Environmental Cues to UV Radiation and Personal Sun Protection in Outdoor Winter Recreation

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Objective: To predict the prevalence of UV radiation (hereinafter, UV) at North American ski resorts using temporal, seasonal, altitudinal, and meteorological factors and associate UV with a set of adult sun protection behaviors.

Design: Ultraviolet radiation observations and cross-sectional survey of adults on sun protection were collected.

Setting: Data were collected at 32 high-altitude ski areas located in western North America from 2001 through 2003.

Participants: The sample consisted of 3937 adult skiers or snowboarders.

Main Outcome Measures: Measurements of direct, reflected, and diffuse UV were performed at 487 measurement points using handheld meters and combined with self-reported and observed sun protection assessed for adults interviewed on chairlifts.

Results: The strongest predictors of UV were temporal proximity to noon, deviation from winter solstice, and clear skies. By contrast, altitude and latitude had more modest associations with UV and temperature had a small positive relationship with UV. Guest sun safety was inconsistently associated with UV: UV was positively related to adults wearing more sunscreen, reapplying it after 2 hours, and wearing protective eyewear, but fewer adults exhibited many of the other sun protection behaviors, such as wearing hats and protective clothing or using lip balm, on days when UV was elevated. Guests took more sun safety precautions on clear-sky days but took steps to maintain body warmth on inclement days.

Conclusions: In future sun safety promotions, adults should be encouraged to wear sunscreen on cloudy days because UV is still high and conditions can change rapidly. They need reminders to rely more on season and time of day when judging UV and the need for sun safety.

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In the cloudier, humid weather of the European Alps, UV radiation increases 24% per 1000 m or 7% per 1000 feet. One study found that UV increased up to 19% for each 1000 m, or about 5% for each 1000 feet, and another reported that UV increased 10% per vertical kilometer. Regardless of the exact increase in UV, studies all show that altitude, clear air, and reflected UV from snow make the alpine environment dangerous.

The present study investigated the association of meteorological, temporal, and geographic variables with UV levels and with decisions by adults in outdoor recreation to protect their skin from UV to provide databased recommendations for outdoor recreation and sun safety campaigns. Accordingly, the following research questions (RQs) and hypotheses (H1) were posited:

- **RQ1:** How much UV exists at recreational ski areas?
- **RQ2:** Is UV positively associated with increased sun protection by adults recreating at ski areas?
- **RQ3:** Are meteorological, temporal, or environmental cues associated with elevated UV positively related to sun protection by adults recreating at ski areas?

Skin damage increases when UV is elevated and more sun protection is needed, but people cannot directly perceive UV, so they need to rely on environmental cues to determine when UV is elevated and sun protection is necessary. Thus, we pose 2 more RQs regarding the association of UV and environmental characteristics on sun protection:

- **RQ2:** Is UV positively associated with increased sun protection (ie, sunscreen and lip balm use, head covering, goggles/sunglasses, and protective clothing) by adults recreating at ski areas (ie, alpine skiers and snowboarders)?
- **RQ3:** Are meteorological, temporal, or environmental cues associated with elevated UV positively related to sun protection by adults recreating at ski areas?

**METHODS**

Over a 3-year period (2001-2003), data were collected at 32 ski areas, located in Alaska, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, and Washington, and British Columbia, Canada, that were members of the National Ski Areas Association (NSAA) and had at least 1 chairlift. The areas varied in size, management, ticket prices, and demographics and were located between 34° N and 61° N latitude and at altitudes ranging from 76.2 to 4158.4 m.

Ultraviolet radiation was measured by project staff as part of a study evaluating a sun protection program, Go Sun Smart (GSS), which sought to improve sun protection by ski area employees and guests. The main trial, in 2001 and 2002, involved 26 ski areas in a pair-matched group-randomized pretest-posttest quasi-experimental evaluation design. In 2003, 6 additional ski areas served as a second control group for a crossover design. Ultraviolet radiation was measured with reliable and valid handheld Optix Tech SunSafe meters (Washington, DC). Optix Tech reported that SafeSun meter equipment was tested by the US Environmental Protection Agency's SunWise program, the World Radiation Center in Switzerland, and the Australian Radiation Laboratory, and tests demonstrated the accuracy of SafeSun UV meters compared with professional UV metering equipment. Data collectors measured UV at prescheduled times each day. Ultraviolet radiation measurements were taken during each 3-day period at each area by the data collector, who recorded direct UV by holding the meter facing the sun, diffuse UV by holding the meter toward the sky away from the sun, and reflected UV by holding the meter toward the snowy slope away from the sun. Data collectors repeated these readings resulting in 6 UV observations (2 direct, 2 diffuse, and 2 reflected) at each time. Test-retest data for the 3 observations were highly reliable ($r=0.97$ for direct UV, $r=0.94$ for diffuse UV, $r=0.91$ for reflected UV). The correlations among the 6 UV measures during each data collection period ranged from 0.80 to 0.97 (Table 1).

<table>
<thead>
<tr>
<th>Type of UV</th>
<th>Mean (SD)</th>
<th>Maximum</th>
<th>Correlation Between Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>2.63 (2.21)</td>
<td>10.0</td>
<td>0.97</td>
</tr>
<tr>
<td>Diffuse</td>
<td>1.84 (1.52)</td>
<td>8.0</td>
<td>0.94</td>
</tr>
<tr>
<td>Reflect</td>
<td>1.49 (1.31)</td>
<td>9.5</td>
<td>0.90</td>
</tr>
<tr>
<td>Total</td>
<td>1.99 (1.62)</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1. Average Direct, Diffuse, and Reflected UV as Measured in UV Index Units**

*The 2 readings taken at each measurement were averaged prior to calculating mean reading; total UV is the mean of all 6 readings at each measurement (n=1487 measurement points).*

Data on sun protection behaviors by 3937 adult guests at 30 of the ski areas, measured in 2001, 2002, and 2003, were used to evaluate RQ2 and RQ3. Consistent with industry demographics, 96% of guests in the present study were white, 4% were classified as other, while 4% of these groups were Hispanic, 67% were college graduates, and 73% were male. This sample was limited to guests interviewed at ski areas not using GSS (ie, all ski areas pretested in the main trial in 2001 and 2003) and ski area randomized to the no-treatment control condition in 2002 and 2003. Interviews were conducted from January to April in 2001 (n=2991; 99.3% completion rate; 0.7% refused to participate [n=23]), 2002 (n=1846; 98.8% completion rate; 1.2% refused to participate [n=24]), and 2003 (n=265; 99.6% completion rate; 0.4% refused to participate [n=11]). A total of 308 guests (n=203 in 2001; n=103 in 2002; n=2 in 2003) were ineligible (they were <18 years [n=49], employed by the ski venue [n=175], had been previously interviewed [n=71], or were non-English speaking [n=13]). Samples varied from 50 to 359 participants at each area owing to the number of guests on the mountain. The subsample of guests that was analyzed included those interviewed on days in which UV readings were recorded (n=2282 in 2001, n=1420 in 2002, and n=235 in 2003).

Guests were interviewed face-to-face on each chairlift during 3-day data collection visits (1 weekend day, 2 weekdays) at each ski area. After boarding, interviewers provide a consent statement. Interviewers recruited the person immediately next to them (if seated in the middle, the person to the right). If the guest refused to participate or was ineligible, another guest on the chairlift was recruited. Only 1 interview was completed per ride.

Sun protection was assessed on chairlifts by asking guests about sunscreen (yes/no or don’t know; sun protection factor [SPF]; where it was worn, time first applied, and reapplied) and sunscreen lip balm (yes/no or don’t know; SPF). Interviewers observed guests’ head cover, neck cover, face cover, gloves, sunscreens, and goggles, and ski or snowboard equipment. An overall sun protection score was obtained by summing sunscreen with at least SPF 15, lip balm with at least SPF 15, goggles, gloves, face cover, neck cover, and head cover (range, 0-7). Interviewers recorded time and date, weather (1, sunny; 2, partly cloudy; 3, cloudy), and temperature (in degrees Fahrenheit), and asked guests whether they were snowboarding or skiing.
the time they started skiing/snowboarding (hour:minute). Proximity to noon was defined as the minutes between when the guest started skiing and noon. The interview date was used to obtain the deviation from winter solstice by counting the days since December 20. Latitude (minutes:seconds) and altitude (in feet) of the ski areas were obtained from area records.

Other questions measured guest demographics, skin sun sensitivity, snow sport expertise (self-reported beginner, intermediate, or expert skier/snowboarder), and number of days spent skiing/snowboarding during that winter. Interviewers also recorded precipitation through direct observation. Protocols were reviewed by the institutional review boards at the participating research organizations and approved as exempt under 4CFR 46.101 (b)(2).

Hypothesis 1 was tested with multiple regression using SAS PROC MIXED statistical software (SAS Inc, Cary, North Carolina). Ultraviolet radiation readings were nested within ski area, so variance was adjusted by including a random ski area effect in the model. Total UV (the mean of 6 measurements) was regressed on altitude, latitude, temporal proximity to noon, deviation from winter solstice, cloud cover, and temperature. Except for cloud cover, all other predictors and mean UV were normalized (0,1).

To test the relationship between UV and sun protection behavior (RQ2), each behavior was regressed separately on total UV in a univariate model. In addition, the composite sun protection score was regressed separately on total UV. Individual-level covariates were included in the model (ie, variables significantly correlated with outcomes and retained in backward stepwise regressions). Thus, each outcome had a unique set of covariates. Covariates were age, education, sex, race, skin sun sensitivity, ability level, days skied that winter, local vs destination skier, and type of equipment (ski vs snowboard). Total UV was standardized, and a random ski area effect was included. For ease of interpretation, SAS PROC MIXED software was used for all guest outcomes, which was justified because clusters (ie, guests per area) were large (minimum, 33, maximum, 463). For RQ3, each sun protection behavior was regressed separately on the 6 environmental cues. Variables (excluding cloud cover) were standardized, significant covariates were included (identified through backward stepwise regression), and a random ski area effect was modeled. To test if the effects of environmental cues on sun protection behaviors differ by sex, age, education, and skin sun sensitivity, regression analyses were repeated to include all 4 demographic variables as moderators (ie, regressed on interactions of environmental cues with demographic variables).

RESULTS

UV INDEX AT SKI AREAS: RQ1

As expected in winter, average UV levels at the 32 ski areas were moderately low but showed substantial variation, with the maximum levels recorded being a standard US Environmental Protection Agency UV Index of 10 for direct UV (Table 1). Direct UV was highest on average, but diffuse and reflected UV levels were still substantial by comparison (70% and 57% that of direct UV).

ENVIRONMENTAL CHARACTERISTICS ASSOCIATED WITH HIGH UV: H1

Hypothesis 1, which predicted that UV levels at ski areas would be associated with temporal, geographic, and meteorological environmental characteristics, including deviation from the winter solstice, temporal proximity to noon, higher altitude, lower latitude, and clear skies, was supported in a regression analysis for all environmental variables (Table 2). The strongest predictors were temporal proximity to noon, deviation from the winter solstice, and clear skies. By contrast, altitude and latitude had more modest associations with UV levels. Although not included in the hypothesis, temperature had a small positive relationship with UV level.

ASSOCIATION OF UV LEVEL WITH SUN PROTECTION BEHAVIORS: RQ2

Sun protection behaviors did not consistently increase when UV levels were elevated (Table 3). As UV increased, guests were more likely to report wearing sunscreen with an SPF of at least 15, more likely to reapply it after 2 hours, and more likely to wear goggles/sunglasses. The positive relationship of UV to sunscreen use was more characteristic of males (slope = 0.05) than females (slope = 0.01; UV × sex F1,352 = 4.31; P = .04). Fewer guests engaged in other sun protection behaviors (head covering and covering over their ears, neck, and face) on days when UV was high. Overall sun protection, measured by summing all sun protection behaviors, was negatively related to UV. Use of sunscreen lip balm, application of sunscreen 30 minutes prior to starting skiing, wearing a head cover with a brim, and wearing gloves were unrelated to UV levels. Use of a head covering with a brim was positively associated with UV for males (slope = 0.02) and negatively associated with UV for females (slope = −0.03; UV × sex F1,352 = 11.98; P < .001).

ASSOCIATION OF ENVIRONMENTAL CUES WITH SUN PROTECTION BEHAVIORS: RQ3

Guests at ski areas made decisions about using sun-protective behaviors in 2 ways, one related to clear skies and sun protection and the other related to inclement weather and cold protection (Table 4). For sun protection, more individuals wore sunscreen, reapplied it after 2 hours, and wore sunscreen lip balm when skies were

Table 2. Results of Multiple Regression of Total UV on Environmental Cues

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Regression Coefficient</th>
<th>Least Squares Means for Cloud Cover</th>
<th>Fb</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>0.137</td>
<td>4.78</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>Latitude</td>
<td>−0.168</td>
<td>4.50</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>Temporal proximity to noon</td>
<td>−0.346</td>
<td>94.14</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Deviation from winter solstice</td>
<td>0.414</td>
<td>78.58</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Cloud covera</td>
<td>Clear, 0.401</td>
<td>Partly cloudy, 0.041</td>
<td>69.58</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cloudy, 0.664</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature, °F</td>
<td>0.164</td>
<td>15.90</td>
<td>&lt;.001</td>
<td></td>
</tr>
</tbody>
</table>

a All variables except cloud cover were standardized N(0,1) prior to analysis. 
b The df = 2276 for cloud cover; 1276 for all others. 
c Low numbers meant closer proximity to noon. 
d Cloud cover was coded as 1, clear sky; 2, partly cloudy; 3, cloudy.
### Table 3. Univariate Association of Total UV and Each Separate Sun Protection Behavior and a Composite Behavior Score

<table>
<thead>
<tr>
<th>Sun Protection Behavior</th>
<th>Factors for Which Regression Coefficient Results Were Adjusted</th>
<th>Regression Coefficient</th>
<th>F</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunscreen</td>
<td>Age, education, sex, skin sun-sensitivity, local vs destination guest</td>
<td>0.048</td>
<td>23.31</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Sunscreen lip balm</td>
<td>Education, sex, skin sun-sensitivity, local vs destination guest, ability level</td>
<td>0.013</td>
<td>1.94</td>
<td>.16</td>
</tr>
<tr>
<td>Apply sunscreen 30 min prior to starting skiing/snowboarding</td>
<td>Age, sex, skin sun-sensitivity, local vs destination guest</td>
<td>-0.020</td>
<td>3.76</td>
<td>.05</td>
</tr>
<tr>
<td>Reapplied sunscreen after 2 h</td>
<td>Local vs destination guest</td>
<td>0.054</td>
<td>23.93</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Goggles/sunglasses</td>
<td>Skin sun-sensitivity, ability level, days skied/snowboarded this season</td>
<td>0.015</td>
<td>8.98</td>
<td>.003</td>
</tr>
<tr>
<td>Head cover</td>
<td>Days skied/snowboarded this season</td>
<td>-0.018</td>
<td>6.95</td>
<td>.01</td>
</tr>
<tr>
<td>Brim on head cover</td>
<td>Age, sex, skin sun-sensitivity, equipment</td>
<td>0.0026</td>
<td>1.43</td>
<td>.23</td>
</tr>
<tr>
<td>Ears covered</td>
<td>Sex, skin sun-sensitivity, days skied/snowboarded this season, and/or equipment</td>
<td>-0.022</td>
<td>8.49</td>
<td>.004</td>
</tr>
<tr>
<td>Neck covered</td>
<td>Age sex, skin sun-sensitivity</td>
<td>-0.082</td>
<td>63.23</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Face covered</td>
<td>Sex, skin sun-sensitivity, local vs destination guest</td>
<td>-0.044</td>
<td>46.14</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gloves</td>
<td>Local vs destination guest</td>
<td>-0.007</td>
<td>2.79</td>
<td>.10</td>
</tr>
<tr>
<td>Overall sun protection</td>
<td>Age, education, sex, skin sun-sensitivity, local vs destination guest, ability level, and/or equipment</td>
<td>-0.078</td>
<td>9.61</td>
<td>.002</td>
</tr>
</tbody>
</table>

Note: Those who were interviewed within 2 hours of first applying sunscreen were removed from analysis.

### Table 4. Results of Multivariate Regression of Sun Protection Behaviors on Environmental Cues

<table>
<thead>
<tr>
<th>Sun Protection Behavior</th>
<th>Factors for Which Results Were Adjusted</th>
<th>Altitude</th>
<th>Latitude</th>
<th>Temporal Proximity to Noon</th>
<th>Deviation From Winter Solstice</th>
<th>Cloud Cover</th>
<th>Temperature, °F</th>
<th>Start Time Deviation From Noon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunscreen</td>
<td>Age, education, sex, skin sun-sensitivity, local vs destination guest</td>
<td>-0.003</td>
<td>-0.080</td>
<td>-0.015</td>
<td>0.024</td>
<td>Clear, 0.533</td>
<td>partly cloudy, 0.428</td>
<td>0.09</td>
</tr>
<tr>
<td>Sunscreen lip balm</td>
<td>Education, sex, skin sun-sensitivity, local vs destination guest, ability level</td>
<td>-0.012</td>
<td>-0.068</td>
<td>-0.010</td>
<td>-0.007</td>
<td>Clear, 0.350</td>
<td>partly cloudy, 0.314</td>
<td>-0.014</td>
</tr>
<tr>
<td>Apply sunscreen 30 min prior to starting skiing/snowboarding</td>
<td>Age, sex, skin sun-sensitivity, local vs destination guest</td>
<td>-0.040</td>
<td>&lt;0.001</td>
<td>-0.007</td>
<td>0.029</td>
<td>Clear, 0.694</td>
<td>partly cloudy, 0.709</td>
<td>-0.023</td>
</tr>
<tr>
<td>Reapplied sunscreen after 2 h</td>
<td>Skin sun-sensitivity</td>
<td>-0.035</td>
<td>0.006</td>
<td>0.055†</td>
<td>-0.011</td>
<td>Clear, 0.258</td>
<td>partly cloudy, 0.233</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Goggles/sunglasses</td>
<td>Skin sun-sensitivity, local vs destination guest, ability level, days skied/snowboarded this season</td>
<td>-0.008</td>
<td>-0.016</td>
<td>-0.003</td>
<td>0.020</td>
<td>Clear, 0.909</td>
<td>partly cloudy, 0.917</td>
<td>-0.005</td>
</tr>
<tr>
<td>Head covering</td>
<td>Days skied/snowboarded this season</td>
<td>0.059d</td>
<td>0.070d</td>
<td>-0.012</td>
<td>-0.012</td>
<td>Clear, 0.865</td>
<td>partly cloudy, 0.930</td>
<td>-0.039</td>
</tr>
<tr>
<td>Brim on head covering</td>
<td>Age, sex, skin sun-sensitivity, and equipment</td>
<td>-0.056d</td>
<td>-0.061d</td>
<td>0.005</td>
<td>0.016</td>
<td>Clear, 0.144</td>
<td>partly cloudy, 0.174</td>
<td>-0.001</td>
</tr>
<tr>
<td>Ears covered</td>
<td>Sex, skin sun-sensitivity, days skied/snowboarded this season, and equipment</td>
<td>0.106e</td>
<td>0.136e</td>
<td>-0.003</td>
<td>0.001</td>
<td>Clear, 0.822</td>
<td>partly cloudy, 0.825</td>
<td>-0.024</td>
</tr>
<tr>
<td>Neck covered</td>
<td>Age, sex, skin sun-sensitivity</td>
<td>-0.041</td>
<td>-0.034</td>
<td>0.011</td>
<td>-0.026</td>
<td>Clear, 0.466</td>
<td>partly cloudy, 0.521</td>
<td>-0.034</td>
</tr>
<tr>
<td>Face covered</td>
<td>Sex, skin sun-sensitivity, local vs destination guest</td>
<td>-0.007</td>
<td>-0.045</td>
<td>-0.018d</td>
<td>0.018</td>
<td>Clear, 0.030</td>
<td>partly cloudy, 0.100</td>
<td>-0.040</td>
</tr>
<tr>
<td>Gloves</td>
<td>Local vs destination guest</td>
<td>-0.013</td>
<td>-0.006</td>
<td>-0.004</td>
<td>-0.002</td>
<td>Clear, 0.948</td>
<td>partly cloudy, 0.958</td>
<td>-0.0001</td>
</tr>
<tr>
<td>Overall sun protection</td>
<td>Age, education, sex, skin sun-sensitivity, local vs destination guest, ability level, and equipment</td>
<td>-0.021</td>
<td>-0.17</td>
<td>-0.055e</td>
<td>0.015</td>
<td>Clear, 4.002</td>
<td>partly cloudy, 4.086</td>
<td>-0.077</td>
</tr>
</tbody>
</table>

Notes:
- All predictors, except cloud cover, were standardized N(0,1) prior to analysis. Standardized regression coefficients are reported for all predictors, except cloud cover for which least squares means are reported by category.
- Low numbers meant closer proximity to noon.
- Cloud cover coded as 1, clear sky; 2, partly cloudy; 3, cloudy.
- P < .05.
- Those who were interviewed within 2 hours of first applying sunscreen were removed from analysis.
clear. Sunscreen and sunscreen lip balm were worn more frequently at lower latitudes. Guests reported more sunscreen use but less lip balm use at higher temperatures. Reapplication was more likely by guests interviewed farther from noon. Brimmed hats were also worn by more guests at ski areas located at lower latitudes and lower altitudes and on days with higher temperatures. Overall, this seems to be a sun protection pattern.

Sun protection was moderated by sun sensitivity, sex, and age. Lighter-skinned people (Fitzpatrick types I and II) reported more sunscreen reapplication at lower latitudes (slope = −0.07) compared with darker-skinned people, whose reapplication decreased at lower latitudes (slope = 0.07; latitude × sun sensitivity \( F_{1,700} = 4.58; P = .03 \)).

Sun-sensitive individuals retained constant rates of sunscreen reapplication with increasing altitude (slope = −0.04), whereas darker-skinned guests reported increased reapplication at higher altitude (slope = 0.09; altitude × sun sensitivity \( F_{1,700} = 4.31; P = .04 \)). Males' use of sunscreen stayed constant across the day (slope = 0.00), but more females reported wearing sunscreen closer to noon (slope = −0.05; minutes from noon × sex \( F_{1,2253} = 0.29; P = .01 \)). Several seasonal effects were moderated by sex: female sunscreen use was constant across the ski season (slope = 0.00); however, male sunscreen use increased toward spring (slope = 0.03; deviation from winter solstice × sex \( F_{1,2253} = 4.81; P = .03 \)). Inversely, males reported constant lip balm use (slope = 0.01), whereas females' lip balm use decreased toward spring (slope = −0.06; deviation from winter solstice × sex \( F_{1,2253} = 8.76; P = .003 \)). An interaction between deviation from winter solstice and sex was found for applying sunscreen 30 minutes before going outside (\( F_{1,1128} = 12.79; P < .001 \)) and overall sun protection (\( F_{1,2120} = 12.27; P < .001 \)) with females decreasing toward spring (slope = −0.03 and −0.13, respectively) and males trending upward (slope = 0.06 and 0.07, respectively) for both behaviors. Last, an inverse relationship between temperature and sunscreen lip balm use was found for guests older than 45 years (slope = −0.07) but not for the other age groups (18-35 years, slope = 0.01; 36-45 years, slope = −0.02; temperature × age \( F_{1,2253} = 3.95; P = .02 \)).

A second pattern was likely motivated by cold protection. More guests wore headgear, used sunscreen 30 minutes before skiing/snowboarding, and covered their ears, neck, and face when the weather was cloudy and cold. More head and ear covering occurred at higher latitudes and latitudes. Ear and neck covering was more frequent further from noon. More face covering occurred close to noon. Face covering significantly decreased in the afternoon. Interactions between head cover and temperature occurred for sun sensitivity and age, with darker-skinned guests (slope = −0.04) and younger groups (18-35 years, slope = −0.03; 36-45 years, slope = −0.07) exhibiting a steeper decline in head covering as temperatures rose (slope = −0.02 and −0.02, respectively; temperature × sun sensitivity \( F_{1,2113} = 4.87; P = .03 \); temperature × age \( F_{1,2113} = 3.28; P = .04 \)).

We also tested if the proximity of the time when guests started skiing/snowboarding was associated with sun protection behaviors. Those who started skiing/snowboarding much earlier than noon were more likely to apply sunscreen 30 minutes prior to skiing/snowboarding; those who started skiing/snowboarding much later than noon were more likely to cover their ears and necks.

At ski areas, average UV was moderate to low during the winter season, although large variation occurred. Adults at ski areas were intermittently exposed to levels of UV, warranting precautions against skin exposure. Ultraviolet radiation was dangerously high on many late winter and early spring days when UV readings of up to 10 were observed. This study found that substantial UV radiation occurred from 2 other sources: diffuse atmospheric radiation and reflected radiation from the snowy surface. The short wavelength of UV causes dispersion resulting in substantial diffuse UV in the atmosphere and considerable UV is reflected off snowy surfaces.

These 3 sources produce a multidirectional barrage of UV that explains ski patrolers' anecdotal accounts of sunburning in their nostrils and underscores the need for comprehensive sun protection. Outdoor enthusiasts should stay in shade and wear brimmed hats, but these practices may be insufficient to fully protect individuals in high altitude, outdoor, snow-covered winter environments where UV is diffuse and reflected not just direct. Shade and hats should be supplemented with broadband high-SPF sunscreen, sunglasses, and clothing that protect skin surfaces from diffuse and reflected UV radiation in addition to direct solar UV radiation.

People cannot directly detect UV when deciding to take precautions. Instead, they must infer UV levels from its link to temporal, geographic, and meteorological characteristics or rely on UV index forecasts. As expected, proximity to noon, deviation from the winter solstice, lower latitudes compared with higher altitudes, and less cloud cover were associated with increased UV. Proximity to noon, deviation from winter solstice, and cloud cover have the most pronounced effect on UV levels at ski areas. The association of temperature with UV may be spurious, produced by increasing infrared radiation toward noon and in early spring when UV also increases.

Skiers and snowboarders evidently monitor outdoor alpine environments in 2 ways, for sun protection and cold protection. For sun protection, they rely mainly on clear skies as a UV cue. They correctly link clear skies with the need for UV protection and use and reapply more sunscreen because more UV is present on clear days. However, extensive diffuse and reflected UV occurs on cloudy days at midday in the spring, and cloud cover can change within hours. Males pay more attention to seasonality when taking precautions, whereas women pay more attention to time of day. Routine use of moisturizers and makeup with sunscreen may account in part for women's consistent sunscreen use across seasons. Lighter-skinned individuals seem to base sun protection decisions correctly on latitude but do not adjust for altitude.

A second judgment is made by outdoor enthusiasts in regard to how much clothing to wear to maintain body heat and avoid frostbite. On cloudy days, when the weather is more inclement, skiers and snowboarders are more likely to wear head covering and cover their ears,
neck, and face. Ironically, these excellent sun safety behaviors are more likely on cloudy days when UV is a bit lower and less likely on sunny days when UV is higher. Older adults rely less on temperature than younger adults, suggesting they learned not to trust this unreliable UV cue. Sun safety promotions should remind skiers and snowboarders to wear sun protective clothing on sunny days as well. In warm weather, changing to lightweight headwear and clothing could help manage overheating and still provide protection.

Unfortunately, little association exists between any sun protection behavior and time of day or season. Skiers and snowboarders seem to ignore the facts that UV increases as spring approaches and that it is higher near solar noon each day. While cloud cover does depress the amount of UV reaching the ski area, this reduction, perhaps by as much as 50%, does not eliminate all UV in late winter and early spring and at midday when UV is high. Individuals should be cautious about cloud cover as a UV indicator and need to consider season and time of day as the most reliable indicators of UV. One good sign is that sunscreen reapplication was more likely nearer to noon. Unfortunately, it seems that warm temperatures, a very unreliable cue to UV levels, continue to be considered in adults' sun protection decisions during winter and spring outdoor recreation just as it is in the summer.

People are both accurate and inaccurate in their UV assessments. People wear sunscreen, lip balm, and headgear with brims based on inferences about UV—using them more frequently on clear days and at lower latitudes. Sunscreen was reapplied when UV was judged to be high. However, protective clothing decisions seem to be motivated by inclement weather concerns rather than elevated UV. Probably people also apply sunscreen more than 30 minutes prior to skiing or snowboarding due to inclement weather rather than due to advice that sunscreen is most effective when applied before going outdoors. They may feel it is more difficult or uncomfortable to apply sunscreen in inclement weather so they do so before arriving on the mountain. Skiers and snowboarders should be encouraged to preapply sunscreen on sunny and cloudy days because sunscreen compounds need time to be absorbed by the skin to be effective.

Outdoor recreation venues should consider publishing UV forecasts to help guests make informed sun safety decisions. However, UV forecasts do not always promote increased sun safety because individuals continue to rely on “rules of thumb” like associating high UV with clear, not cloudy, days, and warm, not cold, days, regardless of season or time of day.

It was surprising that UV was less strongly related to latitude and altitude than other variables. This finding may be due to restricted range of latitudes (all but 1 ski area was located between 34° N and 50° N) and high base altitudes (all but 1 were in high-altitude mountain locations). Despite these findings, outdoor recreators should still take into account latitude and altitude when judging UV because prior research shows that UV is elevated at low latitudes and high elevations, and when combined may result in UV levels in winter that can burn and damage the skin.

This study was limited to ski areas in western North America. It would be valuable to examine if outdoor recreation enthusiasts in countries with more sun safety promotion rely on different environmental cues to UV when making sun protection decisions. Our data are also limited to outdoor recreation during the winter and early spring period and not applicable to summer when UV is high and temperatures are much warmer.

During outdoor recreation in winter and spring people in alpine environments are bathed in UV. Fortunately, they take some precautions when UV is high, but their sun protection is associated with clear skies and temperature, not more reliable temporal cues, season, or proximity to noon, and geographic cues, altitude, and latitude. More sophisticated sun safety promotions are needed that teach people both to take precautions and to judge accurately when UV is high.

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Counseling Patients About Sun Protection Related to an Active Outdoor Life

While the effects of UV light exposure related to cutaneous malignant tumors are well documented, especially with respect to nonmelanoma skin cancers, dermatologists commonly counsel their patients generically without specific information related to real-world behaviors. Multiple studies related to real-world behaviors. Multiple studies related to real-world behaviors. Multiple studies related to real-world behaviors. Multiple studies related to real-world behaviors. Multiple studies related to real-world behaviors.