areas of Utah were asked to wear a UVR monitoring device for 14 days. The sample included 97 children and 97 adults. Data was collected from June to October 2018. Non-parametric Mann–Whitney tests and quantile regression were used to compare UVR exposure levels between urban and rural participants, separately for adults and children. For adults, rural residence significantly increased total UVR dose (β: 24.6; 95% CI 3.75, 42.74) and the UVR dose during peak UVR hours among participants with the highest UVR doses (β: 16.3; 95% CI 17.4, 24.63). Rural children exhibited significantly higher UVR doses for peak UVR hours for the entire study period (β: 4.14; 95% CI 0.83, 7.46) and on weekdays (β: 0.39; 95% CI 0.05, 0.73). The findings from this study indicate that rural residents may receive higher levels of UVR exposure than urban residents, and that prevention efforts could be tailored to address these geographical differences.

Keywords Ultraviolet radiation exposure · Geographical health disparities · Melanoma prevention · Wearable technology

Introduction

Personal ultraviolet radiation (UVR) exposure is a primary modifiable risk factor for melanoma [1]. Reducing UVR exposure during childhood is especially critical because 25% of lifetime UVR exposure occurs during childhood, a key period of melanocyte development and susceptibility [2, 3]. However, adults and children often do not consistently use recommended sun protection methods aimed at reducing UVR exposure (e.g., wearing sunscreen and protective clothing), and subsequently receive sunburns, increasing their risk for melanoma [4–6].

UVR exposure may vary based on an individual's residential area (e.g., urban versus rural residence), due to differences in their engagement in sun protection methods and time spent outdoors. Adults living in rural areas report spending more time outdoors during peak UVR hours (10am–4 pm), less frequent shade-seeking and use of sunscreen, and subsequently experience increased sunburn

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occurrence compared to urban residents [7, 8]. A previous study conducted in Denmark employed wearable UVR monitoring devices and found that suburban children received the most UVR exposure when compared to urban and rural children, due to days spent abroad for vacation [9]. However, rural children had the highest UVR exposure on school days when compared to urban and suburban children [9]. Also, rural adolescents may spend more time outdoors and rural adults may be more likely to have an outdoor occupation, increasing their overall UVR exposure [10].

Given the potential differences in skin cancer prevention (e.g., wearing sunscreen) and risk factors for skin cancer (e.g., sunburn occurrence) between rural and urban adults and adolescents, it is important to objectively measure the amount of UVR exposure received by these two populations. The previous Denmark study focused their rural versus urban comparison on adolescents only. Although prevention in adolescents is critical, sunburn occurrence and high UVR exposure at all ages increases the risk for melanoma, making adults an important population to include in studies of UVR exposure [11]. The purpose of this study was to evaluate differences in UVR exposure between rural and urban residents in an area with high incidence of melanoma in the United States. Such studies are essential for guiding melanoma prevention efforts that could be tailored for individuals with differing patterns of UVR exposure and thus different risk factors for melanoma.

Methods

Study Sample

Participants were recruited from urban and rural areas of Utah, a state with high incidence of melanoma [12]. Study recruitment methods included flyer dissemination at health promotion and community events, distributing flyers in community settings (e.g., grocery stores, coffee shops, libraries), and mailing invitation letters to potential participants. An online marketing resource was used to obtain the addresses of potential participants living in rural and urban zip codes of Utah [13]. Home zip codes were used to categorize each residence as rural or urban based on Rural Urban Commuting Area (RUCA) code classification [14]. RUCA codes utilize census tract-based population estimates and work commuting information to assign census tracts and zip codes to 1 of 33 codes, which were then dichotomized to classify each zip code as urban versus rural [14].

Adults were eligible to participate in the study if (1) they were at least 18 years old, (2) were residents of Utah, (3) had at least one child aged 8–17 years who was willing to participate in the study, (4) did not have a personal history of melanoma, (5) did not have a pacemaker (due to the strong magnet in the UVR device), (6) had and were willing to use a smartphone, (7) were willing to download and use a free app that shared the UVR exposure data with the research team, and (8) were able to read and write in English. Children of eligible parents were eligible to participate if (1) they were 8 to 17 years old, (2) lived with a primary caretaker in Utah, (3) had no previous diagnosis of melanoma, and (4) did not have a pacemaker. Children were provided with a Bluetooth and Wi-Fi enabled smartphone to use during the study if they did not own one.

A total of 224 adults contacted the research team to express interest in participating in the study and of these, 150 were screened for eligibility (the remaining 74 individuals did not respond to further follow up by researchers and could not be screened). Of the adults who completed eligibility screening, 34 were ineligible. Reasons for ineligibility include not having children between the ages of 8 and 17 years old ($n=28$), parent not having a smartphone with Bluetooth and Wi-Fi ($n=5$), and unable to read English ($n=1$). Of the 116 eligible adults, seven did not participate and 12 were unable to participate due to a limited number of devices available for use within the context of this study. A total of 97 adults and 97 children ($n=194$) were enrolled in the study. Data were collected between June and October of 2018. All study procedures were approved by the University of Utah Institutional Review Board.

Study Procedures

All study participants were asked to wear a personal UVR monitoring device (i.e., Shade device) for 14 days during waking hours. We chose 14 days to include two work weeks and two weekends to accurately capture individuals' patterns of UVR exposure. The Shade device is both a dosimeter and radiometer capable of measuring instantaneous UV intensity and accumulated UV dose over time [15]. The device collects personal, time-stamped standard erythemal dose (SED), a standardized measure of UVR exposure [15], over the course of the day and reports accumulated SED every 6 min. The SED is a standardized measure of UVR exposure [15]. One SED is equivalent to radiant exposure of 100 J/m^2 and is independent of skin type [16]. The Shade device was integrated with a research app used for data collection and research purposes only. The Shade research app did not provide participants any information on their UVR exposure.

When participants expressed interest in enrolling in the study, consent/parental permission/assent forms were emailed to participants and the Shade devices were mailed to participants. Enrolled participants provided informed consent by phone. Research assistants reviewed instructions on how to use and care for the Shade devices. For example, participants were instructed to avoid getting the device wet, to sync the device to the Shade research app daily, and to

recharge their device at least every three days. Participants officially began their study activities the day after the phone call with research assistants.

During the 14-day study period, participants were asked to fill out a baseline questionnaire, daily questionnaires, and an exit questionnaire. The baseline questionnaire included items assessing demographic information [17]. The daily questionnaire assessed compliance to wearing the device, as well as the type and duration of outdoor activities performed.

Statistical Analysis

Analyses were conducted separately for adults and children as they have different UVR exposure patterns. Additionally, previous studies have analyzed UVR data for children and we strived to be able to compare our results to previous studies. Descriptive statistics were calculated to summarize participant demographic characteristics. Chi-square tests and Fisher exact tests were performed to compare demographic characteristics between rural and urban participants. Since we collected data from June until October, it was important to account for differences in children's UVR exposure due to whether they were in school at the time of their participation or not. For children, descriptive statistics were calculated for all days of the study period, days during summer break and days when school was in session. Children who started their study participation prior to school being in session were considered to have participated during summer break and children who started their study participation after school started were considered to have participated during the school year. For adults, descriptive statistics were only calculated for all days of the study period, peak UVR hours, week days and weekend days as their schedules, and therefore UVR exposure, is less likely to change due to the academic calendar. Mean and standard deviation were calculated for the number of days that adults and children reported wearing the device, as this data was normally distributed. Because the UVR data for adults and children were highly right-skewed with a few very large SED observations, median SED levels were calculated and non-parametric Mann–Whitney tests were used to compare UVR exposure between urban and rural participants. Quantile regression was used to compare UVR exposure in the 50th and 95th percentile (high SED observations) between rural and urban participants, while controlling for potential confounding variables. Based on previous literature and hypothesis testing of zip code elevation and occupation types between rural and urban residents, the appropriate potential confounders were adjusted for [2]. For adults, the potential confounders included were age, sex, race/ethnicity, income, education level, elevation of home zip code, occupation (outdoor vs. indoor vs. in a motor vehicle), and seasonality (month of participation). For children, potential confounders that were included were age, sex, race/ethnicity, elevation home zip code, seasonality (month of participation) and school enrollment status (school year vs. summer break). All statistical analyses were conducted using Stata version 15 (College Station, TX) [18].

Results

A total of 97 adults and 97 children ($n = 194$ individuals) participated in the study. Of the adults, 87.4% were non-Hispanic White ($n = 83$), 5.3% were Hispanic ($n = 5$), and 76.8% were female ($n = 73$; Table 1). The average age of participating children was 12.7 years (SD = 2.6), 85.3% were non-Hispanic White ($n = 81$), 8.4% were Hispanic ($n = 8$), and 58.9% were female ($n = 56$; Table 1). Fifty-seven percent ($n = 56$ families) of participants resided in urban zip codes and 42% ($n = 41$ families) resided in rural zip codes. Urban adults were more likely to be female and have higher educational attainment compared to rural adults ($p < 0.05$). Rural adults were more likely to work outdoors or in a motor vehicle compared to urban adults ($p < 0.05$). Rural children were older than urban children ($p < 0.05$). Parents reported wearing the Shade device for an average of 12.7 days (SD = 2.5) out of the desired 14 days and children reported wearing their device for an average of 12.2 days (SD = 3.0).

Adults' UVR Exposure

The median exposure per day for adults was 0.45 SED, with over 55% of that exposure (0.25 SED) gained during peak UVR hours (10 am–4 pm; see Table 2). The median UVR exposure on weekend days was 0.47 SED and was 0.45 SED on weekdays. There was no significant difference between median UVR exposure per day for rural adults (0.57 SED) and urban adults (0.44 SED; $p = 0.499$). Rural adults accumulated a median of 7.68 SED during the entire study period compared to a median of 5.73 SED among urban adults, however these are not significantly different. Area of residence (rural versus urban) was not significantly related to UVR exposure per day, UVR during peak hours per day, nor UVR exposure on weekend days at the 50th or 95th percentile when adjusted for confounders (Table 3).

At the 95th percentile for adult's UVR exposure, accumulated UVR exposure for the entire study period was significantly higher (24.6 SED) among rural adults than urban adults, after adjusting for potential confounders. Accumulated UVR exposure during peak UV hours (10am-4 pm) for the entire study period was significantly higher (16.3 SED) for rural adults than urban adults at the 95th percentile after adjusting for potential confounders (Table 3).

Table 1 Demographic characteristics of study participants

	Total sample ($n=97$)	Urban ($n=56$)	Rural ($n=41$)	p value
Adults	n (%)*	n (%)*	n (%)*	
Age (M, SD)	41.6 (6.3)	41.8 (6.1)	41.3 (6.6)	0.513
Sex				
Male	22 (23.1)	9 (16.1)	13 (33.3)	0.050
Female	73 (76.8)	47 (83.9)	26 (66.7)	
Marital status				
Married or marriage-like relationship	84 (88.4)	53 (94.6)	31 (75.6)	0.090
Divorced or separated	9 (9.5)	2 (3.6)	7 (17.1)	
Widowed	2 (2.1)	1 (1.8)	1 (2.6)	
Level of education				
High school graduate or GED	8 (8.4)	0 (0)	8 (20.5)	< 0.001
Vocational or technical school	8 (8.4)	2 (3.6)	6 (15.4)	
Some college, including 2 years degree	33 (34.7)	18 (32.1)	15 (38.5)	
Bachelor's degree	25 (26.3)	18 (32.1)	7 (17.9)	
Master's degree or doctoral degree	21 (22.1)	18 (32.1)	3 (7.7)	
Race				
Non-Hispanic white	83 (87.4)	46 (82.1)	37 (94.9)	0.180
Hispanic	5 (5.3)	4 (7.1)	1 (2.6)	
Asian or Asian American	5 (5.3)	5 (8.9)	0 (0)	
Other	2 (2.1)	1 (1.8)	1 (2.6)	
Family income				
< $60,000	30 (31.6)	13 (23.2)	17 (43.6)	0.089
≥ $60,000	57 (60.0)	38 (67.9)	19 (48.7)	
I would rather not report this	8 (8.4)	5 (8.9)	3 (7.7)	
Occupation environment				
Mainly indoors	82 (86.3)	53 (95.6)	29 (74.4)	0.003
Mainly outdoors	9 (9.47)	1 (1.79)	8 (20.5)	
In a motor vehicle	3 (3.16)	1 (1.79)	2 (5.13)	
Children	($n=97$)	($n=56$)	($n=41$)	
Age (M, SD)	12.7 (2.7)	12 (2.6)	13.7 (2.3)	0.037
Sex				
Male	39 (41.1)	24 (42.9)	15 (38.5)	0.500
Female	56 (58.9)	32 (57.1)	24 (61.5)	
Race/ethnicity				
Non-Hispanic white	81 (85.3)	44 (78.6)	37 (94.9)	0.092
Hispanic	8 (8.4)	7 (12.5)	1 (2.6)	
Asian or Asian American	4 (4.2)	4 (7.1)	0 (0)	
Other	2 (2.1)	1 (1.8)	1 (2.6)	

*n and % reported for demographic variables unless otherwise noted

Children's' UVR Exposure

The median UVR exposure per day for all children was 0.29 SED. The median UVR exposure per day for all children during the school year was 0.39 SED and 0.28 SED during summer break. The median UVR exposure during peak UVR hours for all days of the study period for the total child population was 0.26 SED on days during the school year, and 0.12 SED for days during summer break. On weekend days, the median UVR was 0.28 for all study days, 0.29 SED during the school year and 0.23 SED during summer break. The median UVR on weekdays was similar (0.40 SED for all weekdays, 0.41 SED on weekdays during school, and 0.40 SED on weekdays during summer break). The median UVR exposure for all children can be found in Table 4.

The median UVR exposure per day was 0.25 SED for rural children and rural children accumulated a median of 7.79 SED over the entire study period. Urban children had a median UVR exposure of 0.33 per day and accumulated 7.71 SED over the entire study period (Table 4). On weekdays,

Table 2 UVR exposure among adults and by rural and urban residence

UVR exposure (SED)	Total median (range)	Urban median (range)	Rural median (range)	*p* value
Per day (overall)	0.45 (0.01, 4.73)	0.45 (0.01, 2.16)	0.57 (0.02, 4.73)	0.499
Entire study period	9.98 (0.11, 58.61)	9.35 (0.57, 41.63)	10.1 (0.11, 58.61)	0.551
Peak UVR hours (per day)	0.25 (0.0, 3.29)	0.23 (0.0, 1.48)	0.27 (0.01, 3.29)	0.545
Peak UVR hours (entire study period)	6.36 (0.03, 41.53)	5.73 (0.44, 27.62)	7.69 (0.03, 41.53)	0.570
Weekday (per day)	0.45 (0.01, 4.95)	0.41 (0.01, 2.16)	0.56 (0.01, 4.95)	0.515
Weekend day (per day)	0.47 (0.01, 8.45)	0.47 (0.01, 5.53)	0.45 (0.01, 8.45)	0.464

Peak UVR hours: 10–4 pm

SED standard erythemal dose

Table 3 Quantile regression results for comparison of UVR exposure between rural and urban adults at the 50th and 95th percentiles

UVR exposure (SED)	Unadjusted model Median percentile (CI)	Adjusted model[b] Median percentile (CI)	Unadjusted model 95th percentile (CI)	Adjusted model[b] 95th percentile (CI)
Per day (overall)	0.12 (−0.16, 0.41)	0.07 (−0.36, 0.48)	2.01 (−0.69, 4.01)	0.93 (−0.86, 1.55)
Entire study period	0.75 (−5.18, 5.32)	9.20 (−3.61, 22.01)	20.50 (−2.27, 43.22)	24.6 (3.75, 42.74)*
Peak UVR hours (per day)	0.04 (−0.13, 0.22)	0.01 (−0.33, 0.34)	0.84 (−0.98, 2.66)	0.05 (−1.19, 1.30)
Peak UVR hours (entire study period)	1.96 (−2.49, 5.44)	4.08 (−5.08, 13.21)	14.6 (4.91, 24.2)*	16.3 (17.4, 24.63)*
Weekday (per day)	0.15 (−0.09, 0.40)	0.21 (−0.45, 0.98)	1.71 (0.33, 3.08)*	0.06 (−1.28, 0.97)
Weekend day (per day)	−0.02 (−0.33, 0.29)	−0.17 (−0.93, 0.34)	2.44 (−3.17,8.06)	1.21 (−1.51, 3.61)

Peak UVR hours: 10 am–4 pm

SED standard erythemal dose

[a]Reference category for all models is urban geographic location

[b]Models were adjusted for age, sex, race/ethnicity, education level, income, occupation, elevation and seasonality

*Significance at $p < 0.05$

urban children recorded a median of 0.27 SED while rural children recorded 0.47 SED, however, this was not significantly different. On weekend days, urban children recorded a median of 0.29 SED while rural children recoded 0.21 SED, although not significantly different.

The median UVR exposure for rural and urban children participating during their summer break and once school started can be found in Table 4. For children participating during their summer break, the median UVR dose per day was 0.29 SED among urban children and 0.22 SED among rural children. During summer break, urban children accumulated 8.21 SED across the study period, while rural children accumulated 13.6 SED. For children attending school during their study participation, the median UVR dose per day was 0.39 SED for urban children and 0.25 SED for rural children. On weekdays during school, rural children recorded a UVR exposure of 0.44 SED per day and 0.31 during peak UVR hours on those days. In contrast, on weekdays during the school year, urban children recorded 0.31 SED per day and 0.28 during peak UVR hours (Table 4). The unadjusted median UVR exposure between urban and rural children were not significantly different.

Rural versus urban residence among children did not significantly affect UVR dose per day, UVR dose during peak hours per day, nor UVR exposure on weekend days at the 50th or 95th percentile when adjusting for potential confounders (Table 4). The median (50th percentile) UVR exposure during peak UVR hours for the entire study period was significantly higher (4.14 SED) among rural children than urban children when adjusted for potential confounders (Table 5). The median UVR exposure per day on weekdays was also significantly higher (0.39 SED) for rural children than urban children when adjusting for potential confounders (Table 5). The UVR dose for the entire study period was significantly higher (17.2 SED) among rural children at the 95th percentile compared to urban children when adjusted for potential confounders.

Discussion

The current study assessed UVR exposure levels among adults and children in a geographic area with high incidence of melanoma and compared UVR exposure between

Table 4 Differences in UVR exposure between rural and urban children

UVR exposure (SED)	Total median (range)	Urban median (range)	Rural median (range)	*p* value
Per day (overall)				
All days	0.29 (0.02, 3.54)	0.33 (0.01, 1.89)	0.25 (0.002, 3.54)	0.918
Summer break	0.28 (0.03, 1.89)	0.29 (0.01, 1.89)	0.22 (0.002, 1.74)	0.900
School year	0.39 (0.01, 3.54)	0.39 (0.02, 1.68)	0.25 (0.01, 3.54)	0.962
Entire study period				
All days	7.71 (0.04, 38.31)	7.71 (0.04, 30.22)	7.79 (0.08, 38.31)	0.266
Summer break	8.48 (0.08, 38.31)	8.21 (0.24, 30.22)	13.6 (0.08, 38.31)	0.436
School year	7.57 (0.04, 37.51)	7.47 (0.04, 26.52)	7.57 (0.70, 37.51)	0.208
Peak UVR hours (per day)				
All days	0.15 (0.0, 3.05)	0.16 (0.0, 1.43)	0.15 (0.0, 3.05)	0.813
Summer break	0.12 (0.0, 1.26)	0.13 (0.01, 1.26)	0.08 (0.0, 0.69)	0.421
School year	0.26 (0.0, 3.04)	0.31 (0.0, 1.43)	0.20 (0.0, 3.04)	0.886
Peak UVR hours (entire study period)				
All days	4.85 (0.0, 32.51)	4.75 (0.0, 24.31)	5.71 (0.02, 32.51)	0.256
Summer break	4.78 (0.03, 25.21)	3.72 (0.05, 23.12)	10.5 (0.02, 25.21)	0.580
School year	4.89 (0.0, 32.51)	5.19 (0.0, 24.31)	4.89 (0.54, 32.51)	0.342
Weekday (per day)				
All days	0.40 (0.01, 8.99)	0.27 (0.01, 1.89)	0.47 (0.01, 8.99)	0.196
Summer break	0.40 (0.01, 8.99)	0.27 (0.01, 1.89)	0.67 (0.01, 8.99)	0.218
School year	0.41 (0.02, 3.58)	0.28 (0.02, 1.71)	0.44 (0.017, 3.58)	0.476
Weekend day (per day)				
All days	0.28 (0.01, 5.46)	0.29 (0.01, 5.45)	0.21 (0.01, 5.46)	0.278
Summer break	0.23 (0.01, 5.45)	0.23 (0.03, 5.45)	0.23 (0.01, 1.49)	0.578
School year	0.29 (0.01, 5.46)	0.54 (0.01, 1.90)	0.21 (0.01, 5.46)	0.240
Peak UVR hours (weekdays)				
All days	0.24 (0.0, 8.44)	0.21 (0.0, 1.57)	0.32 (0.0, 8.44)	0.201
Summer break	0.19 (0.0, 8.44)	0.18 (0.0, 1.14)	0.36 (0.0, 8.44)	0.458
School year	0.26 (0.0, 2.45)	0.25 (0.0, 1.57)	0.31 (0.0, 2.45)	0.618
Peak UVR hours (weekend days)				
All days	0.20 (0.01, 5.76)	0.23 (0.01, 2.09)	0.13 (0.01, 5.75)	0.193
Summer break	0.15 (0.01, 1.86)	0.15 (0.01, 1.86)	0.12 (0.01, 1.44)	0.472
School year	0.25 (0.01, 5.75)	0.38 (0.01, 2.09)	0.16 (0.01, 5.75)	0.098

Peak UVR hours: 10 am–4 pm

SED standard erythemal dose

participants living in rural and urban areas. On average, adults and children living in rural areas had higher total objectively-measured UVR exposure at the highest levels of exposure (95th percentile) compared to urban adults and children. Also, rural children accumulated significantly more UVR exposure during the entire study period and during peak UVR hours.

The differences in UVR exposure between rural and urban adults were most apparent at the highest levels of UVR exposure (95th percentile). Rural adult participants in this study were more likely to work outdoors or in a motor vehicle (compared to indoors), which may explain higher mid-day sun exposure dose and high levels of total UVR exposure among rural adults at the 95th percentile. These higher UVR doses could also be due to the type of outdoor activities (e.g., outdoor chores, outdoor recreational activities) and attitudinal factors (e.g., feeling more attractive when tan) that may differ between rural and urban residents. For instance, a previous study that included individuals between ages 4 and 68 found that the highest levels of UVR exposure were obtained by individuals who worked outdoors, gardened, golfed and those who enjoy being in the sun [19]. Future studies focused on adults could explore the role of occupational UVR exposure in UVR exposure differences between rural and urban populations. For the prevention of harmful occupational UVR exposure, it may be beneficial to quantify the amount of UVR exposure typically observed among individuals with different occupations

Table 5 Quantile regression results for the comparison of UVR exposure between rural and urban children at the 50th and 95th percentile

UVR exposure (SED)	Median (50th) percentile		95th percentile	
	Unadjusted model (CI)	Adjusted model (CI)[b]	Unadjusted model (CI)	Adjusted model (CI)[b]
Per day (overall)	−0.08 (−0.41, 0.25)	0.14 (−0.28, 0.56)	0.13 (−1.51, 1.78)	0.17 (−1.54, 1.89)
Entire study period	0.09 (−4.79, 5.27)	5.35 (−3.12, 13.81)	1.62 (−8.43, 11.62)	17.16 (2.44, 31.92)*
Peak UVR hours (per day)	−0.01 (−0.17, 0.16)	0.07 (−0.16, 0.30)	−0.14 (−1.85, 1.56)	0.05 (−0.98, 1.09)
Peak UVR hours (entire study period)	0.96 (−2.74, 5.66)	4.14 (0.83, 7.46)*	−1.99 (−15.12, 11.13)	9.70 (−8.15, 27.51)
Weekday (per day)	0.19 (−0.15, 0.54)	0.39 (0.05, 0.73)*	1.69 (−3.16, 6.55)	2.86 (−2.89, 8.63)
Weekend day (per day)	−0.08 (−0.34, 0.19)	0.05 (−0.49, 0.59)	0.74 (−3.05, 4.53)	1.55 (−0.85, 3.95)

Peak UVR hours: 10 am–4 pm

SED standard erythemal dose

[a]Reference category for all models is urban geographic area

[b]Models were adjusted for age, sex, race/ethnicity, elevation and seasonality

*Significance is p value < 0.05

to identify those at highest risk for developing melanoma and consequently target melanoma prevention efforts and screening towards higher risk occupations.

Similar to the pattern observed for adults, rural–urban differences in UVR exposure existed for the highest levels of exposure (95th percentile) for children. Additionally, children also exhibited rural and urban differences in the median UVR exposure levels on weekdays and during peak UVR hours for the entire study period. Higher UVR exposure among rural children compared to urban children may be due to differences in activity types between rural and urban children. For example, previous studies have found that rural adolescents report spending more time after school and during weekdays completing outdoor chores compared to urban adolescents who reported spending more time engaging in organized sports [20, 21]. Completing outdoor chores may result in spending more time outdoors compared to those participating in organized sports which could be held at times of day with lower UVR exposure levels or occur indoors, reducing UVR exposure. Future studies could examine the types of outdoor activities that are associated with higher UVR exposure. Prevention interventions could be tailored to include information on and strategies for protecting skin during these different types of activities that may vary between rural and urban children. For example, interventions targeting children living in rural areas could include strategies for reducing UVR exposure during activities that may be more common in rural areas (e.g., outdoor chores, ranching, or rodeo).

It is important to note the higher UVR exposure among rural children compared to urban children on weekdays, consistent with previous findings [9, 22]. While some of this exposure may be gained outside of school hours, it is likely that rural students receive more UVR exposure while they are at school compared to urban children. Given that students spend approximately 180 days a year in school, schools may be an effective venue in which to both disseminate melanoma prevention educational materials and to facilitate students in engaging in preventive behaviors [23]. In line with the goals of the U.S. Surgeon General's Call to Action to Prevent Skin Cancer, schools could provide students with shade structures and promote the use of sun protection methods (e.g., applying sunscreen, wearing hats) while outdoors at school as a way to reduce their UVR exposure during the school day [23].

Overall, the UVR exposure of the entire study population varied greatly. For example, for all adults the median UVR exposure per day varied from 0.01 SED to 4.73 SED. Previous studies have found that for individuals with fair skin,1–2 SED is enough to produce a sunburn [24]. This is concerning for the individuals who consistently record daily doses of above 1 SED, as they are most at risk for developing sunburns if not properly engaging in preventive behaviors. Future interventions using UVR wearable devices may benefit from educating individuals on what their UVR dose means and how that relates to their skin type and their subsequent individual risk for melanoma.

The current study has several strengths and limitations worth noting. Strengths of this study are the inclusion of an adult population, which has not been examined in prior studies examining geographical differences in UVR exposure in the US. Other strengths include the use of objective UVR measurement via a sensitive UV wearable device, and the use of a well-established categorization for rural versus urban residence [15]. Limitations of this study include the limited time period of UVR monitoring, which precluded assessment of longer term patterns of UVR exposure. Future studies could benefit from recruiting a larger sample of participants, with equal numbers from rural and urban areas, to evaluate other predictors (e.g., occupation, activity types) of UVR exposure within rural and urban populations. Future studies may benefit from examining potential differences in

amount of time spent outdoors between individuals in rural and urban areas that may account for the different patterns in UV exposure observed. Another limitation of this study includes the use of a study sample from a single geographic area, with a large proportion of Non-Hispanic White individuals, which may make the results less generalizable to other parts of the US. Future studies could include a racially and ethnically diverse, multi-state sample.

Conclusion

This study was among the first to compare objectively measured UVR exposure between rural and urban children and adults in the US. The differences in UVR exposure should be further examined as they relate to sociodemographic (e.g., age, sex, income), behavioral (e.g., activity types, use of sun protection), and attitudinal (e.g., perceptions of tanness) factors. The use of an objective and accurate method for UVR monitoring has great potential for quantifying the amount of UVR exposure among different populations and could be used in future melanoma prevention interventions to help reduce UVR exposure.

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